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Trophic Cascades and Food Scarcity in the Calabar River, Niger Delta: A Case Study of the Silver Catfish (*Chrysichthys nigrodigitatus*)

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ABSTRACT

The Silver Catfish (*Chrysichthys nigrodigitatus*) plays a crucial role in the Calabar River ecosystem, influencing local economies and aquatic biodiversity. This study assesses the trophic cascades and food scarcity effects on the Silver Catfish, focusing on its morphometric parameters and seasonal variations during the dry and wet seasons in the Calabar River. Key parameters, including body weight, total length, and fin lengths, were analyzed, with statistical tests applied to determine seasonal differences. Significant seasonal variations were found in dorsal fin length, caudal fin length, and head length. Specifically, dorsal fin length increased from 6.94 cm in the dry season to 9.69 cm in the wet season ($p = 0.00073$), caudal fin length from 9.31 cm to 12.55 cm ($p = 0.0049$), and head length decreased from 13.75 cm to 11.88 cm ($p = 0.023$). These variations likely reflect changes in feeding behavior due to trophic cascades, where predator-prey interactions and food availability are altered by seasonal factors, resulting in food scarcity during the dry season. This highlights the need for effective seasonal management and conservation strategies to mitigate food scarcity impacts, protect the species, and maintain the health of the Calabar River ecosystem.

Keywords: Trophic cascades, food scarcity, morphometric parameters, seasonal variations.

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1. INTRODUCTION

The study of morphometric analysis provides valuable insights into the structural characteristics of organisms by measuring various body dimensions. In fish species, such analysis is critical for understanding their adaptive strategies, growth patterns, and population dynamics. For species like the silver catfish (*Chrysichthys nigrodigitatus*), morphometric analysis aids in discerning subtle differences among closely related species and is essential for taxonomy, health assessment, and the evaluation of reproductive capabilities. Furthermore, these morphometric traits are not static; they can be influenced by environmental factors, particularly seasonal changes that impact key life stages such as spawning and juvenile development. As such, morphometric studies offer a dynamic view of how species like the silver catfish adapt to fluctuating environmental conditions (Ekpo *et al*., 2021; Asuquo & Ifon, 2019).

In fish populations, seasonal assessments focus on aspects such as abundance, distribution, growth, reproduction, and behavior across different periods of the year (Ekpo *et al.,* 2022). This research is integral to understanding the ecological adaptations of fish species to the shifting environmental conditions that characterize the dry and wet seasons. Such assessments are vital in informing fisheries management, conservation strategies, and sustainable exploitation of aquatic resources. By pinpointing critical periods for feeding, breeding, migration, and population changes, this research can help mitigate the risks posed by overfishing, habitat destruction, and climate change (Fukuda *et al*., 2018).

The Calabar River, located in the Cross River State of Nigeria, is a vital waterway that flows southward for about 150 kilometers before draining into the Atlantic Ocean. This river forms at the confluence of the Great Kwa and Cross Rivers and serves as a significant ecological and commercial hub. It is home to a diverse array of aquatic species, including over 70 fish species that contribute to the region's economic vitality. Among these, the silver catfish (*Chrysichthys nigrodigitatus*) plays a prominent role due to its value as both a food source and a commercial catch (Ekpo *et al*., 2022).

Morphologically, the silver catfish has a distinct slender, elongated, cylindrical body with a slightly flattened head and terminal mouth, which reflect its bottom-dwelling feeding habits (Bergmann et al., 2012). The coloration of silver catfish varies with age and environmental conditions, ranging from a silvery hue with a white belly to darker gray tones in mature individuals. Typically, adults reach lengths of 15 to 20 cm, although they can grow up to 30 cm (Scur *et al*., 2011). The species is known for its adaptability to a variety of freshwater habitats, including rivers, lakes, and ponds. It prefers slow-moving waters with muddy or sandy substrates, often found near submerged vegetation or fallen debris, which provide both shelter and food.

As omnivores, silver catfish feed on a diverse diet consisting of detritus, algae, insects, small crustaceans, and aquatic plants. This flexibility in their diet contributes to their widespread distribution and success in various aquatic environments. During the breeding season, which typically occurs in the warmer months of spring and summer, male silver catfish engage in courtship behaviors, attracting females through specific mating rituals. Fertilization is external, with females releasing eggs that are fertilized by males in open water (Courtenay et al., 2013). The silver catfish's role in African fisheries, particularly as a staple food source and economic commodity, highlights the importance of understanding its biology and ecological requirements for sustainable management and conservation (Gubiani *et al*., 2016).

Morphometric and seasonal assessments are critical for understanding the ecological and physiological factors driving the biological processes of the silver catfish. These analyses enable researchers to track the species' responses to environmental and seasonal fluctuations, offering deeper insights into growth, reproductive cycles, and population dynamics. Such research is essential for enhancing aquaculture practices, improving fish farming efficiency, and ensuring the sustainability of silver catfish populations. By identifying optimal growth periods and favorable environmental conditions, this research can contribute to increasing production efficiency and profitability in aquaculture while minimizing environmental impacts (Ekpo *et al*., 2022).

The silver catfish, a member of the Claroteidae family, is distributed across various regions of West Africa, including Nigeria, Guinea, and the Ivory Coast. It thrives in diverse aquatic habitats, with its reproductive biology and habitat preferences having been extensively studied. In regions like Nigeria, the species contributes significantly to local fish catches and supports small-scale fisheries that are crucial for food security and economic stability (Inieich et al., 2016). Research on the species has uncovered numerous adaptations, such as its tolerance to temperature fluctuations and low oxygen levels, which enable it to survive in a range of environmental conditions (Barreto *et al*., 2019; Ribeiro *et al*., 2020).

Reproductive patterns of *Chrysichthys nigrodigitatus* are influenced by seasonal changes, with the rainy season being the peak breeding period. Male catfish engage in courtship to attract females, and the fertilized eggs are released in sheltered areas to protect them from predators (Owodeinde *et al*., 2014; Adeniran *et al*., 2017). Environmental factors such as food availability and water quality play a crucial role in the success of reproduction and overall population dynamics (Ama-abasi *et al*., 2017).

This study aims to assess the seasonal variations in the morphometric characteristics of silver catfish in the Calabar River, Nigeria. By focusing on these variations, we seek to enhance species identification, understand growth patterns, and evaluate water quality parameters, ultimately contributing to sustainable management and conservation efforts in the region. Understanding these seasonal dynamics is essential for maintaining the health of the Calabar River ecosystem and ensuring the continued viability of silver catfish populations.

2. MATERIALS AND METHODS

2.1. Study Site

The experiment was conducted in the Calabar River, Cross River State, Nigeria. The River flows approximately 150 kilometers into the Atlantic Ocean, with coordinates around 4.95° N latitude and 8.33° E longitude. Known for its rich biodiversity, it supports various fish species and is vital for local communities' fishing and economic activities.

2.2. Collection of Species and Identification

Fish specimens were collected from the Calabar River Estuary sites: Nsidung Beach and Itu Head Bridge. They were then transported in iced cool boxes to the Environmental Laboratory at the Department of Genetics and Biotechnology for identification and morphometric measurements.

2.3. Species Identification

Samples of *Chrysichthys nigrodigitatus* were identified based on their phenotypic characteristics, following established protocols for fish characterization. Observations were made during two distinct seasons: dry and wet (Ekpo*, et al*., 2022).

2.4. Morphometric Measurements

A total of 13 morphometric measurements were taken on one side of each fish specimen (Asuquo & Ifon 2021; Ekpo *et al*, 2022). The following parameters were measured using a weighing balance and a meter rule: Total Length (TL), Standard Length (SL), Head Length (HL), Body Weight (BW), Dorsal Fin (DF), Pectoral Fin (PCF), Pelvic Fin (PVF), Total Body Width (TBW), Caudal Fin Length (CFL), Anal Fin (ANF), Maxillary Barbel (MX), Mandibular Barbel (MD), and Fork Length (FL).

3. DATA ANALYSIS

The morphometric measurements were analyzed using Principal Component Analysis (PCA). To account for size effects, all measurements were scaled as proportions of the Standard Length (SL) of the fish. An Independent T-test was employed to assess significant differences between the seasons at a significance level of $P < 0.05$.

3.1. Duration of Study

The studies were conducted in four months and encompassed both the dry and wet seasons in the Calabar River. Typically, the dry season lasts from November to March, while the wet season occurs from April to October capturing data from both seasonal conditions.

4. RESULTS

4.1. Monthly Variation in Morphometric Parameters

The morphometric analysis revealed intriguing monthly trends across these parameters (Table 1). In March, the mean body weight was 1.34 kg, showing a slight increase in April to 1.84 kg. However, by June, it dropped to 1.24 kg before rebounding to 1.5 kg in July. The standard deviation (SD) in July was notably higher, indicating increased variability in body weight. The total length displayed a similar pattern. April exhibited the highest mean TL at 55.98 cm, while July had the lowest mean TL at 49.9 cm. March and June fell in between these values at 50.34 cm and 51.8 cm, respectively.

Variations were also observed in other morphometric parameters. For instance, Dorsal Fin (DF) length was highest in March, but April showed the lowest. Pectoral Fin (PCF) length was greatest in April and lowest in July. Total Body Width (TBW) reached its peak in April but was lowest in March. Similarly, Caudal Fin (TLC) was longest in April and shortest in March. The differences between months highlighted seasonal shifts in the Silver Catfish's morphology.

Table 1. Morphometric Parameters of Silver Catfish (*Chrysichthys nigrodigitatus*) in Calabar River.

Parameter	March	April	June	July
BW (kg)	1.34 ± 0.32	1.84 ± 0.35	1.24 ± 0.21	1.5 ± 0.99
TL (cm)	50.34 ± 3.42	55.98 ± 2.81	51.8 ± 1.18	49.9 ± 11.13
SL (cm)	40.6 ± 2.81	45.42 ± 2.36	42.16 ± 1.72	44.38 ± 9.52
DF (cm)	6.98 ± 1.21	6.9 ± 0.57	9.6 ± 1.20	9.78 ± 1.74
PCF (cm)	5.88 ± 0.72	6.18 ± 0.31	6.6 ± 0.79	5.9 ± 0.60
PLF (cm)	5.14 ± 0.48	5.36 ± 0.65	5.86 ± 0.49	5.88 ± 1.20
TBW (cm)	24.34 ± 2.44	29.6 ± 1.73	23.54 ± 1.70	25.1 ± 6.32
TLC (cm)	7.94 ± 0.68	10.68 ± 0.79	12.08 ± 1.49	13.02 ± 2.86
ANF (cm)	5.76 ± 0.79	6 ± 0.69	6.38 ± 0.56	5.66 ± 1.96
HL (cm)	13.3 ± 0.65	14.2 ± 0.42	11.8 ± 0.72	11.96 ± 2.69
MX (cm)	6.2 ± 1.58	8.66 ± 0.78	7.34 ± 0.89	8.72 ± 1.25
MD (cm)	3.7 ± 0.94	5.04 ± 0.30	4.72 ± 1.06	4.84 ± 0.59
FL (cm)	44.6 ± 3.66	51.48 ± 3.17	44.02 ± 1.25	49.1 ± 10.70

Key: Body Weight (BW), Total Length (TL), Standard Length (SL), Dorsal fin (DF), Pectoral Fin (PCF), Pelvic Fin (PLF), Total Body Width (TBW), Caudal Fin (TLC), Anal Fin (ANF), Head Length (HL), Maxillary Barbel (MX), Mandibular Barbel (MD), Fork Length (FL)

4.2. Seasonal Variation In Morphometric Parameters

Figure 3 clearly illustrates the differences in these parameters between the dry and wet seasons. For each parameter, the mean values during the dry season are compared to the mean values during the wet season. This comparison allows for an understanding of how these morphometric parameters change in response to seasonal variations. T-test results revealed that Body Weight (BW), Total Length (TL), and Standard Length (SL) show no statistically significant differences between the dry and wet seasons. This suggests that the size and length of Silver Catfish remain relatively consistent throughout the year.

Conversely, Dorsal Fin (DF), Caudal Fin (TLC), and Head Length (HL) exhibit statistically significant differences between seasons. This indicates that the dorsal fin length, caudal fin length, and head length of Silver Catfish vary significantly with changing environmental conditions. Other parameters such as Pectoral fin (PCF), pelvic fin (PLF), total body width (TBW), anal fin (ANF), maxillary barbel (MX), mandibular barbel (MD), and fork length (FL) did not show statistically significant differences between the seasons.

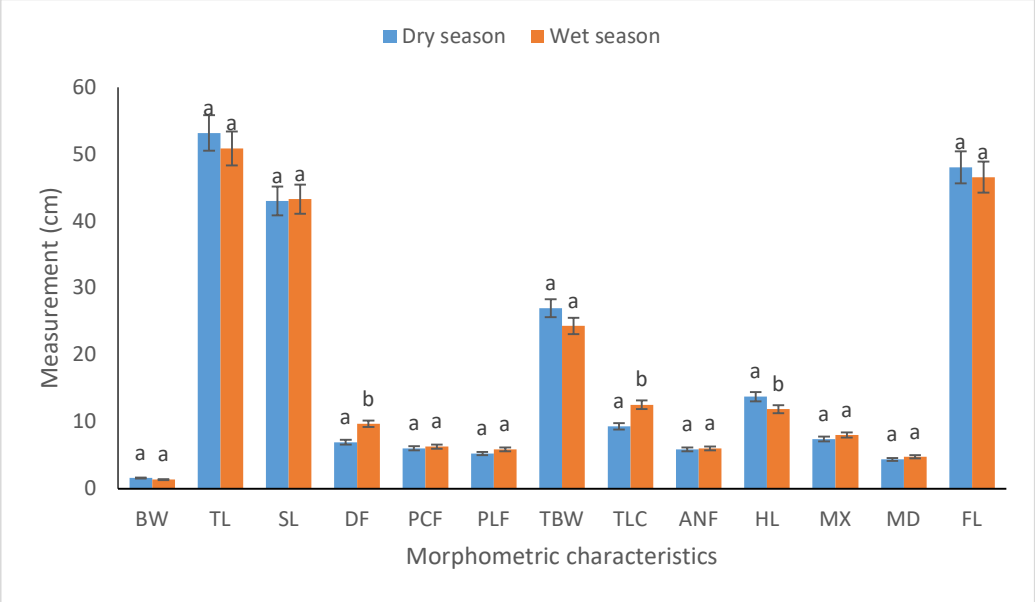

Figure 2. Seasonal variation in morphometric characteristics of *C. nigrodigitatus* from the Calabar River, Nigeria Values with different letters in each column are statistically significantly different at P<0.05.

The statistically significant differences in dorsal fin length (DF), caudal fin length (TLC), and head length (HL) suggest that these morphometric parameters are influenced by seasonal changes in the Calabar River. Understanding these seasonal variations is crucial for the management and conservation of Silver Catfish. It can inform the timing of conservation efforts, such as breeding and feeding season protection. The lack of statistically significant differences in certain parameters, like body weight and total length, may indicate the species' adaptability and resilience to changing environmental conditions.

4.3. Principal Component Analysis (PCA)

The communalities after extraction indicate how much of the variance in the original variables is accounted for by the principal components generated during the PCA. These values are lower than 1.0 (which would indicate 100% variance explained), as they represent the shared variance after the extraction process. This suggests that the principal components have captured a substantial amount of the variance within these variables. From the communalities after extraction, Head length (HL) has a lower communalities value, suggesting that it contributes less to the principal components compared to the other variables. Maxillary and Mandibular barbels (MX and MD) have very high communalities, indicating they contribute significantly to the extracted principal components. The PCA aims to reduce the dimensionality of the data by creating new variables (principal components) that capture the variance in the original variables. High communalities in the extraction phase indicate that those variables are well represented by the principal components and are important in understanding the underlying structure of the data.

Table 2 demonstrates the variance explained by each component derived from the PCA. It is divided into three sections: Initial Eigenvalues, Extraction Sums of Squared Loadings, and Rotation Sums of Squared Loadings. Each section shows the total variance, the percentage of variance, and the cumulative percentage explained by each component. The first component explains 26.178% of the total variance, with subsequent components contributing less individually. The cumulative variance increases steadily with each component. The first few components explain the majority of the variance, reaching 82.309% by the fourth component. Components beyond the fourth explain much less variance individually but are included for a comprehensive view of the data's structure (Fig. 4).

Table 2. Total variance explained by the PCA.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.618	26.178	26.178	2.618	26.178	26.178	2.417	24.167	24.167
2	2.564	25.644	51.822	2.564	25.644	51.822	2.185	21.853	46.019
3	1.992	19.917	71.739	1.992	19.917	71.739	1.883	18.826	64.845
4	1.057	10.570	82.309	1.057	10.570	82.309	1.746	17.464	82.309
5	.652	6.522	88.831						
6	.515	5.150	93.981						
7	.282	2.821	96.802						
8	.164	1.635	98.437						
9	.127	1.272	99.709						
10	.029	.291	100.000						

Extraction Method: Principal Component Analysis.

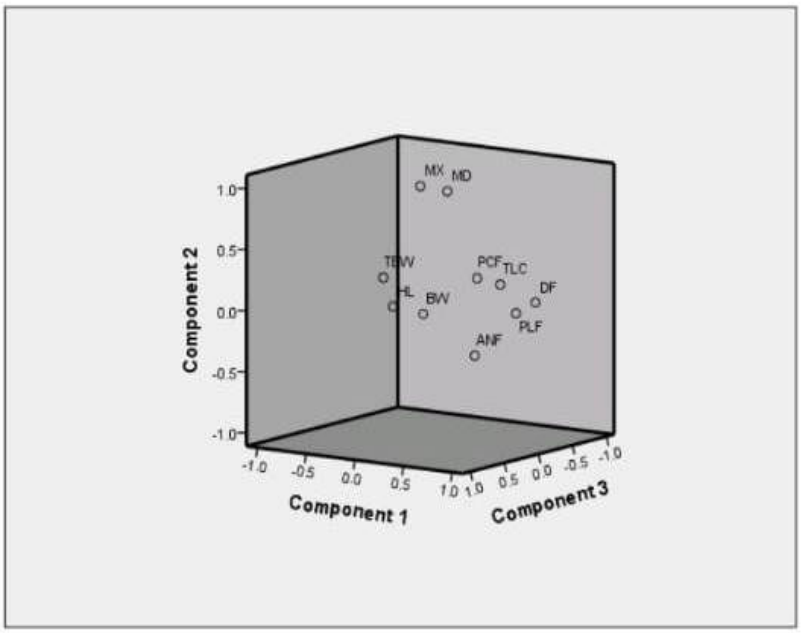

Figure 3. Component plot in rotated space.

5. DISCUSSION

The Calabar River, a key aquatic ecosystem in Nigeria, supports a diverse range of species, with *Chrysichthys nigrodigitatus* (Silver Catfish) being one of the most ecologically significant. This species plays a crucial role in the local food web and the economy, especially through subsistence and commercial fishing. Our study examined the seasonal variations in the morphometric characteristics of the Silver Catfish over four months (March, April, June, and July) to understand how environmental changes, particularly between the dry and wet seasons, influence the growth, habitat preferences, and overall health of the species. By investigating thirteen morphometric parameters, we aimed to gain insights into the Silver Catfish's seasonal behavior, which is crucial for sustainable management and conservation efforts.

Our findings revealed significant seasonal variations in several key morphometric traits. Dorsal fin length, caudal fin length, and head length showed notable seasonal differences, with values increasing in the wet season, indicating that these traits are more sensitive to environmental fluctuations. The significant changes in dorsal fin length ($p = 0.0007$), caudal fin length ($p = 0.0049$), and head length ($p = 0.023$) suggest that these characteristics may be linked to factors such as water temperature, food availability, and reproductive cycles, which vary with the seasons. These results align with previous studies, such as those by Ekpo *et al*. (2022) and Cao *et al*. (2017), who observed similar seasonal changes in fish species. However, our study contrasts with the findings of Mehmood (2021), who suggested that such variations are primarily due to ontogenetic growth. In our case, the observed variations were indeed driven by seasonal factors rather than mere growth progression.

On the other hand, several parameters, including body weight, total length, standard length, pectoral fin length, pelvic fin length, anal fin length, maxillary barbel, mandibular barbel, and fork length, did not exhibit significant seasonal variations. This lack of change suggests that these traits are either less influenced by environmental factors or that they follow a more stable growth pattern throughout the year.

These stable parameters are important as they provide baseline measurements that can be used to assess population health, regardless of seasonal shifts (Ekpo *et al.,* 2017; Ekerette *et al.,* 2024).

The observed seasonal trends in the Silver Catfish's morphometric traits indicate dynamic changes in the species' growth and development. These changes are likely driven by environmental factors such as water temperature, food availability, and reproductive needs (Ekpo *et al*., 2021; Asuquo & Ifon, 2021; Dhinakaran *et al*., 2011). Understanding these patterns is vital for assessing the ecological health of the Calabar River and for the conservation of the Silver Catfish, which is a key species in the river's ecosystem (Ekpo *et al*., 2022; Akongyuure, 2019). The significant fluctuations in morphometric parameters emphasize the need for long-term monitoring and data collection to capture the full range of variability in the species' life cycle. This will allow for more accurate predictions about how the species will respond to future environmental changes.

Another key finding from our study is the importance of habitat preferences and their seasonal nature. During different seasons, the Silver Catfish may favor distinct habitats that offer the best conditions for feeding and reproduction. This understanding can aid in habitat management, ensuring that conservation efforts are focused on areas that are critical for the species' survival during key life stages. Effective habitat management strategies, such as the protection of breeding grounds and critical feeding areas, are necessary to support the species' long-term sustainability (Mesa & Rose, 2014; Ekpo *et al*., 2024).).

The study also has implications for fisheries management. The seasonal variations in morphometric traits, especially those related to reproductive and feeding behaviors, underscore the need for seasonal fishing regulations to protect the species during vulnerable periods. Implementing seasonal fishing restrictions or quotas could help minimize fishing pressure during critical breeding or growth phases, thereby contributing to population stability and sustainability (Puga *et al*., 2018; Ekpo *et al*., 2022)

Lastly, as climate change continues to impact aquatic ecosystems, understanding how the Silver Catfish responds to environmental fluctuations is increasingly important. Climate-induced changes in water temperature, precipitation patterns, and food availability could affect the species' growth, reproduction, and distribution. Ongoing research and continuous monitoring of the species will be crucial for developing adaptive management strategies that can respond to these changing conditions and protect both the Silver Catfish and the broader ecosystem of the Calabar River.

6. CONCLUSIONS

This study highlights the significant impact of trophic cascades and food scarcity on the Silver Catfish (*Chrysichthys nigrodigitatus*) in the Calabar River ecosystem. The observed morphometric variations between the dry and wet seasons underscore the influence of seasonal changes on the species' growth patterns and feeding behavior.

The significant increase in dorsal and caudal fin lengths during the wet season and the decrease in head length during the dry season suggest a direct relationship between food availability and fish morphology, influenced by seasonal shifts in food resources and predator-prey dynamics.

Trophic cascades, where the presence or absence of top predators affects the entire food web, are evident in the Calabar River. During the wet season, food availability is more abundant, likely due to increased primary productivity and a greater abundance of prey species. Conversely, the dry season, characterized by lower water levels and reduced food availability, leads to a scarcity of resources for the Silver Catfish, which may affect their growth and reproductive success. This seasonal food scarcity exacerbates the challenges faced by the species, making it more vulnerable to overfishing, habitat degradation, and other anthropogenic pressures.

The findings of this study underscore the need for seasonal management strategies that account for the dynamics of trophic cascades and food scarcity in the river ecosystem. Effective conservation measures should focus on maintaining ecological balance, protecting the Silver Catfish's habitat, and ensuring sustainable fishery practices. By addressing the seasonal variations in food availability and trophic interactions, we can safeguard the future of the Silver Catfish and the broader Calabar River ecosystem, ensuring both ecological stability and the livelihoods of local communities dependent on this vital resource.

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