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SEXUAL SIZE DIMORPHISM AND SEX DETERMINATION BY MORPHOMETRIC MEASUREMENTS IN LOCALLY ADAPTED MUSCOVY DUCK (*Cairina moschata*) IN NIGERIA [1]

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Sexual size dimorphism and sex determination by morphometric measurements in locally adapted muscovy duck (Cairina moschata) in Nigeria

Sexual size dimorphism (SSD) is a common phenomenon in most mammalian and poultry species. This study was undertaken to investigate SSD in nondescript locally adapted Muscovy ducks in Nigeria by applying descriptive analysis, sexual dimorphism index (SDI), sexual size dimorphism index (SSDI) and Principal Component analysis to morphological variables. Besides, attempt was made to identify best morphological predictors of sex using Stepwise Discriminant analysis. Data on ten morphological traits; body weight, body girth, body length, wing length, shank length, shank circumference, thigh length, total leg length, bill length and bill width were taken from 1,020 extensively managed adult Muscovy ducks comprising 287 males and 733 females. These birds were randomly sampled from Rain Forest, Derived Savanna and Guinea Savanna agro-ecological zones of Nigeria. Sex significantly ($P < 0.001$) affected all morphometric measurements in favour of males. Assessment of relative contribution of morphological traits to SSD through SDI and SSDI revealed that body weight followed by skeletal frame-related variables (body length and wing length) were the most dimorphic traits. Three Principal Components were generated for each sex; accounting for 62.70 % and 54.24 % of the total variance explained of male and female ducks, respectively. In tandem with the SDI and SSDI results, Stepwise Discriminant analysis indicated body weight as the best predictor of sex of adult Muscovy ducks followed by wing length and body length; correctly classifying 98.5 % of ducks and are reliable for sex determination in the field. The established SSD in this study could be employed for description, utilization, selection and planning of improvement programs of male and female Muscovy ducks.

Key words: ducks / Muscovy duck / *Cairina moschata* / sex / size / dimorphism / morphometric measurements / Nigeria

Spolni dimorfizem in določitev spola na osnovi morfometričnih meritev pri lokalno prilagojeni muškatni raci (Cairina moschata) v Nigeriji

Spolni dimorfizem telesne velikosti (SDTV) je splošen pojav pri večini vrst sesalcev in perutnine. To študijo smo zasnovali z namenom, da bi proučili SDTV pri doslej neopisani, na lokalne razmere prilagojeni muškatni raci v Nigeriji s pomočjo opisne analize, indeksa spolnega dimorfizma (ISD), indeksa spolnega dimorfizma telesne velkosti (ISDTV) in analize glavnih komponent variance morfoloških lastnosti. Poskušali smo tudi določiti morfološke lastnosti z največjo napovedno vrednostjo za določitev spola z večstopenjsko diskriminantno analizo. Podatke o desetih morfoloških lastnostih: telesna masa, obseg telesa, dolžina telesa, dolžina krill, dolžina goleni, obseg goleni, dolžina stegna, dolžina noge, dolžina kljuna in širina kljuna, smo zbrali pri 1.020 muškatnih racah iz ekstenzivne reje, med katerimi je bilo 287 samcev in 733 samic. Ptice smo vzorčili naključno v agro-ekoloških conah deževnega gozda, degradirane in gvinejske savane v Nigeriji. Spol statistično značilno ($p < 0,001$) vpliva na morfometrične lastnosti. Analiza relativnega doprinosa posameznih morfoloških lastnosti k SDTV preko ISD in ISDTV je pokazala, da se telesna masa in lastnosti povezane s telesnim okvirjem (dolžina telesa in dolžina kril) najbolj razlikujejo med spoloma. Za vsak spol smo izbrali tri glavne komponente, ki pojasnjujejo največji delež variance pri moških in ženskih živalih. Upoštevaje ISD in ISDTV je večstopenjska diskriminantna analiza pokazala telesno maso kot lastnost z najboljšo napovedno vrednostjo za spol pri odraslih muškatnih racah, sledita pa dolžina telesa in dolžina krill, na osnovi katerih lahko z 98,5 % gotovostjo napovemo spol živali. Sistem za presojo spolnega dimorfizma telesne velikosti, ki smo ga vzpostavili v tej študiji, je primeren za uporabo v selekcijskih programih za izboljšanje lastnosti muškatne race.

Ključne besede: race / muškatna raca / *Cairina moschata* / spol / velikost / dimorfizem / morfometrične lastnosti / Nigerija

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1 INTRODUCTION

Muscovy duck (*Cairina moschata*) is one of the least exploited and underutilized indigenous poultry species in Nigeria in spite of its innate potential for meat and egg production. This might not be unconnected with the myriads of taboos, bias and social stigmas attached to its rearing, consumption, handling and marketing. Besides, the ugly appearance and perceived difficulties in its husbandry with respect to its water-loving nature and watery faeces also contributed to its neglect in Nigeria. The utter neglect suffered by this waterfowl was exemplified further in its low population, low demand of its products and, also dearth of empirical studies directed towards its management and genetic improvement.

Reliable information on how Muscovy ducks were introduced to Nigeria are scanty (Oguntunji and Ayorinde, 2014). However, a report by Blench (1995) suggested that they were probably introduced on the sea-coast by the Portuguese and spread inland. Another undocumented version claimed that they were introduced by the Portuguese and spread inland (Oguntunji and Ayorinde, 2014).

Sexual size dimorphism (SSD) is a difference in body length or mass of sexually mature organisms and has been demonstrated in a great variety of animals including invertebrates and vertebrates (Alexander, 2007) with male-biased dimorphism being the more common, but certainly not the exclusive pattern (Isaac, 2005). In the last three decades, evolutionary biologists have developed a large body of theory for explaining the evolution of sexual size dimorphism in terms of sex-specific differences in the selection of mates, in food preferences, or in response to environmental factors including competitions and population density (Bjorklund and `Linden, 1993; Hedrick and Temeles, 1989).

SSD, which is usually measured in adults, can result from differences between sex in growth patterns or selection and pressures during ontogeny (Teather and Weatherhead, 1994; Merila *et al.,* 1997; Badyaev *et al.,* 2001). In addition, theoretical and empirical works indicate that SSD can evolve and be maintained when selection acts to maintain size differences between sexes, provided that variation in the trait of interest has a heritable component, and the genetic correlation between the sexes is less than one (Reeve and Fairbain, 1996; Merila *et al.,* 1998).

Multifactorial analyses of morphological traits have been proved to be suitable in assessing the variation within a population and can discriminate different population types when all morphological variables are considered simultaneously (Traore *et al.,* 2008; Yakubu and Ibrahim, 2011). Multifactorial analyses of morphological traits have been used to characterize different breeds of livestock as they give idea of body conformation and are used to describe a population or an individual in a better way than the conventional methods of grading and weighing (Pundir *et al.,* 2011). Besides, application of multivariate techniques such as Principal Component Analysis and Discriminant Analyses to morphometric variables have been used extensively for assessing SSD in water birds and proved effective in identifying variables capable of separating sexes (Mc Cracken *et al.*, 2000; Svalgelj and Quintana, 2007; Herring *et al.,* 2011; De Marchi *et al.,* 2012).

Muscovy ducks are waterfowls characterized with conspicuous sexual size dimorphism but scientific study on the relative contribution of the underlying morphological variables are scarce and empirical reports on its SSD are scanty. Apart from sexual differences in total body size, the variation of relative size and shape of different body parts is of special interest in sexual dimorphism studies, because it could reveal differential selection acting on body parts of each sex (Butler and Losos, 2002). In view of the foregoing, the present study was undertaken to describe sexual size dimorphism and to identify best morphological predictor of sex of adult locally adapted Muscovy ducks in Nigeria using univariate and multivariate statistical techniques.

2 MATERIALS AND METHODS

2.1 EXPERIMENTAL ANIMALS AND STUDY AREA

1020 adult male (287) and female (733) locally adapted Muscovy ducks in Nigeria were randomly sampled in three agro-ecological zones of Nigeria; Rain Forest (203), Derived Savanna (598) and Guinea Savanna (289). These birds were reared extensively with little or no provision of food, medication and housing. The prevailing climatic conditions of the study area have been previously described by Yakubu (2011) and Oguntunji (2013).

2.2 MEASUREMENTS OF MORPHOLOGICAL TRAITS

Morphological measurements were taken on body length, body girth, wing length, shank length, thigh length, bill length, bill width, total leg length with the aid of a flexible tape rule in centimeters. Shank circumference was measured using calipers while body weight measurement was taken using a 10 kg weighing scale.The anatomical references of these metric traits were as described by Yakubu (2011) and Oguntunji (2013).

2.3 STATISTICAL ANALYSES

2.3.1 UNIVARIATE ANALYSIS

Student t-test was used to investigate intersexual differences in the morphometric variables. Sexual dimorphism index (SDI) representing the ratio of male to female (De Marchi *et al.,* 2012) and Sexual size dimorphism index (SSDI) were calculated for all variables. Sexual size dimorphism index was calculated as:

$$SSDI = \{(x_m - x_f)/x_f\} /100$$ (Weidinger and van Franeker, 2003)

where x_m and x_f are the mean values of males and females respectively.

Besides, The morphological variables were classified into five anatomical classes using the estimated values of SDI and SSDI as classification criteria into body mass (body weight), skeletal frame (wing length and body length), leg factor (shank length, thigh length, total leg length and shank circumference) body girth and bill factor (bill length and bill width).

2.3.2 MULTIVARIATE ANALYSIS

2.3.2.1 Principal component analysis

Kaiser-Meiyer-Olkin (KMO) measure of sampling adequacy was estimated to determine whether the common factor model was appropriate and a KMO value below five was rejected (Pundir *et al.,* 2011). In addition, Bartlett's Test of Sphericity, which tests the null hypothesis that the original correlation matrix is an identity matrix used to test the validity of the Principal Component analysis (PCA) of the data sets (Shrestha *et al.,* 2008) at $P < 0.01$. The Kaiser's rule criterion (Johnson and Wichern, 1992) was used to decide on the number of components to be retained and only Principal Components (PCs) with Eigen values greater than one was retained. After this, Varimax criterion of the orthogonal rotation method was employed in the rotation of the factor matrix to enhance the interpretations of the PCs.

2.3.2.2 Discriminant analysis

Stepwise Discriminant analysis procedure was run to identify important predictors that could efficiently discriminate adult male and female Muscovy ducks. The relative discriminating ability of the morphological traits was assessed using the level of significance (Pr > F), Wilk's Lambdaand F-statistics (F-to-remove). The effectiveness of discriminant analysis was assessed first in terms of the proportion of the birds of known sex that were correctly classified and finally by a split-sample validation (cross-validation process) (Svagelj and Quintana, 2007). All statistical analyses were performed using the SPSS (2001) version 16.

3 RESULTS

3.1 DESCRIPTIVE STATISTICS OF MALE AND FEMALE MUSCOVY DUCKS

The descriptive statistics of the body measurements of adult male and female Muscovy ducks are presented in Table 1. Sex had highly ($P < 0.001$) significant effect on all body measurements in favour of males.

The anatomical classification of the morphometric traits and results of their respective SDI and SSDI were presented in Table 2. SSD was exhibited in all the morphological variables. The trend of results of SDI and SSDI was similar and was higher in males. Body weight factor was the most sexually dimorphic trait, followed by skeletal frame (body length and wing length) intermediate in leg factor (shank length, thigh length, total leg length and shank circumference) but least in body girth and bill factor (bill length and bill width).

3.2 PRINCIPAL COMPONENT ANALYSIS

The overall significance of correlations tested with Bartllet's test of sphericity for the morphometric traits of adult male (Chi-square 711.842) and female (Chi-square 836.241) ducks were highly ($P < 0.001$) significant. The estimates of KMO (MSA) for male and female ducks were 0.687 and 0.696, respectively. The communality values which represent the proportion of each variable's variance that can be explained by the PC was 0.420–0.919 for male ducks and 0.398–0.641 for female ducks; thus, suggesting their suitability for the factor analysis.

Sexual size dimorphism was revealed in the total variance explained and variables characterizing the PCs of both sexes. Rotation of the component matrix revealed three patterns of variation among the male and female

Table 1: *Univariate statistics of adult male and female locally adapted Muscovy ducks in Nigeria*
Preglednica 1: *Univeriatna statistika odraslih moških in ženskih lokalno prilagojenih muškatnih rac v Nigeriji*

Trait	Sex	No	Mean ± SD
Body weight (kg)	Male	287	2.64 ± 0.37[a]
	Female	733	1.60 ± 0.25[b]
Body girth (cm)	Male	287	46.93 ± 2.92[a]
	Female	733	38.70 ± 2.99[b]
Body length (cm)	Male	287	30.69 ± 2.87[a]
	Female	733	23.96 ± 2.43[b]
Wing length (cm)	Male	287	35.23 ± 3.80[a]
	Female	733	26.71 ± 2.86[b]
Shank length (cm)	Male	287	5.71 ± 0.67[a]
	Female	733	4.57 ± 0.56[b]
Shank circumference(cm)	Male	287	5.33 ± 0.58[a]
	Female	733	4.35 ± 0.40[b]
Thigh length (cm)	Male	287	12.14 ± 1.24[a]
	Female	733	9.90 ± 1.21[b]
Bill length (cm)	Male	287	5.94 ± 0.54[a]
	Female	733	5.03 ± 0.42[b]
Bill width (cm)	Male	287	3.44 ± 0.30[a]
	Female	733	3.10 ± 0.25[b]
Total leg length (cm)	Male	287	17.83 ± 1.37[a]
	Female	733	14.55 ± 1.59[b]

[a, b] Means with different superscripts are significantly different (P < 0.001) / Povprečja z različnimi nadpisi se statistično značilno razlikujejo (p < 0,001)

Table 2: *Anatomical classifications, SDI and SSDI values of morphologicaltraits of adult locally adapted Muscovy ducks in Nigeria*
Preglednica 2: *Anatomske klasifikacije, ISD in ISDTV vrednosti za morfološke lastnosti odraslih lokalno prilagojenih muškatnih rac v Nigeriji*

Anatomical class	Trait	SDI	SSDI (%)
Body mass	Body weight	1.65	65.00
Skeletal frame	Wing length	1.32	31.90
	Body length	1.28	28.09
Leg factor	Shank length	1.25	24.95
	Thigh length	1.23	22.63
	Total leg length	1.23	22.54
	Shank circumference	1.23	22.53
Body girth	Body girth	1.21	21.27
Bill factor	Bill length	1.18	18.09
	Bill width	1.11	10.97

Muscovy ducks that may be of biological relevance. Nevertheless, the total variance explained and variables with high loadings for the PCs generated for the two sexes were different.

Three factors with Eigen values above one accounted for 62.70 % and 54.24 % of the total variance of male (Table 3) and female (Table 4) ducks, respectively. In males, PC one alone accounts for 30 % of the total shared variability and was represented by high positive loadings for body weight, body girth, bill width, shank circumference and body length; while the PC one of the female accounted for 26.92 % of the total variance and was represented by body weight, shank length and shank circumference. The second component for males explained 20.41 % of the total variance and was characterized by wing length, shank length and bill length. Conversely, the second PC of females explained 14.68 % of the total variance with high loadings for bill width and thigh length. The third principal component of males explained only 12.29 % of the generalized variance and had high positive loading for thigh length only. In contrast, 12.64 % of the total variance was explained by the third PC of female and was characterized by body length and wing length.

3.3 DISCRIMINANT ANALYSIS

The result of the stepwise discriminant analysis (Table 5) revealed eight (body weight, body length, wing length, thigh length, bill length, body girth and total leg length) of the ten morphometric traits to be highly (P < 0.001) significant in distinguishing sexes of Muscovy ducks. However, body weight was the most important discriminating variable followed by body length and wing length. Besides, the results of cross-validation classification of the two sexes were very high with overall success rate of 98.5 % (Table 6); all males (100 %) were correctly classified while 98 % of the females were correctly classified.

4 DISCUSSION

4.1 UNIVARIATE ANALYSIS OF MALE AND FEMALE MUSCOVY DUCKS

4.1.1 DESCRIPTIVE STATISTICS OF ADULT MALE AND FEMALE MUSCOVY DUCKS

Significant effect of gender in favour of males in all morphometric traits corroborates earlier studies on Muscovy ducks (Ogah *et al.*, 2009a and b; Yakubu, 2011) and Musk duck (McCracken *et al.,* 2010). Superior mean val-

Table 3: *Eigen vectors, communalities and rotated component matrix of principal Component Analysis of adult male Muscovy ducks*
Preglednica 3: *Lastni vektorji, komunalitete in rotirana matrika faktorjev v analizi glavnih komponent pri odraslih moških muškatnih racah*

Traits	Component 1	2	3	Communality
Body weight	0.790	0.208	0.021	0.668
Body girth	0.785	0.110	0.224	0.679
Body length	0.638	0.108	0.031	0.420
Wing length	0.254	0.754	0.021	0.633
Shank length	0.101	0.785	−0.138	0.645
Shank circumference	0.653	0.409	0.133	0.611
Bill length	0.057	0.644	0.041	0.420
Bill width	0.737	−0.024	−0.322	0.647
Thigh length	0.70	−0.054	0.955	0.919
Eigen value	2.70	1.84	1.11	
Proportion of variation (%)	30.00	20.41	12.29	
Cumulative (%)	30.00	50.41	62.70	

ues recorded for male agreed with earlier submission that a unique characteristics of this waterfowl is its sexual dimorphism, the male being much bigger than the female (Rodenburg *et al.*, 2005). The longer body length and higher mean values for body girth in males are indicative of meatiness. Body girth has been reported in different studies to be a good indicator of body weight.

4.1.2 SEXUAL DIMORPHISM INDEX AND SEXUAL SIZE DIMORPHISM INDEX

It could be inferred that traits classified into the same anatomical class had comparable SDI and SSDI values. The order of arrangement of the anatomical classes and ranking of the SDI and SSDI values for different anatomical modifications for Muscovy ducks in the present

Table 4: *Eigen vectors, communalities and rotated component matrix of Principal Component Analysis of adult Female Muscovy ducks*
Preglednica 4: *Lastni vektorji, komunalitete in rotirana matrika faktorjev v analizi glavnih komponent pri odraslih ženskih muškatnih racah*

Traits	Component 1	2	3	Communality
Body weight	0.702	0.309	0.194	0.625
Body girth	0.478	0.463	0.110	0.455
Body length	−0.006	−0.083	0.727	0.535
Wing length	0.044	0.321	0.658	0.538
Shank length	0.734	0.128	−0.135	0.574
Shank circumference	0.768	−0.232	0.068	0.649
Thigh length	0.145	0.551	0.270	0.398
Bill length	0.485	−0.171	0.449	0.466
Bill width	−0.134	0.764	−0.197	0.641
Eigen value	2.42	1.32	1.14	
Proportion of variation (%)	26.92	14.68	12.64	
Cumulative (%)	26.92	41.60	54.24	

Table 5: *Summary of the step-wise discriminant analysis of the adult male and female locally adapted Muscovy ducks in Nigeria*
Preglednica 5: *Povzetek večstopenjske diskriminantne analize odraslih moških in ženskih lokalno prilagojenih muškatnih rac v Nigeriji*

Step	Variable entered	Wilk's lambda	F-value	Pr > F
1	Body weight	0.279	2.628 E3	0.000
2	Body length	0.233	1.578 E3	0.000
3	Wing length	0.207	1.299 E3	0.000
4	Thigh length	0.195	1.047 E3	0.000
5	Bill length	0.191	859.052	0.000
6	Body girth	0.188	729.905	0.000
7	Shank length	0.187	628.995	0.000
8	Total leg length	0.184	561.653	0.000

study indicates their relative contribution to the overall sexual dimorphism.

Related studies on SDI and SSDI of Muscovy ducks that could be used to validate the result of the present study are scarce; however, higher SDI values in favour of males in the present study is consistent with reports on other water birds such as Musk duck (*Biziura lobata*) (McCracken *et al.,* 2000), Painted Stork (*Mycteria leucocephala*) (Urfi and Kalan, 2006), Great Cormorants (*Phalacrocorax carbo sinensis*) (Liordos and Gountner, 2008), and Crab Plovers (*Dromas ardeola*) (De Marchi *et al.,* 2012). Furthermore, highest SDI value for body weight compared to other biometric traits agrees with results of related studies on water birds (Svagelj and Quintana, 2007; Liords and Gountner, 2008; Herring *et al.,* 2010) but contradicts reports of Bluso *et al.* (2006) on Forster's Terns (*Sterna fosteri*) whereby length of the outermost rectrix of the tail was highest.

The SDI value obtained for the body weight in this study is comparable to 1.55 reported for Musk ducks (McCracken *et al.,* 2000). It is worth emphasizing that SDI obtained in the present study was higher than earlier reports that average body mass dimorphism in most waterfowls is well below 1.4 (Marchant and Higgins, 1990; Dunning, 1993). Higher value of body weight dimorphism of Muscovy ducks in the present study in contrast to lower values reported for other waterfowls might be attributed to species differences in anatomical modifications.

Skeletal frame-related traits contributed next to the body mass. This might be attributed to the fact that they were made of bones on which bulk of body muscle and viscerals are attached. The moderate contribution of leg factor to sexual dimorphism could probably be attributed to the fact that their principal role was to provide structural support for the massive body weight of ducks. Contrary to the expectation, body girth, an environmentally sensitive morphological trait known to be highly correlated to live weight, had low contribution to size dimorphism in this study. Neither the remote nor immediate cause of this anomaly is clearly understood.

Least values of bill factor (bill length and bill width) are indications that these traits contributed little and are not important in describing SSD of this waterfowl.

The genetic basis of sexual dimorphisms is an intriguing problem of evolutionary genetics because dimorphic traits are limited to one sex (Coyne *et al.,* 2007). The genetic basis of variation in metrical characters, including that in sexual dimorphism between families or lines, is usually polygenic (Ehrman and Parsons, 1976). According toCoyne *et al.* (2007), such traits can arise genetically in two ways: first the alleles that cause dimorphism could be limited in expression to only one sex at their first appearance. Alternatively, dimorphism alleles could initially be expressed in both sexes, but subsequently be repressed or promoted in only one sex by the evolution of modifier genes or regulatory elements. The third possibility is that alleles could be male-limited from the outset, perhaps because they arose at genes that were already male-limited, or arose fortuitously in regions under control of cis-dominant elements activated only in males (Coyne *et al.,* 2007).

Explaining further the possible cause of size dimorphism, John-Alder *et al.* (2007) adduced the proximate cause of sexual dimorphism to the factor that produces intersexual differences in growth rate, such as differences in growth hormone concentrations or trade-offs in allocating energy between growth and reproduction. Postulating on possible reasons for superior SDI value in favour

Table 6: *Classification results of the Discriminant Analysis*
Preglednica 6: *Klasifikacija rezultatov diskriminantne analize*

		Predicted group membership		Total
Sex		1 (N = 287)	2 (N = 733)	N = 1020
Original count (%)	1	287	0	287
		15	718	733
	2	100.0	0	100.0
		2.0	98.0	100.0
Cross validated		287	0	287
		15	718	733
Count (%)	1	100	0	100.0
	2	2	98	100.0

1 = Male / moški, 2 = Female / ženske

of males; Georgiadis (1985) submitted that males of sexually dimorphic species attain a mature weight that is greater than females and more importantly, by continuing to grow after female growth has stopped; conversely, Bradley and Philip (1984) related selection for smaller body size of the female to female reproductive energetics.

4.2 MULTIVARIATE ANALYSIS

The KMO values obtained for adult male (0.687) and female (0.696) Muscovy ducks in the present study were higher than the threshold value (0.5); thus indicating that the sample size was adequate to apply PCA (Pundir *et al.*, 2011). In addition, values obtained for Bartllet's test of sphericity for male (Chi-square 711.842) and female (Chi-square 836.241) were significant and validated further the suitability of the data analyzed for PCA.

4.2.1 PRINCIPAL COMPONENT ANALYSIS OF MALE MUSCOVY DUCKS

The total variance explained (62.70 %) and three principal components extracted for drakes in the present study were lower compared to reports of related studies: Ogah *et al.* (2009a) and Ogah *et al.* (2009b) extracted four factors each accounting for 71.85 % and 69.7 % of the total variation explained respectively, for adult male Muscovy ducks. Mc Cracken *et al.* (2000) also reported 75.2 % for five components extracted in male Musk ducks. Conversely, in a similar study on another water bird, Urfi and Kalan (2006) extracted two PCs for male Painted Stork accounting for 85 % of the total variance. Discrepancies observed in the total variance explained and the number of the extracted factors in the present study and the earlier ones might be attributed to the differences in the number of variables measured, age of the birds and species involved.

Variables extracted in PC1 alongside body weight were indicators of meatiness and mostly measures of width (body girth, shank circumference) except body length. Variables characterizing PC 2 in males were projected body parts, depicting appendage and are connected with flight, diving in water and defence.The trend of variables characterizing highest loadings in PC two (wing length and shank length) corroborated the report of Mc Cracken *et al.* (2000) that appendage-related variables (tarsus bone length, wing span, wing chord and tarsus length) had the highest positive loadings in PC two of male musk duck and were suggested to relate to flight and diving proficiency. Inclusion of bill length in this PC suggests it to be an adaptive feature in males for defence against both aquatic and terrestrial predators.

High loading of thigh length as the only variable in PC 3 of male Muscovy duck could be termed skeletal support factor. Drumstick and thighbones have been shown to have highest loadings in the third component of Japanese quails (Shahin, 1997) and Egyptian strain of Pekin ducklings (Shahin, 1996); and were termed 'weight support factor'. Of recent, Udeh and Ogbu (2011) reported drumstick length as the only variable having high loading in component three of Ross broiler. Furthermore, the reported differences in the two sexes in the live body weight as reflected in SDI and SSDI in favour of male Muscovy duck in the present study suggested the need for anatomical modification to support heavy body mass of drakes; hence, longer thigh bone compared to females. Shahin (1996) corroborated this assertion that generally, the drumstick region (distal hind leg) is essential for locomotion (walking and perching), and is responsible in part, for supporting the weight of the body.

4.2.2 PRINCIPAL COMPONENT ANALYSIS OF FEMALE MUSCOVY DUCKS

The cumulative total variance explained by PCs extracted for female ducks (54.24 %) in the present study are comparable to the 53.0 % and 54.5 % reported by Ogah *et al.* (2009a and b) respectively for adult female Muscovy ducks. However, discrepancies were also observed in the number of PCs generated; while three PCs were generated in this study; Ogah *et al.* (2009a) and Ogah *et al.* (2009b) reported two and four, respectively.

The first component extracted for female ducks revealed unusual combination of body weight and shank-related variables (Shank length and shank circumference). It is suggestive that shank factors are related to live body weight in the female of this species. Informative anatomical trend is not evident in the second PC of the female characterized by bill width and thigh length; probably because of two variables associated with it and or problems associated with difficulty in interpretation of factor loadings of principal components even when variables concerned are many. Body length and wing length having highest loadings in PC 3 are possibly anatomical modifications for incubation. Female Muscovy ducks are highly fecund; having higher clutch sizes compared to other indigenous poultry species. These anatomical features play prominent roles in covering large number of eggs during incubation. Besides, moderate correlation of bill length with PC 3, an adaptive feature for nest making and egg turning during incubation corroborated earlier assertion in the present study that variables with high loadings in the third PC are possibly related to reproductive activities.

The factor loadings of the extracted PCs for each sex accentuated the widely reported sexual dimorphism between male and female ducks. The observed differences in morphostructural variables characterizing extracted components of male and female ducks indicated differences in association of each measurement with bone, which varies with sexes (Salako, 2006). Besides, the way the weight is distributed over the body and genetic adaptations to physiological needs might be additional reasons for the differences in these factors (Goss, 1981).

The observed SSD in the two sexes as reflected in the variables strongly correlating with their respective PCs substantiates further the orthogonality of the underlying variables related with the PCs generated for each sex. Since the correlation between the principal components is zero, it is certain that selection of animals for any principal component will not cause correlated response in other principal components (Pinto *et al.,* 2006).

4.2.3 DISCRIMINANT ANALYSIS

The highest discriminating power of body weight is not unexpected. Muscovy ducks are sexually dimorphic, males are conspicuously bigger in size than females. It is worth emphasis that the trend of variables with highest discriminating power (body weight, body length and wing length) is in tandem with those with highest degrees of SDI and SSDI in the present study (Table 2); whereby body weight was identified as the most dimorphic trait. The observed concordance in the trend of their degrees of contribution to SDI and SSDI, and discrimination of the sexes in this waterfowl is suggestive that those aforementioned traits are important for sexing and assessing SSD in adult Muscovy ducks. Related studies on sex discrimination of Muscovy ducks using morphological variables are scarce to compare with the results of the present study. Nevertheless, of recent, Yakubu (2011) reported wing length, body weight and neck circumference as the morphological measurements with highest discriminating power to separate male and female Muscovy ducks. In a related study on water birds, Perkins *et al.* (2009) reported wing length, tarsus and culmen; and wing length and tarsus as the most important traits for sex separation respectively, in Clapper Rails (*Rallus longirostris*) and King Rails (*Rallus elegans*).

The results of cross-validation for both sexes in this study were higher compared with reports on water birds whereby 85.3 % and 96 %, and 89 % and 83 % were reported respectively, for male and female Muscovy ducks (Yakubu, 2011) and Clapper Rails (*Rallus longirostris*) (Perkins *et al.,* 2009). Putting into consideration the higher classification success rate of male (100 %) and female (98 %) and overall success rate of 98.5 % for adult Muscovy ducks in this study, this demonstrated that morphologically the body conformation of the two sexes differs. This implies further that those morphological variables with higher separating power (body weight, body length and wing length) are reliable predictor of sex and capable of separating Muscovy ducks into sexes.

5 CONCLUSION

The present study demonstrated and provided additional information on the existence of SSD in Muscovy ducks. Higher SSD (SDI and SSDI) values in favour of males are consistent with the widely-reported existence of sexual dimorphism in male and female Muscovy ducks.

Besides, the observed differences in anatomical architectural make-up of the sexes as reflected by the variable loadings of their PCs provides insight into possible differences in the utilization of male and female Muscovy ducks. It suggests further the need for separate selection and genetic improvement programs for males and females of this waterfowl. This study demonstrated further the practical application and possibility of using morphological variables in discriminating between sexes of adult Muscovy ducks.

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