Abstract of the Thesis Entitled

Mullet Fish Resources of Coastal Gujarat with Special Reference to Biological Aspects and Aquaculture Potential of *Mugil cephalus* (Linnaeus, 1758)

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By

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Oceans and seas cover 71% of Earth's surface, with a coastline stretching over 1.6 million km. Coastal and marine ecosystems, spanning 123 countries, include diverse habitats like estuaries and lagoons. The Indian Ocean, ranking as the third largest ocean, is a significant part of the central Indian Ocean region, which India shares with countries like Bangladesh and Indonesia. India's coastline, about 8000 km long, features three distinct marine ecosystem zones: the Arabian Sea to the west, the Bay of Bengal to the east, and the Indian Ocean to the south. (Venkatraman & Raghunathan, 2015; Gopi & Mishra, 2015).

The coastline encompasses diverse habitats such as estuaries, lagoons, mangroves, and coral reefs, with the estuarine zone serving as a crucial transition area between marine and freshwater ecosystems (Sarkar et al., 2012). India boasts 14 major and 228 minor estuaries, alongside coastal lagoons and backwaters covering approximately 2000 km^2 hinterland (Sarkar et al., 2012; Venkatraman & Raghunathan, 2015). Estuaries, known for their high productivity, support abundant autotrophs, oxygen-rich waters, and nutrient regeneration (Acharya et al., 2019). These dynamic habitats experience fluctuations in temperature, salinity, and turbidity, playing a vital role in the life cycles of fish species, acting as breeding and nursery grounds (Whitfield, 1994). Estuaries are defined as partially enclosed coastal bodies of water with varying salinity due to the mixing of seawater and freshwater (Day, 1981). They provide essential habitats for fish species and are classified into different categories based on salinity and connectivity to the sea (Blaber, 1997a). Despite lower species diversity, estuarine environments harbor highly abundant populations compared to adjacent aquatic ecosystems (Chang & Iizuka, 2012), making them significant contributors to local economies and fisheries in tropical countries.

Globally, ichthyofaunal diversity comprises approximately half of the total members of the subphylum Vertebrata, totaling 35,588 valid fish species (Fricke et al., 2020). Recent studies have increased the estimated number of valid fish species in India to 3,231, including freshwater, brackish water, and marine species (Gopi & Mishra, 2015). Among these, marine waters host 2,443 species, freshwater habitats support 675 species, and brackish waters harbor approximately 113 species (Sarkar et al., 2012; Gopi & Mishra, 2015).

The Mugilidae family, commonly known as grey mullets, is one of the most widespread teleost families in coastal waters worldwide, belonging to the class Actinopterygii, order Mugiliformes (Fricke et al., 2020). While previously classified in the order Perciformes, grey mullets are now the sole representatives of the Mugiliformes order (Nelson, 1984). Typically reaching a maximum size of 120 cm standard length, they are commonly found around 30 cm standard length, with a subcylindrical body and a dorsally flattened head (Harrison & Howes, 1991). Grey mullets inhabit temperate, sub-tropical, and tropical waters in both hemispheres, with the majority of species being euryhaline, found in various environments ranging from coastal marine waters to freshwater habitats (González-Castro, 2007). They exhibit extraordinary adaptability, thriving in environments ranging from clear coral reefs to turbid estuaries and freshwater, even in highly polluted areas such as the Visakhapatnam harbor in India (Blaber, 2000). Grey mullets play a unique role in food webs as primarily detritivores, efficiently converting particulate organic matter, detritus, and benthic microalgae into high-quality fish protein, thereby supporting top predators (Whitefield et al., 2012).

The euryhaline ecosystem provides an ideal habitat for mullets due to its fluctuating environmental conditions, influencing their growth and development. Mullets, highly adapted to a wide salinity range (Thomson, 1966; Kutty, 1980; Whitfield, 1996), thrive in environments like brackish water lagoons and coastal wetlands, making them suitable for aquaculture (Ravagnan, 1992). Assessments of mullet growth and condition utilize isometric and allometric measurements, such as length-weight relationships and condition factors (Mendes et al., 2004). For example, studies on gold spot mullet (Liza parsia) reveal positive allometric growth patterns (Renjini & Bijoy, 2011), while investigations into Liza parsia in Visakhapatnam highlight pollution-related variations (Rao et al., 2005). The spawning seasons of mullets are determined using the gonadosomatic index (GSI), offering vital insights for fisheries and aquaculture management (Meien, 1927). Additionally, hepatosomatic index measurements provide information on gonadal development and reproductive energy allocation (Albieri & Araújo, 2010). Mullet fish are valued for their high-quality protein content and wide consumption (Kumaran et al., 2012; Tulgar & Berik, 2012), supporting commercial fisheries and aquaculture globally. In India, mullets play a significant role in brackish

water fisheries, particularly in Gujarat (Joshi et al., 2018). However, further research is necessary to understand mullet diversity, biology, and aquaculture potential in Gujarat for effective fisheries management and aquaculture development.

OBJECTIVES:

1) **Species Diversity and Distribution of Mullets - [Family: Mugilidae Jarocki, 1822] from Coastal Waters of Gujarat, India.**
    a. Taxonomy based on Morphology, Morphometry and Meristic analysis.
    b. Molecular taxonomy and Phylogenetics.
    c. Present Distribution status of Mullets in Gujarat.
2) **Environmental (Water Parameters) and biological aspects of *Mugil cephalus* (Linnaeus 1758) from selected Coastal and Estuarine Zone of Gujarat.**
    a. Water parameters analysis of selected stations of Marine and Estuarine Zones of Gujarat.
    b. Length-Weight Relationship and Fulton's Condition Factor of *Mugil cephalus* (Linnaeus, 1758).
    c. Gonadosomatic Index and Hepatosomatic Index of *Mugil cephalus* (Linnaeus, 1758).
3) **Status and Potential assessment of Mullet culture in Gujarat, India.**
    a. A proximate analysis - Moisture, Total Ash, Total Fat, Total Protein and Carbohydrate content of *Mugil cephalus* (Linnaeus, 1758).
    b. Organoleptic study of *Mugil cephalus* (Linnaeus, 1758).

MATERIALS & METHODS:

STUDY SITES:

To study the species diversity of family Mugilidae Jarocki, 1822, samples were collected from major landing centres of the Gujarat coast. To study the biological aspects and aquaculture potential of *Mugil cephalus* (Linnaeus 1758), two sites were compared *viz.* Narmada estuary and Diu backwaters (20° 43' 46"N 70° 59' 13"E (Fig. 1).

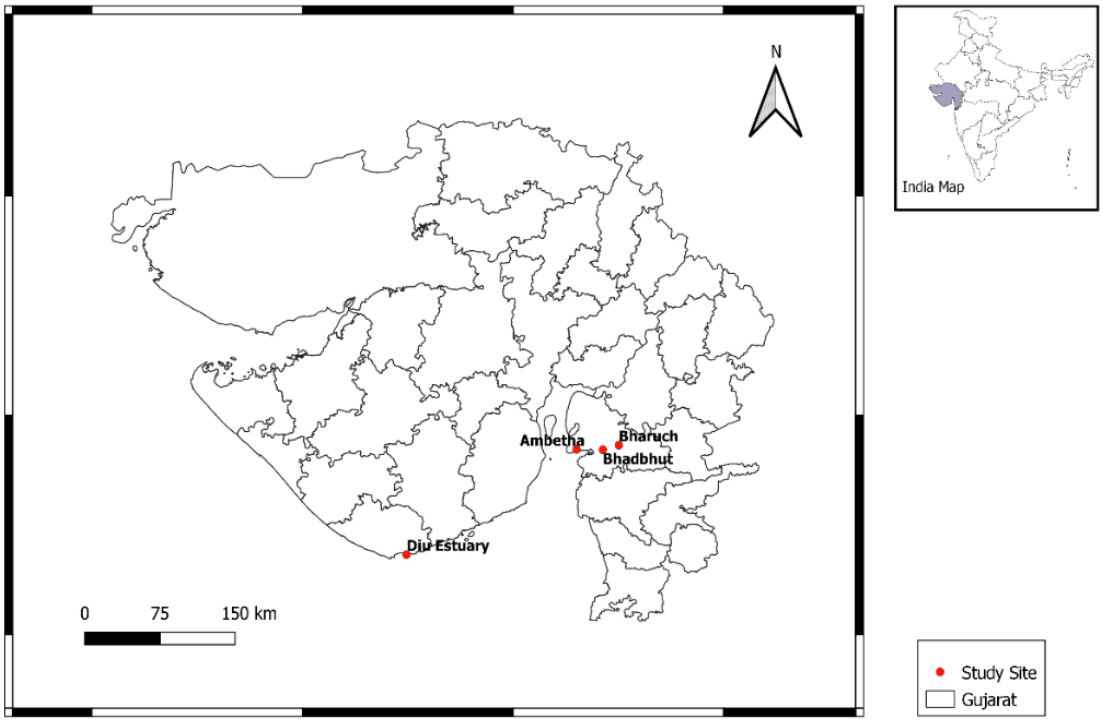

Figure 1: Gujarat State, India: Study sites: (01) Narmada estuary: Bharuch, Bhadbhut and Ambetha (02) Diu lagoon.

METHODOLOGY:

Methodology will be mainly categorised under three parts.

01) To study the diversity and distribution of Family Mugilidae Jarocki, 1822

- To study the existing species diversity of mullets, fresh samples were collected from the major estuarine area and fish landing centres of Gujarat Coast over a period of two years *i.e.,* from December 2020 to November 2022.

1a. To study Morphology, Morphometry and Meristic characters of mullets.

In the field, morphological characteristics such as the presence of adipose eyelid and coloration were observed, and photographs were taken. Specimens were then preserved and transported to the laboratory at The Maharaja Sayajirao University of Baroda for further examination. In the laboratory, morphological features were examined meticulously. Species identification was confirmed using authenticated literature (Day, 1888; Thomson, 1997). Seventeen morphometric characters were recorded, measured

using a centimeter scale, divider, and forceps to the nearest centimeter. Meristic analysis involved counting branchiostegal rays, fins, spines, rays, lateral, and transverse scales.

1b. Molecular taxonomy and Phylogeny

The tissue from frozen specimens was collected and stored at -20°C. DNA extraction was conducted in the Freshwater and Marine Biology laboratory at The Maharaja Sayajirao University of Baroda. The mitochondrial gene Cytochrome Oxidase I (COI) was amplified from extracted DNA. After DNA extraction, quantification was performed by measuring the absorbance ratio at 260nm and 280nm. Agarose Gel Electrophoresis was then conducted. For DNA amplification, Polymerase Chain Reaction (PCR) was carried out using One Taq® Standard Buffer and template DNA. The PCR products were sent for Sanger sequencing. Sequence analysis was performed using sequencing analysis version 5.4 (Applied Biosystems) and BioEdit (Hall, 2013). Consensus sequences were generated by aligning gene sequences from forward and reverse primers. These sequences were analyzed using Basic Local Alignment Search Tool (BLAST) on NCBI (Altschul et al., 1990; Lobo, 2008). A phylogenetic tree will be constructed using MEGA-10 software (Kumar et al., 2016).

1c. Distribution status of mullets:

Data on the distribution of mullets in Gujarat was compiled from available literature and field visits. Environmental parameters such as pH, temperature, salinity, dissolved oxygen, and total dissolved solids were measured at selected stations using standard equipment. Measurements were taken in triplicate for validation.

(i) pH: Aquasol Digital Handheld pH Meter (AM-PH-01) was used for pH measurements over a two-year period.

(ii) Temperature: Digital thermometer (MEXTECH – ST9264) was used to measure temperature.

(iii) Salinity: Erma Handheld Portable Refractometer (Brix 0-100‰ Salinity) was used to measure salinity.

(iv) Total Dissolved Solids (TDS): Aquasol Digital Handheld TDS Meter (AM-TDS-01; 0 to 19990 PPT) was used to measure TDS.

(v) Dissolved Oxygen (DO): Winkler method was employed to determine DO levels.

Length-weight relationships (LWR) and Fulton's condition factor (K) of *Mugil cephalus* were assessed over 24 months based on lunar cycles. Total length and body weight were measured to calculate LWR using the equation W = aLb (Le Cren, 1951). Fulton's condition factor (K) was calculated using the formula K = 100 × (BW/TL3), where BW is total body weight and TL is total length (Fulton, 1904).

Gonadosomatic index (GSI) and hepatosomatic index (HSI) of *Mugil cephalus* were determined monthly. GSI was calculated as (BW - GW/BW) × 100, where GW is gonad weight, and HSI was calculated as (BW - LW/BW) × 100, where LW is liver weight (Render et al., 1995; Albieri & Araújo, 2010).

Status and Potential assessment of Mullet culture in Gujarat, India.

Moisture Content Analysis: Take 5g of tissue and place it onto a Petri dish. Transfer to an oven set at 100°C for 3 hours. Calculate moisture content using the formula: Moisture content (%) = (Weight of Wet sample - Weight of dried sample) / Weight of wet sample x 100 (AOAC, 1995).

Determination of Total Ash: Calculate ash content using the formula: Ash content (%) = (Z - X) / (Y - X) x 100, where X is the weight of empty crucible, Y is the weight of crucible + sample, and Z is the weight of crucible + ash after complete ashing (AOAC, 1995).

Carbohydrate Analysis: Carbohydrate content is analyzed using the anthrone method (Hedge and Hofreiter, 1962), with glucose as the standard.

Lipid Estimation Method: The lipid content is analyzed using the chloroform-methanol method (Folch et al., 1957).

Protein Estimation: Protein content is analyzed using the Coomassie Brilliant Blue G-250 method, commonly known as the Bradford Assay.

Organoleptic Study: Post-mortality changes such as aroma, color, texture, and acceptability are evaluated using the hedonic scale, ranging from 1 (extreme dislike) to 5 (extreme liking) (Klein & Bardy, 1984; Rana et al., 2020). Five samples of *Mugil cephalus* are assessed until deterioration occurs.

RESULTS:

Seven species of mullets were recorded along the Gujarat coast: *Crenimugil seheli*, *Mugil cephalus*, *Planiliza parsia*, *Planiliza planiceps*, *Planiliza tade*, *Planiliza subviridis*, and *Rhinomugil corsula*. They belong to the Mugilidae family and Mugiliformes order. Morphological descriptions were provided for each species. Molecular identification confirmed the presence of *Mugil cephalus*, *Planiliza tade*, and *Planiliza subviridis*, with *P. subviridis* being newly barcoded from the Gujarat coast. Phylogenetic analysis revealed relationships among these species, with *P. subviridis* forming a monophyletic group with *Moolgarda seheli* and displaying paraphyly to other mullet species. Mugil cephalus exhibited paraphyly to *Planiliza tade* and polyphyly to other mullet species. The phylogeny resolved as (*Oedalechilus labiosus* + *Osteomugil cf. perusii* + (*Planiliza subviridis* + *Moolgarda seheli* + (*Liza parsia* + *Liza klunzingeri* + (*Planiliza tade* + *Mugil cephalus* + (*Planiliza macrolepis* + *Moolgarda perusii* + (*Rhinomugil corsula* + (*Chelon carinatus* + (*Valamugil buchanani* + *Minimugil cascasia*)))))))) (Fig. 2).

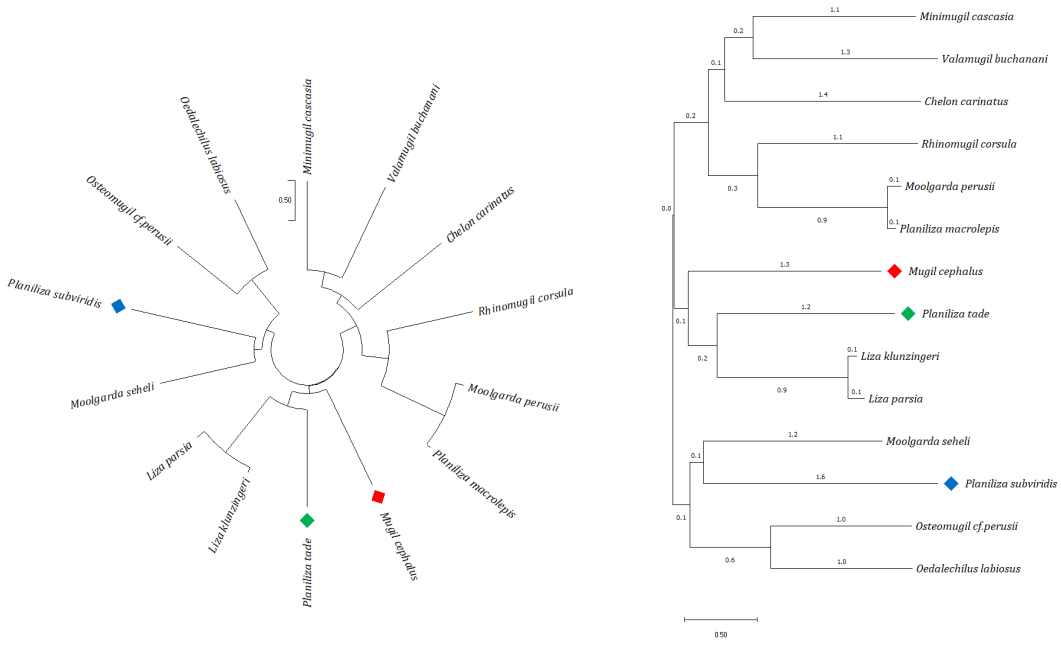

Figure 2: Phylogenetic Analysis of Mullets of Gujarat.

The analysis of environmental parameters, including pH, temperature, salinity, dissolved oxygen (DO), and total dissolved solids (TDS), in Diu Lagoon and Narmada Estuary over two consecutive years yielded significant findings. Firstly, in Diu Lagoon, pH remained relatively stable over the study period, with a slight decrease observed in the

upstream area of Ambetha in August 2022. Temperature showed consistent variations, with the coldest temperature recorded in December 2020 and the hottest in June 2022. Salinity exhibited fluctuations, with the lowest recorded in January 2021 and the highest in February 2022. Dissolved oxygen levels fluctuated as well, with the lowest in June 2021 and the highest in January 2021. Total dissolved solids also varied, with the lowest in December 2021 and the highest in August 2022. In the Narmada Estuary, distinct patterns emerged at different sites. In Bharuch, pH showed a strong negative correlation with salinity, indicating an inverse relationship, while temperature displayed a significant negative correlation with pH and a positive correlation with salinity. Dissolved oxygen exhibited a significant positive correlation with temperature and a negative correlation with salinity. In Bhadbhut, similar correlations were observed, with pH negatively correlated with salinity and temperature positively correlated with salinity. Dissolved oxygen showed a significant negative correlation with temperature. Ambetha exhibited weaker correlations overall, with pH showing a weak positive correlation with salinity, temperature negatively correlated with pH and DO, and DO negatively correlate with temperature and TDS (Table 1-4).

Table 1: Correlation matrix among physico-chemical parameters of water from Diu Lagoon region, Gujarat, India

	pH	*Temp.*	*Salinity (ppt)*	*DO*	*TDS*
pH	1				
Temp. (°C)	-0.039**	1			
Salinity (ppt)	-0.128**	0.107**	1		
DO (mg/l)	0.201**	-0.728**	-0.019**	1	
TDS (mg/l)	-0.071**	0.406**	0.039**	-0.525**	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 2: Correlation matrix among physico-chemical parameters of water from Bharuch, Narmada Estuary, Gujarat, India

	pH	*Temp.*	*Salinity (ppt)*	*DO*	*TDS*
pH	1				
Temp. (°C)	-0.681**	1			
Salinity (ppt)	-0.855**	0.529**	1		
DO (mg/l)	0.389**	-0.694**	-0.207**	1	

TDS (mg/l)	-0.838**	0.497**	0.919**	-0.268**	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 3: Correlation matrix among physico-chemical parameters of water from Bhadbhut, Narmada Estuary, Gujarat, India

	pH	*Temp.*	*Salinity (ppt)*	*DO*	*TDS*
pH	1				
Temp. (°C)	-0.209**	1			
Salinity (ppt)	-0.787**	0.546**	1		
DO (mg/l)	0.123**	-0.680**	-0.307**	1	
TDS (mg/l)	-0.653**	-0.334**	0.389**	0.142**	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 4: Correlation matrix among physico-chemical parameters of water from Ambetha, Narmada Estuary, Gujarat, India

	pH	*Temp.*	*Salinity (ppt)*	*DO*	*TDS*
pH	1				
Temp. (°C)	-0.026**	1			
Salinity (ppt)	0.077**	0.110**	1		
DO (mg/l)	0.044**	-0.703**	-0.121**	1	
TDS (mg/l)	-0.065**	0.309**	0.005**	-0.431**	1

** Correlation is significant at the 0.01 level (2-tailed).

Biological aspects of *Mugil cephalus* (Linnaeus 1758) from selected Coastal and Estuarine Zone of Gujarat:

Length-Weight Relationship:

Table 5. The data represents the Length-Weight Relationship of *M. cephalus* from the Diu lagoon and Narmada estuary.

Study Site	Year	Sex	N	Total Length (cm)		Total Weight (g)		Regression Parameters					Growth (t-test)	P-value
				Min	Max	Min	Max	"a"	95% CI of "a"	"b"	95% CI of "b"	R^2		
Diu	Dec-20 to Nov-21	♂	120	10	23.8	10.76	108.26	0.166	0.147-0.187	2.817	2.717-2.918	0.963	**b<3**	HS
		♀	120	12.5	29.4	21.37	251.73	0.18	0.157-0.207	2.772	2.667-2.878	0.958	**b<3**	HS
	Dec-21 to Nov-22	♂	120	11	24	12.76	112.16	0.176	0.153-0.203	2.789	2.673-2.899	0.953	**b<3**	HS
		♀	120	13	29.2	28.33	258.39	0.191	0.169-0.217	2.753	2.565-2.849	0.964	**b<3**	HS
Bharuch	Dec-20 to Nov-21	♂	120	13.8	24.7	25.64	120.46	0.165	0.096-.0282	2.86	2.436-3.284	0.602	**b<3**	HS
		♀	120	15.8	26.7	48.46	216.92	0.325	0.256-0.412	2.369	2.190-2.547	0.854	**b<3**	HS
	Dec-21 to Nov-22	♂	120	13.2	25.4	25.86	128.09	0.192	0.137-0.267	2.733	2.472-2.994	0.784	**b<3**	HS
		♀	120	15.3	30.2	41.98	243.11	0.294	0.221-0.393	2.425	2.209-2.641	0.807	**b<3**	HS
Bhadbhut	Dec-20 to Nov-21	♂	120	11.6	26.2	24.66	119.65	0.657	0450-0.959	2.472	2.146-2.646	0.544	**b<3**	S
		♀	120	14.5	28.2	39.38	238.9	0.302	0.248-.368	2.411	2.256-2.563	0.892	**b<3**	HS
	Dec-21 to Nov-22	♂	120	12.6	25.6	29.26	130.27	0.368	0.268-0.504	2.238	1.992-2.483	0.734	**b<3**	S
		♀	120	13.6	27.3	35.74	233.48	0.254	0.214-0.301	2.549	2.416-2.682	0.924	**b<3**	HS
Ambetha	Dec-20 to Nov-21	♂	120	10.3	23.9	12.8	106	0.236	0.201-0.277	2.532	2.403-2.662	0.927	**b<3**	HS
		♀	120	14.6	29.1	38.21	249.72	0.261	0.206-0.331	2.498	2.315-2.681	0.861	**b<3**	HS
	Dec-21 to Nov-22	♂	120	12.2	24.5	19.11	141.46	0.213	0.168-0.270	2.648	2.458-2.835	0.866	**b<3**	HS
		♀	120	13.4	29.6	34.45	269.17	0.224	0.195-0.257	2.46	2.353-2.745	0.954	**b<3**	HS

The results revealed that all the study sites show the negative allometric growth (Table 5). It indicates that the fish is not gaining weight as the length increases. This may be due to the less availability of the food, competition for the food, stress and anthropogenic activities. The population of Diu shows better growth compare to Narmada estuarine area. At Narmada, the Bhadbhut shows comparatively higher negative allometric growth then the Bharuch and Ambetha. Bhadbhut is a major landing centre and this may also be a hurdle in fish growth.

Condition Factor:

The results of Fulton's condition factor revealed that the condition of the population of *M. cephalus* from Diu is better than the Narmada River. The female population shows the fluctuation in the condition throughout the year which indicates the biological changes in their body (Fig 3).

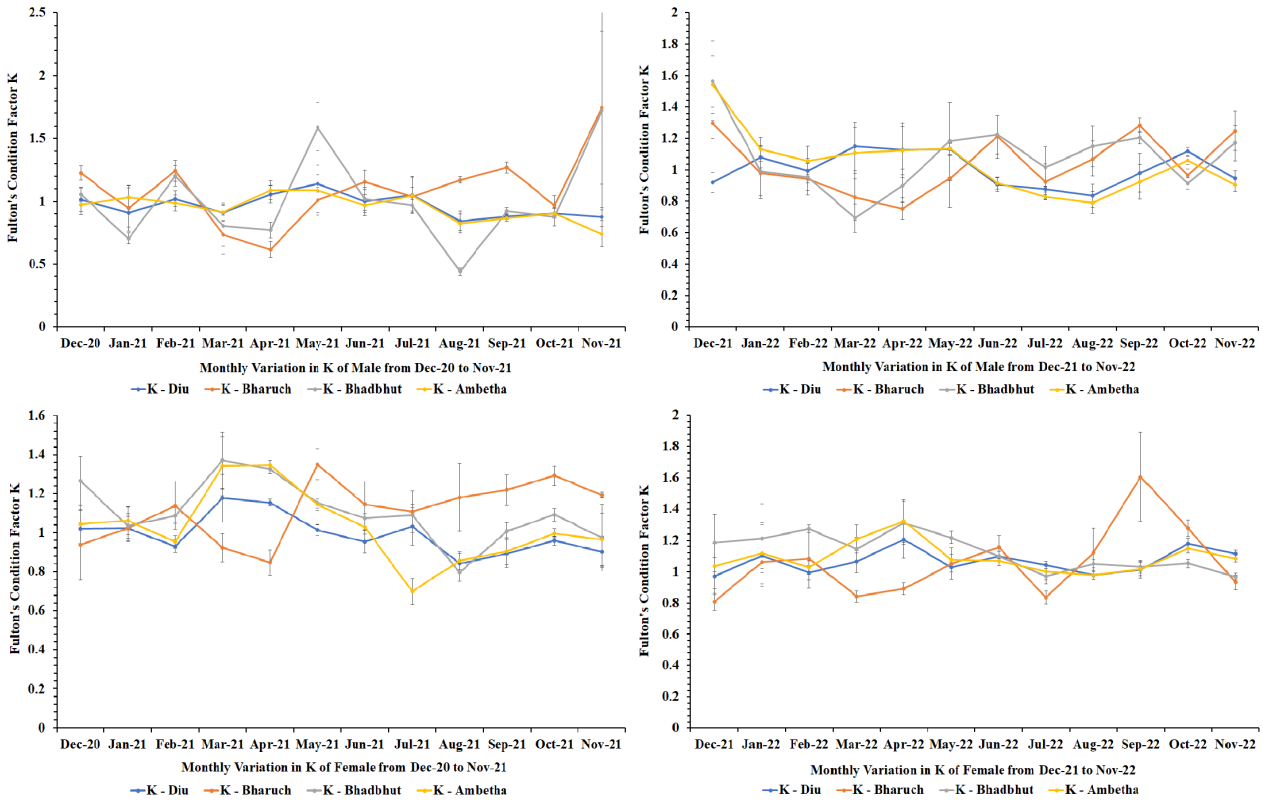

Figure 3: Monthly Variation in Fulton's CF from Diu, Bharuch, Bhadbhut and Ambetha respectively from Dec-2020 to Nov-2022: (a) Male from Dec-20 to Nov-21, (b) Male from Dec-21 to Nov-22, (c) Female from Dec-20 to Nov-21, (d) Female from Dec-21 to Nov-22.

Gonadosomatic Index and Hepatosomatic Index

I_g levels varied across sites and years, with males generally showing lower I_g levels compared to females. In males, lowest I_g levels were in Diu (Nov-21) and Bharuch, Bhadbhut, and Ambetha (May-21). Highest I_g levels for males were in Ambetha (Dec-20) and Bhadbhut (Jan-21) during 2020-2021, and in Ambetha (Jan-21) and Diu (Jan-22) during 2021-2022. Females showed lowest I_g levels in Bharuch (Jun-21) and Ambetha, Bhadbhut, and Diu (Jul-21) during 2020-2021, and in Bharuch (May-22) during 2021-2022. Highest I_g levels for females were in Bhadbhut (Nov-21) and Diu (Mar-21) during 2020-2021, and in Bhadbhut (Dec-21) and Diu (Dec-21) during 2021-2022.

I_h values varied across sites and years, with males generally showing lower values compared to females. Lowest I_h values for males were in Diu (Jan-21) and Bharuch, Bhadbhut, and Ambetha (Jan-21) during 2020-2021, and in Bhadbhut (Feb-22) during 2021-2022. Highest I_h values for males were in Ambetha (Jul-21) during 2020-2021, and in Diu (Dec-21) during 2021-2022. Lowest I_h values for females were in Ambetha, Diu, Bhadbhut, and Bharuch (Jan-21) during 2020-2021, and in Ambetha (Jan-22) during 2021-2022. Highest I_h values for females were nearly identical in Ambetha and Diu (May-21) during 2020-2021, and in Diu (May-22) during 2021-2022 (Fig 4-10).

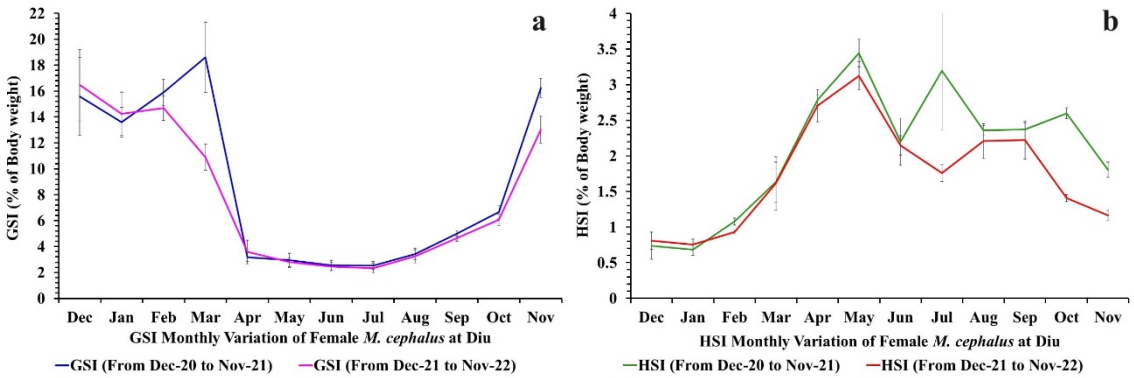

Figure 4 a & b: (a) Gonadosomatic Index (I_g) and (b) Hepatosomatic Index (I_h) of Female *M. cephalus* in Diu lagoon from December 2020 to November 2022

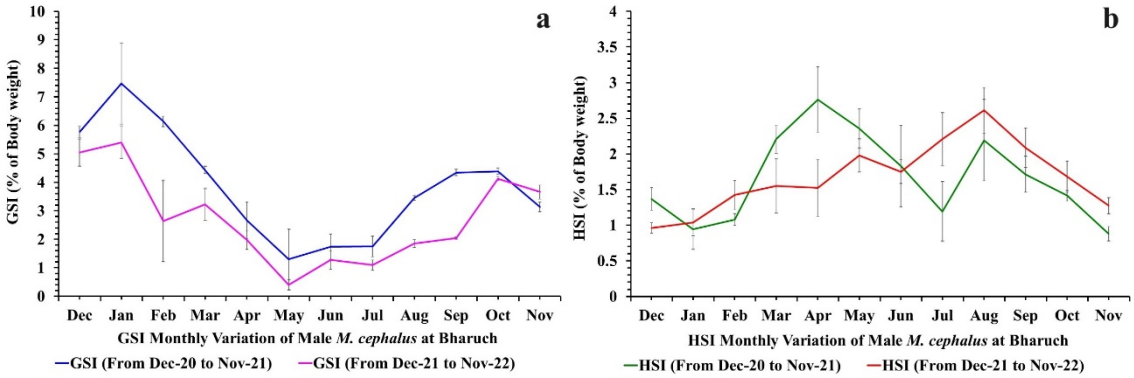

Figure 5 a & b: (a) Gonadosomatic Index (I_g) and (b) Hepatosomatic Index (I_h) of Male *M. cephalus* in Bharuch, Narmada Estuary from December 2020 to November 2022

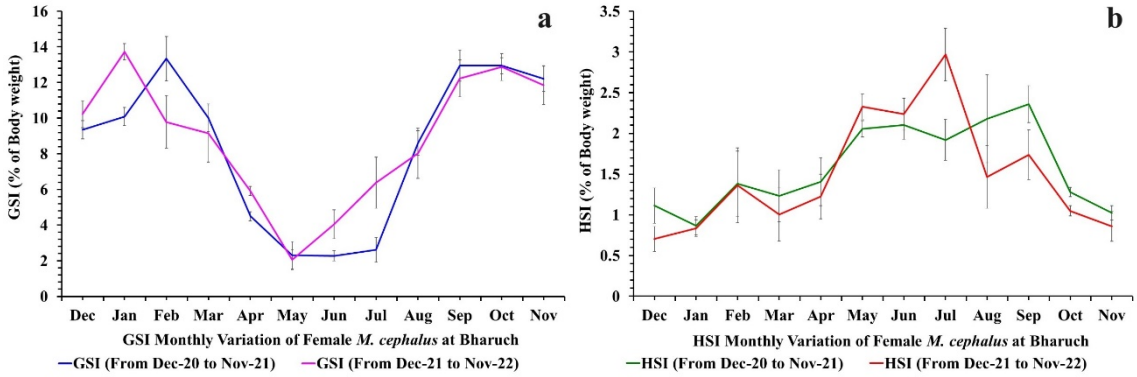

Figure 6 a & b: (a) Gonadosomatic Index (I_g) and (b) Hepatosomatic Index (I_h) of Female *M. cephalus* in Bharuch, Narmada Estuary from December 2020 to November 2022

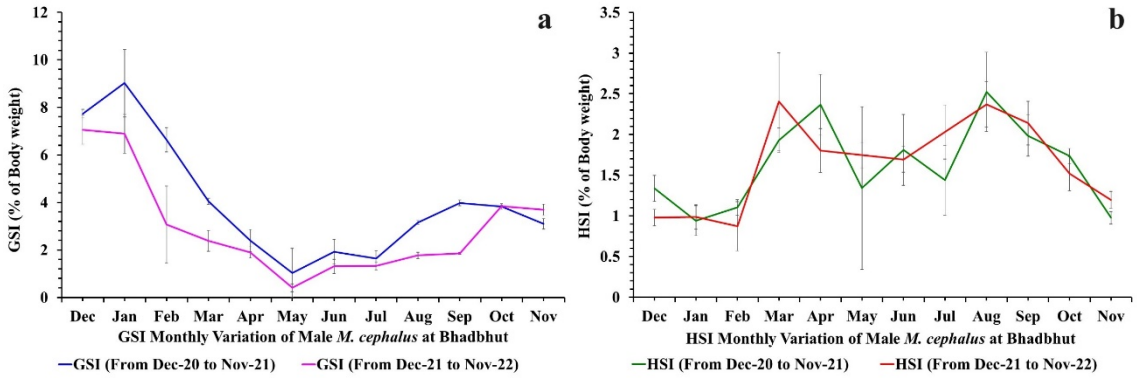

Figure 7 a & b: (a) Gonadosomatic Index (I_g) and (b) Hepatosomatic Index (I_h) of Male *M. cephalus* in Bhadbhut, Narmada Estuary from December 2020 to November 2022

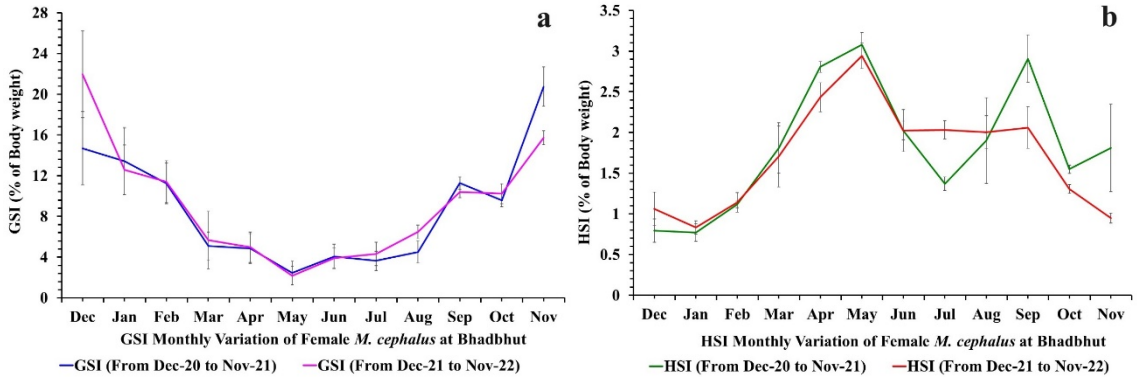

Figure 8 a & b: (a) Gonadosomatic Index (I_g) and (b) Hepatosomatic Index (I_h) of Female *M. cephalus* in Bhadbhut, Narmada Estuary from December 2020 to November 2022

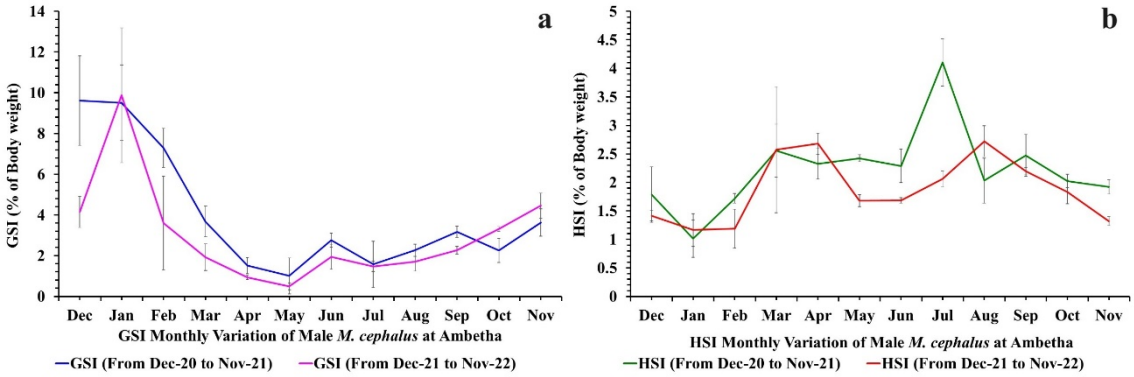

Figure 9 a & b: (a) Gonadosomatic Index (I_g) and (b) Hepatosomatic Index (I_h) of Male *M. cephalus* in Ambetha, Narmada Estuary from December 2020 to November 2022

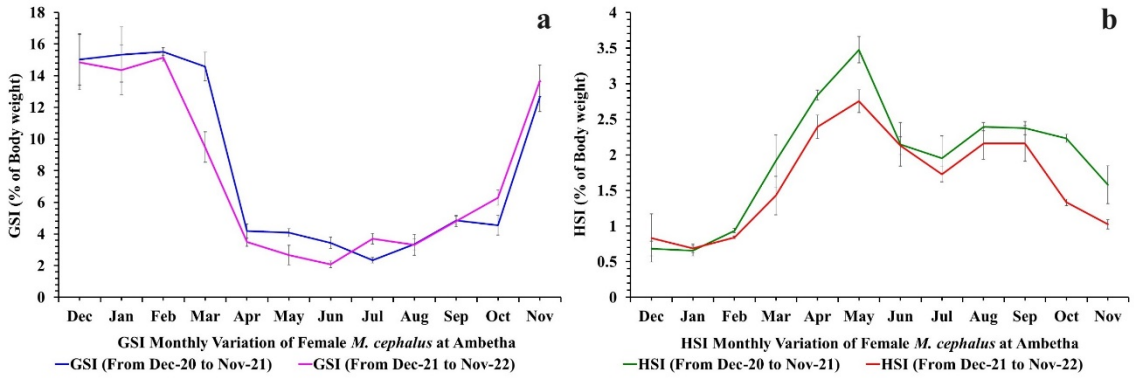

Figure 10 a & b: (a) Gonadosomatic Index (I_g) and (b) Hepatosomatic Index (I_h) of Female *M. cephalus* in Ambetha, Narmada Estuary from December 2020 to November 2022

The proximate content analysis of *Mugil cephalus* revealed significant variations in moisture, ash, lipid, protein, and carbohydrate content across different study sites and months. Moisture content ranged from 73.13% to 80.97%, with higher values observed during spawning and post-spawning months. Ash content varied from 0.81% to 1.84%, with higher values during post-spawning and summer months. Lipid content ranged from 9.10% to 24.95%, with higher levels observed during breeding and post-spawning periods. Protein content ranged from 49.25% to 65.78%, with higher values during winter and post-spawning months. Carbohydrate content varied from 5.63% to 8.67%, with higher levels observed during spawning and post-spawning seasons. Additionally, an aquaculture potential study indicated that the optimal salinity range for *M. cephalus* survival was around 20ppt, based on growth rate observations over six months. Furthermore, the proximate content analysis of specimens reared in different salinity tanks showed higher moisture, ash, lipid, protein, and carbohydrate content in the 20ppt tank compared to the others. These findings provide valuable insights into the nutritional composition and growth dynamics of *M. cephalus*, contributing to its aquaculture potential assessment (Fig. 11-19).

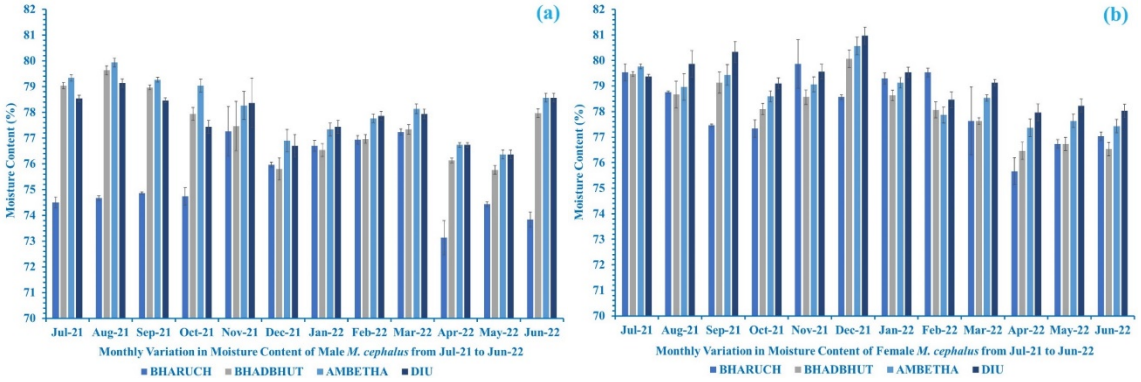

Figure 11: Monthly variation in Moisture Content (%) analysis of (a) Male and (b) Female *Mugil cephalus* from Diu lagoon and Narmada estuary of Gujarat, India

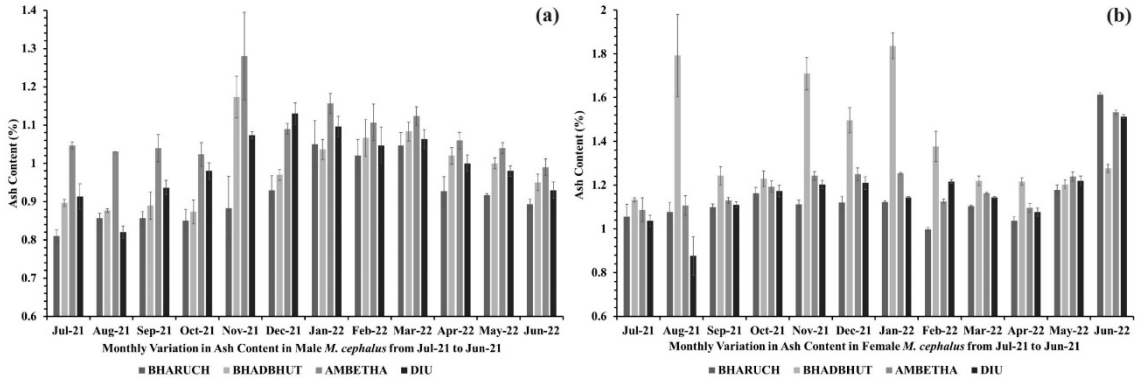

Figure 12: Monthly variation in Ash Content (%) analysis of (a) Male and (b) Female *Mugil cephalus* from Diu lagoon and Narmada estuary of Gujarat, India

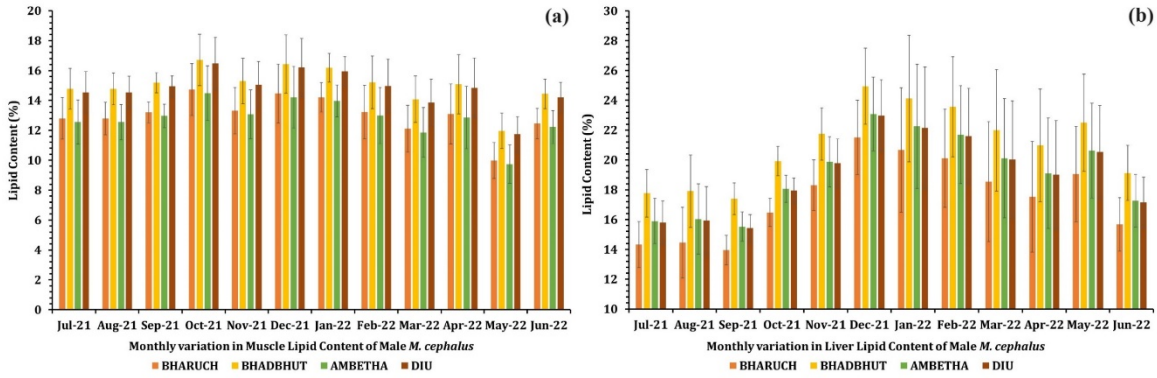

Figure 13: Monthly variation in Lipid Content (%) analysis of (a) Male – Muscle tissue and (b) Male – Liver tissue of *Mugil cephalus* from Diu lagoon and Narmada estuary of Gujarat, India

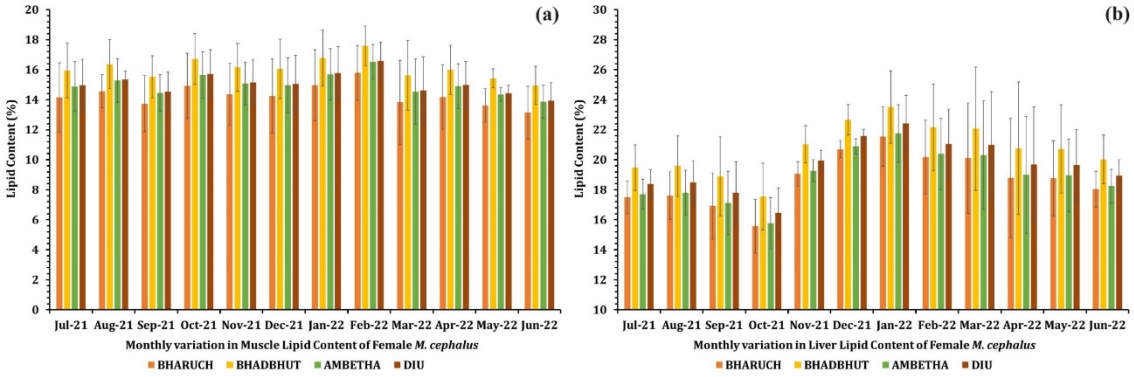

Figure 14: Monthly variation in Lipid Content (%) analysis of (a) Female – Muscle tissue and (b) Female – Liver tissue of *Mugil cephalus* from Diu lagoon and Narmada estuary of Gujarat, India

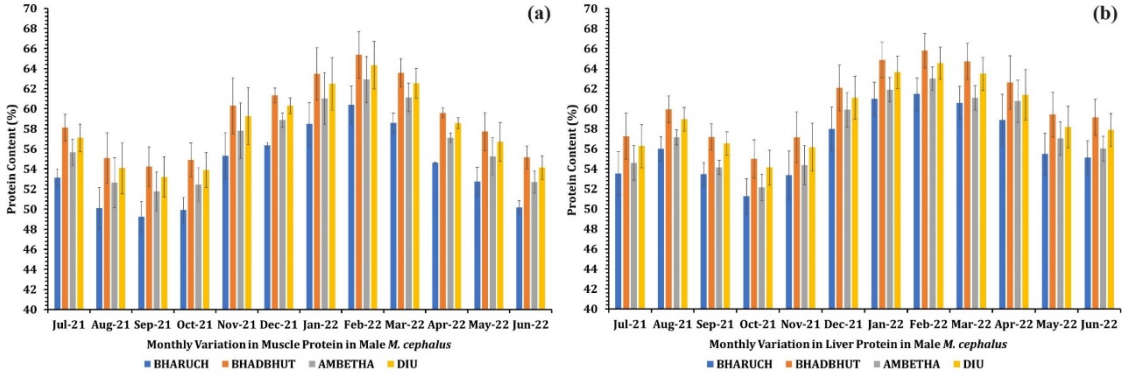

Figure 15: Monthly variation in Protein Content (%) analysis of (a) Male – Muscle tissue and (b) Male – Liver tissue of *Mugil cephalus* from Diu lagoon and Narmada estuary of Gujarat, India

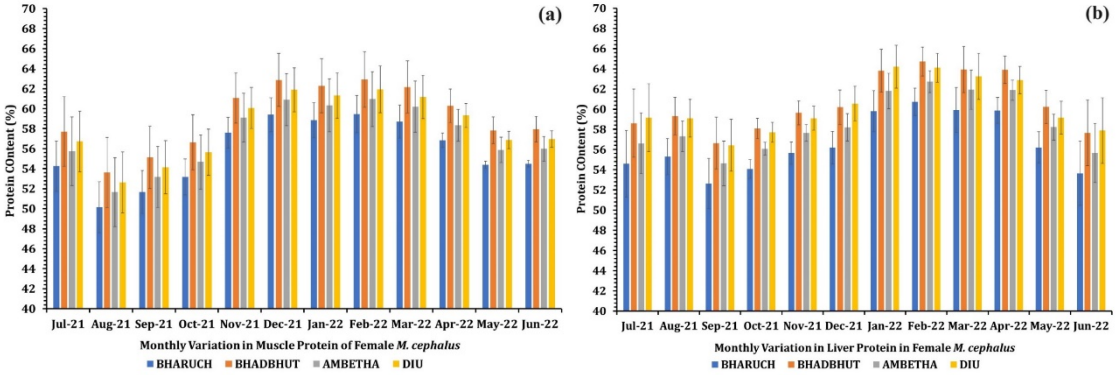

Figure 16: Monthly variation in Protein Content (%) analysis of (a) Female – Muscle tissue and (b) Female – Liver tissue of *Mugil cephalus* from Diu lagoon and Narmada estuary of Gujarat, India

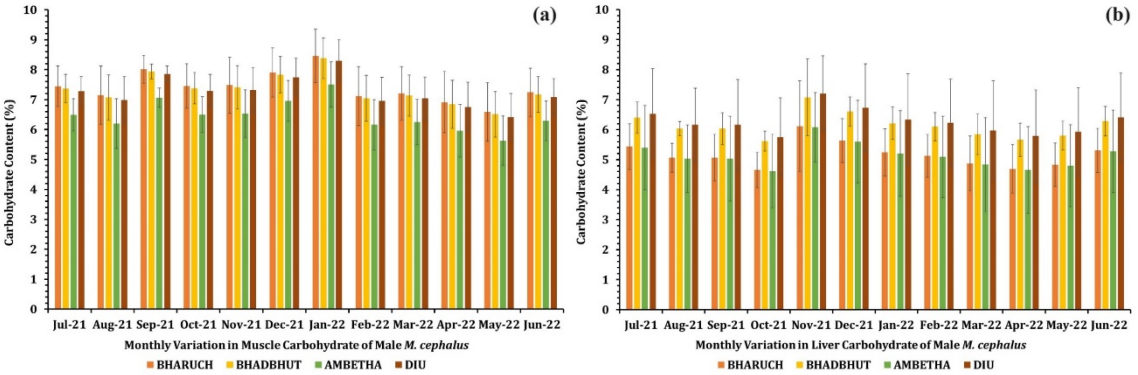

Figure 17: Monthly variation in Carbohydrate Content (%) analysis of (a) Male – Muscle tissue and (b) Male – Liver tissue of *Mugil cephalus* from Diu lagoon and Narmada estuary of Gujarat, India

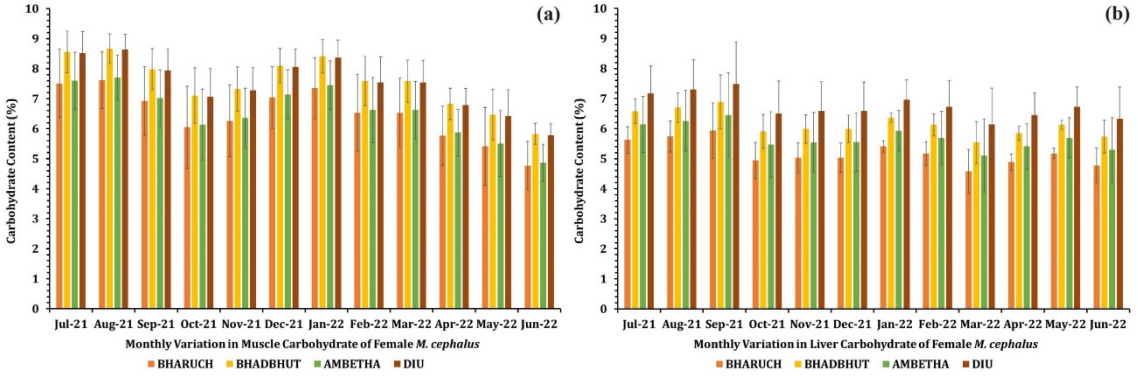

Figure 18: Monthly variation in Carbohydrate Content (%) analysis of (a) Female – Muscle tissue and (b) Female – Liver tissue of *Mugil cephalus* from Diu lagoon and Narmada estuary of Gujarat, India

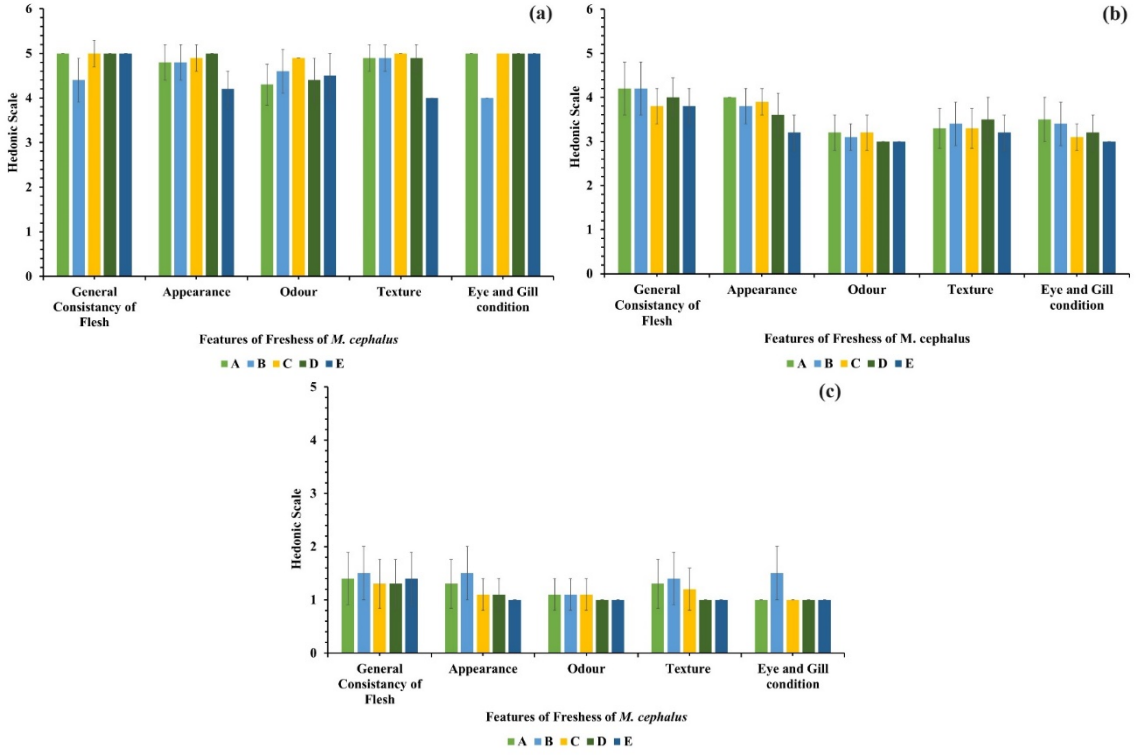

Figure 19: Organoleptic Study of *Mugil cephalus* based on hedonic scale of five points

Concluding Remarks:

In conclusion, this study conducted along the Gujarat coast provides valuable insights into the diversity and genetic structure of mullet species, particularly *Mugil cephalus*, contributing to our understanding of marine biodiversity. Molecular techniques identified seven mullet species, with *Planiliza subviridis* identified for the first time in Gujarat. The study highlights the suitability of different sites for aquaculture based on physico-chemical parameters, with Diu emerging as the most conducive location for *M. cephalus* growth and survival. Additionally, length-weight relationships, condition factors, and biochemical analyses offer important data for fisheries management and aquaculture development. Future research should focus on habitat-specific investigations, aquaculture policies, and further enhancing the nutritional value of *M. cephalus*, ultimately contributing to sustainable aquaculture practices and conservation efforts.

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