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Morphometric analysis of fish intestines in relation to their dietary preferences

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Abstract
This study investigates the relationship between intestinal morphology and feeding habits in selected freshwater fish species collected from local markets in Pune, India. Seven species of freshwater fish *Oreochromis spp.* (Tilapia), *Labeo rohita* (Rohu), *Catla catla* (Catla), *Colossoma macropomum* (Tambaqui), *Pangasius sutchi* (Silan), *Wallago attu* (Wallago), and *Channa spp.* (Channa) were categorized into herbivores, carnivores, and omnivores based on their dietary preference. For each specimen, intestinal length and weight were measured and compared with their dietary preference.

The results revealed significant variation in gut morphometry correlated with feeding habits. Herbivorous species displayed longer intestines to aid in cellulose digestion, while carnivorous species had shorter, heavier guts adapted for protein-rich diets. Omnivorous fish showed intermediate values. These findings align with established research and highlight the role of diet in shaping digestive anatomy. The results have practical implications for fish ecology, aquaculture nutrition, and species-specific feed optimization.

Keywords: Freshwater fish, intestine length, gut weight, feeding habits, digestive adaptions.

1. Introduction
Fish display remarkable diversity in their feeding strategies, which are closely linked to their habitat, dietary preferences, and ecological roles. The structure and morphology of the digestive system, particularly the intestines, play a fundamental role in determining how effectively a fish can process different types of food (Wilson & Castro, 2010) [1]. Intestinal length and weight, in particular, are important parameters as they provide insight into the digestive efficiency and metabolic adaptations of fish to their diets (Horn, 1989; Kapoor *et al*., 1975) [2, 3].. Variations in intestinal length and weight have been documented among different species and are often influenced by feeding habit herbivorous, carnivorous, or omnivorous that dictate the necessary digestive processes (Clements & Raubenheimer, 2005) [4].

Herbivorous fish tend to have relatively longer intestines to facilitate the breakdown of plant material, which requires extended digestion times due to the complexity of fibrous plant matter (German & Horn, 2006). [6] In contrast, arnivorous species generally possess shorter intestines adapted for the rapid digestion of protein-rich diets (Kramer & Bryant, 1995). [7]. Omnivores, which consume a mixed diet, exhibit intermediate intestinal lengths, reflecting the need for versatile digestive capability (Clements & Raubenheimer, 2006). [9] Understanding these anatomical adaptations is crucial for comprehending how fish meet their nutritional requirements and optimize energy extraction from their respective diets (Hidalgo *et al*., 1999).

Fishes exhibit diverse feeding habits, from herbivorous and omnivorous diets to strict carnivores, as well as a range of freshwater habitats. Fish based on their main diet are classified as herbivores whose main diet is plants which requires a longer gut for effective digestion due to the fibrous content, Omnivores whose main diet is a mixture of plant and animal feed their intestine weight and length are intermediate, supporting a flexible digestive process, and carnivores whose main diet is animal feed requiring a less extensive digestive tract (Buddington & Diamond, 1987; Jobling, 1994).

The present study explains the intestinal length and weight of various freshwater fish species from different trophic levels in relation to their feeding habits. By investigating these morphometric parameters across species with distinct diets, this research aims to provide a

clear understanding of how dietary habits shape intestinal morphology in freshwater fishes (German, 2009; Day *et al*., 2011). The findings of this study hold relevance for fields such as fish ecology, evolutionary biology, and aquaculture, as they contribute to our knowledge of dietary adaptations and the potential for selective breeding of species with efficient digestive systems for aquaculture practices (Sibly & Calow, 1986) [8]

2. Methodology

The research was conducted by survey method with sampling at one location. The material for the present study has been collected from different places in Pune and immediately after collection the specimens were transferred in ice box, brought to laboratory and were preserved in 10% formalin. Guts of the specimens were carefully dissected out, uncoiled and total length and total weight of gut was recorded and measurements were taken for individuals of different lengths as from mouth to anus. Gut contents were also analyzed to know their feeding habit. The feeding habits considered were carnivore, omnivore and herbivore. Several samples were studied for each species and each lot consisted of both male and female specimens of adult size; immature specimens. Species were considered carnivores, omnivores or herbivores only when references stated that at least 80% of their meal was based on the specified food.

2.1. Species selection

Selected freshwater fish species of interest, ideally representing different feeding habits (e.g., herbivores, carnivores, omnivores). There are seven freshwater fish species were selected depending on their availability and importance. The fishes selected were weighing about ½ kg. The freshwater fishes were Tilapia. (*Oreochromis spp.*) from family Cichlidae, Catla (*Catla catla*) belonging to family Cyprinidae, Silan (*Pangasius sutchi*) and family pangasiidae Rohu (*Labeo rohita*) from family Cyprinidae Tambaqui (*Colossoma macropomum*) family Serrasalmidae, Wallago (*Wallago attu*) belonging to family Siluridae, and Channa (*Channa spp.*) from family Channidae. In Maharashtra, these fishes like Tilapia, *Catla, Rohu, Tambaqui*, *Wallago,* and *Channa* are commonly found and farmed in regions around reservoirs and rivers like the Krishna, Bhima, and Godavari, as well as in places like Pune, Kolhapur, and Solapur.

2.2. Collection of fishes

The selected species of fishes were collected from the local markets of Pune. Most of the fish species were collected in fresh condition from Chatrapati Shivaji fish market and Ganesh peth. Many individuals of different sizes of each species were collected.

2.3. Dissection and Intestine Extraction

With the ventral or lateral incision from the gill cover to the anal region to exposed internal organs. Carefully extracted the intestine by using blunt dissection tools to avoid damage, measured the extracted intestine immediately or preserve it in formalin for further study.

2.4. Morphometric Measurements

The total length and weight were measured of each fish sample. Data were recorded to the nearest millimetre for length and gram for weight. Measurement of the length of intestine from the pyloric region to the anus and the intestine were carefully laying out without stretching. The weight of the dissected intestine for each fish were measured by using a high-precision balance.

2.5. Data Collection for Analysis

Recorded feeding behavior from available literature or observation and categorized fish as herbivorous, carnivorous, or omnivorous.

a. *Catla catla*

b. *Wallago attu*

c. Dissection of fish to expose intestine

d. Intestine laid out for measurement

e. Measurement of Intestine **f. Preservation of intestine**

Fig 1: Laboratory work for morphometric analysis of fish intestines.

3. Findings and Results

Present findings on intestinal morphology in relation to diet, including tables and graphs illustrating the relationships. Highlighted adaptations, such as longer intestines in herbivorous fish (for cellulose digestion) versus shorter intestines in carnivorous fish (for protein digestion).

The study of fish anatomy, specifically the length and weight of the intestine, along with external morphology, provides insight into how different diets influence these parameters across species. Various fish species exhibit anatomical differences based on their dietary preferences such as herbivorous, carnivorous, and omnivorous diets all drive distinct adaptations in the intestinal structure and external morphology to optimize nutrient absorption and processing.

Table 1: Intestinal length and weight of selected fishes

Family	Fish Species	Feeding habits	Intestine Length (cm)	Intestine Weight (g)
Cichlidae	*Oreochromis spp.*	Herbivorous	351.33 ± 2.87	55.98 ± 1.86
Cyprinidae	*Labeo rohita*	Herbivorous	267.67 ± 4.19	53.1 ± 1.56
Cyprinidae	*Catla catla*	Herbivorous	347.67 ± 37.57	42.28 ± 1.32
Pangasiidae	*Pangasius sutchi*	Carnivorous	177.67 ± 7.58	84.44 ± 1.25
Siluridae	*Wallago attu*	Carnivorous	35.67 ± 0.47	32.23 ± 1.21
Channidae	*Channa spp.*	Carnivorous	26 ± 0.82	33.43 ± 0.85
Serrasalmidae	*Colossoma macropomum*	Omnivorous	63.67 ± 3.86	49.19 ± 1.13

The experiment performed in triplicates, n=3 ± SD

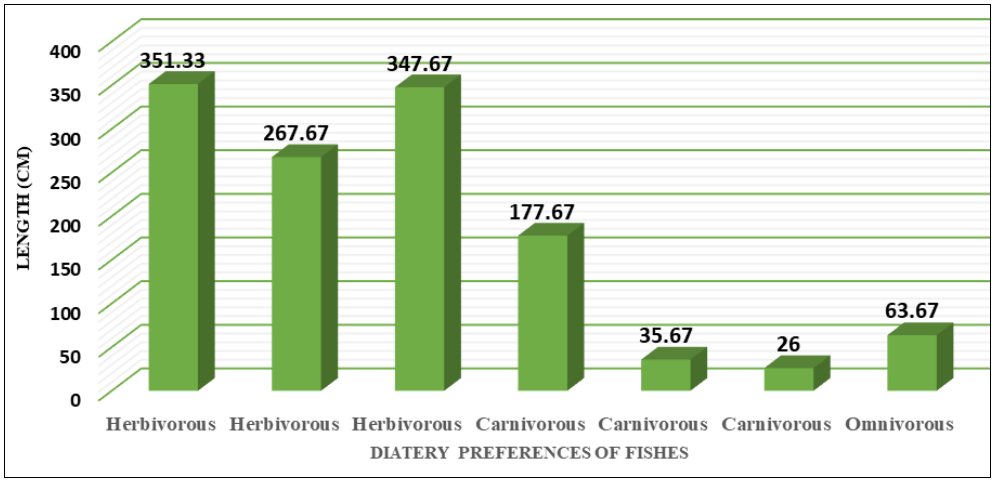

Fig 2: Intestine length of freshwater fishes in relation to their feeding preference

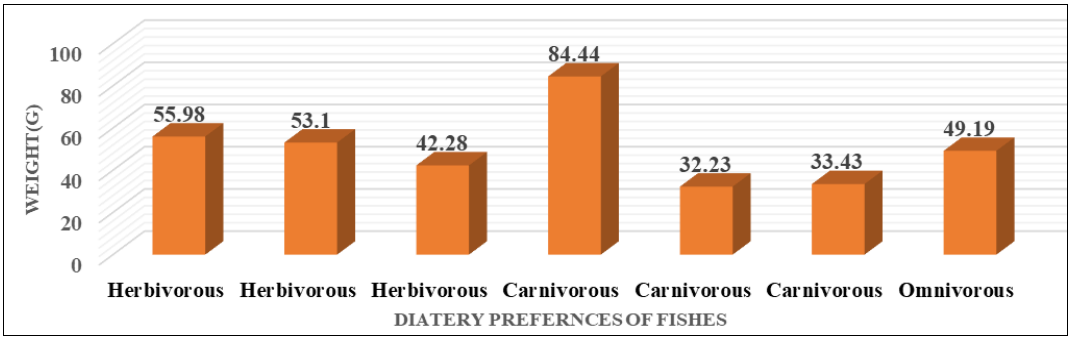

Fig 3: Intestine weight of freshwater fishes in relation to their feeding preference

Herbivores like Rohu, Catla and some Tilapia species typically have longer intestines, often exceeding 10 times

their body length. This adaptation helps in the breakdown of cellulose and other plant fibers, which require more time and a larger surface area for efficient digestion and nutrient extraction. The extensive length allows for a prolonged digestive process, maximizing nutrient absorption from fibrous plant material. Carnivores such as *Wallago* and *Channa* spp., on the other hand, usually have shorter intestines relative to body length, around 1-3 times the body length. Carnivores digest protein and fat more efficiently, requiring less digestive surface area and a shorter time for nutrient breakdown. The shorter intestine is sufficient for absorbing amino acids and other nutrients from animal tissues, which are easier to digest than plant matter. Omnivores like *Tambaqui* fall between these two extremes. They consume both plant and animal matter, so their intestinal length is moderate, allowing them to process both types of food efficiently without being highly specialized for one.

4. Discussion

The present study examined the relationship between intestinal length, weight, and the feeding habits of various freshwater fish species. Intestinal morphology, particularly length and weight, is often strongly influenced by dietary preferences, which align with the specific physiological requirements of herbivorous, carnivorous, and omnivorous fish species (Kramer & Bryant, 1995; Horn, 1989) [16]

The present findings indicate that herbivorous fish tend to have longer intestines relative to their body length compared to carnivorous species. This result aligns with previous studies suggesting that herbivores require extended intestinal tracts to digest plant-based diets that are rich in fibrous material and require prolonged enzymatic activity (German & Horn, 2006). [13] In herbivores, the increased intestinal length facilitates greater surface area and residence time for microbial fermentation and nutrient absorption, a necessary adaptation given the relatively low caloric density of plant matter (Hidalgo *et al*., 1999).[10]

In contrast, the carnivorous species analyzed in this study exhibited shorter, heavier intestines relative to body length. This pattern supports findings from other studies which suggest that carnivores, relying primarily on protein-rich diets, have more compact intestines designed for efficient digestion and absorption of high-calorie food sources, which require less processing time (Kapoor *et al*., 1975). [4] Additionally, the higher weight of carnivorous intestines may be attributed to greater muscle thickness, potentially enhancing nutrient processing efficiency, which has been documented in predatory fish species (Day *et al*., 2011). [15]

Omnivorous fish species showed intermediate values for intestinal length and weight, consistent with their flexible dietary habits. This group's intestinal morphology likely reflects an adaptation for a mixed diet, allowing for both efficient protein absorption and moderate processing of plant materials (Clements & Rauben heimer, 2006). [9] Our findings are supported by studies that have noted the plasticity of omnivorous intestines, which allow these species to exploit a wide variety of food resources depending on availability (Buddington *et al*., 1987). [11]

The variability in intestinal length and weight among the studied species provides valuable insight into the functional morphology of the digestive system as it relates to dietary specialization. Such morphological differences also underscore the evolutionary adaptations that enable each species to optimize digestion and energy extraction based on dietary needs. These findings could aid in the development of optimized feeding practices in aquaculture, as a deeper understanding of digestive morphology can contribute to more species-specific diet formulations, improving both growth efficiency and overall fish health**.**

5. Conclusion

This study has provided valuable insights into the relationship between intestinal morphology, specifically length and weight, and the feeding habits of selected freshwater fish species. Our findings indicate a strong correlation between diet type and intestinal adaptations, with herbivorous and omnivorous fishes generally displaying longer and heavier intestines relative to their body size compared to carnivorous species. These morphological differences likely reflect dietary requirements, as longer intestines facilitate the digestion of fibrous plant material, while shorter intestines are more suited to the rapid digestion of animal protein.

Understanding these adaptive traits contributes not only to our knowledge of fish physiology and ecology but also to sustainable fishery management and aquaculture practices. Recognizing the dietary and morphological requirements of these species can aid in formulating species-specific diets and creating optimal rearing conditions, which can enhance growth, health, and productivity in aquaculture.

In conclusion, this research emphasizes the importance of intestinal adaptations to dietary preferences in freshwater fishes, offering foundational knowledge for further studies on fish digestion and nutrition. By deepening our understanding of how feeding habits shape intestinal morphology, it can be contribute to better-informed conservation strategies and more sustainable practices within the aquaculture industry.

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