Kwaghe International
Journal of Sciences and Technology

ISSN: 1595-7977
Index: Harvard, Boston, Sydney University, Dimensions, Lens, ResearchGet Scilit, Semantic, Google Scholar, Base etc

https://doi.org/10.58578/KIJST.v2i2.6247

Genetics of Quantitative Phenotype of African Fan Shrimp (*Atya gabonensis*) from Lower River Benue, Makurdi, Nigeria Using Principal Component Analysis

Uruku Ndekimbe Mamndeyati[1], Ameh Oyibinga Rose[2], Gabriel Shola Solomon[3]
[1,2]Federal University Wukari, Taraba State. Nigeria
[3]Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria
uruksme@gmail.com

Article Info:

Submitted:	Revised:	Accepted:	Published:
May 1, 2025	May 28, 2025	Jun 10, 2025	Jun 15, 2025

Abstract

The African fan shrimp (*Atya gabonensis*), a non-clawed, filter-feeding decapod of ecological and nutritional importance, remains understudied regarding its population structure and phenotypic variability in Nigerian freshwater ecosystems. This study assessed quantitative phenotypic traits and inferred population structure of *A. gabonensis* from the Lower River Benue, Makurdi, Nigeria, using Principal Component Analysis (PCA). One hundred adult specimens were measured for 14 morphometric traits, including total length, carapace dimensions, and abdominal parameters. After standardizing data via allometric transformation, PCA was performed to identify key contributors to phenotypic variation. Data suitability was confirmed (KMO = 0.73, Bartlett's test $p < 0.001$). The first four principal components, with eigenvalues greater than one, explained 75.65% of total variance. PC1 (32.31%) was dominated by total length, standard length, and body weight, reflecting overall body size. PC2 (19.91%) emphasized carapace and abdominal length, indicating internal body capacity variation. PC3 (11.89%) and PC4 (11.54%) represented differences in gut and carapace width, respectively, suggesting morphological variation linked to environmental adaptation or sexual dimorphism. These morphometric patterns reveal significant phenotypic variability within the population, providing insights into potential genetic divergence and local adaptation. The findings offer foundational data to support species management, aquaculture development, and conservation strategies. This study demonstrates the efficacy of PCA in elucidating key phenotypic traits and highlights the value of integrating morphometric and genetic analyses for comprehensive crustacean stock assessments.

Keywords: *Atya gabonensis*; Morphometrics; Phenotypic Variation; Principal Component Analysis; Population Structure; Genetic Divergence

INTRODUCTION

The African fan shrimp (*Atya gabonensis*) is a non-clawed, filter-feeding decapod crustacean widely distributed in freshwater ecosystems across West and Central Africa. It plays an ecologically significant role in nutrient cycling and substrate filtration, while also serving as a protein-rich food source and having emerging value in the ornamental aquatic industry (Powell, 1982; Adeogun *et al.*, 2016). Despite its ecological and economic importance, *A. gabonensis* remains under-researched in terms of its population structure and genetic diversity, particularly in Nigerian inland waters such as the Lower River Benue.

Quantitative phenotypic traits such as body length, carapace width, and rostrum length serve as crucial indicators for stock assessment, selection programs, and conservation planning (Teletchea & Fontaine, 2014). These traits, which often display continuous variation, are influenced by both genetic and environmental factors. Their analysis through multivariate statistical tools such as Principal Component Analysis (PCA) helps in distinguishing phenotypic variability among and within populations (Ihensekhien *et al.*, 2021). However, the phenotypic plasticity and genetic variability of *A. gabonensis* populations in Nigerian freshwater systems remain largely undocumented.

The lack of genetic and morphometric baseline data presents significant limitations for the sustainable management and conservation of *A. gabonensis* populations. Particularly, the Lower River Benue, which experiences intense anthropogenic pressures including overfishing, pollution, and habitat degradation, has not been extensively studied for intra-species genetic variability and phenotypic structuring of its decapod crustacean fauna (Moses *et al.*, 2019; Oben *et al.*, 2020). This knowledge gap hinders effective management, potential aquaculture domestication, and conservation programs tailored to preserve the genetic integrity of the species.

Recent advances in quantitative genetics have demonstrated that phenotypic traits can be utilized to infer population structure and genetic divergence, especially when supported by multivariate methods such as PCA, which reduces data dimensionality and reveals trait combinations that best differentiate individuals or populations (Yakubu & Madu, 2014; Njoku *et al.*, 2022). Such approaches are essential in bridging the gap between phenotypic assessments and molecular data, especially in resource-limited settings.

There is a paucity of empirical data on the genetic and phenotypic structure of *Atya gabonensis* in Nigerian inland waters, particularly in the Lower River Benue. This scarcity impedes efforts aimed at stock improvement, conservation, and aquaculture development. Furthermore, no previous studies have applied Principal Component Analysis to decipher the quantitative phenotypic traits of this species in the region. Without such data, it is difficult to monitor population health, detect signs of genetic erosion, or develop informed breeding and conservation strategies.

This study aims to investigate the genetic structure of *Atya gabonensis* populations in the Lower River Benue, Makurdi, Nigeria, by analyzing quantitative phenotypic traits using Principal Component Analysis. The findings will provide baseline data for stock characterization and contribute to conservation and aquaculture strategies for the species.

MATERIALS AND METHODS

Study Area

The study was conducted in Makurdi, the capital of Benue State, Nigeria (7°43'N, 8°32'E), located along the River Benue figure 1. This perennial river, which originates from the Adamawa Plateau in Cameroon and flows through several Nigerian towns before merging with the Niger River at Lokoja, supports diverse aquatic life and significant artisanal fisheries. The river exhibits seasonal fluctuations, with peak flooding from May to October, creating extensive floodplains (up to 310,000 ha) that serve as breeding grounds for various fish species.

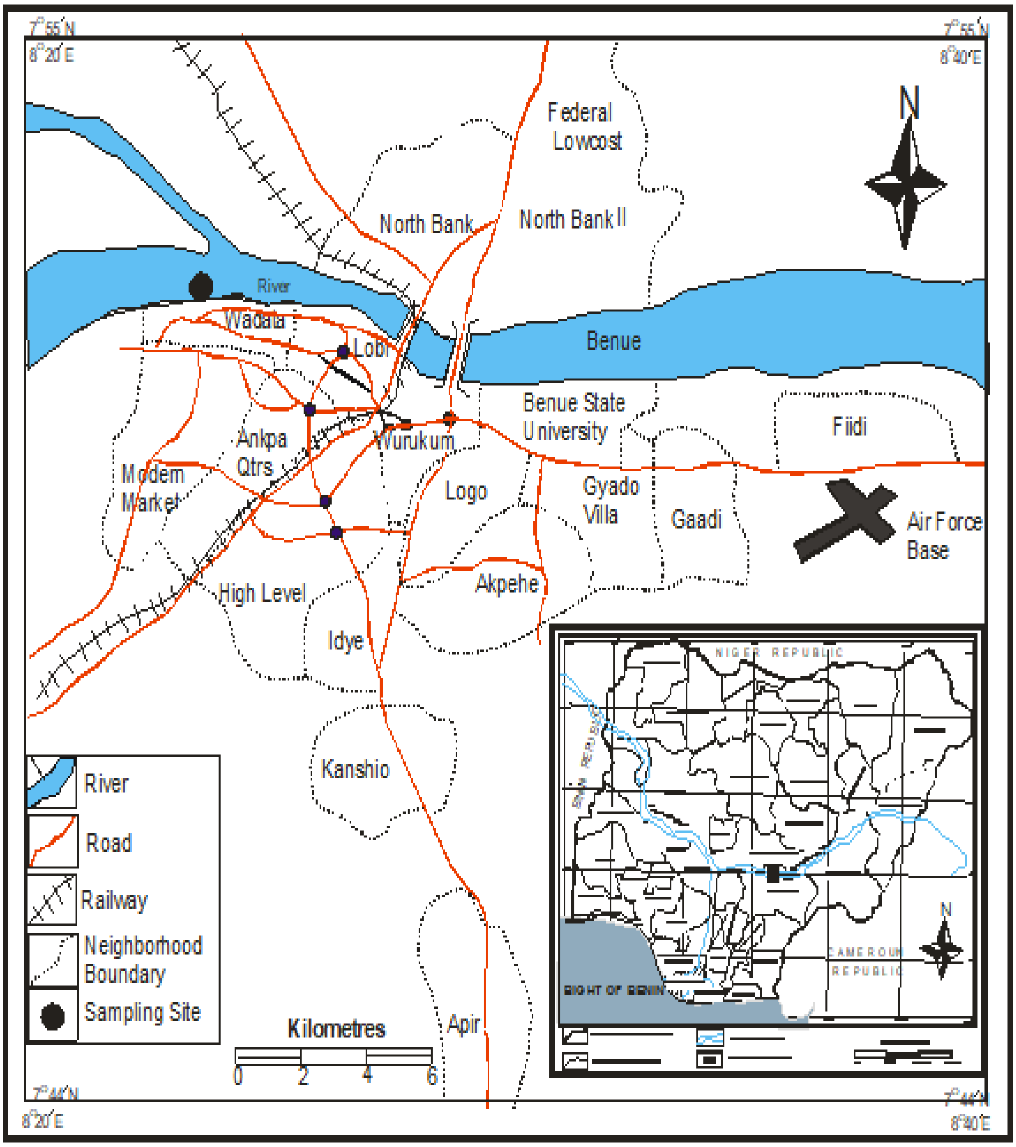

Figure 1. Map of Makurdi, Benue State showing sampling river.

Source: Benue State Ministry of Land and Survey

Sample Collection

Specimens of *Atya gabonensis* were collected bi-monthly from February to June 2023 using hand nets and baited local traps. Live samples were transported to the laboratory in aerated containers. Only adult individuals were used to minimize ontogenetic variation.

Identification and Sexing

Species identification followed the taxonomic keys of Powell (1982). Sex was determined using morphological features such as the appendix masculine, reproductive chamber, and abdominal segment characteristics, as described by Grooves (1985).

Morphometric Measurements

One hundred adult individuals were measured for 14 morphometric traits figure 2 (e.g., total length, standard length, carapace dimensions, abdominal length, gut parameters) using digital Vernier calipers (±0.01 mm). Measurements were taken on the left body side to avoid asymmetry bias.

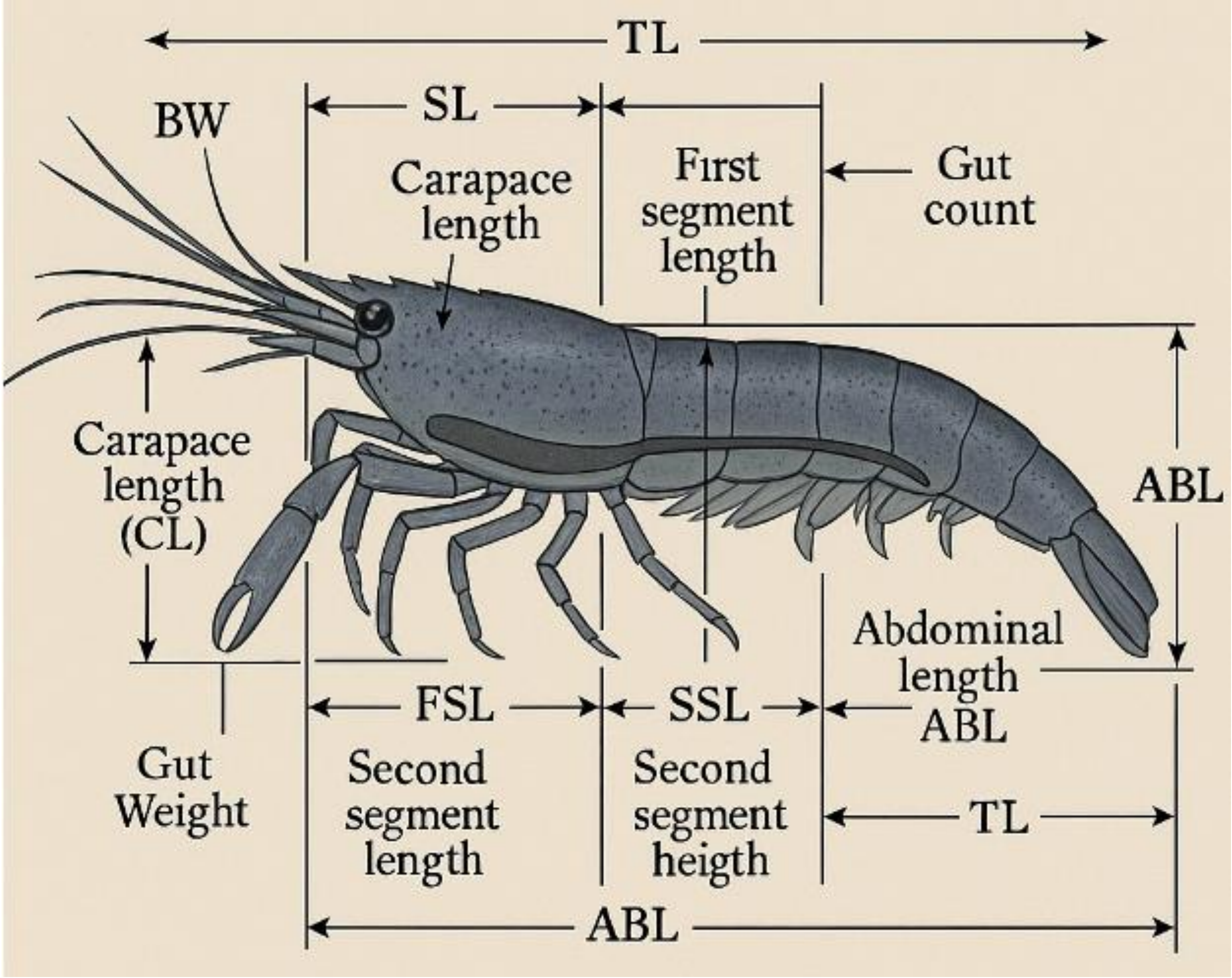

Figure 2: land mark showing measured morphometric trades of *Atya gabonensis*

Length and Weight Measurement

Total length (TL) and body weight (BW) were measured to the nearest 0.1 cm and 0.01 g, respectively, using standard procedures (Froese, 2006).

Data Standardization

Morphometric data were standardized using allometric transformation methods (Elliott *et al.*, 1995; Reist, 1985) to control for size variation.

Statistical Analysis

Principal Component Analysis (PCA), Canonical Variate Analysis (CVA), and Discriminant Function Analysis (DFA) were conducted using PAST v4.03, SPSS v25, and R software (Morpho and stats packages) to examine variation and population structure.

Ethical Considerations

All procedures adhered to ethical guidelines for animal research, minimizing stress and harm during handling and measurement.

RESULTS

Principal Component Analysis of the Variations in Morphometric Attributes of the Studied

1. gabonensis Population

Results of the preliminary test for adequacy of morphometric data for Principal Component Analysis are shown in Table 1. The Kaiser-Meyer-Olkin measure of sampling adequacy indicated 0.73 at P = 0.00 Bartlett's test of sphericity.

Table 1. Principal Component Analysis of the Phenotypic Descriptors of Morphometric Attributes of the Studied *atya gabonensis* Population from Lower River Benue, Makurdi Nigeria.

KMO and Bartlett's Test		Values
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.73
Bartlett's Test of Sphericity	Approx. Chi-Square	934.09
	df	78
	Sig.	0.00

Table 2 presents the summary of the Principal Component Analysis (PCA) conducted on the morphometric attributes of *Atya gabonensis* populations. The analysis revealed that the first four principal components (PCs) had eigenvalues greater than 1.00, indicating they are the most significant contributors to the variation in the dataset based on Kaiser's criterion. Specifically, PC1 accounted for 32.31% of the total variance with an eigenvalue of 4.20, followed by PC2 with 19.91% (eigenvalue = 2.59), PC3 with 11.89% (eigenvalue = 1.55), and PC4 with 11.54% (eigenvalue = 1.50). Collectively, these four components explained 75.65% of the total morphological variation observed among the *A. gabonensis* populations. The remaining components contributed minimally to the variance, each explaining less than 10%.

Table 2. Summary of Principal Component Analysis (PCA) for the morphometric Attributes of *A. gabonensis* Populations

Component	Eigenvalues	% of Variance	Cumulative %
1	4.20	32.31	32.31
2	2.59	19.91	52.23
3	1.55	11.89	64.12
4	1.50	11.54	75.65
5	0.98	7.57	83.23
6	0.60	4.58	87.80
7	0.54	4.13	91.93
8	0.34	2.62	94.55
9	0.28	2.13	96.69
10	0.18	1.42	98.11
11	0.15	1.15	99.26
12	0.06	0.42	99.68
13	0.04	0.32	100.00

Extraction Method: Principal Component Analysis (PCA).

Principal Component Analysis (PCA) was performed on the morphometric variables of *Atya gabonensis* populations to identify the major components contributing to shape variation. The scree plot (Figure 3) revealed a sharp decline in eigenvalues after the third component, indicating that the first three principal components (PCs) account for most of the variation in the dataset.

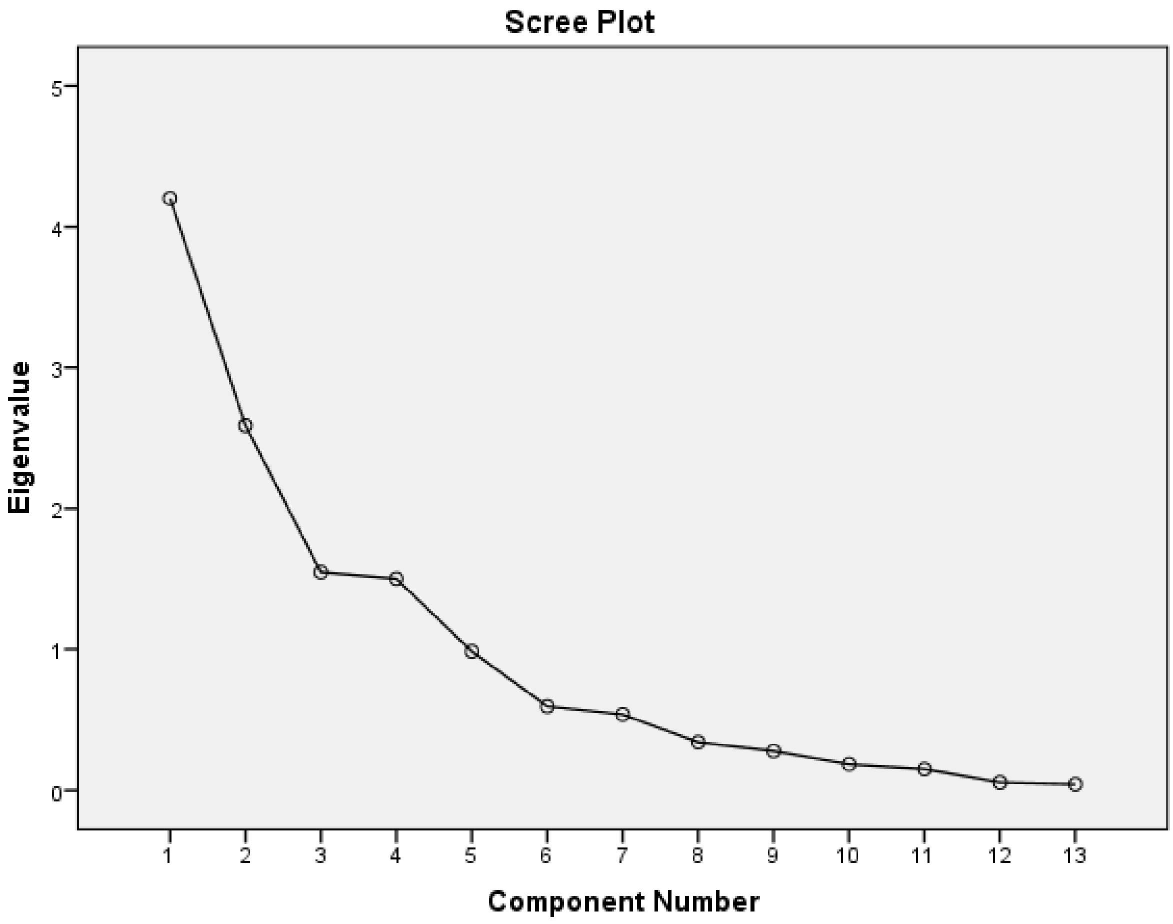

Figure 3. Scree plot of Principal Component Analysis (PCA) for the morphometric variables of *A. gabonensis* Populations

As shown in Table 3, the first four PCs explained the majority of the variance, with the following loadings:

PC1 showed high positive loadings for Total Length (TL = 0.904), Standard Length (SL = 0.919), Body Weight (BW = 0.842), and negative loadings for Soft Spine Length (SSL = -0.617) and Second Soft Spine Height (SSH = -0.595).

PC2 had strong positive loadings for Carapace Length (CL = 0.800), Abdominal Length (ABL = 0.806), and Carapace Height (CH = 0.543).

PC3 was primarily associated with Gut Width (GUTW = 0.626) and Fused Spine Length (FSL = 0.500), indicating variation in abdominal characteristics.

PC4 was moderately associated with Carapace Width (CW = -0.812), suggesting variation in overall robustness or width of the individuals.

Table 3. Factor loadings for the first four principal components formed from the morphometric variables of *A. gabonensis* populations

Variables	**Components**			
	1	2	3	4
TL	**0.904**	**0.271**	**0.142**	**-0.140**
SL	**0.919**	**0.173**	**0.105**	**-0.229**
CL	**0.330**	**0.800**	**-0.305**	0.019
CH	0.093	**0.543**	**-0.559**	**0.313**
CW	0.071	**0.267**	0.095	**0.812**
FSL	0.063	**0.215**	**0.500**	**0.640**
FSH	**-0.489**	**0.570**	**-0.302**	**-0.194**
SSL	**-0.617**	**0.484**	**0.419**	**-0.052**
SSH	**-0.595**	**0.240**	**0.289**	**-0.298**
ABL	**-0.149**	**0.806**	**0.307**	**-0.158**
GUTL	**-0.830**	**0.232**	-0.067	**-0.147**
BW	**0.842**	**0.336**	0.093	**-0.278**
GUTW	**0.133**	-0.007	**0.626**	-0.093

Bold indicates high loading at ±0.10

DISCUSSION

Based on the data presented in Table 1, the Principal Component Analysis (PCA) of the phenotypic descriptors of *Atya gabonensis* from the Lower River Benue, Makurdi, Nigeria, was deemed appropriate given the results of the Kaiser-Meyer-Olkin (KMO)

Measure of Sampling Adequacy and Bartlett's Test of Sphericity. These preliminary tests are essential in determining the suitability of the dataset for PCA and form the foundation of the multivariate analysis.

The KMO value obtained was 0.73, which falls within the acceptable range for factor analysis. According to Kaiser (1974), KMO values between 0.7 and 0.8 are considered "good," indicating that the data are adequate for PCA. The KMO statistic measures the proportion of variance among variables that might be common variance, and a value closer to 1 suggests that patterns of correlations are relatively compact and thus factor analysis should yield distinct and reliable factors (Field, 2013).

In studies involving morphometric traits of aquatic species, a KMO value above 0.6 is generally taken as a strong indication of data adequacy for dimension reduction techniques like PCA (Jolliffe & Cadima, 2016). Therefore, the KMO value of 0.73 indicates a strong interrelationship among the morphometric descriptors of *Atya gabonensis,* supporting their inclusion in the PCA.

Bartlett's test returned a highly significant result (Chi-Square = 934.09, df = 78, Sig. = 0.00), confirming that the correlation matrix is not an identity matrix and that there are statistically significant relationships among the variables. This test evaluates the null hypothesis that the variables are orthogonal, meaning unrelated. A significance value ($p < 0.05$) justifies the use of PCA, as it implies that there are enough correlations in the data to form reliable components (Hair *et al.*, 2010).

In biological studies involving fish and crustaceans, including morphometric and meristic traits, Bartlett's test is routinely applied to validate the assumptions for PCA. The significant result here implies that the phenotypic descriptors measured are interrelated, allowing for data reduction and pattern recognition through PCA (Zelditch *et al.*, 2012).

The results in Table 2 of the PCA suggest that a substantial proportion of morphometric variation in *A. gabonensis* populations can be explained by a few key components, with the first four accounting for over 75% of the cumulative variance. This pattern is indicative of a high level of morphological structuring within the population, and implies that a limited number of traits are primarily responsible for the observed differences.

Similar findings have been reported in related crustacean and fish studies. For example, [Ihese *et al.* (2020)] demonstrated that in *Macrobrachium vollenhovenii*, the first three principal components explained over 70% of morphometric variation across riverine populations. Likewise, [Adeyemi *et al.* (2019)] in their study on *Clarias gariepinus* found that the first few PCs were sufficient to account for the bulk of phenotypic differentiation, supporting the effectiveness of PCA in morphometric discrimination.

The dominance of the first principal component (PC1) suggests a general size factor, which is often observed in morphometric studies (Rohlf & Marcus, 1993). The contributions of PC2 through PC4 may represent shape-related variations that could reflect adaptation to specific environmental conditions, such as water flow, substrate type, or resource availability (Wimberger, 1992; Turan, 2004).

This high-resolution morphometric approach provides a robust basis for delineating stock structure in crustacean populations and can inform conservation strategies. Specifically, the morphological divergence revealed by PCA could be useful in identifying distinct population units for management, especially under increasing anthropogenic pressures and climate change impacts on aquatic ecosystems.

The PCA revealed that the first three to four components are sufficient to describe the major patterns of morphological variation in *Atya gabonensis*, with PC1 explaining the largest proportion of variance. These findings are consistent with previous morphometric studies where body length and weight tend to dominate the first component due to their strong influence on overall body size and shape (Kumar et al., 2020; Ighwela *et al.*, 2011).

The high loadings of TL, SL, and BW on PC1 Table 3 indicate that this component largely represents overall body size, while the negative loading for SSL and SSH suggests inverse relationships between size and some spine features. This aligns with findings by Silva *et al.* (2015), who reported that morphometric differentiation in crustaceans often reflects both size and habitat-specific adaptations.

PC2 and PC3 highlight internal body dimensions (CL, ABL, GUTW), which may relate to differences in reproductive or digestive capacity among populations. This agrees with the interpretation of morphometric traits as being partly under genetic control but also influenced by environmental factors such as food availability and water current (Adepoju *et al.*, 2021; Turan *et al.*, 2006).

The relatively high loading of CW on PC4 could point to width differences due to environmental stress or sexual dimorphism, a pattern observed in other decapod crustaceans (Mariappan *et al.*, 2000).

In summary, the morphometric variation in *A. gabonensis* is driven primarily by overall size and secondary shape traits, with implications for stock differentiation and possible adaptive divergence. These findings could support future conservation and aquaculture strategies by identifying key traits of population differentiation.

CONCLUSION

This study revealed significant morphometric variation within *Atya gabonensis* populations in the Lower River Benue, with four principal components accounting for over 75% of total variance. PCA identified body length, carapace and abdominal dimensions as primary discriminators. These results suggest potential stock differentiation, likely influenced by genetic and environmental factors. The findings provide a morphometric baseline essential for conservation, breeding, and aquaculture programs targeting *A. gabonensis*. Phenotypic traits proved useful for assessing population structure where molecular tools are unavailable.

REFERENCES

Adeogun, A. O., Ibor, O. R. and Arukwe, A. (2016). Biomarker responses in African fan shrimp (*Atya gabonensis*) from a Niger Delta River impacted by oil-related activities. *Ecotoxicology and Environmental Safety*, 124, 351–358. https://doi.org/10.1016/j.ecoenv.2015.11.031

Adepoju, S. A., Fashina-Bombata, H. A. and Oketoki, O. T. (2021). Morphometric and meristic characterization of African riverine fishes. *Journal of Fisheries Science*, 35(1), 56–63.

Adeyemi, S. O., Bankole, N. O. and Yusuf, H. B. (2019). Morphometric and meristic characterization of *Clarias gariepinus* (Burchell, 1822) from different water bodies in Nigeria. *International Journal of Fisheries and Aquatic Studies*, 7(2), 110–116.

Elliott, N. G., Haskard, K. and Koslow, J. A. (1995). Morphometric analysis of orange roughy (*Hoplostethus atlanticus*) off the continental slope of southern Australia. *Journal of Fish Biology*, 46(2), 202–220. https://doi.org/10.1111/j.1095-8649.1995.tb05962.x

Field, A. (2013). Discovering Statistics Using IBM SPSS Statistics (4th ed.). SAGE Publications.

Froese, R. (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal of Applied Ichthyology*, 22(4), 241–253. https://doi.org/10.1111/j.1439-0426.2006.00805.x

Grooves, R.F. (1985). The Prawn, its nature and nurture. Fishery News Books Survey. England, 95 P.

Hair, J. F., Black, W. C., Babin, B. J. and Anderson, R. E. (2010). Multivariate Data Analysis (7th ed.). Pearson Education.

Ighwela, K. A., Ahmed, A. B. and Abol-Munafi, A. B. (2011). Condition factor as an indicator of growth and feeding intensity of Asian catfish (*Clarias batrachus*). *Iranian Journal of Fisheries Sciences*, 10(3), 527–536.

Ihensekhien, E. M., Solomon, S. G. and Ivoke, N. (2021). Morphometric characterization and phenotypic differentiation of wild and cultured populations of *Clarias gariepinus* using multivariate analysis. *Journal of Fisheries and Aquatic Science,* 16(2), 45–53.

Ihese, F. N., Okeke, O. C., and Onuoha, E. (2020). Morphometric and meristic variations of Macrobrachium vollenhovenii from selected rivers in Nigeria. *Journal of Applied Sciences and Environmental Management*, 24(3), 493–499.

Jolliffe, I. T. and Cadima, J. (2016). Principal component analysis: A review and recent developments. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 374(2065), 20150202.

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika*, 39(1), 31–36. https://doi.org/10.1007/BF02291575

Kumar, R., Sinha, M. R., and Lal, K. K. (2020). Morphometric and meristic traits for fish stock identification: A brief overview. *Journal of Experimental Zoology India*, 23(1), 211–216.

Mariappan, P., Balasundaram, C., and Schmitz, B. (2000). Decapod crustacean chelipeds: An overview. *Journal of Biosciences*, 25(3), 301–313. https://doi.org/10.1007/BF02703939

Moses, M. E., Umeh, E. D. and Agbede, S. A. (2019). Assessment of anthropogenic effects on water quality in River Benue, Makurdi, Nigeria. *Nigerian Journal of Environmental Sciences and Technology*, 3(1), 65–74.

Njoku, D. C., Nwani, C. D. and Ugwumba, A. A. (2022). Application of principal component analysis for morphometric differentiation of fish populations from the Niger River Basin. *Aquaculture Reports*, 22, 100950. https://doi.org/10.1016/j.aqrep.2021.100950

Oben, P. M., Agbo, F. C. and Gevera, K. C. (2020). Human-induced threats and habitat degradation in freshwater systems of Benue State. *Environmental Monitoring and Assessment*, 192, 1–13. https://doi.org/10.1007/s10661-020-8224-2

Powell, C. B. (1982). Fresh and brackish water shrimps of economic importance in the Niger Delta. *Proceedings of the 2nd Annual Conference of the Fisheries Society of Nigeria*, 254–261.

Powell, C. B. (1982). Freshwater decapods of Nigeria: species richness, higher taxa and size distribution. *Freshwater Biology*, 12(4), 345–364. https://doi.org/10.1111/j.1365-2427.1982.tb00633.x

Reist, J. D. (1985). An empirical evaluation of several univariate methods that adjust for size variation in morphometric data. *Canadian Journal of Zoology*, 63(6), 1429–1439. https://doi.org/10.1139/z85-213

Rohlf, F. J. and Marcus, L. F. (1993). A revolution in morphometrics. *Trends in Ecology & Evolution*, 8(4), 129–132. https://doi.org/10.1016/0169-5347(93)90024-J

Silva, R. M., Santos, C. M. and Costa, R. M. (2015). Morphological variation in populations of *Macrobrachium amazonicum* from different Brazilian regions. *Zoologia*, 32(1), 48–58. https://doi.org/10.1590/S1984-46702015000100007

Teletchea, F. and Fontaine, P. (2014). Levels of domestication in fish: Implications for the sustainable future of aquaculture. *Fish and Fisheries*, 15(2), 181–195. https://doi.org/10.1111/faf.12006

Turan, C. (2004). Stock identification of Mediterranean horse mackerel (*Trachurus mediterraneus*) using morphometric and meristic characteristics. *ICES Journal of Marine Science*, 61(5), 774–781. https://doi.org/10.1016/j.icesjms.2004.05.001

Turan, C., Ergüden, D., Gürlek, M. and Yalçin, S. (2006). Morphometric structuring of the anchovy (*Engraulis encrasicolus*) in the Black, Aegean and North-eastern Mediterranean Seas. *Turkish Journal of Veterinary and Animal Sciences*, 30, 145–150.

Wimberger, P. H. (1992). Plasticity of fish body shape. *The American Zoologist*, 32(2), 656–665.

Yakubu, A. and Madu, T. (2014). Principal component analysis of body measurements in Nigerian indigenous sheep populations. *Journal of Animal Science and Advances*, 4(6), 826–834.

Zelditch, M. L., Swiderski, D. L. and Sheets, H. D. (2012). Geometric Morphometrics for Biologists: A Primer. Academic Press.