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Adaptive radiation analysis via UPGMA on the basis of morphometric measurements of selected freshwater fish species combinations.

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ABSTRACT:

Adaptive radiation is useful to lessen competition among the species. Fishes in a pond confined in a closed ecosystem. Because of enclosed ecosystem, the competition is higher than riverine system. Ecomorphology is the study of the relationship between an organism's morphology and its environment.Ecomorphological investigations helps to predict fish populations adaptive capacity to environmental changes. In this study morphometry and meristic characters of five local freshwater fishes were considered to understand their feeding guilds on the basis of ecomporphological analysis. Collected meristic and morphometric data was subjected to UPGMA cluster analysis to understand their adaptive radiative capacity and the basis of clustering of characters. Analysed results presented that in severe food crisis, *Mystus tengra* will compete with *Ompok bimaculatus* although they both share same cohort with *Labeo bata*. So they predate upon *Labeo bata* mainly. *Sperata aor* can predate on all, but do not prefer *Mystus tengra* for spine. *Labeo rohita*, become a large fish will separate, though the fingerlings are susceptible for all kinds of predation. The analyzed character weightage showed that the "mouth size" of the head is distinctiveness feature along with another charecter i.e. body depthness. All the antennas, fins and finrays count, RGL to caudal peduncle etc. are bearing same weightage.The dietary habit is related with sight (eye diameter) specially incase of predator fishes. This kind of study may serve to understand the competition model. When we plan to release an "exotic species" for economic importance, possible ecological effect can be assessed from this kind of study.

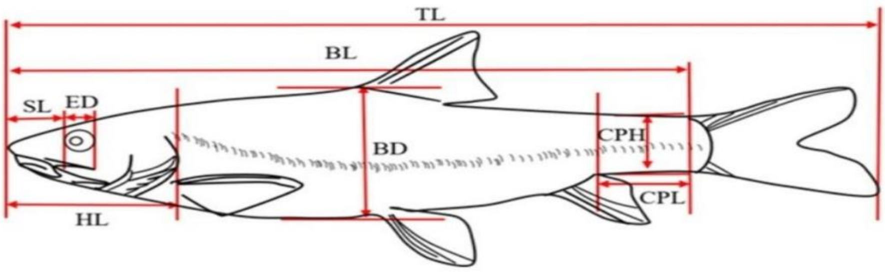
Key Words: Adaptive radiation,UPGMA, meristic and morphometric measurements, Character weightage, competition model.

1.Introduction:

India carries more than 10% of the world's fish diversity (Abdurrahman et al., 2017). Indian output presented 162.48 lakh tonnes of fish production, of which approximately 121.21 lakh tonnes and 41.27 lakh tonnes from inland and marine fisheries respectively (Department of Fisheries, 2022). The majority of economically weak fisherman of Indian, particularly those residing in rural regions, rely on the fisheries and aquaculture sector for their primary source of income (Khatua,2022). An efficient fish marketing system is also an important aspect on which growth of the fishery industry relies (Chourey et al., 2014). Nearly 60% of Indians like eating fish because of its many health benefits (Shyam, 2013). About 16.52 lakh tons of fish production is from West Bengal's inland fisheries reported in 2021–2022 (Department of fisheries, 2022). Fishing accounts for 1.1% of the nation's overall GDP and roughly 5.15% of its agricultural GDP (Vala et al, 2020) in Indian economy. West Bengal contains 6.08 lakh hectares of freshwater fisheries resources, including canals (0.80 lakh hectares), reservoirs (0.27 lakh hectares), 22 river drainage basins (1.72 lakh hectares), ponds and tanks according to report of Fisheries Department, Government of West Bengal, 2016.West Bengal's freshwater fish biodiversity is greatly aided by the Ganga (81% of the region), Brahmputra (21%), Subernarekha (4%), and two minor coastal rivers (3%), as well as their basins accroding to Bandyopadhyay et al. (2014). Adaptive radiation is useful to lessen competition among the species. Fishes in a pond confined in a closed ecosystem. Because of enclosed ecosystem, the competition is higher than riverine system. Ecomorphology is the study of the relationship between an organism's morphology and its environment (Wainwright and Reilly, 1995; Bhat, 2025). Ecomorphological investigations helps to predict fish populations adaptive capacity to environmental changes, which could be applied for fisheries management, conservation and aquaculture researches (Nair, 2024; Scocco and Felice, 2025). The initial stage in studying a species is taxonomic identification (Nayman, 1965; Langer et al., 2009). In addition to the species identification, morphology is considered as a valuable source for fish population studies (Deesri et al., 2009). Morphometric characters have been commonly used in fish biology as powerful tools for exact identification of species, measuring discreteness and relationships among various taxonomic categories (Cavalcanti et al., 1999; Quiling et al., 2007). In this study morphometry and meristic characters of five local freshwater fishes were considered to understand their feeding guilds on the basis of ecomporphological analysis. After meristic and morphometric data collection, it was subjected to UPGMA (Unweighted Pair Group Method with Arithmetic Mean) cluster analysis, which is a type of unsupervised machine learning algorithm that groups similar data points or observations into clusters. This technique helps identify patterns and structures in data, enabling artificial intelligence (AI) systems to make informed decisions or predictions. Cluster analysis is a statistical technique used to group individuals or species based on morphological characteristics. Cluster analysis helps identify patterns in morphological data, enabling researchers to distinguish between different species, populations, or stocks. UPGMA can be employed in bioinformatics to construct phylogenetic trees, which can then be used as input for machine learning models to predict evolutionary relationships or identify patterns in genomic data. Therefore, the collected data of meristic and morphometric characters of the specimens (*Labeo bata, Labeo rohita, Sperata aor, Ompak bimaculatus and Mystus tengara*) were analysed via UPGMA method to understand their adaptive radiative capacity and the basis of clustering of characters, on which basis their adaptive diversity were developed.

2.Methodology:

2A.Fish samples of five species [*Labeo bata* (Common name: Bata fish), *Labeo rohita* (Common name: Rohu fish), *Sperata aor* (Common name: Aar Fish), *Ompok bimaculatus* (Common name: Pabda Fish), *Mystus tengara* (Common name: Small Tengara Fish)] were collected from the two fish markets namely Bagmari (22.5898^{O}N, 88.3584^{O} E) and Maniktala (22.5856^{O}N, 88.3742^{O} E). Fishes were purchased from fish marketplaces and brought to laboratory of Department of Zoology, Rammohan College for capturing of photographs and conduct further scientific investigations. Meristemic and morphometric measurements of total length (TL), body length (BL), eye diameter (ED), head length (HL), body depth (BD), snout length (SL) etc. and counting of fin rays of dorsal fin, caudal fin, pectoral fin, pelvic fin and anal fins were done following Hu *et al.,* 2024.



2B.Selection criteria of Fishes: Coloumn feeder, herbivore, planktivore *Labio rohita, Labio bata* is a prey fish in this analysis. Three predator fish, predate upon smaller size of these prey are selected to estimate selection pressure.

2C. Each samples were then dissected for measurement of gut length (GL) by using scale. We also calculated the Relative Gut Length (RGL) index to understand the feeding habits of fishes by comparing the gut length to the overall body size (Alhassan et al., 2023). Relative Gut Length helps to determine an organism feeding habit, like a herbivore, carnivore, omnivore, or in some combinations. This is because herbivores have longer intestines to digest plant matter, while carnivores have shorter intestines. RGL provides insights into the digestive adaptation of an organism and how its diet influences its gut length.

2D. The Relative Gut Length (RGL) is calculated by using the formula:

❖ RGL =Total Length of Gut /Total Length of Fish

This index is used to classify fish based on their dietary preferences and can be further supported by analyzing gut content and other morphological characteristics.

▪ For, Carnivores : RGL values are typically less than 1.0 .

▪ Omnivores : RGL values are often between 1.0 and 3.0 .

▪ Herbivores : RGL values are generally greater than 3.0 .

3.Results:

The studied five fish samples [*Labeo bata* (Bata Fish), *Labeo rohita* (Rohu Fish), *Sperata aor* (Aar Fish),*Ompok bimaculatus* (Pabda Fish), *Mystus tengara* (Small Tengara Fish)] systematic position, IUCN status, common name, species authority etc. was presented in Table-1. Photographs of studied five fish samples was presented in Figure-1 and the representation of the measurements of the morphometric and meristic characters were documented in Table-2 along with UPGMA analysis of distance matrix (Table-3) of character vs characters and the cumulative distance matrix (Table-4) of species vs species in all together. The study also represented the adaptive radiation of 5 fish species (Figure-2) on the basis of clustering of characters. The weightage of characters on the basis of which the clustering observed in different groups were represented (Figure-3) in studied fish species. The adaptive radiation analysis showed *Ompok bimaculatus and Mystus tengara* are closely linked to each other due to their dietary habit of carnivores in nature, whereas *Sperata aor* is also carnivory in nature, but due to their body size variation, it relates less distantly to the group of *Ompok bimaculatus and Mystus tengara.* On the other hand, *Labeo rohita* and *Labeo bata* are surface feeder and coloumn feeder in feeding habit and therefore adaptively forms a separate group relatively than the rest fish species. The adaptive radiation of fishes depends on the weightage of character and their relative clustering groups, where head length, body depth are main features of comparison from the rest clusters of charters like: antenna size, eye diameter, gut length, number of different fins and fin rays etc.

Fish Name-	***Labeo bata*** **(Hamilton 1822)**	***Labeo rohita*** **(Hamilton 1822)**	***Ompak bimaculatus*** **(Bloch 1794)**	***Sperata aor*** **(Hamilton 1822)**	***Mystus tengra*** **(Hamilton 1822)**

Kingdom:	Animalia	Animalia	Animalia	Animalia	Animalia
Phylum:	Chordata	Chordata	Chordata	Chordata	Chordata
Class:	Actinopterygii	Actinopterygii	Teleostei	Actinopterygii	Actinopterygii
Order:	Cypriniformes	Cypriniformes	Siluriformes	Siluriformes	Siluriformes
Family:	Cyprinidae	Cyprinidae	Siluridae	Bagridae	Bagridae
Genus:	*Labeo*	*Labeo*	*Ompak*	Sperata	*Mystus*
Species:	*bata*	*rohita*	*bimaculatus*	aor	*tengra*
IUCN status:	LC	LC	NT	LC	LC
Local/Common name:	Bata	Rohu/ Rui/ Roho	Deshi pabda/ Pabda	Aar/ Daryai tengra	Bojre tengra/Tengra

Table. 1: Systematic position, IUCN status, common name, species authority of studied five fish species.

Labeo bata

Labeo rohita

Ompok bimaculatus

Sperata aor

Mystus tengra

Figure.1: Photographs of studied five fish species

	Labeo rohita	*Labeo bata*	*Sperata aor*	*Ompok bimaculatus*	*Mystus tengara*
TOTAL LENGTH (cm)	21.5	15.7	35.0	20.3	11.0
BODY LENGTH (cm)	17.5	12.9	26.0	17.6	8.7
BODY DEPTH (cm)	5.0	3.4	4.5	3.9	2.2
EYE DIAMETER (cm)	1.0	0.8	1.5	0.7	0.4
HEAD LENGTH (cm)	4.5	2.9	7.5	2.9	1.9
CAUDAL PEDUNCLE LENGTH (cm)	3.0	2.4	3.5	1.2	1.7
CAUDAL PEDUNCLE HEIGHT (cm)	2.0	1.3	1.5	1.1	1.5
SNOUT LENGTH (cm)	1.5	1.0	2.0	0.9	0.7
MOUTH GAIT LENGTH (cm)	0.5	0.4	1.5	0.7	0.4
MOUTH POSITION	2.0	1.0	4.0	1.0	1.0
LATERAL LINE SCALES	40.0	36.2	0.0	0.0	0.0
NO. OF DORASAL FIN RAY	14.0	10.8	8.0	2.5	7.8

N0. PECTORAL FIN RAY	14.0	15.4	1 + 9	6.3	3.0
NO. OF PELVIC FIN RAY	9.0	11.6	6.0	8.5	5.8
NO. OF ANAL FIN RAY	7.0	7.0	11.0	69.0	7.8
NO. OF TAIL FIN RAY	21.0	19.8	24.0	17.0	19.2
GUT LENGTH (cm)	189.0	91.8	38.0	14.5	7.1
RELATIVE GUT LENGTH	8.8	5.5	1.1	0.7	0.7
1st ANTENNA (cm)	0.0	0.0	15.0	5.1	6.5
2nd ANTENNA (cm)	0.0	0.0	4.5	1.0	2.8
3rd ANTENNA (cm)	0.0	0.0	3.5	0.0	1.9
4rth ANTENNA (cm)	0.0	0.0	1.0	0.0	1.5
DIETARY HABITS	1.0	1.0	2.0	0.0	0.0

Table.2: Morphometric and meristic measurements of the studied five fish species

Character VS Character:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
A	0.0	17.5	5.0	1.0	4.5	3.0	2.0	1.5	0.5	2.0	40.0	14.0	14.0	9.0	7.0	21.0	189.0	8.8	0.0	0.0	0.0	0.0	1.0
B		0.0	4.5	1.5	7.5	3.5	1.5	2.0	1.5	4.0	0.0	8.0	5.0	6.0	11.0	24.0	38.0	1.1	15.0	4.5	3.5	1.0	2.0
C			0.0	0.8	2.9	2.4	1.3	1.0	0.4	1.0	36.2	10.8	15.4	11.6	7.0	19.8	91.8	5.5	0.0	0.0	0.0	0.0	1.0
D				0.0	2.9	1.2	1.1	0.9	0.7	1.0	0.0	2.5	6.3	8.5	69.0	17.0	14.5	0.7	5.1	1.0	0.0	0.0	0.0
E					0.0	1.7	1.5	0.7	0.4	1.0	0.0	7.8	3.0	5.8	7.8	19.2	7.1	0.7	6.5	2.8	1.9	1.5	0.0
F						0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
G							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H								0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
I									0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J										0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K											0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
L												0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M													0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N														0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
O															0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P																0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q																	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R																		0.0	0.0	0.0	0.0	0.0	0.0
S																			0.0	0.0	0.0	0.0	0.0
T																				0.0	0.0	0.0	0.0
U																					0.0	0.0	0.0
V																						0.0	0.0
W																							0.0

SYMBOL	CHARACTERS
A	TOTAL LENGTH cm
B	BODY LENGTH cm
C	BODY DEPTH cm
D	EYE DIAMETER cm
E	HEAD LENGTH cm
F	CAUDAL PEDUNCLE LENGTH cm
G	CAUDAL PEDUNCLE HEIGHT cm
H	SNOUT LENGTH cm
I	MOUTH GAIT LENGTH cm
J	MOUTH POSITION
K	LATERAL LINE SCALES
L	NO OF DORASAL FIN RAY
M	N0 PECTORAL FIN RAY
N	NO OF PELVIC FIN RAY
O	NO OF ANAL FIN RAY
P	NO OF TAIL FIN RAY
Q	GUT LENGTH cm
R	RELATIVE GUT LENGTH RGL
S	1st ANTENNA cm
T	2nd ANTENNA cm
U	3rd ANTENNA cm
V	4rth ANTENNA cm
W	DIETARY HABITS

Table 3: Distance matrix using UPGMA of 5 fish species

Species VS Species:

	Labeo rohita	*Sperata aor*	*Labeo bata*	*Ompok bimaculatus*	*Mystus tengara*
Labeo rohita	0	35	15.74	20.25	11.04
Sperata aor		0	12.86	17.55	8.72
Labeo bata			0	3.9	2.16
Ompok bimaculatus				0	0.44
Mystus tengara					0

Table 4: Cumulative distance matrix among the fishes using UPGMA

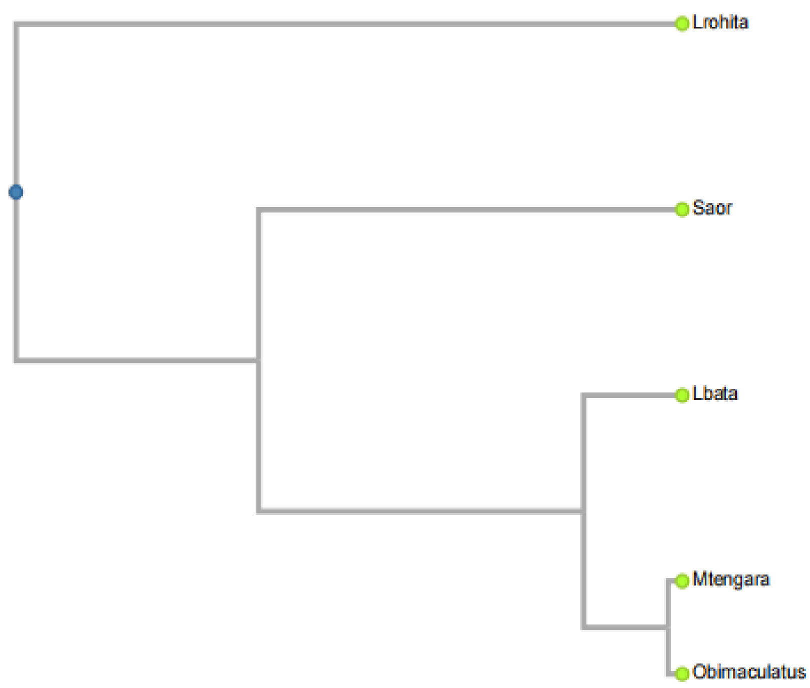


Figure 2: Adaptive radiation of 5 fish species on the basis of clustering of character.

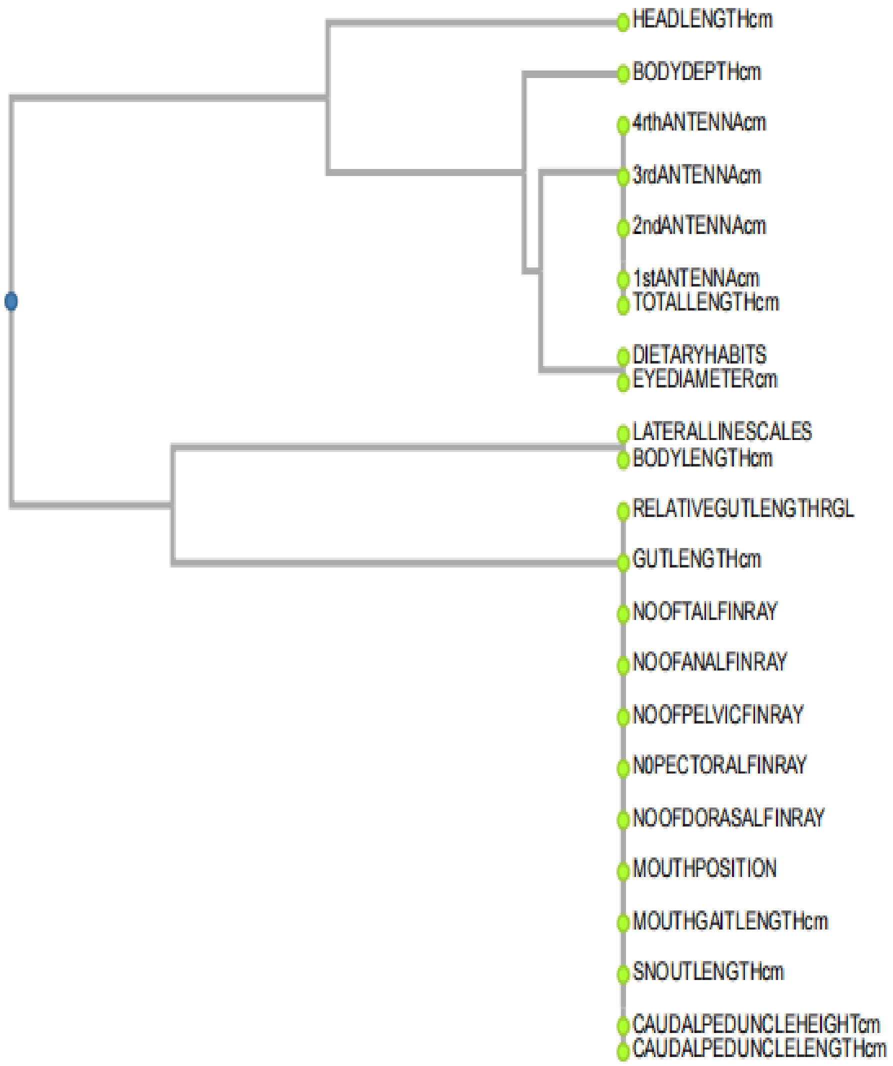


Figure 3: Weightage of character and clustering of character in studied fish species

Discussion:

In severe food crisis, *Mystus tengra* will compete with *Ompok bimaculatus* (Figure. 2). Both *Mystus tengra* and *Ompok bimaculatus* will share same cohort with *Labeo bata*. So they predate upon *Labeo bata* mainly. *Sperata aor* can predate on all, but do not prefer *Mystus tengra* for spine. *Labeo rohita*, become a large fish will separate, though the fingerlings are susceptible for all kinds of predation.

As, in combination, 3 of 5 selected species are predators, the "mouth size" of the head is showing distinctiveness (Figure. 3). The overall size is also a distinct character(body depth). All the antennas, fins and finrays count, RGL to caudal peduncle are bearing same weightage. The dietary habit is related with sight (eye diameter) specially incase of predator fishes.

Conclusion:

Fish ecomorphology studies are crucial for understanding of adaptive radiation of feeding guilds of various fishes, which competes and exists with each other in an aquatic environment. Fish body shapes, fin shapes, mouth size and position, scale characteristics and relative gut lengths etc. provides insights into its lifestyle, habitat, locomotion, feeding strategies and predator avoidance mechanisms. Such character analysis studies via UPGMA has a potential role for knowing adaptive radiation capacities of various fishes providing weightage of character clustering's. Further, such fish ecomorphology studies has pivotal role in gathering information of adaptive radiative features of a variety of fishes, which might help in development of conservation efforts, sustainable aquaculture practices and fisheries management in near future. This study may serve to understand the competition model. When we plan to release an "exotic species" for economic importance, possible ecological effect can be assessed from this kind of study.

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Conflict of Interest: Authors declares no conflict of interest.

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