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Understanding the Environmental Drivers of Hilsa Fish (*Tenualosa ilisha*) Distribution and Morphology in The Haldi Estuarine Wetlands of South Bengal

Jyoti Das
Research Scholar, RKDF University, Ranchi, India
Assistant Professor, Raja Peary Mohan College, West Bengal, India

Corresponding Author: * Jyoti Das

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Abstract

Hilsa shad (*Tenualosa ilisha*) is one of the most economically and ecologically important anadromous fish species of the northern Bay of Bengal and associated estuarine and wetland systems. Increase in environmental fluctuations and habitat degradation has highly influenced the distribution of hilsa and its biomass composition in estuarine wetlands. The present study investigates limnological, pedological, hilsa biomass and biomass composition in estuarine wetlands of Haldi river tributaries of southern Bengal.

The present investigation was conducted year-long across three wetland stations, Geonkhali, Sutahata, Nayachar where varying environmental conditions were present. Seasonal and spatial variations in limnological parameters including pH, temperature, DO, free CO2, nitrate, salinity, and phosphate. The pedological characters such as soil pH, available nitrogen, available phosphorus, sand, silt, and clay content were also assessed. Hilsa biomass was classified into different classes as per their weight and statistically evaluated using one-way ANOVA, Spearman's rank correlation, and Principal Component Analysis (PCA).

The research revealed important variances in space of a number of environmental variables as well as hilsa resource biomass and distribution. Highest seasonal variability was exhibited by salinity. Phosphate concentration was displayed a strong positive relationship with hilsa biomass in Stations 1 and 2 ($p < 0.01$). Station 3 had the highest total biomasses of hilsa and also a larger proportion of bigger-sized individuals at low salinities. The second season peak in biomass was post-monsoon and monsoon seasonal. PCA revealed that water phosphate concentration and soil nitrogen were positively correlated and also that salinity and silt content were negatively related to total hilsa biomass. The first two principal components account for 42.78% of the total variance.

The results in the present study suggests that nutrient availabilities, particularly phosphorus and nitrogen positively regulate hilsa biomass and increase in salinity restricts hilsa distribution within estuarine wetlands. This study emphasizes the significance of limnological and pedological parameters in shaping the productivity of hilsa and gives baseline information for estuarine fisheries management and conservation planning in Sundarban – associated wetland.

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KEYWORDS: *Tenualosa ilisha*, hilsa biomass, estuarine wetlands, salinity, limnological parameters, pedological characteristics, PCA.

I. INTRODUCTION

The hilsa shad (***Tenualosa ilisha***) is an anadromous clupeid fish inhabiting the northern parts of Bay of Bengal and adjoining river system which migrates between marine, estuarine and freshwater habitats [1-3]. It underpins one of the region's largest single-species fisheries and holds major economic and cultural value in Bengal through its contribution to national fish production, GDP and fishing livelihoods [1,4,5] However, hydrological alteration, overfishing and habitat degradation threaten long-term sustainability [6,3,7].

Hilsa occupy coastal and shelf waters for feeding and migrate into estuaries and freshwater wetlands for spawning and early development; their distribution and migration are tightly coupled to river discharge, productivity and plankton dynamics [8,9,6] Peak catches coincide with enhanced primary productivity and high river flow in the Ganga–Brahmaputra–Meghna delta, while dams and barrages that alter flow regimes reduce migratory habitat quality and commercial yields in south Bengal estuaries [8,6].

Hooghly-type tropical estuarine wetlands show strong spatial and temporal variability in salinity, nutrients, dissolved oxygen and turbidity due to rainfall, tidal mixing and human impacts, shaping plankton communities and fish assemblages [8,10,11]. Eutrophication can depress species richness and favour tolerant taxa, signalling environmental stress (Duque et al., 2020). For hilsa, such gradients interact with fishing pressure to influence migration timing and the availability of spawning and nursery zones [9,6].

Individually, hilsa exhibit marked phenotypic and physiological plasticity across habitats, with growth, condition and life-history traits reflecting environmental quality and exploitation intensity [12,7,13]. Evidence of growth overfishing, habitat-linked variation in condition and stress physiology, together with panmictic but low-diversity stocks, underscores the need for site-specific studies, especially in degraded systems like the upper Haldi estuarine wetland [3,14].

II. LITERATURE REVIEW

Salinity emerges as a central control: seasonal river discharge, climate-driven sea-level rise and upstream regulation alter salinity fields, forcing contraction or upstream shifts of spawning grounds during dry seasons or under intensified saltwater intrusion [15,16]. Hydrological change also restructures productivity cycles and planktonic food webs, critically affecting juvenile survival [15]. Hilsa show marked morphological plasticity along these gradients; morphometric studies indicate habitat-linked differences in body size and shape across salinity and hydrodynamic conditions, likely reflecting adaptive optimization of swimming performance and osmoregulation, while intensive fishing selectively removes larger size classes and modifies population structure [13,17].

Overexploitation, habitat degradation (pollution, land-use change, siltation) and sub-optimal sanctuary management have driven regional stock declines [13,16]. Hydrology-based modelling in the Narmada system shows that composite indices of migratory habitat availability and quality explain most hydrological variability and strongly predict Hilsa catches, with future declines projected under current flow regimes [16]. Empirical thresholds—such as <0.1 psu for spawning and 0–2 psu for nurseries in Tetulia–Meghna—further underscore the tight coupling between freshwater influx, salinity and reproductive habitat suitability [18 9].

Heavy metal contamination in spawning and feeding grounds (e.g., elevated Cr, Cd, Pb in Tetulia and Padma–Meghna) has been documented, with organs like gill and liver accumulating higher burdens than muscle and some non-carcinogenic risks indicated for consumers [14,19,20]. However, across riverine and marine systems, most studies emphasize that metal uptake is mediated by habitat, behaviour and water chemistry, and clear causal links to Hilsa morphology or abundance remain unproven, prompting calls for targeted experimental bioaccumulation research [21,22]. Socio-economically, estuarine fishing communities are acutely vulnerable to ecological change and climate variability but employ adaptive strategies such as livelihood diversification, aquaculture, and participatory conservation **[16]**.

III. RESEARCH METHODOLOGY

A. Study Area-

The present study was conducted in the southern Bengal wetlands of the Sundarban region, West Bengal, India. Three major fishing wetland sites namely Nayachar (Station 1), Sutahata (Station 2) and Geonkhali (Station 3) were selected for the survey due to their active fisheries-dependent communities and livelihood reliance on estuarine fishing activities.

B. Sampling Design -

A cross-sectional survey design was undertaken for the study. A total of 150 fishermen (N = 150) were selected through purposive random sampling, and the individual fisherman was taken as the unit of analysis. Data were collected using a structured questionnaire covering socio-economic, occupational and yield variables. The interview schedule comprised of both open-ended and close-ended questions. A pioneer interview was conducted and the necessary changes were incorporated into the final interview.

C. Data Collection-

Primary data were collected through face-to-face interviews conducted at the selected fishing sites using the structured interview schedule. Water and soil samples were collected from the three sites and they were analysed for seven limnological characters (pH, Temperature, DO, free CO2, salinity, Nitrate and Phosphate concentrations) and pedological characters (soil pH, available Nitrogen, available Phosphorous, Sand content, silt content and clay content)

D. Statistical Analysis-

Data are expressed as mean ± standard deviation (SD). The normality of the data was evaluated using the Shapiro-Wilk test. Differences among sampling stations were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's multiple comparison test. Statistical significance was at p level of, $p < 0.05$.

Spearman's rank correlation coefficient (ρ) was used to evaluate the correlation between hilsa biomass and environmental factors. A correlation heatmap and scatter plots were employed to illustrate correlation coefficients and significance levels.

The multivariate correlations between limnological variables, pedological properties and hilsa biomass were studied using Principal Component Analysis (PCA). For PCA, all variables were z-score scaled to avoid scale effects before PCA. PCA biplots were utilised to show the variable loadings and sample scores. The percentage variance explained by each principal component is calculated. The statistical analyses were performed using Origin Pro and PAST 4(1):9 (Paleontological Statistics Software).

D. RESULTS

A. Spatial and temporal variability of limnological parameters across sampling stations.

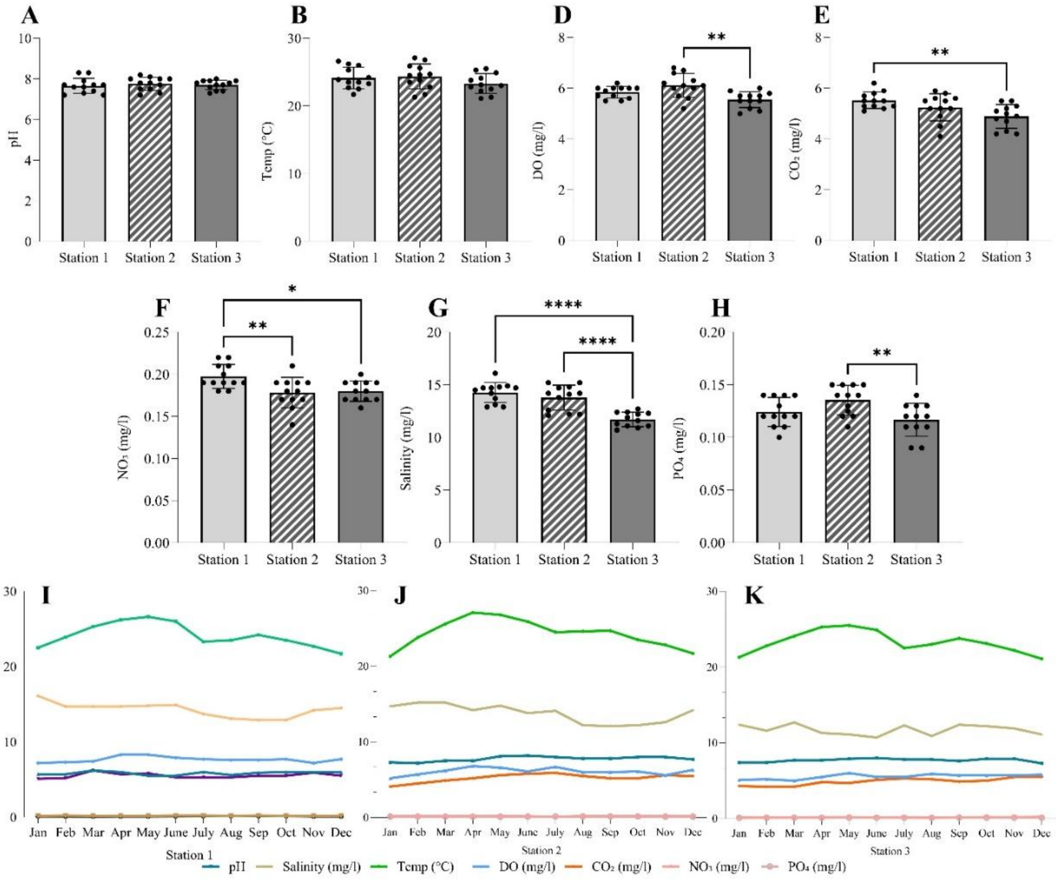

Figure 1: (A) Water pH, (B) water temperature (°C), (C) dissolved oxygen (DO; mg L^{-1}), (D) free carbon dioxide (CO_2; mg L^{-1}), (E) nitrate (NO_3^-; mg L^{-1}), (F) salinity (mg L^{-1}), and (G) phosphate (PO_4^{3-}; mg L^{-1}) recorded across the three stations. Panels (H–J) illustrate the monthly variation of limnological parameters at Station 1, Station 2, and Station 3, respectively, from January to December. Data were tested for normality by Shapiro-wilk test. Statistical differences among stations were analysed using one-way ANOVA followed by Tukey's multiple comparison test. Data are presented as mean ± SD. (n=12, *$p < 0.05$, **$p < 0.01$, and ****$p < 0.0001$)

The spatial variation of limnological parameters (Figure 1) among the three sampling stations revealed that pH and temperature (Figure 1A-B) was relatively stable across stations and the difference among the three stations were non-significant. The dissolved oxygen (DO) concentration (Figure 1C) varied significantly among the stations, with the highest DO level at Station 2 (≈6.0 mg/L). Free carbon dioxide (CO_2) concentration (Figure 1D) was observed to be significantly lower at Station 3 compared to Station 1 ($p < 0.01$). Nitrate (NO_3^-) concentration (Figure 1E) was significantly elevated at Station 1 (≈0.20 mg/L) compared with the other two stations, Station 2 ($p < 0.01$) and Station 3 ($p < 0.05$). Salinity (Figure 1F) showed the greatest spatial variation, with the highest level recorded at Station 1 (≈14.5 mg/L), followed by Station 2 (≈13.8 mg/L) and significantly lower salinity was observed at Station 3 (≈11.5 mg/L; $p < 0.0001$). Phosphate concentration (PO_4^{3-}) (Figure 1G) was significantly higher at Station 2 (≈0.14 mg/L) compared to Station 3 (≈0.11 mg/L) ($p < 0.01$).

Seasonal variations were observed in all the seven measured parameters (Figure 1H–J). Water temperature and salinity increased during the pre-monsoon period and reduced during the monsoon and post-monsoon periods. Dissolved oxygen was observed to be within the range of 6 to 8 mg/L throughout the year, whereas nitrate and phosphate concentrations exhibited very minute monthly variations.

B. Spatial and seasonal variations in pedological characteristics across the three sampling stations.

Soil pH (Figure 2A) was observed to be alkaline within the range of 8.5–8.8. Soil pH was significantly higher at Station 2 compared to Station 3 ($p < 0.05$). At station 2, the available nitrogen and phosphorus (Figure 2B-C) increased significantly ($p<0.01$) compared to the other two stations. Sand content (Figure 2D) was distributed homogeneously and non-significantly among the stations. In contrast, the silt content (Figure 2E) was significantly higher at Station 1 compared to Station 2 ($p < 0.001$–0.0001). There was a significant increase in the clay content at Station 2 compared to Stations 1 and 3 (Figure 2F; $p < 0.0001$). Seasonal variations were observed in all the pedological parameters (Figure 2G–I). Available nitrogen and phosphorus increased before monsoon and decreased during monsoon months. Soil pH remained relatively consistent throughout the year. During monsoon period silt content was reduced and during post-monsoon period, it increased while sand content remained constant at all the three stations.

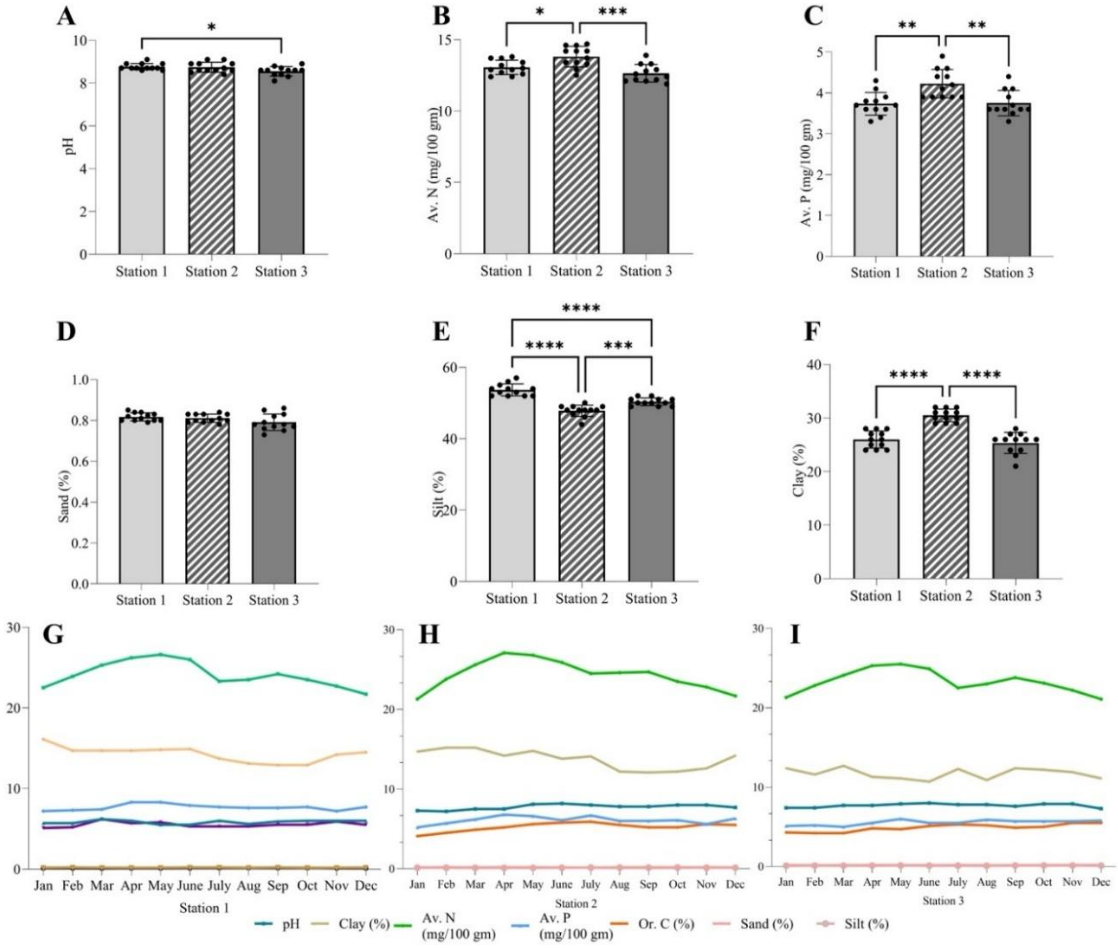

Figure 2: The pedological characteristics varied significantly among the three sampling stations. Comparison of pedological parameters among the three sampling stations showing (A) soil pH, (B) available nitrogen (Av. N), (C) available phosphorus (Av. P), (D) sand content, (E) silt content, and (F) clay content. Panels (G–I) illustrate monthly fluctuations in pedological parameters at Stations 1, 2, and 3, respectively, from January to December. Data were tested for normality by Shapiro-wilk test. Statistical differences among stations were analysed using one-way ANOVA followed by Tukey's multiple comparison test. Data are presented as mean ± SD. ($n=12$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, ****$p < 0.0001$).

C. Spatial and temporal variation in hilsa biomass composition among the three sampling stations.

Among the different weight classes, the 1.1 kg hilsa category (Figure 3A) exhibited the highest average biomass at Station 3, with non-significant difference. Similarly, the 0.95 kg weight class (Figure 3B) showed significantly higher biomass at Station 3 compared to Station 2 ($p < 0.05$). The 0.75 kg, 0.55 kg and 0.35 kg (Figure 3D-E) weight classes showed low to moderate variation among stations but no significant differences were observed.

The proportional biomass distribution (Figure 3F) exhibited striking differences among the three stations. Station 1 was dictated by the 0.35 kg and 0.55 kg classes, whereas Station 2 showed a greater incidence of the 0.75 kg class. On the other hand, Station 3 showed a higher proportion of the 1.1 kg and 0.95 kg classes. Total biomass (Figure 3G) was highest at Station 3 and differed significantly from Stations 1 and 2 ($p < 0.05$) while no significant difference was observed between Stations 1 and 2.

Seasonal fluctuations in biomass were observed at all stations (Figure 3H–J). Peak biomass was recorded during July–September with the highest proportion from the 0.35 kg and 0.55 kg weight classes. Marked seasonal peak was seen during the monsoon and post-monsoon phases at station 3, while reduced biomass levels were noted in winter and early summer in all the stations.

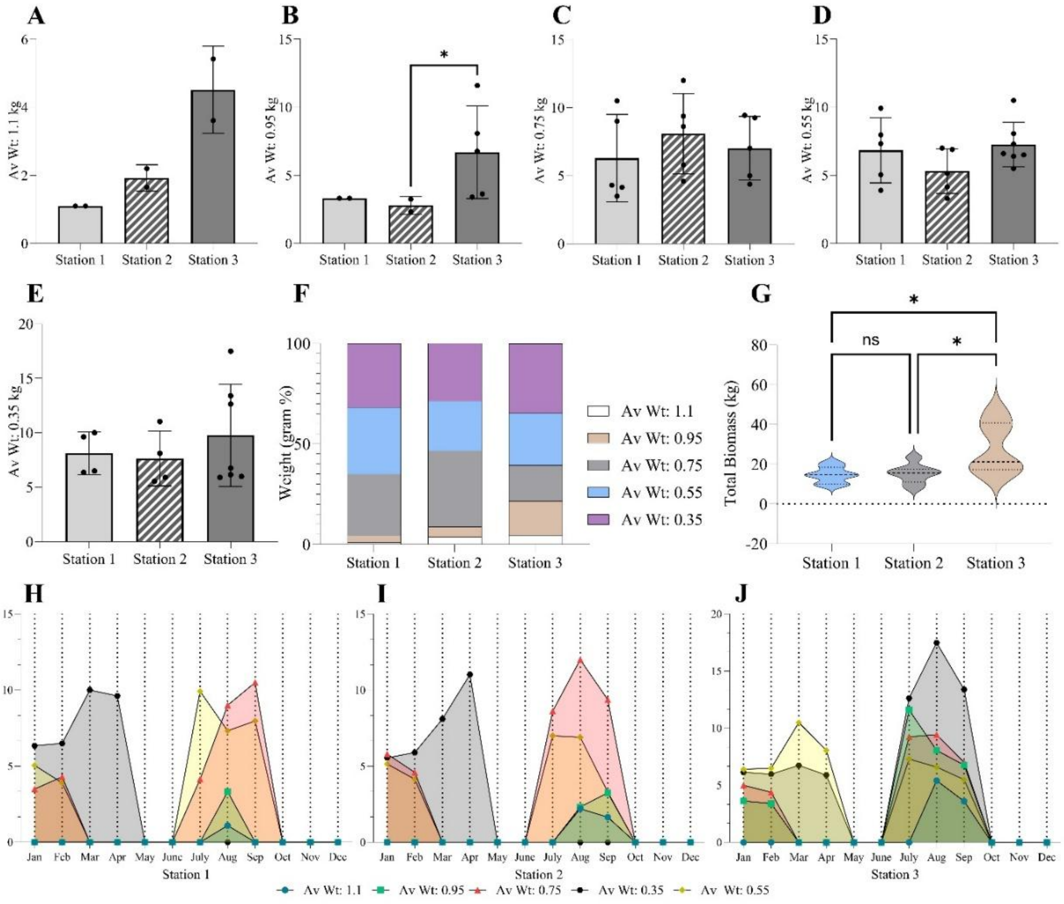

Figure 3: Spatial and seasonal variation in fish biomass composition across different weight classes at the three sampling stations. Distribution of fish biomass among five weight classes (1.1 kg, 0.95 kg, 0.75 kg, 0.55 kg, and 0.35 kg) across three sampling stations. Panels (A–E) represent the mean biomass (kg) of individual weight classes at Stations 1–3. Panel (F) shows the proportional contribution of each weight class to the total biomass. Panel (G) illustrates the variation in total biomass among stations using violin plots. Panels (H–J) depict monthly fluctuations in biomass of different weight classes at Stations 1, 2, and 3, respectively. Data were tested for normality by Shapiro-wilk test. Statistical differences among stations were analysed using one-way ANOVA followed by Tukey's multiple comparison test. Data are presented as mean ± SD. (n=12, $^*p < 0.05$; ns = non-significant)

D. Correlation of fish biomass with limnological and pedological variables across sampling stations.

Correlation analysis (Figure 4) revealed clear associations between hilsa biomass, incidence, limnological and pedological variables across the three sampling locations. A positive correlation was recorded between hilsa biomass and phosphate concentration at Station 1 (Figure 4A) and Station 2 (Figure 4B), while a negative correlation was recorded between hilsa biomass and salinity at Station 1 (Figure 4C).

Heatmap analysis (Figure 4D) revealed that at Station 1 hilsa biomass was positively correlated with water pH, nitrate, phosphate, available nitrogen, available phosphorus, silt, and clay content while negative correlated with temperature, dissolved oxygen, free carbon dioxide, salinity, soil pH, organic carbon, and sand content. A substantially positive correlation was observed between water phosphate concentration and hilsa biomass ($p < 0.01$).

A positive correlation was observed in hilsa biomass in station 2 with water pH, carbon dioxide, phosphate, nitrogen, organic carbon, and sand content while negative correlation was observed with temperature, dissolved oxygen, salinity, available phosphorus, silt, and clay content. Significant positive and negative correlations were recorded for phosphate concentration ($p < 0.01$) and salinity ($p < 0.05$) respectively.

At Station 3, positive correlations were recorded with water pH, dissolved oxygen, carbon dioxide, salinity, available nitrogen and clay content while negative correlations were recorded with temperature, soil pH, nitrate, phosphate concentration, available phosphorus, organic carbon, sand content and silt content. No significant correlations were observed at Geonkhali, Station 3. Phosphate was the most important positive index for hilsa biomass, showing significant positive associations at Stations 1 and 2. However, salinity was negatively correlated with hilsa biomass and a significant inverse link was found at Station 2.

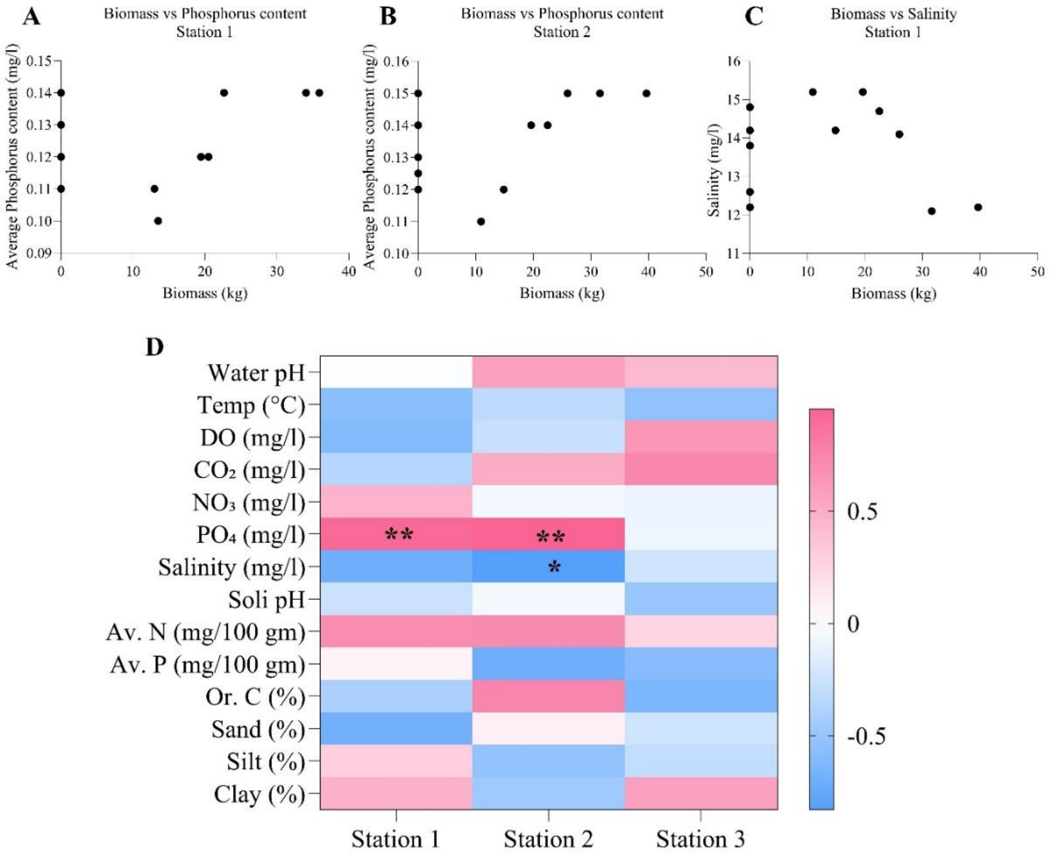

Figure 4: Relationships between fish biomass and environmental variables in the study area. Scatter plots showing the relationships between fish biomass and phosphate concentration (PO_4^{3-}) at Station 1 (A) and Station 2 (B), and between fish biomass and salinity at Station 1 (C). Panel (D) presents a heatmap of Spearman's correlation coefficients between fish biomass and selected limnological and pedological variables across the three sampling stations. Red and blue colours indicate positive and negative correlations, respectively, with colour intensity reflecting the strength of the association. Spearman's rank correlation was performed to check correlation ($*p < 0.05$, $**p < 0.01$). pHw = water pH; pHs = soil pH; Pw = water phosphate concentration (PO_4^{3-}); N = water nitrate concentration (NO_3^-); Soil N = available soil nitrogen; Ps = available soil phosphorus; OC = organic carbon; DO = dissolved oxygen; CO_2 = carbon dioxide.

E. Principal Component Analysis (PCA) of environmental variables and hilsa biomass across sampling stations.

Principal Component Analysis (PCA) (Figure 5) was carried out to evaluate the relationships among limnological variables, pedological parameters, hilsa biomass and hilsa incidences. The first two principal components specified 42.78% of the total variance with PC1 and PC2 accounting to 23.94% and 18.84% variances respectively.

PC1 had positive loadings for silt content, salinity, available nitrogen, and organic carbon, while negative loadings were observed for clay content, soil phosphorus, dissolved oxygen, water pH, soil pH, temperature, and sand content. PC2 was positively correlated with water phosphorus, total hilsa biomass, soil nitrogen, clay content and organic carbon. Carbon dioxide, salinity, temperature, sand content, dissolved oxygen and soil pH had negative loadings. The PC1 and PC2 scores are shown in Table 1.

Total hilsa biomass was significantly correlated with water phosphorus and soil nitrogen. Salinity and silt content were clustered on the positive side of PC1 and were positioned away from the biomass vector. Similarly, carbon dioxide and temperature were negatively loaded on PC2.

All four quadrants showed a large spread of sample scores indicating a great deal of spatial and temporal variability between the sampling stations.

PC1 was positively associated with silt content, salinity, available nitrogen, and organic carbon, whereas negative loadings were observed for clay content, soil phosphorus, dissolved oxygen, water pH, soil pH, temperature, and sand content. PC2 was positively associated with water phosphorus, total hilsa biomass, soil nitrogen, clay content, and organic carbon, while negative loadings were recorded for carbon dioxide, salinity, temperature, sand content, dissolved oxygen, and soil pH. The PC1 and PC2 scores are represented in Table

1. Total hilsa biomass was significantly positively correlated with water phosphorus and soil nitrogen. Salinity and silt content were clustered on the positive side of PC1 and were positioned away from the biomass vector. Similarly, carbon dioxide and temperature were negatively loaded on PC2.

A wide dispersion of sample scores was observed across all four quadrants, indicating substantial spatial and temporal variability among the sampling stations.

Abbreviations: pHw = water pH; pHs = soil pH; Pw = water phosphate concentration (PO_4^{3-}*); N = water nitrate concentration (*NO_3^-*); Soil N = available soil nitrogen; Ps = available soil phosphorus; OC = organic carbon; DO = dissolved oxygen;* CO_2 *= carbon dioxide.*

Table 1: PC1 and PC2 scores of all the variables of the Biplot

Var	PC1	PC2
Total Biomass (kg)	-0.11614	0.505658
pHw	-0.34401	-0.36123
°C	-0.21249	-0.68821
O	-0.56373	-0.53452
CO_2	-0.00936	-0.65917
N	0.577099	-0.01559
Pw	-0.44628	0.625182
Salinity	0.362582	-0.35833
pHs	-0.20483	-0.44155
Soil N	-0.67676	0.370004
Ps	-0.65637	-0.25042
OC	0.244921	0.182284
Sand	-0.18827	-0.49441
Silt	0.852602	-0.07027
Clay	-0.82452	0.222637

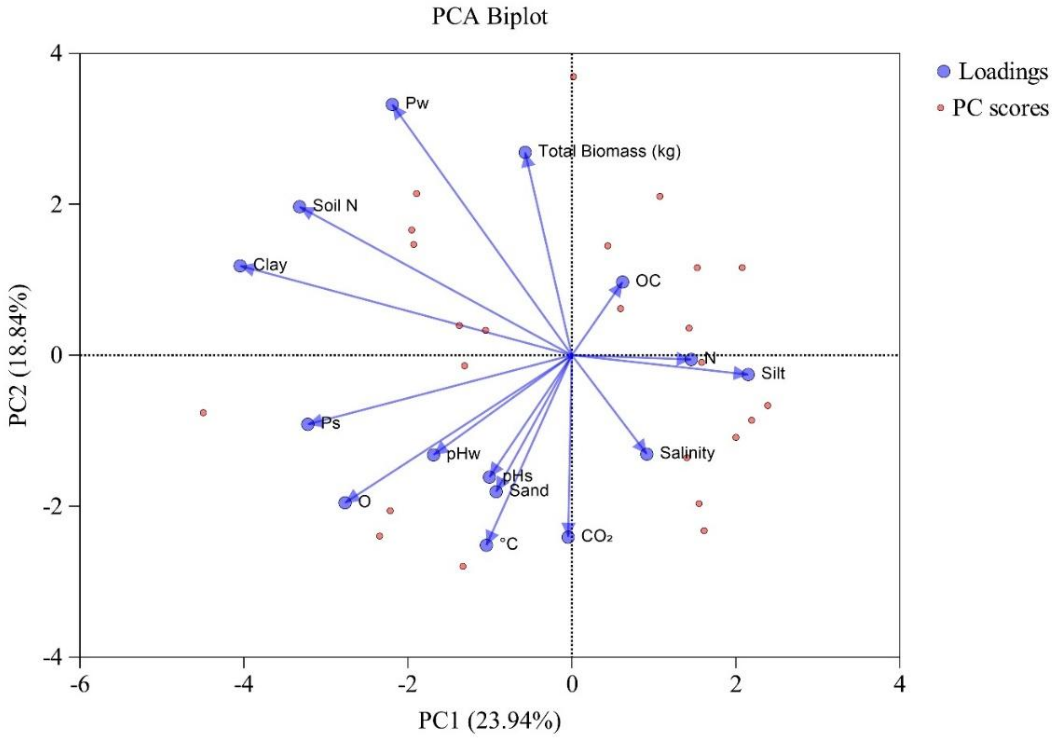

Figure 5: Principal component analysis (PCA) biplot showing the relationships among limnological variables, pedological characteristics, and fish biomass. Principal Component Analysis (PCA) biplot illustrating the association between fish biomass and selected limnological and pedological variables across the three sampling stations. Blue vectors represent variable loadings, while red points represent sample scores. The first principal component (PC1) explained 23.94% of the total variance and the second principal component (PC2) explained 18.84%, accounting for a cumulative variance of 42.78%. Variables with vectors pointing in similar directions are positively correlated, whereas vectors oriented in opposite directions indicate negative correlations. The length of each vector reflects its contribution to the principal components. *pHw = water pH; pHs = soil pH; Pw = water phosphate concentration (*PO_4^{3-}*); N = water nitrate concentration (*NO_3^-*); Soil N = available soil nitrogen; Ps = available soil phosphorus; OC = organic carbon; DO = dissolved oxygen;* CO_2 *= carbon dioxide.*

E. DISCUSSION

The present study revealed substantial geographical variation in limnological, pedological, hilsa biomass and incidence among the three sampling stations indicating a complex interplay of physicochemical gradients with ecological productivity. While parameters like pH and water temperature were found to be relatively uniform across the study area; parameters like salinity, dissolved oxygen, nutrient concentrations and soil texture displayed significant spatial variation which explains the pattern observed in hilsa biomass distribution to a certain extent.

The uniformity of water pH within marginally alkaline ranges of all stations indicates that this parameter was not a limiting factor for aquatic biota. This is in agreement with the findings of similar estuarine and brackish water systems where the stability of pH supports diverse biological communities [22]. So too the slight variation in the water temperature.

In contrast, considerable spatial variance in DO concentration was observed with Station 2 exhibiting highest DO levels (implicating higher variability in water quality and habitat compatibility across locations). High concentrations of dissolved oxygen are often related with greater aerobic respiration capability of aquatic organisms and often indicate low organic loading or increased photosynthesis [23]. This conclusion is supported by the comparable trend of carbon dioxide concentration being lowest at Station 3, implying that the sites differed in the balance of respiratory and photosynthetic processes. This variance could be caused by changes in the density of aquatic vegetation, the intake of organic matter or the hydrological connectivity as these factors affect the metabolic regime of the wetland habitats [24].

Nutrient dynamics contrasted the three stations, viz., water nitrate and phosphate concentrations. The high nitrate concentrations at Station 1 may be the result of increased allochthonous input of nutrients, perhaps from agricultural runoff or decomposition of organic matter, and the increased concentrations of phosphate at Station 2 may be an indication of local enrichment from sediment-water exchanges or point sources [25]. Correlation analysis showed a consistent positive relation between hilsa biomass and phosphate concentration at several sites, highlighting the function of phosphorous as a limiting factor in aquatic food web. Primary productivity increases with phosphorus availability and this cascades through trophic levels to promote larger hilsa yields [26]. This observation corroborates the results of principal component analysis where water phosphorus and soil nitrogen grouped closely with total hilsa biomass further emphasising that nutrient enrichment is the basis of biological productivity in this system.

Highest spatial variation was observed in salinity with Station 3 showing significantly lower salinity levels compared to the other stations. The negative connection of salinity with hilsa biomass in Stations 1 and 2 indicated that high salinity may exert physiological restrictions on hilsa populations, particularly so for species with weak osmoregulatory capacity [27]. Notably the reduced salinity at station 3 along with reduced nutrient levels appears to support a high hilsa biomass with a higher proportion of large-sized individuals. This finding could indicate a separate hilsa assemblage which has adapted to lower salinity or lesser competition or predatory pressure in regions of moderate productivity.

The pedological investigation also contributed to the knowledge of the habitat differentiation. Station 2 had far higher accessible nitrogen and phosphorus, and more clay, traits associated with better nutrient retention and soil fertility [28]. The high silt content at Station 1 might affect the sediment stability and the benthic habitat structure in a different manner. The sandy soils found at all locations are representative of the typical substrate of coastal wetlands, but also show that small-scale variations in the clay and silt fractions are capable of producing important ecological differences.

Seasonal trends in hilsa biomass showed that hilsa biomass peaks during the monsoon and post-monsoon periods which is correlated with increased nutrient mobilisation and corollarial increased primary productivity by the planktons [29]. These temporal patterns, combined with the spatial heterogeneity documented herein, emphasise that wetland hilsa communities are shaped by the dynamic intersection of hydrological, edaphic, and nutrient regimes operating across multiple spatial and temporal scales.

F. CONCLUSION

This study evolved into the limnological and pedological characteristics that influences hilsa population of three wetlands associated with Haldi River tributaries. Salinity of water was found out to be one of the important parameters that affects hilsa population. The amount of PO_4^{2-} in water and N_2 in soil are important for hilsa biomass.

Station 3 showed highest salinity.

Hilsa biomass and number was found to be significantly higher in station 3, the station with the least salinity. This shows that hilsa likes to reside in areas with low salinity.

The present work also tried to assess the change in hilsa population across the year. It was found that hilsa populations reached peak during the monsoon and post-monsoon period when the water is nutrient rich. This nutrient rich water actually leads to greater hilsa population.

The present study thus showed that hilsa fish lives in areas with lot of nutrients but less salinity and prefers less sedimented water. These findings are crucial for fishery management and habitat conservationists. They are also integral for monitoring and maintaining the health of wetlands which are under immense stress due to environmental change.

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Conflict of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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About the Corresponding Author

Jyoti Das is a Research Scholar at RKDF University, Ranchi, India, and also serves as an Assistant Professor at Raja Peary Mohan College, West Bengal, India. Her academic interests include teaching and research in her field, with a focus on higher education, academic development, and research-oriented scholarly activities.