The Use of Culmen Length to Determine Sex of the American White Pelican

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Abstract.—Culmen length has been suggested as being diagnostic for sex in the American White Pelicans (*Pelecanus erythrorhynchos*). However, the literature on the use of culmen length to determine sex is inconsistent, with reported overlap in culmen lengths for males and females ranging from 1 mm to >120 mm. Morphological measurements from 188 American White Pelicans collected in Mississippi and Louisiana whose sex was determined by dissection and gonadal inspection were measured. The use of culmen length alone was used to determine gender for this sample by establishing the minimum observed culmen length for males and the maximum observed culmen length for females that provided the fewest incorrect determinations for each gender. A multivariate discriminant function model was developed to determine sex from our data and compared the diagnostic accuracy of the model with the accuracy based on culmen length alone. Both methods were validated using an independently collected sample of 22 pelicans from Florida. A culmen length of ≥310 mm for males and ≤309 mm for females from our data correctly classified sex for 99% of American White Pelicans from our Mississippi and Louisiana samples and 95% of AWPE for the Florida sample. Culmen length and wingcord length were significant variables in the discriminant function model. The resulting model correctly classified sex of 97% of the birds and 94% of the independent Florida sample. The culmen length alone predicted the sex of American White Pelicans as well as multivariate methods and provides an accurate simple, non-lethal method for sexing the species.

Key words.—gender, discriminant analysis, morphometrics, American White Pelican.

Waterbirds 28 (Special Publication 1): 102-106, 2005

The ability to identify the sex of individual birds under study in sexually monochromatic species, such as the American White Pelican (*Pelecanus erythrorhynchos*) is often of interest to researchers. Relatively easy, non-lethal techniques to identify sex are useful for studying aspects of avian biology including foraging ecology, behavior, evolutionary and conservation genetics, survivorship and dispersion (Anderson and Norberg 1981; Clutton-Brock 1986; Newton *et al.* 1983; Griffith and Tawari 1995).

The American White Pelican (AWPE) has been described as being sexually dimorphic with respect to culmen length, weight, wingcord and cloacal characteristics (Bent 1964; Palmer 1962; Lingle and Sloan 1979). However, differing cloacal characteristics have only been determined soon after breeding occurs and does not include pre-breeding birds (Lingle and Sloan 1979). Additionally, considerable overlap in most of these measurements suggests that univariate techniques to sex AWPE may be inaccurate. A univariate measure that may serve to distinguish gender is culmen length. Palmer (1962) reported that male (N = 9) culmen lengths are ≥320 mm and female (N = 10) culmen lengths are ≤320 mm (1 mm overlap). However, Lingle and Sloan (1979) reported a much greater overlap (~120 mm) in adult AWPE (N = 47), and Lingle and Sloan (1979) indicated that only males (N = 26) with culmen lengths ≥345 mm and females (N = 21) of ≤245 mm (i.e., at least a 100 mm difference) could be accurately (P < 0.05) sexed.

Multivariate approaches such as discriminant analyses (DA) of external measurements have been used to distinguish sex of birds and often has proved to be of greater accuracy than univariate methods. This method has been used to determine sex of other Pelecaniformes such as the King Cormorant (*Phalacrocorax atriceps albiventer*) and Double-crested Cormorant (*Phalacrocorax auritus*) (Malacalaza and Hall 1988; Bedard *et al.* 1995; Glahn and McCoy 1995). This technique has been utilized for many other monochromatic species (Brennan *et al.* 1984; Clark *et al.* 1991; Fox *et al.* 1981; Hanners and Patton 1985; Haywood and Haywood 1991; Maron and Myers 1984; McCloskey and Thompson 2000). The objectives of this study were to: (1) clarify inconsistencies in the published literature on the use of culmen length to sex AWPE, (2) evaluate the accuracy of culmen length to sex AWPE versus a multivariate model and (3) develop an accurate and non-lethal field technique to sex these birds.

METHODS

From April 1998 to April 1999, AWPE were collected from eight locations in the delta region of Mississippi and in coastal regions and inland areas along the Atchafalaya River basin in Louisiana. Three linear measurements were selected that would be repeatable, had been shown to provide a minimum of measurement error in other bird species and had been suggested by previous research as being diagnostic for sex (Palmer 1964; Lingle and Sloan 1979; Lougheed *et al.* 1991). Measurements were taken on all birds for culmen length (straight line down the center of the bill from most distal point to the feathered edge at the base), (flattened) wing cord (wrist joint to the tip of the longest primary) and tarsal length (metatarsus measured from proximal to distal joint). In addition to these measurements, body mass of each individual was recorded. Measurements for culmen and wingcord were taken to the nearest millimeter using a stopped metric ruler. A vernier caliper was used to measure tarsus length to the nearest 0.1 mm. Body mass was measured to the nearest 0.2 kg with a 20 kg Pesola spring scale and sex was determined from dissection and gonadal inspection. Age (adult, subadult or juvenile) was determined from plumage based on characteristics described by Lingle and Sloan (1979) and Evans and Knopf (1993).

Equality of group means between sexes was investigated by performing a *t*-test on each of the variables considered (SAS Insititute 1994). The use of culmen length alone was evaluationed for determining gender by establishing the minimum observed culmen length for males and the maximum observed culmen length for females that provided the fewest incorrect determinations for each gender. These values were then qualitatively evaluated against an independently collected sample from Florida.

Determination of gender was evaluated to determine if accuracy could be improved by inclusion of additional morphological metrics. We used stepwise DA (PROC STEPDISC; SAS Insititute 1994; SAS Insititute 1996) to select (criteria $P \leq 0.10$) variables for the model (Costanza and Affii 1979). The resulting model was tested by cross-validation methods to estimate accuracy (SAS Insititute 1994).

The applicability of field measure to determine gender is best evaluated against independently collected samples. Additionally, discriminant function models often fit the sample from which they were derived better than they fit other samples, possibly resulting in inflation of the true performance of the model (Norusis 1988; SAS Insititute 1994). Therefore, an independent sample of AWPE collected in Florida was used to validate the accuracy of each of the methods (i.e., DA *vs.* culmen length). The performance of each method in determining gender were then qualitatively compared.

The birds from the Florida sample were collected freshly dead or moribund from Orange, Marion, Brevard, Columbia, Dade, Lake, Monroe, Volusia and Wakulla Counties from 8 January to 5 April 1999 and 26-28 January 2000. Measurements taken were similar to our data except the wing cord for this sample was not flattened. In addition to validation of methods developed from our data, the independent sample provided a measure of the regional applicability of the methods evaluated and robustness with respect to measurements taken by different observers.

RESULTS

A total of 198 AWPE were collected at ten locations in Mississippi and Louisiana. Of these, 188 were suitable for use in the resulting discriminant function model (i.e., they did not have gross indications of disease, or injury that precluded their use in the model). Of these, 160 were male and 28 were female. For males, 73 were classified as adult and 87 as subadult. For females, 18 were classified as adult and 10 as subadult. Means for all measurements were significantly larger for males than for females; however, there was overlap for all categories including culmen length (Table 1). The minimum culmen length recorded for males was 287 mm and the maximum recorded for females was 360 mm.

There were 28 pelicans in the Florida validation sample, 22 of which had the required information for validation of the discriminant function model and culmen length. Of these, nine were female and 13 were male. For males, five were classified as adult, two as first year birds and six as subadult. For fe-

Table 1. Mean, standard error (SE), range, *t*-value (t) and probability (P) of a larger morphometric measurements of male and female American White Pelicans collected in Mississippi and Louisiana, April 1998-April 1999, based on 160 males and 28 females.

Measurements	Males mean ± SE (range)	Females mean ± SE (range)	t	P
Body mass (g)	6,486 ± 530 (5,000-8,000)	5,154 ± 129 (4,200-6,200)	9.6	<0.0001
Wing cord (mm)	606.0 ± 1.6 (541-675)	560.0 ± 4.7 (511-598)	10.9	<0.0001
Culmen length	349.0 ± 1.2 (287-385)	283.0 ± 2.3 (260-360)	21.7	<0.0001
Tarsal length	120.4 ± 0.4 (105-137)	111.0 ± 1.2 (100-120)	8.1	<0.0001

males, four were classified as adult and five in their first year. Means for all measurements except tarsus length were significantly larger for males than for females. As in our sample, there was overlap for all categories of measurements including culmen length. (Table 2). The minimum value recorded for males was 345 mm and the maximum for females was 356 mm.

Qualitative analysis of the data indicated a minimum culmen length for males of 310 mm and a maximum culmen length for females of 305 mm, provided the minimum number of incorrect gender classifications. Because we had a larger sample-size for males than females we used a value of ≥310 mm for males and ≤309 mm for females for evaluating the independently-collected Florida sample. Based on these criteria, culmen length alone correctly classified sex for 98% (N = 188) AWPE for our data and 95% (N = 22) of pelicans for the Florida sample. Only two birds were misclassified from our data, one male with a culmen length of 287 mm, and one female with a culmen length of 360 mm. Only one observation was misclassified for the Florida sample, a female with a culmen length of 356 mm.

The stepwise selection procedure selected only culmen length and wingcord length as significant variables in the discriminant function model (Table 3). Within model cross-validation correctly predicted females in 96% (N = 28) of the samples and for males in 97% (N = 160) of the samples. Overall prediction for both sexes was correct for 97% of AWPE. The independent sample cross-validation correctly predicted females in 89% (N = 9) of the samples and for males in 100% (N = 11) of the samples.

Table 2. Mean ($\bar{x}$), standard error (SE), range, *t*-value (t) and probability (P) of a greater t for morphometric measurements of 13 male and 9 female American White Pelicans collected in Florida, 8 January, 5 April 1999 and 26-28 January 2000 and used for validation purposes. The notation (n.s.) means not significant at P ≤ 0.05.

Measurements	Males $\bar{x}$ ± SE (range)	Females $\bar{x}$ ± SE (range)	t	P
Body mass (g)	5,451 ± 173 (4,600-6,250)	4,124 ± 278 (3,327-5,780)	4.05	<0.001
Wing cord (mm)	576.0 ± 6.8 (543-620)	506.0 ± 24.4 (320-570)	2.74	<0.02
Culmen length	359.0 ± 3.0 (345-380)	298.0 ± 7.5 (280-356)	7.53	<0.001
Tarsal length	118.0 ± 2.4 (100-136)	114.0 ± 2.6 (103-128)	1.07	n.s.

Table 3. Stepwise analysis of morphometric measurements of 160 male and 28 female American White Pelicans collected in Mississippi and Louisiana, April 1998-April 1999. The notation (n.s.) means not significant.

Step	Variable entered	Partial R^2	F-value	P
1	Culmen (mm)	0.66	359.70	<0.0001
2	Wing cord (mm)	0.08	15.80	<0.0001
3	Mass (kg)	<0.01	0.39	n.s.
4	Tarsus (mm)	<0.01	0.58	n.s.

DISCUSSION

Overlap and ranges of culmen lengths for both our sample and the sample collected from Florida were within the range of values previously reported (Palmer 1962; Lingle and Sloan 1979). However, overlap with respect to culmen length was represented by only two individuals (one male and one female) from our sample population and one female from the Florida sample. Unlike Lingle and Sloan (1979) who reported considerable overlap in culmen length between sexes, our results concur with those of Palmer (1962) whose data suggested that AWPE could be accurately sexed using culmen length alone. Moreover, the addition of other morphological metrics in a discriminant function model did not provide greater accuracy in gender determination. Thus a culmen length of ≥310 mm for males and ≤309 mm for females provides an accurate simple, non-lethal method for determining gender of AWPE.

Unlike research conducted on the Double-crested Cormorant (Glahn and McCoy 1995), there were no regional differences in morphometric characteristics between samples collected in Mississippi and Louisiana or Florida. Although, the overall percentage of samples correctly classified for the independently collected Florida sample was lower than for our sample, a small sample-size for females (N = 9) from the independent sample may have inflated the error estimate.

The use of culmen length for gender determination of the AWPE should be useful to researchers and biologists. The field method is rapid, easy and unobtrusive compared to techniques such as laparotomy or molecular methods (Ellegren 1996; Balbontin *et al.* 2001). Although, Lingle and Sloan (1979) developed useful field techniques to identify the gender of adult AWPE soon after breeding, the use of culmen length provides a method for doing this on AWPE year-round throughout their life. Additionally, the culmen would likely degrade more slowly than internal organs, so it may be useful for identifying the sex of AWPE carcasses.

The use of culmen length to determine sex appears to be applicable to AWPE ranging from Louisiana to Florida. However, we have no information on the applicability of this measure to AWPE from elsewhere in their range (such as west of the Rocky Mountains). We encourage researchers to verify this method with individuals collected outside the regions encompassed in this study.

ACKNOWLEDGMENTS

We thank Dwight LeBlanc and his staff with Louisiana Wildlife Services; Bo Sloan, Greg Ellis and staff with Mississippi Wildlife Services; and staff with the Louisiana Department of Wildlife and Fisheries for their help with access, collections and processing of specimens. We thank catfish producers in Louisiana and Misssissippi for helping with collections and allowing us access to their facilities. We also thank S. Werner, M. Tobin and J. Jones for their reviews of this manuscript.

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