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Sexual dimorphism of ducks (*Cairina moschata*, Linnaeus 1758) reared in the southern forest of Côte d'Ivoire

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Abstract

Sexual dimorphism was studied on 213 ducks including 92 males and 121 females of the species *Cairina moschata* in the southern forest of Côte d'Ivoire. Measurements were made using a tape measure and weighing with an electronic scale. A step-wise discriminant analysis made it possible to examine 21 morphometric descriptors. All linear measures except beak and head with were significantly higher in males than in females. 18 of these 21 parameters are statistically significant with the Mann-Whitney U test. Of these 18 significant descriptors, nine are strongly correlated positively for the first two and the fourth axis while it is negatively for the third factorial axis. The projection of the individuals in the plane of the principal component analysis shows a separation of the batches so that along axis 1 the male individuals gather towards the negative coordinates and the female individuals towards the positive coordinates. The values recorded with the discriminant factor analysis confirm to 92.49% the membership of the specimens to the different defined groups. This analysis proposes a reclassification of two females in the group of males and of 14 males among the females.

Keywords: *Cairina moschata*; Sexual dimorphism; Morphometry; Southern forest; Ivory Coast

1. Introduction

Local poultry breeds represent an original and unique heritage because they have developed particularly useful zootechnical aptitudes, in terms of production performance and adaptability [1]. In Côte d'Ivoire, as in the other countries of Sub-Saharan Africa, traditional poultry farming represented, until the 1960s, the only source of poultry production, but the development of the industrial sector led to the progressive marginalization of the traditional sector [2,3]. In these countries, the emphasis is on the development of a single species of poultry, in this case chicken. Considering the economic and nutritional benefits, the conservation of other species, such as ducks, would be attractive with certain strains that are fast growing, resistant to many domestic bird diseases and can produce up to 300 eggs per year [4,5]. On the other hand, poultry products from traditional farms still remain a well-appreciated, economical and easily available source of meat for the rural population [6]. Strategies for the management and development of local poultry resources are therefore necessary both for rural economic development and the safeguarding of biodiversity. Morphological variation within a species is of great biological interest, both as a descriptive and as an analytical tool. Sex differences in external morphology are of interest in studies of reproductive biology and descriptively, to analyze population composition [7,8]. Sexual dimorphism defined as a morphological differentiation of sexually mature males and females is a visible difference in body length or mass of sexually mature organisms. Male dimorphism being the most common, but certainly not the exclusive pattern. It has been demonstrated in a wide variety of animals, both vertebrates and invertebrates. One of the most popular models is an allometric relationship between the body sizes of males and that of females, called Rensch's rule [9]. According to this rule the males of many animal lines tend to be

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larger than the females. Thus, sexual size dimorphism increases with size when males are more numerous and decreases when females are more numerous in a sample. The aim of this study is to show, through morphological measurements, the differences in size between males and females in ducks reared in the southern forest of Côte d'Ivoire.

2. Material and methods

The study was carried out in the southern forest of Côte d'Ivoire. This zone is located in the Guinean domain with a subequatorial climate which presents four facies linked to the abundance of precipitation. Côte d'Ivoire is a coastal country with an area of 322,463 km^2 whose territory is limited to the south by the Atlantic Ocean (about 600 km of coastline). The country is characterized by a dense hydrographic network, covering 90% of the territory and is located in the northern hemisphere between the Tropic of Cancer and the meridian of Greenwich. Its coordinates are between 10° and 4° north latitude and 10° and 0° west longitude. Data were collected on 213 ducks including 121 females and 92 males in five localities. Measurements were limited to apparently healthy birds that met the classification descriptors for the species. The birds were selected from their breeding grounds in some small farms. The animals were reared in a confinement or semi-confinement system. The length and circumference measurements were made using a measuring tape calibrated in centimeters (cm) and the weighing with an electronic scale. The descriptors (Figure 2) were chosen according to the six conditions formulated by Simpson [10].

2.1. Data analysis

To study sexual dimorphism, measurements were taken on ducks that were at least three months old. were standardized according to the following equation: MS = M0 (LS / L0) b MS = standardized measurement. M0 = measured character length. LS = arithmetic mean of the standard length of all specimens L0 = standard length of each specimen. The value of parameter b was estimated for each character using the equation $M=aL^b$. Parameter b is the regression slope of log10M0 on log10L0 using all ducks in each group [11]. The differences between the means were signified using descriptive statistics by group. The significant differences marked at the threshold of 0.05 were revealed using the Mann-Whitney test. The stepwise discriminant method was used to identify morphological characters with high discriminatory power. Variables that were found to be significant with the Mann-Whitney Test were subjected to Principal Component Analysis (PCA) which is a factor analysis used to identify variables that may contribute more to morphometric variation between specimens. The discriminant factor analysis (DFA) classification matrix made it possible to classify the females that are found in the batch of males and the males in the batch of females. The relative distinguishability of morphometric traits was assessed using Wilk's lambda test. Statistical analyzes were performed with STATISTICA 7.1 [12]and R [13] software.

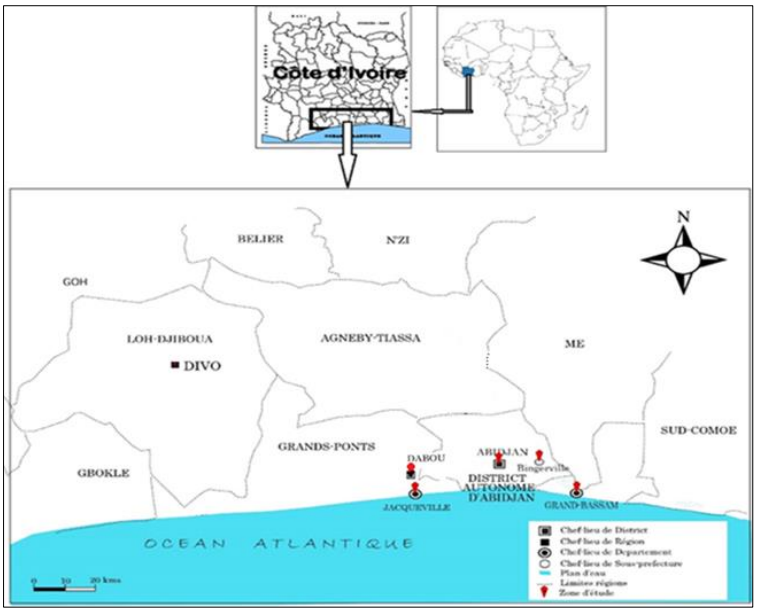
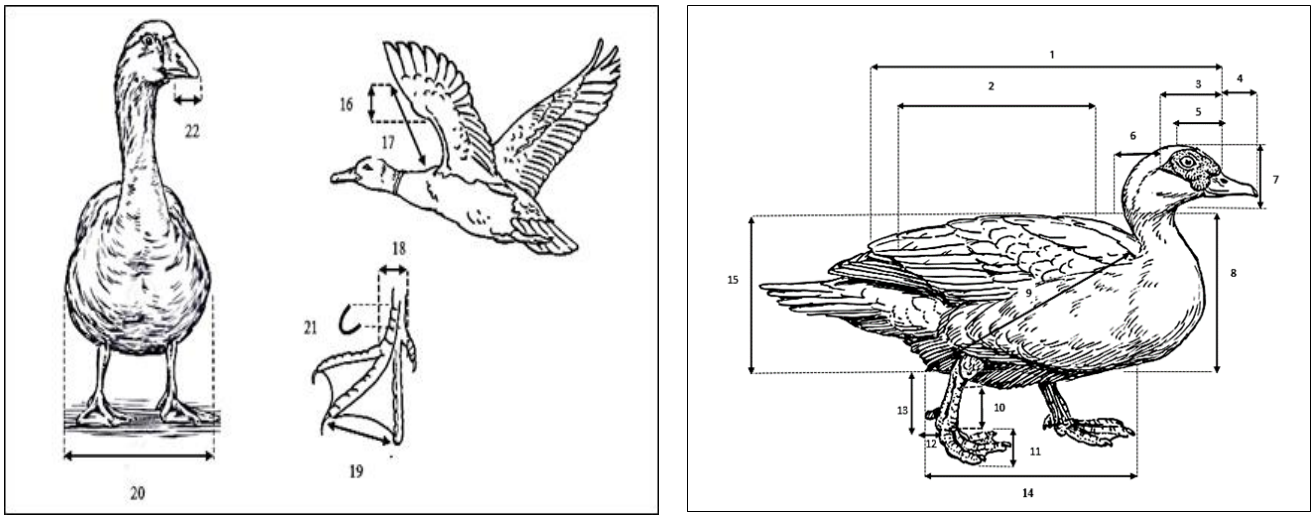


Figure 1 Geographical location of the study area [14]



1-Body length (LCo) ; 2-trunk length (LTr) ; 3- length of the barbel (Lba) ; 4-beak length (LBc) ; 5- head length (Lte) ; 6- length of the neck (Lcou) ; 7-head width (lTe) ; 8-rib cage width (lCT) ; 9- length of the whites (LBl) ; 10- drumstick length (Lpi) ; 11- leg diameter (Dpa) ; 12- length of the tarsus (Lta) ; 13- leg length (Lpa) ; 14-wishbone length (LBr) ; 15-chest height (HP) ; 16- forearm length (Lav) ; 17-wing length (Lail) ; 18-diameter of the tarsus (DTa) ; 19- width of the palms (lpal) ; 20-thoracic perimeter ; 21-circumference of the drumstick (Tpi) ; 22-beak width.

Figure 2 Main measurement taken on ducks

All linear measures except beak and head with were significantly higher in males than in females (Table 1). Of the twenty-two (22) parameters studied, eighteen (18) are statistically significant with the Mann-Whitney U test. The most dimorphic traits in terms of statistical significance ($p<0.001$) were wing length (Lail), forearm length (Lav), neck length (Lcou), the length of the barbel (Lba), the length of tarsus (Lta), the width of the palms (lpal), a circumference of the drumstick (Tpi), drumstick length (Lpi), leg length (Lpa), leg diameter (Dpa).

The females on which the morphometric measurement were taken have an average weight of 1969.3g or 31% while the males have an average weight of 2850g or 69%. Figure 3 shows the diagram of this distribution.

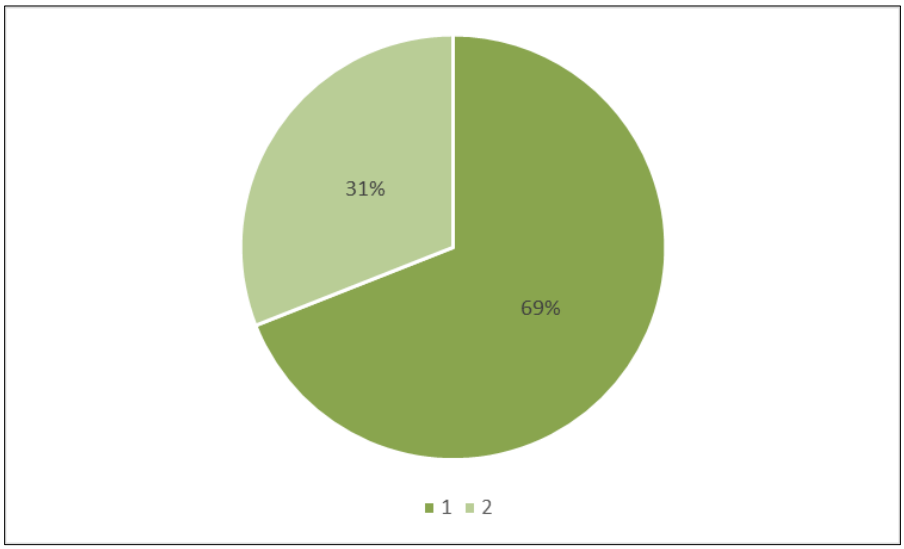


Figure 3 Weight of male and female ducks

Lot differentiation by PCA was performed based on metric descriptors that varied significantly between the two groups. The eigenvalues and the proportions of the variance expressed by the first five PCA axes are shown in Table 3. Only the axes expressing an eigenvalue greater than or equal to 1 were retained for this analysis. Thus, the first five axes accumulating 65.83% of the morphometric variability of the ducks analyzed were recorded. The first four combine more than half (59.56%) of the variability expressed by all the principal components. In the ordination analysis, only axes 1, 2 and 3, which alone express the greatest variability, were considered.

Table 1 Mann-Whitney U test comparing metric variables between males and females

Parameters	Females	Males	p
PTh	27.97 ± 3.81	28.08 ± 5.07	NS
Lail	27.48 ± 2.74	32.79 ±3.92	***
HP	17.34 ± 1.98	17.45 ± 1.89	NS
lCT	13.65 ± 2.28	14.48 ± 2.70	*
Lav	12.42 ± 1.62	16.51 ± 2.46	***
LTr	19.52 ± 2.56	20.32 ± 2.27	**
LBr	20.39 ± 3.27	21.47 ± 3.96	*
LBl	25.68 ± 2.95	29.03 ± 3.41	***
Lcou	13.43 ± 1.68	15.07 ± 1.59	***
LTe	6.91 ± 0.73	7.22 ± 1.11	NS
lTe	4.88 ± 0.85	4.69 ± 0.66	**
LBc	4.57 ± 1.16	5.49 ± 1.48	***
lBc	2.48 ± 1.11	2.24 ± 0.65	*
Lba	4.74 ± 2.11	6.16 ± 2.79	***
Lta	2.48 ± 1.05	2.77 ± 1.08	***
Dta	2.52 ± 1.05	2.63 ± 0.95	**
lPal	4.20 ± 1.67	4.47 ± 0.70	***
Tpi	5.23 ± 0.78	5.95 ± 0.81	***
Lpi	4.34 ± 0.63	5. 12 ± 0.98	***
Lpa	6.27 ± 0.66	7.91 ± 1.27	***
Dpa	6.89 ± 1.12	7.55 ± 1.33	***

p: probability; *: $p < 0.05$; **: $p<0.01$; ***: $p<0.001$; NS: Not significant

Table 2 Eigenvalues with the percentages of variances of the first five axes in the principal component analysis of the metric variables of males and females

	Own value	% Total	Cumuli	Cumuli
1	4.47	24.85	4.47	24.85
2	2.36	13.13	6.83	37.97
3	2.21	12.33	9.05	50.29
4	1.66	9.26	10.72	59.56
5	1.13	6.26	11.85	65.82

Table 3 indicates the correlations of the characters to the first four axis of the principal component analysis. These four axes which contribute more to the discrimination of the two lots are strongly correlated at nine characters out of 18. Indeed, axis 1 is strongly correlated with the wing length (Lail: r = 0.87), l forearms and legs (Lav: r = 0.86). Axis 2 is strongly correlated with the width of the rib cage (lCT: r = 0.74) and the length of the tarsus (Lta: r = 0.84). Axis 3 is strongly positively correlated with chest circumference (PTH: r = 0.73) and negatively correlated with head width (lTe:

r = -0.83) and beak length (Lbc: r = - 0.81). Axis 4 is strongly correlated with the length of the barbel (Lba: r = 0.94) and of the tarsus (Lta: r = 0.94).

Table 3 Factorial weight of the metric variables on the first four axes of the principal component analysis

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
PTH	-0.15	0.03	**0.73**	-0.13
Lail	**0.87**	0.21	0.00	0.03
lCT	0.24	**0.74**	0.09	-0.00
Lav	**0.86**	0.23	0.15	0.02
LTr	0.18	-0.59	0.23	-0.05
LBl	0.66	-0.46	0.23	0.12
Lcou	0.35	-0.01	0.34	0.03
lTe	-0.01	0.09	**-0.83**	0.05
LBc	-0.29	0.03	**-0.81**	-0.07
lBc	-0.06	0.01	-0.14	**0.94**
Lba	0.16	0.00	0.09	**0.94**
Lta	0.13	**0.84**	-0.02	0.02
Dta	0.16	0.23	0.09	0.03
lPal	0.14	0.10	0.15	0.04
Tpi	0.56	0.19	0.44	-0.01
Lpi	0.34	0.43	0.55	0.00
Lpa	0.77	-0.06	0.06	0.11
Dpa	0.59	-0.39	-0.17	-0.02

The results of the discriminant factor analysis are presented in Table 4. The values recorded in this table confirm to 92.49% the membership of the specimens to the different defined groups. This analysis proposes a reclassification of two females in the group of males. Thus, out of 121 females, 119 are recognized as actually presenting the characteristics that define females i.e. 98.35% of correct classification. While out of 92 males in this study, 14 are classified as female. These last have characteristics specific to females. Only 78 specimens present the values descriptors which effectively define the males, i.e. 84.78% of correct classification.

Table 4 Distribution of individuals in the male and female batches defined at from the discriminant analysis of the metric data

	Percent	**F**	**M**
F	98.35	119	2
M	84.78	14	78
Total	92.49	133	80

On all of the eighteen (18) characters, expressing variability between the different sexes, the discriminant analysis from Wilk's Lambda test (Table 5) reveals that six of these descriptors are the most discriminating at $p \leq 0.05$. These are in descending order the length of the forearm (Lav), the length of the neck (Lcou), the width of the beak (lBc), the length of the legs (Lpa), the length of the barbel (Lba) and the pestle length (Lpi). The discriminating power of the metric descriptors that varied significantly between the two lots implies that the measurements of these traits are consistent in separating the lots.

Table 5 Metric traits most discriminating between the two sexes from Wilk's lambda test

	λ	F	p
Lav	0.884	25.443	***
Lcou	0.953	9.533	**
lBc	0.961	7.794	**
Lpa	0.963	7.335	**
Lba	0.968	6.405	**
Lpi	0.978	4.200	*

λ: statistical value of the test; p: probability, *: p < 0.05; *: p<0.01; * p < 0.001

Figure 4 was constructed from the first two factorial axes which contribute 37.98% of the information. While Figure 5 was constructed from factorial axes 1 and 3 which contribute 37.16% of the information. When male and female individuals are projected into the factorial planes, along axis 1 the male individuals gather towards the negative coordinates and the female individuals towards the positive coordinates. This shows a separation of the two lots. However, a large overlap is observed between the two polygons.

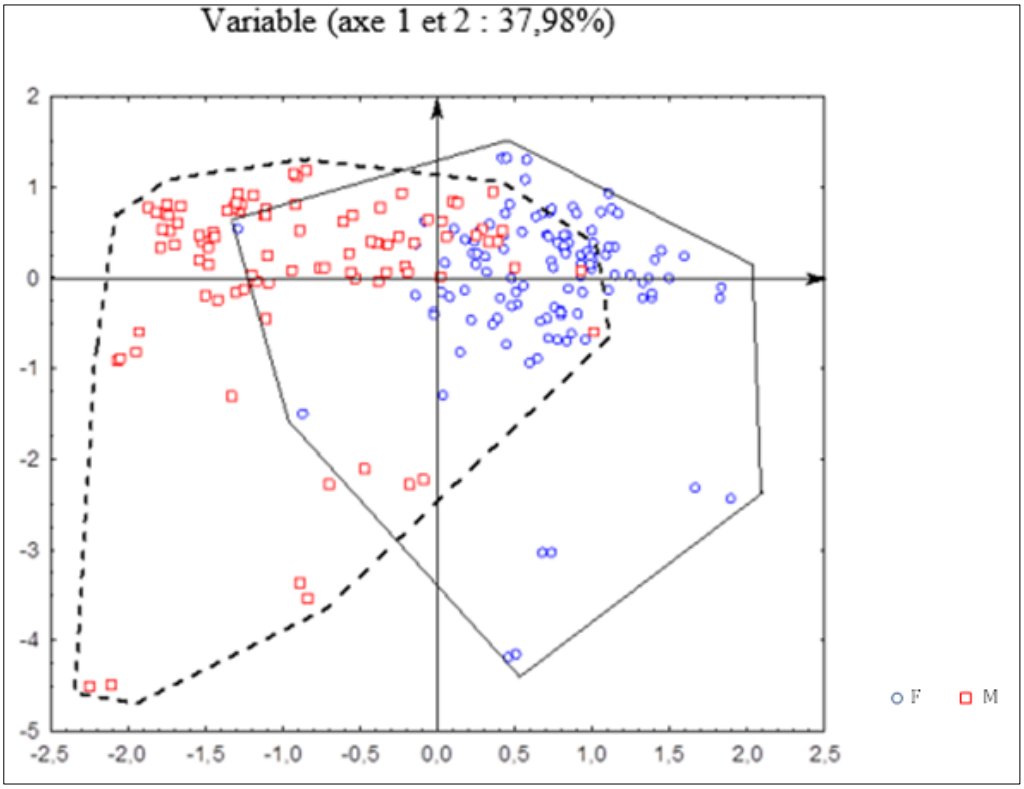


Figure 4 Projection of male and female individuals in factorial plane 1 and 2 of principal component analysis of metric traits

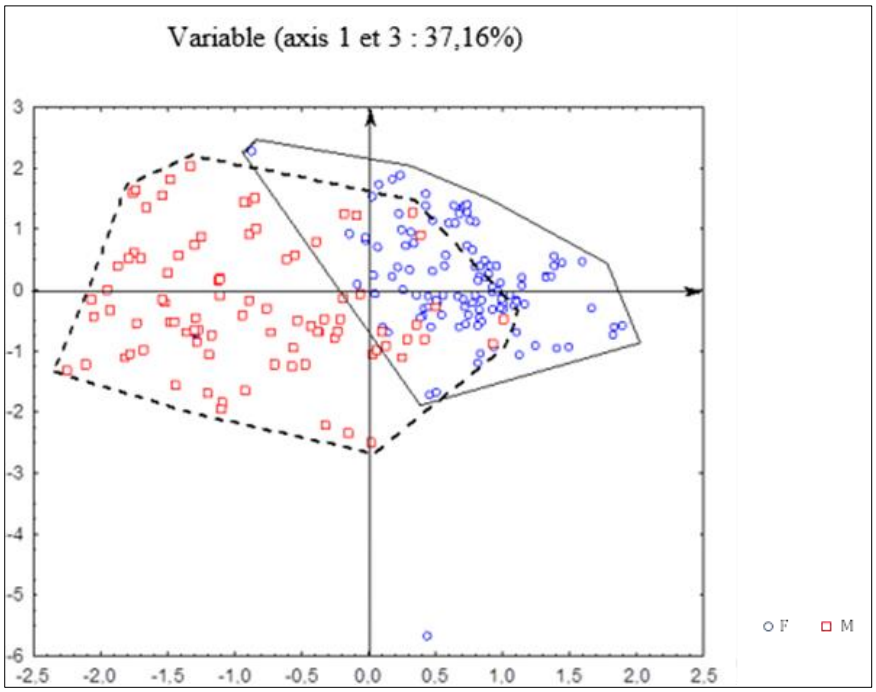


Figure 5 Projection of male and female individuals in factorial plane 1 and 3 of principal component analysis of traits metrics

3. Discussion

The number of individuals used in this experiment reflects the sex ratio. Indeed, data was collected on more females than males. This could be attributed to the fact that males were more frequently offered for sale to generate income and for festive purposes, while more females are needed in the breeding sector for procreation. Sex-related differences were found in all traits and body indices of ducks studied. Concerning the averages of the morphometric traits, 18 of the 22 chosen descriptors are significant, this shows that the chosen parameters are good separators. At the level of the females, the characters whose measurements are greater than those of the males are related to the head. Indeed, the width of the head and the beak are measurements that do not confer a greater height of the waist. The large head and beak of the females could be explained by the fact that on the farms selected for this work, the females are older than the males. The age of the ducks would influence the width of the head and the beak. The length of the legs of the males gives them a greater body height, this result is contrary to that of [15] who obtained a total length of the legs of the females greater than that of the males. On the other hand, the length of the body, the wings, the neck, the beak as well as the thoracic perimeter are high in males similar to the work of [15]. It's also affirmed that male musk ducks have a chest, a drumstick and a greater weight than females in accordance with our work [16]. The greater difference in beak length between the sexes suggests that this trait may play an important role, possibly in sexual display and territorial defense of males [17]. In addition, the superiority of males over females could result from their ability to feed at greater depth and from a better feed conversion efficiency [18]. Sexual dimorphism can also be attributed to different hormonal actions linked to the sexes [19] which leads to different growth rates. Another possible explanation for the occurrence of extreme sex-related differences in Muscovy duck biometrics is strong female selection for high-quality males or competition between males for limited access to females, which has led to fixation of larger body size and other secondary sex characteristics in males [20]. The projection of the males and females in the PCA factorial plane revealed a large overlap between the lots despite the differences in size highlighted by the Mann Whitney test. The stepwise discriminant analysis used in the present study revealed a size difference among the ducks examined. This difference is attributed to a strong variation in morphometric characters. In addition, percentages of total correct classification of more than 92% demonstrate that the morphometric descriptors considered have an important weight. The axis correlations are low for some characters, high for others and negative in other cases. Indeed, axis 1 is strongly correlated to the length of the wing, the forearm and the legs which are parts related to the limbs. While axis 3 is strongly negatively correlated to head-related parts. These observations are similar to the results obtained by [21] who found a strong correlation in wing length in Muscovy ducks. According to Wilk's lambda test six characters are the most discriminating. These are forearm length (Lav), neck length (Lcou), beak width (lBc), leg length (Lpa), barbel length (Lba) and drumstick length (Lpi). These characteristics therefore make it possible to distinguish the different groups and to assess the

performance of each batch. Previous studies confirm that the variation in size of ducks from different agro-ecological zones in Nigeria is particularly related to neck length [22].

4. Conclusion

The morphometric descriptors used in the comparison between males and females show significantly higher values in males than in females. This study reveals that the length of the forearm length (Lav), neck length (Lcou), beak width (lBc), leg length (Lpa), barbel length (Lba) and drumstick length (Lpi) are the most discriminating characters that highlight the sexual dimorphism between males and females duck. The present results might aid in breed conservation studies and improvement of duck breeding.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors declare that they have no any conflict of interest.

Statement of ethical approval

Informed consent was obtained from all individual participants included in the study.

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