Morphological divergence between two populations of Nile tilapia from Burkina Faso

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Abstract

Nile tilapia, *Oreochromis niloticus*, exhibits remarkable phenotypic plasticity driven by adaptation to diverse ecological environments. As a major aquaculture species, Nile tilapia is typically subject to strain selection guided by phenotypic variability within natural populations. This study aimed to characterize the morphological variability in two natural populations (Lake Kou and Lake Tengrela) to support selective breeding programs in Burkina Faso. For each population, 50 specimens were analyzed using 25 morphometric variables, 6 meristic variables, and 4 biological indices. Univariate and multivariate analyses identified six morphometric variables, three meristic traits, and three biological indices as the main discriminant factors between the two populations. The results revealed a shared morphological foundation but contrasting phenotypic structures. Indeed, the Tengrela population displayed strong homogeneity, suggesting genetic stability and a predictable response to selection. Whereas the Kou population showed significant intra-population variability, reflecting fine-scale ecological adaptation and high evolutionary potential. These differences indicate a strategic complementarity between the two stocks. The homogeneous Tengrela population offers a favorable basis for establishing pure lines and producing standardized fry, while the genetic diversity within the Kou population represents a valuable genetic reservoir for enhancing the robustness and resilience of local strains. This study provides important data to guide the genetic selection of improved Nile tilapia strains in Burkina Faso.

Keywords: Nile tilapia; natural population; morphological variability; genetic selection; Burkina Faso.

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Divergence morphologique de deux populations de tilapia du Nil du Burkina Faso

Résumé

Le tilapia du Nil, *Oreochromis niloticus*, présente une plasticité phénotypique remarquable due à sa large amplitude écologique. Espèce aquacole majeure, il fait l'objet de sélection génétique basée sur la variabilité phénotypique des populations naturelles. Cette étude visait à caractériser la variabilité morphologique de deux populations naturelles (lac Kou et lac Tengrela) dans le cadre de programmes de sélection de souches améliorées mis en œuvre au Burkina Faso. Pour chaque population, 50 spécimens ont été caractérisés morphologiquement en analysant 25 variables morphométriques, 6 variables méristiques et 4 indices biologiques. Des analyses univariées et multivariées ont permis d'identifier six variables morphométriques, trois paramètres méristiques et trois indices biologiques comme principaux facteurs discriminants entre les deux populations. Les résultats révèlent une base morphologique commune, mais des structures phénotypiques contrastées. En effet, la population du lac Tengrela a montré une forte homogénéité, suggérant une stabilité génétique et une réponse prévisible à la sélection. Elle offre ainsi une base favorable pour établir des lignées pures et produire des alevins homogènes, Par contre, la population du lac Kou a montré une variabilité intra-populationnelle significative, reflétant une adaptation écologique à petite échelle et un potentiel évolutif élevé. Cette diversité représente un précieux réservoir génétique pour améliorer la robustesse et la résilience des souches locales. Ces différences indiquent une complémentarité stratégique entre les deux populations. L'ensemble de ces résultats constitue une base de données importante pour orienter la sélection génétique de souches améliorées de tilapia du Nil au Burkina Faso.

Mots clés : Tilapia du Nil ; population naturelle ; variabilité morphologique ; sélection génétique ; Burkina Faso.

Introduction

Morphological characterization is a fundamental approach in fish biology, providing a reliable means to identify phenotypic variation within and among individuals, populations, and species, and to understand the evolutionary and adaptive processes underlying this diversity (DONATI *et al.*, 2025; SCOCCO and DE FELICE, 2025). This approach relies on the analysis of morphometric and meristic characters, which are simple, non-destructive, and cost-effective tools that offer essential information on intra- and inter-population variability, environmental adaptation, and domestication potential (JAWAD *et al.*, 2020; ADEDEJI et al., 2024).

The study of morphological variability is particularly important for Nile tilapia (*Oreochromis niloticus*), a species widely distributed across

Africa and introduced to numerous regions worldwide (EL-SAYED and FITZSIMMONS, 2023). Owing to its high phenotypic plasticity, this species can adapt to a wide range of aquatic environments, resulting in pronounced morphological variations among populations inhabiting different ecosystems (ASMAMAW and TESSEMA, 2021; KWIKIRIZA *et al*., 2023; TIBIHIKA et al., 2023). Previous studies have reported significant morphometric variations influenced by strain, habitat type, food availability, and both natural and anthropogenic selection pressures.

ADEDEJI *et al.* (2024) demonstrated that traits such as head length, caudal peduncle length, and gill raker counts vary across environments, reflecting adaptive responses to local ecological conditions and resource availability. Similarly, TIBIHIKA *et al.* (2023) reported morphological differences associated with human activities, while KWIKIRIZA *et al.* (2023) observed morphometric variability among strains reared in different Ugandan aquaculture systems. Morphological analysis can therefore be used to assess intra- and inter-population variability, distinguish between local and introduced populations, detect potential hybridization with other tilapia species, and identify traits relevant for domestication and selection (BOUSSOU *et al*., 2024; HALA AINOU, 2024). Furthermore, it is an indispensable tool for the conservation and sustainable management of fishery resources, as it contributes to the preservation of genetic diversity in natural populations, which are often threatened by uncontrolled crossbreeding (TIBIHIKA *et al.,* 2023; WASSO *et al.,* 2025).

Globally, Nile tilapia has become one of the major aquaculture species due to its rapid growth, remarkable tolerance to various environments, and high nutritional value (AL-TAEE *et al*., 2022; WANG and DONG, 2025). Across Africa, it contributes significantly to food security, fishermen's incomes and the development of aquaculture industries (KAMINSKI *et al*., 2024; ABAHO *et al*., 2025). In Burkina Faso, Nile tilapia is among the most exploited species, both in artisanal fisheries and aquaculture, and plays a central role in the national diet and economy (FAO, 2024; OUÉDRAOGO *et al.*, 2025). However, despite its socio-economic importance, farming of this species faces a chronic shortage of quality fry (SISSAO *et al.,* 2019; SANTI *et al*., 2023), leading to a strong dependence on imported exogenous strains, with associated increases in production costs, health risks, and threats to the genetic diversity of local populations (SHINN *et al*., 2023; WASSO *et al*., 2025).

To address this problem, several programs for the selection and improvement of Nile tilapia strains have been implemented since 2012 at the Laboratory for Studies and Research on Natural Resources and Environmental Sciences (LERNSE) at Nazi BONI University in Bobo-Dioulasso, Burkina Faso. In addition, the country possesses an extensive hydrographic network of rivers, reservoirs, and natural lakes that harbor diverse endogenous genetic resources of Nile tilapia. These populations evolve in distinct ecological contexts (e.g., temperature, turbidity, productivity, and trophic resource availability), which are likely to drive phenotypic and biological differentiation, particularly in traits related to growth and resilience *(LIND et al., 2019; TIBIHIKA et al.*, 2020).

In this context, the morphological characterization of local populations represents an essential step in identifying high-performing strains that are adapted to the country's ecological conditions and capable to reduce dependence on imported exogenous strains. However, the morphological characterization of fish remains largely unexplored in Burkina Faso. The few studies available have mainly focused on African catfish (COMPAORÉ *et al*., 2015), while knowledge of the morphological variability of Nile tilapia remains limited.

The present study therefore aims to fill this gap by analyzing the biological variability of these two local populations of Nile tilapia, from the Volta basin (Kou) and the Comoé basin (Tengrela). Specifically, it compares their morphometric and meristic characteristics, along with key biological indices, to identify traits of relevance for the selection and domestication of local strains.

I. Materials and Methods

I.1. Sampling and study sites

Two wild populations of Nile tilapia from Lakes Kou and Tengrela, located in the Volta River and Comoé basins, respectively, were used for this study (Figure 1). The main characteristics of these two lakes are summarized in Table I. For each population, 50 fish weighing 60 g or more were collected. After sampling, the fish were transported to the experimental aquaculture station (geographical coordinates: 11°12'10“N / 4°25'3”W) of the Laboratory for the Study and Research of Natural Resources and Environmental Sciences (LERNSE) for data collection.

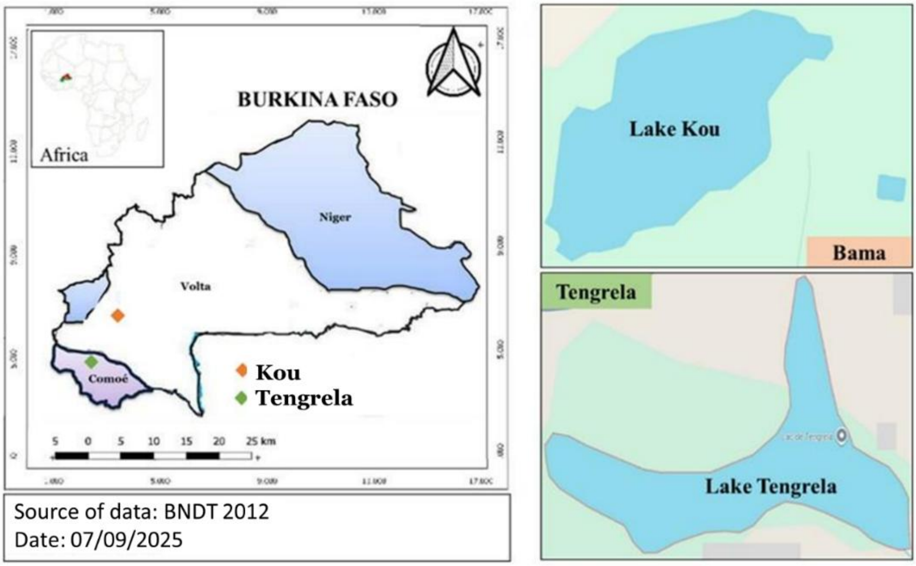

Figure 1 : Location of Lake Kou and Lake Tengrela in Burkina Faso.

Table I: key characteristics of the two study sites (RSIS 2009; Traoré 2012)

Characteristics	Lake Kou	Lake Tengrela
Burkina Faso river basin	Volta	Comoé
Administrative Region	Guiriko	Tannounyan
Type of water body	Semi-natural	Natural
Climate	Sudanian-Sahelian	Sudanian-Sahelian
Temperature (°)	19-36°C	17-36°C
Rainfall measurement (mm)	600-1500 mm	1000-1200 mm
Major activities	Agriculture, fishing, tourism	Fishing, tourism, conservation (Ramsar site since 2009)
Geographical coordinates	11°23′44″ N / 4°23′31.0″ W	10°38’44.7”N / 4°50’08.0”W

I.2. Metric data collection

A total of 25 morphometric measurements were recorded for each specimen (KONAN et al., 2018), including total length (TL), standard length (SL), head height (HH), head length (HL), snout length (SnL), eye diameter (ED), predorsal distance (PrDD), preanal distance (PrAD), prepectoral distance (PrPcD), prepelvic distance (PrPeD), dorsal fin base length (DFBL), anal fin base length (AFBL), dorsopedicular distance (DPD), pelvic-anal distance (PeAD), anopedicular distance (APD), caudal peduncle height (HPC), pectoral-pelvic distance (PcPeD), pectoral-anal distance (PcAD), pectoral-orbital distance (PcOD), dorso-anal distance (DAD), pectoral-pelvic height (PcPeH), minimum body height (MBH), height of the first anal fin spine (AFSH1), pelvic-pelvic distance (PePeD), and interorbital diameter (IOD). Total length and standard length were measured using a graduated ruler with an accuracy of 1 cm, while the remaining 23 measurements were taken with a digital caliper (accuracy of 0.01 mm).

I.3. Meristic data collection

Six meristic parameters were recorded for each individual using a magnifying glass (Figure 2). These included the number of dorsal fin spines (DFS), the number of dorsal soft rays (DSR), the number of anal fin spines (AFS), the number of anal soft rays (ASR), the number of scales on the upper lateral line (SULL), and the number of scales on the lower lateral line (SLLL).

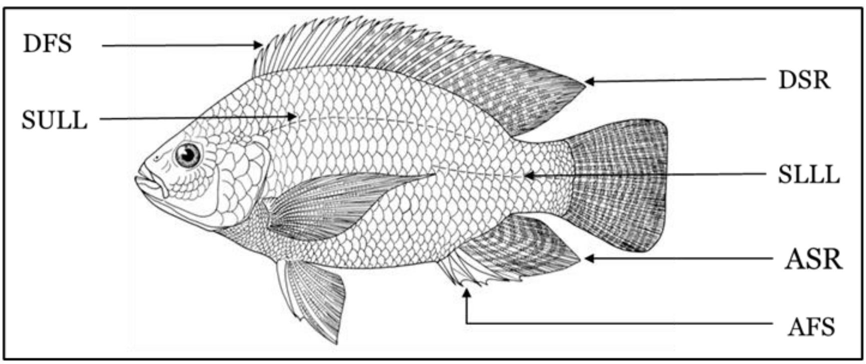

Figure 2: Schematic representation of the different meristic counted variables.

I.4. Weight data collection

Weight data were recorded for all specimens. For each sampled fish, five weight-related variables were measured: total body weight, body eviscerated weight, gonad weight, liver weight, and fat weight, using a precision balance an accuracy of ±0.0001 g. These measurements were subsequently used to calculate several biological indices, providing information on the fish's condition, energy reserves, and reproductive potential. The indices were calculated as follows:

$$\text{Carcass yield (CR, \%)} = \frac{\text{Eviscerated weight}}{\text{Total body weight}} \times 100$$

$$\text{Gonadosomatic index (GSI, \%)} = \frac{\text{Gonad weight}}{\text{Eviscerated weight}} \times 100$$

$$\text{Hepatosomatic index (HSI, \%)} = \frac{\text{Liver weight}}{\text{Eviscerated weight}} \times 100$$

$$\text{Fat index (FI, \%)} = \frac{\text{Fat weight}}{\text{Eviscerated weight}} \times 100$$

I.5. Statistical data analysis

All statistical analyses were conducted using R software (version 4.5.1, 2025). Morphometric data were first standardized to eliminate the effect of size: head measurements were expressed as a percentage of total head length, and body measurements as a percentage of standard length. Descriptive statistics, including the mean and standard deviation, were calculated for each morphometric and meristic variable, as well as for each biological index. The normality of distributions was assessed using the Shapiro-Wilk test, and homogeneity of variances was evaluated with Levene's test. As most variables did not meet the assumptions of normality and homogeneity of variances, nonparametric analyses were performed using the Kruskal-Wallis test, followed by Dunn’s post hoc test with Bonferroni correction to identify significant differences between groups. In addition to univariate analyses, Principal Component Analysis (PCA) and Functional Discriminant Analysis (FDA) were carried out to identify the most discriminating traits between the studied populations. The PCA was performed on all variables that showed significant differences between populations, in order to summarize the total variance and identify the main axes of differentiation. The DFA was then applied using the same variables to maximize the separation between groups. The model’s performance was evaluated using the classification matrix, which indicates the percentage of individuals correctly reassigned to their original population.

II. Results

II.1. Variation in morphological parameters of Nile tilapia populations in Kou and Tengrela

II.1.1. Metric variables

The comparative analysis of morphometric variables between the Kou and Tengrela populations reveals overall morphometric homogeneity, as the majority of measured parameters do not differ significantly ($p \geq 0.05$). Nevertheless, five of the 24 variables analyzed exhibit statistically significant differences ($p < 0.05$): eye diameter (ED), pectoral-pelvic distance (PcPeD), pectoral-orbital distance (PcOD), minimum body height (MBH), and pelvic-pelvic distance (PePeD). Among these, three variables - pectoral-pelvic distance (PcPeD), minimum body height (MBH), and pelvic-pelvic distance (PePeD) - show highly difference ($p < 0.001$) between the two populations (Table II). Specimens from Lake Kou display larger eye diameter (ED), greater minimum body height (MBH), and longer pectoral-pelvic distance (PcPeD) compared to those from Lake Tengrela. Conversely, pelvic-pelvic distance (PePeD) and pectoral-orbital distance (PcOD) are greater in the Tengrela population than in Kou population.

Table II: Mean values of metric parameters according to Kou and Tengrela populations of Nile tilapia

Metric variables	Kou N=50 Mean ± SD	Tengrela N=50 Mean ± SD	P-Value
TL (%LS)	126.07 ± 18.10[a]	120.02 ± 17.95[a]	0.2553
HH (%HL)	47.20 ± 7.6[a]	46.59 ± 6.91[a]	0.27
HL (%LS)	34.80 ± 6.28 [a]	34.74 ± 6.85[a]	0.5955
SnL (%HL)	29.81 ± 11.45[a]	26.94 ± 5.65[a]	0.06618
ED (%HL	21.76 ± 2.91[b]	20.48 ± 5.09[a]	0.020*
PrDD (%LS)	33.84 ± 7.68[a]	33.59 ± 5.41[a]	0.4777
PrAD (%LS)	71.38 ± 15.99[a]	69.60 ± 15.75[a]	0.3379
PrPcD (%LS)	35.70 ± 6.78[a]	35.40 ± 6.08[a]	0.1285
PrPeD (%LS)	41.94 ± 6.72[a]	39.94 ± 6.90[a]	0.3043
DFBL (%LS)	57.46 ± 14.03[a]	58.64 ± 10.09[a]	0.1627
AFBL (%LS)	17.46 ± 2.57[a]	18.05 ± 8.68[a]	0.5103
DPD (%LS)	11.58 ± 4.31[a]	11.24 ± 2.12[a]	0.4219
PeAD (%LS)	32.90 ± 4.92[a]	30.94 ± 6.20[a]	0.3043
APD (%LS)	12.14 ± 3.95[a]	11.19 ± 1.93[a]	0.3538
HPC (%LS)	14.28 ± 2.71[a]	14.30 ± 3.38[a]	0.3683
PcPeD (%LS)	8.93 ± 2.50[b]	6.84 ± 1.41[a]	0.0000***
PcAD (%LS)	38.44 ± 3.99[a]	36.51 ± 6.05[a]	0.1234
PcOD (%LS)	19.23 ± 8.12[a]	19.73 ± 5.10[b]	0.0047**
DAD (%LS)	55.75 ± 10.32[a]	54.63 ± 8.32[a]	0.8686
PcPeH (%LS)	7.84 ± 6.81[a]	6.31 ± 1.64[a]	0.0966
MBH (%LS)	36.56 ± 6.33[b]	33.42 ± 5.36[a]	0.0001***
AFSH1 (%LS)	6.68 ± 1.46[a]	6.37 ± 1.39[a]	0.5192
PePeD (%LS)	9.46 ± 2.37[a]	10.40 ± 2.02[b]	0.0000***
IOD (%HL)	14.71 ± 4.73[a]	15.11 ± 2.88[a]	0.361

SD *= standard deviation,* ***N*** *= sample size per population,* ***P*** *= probability value; * indicates $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$,* ***TL*** *= total length,* ***SL*** *= standard length,* ***HH*** *= head height,* ***HL*** *= head length,* ***SnL*** *= snout length,* ***ED*** *= eye diameter,* ***PrDD*** *= predorsal distance,* ***PrAD*** *= preanal distance,* ***PrPcD*** *= prepectoral distance,* ***PrPeD*** *= prepelvic distance,* ***DFBL*** *= dorsal fin base length,* ***AFBL*** *= anal fin base length,* ***DPD*** *= dorsopedicular distance,* ***PeAD*** *= pelvic-anal distance,* ***APD*** *= anopedicular distance,* ***HPC*** *= height of the caudal peduncle,* ***PcPeD*** *= pectoral-pelvic distance,* ***PcAD*** *= pectoral-anal distance,* ***PcOD*** *= pectoral-orbital distance,* ***DAD*** *= dorso-anal distance,* ***PcPeH*** *= pectoral-pelvic height,* ***MBH*** *= minimum body height,* ***AFSH1*** *= height of the first anal fin spine,* ***PePeD*** *= pelvic-pelvic distance, and* ***IOD*** *= interorbital diameter. Means with the same letters in each line did not differ significantly at $p < 0.05$.*

II.1.2. Meristic variables

Analysis of meristic variables between the Kou and Tengrela populations reveals that, of the six variables analyzed, three show significant differences ($p < 0.01$) between the two populations. These are the number of dorsal fin spines (DFS), the number of dorsal soft rays (DSR), and the number of scales on the upper lateral line (SULL) (Table III). The results indicate that Tengrela fish have higher average numbers of these traits than Kou fish.

Table III: Average values of meristic parameters according to Kou and Tengrela populations of Nile tilapia

Meristic variables	Kou	Tengrela	P-Value
	N = 50	N = 50	
	Mean ± SD	Mean SD	
DFS	16.82 ± 0.39[a]	17.06 ± 0.31[b]	0.0012**
DSR	11.50 ± 0.81[a]	11.88 ± 0.59[b]	0.0031**
AFS	3.00 ± 0.00[a]	3.00 ± 0.00[a]	1
ASR	8.82 ± 0.69[a]	9.00 ± 0.53[a]	0.1027
SULL	21.32 ± 2.33[a]	22.56 ± 1.26[b]	0.0039**
SLLL	15.10 ± 2.29[a]	14.64 ± 1.77[a]	0.1815

***SD** = standard deviation, **N** = sample size per population, **P** = probability value; ** indicates p < 0.01, **DFS** = the number of dorsal fin spines, **DSR** = the number of dorsal soft rays, **AFS** = the number of anal fin spines, **ASR** = the number of anal soft rays, **SULL** = the number of scales on the upper lateral line, and **SLLL** = the number of scales on the lower lateral line. Means with the same letters in each line did not differ significantly at p < 0.05.*

II.1.3. Biological indices

The results show that biological indices vary significantly between the two populations. Of the four indices analyzed, three proved to be discriminatory for the two populations (Table IV). These are carcass yield (CR), hepatosomatic index (HSI), and body fat index (FI). CR and FI are higher in Tengrela individuals than in Kou individuals, while HSI is significantly higher in fish from Lake Kou than in those from Lake Tengrela. Only the gonadosomatic index (GSI) shows no significant difference between the two populations.

Table IV: Average values of biological indices according to Kou and Tengrela populations of Nile tilapia

Biological indices	Kou	Tengrela	P-Value
	N = 50	N = 50	
	Mean ± SD	Mean ± SD	
CR (%)	84.17 ± 12.9[a]	88.22 ± 2.58[b]	0.0022**
GSI (%)	0.49 ± 1.29[a]	0.24 ± 0.31[a]	0.7046
HSI (%)	2.86 ± 8.41[b]	2.43 ± 0.85[a]	0.0001***
FI (%)	0.17 ± 0.35[a]	0.24 ± 0.27[b]	0.0007***

***SD** = standard deviation, **N** = sample size per population, **P** = probability value; ** indicates $p < 0.01$, *** indicates $p < 0.001$, **CR** = Carcass yield, **GSI** = Gonadosomatic index, **HSI** = Hepatosomatic index and **FI** = Fat index. Means with the same letters in each line did not differ significantly at $p < 0.05$.*

II.2. Principal Component Analysis (PCA) of morphological parameters of Nile tilapia populations in Kou and Tengrela

To visualize the relationships among measured traits and the differentiation between populations, a principal component analysis (PCA) was performed. Figure 3 illustrates both the relative contribution of each variable to the main axes and the distribution of individuals in the factorial space according to their lake of origin. The first two axes together explain 41.9% of the total variance (Dim1 = 24.9%; Dim2 = 17%) and reflect the most significant structuring of the data. Dim1 is strongly correlated with minimum body height (MBH), pectoral-pelvic distance (PcPeD), pectoral-orbital distance (PcOD), and pelvic-pelvic distance (PePeD), while Dim2 is mainly explained by the hepatosomatic index (HSI) and carcass yield (CR) (Figure 3a). These variables appear to contribute most to the differentiation between the two populations.

The projection of individuals on the factorial plane (Figure 3b) highlights two distinct clusters corresponding to the Kou and Tengrela populations. Individuals from Lake Kou are characterized by significant dispersion, while those from Tengrela form a more compact group.

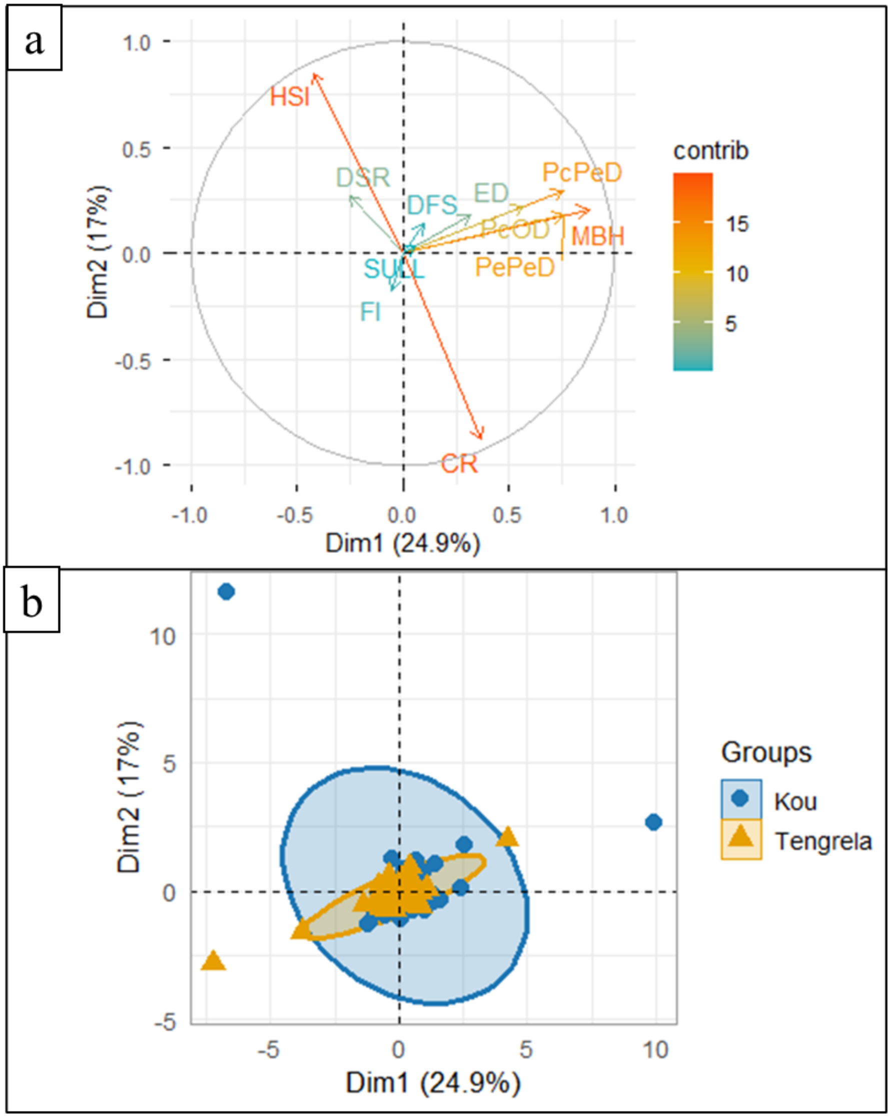

Figure 3: Projection of morphological variables (a) and individuals from both populations (b) in the PCA factorial plane.

II.3. Discriminant Factor Analysis (DFA) of morphological parameters of Nile tilapia populations in Kou and Tengrela

Discriminant factor analysis (DFA) was conducted to identify and visualize the most influential variables contributing to the separation between the two populations of Nile tilapia from Lakes Kou and Tengrela (Figure 4). The main discriminating variables were the number of dorsal spines (DFS), the pelvic-pelvic distance (PePeD), and the number of dorsal soft rays (DSR), which exhibited the strongest positive loadings on the discriminant function. In contrast, the pectoral-pelvic distance (PcPeD) and fat index (FI) showed negative contributions (Figure 4a).

The projection of individuals onto the first discriminant function (LD1) revealed that the Kou population, predominantly distributed on the negative side of the axis, was characterized by higher values of PcPeD and FI. Conversely, the Tengrela population, located on the positive side of axis, was associated with DFS, PePeD, and DSR. The DFA results indicated a clear, although partial, separation between the two populations (Figure 4b). Individuals from Lakes Kou and Tengrela formed two distinct clusters with a small overlap zone at the center.

The dispersion ellipses suggested a more homogeneous structure for the Tengrela population, while the Kou population exhibited greater variability in the discriminant space. Overall, the AFD highlighted significant morphological differentiation between the two populations, primarily driven by DFS, PePeD, DSR, PcPeD, and FI. Furthermore, the classification matrix showed correct classification rates of 86% for the Kou and 96% for the Tengrela population.

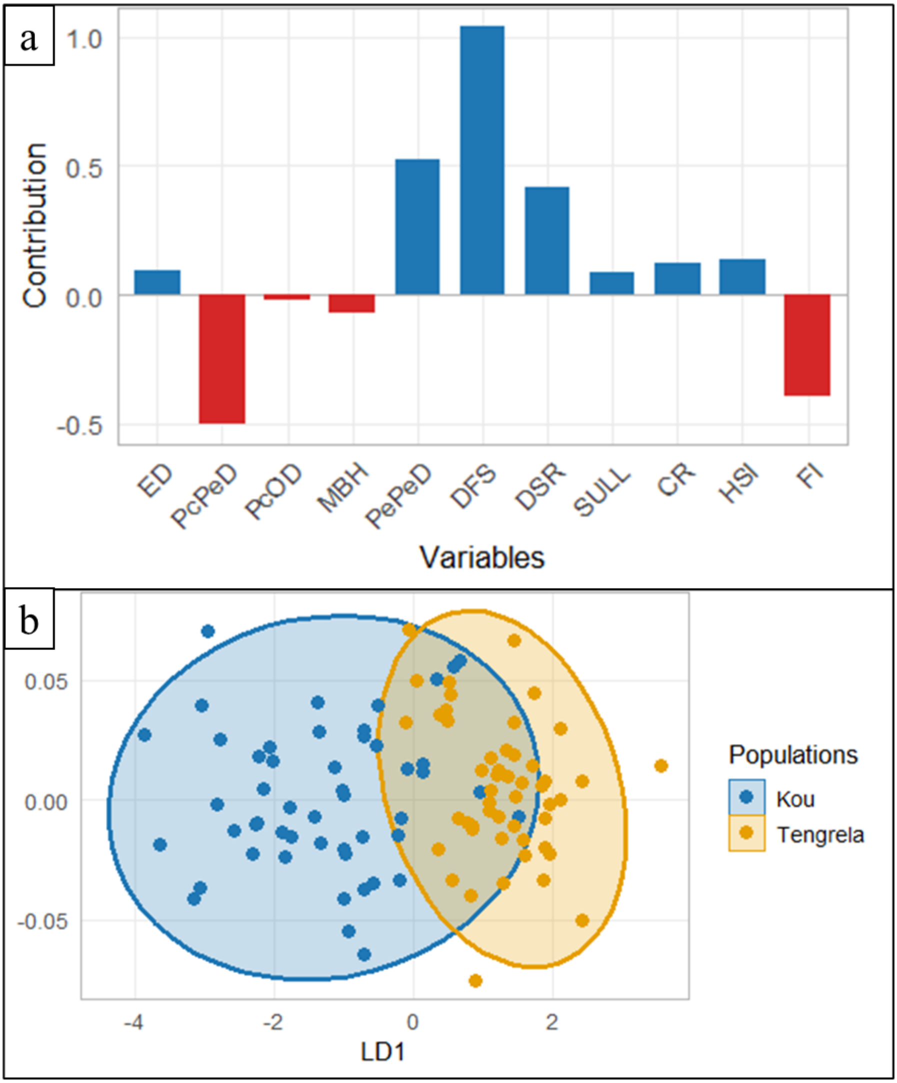

Figure 4: Contribution of morphological variables (a) and projection of individuals from both populations (b) on the first discriminant function LD1.

III. Discussion

III.1. Variability of morpho-biological parameters

A comparative analysis of the two populations reveals a shared morphological foundation between Nile Tilapia from Lakes Kou and Tengrela, along with significant differentiation in several key variables. In terms of morphometry, eye diameter (ED), minimum body height (MBH), pectoral-pelvic distance (PcPeD), and pelvic-pelvic distance

(PePeD) appear to be the main factors distinguishing the two populations. The larger ED, MBH, and PcPeD observed in the Lake Kou population suggest that this environment exerts strong ecological constraints such as reduced light availability, higher turbidity, micro-currents, and increased predation pressure (NDIWA *et al.,*2016; OYEWUMI *et al*., 2019). These conditions likely favor the development of larger eyes, a deeper body, and greater spacing between paired fins. Such observations are consistent with the work of MAHMOUD and HASSAN (2019) and OYEWUMI *et al.* (2019) , who emphasized the discriminating role of ED in cichlid differentiation, as well NDIWA et al. (2016), who demonstrated the adaptive significance of body depth in lacustrine environments.

Conversely, the Tengrela population exhibits higher PePeD, reflecting a wider spacing of the pelvic fins, which enhances lateral stability. This finding aligns with ATAGUBA *et al.*, (2021), who reported the discriminating potential of fin-related morphometric variables, such as pre-pectoral and pre-pelvic distances, analogous to the PcPeD and PePeD in the present study. The PCA results further confirm the clear structuring of Kou and Tengrela populations of *Oreochromis niloticus*, indicating significant morpho-biological differentiation between the two basins. Axis 1, dominated by morphometric variables (MBH, PcPeD, PePeD, PCOD), suggests that body shape is the primary factor distinguishing the two populations (ASADUZZAMAN *et al*., 2025). According to the AFD, PcPeD and PePeD are the most discriminating morphometric variables, characterizing the Kou and Tengrela populations, respectively. This morphological differentiation likely reflects local adaptation to environmental conditions, particularly turbidity, depth, and trophic availability.

The analysis of meristic traits also supports this differentiation between the Kou and Tengrela populations. Three characteristics - number of dorsal spines (DFS), number of dorsal soft rays (DSR), and number of scales on the upper portion of the lateral line (SULL) - proved to be discriminating, with consistently higher values in individuals from Tengrela. Among these, the DFS and DSR were the strongest contributors to the discriminant axis, underlining their role in populations separation. This divergence likely reflects inter-population differentiation driven by genetic and/or environmental contrasts (EHEMANN *et al.,* 2024; HVAS *et al*., 2025; SANKAR *et al*., 2025). According to HVAS *et al*., (2025), meristic traits, although established early in development, can remain influenced by the environmental factors such as temperature. Similar observations have been reported in other studies, where dorsal spines, soft rays, and lateral line scales effectively distinguished local tilapia populations (JUSMALDI *et al*., 2025 ; MAHMOUD and HASSAN, 2019).

The analysis of biological indices provides a functional complement to these morphometric results. Significantly higher carcass yield (CR) and body fat index (FI) in fish from Lake Tengrela indicate greater productive potential and a resource-rich environment with low energy expenditure, favoring lipid accumulation (VANDEPUTTE *et al.*, 2019; NING *et al*., 2023; LIU *et al*., 2024). Conversely, a higher hepatosomatic index (HSI) in Kou population suggests relatively larger liver size, consistent with higher energy reserves (glycogen/lipids) and good nutritional status - HSI being a recognized indicator of metabolic condition (SAMAD *et al*., 2025). The positive correlation of CR and HSI with PCA axis 2 indicated that Tengrela individuals possess better energy efficiency and physiological stability, whereas the greater dispersion in Kou reflects dietary and metabolic heterogeneity. This pattern supports findings from previous studies with several studies showing that CR and FI as reliable indicators of zootechnical performance, while HSI better reflects physiological adaptations to local conditions (VANDEPUTTE *et al*., 2020).

Overall, nine key traits - four morphometric (PCOD, MBH, PcPeD, PePeD), two meristic (DFS and DSR), and three biologicals (CR, FI, HSI), emerge as the main discriminants between the populations. These differences suggest that the Kou and Tengrela populations have developed distinct adaptive strategies in response to contrasting ecological conditions, while retaining the common morphological foundation characteristic of *O. niloticus*.

III.2. Ecological and zootechnical implications

The integrated analysis of morphometric, meristic, and biological parameters of *Oreochromis niloticus* from Lakes Kou and Tengrela highlights marked structural contrasts with significant ecological and zootechnical implications. The high classification accuracy in the Tengrela population (96%) reflects strong phenotypic homogeneity and genetic cohesion, favorable conditions for selective breeding and predictable responses to selection (MARJANOVIC *et al*., 2016; CAMPOS, 2024). Conversely, the Kou population shows greater intra-population variability (86%), likely resulting from habitat heterogeneity and phenotypic plasticity (TIBIHIKA *et al*., 2020; KWIKIRIZA *et al*., 2023).

This contrast between stability and variability represents a major strategic advantage for genetic improvement. While Tengrela's uniformity provides a solid foundation for the creation of standardized breeding lines, Kou's diversity constitutes a valuable reservoir of adaptive traits. Morphological variables such as minimum body height (MBH), pectoral-pelvic (PcPeD) and pelvic-pelvic (PePeD) distances, and meristic traits like dorsal spines (DFS) and dorsal soft rays (DSR) can serve as reliable phenotypic markers for selection (DZYUBA *et al*., 2017; GJEDREM and RYE, 2018). Similarly, biological indices including carcass yield (CR), gonadosomatic index (GSI), and hepatosomatic index (HSI) help identify populations with superior physiological and reproductive performance, key for developing efficient and sustainable strains (EKNATH *et al*., 2007; TRONG *et al*., 2013).

Beyond their zootechnical value, these differentiations reflect the ecological richness of Burkina Faso's aquatic ecosystems. The Kou population's greater adaptive capacity suggests better tolerance to environmental fluctuations, whereas Tengrela's stability favors domestication. Recognizing these populations as distinct ecological units thus supports sustainable management of fish resources amid climate change (TIBIHIKA *et al*., 2023; WASSO *et al*., 2025). Promoting locally adapted strains of *O. niloticus* reduces dependence on exotic tilapia (LIND *et al*., 2019) and aligns with sustainable aquaculture strategies aimed at resilience, food security, and local development (ELHADDAD and AL-FAWWAZ 2023; ABAHO *et al*., 2025).

Conclusion

This study analyzed the biological variability of two local Nile tilapia populations originating from Lakes Kou and Tengrela in Burkina Faso. Although the two stocks share a common morphological foundation, they differ significantly in several key variables, including pectoral-orbital distance (PCoD), minimum body height (MBH), pectoral-pelvic (PcPeD) and pelvic-pelvic (PePeD) distances, number of dorsal spines (DFS), dorsal soft rays (DSR), carcass yield (CR), hepatosomatic index (HSI), and body fat index (FI).

The Tengrela population exhibits pronounced phenotypic homogeneity, suggesting genetic stability and predictable selection responses, and stands out for its superior zootechnical potential - favorable for the establishment of pure breeding lines. Conversely, the Kou population displays greater intra-population variability, reflecting a fine-scale ecological adaptation to fluctuating environmental conditions. This diversity represents a vital reservoir for the development of robust and environmentally resilient strains.

The complementarity between the two populations thus offers a major strategic opportunity for local Nile tilapia improvement programs. Their combined use could form the basis of a sustainable breeding strategy that integrates performance, variability, and adaptability, contributing to the competitiveness and long-term sustainability of aquaculture in Burkina Faso.

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Declaration of competing interest

The authors declare that they have no conflicts of interest.

Credit authorship contribution statement

EPS: field sampling, data collection, statistical analyses, and drafting of the manuscript. AT and RS: supervision, contribution to interpretation of results, and manuscript revision. OT, AS and SS: manuscript revision. AAT and BR: data collection.

All authors have read and approved the final version of the manuscript.

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