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MORPHOMETRIC DIFFERENCES BETWEEN SEXES IN THE WHITE-FACED IBIS (*PLEGADIS CHIHI*)

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ABSTRACT.—Sexual dimorphism in birds may express itself as differences in body size, plumage, color and/or behavior. Many species are monomorphic in color, which makes sex determination difficult in the field. In order to develop a tool to distinguish between male and female specimens of the White-faced Ibis, *Plegadis chihi*, by using external body measurements, the objective of this work was to quantify morphometric differences between sexes in adults of this species. The following variables were measured: culmen length, bill height and width, tarsus length, middle toe (with claw) length, wing chord, tail length and body mass. Males were larger than females in all of these variables, and presented statistically significant differences for six out of eight parameters. Three discriminant classification functions were obtained with an accurate total classification rate in >85% of the cases. The length of the culmen, tarsus, middle toe with claw, and wing chord, were among the most useful variables to discriminate between sexes. The classification functions are useful for the discrimination of sexes in the White-faced Ibis, with easy-to-take measurements. This information may be used by avian ecologists in future behavioral ecology, conservation biology, or evolutionary biology studies. The use of external morphometrics to sex monomorphic birds is of great value, being an inexpensive, less invasive and more immediate method.
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Key words: morphometrics, sexual dimorphism, southern South America, Threskiornithidae, White-faced Ibis.

In many avian species, sex can be determined by observing plumage or sex-specific structural characteristics (such as colored soft-tissue), sex-specific behavior, or by measuring morphological characteristics (Jodice et al. 2000). It is not possible to use these methods if both sexes are similar in size and monomorphic in coloration; methods that involve nuptial plumage or behavior associated with breeding season are restricted to breeding individuals and can only be used during part of the year (Coulson et al. 1983). In such cases, other methods such as anatomical examination (Boersma and Davies 1987, Richter and Bourne 1990, Richter et al. 1991) and collection of blood or feather samples for genetic analysis (Bertault et al. 1999, Fridolfsson and Ellegren 1999, Childress et al. 2005) are used to identify the sex of birds. In both techniques the capture of birds is required, causing a disturbance in their natural behavior (Dechaume-Moncharmont et al. 2011). As an alternative to avoid destructive or invasive techniques, the use of external morphometrics to sex birds is of value, being inexpensive and immediate in sex determination (Montalti et al. 2012). Discriminant Function Analysis (DFA; Sokal and Rohlf 1995) has been successfully applied to a wide variety of bird species from different groups including penguins (Scolaro et al. 1983, Gales 1988), divers (Okill et al. 1989), petrels (Genevois and Bretagnolle 1995, Albores-Barajas et al. 2010), cormorants (Casaux and Baroni 2000, Riordan and Johnston 2013), vultures (López-López et al. 2011), gulls (Herring et al. 2010), skuas (Hamer and Furness 1991, Montalti 2005), moorhens (Anderson 1975), rooks (Green 1982), flamingos (van Couteren and Verheyen 1988, Childress et al. 2005, Montalti et al. 2012), owls (Baladrón et al. 2015), and passerines (Montalti et al. 2004). The use of morphological measurements to assign sexes might be limited to living birds, and the accuracy of a classification function may change when it is applied to a group of individuals different from the one where it originated (Montalti et al. 2012).

While external morphometric indexes have been used widely to assist in the sexing of birds, little is known about the morphometrics of most Neotropical birds (Oniki 1986, Torlaschi et al. 2000, Montalti et al. 2004, Baladrón et al. 2015). The White-faced Ibis (*Plegadis chihi*) is a member of the order Pelecaniformes (Remsen et al. 2016), within the *Threskiornithidae* family, which is comprised of gregarious, wading birds with long legs and elongated specialized bills to facilitate

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feeding in shallow waters (Matheu and del Hoyo 1992).

White-faced Ibis is a resident species in Uruguay, Paraguay, southeastern Brazil, Chile, eastern Bolivia, Peru, Venezuela, Mexico, and central-west USA. In Argentina, it is distributed from the northern stretches of the country to the northwest of Chubut province, mainly in the Chaco-Pampean plain. This species lacks sex-specific plumage, but they show breeding plumage during spring-summer (Navas 1995).

The objective of this study was to analyze morphometric data of White-faced Ibises to search for metric differences in anatomical features between males and females. Our intention was to develop classification functions to assign the sex of this species.

METHODS

We measured adult male and female White-faced Ibises from the following museum collections in Argentina: Museo de La Plata (La Plata), Fundación Miguel Lillo (Tucumán) and Museo Argentino de Ciencias Naturales (Buenos Aires). We examined a total of 83 (41 males and 42 females) White-faced Ibises, all coming from Buenos Aires province (Argentina).

External measurements were taken following Baldwin et al. (1931) and including the suggestions given by Winker (1998): length of exposed culmen (Cu) from the anterior end of the nostril to the tip of the bill; bill height (BH) and bill width (BW) measured at the base; tarsus length (Ts) from the notch on the back of the intertarsal joint to the ventral surface of the foot with toes extended; middle toe length including claw (MT) (these measurements were all taken using a Vernier caliper); wing chord (WC) defined as the distance from the distal portion of the carpus to the tip of the largest primary feather; and length of tail (Ta) from the base of the tail to the tip of the longest rectrices (measured using metal ruler with a perpendicular stop at zero). Measurements taken using a Vernier caliper had 0.01-mm accuracy, and those taken with metal ruler were accurate $\pm$ 1 mm. Since McNeil and Martínez (1967) found bilateral asymmetry in some species (one of the sides being larger than the other), all measurements were taken from the right side of each bird. Sex and body mass (Wg, in g) were recorded from collection tags attached to each specimen. Since the museum specimens were prepared to enter the ornithological collections, sex determination was made at the time of this procedure, through direct anatomical examination.

We evaluated differences in body measurements between males and females by using Student's *t*-tests (Sokal and Rohlf 1995, Zar 2010). We tested normality and homogeneity of variance by using Shapiro-Wilks and Levene tests. Discriminant analyses (IBM Corp. 2010) were performed to develop classification functions as tools to predict the sex of unknown White-faced Ibises by their morphometric characteristics. Given that body mass may not be a reliable measure to include in discriminant functions since it may vary throughout the year and also during the day (Brothers 1985, Croxall 1995, Casaux 1998), we omitted this variable from the analysis. We excluded bill height and width, because we did not have these measurements for half of the individuals. We also disqualified tail length. Therefore, discriminant functions were performed with all possible combinations of culmen, tarsus, middle toe with claw, and wing chord. We evaluated the performance of each variable as discriminant (univariate discriminant analysis). Forward discriminant analyses were applied to obtain combinations of characteristics (discriminant functions) that best distinguished the sexes. The associated cutting point value was calculated following Phillips and Furness (1997). Ibises with a discriminant score higher than the cut-off value were classified as males, and those with a lower score as females. The effectiveness of the discriminant analyses was checked in terms of the proportion of birds that were classified correctly and by a jackknifed validation (Sokal and Rohlf 1995, Tabachnick and Fidell 1996, Phillips and Furness 1997).

We report the *F*-value, significance level (*P*-value), Wilks's Lambda, and the percentage classified correctly for each sex and for both sexes together. Only results corresponding to the discriminant functions representing $>$85% of correct classification, for both sexes pooled together, are presented.

TABLE 1. Morphometric data of White-faced Ibises *Plegadis chihi* from Buenos Aires province, Argentina; presented as mean ± standard deviation (SD), range. Significant differences between sexes (*t*-test) are indicated in bold (NS: $P > 0.05$, **: $P < 0.001$).

	Males			Females				
Measurements	Mean ± SD	Range	*N*	Mean ± SD	Range	*N*	T	*P*
Cu	**118.84 ± 10.95** **	**95.94–136.00**	**41**	**102.37 ± 8.67** **	**92.00–127.85**	**42**	**− 7.61**	**
BH	**15.42 ± 0.92** **	**13.56–17.73**	**22**	**14.63 ± 0.92** **	**13.12–16.21**	**28**	**− 3.01**	**
BW	12.89 ± 1.43	10.54–15.84	23	12.32 ± 1.43	9.70–16.15	31	− 1.45	NS
Ts	**93.85 ± 8.31** **	**77.60–121.00**	**41**	**80.41 ± 6.96** **	**66.90–105.70**	**42**	**− 8.00**	**
MT	**78.20 ± 4.97** **	**67.12–87.00**	**40**	**70.04 ± 5.04** **	**57.23–81.45**	**41**	**− 7.34**	**
WC	**248.19 ± 9.01** **	**229.00–265.00**	**37**	**233.88 ± 7.94** **	**220.00–255.00**	**40**	**− 7.41**	**
Ta	90.55 ± 7.39	74.00–109.00	40	88.54 ± 7.42	73.00–110.00	41	− 1.22	NS
Wg	**568.69 ± 35.90** **	**520.00–628.00**	**13**	**476.00 ± 42.66** **	**385.00–543.00**	**10**	**− 5.66**	**

RESULTS

Male White-faced Ibises were larger than females in all body size measurements (Table 1); in six of them, these differences were highly significant: culmen, tarsus, middle toe with claw, wing chord, weight ($P = 0.0001$) and bill height ($P = 0.004$). However, bill width and tail length were not significantly different (Table 1).

Forward discriminant analysis provided three significant functions that had total percentage of correct classification >85%. The discriminant function that best classified sexes was the one incorporating the following measurements: culmen, tarsus, middle toe with claw, and wing chord (D1). This function misclassified six males and four females. The function including: culmen, tarsus, and wing chord (D2) misclassified four males and five females. Lastly, the function incorporating culmen, tarsus, and middle toe with claw (D3) incorrectly sexed six males and five females (Table 2). The jackknifed validation provided the same classifications as those produced by the discriminant functions.

DISCUSSION

This study showed that the sex of an adult White-faced Ibis can be determined effectively using body measurements. Both multivariate and univariate analyses of body measurements showed that male White-faced Ibises are larger than females. Significant differences were found in culmen length, bill height, tarsus length, middle toe length, wing chord, and body mass. We observed some overlap in the morphological measurements between male and female White-faced Ibises in this study, which reduced the probability of correctly classifying an individual. Discriminant function analysis including culmen, tarsus, middle toe with claw, and wing chord provided the higher total correct clasification.

Blake (1977), Navas (1995), and Soave et al. (2006) have shown that males of the White-faced Ibis are larger than females, as we too found. Soave et al. (2006) measured significant differences in culmen length (males 124.7 ± 6.9 mm, $n = 9$; females 101.8 ± 4.6 mm, $n = 9$; $P < 0.001$) on individuals from Buenos Aires province. Our

TABLE 2. Classification functions generated by Discriminant Function Analysis from morphometric characters of White-faced Ibises *Plegadis chihi* from Buenos Aires province, Argentina (** $P < 0.001$).

			Correct Classification %					
Function	*N*	Cutting Point	Total	Male	Female	Wilks' λ	*F*	*P*
D1 = 0.029 Cu + 0.039 Ts + 0.071 MT + 0.038 WC − 20.988	75	0.042	88.0	86.1	89.7	0.465	54.43	**
D2 = 0.04 Cu + 0.066 Ts + 0.038 WC − 19.310	77	0.040	87.0	83.8	90.0	0.473	55.00	**
D3 = 0.034 Cu + 0.059 Ts + 0.072 MT − 14.290	81	0.012	86.4	85.0	87.8	0.507	52.62	**

study found differences not only in culmen length but also in bill height, with males being larger in both parameters. Since Soave et al. (2006) studied diet, they attributed this difference to males consuming more snails (i.e., *Pomacea canaliculata*) than females ate. These snails were the largest prey discovered during their study.

Soave et al. (2006) also found significant differences in body mass between sexes (males 537 ± 68 g, $n = 55$; females 469 ± 40 g, $n = 33$; $P < 0.001$) with males being heavier. Likewise, highly-significant differences in body mass between sexes are reported in this study. The mean body mass was found to be closer to that reported by Soave et al. (2006). Since Soave et al. (2006) considered the same geographic zone (Buenos Aires province) as this study, similar body mass might be correlated with similar diet and food resources. However, body mass in this study is below that presented by Dunning (2008; males 697 ± 58.9 g, $n = 32$; females 546 ± 45.3 g, $n = 35$). The discrepancies might be explained by considering that body mass reflects a summation of elements, skeleton, internal organs, and nutrient reserves, with this last item being related directly to an individual's condition (Dunning 2008). Body mass also depends upon the time elapsed from food intake and breeding stage (Winker 1998).

The discriminant function that yielded the highest percentage of total correct classification comprised the following parameters: culmen, tarsus, middle toe with claw, and wing chord. The other two functions, one that included culmen, tarsus, and wing chord and the other with culmen, tarsus, and middle toe with claw, were also highly efficient in the classification.

Sexual divergence is often thought to have adaptive value in alleviating intersexual competition for food (Selander 1966). Other studies in ibises suggest that differences in bill size and body mass might be related to specific nesting behavior (e.g., White Ibis *Eudocimus albus*, Scarlet Ibis *E. ruber*; Kushlan 1977, Babbitt and Frederick 2007). Larger size might be important for male White Ibises, since they spend much of their time defending the nest (Kushlan 1977). Because male Scarlet Ibises participate in bill-sparrings during breeding season, bill length might be determinant on this struggle where males with larger bills have more chances to win (Babbitt and Frederick 2007).

These discrimination characters constitute a useful tool for the management and conservation of bird species and for accurate implementation of research projects and monitoring programs. Our results indicate that the use of morphological measurements on museum skins can reliably assign sexes; this should be transferrable to determining the sex of living birds. Since the DFA correctly classified a high percentage of birds using only four parameters, it does provide an efficient tool for sexing White-faced Ibises.

The information presented here contributes to our knowledge of the morphometric characters of the White-faced Ibis. Morphometric information about birds is essential for understanding taxonomical, ecological, behavioral, physiological, and evolutionary matters (Jodice et al. 2000, Møller 2000, Ruckstuhl and Clutton-Brock 2005). Taking into account that discriminant analyses have proven useful for the determination of sex in this and other bird species (e.g., the Chilean Flamingo; Montalti et al. 2012), the use of DFA is an important investigative statistical technique with applications in species management and research.

The use of external morphometrics to sex birds is of great value, being inexpensive and less invasive than laparotomy/anatomical examination and collection of blood samples (Montalti et al. 2012). And, it is a more immediate method for determining sex.

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