J. Field Ornithol., 70(4):514–519

SEX DETERMINATION OF THE ACADIAN FLYCATCHER USING DISCRIMINANT ANALYSIS

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Abstract.—I used five morphometric variables from 114 individuals captured in Arkansas to develop a discriminant model to predict the sex of Acadian Flycatchers (*Empidonax virescens*). Stepwise discriminant function analyses selected wing chord and tail length as the most parsimonious subset of variables for discriminating sex. This two-variable model correctly classified 80% of females and 97% of males used to develop the model. Validation of the model using 19 individuals from Louisiana and Virginia resulted in 100% correct classification of males and females. This model provides criteria for sexing monomorphic Acadian Flycatchers during the breeding season and possibly during the winter.

DETERMINACIÓN DEL SEXO EN *EMPIDONAX VIRESCENS* UTILIZANDO ANÁLISIS DISCRIMINATIVO

Sinopsis.—De una muestra de 114 individuos, capturados en Arkansas, utilicé cinco variables morfométricas para desarrollar un modelo discriminativo para predecir el sexo de individuos del papamoscas *Empidonax vicescens*. Un análisis de función discriminativa seleccionó el largo del ala y del rabo como las variables más adecuadas para discriminar el sexo de éstas aves. El modelo de dos variables, clasificó correctamente el 80% de las hembras y el 97% de los machos. La validación del modelo en donde se utilizaron individuos de Louisiana y Virginia, permitió determinar el sexo de 19 individuos examinados. El modelo provee criterios morfométricos, para sexar a esta especie de papamoscas durante la época de reproducción y posiblemente durante el invierno.

Ornithologists have long struggled over the sexing and aging of *Empidonax* flycatchers. Although researchers have documented several criteria for differentiating species, criteria for sexing these sexually monomorphic birds outside of the breeding season are lacking. Currently, the only reliable method for sexing such monomorphic birds is the presence of a cloacal protuberance in males or brood patch in females (Pyle 1997a). However, this method is restricted to reproductively active birds during the breeding season. Even so, male flycatchers, especially among *Empidonax*, do not develop large cloacal protuberances, such that males may often be mis-sexed as females during the breeding season. Furthermore, non-mated individuals, as well as birds outside of the breeding season, exhibit neither a cloacal protuberance or a brood patch. Thus, these individuals cannot be readily sexed in the field, complicating estimation of sex-specific demographic parameters.

Interspecific differences in morphometric characteristics (e.g., wing morphology and bill shape) have been documented for *Empidonax* flycatchers (Pyle 1997a:218), suggesting that intersexual differences may exist. Indeed, Phillips et al. (1966) were able to sex correctly 90% of Alder Flycatchers (*Empidonax alnorum*) and 93% of Least Flycatchers (*Empidonax minimus*) using wing morphology. Likewise, Pyle (1997b), was able to sex correctly 83% of Acadian Flycatcher (*Empidonax virescens*) museum specimens using an equation based on wing morphology. Here, I present a simple model based on morphometric measurements of live Acadian Flycatchers as a means of elucidating intersexual differences and subsequently apply the model to two independent data sets for validation.

METHODS

From 1994–1997, 114 adult (after-hatching-year) Acadian Flycatchers were captured and banded (30 April–9 August) on the White River National Wildlife Refuge in eastern Arkansas (34°14′N, 91°05′W). During 1997, an additional 16 Acadian Flycatchers were captured and banded (24 April–22 July) on the Atchafalaya National Wildlife Refuge in central Louisiana (30°28′N, 91°42′W; C. Fuller, unpubl. data) and eight Acadian Flycatchers were captured and banded (27 May–19 July) on the George Washington National Forest in western Virginia (38°07′N, 79°22′W; G. Gale, unpubl. data). All individuals were captured using mist nets.

Sex of each captured bird was determined from the presence of cloacal protuberance or brood patch (Pyle 1997a). Body mass, tarsus, culmen length, wing chord, and tail length were measured. Bill length was recorded as "exposed culmen", from the distal tip to the tip of the forehead feathering at the proximal base of the bill. Tarsus length was measured from the most anterior medial condyle to the exterior portion of the skin resulting in a total tarsus length (see Fig. 1 in Byers and Cary 1991). Unflattened wing chord was recorded from the carpal joint to the distal end of the longest primary. In Arkansas and Virginia, tail length was recorded by placing a ruler parallel to the tail and inserting it between the tail and undertail coverts, whereas in Louisiana tail length was measured by holding the ruler perpendicular to the tail and inserting between the central rectrices (sensu Pyle 1997a).

Summary statistics ($\bar{x} \pm$ SE) were calculated for each location and sex combination. I used multivariate analysis of variance to test for an overall location effect and for a sex effect using only Arkansas data. Two-way analysis of variance (ANOVA) with contrast statements was used to test specific hypotheses about group means. Individuals from Arkansas were subjected to stepwise discriminant analysis (PROC STEPDISC, SAS Institute 1989) to select the best subset of variables that differentiated the sexes (training set). Variables with missing values were excluded before analysis and prior probabilities were set proportional to group membership. A significance level of $P = 0.15$ was selected for entry into the model and variables were retained in the stepwise model at the $P = 0.05$ significance level. Model accuracy was then assessed using PROC DISCRIM to calculate classification error rates for the training set and validated using an independent data set of 19 individuals from Virginia and Louisiana.

RESULTS

Multivariate analysis of variance revealed a significant overall location effect (Wilks' $\lambda = 0.143$, $F_{10,232} = 38.04$, $P < 0.001$), and males were significantly larger than females in Arkansas (Wilks' $\lambda = 0.392$, $F_{5,100} = 30.97$, $P < 0.001$). Using contrast statements, I found that Arkansas males had significantly longer wing chords, tail and tarsus lengths, and larger body masses than Arkansas females ($P \leq 0.03$) and significantly longer tarsus lengths and culmens than Virginia males ($P < 0.001$). Likewise, Arkansas females had significantly longer wing chords, tail, tarsus, culmen lengths, and larger body masses than Louisiana females ($P < 0.001$; Table 1).

Stepwise discriminant analyses selected wing chord ($F_{1,105} = 135.2$, $P < 0.001$) and tail length ($F_{1,105} = 4.2$, $P < 0.04$) as significant morphological measurements for discriminating between the sexes. Thus, the following discriminant functions were developed to distinguish between male and female Acadian Flycatchers:

$$\text{If sex} = \text{female,} \quad \text{then } \phi = -700.64 + 18.60(\text{wing chord}) + 1.09(\text{tail length}) \tag{1}$$

$$\text{If sex} = \text{male,} \quad \text{then } \phi = -801.14 + 20.18(\text{wing chord}) + 0.84(\text{tail length}) \tag{2}$$

where ϕ = the discriminant score. Substituting for wing chord and tail length in each equation, an individual was classified into the sex of the equation that yielded the highest score (ϕ). This discriminant model correctly classified 80% (20/25) of the females and 96% (86/89) of the males used for model construction. When equations (1 and 2) were applied to independant data sets for model validation, the model correctly classified 100% of female (10/10) and 100% of male (1/1) Acadian Flycatchers from Louisiana and 100% of females (1/1) and 100% of the males (7/7) from Virginia.

DISCUSSION

Larger body sizes of male and female Acadian Flycatchers in Arkansas compared with both Louisiana and Virginia suggests geographical variation, measurement error, or differences in measurement methodologies. I believe they are likely the result of a combination of the last two due to slightly different methods of data collection (Eason et al. 1996). For example, Pyle (1997a:5) states that the flattened wing length is 0.5–2% longer than the wing chord and that the amount of pressure applied to the carpal joint can be a source of variation (Yunick 1986). As such, variation in methodologies and observers could explain the Arkansas and Virginia differences, whereas the Arkansas and Louisiana differences could be real (but see below). For example, many species of migrants show this type of variation, being smaller and shorter-winged as migration distance decreases (Mulvihill and Chandler 1990, 1991). However, Acadian Flycatchers do not replace primaries or rectrices until their second prebasic molt (Pyle 1997a:223). Thus, second-year birds typically have more worn primaries, resulting in shorter wing chord measures than after-hatching-year birds.

TABLE 1. Measurements (mm) and weight (g) of adult Acadian Flycatchers from three different locations, April–August 1994–1997.

Variable	Arkansas			Louisiana			Virginia		
	n	Mean ± SE	Range	*n*	Mean ± SE	Range	*n*	Mean ± SE	Range
Males									
Wing	89	76.7 ± 0.19	72–82	2	71.0 ± 3.0	68–74	7	76.1 ± 0.48	74.5–78.5
Tail	89	61.7 ± 0.26	55–68	1	58.0	—	7	60.2 ± 0.83	57–64
Tarsus	87	18.7 ± 0.08	17–21	2	15.1 ± 0.4	14.7–15.5	6	15.5 ± 0.07	15.2–15.8
Culmen	89	13.9 ± 0.12	11–16	2	11.7 ± 1.6	10.1–13.4	6	11.2 ± 0.37	10.2–12.6
Mass	86	13.1 ± 0.06	11.6–14.4	3	12.4 ± 0.4	11.6–13	6	13.6 ± 0.22	13–14.4
Females									
Wing	25	71.6 ± 0.44	67–78	13	66.9 ± 0.54	64–70	1	65.0	—
Tail	25	59.5 ± 0.76	52–69	10	52.7 ± 0.93	47–56	1	54.0	—
Tarsus	25	18.0 ± 0.16	17–20	10	13.9 ± 0.50	10.5–15.6	0	—	—
Culmen	25	13.6 ± 0.26	11–16	10	11.1 ± 0.24	10.2–12.4	1	10.6	—
Mass	22	12.7 ± 0.19	11.4–15	13	11.6 ± 0.24	10.5–13.2	1	12.2	—

Further, as the breeding season progresses, feathers become increasingly frayed, especially in females due to there incubation duties. Hence, observed differences in wing chord and tail length measurements could simply relate to age or time (season) of capture. As all captures occurred during the same time period (late April–early August), the observed differences are likely a function of measurement error and or differences in methodologies, although the influence of age is unknown.

Nonetheless, the results of this study agree with those of Phillips et al. (1966) and Pyle (1997b), that *Empidonax* flycatchers can be readily sexed using a combination of morphological measurements. Only two measurements (wing chord and tail length) were needed to successfully discriminate between the sexes in Acadian Flycatchers. Based on these two measurements, I was able to correctly classify 94% (107/114) of the individuals used to build the model and 100% (19/19) of the individuals used to validate the model. As species-specific population models require detailed information on age- and sex-specific parameters (e.g., survival of adult females), this equation provides researchers with an alternative method to sex adult Acadian Flycatchers. However, I recommend that researchers continue to validate and refine this model and to extend its applicability to discriminating age classes (e.g., Donovan and Stanley 1995) and sexing Acadian Flycatchers outside of the breeding season.

ACKNOWLEDGMENTS

Thanks to C. Fuller and G. Gale for sharing their unpublished data. R. Cooper, P. Pyle, D. Twedt, and an anonymous reviewer provided comments and suggestions on earlier drafts of this paper and D. Twedt provided assistance with the statistical design. Arkansas data were collected as part of the author's thesis research funded by grants between the University of Memphis, the U.S. Forest Service and the Arkansas Nature Conservancy (contract 19-92-063), and between the University of Memphis and the U.S. Fish and Wildlife Service (contract 1448-0004-94-9177).

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Received 24 Jun. 1998; accepted 4 Mar. 1999.