Hindawi
Journal of Applied Ichthyology
Volume 2024, Article ID 7208918, 11 pages
https://doi.org/10.1155/2024/7208918

WILEY | Hindawi

Research Article

Stock Evaluation of the Euryhaline Cichlid, *Etroplus suratensis* (Bloch, 1790), from Significant Brackish and Freshwater Regions of India

Ramjanul Haque [1] **Paramita Banerjee Sawant** [1] **Jitendra Kumar Sundaray** [2] **Rajesh Kumar,** [2] **Narinder Kumar Chadha,** [1] **Gouranga Biswas** [1] **Avinash Rasal,** [2] **Priyanka Nandanpawar,** [2] **and Jackson Debbarma** [2]

[1] *ICAR- Central Institute of Fisheries Education, Versova, Mumbai 400061, Maharashtra, India*
[2] *ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar 751002, Odisha, India*

Correspondence should be addressed to Paramita Banerjee Sawant; paramitabanerjee1006@gmail.com

Received 12 September 2023; Revised 4 January 2024; Accepted 23 January 2024; Published 9 February 2024

Academic Editor: Jorge Paramo

The present study evaluates stocks of *Etroplus suratensis* concerning length-weight relationships (LWRs), condition factor (K), and truss analysis from different habitats, *viz.*, West Bengal (freshwater hatchery), Gujarat (brackish water grow-out pond), and Odisha (Chilika lagoon) in India. All the stocks were collected using gill nets with various mesh sizes of 20–50 mm and cast nets with mesh size of 15 mm from February 2021 to September 2021. The total length (L), weight (W), and digital pictures were taken for LWRs and principle component analysis (PCA). The total length (L) and total weight (W) were measured to the nearest 0.1 cm and 0.01 gm, respectively, followed by regression analysis. The values of parameters "b" in the LWRs equation were estimated within the range of 2.50–3.82 and intercept "a" values (0.235–0.779) and "K" (1.07–3.37), respectively, for all different habitats and ecosystems with significant correlation values ($R^2 \geq 0.85$). In truss morphometric analysis, principal component 1 (PC1) contributed the highest (93.1%) and principal component 2 (PC2) contributed 4.6% to the size and shape variation amongst the stocks from different habitats and ecosystems. The scatter plot analysis and canonical variate analysis (CVA) have shown that the Gujarat and West Bengal stocks are closely placed and separated from the Chilika-Odisha stock. Similar variations were also observed in the ANOSIM boxplot analysis, where Chilika-Odisha stock scored higher than the other two stocks. Since data available regarding LWRs and truss morphometry studies of *E. suratensis* from different habitats are limited, the present study will provide a clear insight into the differentiation of *E. suratensis* stocks from different habitats in India. The overall findings of the present study could be utilized for the conservation and sustainable management of *E. suratensis.*

1. Introduction

The pearl spot, *Etroplus suratensis*, is an euryhaline cichlid that is distributed mainly in brackish water along with freshwater ecosystems in India and Sri Lanka [1]. In India, the wild populations have been recorded primarily from the states of Kerala and Tamil Nadu, and some introduced populations were also reported in Goa, Andhra Pradesh, Odisha, and West Bengal [2, 3]. This species has been introduced to many states along India's east, south, and west coast to promote sustainable aquaculture [4]. Understanding population diversity between freshwater and brackish water, wild stock, and hatchery-reared stock from east, south, and west coast of India is essential for stock assessment, its management, and the conservation of an endemic population like *E. suratensis* [5]. Despite this fish's economic and evolutionary importance, there is a dearth of comparative studies of its population or stock characteristics from significant habitats in India, with reference to LWRs, "*K*", truss network system, and PCA-based stock characterization.

Every animal exhibits growth in length and weight during its lifetime, and the relationship between the two has practical and fundamental significance. In fishery assessments, the length-weight relationship is one of the fundamental techniques that produce reliable biological data [6]. Growth parameters used to indicate demographic differences, biological characteristics, and habitat conditions of fish species include the LWR and "*K*" [7]. The "**K**" value gives information on the physiological state of the fish and its well-being. The LWRs can also be used to determine possible differences between distinct stocks of the same species and provide information about the stock condition [8].

The truss network system is an alternative to traditional measurements and is highly impressive in gathering information on size and shape changes [9] among different stocks. It involves systematic measurement of distances (i.e., truss lines) between pairs of landmarks across the body, thus forming a sequential series of connected polygons termed a "trussed" box [10], which covers the entire shape of the fish in the form of a uniform network. Thus, the probability of delineating the morphometric differences among the different fish stocks is increased [11]. Despite the ecological importance of freshwater and brackish water fishes, information on length-weight relationships and condition factors is often limited. Even though there has been some work on truss analysis of riverine and lake fish populations [12, 13], there is no report on truss analysis of *E. suratensis* from varying habitats or ecological regions to date. *E. suratensis* has been reported in the IUCN red list [5] due to anthropogenic interventions such as pollution of water bodies, over-exploitation, and natural habitat destruction [14]. Hence, it is imperative to study the growth variation in population from different habitats and ecosystems of this species from various water bodies, either in the wild or under domestication throughout India. Therefore, the objective of the present study was to evaluate the population characteristics of *E. suratensis* to identify any morphological distinctions that could be useful in differentiating possible stocks occurring in significant habitats and coastal regions of India.

2. Materials and Methods

2.1. Stock Collection. This study was carried out in three different parts of India, such as hatcheries from West Bengal, the grow-out pond of Gujarat, and the Chilika lagoon. Hatcheries near the brackish water region in West Bengal are well established, and the cultural practices depend on formulated feed. The brackish water pond in Gujarat (Navsari region) is 5 km west of Dandi beach, adjacent to the Purna river estuary, bringing in nutrient-rich brackish water for aquaculture. This entire culture is also being practiced by applying formulated feed and natural food. Hydrologically, the Chilika lagoon is influenced by three subsystems, including the Mahanadi river system, rivers flowing in the lagoon from the western catchment, and the Bay of Bengal. This Chilika lagoon receives freshwater from a series of 52 channels in Odisha. Sampling was performed periodically every month from February 2021 to September 2021 at respective sampling stations. The coordinates of the sampling stations are given in Table 1. A total of 440 numbers of *E. suratensis* were collected using gill nets with various mesh sizes (20–50 mm) and cast nets with a 15 mm mesh size [15, 16], and their identity was confirmed with the study of Gunawickrama [17]. The current ecological scenario of *E. suratensis* is depicted in Figure 1.

2.2. Length-Weight Relationship. Total length (L) was measured with a digital caliper (with ±0.1 mm precision) and weighed with an electronic scale to the nearest ± 0.01 g. The length-weight relationship was calculated by the method of least squares using the equation of $W = \mathrm{aL}^{\mathrm{b}}$ with 95% confidence limits of "*a*" and "*b*" along with the coefficient of determination (R^2) determined and logarithmically transformed (Log base 10) into $\mathrm{LogW} = \mathrm{Loga} + \mathrm{bLogL}$ [18, 19], where **W** is the total body weight (g), **L** is the total length (cm), **b** is the regression coefficient, and **a** is the intercept of the regression. LWRs were estimated for both sexes together.

2.3. Condition Factor. The relative condition factor (Krel) of *E. suratensis* was determined according to the following equation of $\mathrm{Krel} = W/(\mathrm{aL}^{\mathrm{b}})$ [6, 20], where, W is the observed total body weight (g) and aL^{b} is the estimated weight from the length-weight relationships. Outliers were detected and removed before fitting linear regression [6]. A good growth state of the fish was identified when the Krel value ≥ 1.0, while a fish in poor growth conditions, the Krel value < 1.0 [20, 21]. A one-sample t-test was used to verify significant differences between the Krel and the expected value of Krel = 1.0 [22].

2.4. Truss Analysis. For digitizing images of fishes, a cyber-shot DSC-W300 digital camera was used. The files were converted from jpeg format to tps format by using tpsUtil [23]. The extraction of truss distances from the digital images of specimens was done with the help of tpsDig2 V2.1 [23] and analyzed using Paleontological Statistics (PAST) software [24]. A total 11-point truss network [25] was constructed using standard morphological landmarks in digitized images, and all landmarks are represented in Table 2 and Figure 2. Truss measurements were taken on 93 specimens of *E. suratensis* fish from three different habitats. Data regarding length, weight, and trusses were recorded for different stocks of *E. suratensis*. During analysis, the outliers were removed.

2.5. Statistical Analysis. Before proceeding with PCA, the data were analyzed for normal distribution and significant differences using one-way ANOVA along with Levene's and Welch's F tests. The data obtained from truss analysis were subjected to data reduction, and interpretation was completed using PCA and CVA in PAST software. Further, the data were analyzed for similarities using ANOSIM. This test

Table 1: Latitude and longitude location of sampling station from different habitats.

Sr. no.	Station	Location/source of collection	Latitude and longitude
1	West Bengal 1	Namkhana (freshwater hatchery 1) (east coast)	21.7699° N, 88.2315° E
2	West Bengal 2	Kakdwip (freshwater hatchery 2) (east coast)	21.8760° N, 88.1853° E
o	Chilika-Odisha 1	Balugaon (brackish water lagoon) (east coast)	20.1783° N, 85.1129° E
o	Chilika-Odisha 2	Brahmagiri (brackish water lagoon) (east coast)	19.7889° N, 85.6126° E
5	Gujarat 1	Navsari (brackish water grow-out pond 1) (west coast)	20.9467° N, 72.9520° E
6	Gujarat 2	Veraval (brackish water grow-out pond 1) (west coast)	20.9159° N, 70.3629° E

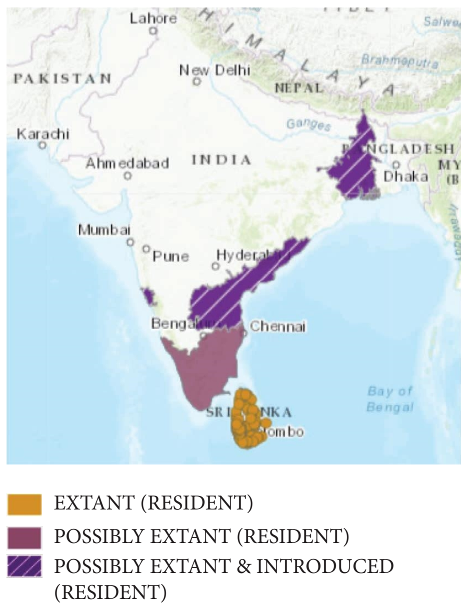

Figure 1: Current scenario of ecological distribution of *E. suratensis* in India. †Source: the IUCN Red List of Threatened species (2019), version 2021-3.

Table 2: Details of landmark and particulars of truss distance.

Sr. no.	Landmark no.	Particulars of truss distance	Nomenclature
1	1	Tip of the snout	TOS
2	2	Upper end of operculum	UEO
3	3	Origin of dorsal fin	ODF
4	4	End of dorsal fin	EDF
5	5	Origin of caudal peduncle (upper side)	OCPU
6	6	End of caudal peduncle (upper side)	ECPU
7	7	End of caudal peduncle (lower side)	ECPL
8	8	Origin of caudal peduncle (lower side)	OCPL
a	9	End of Anal fin	EAF
10	10	Origin of pelvic fin	OPF
11	11	Lower end operculum	LEO

is a generalization of the univariate ANOVA and has the property to consider all variables while calculating similarity among populations based on the Euclidean distance matrix. Statistical analyses, including regression and correlation estimation, were done with Microsoft Office Excel (2013), SPSS ver.22.0, and PAST ver.3.26 software.

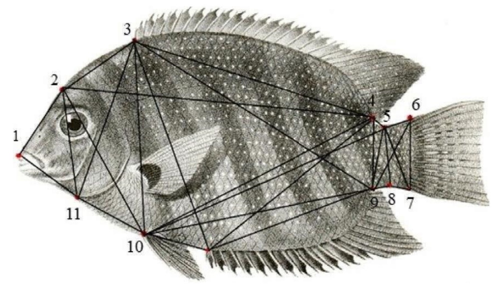

Figure 2: Truss distances with meaningful loadings on *E. suratensis* as evidenced by PCA.

3. Results

3.1. Length-Weight Relationship. In the present study, 440 specimens of *E. suratensis* belonging to *Cichlidae* family from three different habitats and coastal areas of India are considered. LWRs of the specimen studied were highly significant, with the coefficient of determination (R^2) ranging from 0.894 to 0.974 among three different stocks (0.829–0.953) among male and female stocks of three respective habitats. The Chilika-Odisha stock showed positive allometric growth ($b = 3.82$), whereas the Gujarat and West Bengal stock showed negative allometric growth with $b = 2.57$ and $b = 2.60$, respectively. The values for sample size (n), total length (in cm), and body weight (in gm) range and LWRs equations with 95% confidence limit of "a" and "b" are represented in Tables 3 and 4. LogL-LogW relationship among the stocks from three different habitats (in Figures 3(a)–3(c)) and their combined relationship (in Figure 3(d)) are highly correlated. A boxplot summarizing the length distribution of *E. suratensis* by stock and sex is shown in Figure 4. In Figure 4, it was mentioned that the length-weight relationship of *E. suratensis* by stock and sex wise is highly correlated for Chilika (CH) and West Bengal (WB) regions and comparatively lesser in Gujarat (GJ) region.

3.2. Condition Factor. The mean estimated condition factor of the stocks from different habitats with a 95% confidence interval for all 440 *E. suratensis* species is given in Table 5. All values were higher than "1", indicating that all stocks were in good condition. The result of Kruskal–Wallis for test independent samples indicated no significant differences in the distribution of condition factors across all of the stocks ($p > 0.05$). The effect of sex ratio on condition factor of stocks from different habitats stock was also not significant in the present study ($p > 0.05$).

3.3. Truss Morphometric Analysis. The univariate statistics (ANOVA) of truss measurements showed significant differences between all three groups ($p < 0.001$) with variable F-stat values. Multivariate analyses using Pillai's trace, Wilks' lambda, and Hotellings's trace showed a significant contribution of all groups to the total variation with $p < 0.001$. The mean ± SE for all landmark distances is given in Table 6. To assess the size and shape variation in all three stocks of *E. suratensis*, PCA was performed on log-transformed measurements of 11 landmarks with Jolliffe cut-off of 0.01. The eigenvectors and eigenvalues obtained from the covariance matrix allowed the representation of the largest part of the variance of original variables in the first two components, viz., PC1 and PC2. It was observed that PC1 contributed the highest (93.1%), followed by PC2 (4.6%) to the size and shape variation, respectively, amongst the three stocks (Table 7). Eigenvalues for PC1 was 1.28 with 83% variance, while for PC2, it was 0.3, explaining 17.9% variance (Table 8).

Contribution by the third principal component (PC3) was not significant (0.8%). The scatter plot showed that the West Bengal and Gujarat stocks were closely spaced, while the Chilika-Odisha stock was grouped separately (Figure 5). Highest separation was observed between Gujarat and Chilika ($R = 0.84$), followed by West Bengal (W.B.) and Chilika ($R = 0.66$). The quantum of separation between Gujarat and West Bengal was low ($R = 0.27$), possibly because the former were grow-out and Chilika stock was collected from wild (Table 9). The analysis of similarity by Bray–Curtis distance measure ANOSIM method showed significant separation of all groups with p value <0.001 (presented in Table 9). The ANOSIM boxplot for different stocks showed highest variation and ranked distances in Chilika stock (Figure 6). The results of the scree plot were in agreement with the results of PCA plot is presented in Figure 7. When the correlation matrix based on PCA was analyzed, it was found that PC1 contributed the highest (71.1%), followed by PC2 (15%), with significant loadings on PC2. The truss distances with meaningful loadings on PC1 were (1–4), (1–5), (1–6), (1–7), (1–8), and (1–9), while for PC2, it was (7–11), (6–11), (5–11), (8–11), (2–7), and (2–9) and significant landmarks are being represented in Table 2 and Figure 2.

Fish stock evaluation often involves the analysis of multiple variables, such as environmental factors, biological characteristics, and habitat conditions. The PCA identifies the dominant patterns or trends in the data by capturing the maximum variance in the first few principal components. These components often represent the most significant sources of variation in the dataset, revealing underlying patterns that may be critical for understanding fish stock dynamics. The results of PCA were reconfirmed with canonical variate analysis (CVA), and it was observed that CVA indicated three separate clusters of each population (Figure 8). However, the Gujarat and West Bengal populations were clustered closely but separately as against to PCA, where they are closely placed and overlapped as compared to Chilika indicating their morphological proximity.

Table 3: Descriptive statistics and estimated length-weight relationship parameters of three different stocks of *E. suratensis* from east and west coast of India.

Stock	n	Length (cm) min	Length (cm) max	Weight (g) (gm.) min	Weight (g) (gm.) max	a	95% CL of a	b	95% CL of b	R	R^2	Logarithmic equation Log W = log $a + b$ log L
CH	140	8.7	21.3	9.5	259	0.779	0.800–0.756	3.822	3.708–3.936	0.987	0.974	Log W = log0.779 + 3.822 log L
WB	160	14.8	24	88	292	0.349	0.406–0.283	2.575	2.367–2.594	0.963	0.928	Log W = log0.349 + 2.575 log L
GJ	140	12	25.6	52.3	392	0.428	0.495–0.349	2.602	2.439–2.766	0.945	0.894	Log W = log0.428 + 2.602 log L
		p value				0.000	0.000	0.001	0.000	0.000	0.000	

CH: Chilika-Odisha, WB: West Bengal, and GJ: Gujarat.

Table 4: Sex-wise length-weight regression analysis in three stocks from different habitats.

Stock	n	Sex	a	95% CL of a	b	95% CL of b	R	R^2	p value
CH	68	Male	0.645	0.715–0.5611	3.264	2.992–3.536	0.973	0.946	0.000
	72	Female	0.722	0.812–0.609	3.574	3.138–4.010	0.976	0.953	0.000
WB	83	Male	0.368	0.537–0.085	2.507	2.130–2.884	0.957	0.916	0.000
	77	Female	0.336	0.582–0.013	2.501	1.906–3.014	0.910	0.829	0.000
GJ	65	Male	0.235	0.029–0.530	2.859	0.312–2.959	0.901	0.851	0.002
	75	Female	0.486	0.705–0.018	2.805	2.023–3.587	0.938	0.880	0.000
All male stock combined			0.442	0.516–0.352	2.675	2.493–2.857	0.965	0.932	0.000
All female stock combined			0.427	0.508–0.326	2.637	2.441–2.832	0.970	0.941	0.000
All sex stock combined			0.648	0.0.669–0.626	3.243	3.163–3.324	0.970	0.941	0.000

CH: Chilika-Odisha, WB: West Bengal, and GJ: Gujarat.

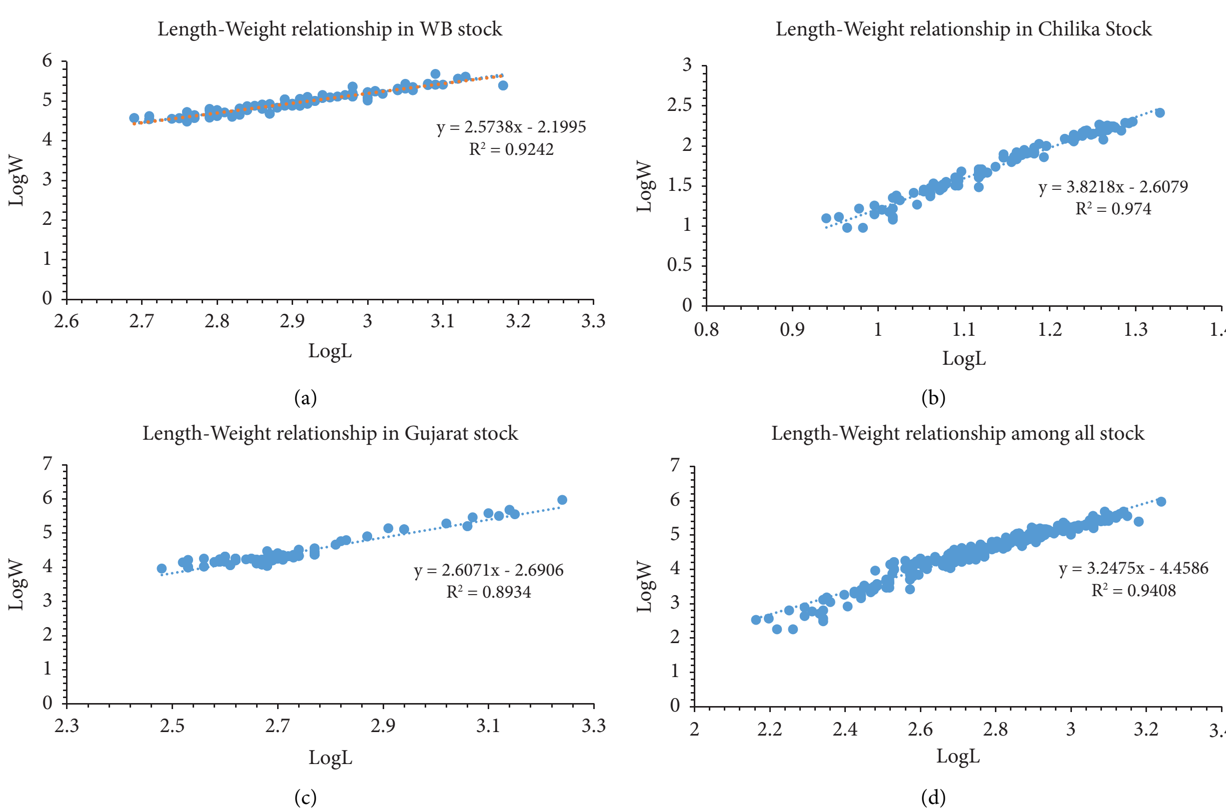

Figure 3: (a) Length (cm)-weight (g) relationship of *E. suratensis* in West Bengal coast stock. (b) Length (cm)-weight (g) relationship of *E. suratensis* in Chilika-Odisha stock. (c) Length (cm)-weight (g) relationship of *E. suratensis* in Gujarat coast stock. (d) The combined length (cm)-weight (g) relationship of *E. suratensis* from all three stocks.

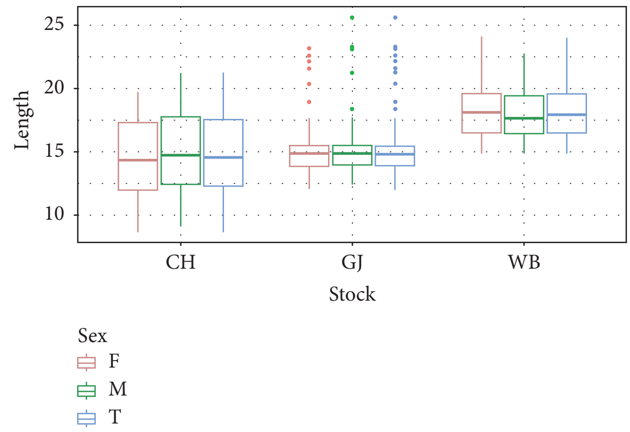

FIGURE 4: The boxplot summarizing the length (cm) distribution of *E. suratensis* by stock and sex.

TABLE 5: Condition factor analysis of three stocks from different habitats.

Parameters	Stock	*n*	Values range		Mean ± SE		95% confidence interval for mean	
			min	max	Mean	S.E	Lower	Upper
Condition factor	CH	140	1.067	3.121	2.243	0.041	2.161	2.325
	WB	160	1.584	3.022	2.360	0.018	2.326	2.395
	GJ	140	1.835	3.374	2.356	0.033	2.292	2.421

CH: Chilika-Odisha, WB: West Bengal, and GJ: Gujarat.

TABLE 6: Location of morphometric landmarks for higher truss morphometric measurements in *E. suratensis*.

Sr. no.	Landmarks	Mean ± SE (unit)
1	1–4	0.535 ± 0.036
2	1–5	0.541 ± 0.037
3	1–6	0.554 ± 0.037
4	1–7	0.551 ± 0.037
5	1–8	0.538 ± 0.037
6	1–9	0.530 ± 0.037
7	2–7	0.446 ± 0.023
8	2–9	0.427 ± 0.022
9	5–11	0.392 ± 0.018
10	6–11	0.406 ± 0.019
11	7–11	0.388 ± 0.019

TABLE 7: Overall eigenvalues and variance associated with principal components (PCs).

PC	Eigenvalue	% variance
1	0.520877	93.169
2	0.0259649	4.6443
3	0.00451841	0.8082
4	0.00414725	0.74181
5	0.00163255	0.29201
6	0.00116024	0.20753
7	0.00029547	0.05285
8	0.000151289	0.027061

Table 8: Eigenvalues and variance values in PC1 and PC2.

PC	Eigenvalue	% variance
1	1.28380	83.106
2	0.30254	17.984

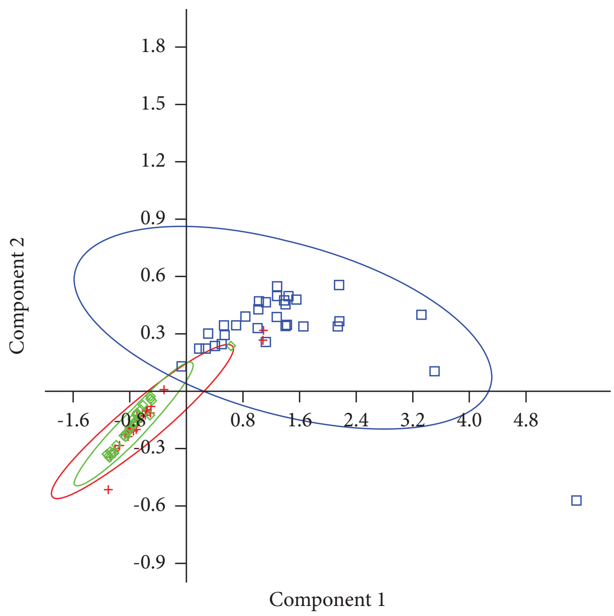

Figure 5: Principal component analysis (PCA) scatter plot showing size and shape variation between three different stocks of *E. suratensis*. ††(Blue colour: Chilika-Odisha stock, red colour: West Bengal stock, and green colour: Gujarat stock).

Table 9: Bray–Curtis *R* values for ANOSIM among different stocks.

	WB	GJ	CH	*p* value (Bonferroni corrected)
WB	0	0.2765	0.6604	0.000
GJ	0.2765	0	0.8394	0.002
CH	0.6604	0.8394	0	0.001

CH: Chilika-Odisha, WB: West Bengal, and GJ: Gujarat. ** *R* value close to 1 indicates high separation between two stocks, while *R* value close to 0 indicates no separation between two stocks.

4. Discussion

4.1. Length-Weight Relationship. In fishery assessments, the length-weight relationship is one of the established techniques that produce reliable biological data. It establishes the mathematical relationship between the two variables, length and weight. It aids in determining deviations from the expected weight for known length groups, estimating biomass, evaluating fish stocks, researching growth rates, comprehending the life cycle of fisheries, and identifying changes in allometric growth in fish [6, 26–28]. Every fish species will have a unique length-weight relationship for a particular length and weight range. In addition, it may vary between sexes, stocks, or those from other geographical regions. The parameter "**a**" is a scaling factor for the fish species' weight at a specific length. The shape parameter "**b**" refers to the fish species' particular body type. In 1968, von Bertalanffy created a growth equation for length and its counterpart in weight [6]. In other words, a cubic relationship exists between a fish's weight and length. For an ideal fish that maintains the same shape, "**b** = 3" and values of "**b**," which is smaller, equal, and larger than 3, indicate isometry, negative allometry, and positive allometry, respectively. In addition, it has been discovered that even if "*b*" may vary for fish from various environments, different sexes, or for larval, juvenile, and mature fish, it is frequently consistent for comparable fish. The aim of our present study was to evaluate the stock assessment of *E. suratensis* from two different ecosystems, i.e., freshwater and brackish water region of India. The previous studies were reported about the stock of this species in coastal region mainly. Although the stock evaluation study of *E. suratensis* in freshwater and brackish water regions is important for several reasons, as it helps to assess and manage the fish populations effectively like understanding the status and health of fish stocks in freshwater and brackish water ecosystems is crucial for biodiversity conservation. Therefore, freshwater and brackish water ecosystems are sensitive to climate change and studying about these fish stocks allows researchers to monitor the impact of climate change on aquatic environments and identify strategies to mitigate its effects on fish populations. In the present study, the values of the parameter "**b**" were found within the range of 2.5–3.8, which is within limits for most fish species [6]. The values of the intercept and slope "*a*" and "*b*" have indicated stock characteristics for the first time in this species from three different regions of India (freshwater and brackish water regions). The present study provides a first-hand and new LWRs data for *E. suratensis* from different habitats, i.e., freshwater, brackish water, wild and hatchery-reared stock in India. The higher "*b*" values of the regression slope indicate that the LWRs of a particular species follow the cube law. High "*b*" values are a reflection of the general condition of appetite and gonad content of the fish [29], wherein fish weight increased in proportion to the utilization of food items that are available for growth and energy [30, 31]. All LWRs are depicted in Tables 3 and 4. Hydrodynamic circulation is a primary factor for most of the lagoon environments' physical and ecological processes. Freshwater run-off from the drainage basin, combined with saline water inflows from the ocean, results in a wide range of fresh, brackish, and saline water environments within the lagoon, and this spatially and temporally diverse water environment supports an exceptionally productive ecosystem. This might be the reason for higher "b" values were found for the Chilika lagoon site compared to the other two sites. The goodness of fit of the regression model is indicated by the "$\mathbf{R^2}$" value in the output. It should be high for the model fitted to be good. In the present study, the estimated coefficients of determination (R^2) were within the range of (0.85–1.0), which shows better predictive power and smaller dispersion of LWRs data [32, 33]. Generally, variations in LWR parameters of each fish species occur mainly due to abiotic factors such as seasons, habitats, and biological parameters like size range, sex, maturity stages, and feeding habits [34–36]. Froese [37] provided estimated values of

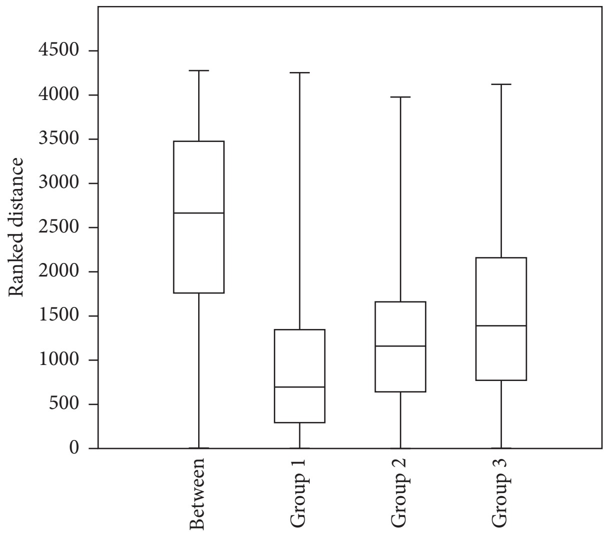

Figure 6: ANOSIM boxplot for three different stocks. Group 1: West Bengal stock, Group 2: Gujarat stock, and Group3: Chilika-Odisha stock.

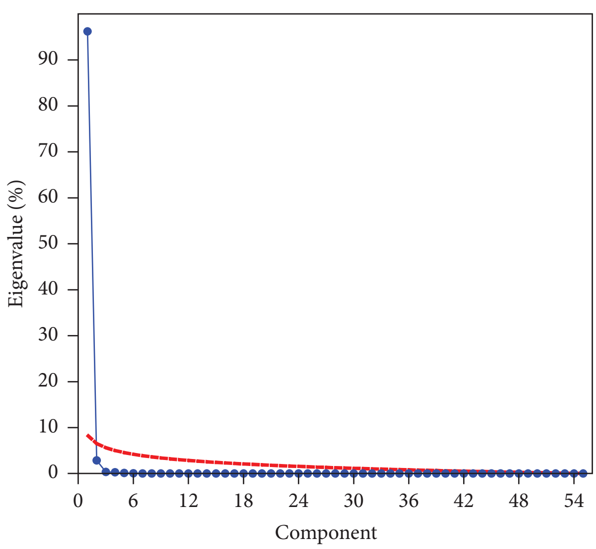

Figure 7: Eigenvalue (%) with components was presented in scree plot analysis among all three different stocks.

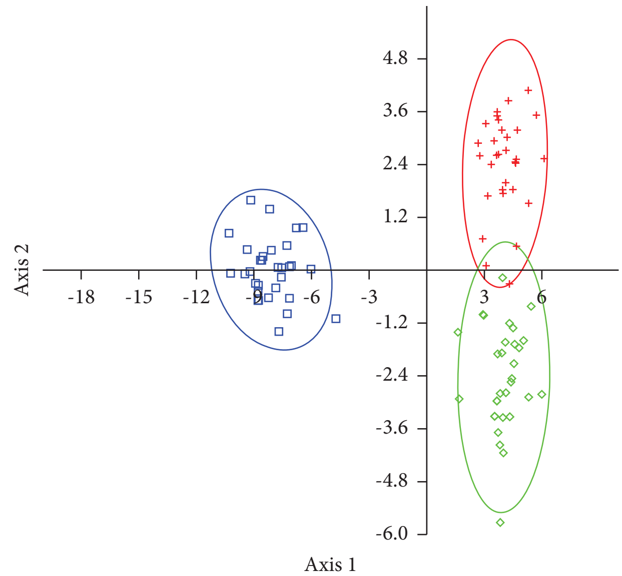

Figure 8: Canonical variate analysis (CVA) scatter plot showing size and shape variation between three different stocks of *E. suratensis*. ††(Blue colour: Chilika-Odisha stock, red colour: West Bengal stock, and green colour: Gujarat stock).

LWR parameters for all known fish species available at FishBase using Bayesian analysis. However, some biological traits of *Etroplus suartensis* have already been reported at FishBase. No such data are available on the variation in LWR, condition factor, and morphology of the population of this fish from different habitats. This study provides baseline biological information about euryhaline species from different habitats and ecosystems in India.

4.2. Condition Factor. The "*K*" and seasonal variations in the condition factor, which are helpful in identifying the biological changes in the fish, can also be found using the length-weight relationship. The "*K*" can be used to determine whether a particular body of water is suitable for fish growth and to distinguish between ecological variables, such as seasonal fluctuations, and the type of aquatic system present, such as rivers or lakes [38]. The level of sexual maturation, the degree of food source availability, the age, and the sex of some species are all indicated by different values in a fish's condition. Cren [20] also compared the length-weight relationship for perch, *Perca fluviatilis*, at various life stages, sexes, gonad development phases, and seasons in Lake Windermere. According to Mozsár et al. [39], if the **Krel** value is less than 1.00, the fish is in poor, lengthy, and thin condition. A decent fish with proper proportions would have a **Krel** value of roughly 1.40. In the present study, fishes from all the stock showed good condition with "Krel" values above (>1). This can be correlated to the abundance of food and good water quality in the brackish water habitat, i.e., Chilika Lake, a coastal pond of West Bengal and Gujarat, which had a positive effect on the fish condition. Ighwela et al. [40] found that Nile tilapia raised in aquaculture ponds in the USA had values greater than 1. Uganda's Lake Nyamusingiri and Lake Kyasanduka have values between 1.5 and 1.8, according to Bwanika et al. [41]. When fish usually grow, the condition factor of *Oreochromis niloticus* is around "1", rising as sexual maturation approaches [42, 43]. The exponent or slope "**b**" is essential in determining fish health because the condition factor value has a high correlation to LWR.

4.3. Truss Analysis. Fishes exhibit the highest variance in morphometric traits within and between populations compared to animals. At the same time, they are also vulnerable to morphological variation induced by natural forces [44–46]. Distinctness of morphometric traits can be correlated positively to the divergence and topographical segregation between populations. When geographic barriers separate populations, they evolve different phenotypic characters or features which are often shaped by environment, genetic inflow, and epigenetic factors [47]. These lead to forming or evaluating separate strains, races, populations, and stocks.

In fisheries biology, morphological traits are frequently utilized to assess relationships and discreteness among diverse taxonomic groupings. Numerous well-documented morphometric investigations support stock discreteness. For example, the morphological variation of European cyprinid, the chub, and *Leuciscus cephalus*, within and across Central European drainages was successfully differentiated by morphometries [48]. The identification of stock becomes a crucial component in any management regime. The study of population factors, as well as physiological, behavioral, morphometric, meristic, calcareous, biochemical, and cytogenetic traits, is helpful for the practical identification of these potential stocks. The morphometric investigations are the most important for taxonomic and management considerations [49, 50]. They are based on a series of measures of the body form.

In the present study, the Jolliffe cut-off value is 0.01 [51], giving an informal indication of how many factors or principal components should be considered as significant. In our case, only two components were found to be contributing maximally to the morphological variation due to their highest eigenvalues. Eigenvalues expected under the Broken Stick Model Curve represent nonsignificant components (scree plot, Figure 7). The PCA analysis indicated morphological similarity between Gujarat and West Bengal even though the geographical distance between them is more. On the other hand, the Chilika-Odisha stock is grouped separately. The reason for this grouping might be the closed native population of *Etroplus* in Chilika lagoon, where the possibility of population admixture is less. West Bengal and Gujarat stocks are from different habitats, i.e., freshwater and brackish water, respectively. It is speculated that there is a mixing of population from West Bengal and Gujarat despite the distances between them, which can be attributed to several factors such as seed ranching in rivers and stocking from common seed markets. Results from ANOSIM analysis also indicated a similar trend of stock differentiation. An R value close to 1 indicates high separation between stocks, while a lesser value indicates more resemblance between stocks. In this study, Gujarat and Chilika stocks had the highest R (0.83) value, indicating significant separation. In contrast, W.B. and Gujarat stocks had the least R value (0.27), showing little separation amongst stocks with p value <0.01.

A careful observation of the PCA component 1 loadings suggests that significant loadings were present on the anterior portion of the fish, as described by Silva [52]. In contrast to this, the second component, which is termed caudal, represented significant loadings on the posterior portion of the fish body. Hence, it can be concluded that the size variation was evident for the anterior portion while shape variation was primarily found near the posterior portion. However, the CVA factor 1st and 2nd loadings indicated size and shape variation in the posterior region of the fish body.

5. Conclusion

The present study provided insight into the stocks of *E. suratensis* from three different habitats and ecosystems in India. It also provides a comparative analysis between the stocks from hatchery and grow-out pond-reared conditions with wild ones. Most fish exhibit allometric growth patterns; thus, long-term studies on fish biology shall be beneficial for a better understanding of factors that influence the growth and physiology of fish. The present study has preliminarily indicated the stock characteristics of *E. suratensis* from three different ecological habitats for the first time.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Ramjanul Haque performed data curation, investigated the study, provided software, and wrote the original draft. Paramita Banerjee Sawant conceptualized the study, supervised the study, and reviewed and edited the manuscript. Jitendra Kumar Sundaray and Rajesh Kumar supervised the study, proposed the methodology, and reviewed and edited the manuscript. Narinder Kumar Chadha supervised the study, provided software, and performed data curation. Gouranga Biswas edited the article and performed formal analysis. Avinash Rasal provided software, performed data curation, and edited the article. Priyanka Nandanpawar provided software, performed data curation, and edited the article. Jackson Debbarma edited the article and performed formal analysis.

Acknowledgments

The authors would like to acknowledge the director and vice-chancellor of Indian Council of Agricultural Research-Central Institute of Fisheries Education, Mumbai, India, and the director of Indian Council of Agricultural Research-Central Institute of Freshwater Aquaculture, Bhubaneswar, India, for their support and encouragement.

References

[1] L. Bindu and K. G. Padmakumar, "Reproductive biology of *E. suratensis* (Bloch) from the Vembanad wetland system, Kerala," *Indian Journal of Geo-Marine Science*, vol. 43, no. 4, pp. 646–654, 2014.

[2] S. Chandrasekar, R. Sivakumar, J. Subburaj, and M. Thangaraj, "Geographical structuring of Indian pearl spot, *E. suratensis* (Bloch, 1790) based on partial segment of the CO1 gene," *Current Research Journal of Microbiology and Biotechnology*, vol. 5, no. 214, p. e217, 2013.

[3] K. C. Jayaram, *The freshwater fishes of the Indian region*, Narendra Publ. House, New Delhi, India, 1999.

[4] S. Chandrasekar, R. Sivakumar, R. Mathialagan, J. Subburaj, and M. Thangaraj, "Population genetic structure of *E. suratensis* Bloch, 1790 in South India: preliminary evidence of founder haplotypes shared among populations," *Journal of Asia-Pacific Business*, vol. 12, no. 3, pp. 376–381, 2019.

[5] R. Abraham, *Etroplus suratensis the IUCN Red List of Threatened Species 2013: e.T172368A6877592*, 2013, https://doi.org/10.2305/IUCN.UK.2011-1.RLTS.T172368A6877592.en.

[6] R. Froese, "Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations," *Journal of Applied Ichthyology*, vol. 22, no. 4, pp. 241–253, 2006.

[7] T. Yesilcicek, F. Kalayci, and C. Sahin, "Length-weight relationships of 10 fish species from the southern Black Sea, Turkey," *Journal of Survey in Fisheries Sciences*, vol. 9, no. 1, pp. 21–24, 2015.

[8] A. F. González Acosta, G. De La Cruz Agüero, and J. De La Cruz Agüero, "Length–weight relationships of fish species caught in a mangrove swamp in the Gulf of California (Mexico)," *Journal of Applied Ichthyology*, vol. 20, no. 2, pp. 154-155, 2004.

[9] M. J. Cavalcanti, L. R. Monteiro, and P. R. Lopes, "Landmark-based morphometric analysis in selected species of serranid fishes (Perciformes: teleostei)," *Zoological Studies-Taipei*, vol. 38, no. 3, pp. 287–294, 1999.

[10] A. Mallik, P. Chakraborty, and S. Swain, "Truss networking: a tool for stock structure analysis of fish," *Research Trends in Fisheries and Aquatic Sciences*, vol. 97, 108 pages, 2020.

[11] M. Singh, A. Kashyap, J. A. Ansari, and M. Serajuddin, "Spatial variations in the shape and chemistry of sagittal otoliths in *Channa punctatus* (channidae) populations of ganga basin, India," *Inland Water Bio*, vol. 52, 2022.

[12] V. K. Balai, L. L. Sharma, and N. C. Ujjania, "Morphometric relationship of Indian major carps (*Catla catla, Labeo rohita* and *Cirrhinus mrigala*) form Jaisamand Lake, Udaipur (India)," *Journal of Entomology and Zoology Studies*, vol. 5, no. 3, pp. 547–550, 2017.

[13] S. Rawat, S. Benakappa, J. Kumar, K. Naik, G. Pandey, and C. W. Pema, "Identification of fish stocks based on Truss Morphometric: a review," *Journal of Fisheries and Life Sciences*, vol. 2, no. 1, pp. 9–14, 2017.

[14] K. G. Padmakumar, L. Bindu, and P. S. Manu, "Etroplus suratensis (bloch), the state fish of Kerala," *Journal of Bio-Science*, vol. 37, no. S1, pp. 925–931, 2012.

[15] P. K. Talwar and A. G. Jhingran, *Inland Fishes of India and Adjacent Countries*, Oxford and IBH, New Delhi, India, 1991.

[16] K. C. Jayaram, *The Freshwater Fishes of the Indian Region*, Narendra Publishing House, New Delhi, India, 2010.

[17] K. B. S. Gunawickrama, "Morphological heterogeneity and population differentiation in the green chromid *Etroplus suratensis* (Pisces: cichlidae) in Sri Lanka," *Ruhuna Journal of Science*, vol. 21, 2012.

[18] N. Jisr, G. Younes, C. Sukhn, and M. H. El-Dakdouki, "Length-weight relationships and relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon," *The Egyptian Journal of Aquatic Research*, vol. 44, no. 4, pp. 299–305, 2018.

[19] J. H. Zar, *Biostatistical Analysis*, Prentice-Hall, London, UK, 2010.

[20] R. Froese, D. Zeller, K. Kleisner, and D. Pauly, "What catch data can tell us about the status of global fisheries," *Marine Biology*, vol. 159, no. 6, pp. 1283–1292, 2012.

[21] T. W. Fulton, "The rate of growth of fishes," Fisheries Board of Scotland, Edinburgh, Scotland, 1904.

[22] E. D. L. Cren, "The length-weight relationship and seasonal cycle in gonadal weight and condition of perch (*Perca fluviatilis*)," *Journal of Animal Ecology*, vol. 20, no. 2, pp. 201–219, 1951.

[23] F. J. Rohlf, *tpsDIG, Version 2.10*, Department of Ecology and Evolution,, New York, NY, USA, 2006.

[24] Ø. Hammer, D. A. Harper, and P. D. Ryan, "PAST: Paleontological statistics software package for education and data analysis," *Palaeontologia Electronica*, vol. 4, no. 1, p. 9, 2001.

[25] R. E. Strauss and F. L. Bookstein, "The truss: body form reconstructions in morphometrics," *Systematic Biology*, vol. 31, no. 2, pp. 113–135, 1982.

[26] A. Jafari-Patcan, S. Eagderi, and A. Mouludi-Saleh, "Length-weight relationship for four fish species from the Oman Sea, Iran," *International Journal of Aquatic Biology*, vol. 6, no. 5, pp. 294-295, 2018.

[27] A. Mouludi-Saleh and S. Eagderi, "Length-weight relationship and condition factor of ten fish species (Cyprinidae, Sisoridae, Mugilidae, Cichlidae, Gobiidae and Channidae) from Iranian inland waters," *Journal of Wildlife and Biodiversity*, vol. 3, no. 4, pp. 12–15, 2019.

[28] A. Radkhah and S. Eagderi, "Length-weight and length–length relationships and condition factor of six cyprinid fish species of Zarrineh River (Urmia Lake basin, Iran)," *Iranian Journal of Ichthyology*, vol. 1, pp. 61–64, 2015.

[29] M. R. Pervin and M. G. Mortuza, "Notes on length-weight relationship and condition factor of fresh water fish, *Labeo boga* (Hamilton)(Cypriniformes: cyprinidae)," *University Journal of Zoology, Rajshahi University*, vol. 27, pp. 97-98, 1970.

[30] M. S. Kamarudin, E. Ramezani-Fard, C. R. Saad, and S. A. Harmin, "Effects of dietary fish oil replacement by various vegetable oils on growth performance, body composition and fatty acid profile of juvenile Malaysian mahseer, Tor tambroides: effect of dietary vegetable oils on mahseer," *Aquaculture Nutrition*, vol. 18, no. 5, pp. 532–543, 2012.

[31] B. O. Offem, Y. Akegbejo-Samsons, and I. T. Omoniyi, "Biological assessment of *Oreochromis niloticus* (Pisces: cichlidae; Linne, 1958) in a tropical floodplain river," *African Journal of Biotechnology*, vol. 6, no. 16, pp. 1966–1971, 2007.

[32] M. A. Hanif, M. A. Siddik, and M. M. Ali, "Length-weight relationships of seven cyprinid fish species from the Kaptai Lake, Bangladesh," *Journal of Applied Ichthyology*, vol. 36, no. 2, pp. 261–264, 2020.

[33] A. T. Correia, P. Gomes, J. M. S. Gonçalves, K. Erzini, and P. A. Hamer, "Population structure of the black seabream *Spondyliosoma cantharus* along the south-west Portuguese coast inferred from otolith chemistry," *Journal of Fish Biology*, vol. 80, no. 2, pp. 427–443, 2012.

[34] M. S. B. Oliveira, L. M. A. Silva, L. Prestes, and M. Tavares-Dias, "Length-weight relationship and condition factor for twelve fish species from the Igarapé Fortaleza basin, a small tributary of the Amazonas River estuary," *Acta Amazonica*, vol. 50, no. 1, pp. 8–11, 2020.

[35] L. Prestes, F. C. D. Cunha, M. G. M. Soares, M. S. B. Oliveira, N. I. Oliveira, and A. C. Florentino, "Stock assessment: sustainable management in high and medium araguari river, amapá, Brazil," *Ciencia e Natura*, vol. 42, p. 71, 2020.

[36] M. A. Hanif, M. A. Siddik, M. A. Islam, M. R. Chaklader, and A. Nahar, "Multivariate morphometric variability in sardine, *Amblygaster clupeoides* (Bleeker, 1849), from the Bay of Bengal coast, Bangladesh," *The Journal of Basic and Applied Zoology*, vol. 80, no. 1, 2019.

[37] R. Froese, N. Demirel, G. Coro, K. M. Kleisner, and H. Winker, "Estimating fisheries reference points from catch and resilience," *Fish and Fisheries*, vol. 18, no. 3, pp. 506–526, 2017.

[38] G. V. Nikolski, *Theory of Fish Population Dynamics as the Biological Background for Rational Exploitation and Management of Fishery Resources*, Oilver and Boyd, Edinburgh, Scotland, 1969.

[39] A. Mozsár, G. Boros, P. Sály, L. Antal, and S. A. Nagy, "Relationship between Fulton's condition factor and proximate body composition in three freshwater fish species," *Journal of Applied Ichthyology*, vol. 31, no. 2, pp. 315–320, 2015.

[40] K. A. Ighwela, A. B. Ahmed, and A. B. Abol-Munafi, "Condition factor as an indicator of growth and feeding intensity of Nile tilapia fingerlings (*Oreochromis niloticus*) feed on different levels of maltose," *American-Eurasian Journal of Agricultural and Environmental Sciences*, vol. 11, no. 4, pp. 559–563, 2011.

[41] G. N. Bwanika, B. Makanga, Y. Kizito, L. J. Chapman, and J. Balirwa, "Observations on the biology of Nile tilapia, *Oreochromis niloticus L.*, in two Ugandan crater lakes," *African Journal of Ecology*, vol. 42, no. 1, pp. 93–101, 2004.

[42] K. B. Olurin and O. A. Aderibigbe, "Length-weight relationship and condition factor of pond reared juvenile *Oreochromis niloticus*," *World Journal of Zoology*, vol. 1, no. 2, pp. 82–85, 2006.

[43] S. Srithongthum, T. Amornsakun, P. Musikarun et al., "Length-weight relationship and relative condition factor of the Sultan fish, *Leptobarbus hoevenii* broodstock farmed in earthen ponds," *Egyptian Journal of Aquatic Biology and Fisheries*, vol. 24, no. 3, pp. 53–59, 2020.

[44] A. K. Dwivedi, "Differentiating three Indian shads by applying shape analysis from digital images," *Journal of Fish Biology*, vol. 96, no. 6, pp. 1298–1308, 2020.

[45] S. Hockaday, T. A. Beddow, M. Stone, P. Hancock, and L. G. Ross, "Using truss networks to estimate the biomass of *Oreochromis niloticus*, and to investigate shape characteristics," *Journal of Fish Biology*, vol. 57, no. 4, pp. 981–1000, 2000.

[46] P. H. Wimberger, "Plasticity of fish body shape. The effects of diet, development, family and age in two species of Geophagus (Pisces: cichlidae)," *Biological Journal of the Linnean Society*, vol. 45, no. 3, pp. 197–218, 1992.

[47] J. Hu and R. D. H. Barrett, "Epigenetics in natural animal populations," *Journal of Evolutionary Biology*, vol. 30, no. 9, pp. 1612–1632, 2017.

[48] D. R. Jerry and S. C. Cairns, "Morphological variation in the catadromous Australian bass, from seven geographically distinct riverine drainages," *Journal of Fish Biology*, vol. 52, no. 4, pp. 829–843, 1998.

[49] I. S. Park, S. R. Woo, Y. C. Song, and S. H. Cho, "Effects of starvation on morphometric characteristics of olive flounder, *Paralichthys olivaceus*," *Ichthyological Research*, vol. 54, no. 3, pp. 297–302, 2007.

[50] S. A. Bonar, G. L. Thomas, and G. B. Pauley, "Evaluation of the separation of triploid and diploid grass carp, *Ctenopharyngodon idella* (Valenciennes), by external morphology," *Journal of Fish Biology*, vol. 33, no. 6, pp. 895–898, 1988.

[51] I. T. Jolliffe, "Choosing a subset of principal components or variables," in *Principal Component Analysis*, Springer Series in Statistics, Berlin, Germany, 1986.

[52] A. Silva, "Morphometric variation among sardine (*Sardina pilchardus*) populations from the northeastern Atlantic and the western Mediterranean," *ICES Journal of Marine Science*, vol. 60, no. 6, pp. 1352–1360, 2003.