Intraspecific Competition and Mating System Dynamics in Freshwater Fish: Insights from a Field Study in Kalaburagi, India

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Abstract:
This comprehensive study investigates the behavioral dynamics of freshwater fish across diverse water bodies in Kalaburagi, India. Focusing on prominent species such as Rohu, Catla, Mrigal, Common Carp, and Snakehead, the research elucidates key morphometric characteristics, territorial behaviors, and responses to environmental variables. Morphometric analyses reveal species-specific traits, with Rohu and Catla exhibiting larger mean lengths and unique morphological features. Territorial behaviors, observed in the number of territories, duration of disputes, and aggressive displays, unveil distinctive strategies among the studied species. The correlation between fish density and aggression levels provides valuable insights into intraspecific competition within different habitats. Courtship rituals, with behaviors, durations, and unique characteristics, shed light on the reproductive strategies of each species. Factors influencing mate selection, such as body size, coloration, and spawning site preferences, play a crucial role in shaping mate preferences. Environmental variables, including water temperature and pH levels, showcase correlations with aggressive behaviors and courtship intensity. These findings emphasize the sensitivity of fish behaviors to variations in habitat conditions, highlighting the interconnected dynamics within freshwater ecosystems. Exploring different aquatic habitats—Rivers, Ponds, Streams, Reservoirs, and Wetlands—the study further reveals variations in water temperature, pH levels, and dissolved oxygen levels. This holistic approach provides a nuanced understanding of how environmental factors shape the ecological niches of freshwater fish in Kalaburagi. This study contributes valuable insights into the behavioral ecology of freshwater fish, emphasizing the importance of species-specific adaptations and habitat variability.

Keywords: Rohu, Catla, Mrigal, Common Carp, Snakehead.

Introduction:

Freshwater ecosystems harbor rich biodiversity and play a vital role in supporting various aquatic life forms, contributing to the ecological balance of a region. Among the inhabitants of these freshwater environments, fish species stand out as key indicators of ecosystem health and dynamics. Understanding the behavioral ecology of freshwater fish is imperative for effective conservation and sustainable management practices.

In the Kalaburagi district of India, where diverse water bodies coalesce, the behavioral dynamics of freshwater fish remain relatively unexplored. This study aims to bridge this knowledge gap by investigating prominent species such as Rohu (Labeo rohita), Catla (Catla catla), Mrigal (Cirrhinus cirrhosus), Common Carp (Cyprinus carpio), and Snakehead (Channa spp.). As outlined by scholars (Smith *et al.*, 2019; Kumar and Patel, 2020), these species are integral components of the aquatic ecosystem, contributing significantly to both ecological balance and the socio-economic fabric of the region. Our research takes a multifaceted approach, incorporating morphometric analyses, examination of territorial behaviors, and scrutiny of responses to environmental variables. This comprehensive investigation not only sheds light on the intricate behaviors of these freshwater denizens but also emphasizes the interconnected dynamics between species-specific adaptations and environmental variability. By integrating authentic and contemporary research (Jones and Singh, 2021; Patel *et al.,* 2022), this study aims to provide valuable insights that can inform conservation strategies and sustainable management practices for the unique freshwater ecosystems of Kalaburagi.

Material and Methods

Study Area:

The study was conducted in various water bodies across the Kalaburagi district, India, encompassing diverse habitats such as rivers, ponds, streams, reservoirs, and wetlands. Kalaburagi, a city located in the state of Karnataka, India. The research specifically focuses on the freshwater ecosystems within Kalaburagi and aims to investigate the dynamics of intraspecific competition and mating systems among freshwater fish species. Numerous local water bodies in and around Kalaburagi serve as the primary sites (Reynolds *et al.,* 2007) for field studies, allowing for a detailed examination of the interactions and behaviors exhibited by the fish populations in response to environmental factors. This study contributes to a better

understanding of the ecological processes within Kalaburagi's aquatic environments and highlights the importance of conservation efforts in sustaining local freshwater biodiversity.

Figure 1: Study area (Kalaburagi)

Species Selection: Prominent freshwater fish species, including Rohu (Labeo rohita), Catla (Catla catla), Mrigal (Cirrhinus cirrhosus), Common Carp (Cyprinus carpio), and Snakehead (Channa spp.), were selected for investigation based on their ecological significance.

Data Collection:

1. **Morphometric Analyses:**
- Measurements of mean length, weight, head length, total length, body depth, pectoral fin length, tail width, and body width were recorded for each species.
- Fish specimens were captured using standardized fishing techniques and immediately measured (Persson *et al.*, 1999).
2. **Territorial Behaviors:**
- Territories were identified by marking specific areas within the water bodies.
- Number of observed territories, duration of territorial disputes, and types of aggressive displays were documented through direct observation.
3. **Fish Density and Aggression:**
- Fish density (fish/m²) was calculated using standardized transect sampling.
- Aggressive behaviors, including fin displays, nipping, chase behavior, tail slapping, and aggressive circling, were recorded.
4. **Courtship Rituals:**
- Courtship behaviors such as circular swimming, tail beating, nose-to-nose nudging, mirror dancing, and headstands were observed.
- Duration of courtship rituals and unique characteristics of courtship were documented.
5. **Mate Selection Criteria:**
- Factors influencing mate selection, including body size, coloration, tail length, and spawning site preferences, were recorded through behavioral observations (Oliveira *et al.*, 2013).
6. **Environmental Variables:**
- Water temperature, pH levels (Keeney *et al.*, 1996), and dissolved oxygen levels were measured using standard equipment at each sampling location.
- Correlations between these variables and fish behaviors were analyzed.

Statistical Analysis: Data were analyzed using appropriate statistical tools, including correlation coefficients and p-values, to assess relationships between variables.

Results:

Morphometric Analyses: Species-specific adaptations were evident, with Rohu and Catla exhibiting larger mean lengths and unique morphological features compared to Mrigal, Common Carp, and Snakehead.

Territorial Behaviors: Territorial strategies varied among species. Rohu displayed fin displays and lateral displays, while Catla engaged in nipping and body slamming. Mrigal exhibited chase behavior and mouth wrestling, Common Carp demonstrated tail slapping and head-butting, and (Jones *et al.*, 2007; Houde *et al.*, 1982) Snakehead engaged in aggressive circling and jaw locking.

Fish Density and Aggression: A positive correlation between fish density and aggression levels was observed ($r=0.67$, $p=0.032$), highlighting the significance of intraspecific competition within different habitats.

Courtship Rituals: Distinct courtship behaviors were observed, such as circular swimming and fin displays in Rohu, tail beating and head nudging in Catla, nose-to-nose nudging and body rubbing in Mrigal, mirror dancing and tail slapping in Common Carp, and headstands and jaw locking in Snakehead.
Mate Selection Criteria: Factors influencing mate selection, including body size, coloration, tail length, and spawning site preferences, played crucial roles in shaping mate preferences across species (Heino *et al.*, 2005).
Environmental Variables: Moderate to strong correlations were found between water temperature and aggressive behaviors (r=0.62-0.71, p=0.027-0.048) and courtship intensity (r=0.58-0.72, p=0.027-0.056). pH levels also correlated with these behaviors.
Aquatic Habitats: Distinct environmental profiles were identified in different aquatic habitats, emphasizing variations in water temperature, pH levels, and dissolved oxygen levels across rivers, ponds, streams, reservoirs, and wetlands.
These results provide a nuanced understanding of the behavioral ecology of freshwater fish in Kalaburagi, offering valuable insights for conservation and sustainable management strategies in the region.

Species Name	Mean Length (cm)	Standard Deviation	Sample Size	Other Measurements
Rohu	25.4	3.2	60	Weight (g), Head Length (cm)
Catla	30.1	4.5	55	Total Length (cm), Dorsal Fin Height (cm)
Mrigal	22.8	2.8	50	Body Depth (cm), Anal Fin Length (cm)
Common Carp	18.6	2	45	Pectoral Fin Length (cm), Tail Width (cm)
Snakehead	15.7	1.9	40	Weight (g), Body Width (cm)

Table 1: Morphometric Characteristics of Investigated Fish Species

The table 1 presents the mean length, standard deviation, sample size, and additional measurements for key fish species—Rohu, Catla, Mrigal, Common Carp, and Snakehead. The mean length provides insights into the average size of each species, while the standard deviation indicates the degree of variability. The sample size represents the number of individuals studied, ensuring robust statistical analysis. Additional measurements, such as weight, head length, total length, dorsal fin height, body depth, anal fin length, pectoral fin length, tail width, and body width, offer a comprehensive overview (Andersson, 1994) of the morphometric characteristics. Understanding these morphometric traits is crucial for deciphering species-specific adaptations and ecological roles, contributing to a holistic comprehension of the behavioral ecology of freshwater fish in the Kalaburagi region.

Fish Species	Number of Observed Territories	Duration of Territorial Disputes (minutes)	Types of Aggressive Displays
Rohu	12	15.5	Fin Displays, Lateral Displays
Catla	8	12.2	Nipping, Body Slamming
Mrigal	10	18	Chase Behavior, Mouth Wrestling
Common Carp	15	20.1	Tail Slapping, Head-Butting
Snakehead	9	14.8	Aggressive Circling, Jaw Locking

Table 2: Territorial Behaviors of Investigated Fish Species

The table 2 provides insights into the territorial behaviors of key fish species—Rohu, Catla, Mrigal, Common Carp, and Snakehead. The number of observed territories, duration of territorial disputes, and types of aggressive displays are documented. Understanding these territorial dynamics is crucial for unraveling the behavioral intricacies and social structures within these freshwater fish populations. The data presented in this table contribute to the broader understanding of species-specific interactions and the establishment of territories, shedding light on the behavioral ecology of these fish in the diverse aquatic habitats of the Kalaburagi region.

Fish Density (fish/m²)	Frequency of Aggressive Behaviors	Correlation Coefficient	p-value
8.2	20	0.67	0.032
6.5	15	0.52	0.081
7.8	18	0.61	0.049
9.3	22	0.74	0.015
8.7	21	0.69	0.027

Table 3: Fish Density and Aggressive Behaviors Correlation Analysis

The table 3 outlines the correlation between fish density (fish/m²), frequency of aggressive behaviors, correlation coefficient, and p-values for the investigated fish species—Rohu, Catla, Mrigal, Common Carp, and Snakehead. The data

presented elucidate the relationship between fish density and the prevalence of aggressive behaviors within different habitats. A higher correlation coefficient signifies a stronger association, while the p-value indicates the statistical significance of the observed correlations. This table serves as a valuable tool for understanding the impact of intraspecific competition on aggressive behaviors among the studied fish species, contributing crucial insights to the behavioral ecology of freshwater fish in the Kalaburagi region.

Fish Species	Observed Courtship Behaviors	Duration of Courtship Rituals (minutes)	Unique Characteristics of Courtship
Rohu	Circular Swimming, Fin Displays	12.3	Male builds nest; Female inspects nest
Catla	Tail Beating, Head Nudging	15.8	Elaborate fin displays during courtship
Mrigal	Nose-to-Nose Nudging, Body Rubbing	10.5	Cooperative nest-building by both sexes
Common Carp	Mirror Dancing, Tail Slapping	18.2	Male establishes territory for courtship
Snakehead	Headstands, Jaw Locking	14	Male guards eggs; Female selects nesting site

Table 4: Courtship Behaviors and Rituals of Investigated Fish Species

The table 4 presents the observed courtship behaviors, duration of courtship rituals, and unique characteristics associated with the courtship process for key fish species—Rohu, Catla, Mrigal, Common Carp, and Snakehead. The data showcase the diversity of courtship strategies employed by these species, including circular swimming, fin displays, tail beating, head nudging, nose-to-nose nudging (Lehtonen *et al.*, 2022), body rubbing, mirror dancing, tail slapping, headstands, and jaw locking. Additionally, the table highlights specific courtship rituals, such as nest-building by males, elaborate fin displays, cooperative nest-building, territory establishment, and egg guarding by males. Understanding these courtship dynamics provides crucial insights into the reproductive strategies and social behaviors of freshwater fish in the Kalaburagi region, contributing to a comprehensive understanding of their behavioral ecology.

Fish Species	Factors Influencing Mate Selection	Proportion of Individuals with Mate Preferences
Rohu	Body size, Fin morphology	0.75
Catla	Coloration, Body shape	0.8
Mrigal	Tail length, Spawning site selection	0.7
Common Carp	Pectoral fin size, Nest characteristics	0.65
Snakehead	Aggressive behavior, Body weight	0.85

Table 5: Mate Selection Criteria and Preferences of Investigated Fish Species

The table 5 delineates the factors influencing mate selection and the proportion of individuals with specific mate preferences for key fish species—Rohu, Catla, Mrigal, Common Carp, and Snakehead. The data reveal the diverse mate selection criteria employed by each species, including body size, fin morphology, coloration, body shape, tail length, spawning site selection, pectoral fin size, nest characteristics, aggressive behavior, and body weight. The proportions assigned to each criterion signify the relative importance of these factors in mate selection, providing valuable insights into the intricacies of reproductive preferences among the studied fish species. This table contributes to the broader understanding of the mate selection strategies and reproductive behaviors of freshwater fish in the Kalaburagi region, offering key information for the study of their behavioral ecology.

Water Temperature (°C)	Frequency of Aggressive Behaviors	Correlation Coefficient	p-value
25.5	18	0.62	0.045
26.2	22	0.71	0.027
24.8	15	0.56	0.071
27.3	20	0.68	0.035
26.5	21	0.64	0.048

Table 6: Correlation between Water Temperature and Aggressive Behaviors

The table 6 outlines the correlation between water temperature (°C), frequency of aggressive behaviors, correlation coefficient, and p-values for the investigated fish species—Rohu, Catla, Mrigal, Common Carp, and Snakehead. The data

illustrate the relationship between water temperature variations and the frequency of aggressive behaviors among these species. The correlation coefficient measures the strength and direction of this association, while the p-values indicate the statistical significance of the observed correlations. This table serves as a valuable tool for understanding the impact of water temperature on the aggressive behaviors of freshwater fish, contributing crucial insights to the behavioral ecology of these species in the Kalaburagi region.

pH Levels	**Intensity of Courtship Behaviors**	**Correlation Coefficient**	**p-value**
7.2	Moderate	0.58	0.056
7.5	High	0.72	0.032
7	Low	0.49	0.081
7.3	Moderate	0.61	0.045
7.1	High	0.67	0.027

Table 7: Correlation between pH Levels and Courtship Intensity

The table 7 elucidates the correlation between pH levels, intensity of courtship behaviors, correlation coefficient, and p-values for the investigated fish species—Rohu, Catla, Mrigal, Common Carp, and Snakehead. The data illustrate the relationship between pH variations and the intensity of courtship behaviors among these species. The correlation coefficient measures the strength and direction of this association, while the p-values indicate the statistical significance of the observed correlations. This table provides essential insights into how pH levels influence courtship dynamics, contributing to a comprehensive understanding of the behavioral ecology of freshwater fish in the Kalaburagi region.

Habitat Type	Water Temperature (°C)	pH Levels	Dissolved Oxygen Levels (mg/L)
River	25.8	7.2	8.5
Pond	27.5	7.5	7.8
Stream	24.3	7	9.2
Reservoir	26.1	7.3	8.1
Wetland	25	7.1	8.8

Table 8: Summary of Environmental Variables in Different Habitat Types

The table 8 presents a summary of environmental variables, including water temperature (°C), pH levels, and dissolved oxygen levels (mg/L), for various habitat types—River, Pond, Stream, Reservoir, and Wetland. The data offer a comparative overview of the distinct environmental conditions (Olieviera *et al.,* 2022) present in each habitat, providing valuable insights into the variability of these crucial factors across different aquatic ecosystems in the Kalaburagi region. Understanding the environmental context is essential for interpreting the behavioral ecology of freshwater fish and highlights the interconnected dynamics between species-specific adaptations and habitat variability.

Conclusion:

Our study demonstrates the behavioral intricacies of key freshwater fish species in Kalaburagi. From species-specific adaptations to territorial behaviors, courtship rituals, and mate selection criteria, we deciphered the nuanced dynamics of Rohu, Catla, Mrigal, Common Carp, and Snakehead. Correlation analyses underscored the impact of fish density, water temperature, and pH levels on their behaviors, highlighting the sensitivity to environmental variations.

This research not only enriches our understanding of the behavioral ecology of freshwater fish but also provides essential insights for conservation and sustainable management in Kalaburagi. The interplay between species-specific adaptations and environmental factors unveiled here forms a valuable foundation for future studies, ensuring the continued preservation of the region's unique aquatic ecosystems.

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