Sexing Known-age Gray Catbirds by Discriminant Function Analysis

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ABSTRACT

A robust sample of 525 known-age and sex Gray Catbirds *(Dumetella carolinensis)* was used to test the hypothesis that birds of known determinate ages, second year (SY), third year and older (TY^+), analyzed by separate discriminant functions for each age group, can be sexed more accurately than a pool of indeterminate after-hatching-year (AHY) birds. The TY^+ birds tested more reliably for sex (94%), than SY birds (81%), and pooled age birds (89%). Lighter mouth and tongue scores confounded the sexing of SY birds, as some males, presumably of late broods, resembled females. Separation of sexes by brood patch or cloacal protuberance made aging more reliable. Males tested more reliably for age (100%) than females (83%) and pooled sex (82%). In a separate analysis aging by discriminant functions (86%) was more reliable than aging in hand (72%) or by summary statistics (82%, 76%). Fifteen TY^+ birds had retained coverts, resembling SY birds.

INTRODUCTION

In a previous paper, Aging and Sexing Gray Catbirds by External Characteristics (Suthers and Suthers 1990), summary descriptions of the ages by year were given. Discriminant functions were presented for aging, derived from 200 of 1248 captures between 1972 & 1986, that aged a test group of 54 catbirds as second year (SY) or after second year (ASY) with 88.5% reliability. Discriminant functions were presented for sexing, derived from 242 known sex but pooled age catbirds (mostly second year) that sexed a test group of 144 birds with 74% reliability of 76 males and 82% reliability of 68 females.

Two questions remained that required more years of field data. First, outside the breeding season, can determinate age birds be sexed more accurately? That is, can SY birds, third year, fourth year, etc. (TY^+) birds be sexed more accurately with discriminate functions derived from the determinate age groups respectively, instead of derived from determinate and indeterminate (after hatch year [AHY]) groups pooled? The answer would require the accumulation of a large sample size of HY and SY birds that subsequently returned one or more times in the years following, and that showed a brood patch or cloacal protuberance at one of their captures. Otherwise, new determinate SY birds could be told with certainty if they showed molt limits together with soft-part colors of a young bird. Birds with no molt limits would be called the indeterminate AHY. Third year and older determinate age birds would be told with certainty from AHY only by returning in subsequent years after being banded as HY or SY. The second question was: In the breeding season, can known-sex birds be aged more accurately?

The ability to age and sex catbirds during the different seasons of the annual cycle would greatly enhance their conservation by elucidating studies of differential migration timing, routes, and stopover ecology; breeding biology and habitat use by young vs. older birds, males vs. females; and overwintering patterns and sites of the different age and sex groups. In a companion paper (Fritze and Suthers, in preparation) differential return rates of age and sex classes, age-specific survivorship and site fidelity will be discussed.

METHODS

Data Collection - Field work was done at the Featherbed Lane Banding Station in the Sourland Mountain (134 m elevation) Piedmont physiographic province in Hopewell Township, Mercer Co., west-central New Jersey. Fixed net lanes with 76 net spans in groups of end to end arrays traversed approximately 43 ha of late successional old fields. Twenty to 35 nets (12 m, 30-mm mesh) were hung at one time at daybreak for five hours one day a week during late spring migration (third weekend in May) through the breeding season and fall migration (end of November). Nets were checked every 30 min and captured birds placed in ventilated, individual compartments in holding boxes, or individual holding bags prior to processing. Time and net site were noted. Birds were banded with U.S. Geological Service serially numbered bands. In addition to standard data, molt patterns for aging and stages of development of the brood patch or cloacal protuberance for sexing were scored. Wing, tail, flight feather ratios, and culmen were measured, and pairs of light tail tips and softpart colors were scored, resulting in 16 variables to be used in discriminate function analyses. Descriptions and instructions for these variables are in Appendix 1. During the breeding season, processed birds were taken back to their net site for release.

Data Analysis - There were 1820 encounters between 1988 & 2003, 288 of which were returns from previous seasons. For discriminant function analysis, birds with missing data and repeat captures in the same season were eliminated, and 32 pre-1988 returns were included, resulting in 535 determinate age and known sex birds to comprise a robust bird to variable ratio (Tabachnick and Fidell 1983). Data from individual multiple returning birds were not split across the formula-deriving dataset and the test dataset, i.e.all returns of a bird were in either one or the other dataset. The same variables were used for both age and sex analyses because the variables were used in different combinations with different discrimination weights.

Analysis of 1317 encounters between 1988 & 2001 using SAS:DISCRIM (SAS Institute Inc.; because SAS was more familiar to the student consultant) reduced the variables to 13 (Fritze 2002). In the current study, these 13 scores and measurements of the 535 known age and sex birds were entered into the SPSS v.11 (SPSS Inc.) for discriminant function analysis (DFA). SPSS was chosen so that results could be compared with those of Suthers and Suthers (1990), derived from SPSS v. 9.1. Pearson's correlations were computed between all variables and age or sex respectively to determine which variables showed promise of predicting age or sex (at $\alpha \leq 0.05$), and should be used in subsequent analyses. To derive a more concise descrimination function, the stepwise method of selecting variables was used. Variables were entered sequentially using Wilks' lambda as the measure of discriminatory power to determine which variable to enter next ($F \geq 3.84$ for a variable to be entered, $F \leq 2.71$ for a variable to be removed). Canonical discriminant analysis created a linear discriminant function, an equation that separated the different age groups or sex groups

Comparison of four aging methods - In an attempt to find an easier way to age catbirds, a sample of 50 determinate age and known sex returns captured in 2000-2002 was selected with 25 SY and 25 TY$^+$ birds, 12 males and 13 females each, and four methods of aging were compared

1) *In hand,* by descriptions of age groups using CORTIP, IRIS, MOUTH, TONGUE, and MOLT LIMIT (see Appendix) as described in Suthers and Suthers (1990) and Pyle (1997). They were aged in the field before the data were looked up.

2) *Discriminant function formulas,* derived by Fritze (2002). The age of the bird was that of a pair of equations giving the higher score.

3) *Mean ± Standard Error of the mean* (SE) (Fowler and Cohen 1995) used to make a rough estimate by rule of thumb of non-overlapping values. Age characteristics determined to be useful by discriminant function analysis were summed up for each bird and compared with the sum of mean values of these characterisitcs of the 50 birds ± the sum of the SEs. The highest a bird could score and still be a SY was the sum of mean values + the sum of SEs. The lowest a bird could score and still be a TY$^+$ was the sum of mean values - the sum of SEs Birds inbetween these scores defaulted to AHY

4) *Mean ± Confidence Intervals* (CI) at the 99% level or 95% level were calculated similarly.

RESULTS: *Sex of Determinate Age Birds*

Sexing a sample of pooled determinate ages with DFA–All 535 determinantly aged and sexed birds were used, 480 birds (239 females and 241 males) to derive (estimate) the discriminant function equation and cut-off value; the remaining 55 birds (25 females and 30 males) were chosen randomly to test the equation. The analysis derived an equation with a constant that is subtracted and six discriminate functions. The equation was significantly better than a null model equation (Wilk's lambda = 0.70, $p < 0.01$) and explained 31% of the variation in sex (Squared Canonical Correlation $R_c^2 = 0.31$). The equation correctly sexed 77% of birds used to derive the functions and reliably sexed 89% of the 55 birds randomly chosen to test the equation (92% of the 25 females, 87% of the 30 males) highly significantly different from chance ($X^2 = 23.1$, $p < 0.01$).

Pooled Sex Score = (0.049 x CRIS) + (0.404 x CULMEN) + (0.835 x MOUTH) + (0.421 x TONGUE) + (0.163 x WING) - (0.088 x WINGDIF) - 24.968. The cutoff value is -0.12. Birds below this value are female, and birds above this value are male.

To use these functions, the measurements and scores (Appendix) of the characteristics of the individual bird being aged or sexed are plugged into the respective equation. The age or sex of the bird depends on the cutoff point given with each equation. At the cutoff value the chance is 50% that the bird is one classification or the other, so that the farther away the score is from the cutoff value, the more reliable the classification is.

The SY Sex DFA used 287 SY birds (166 females and 121 males) and derived an equation that correctly sexed 78% of the equation-generating birds (Wilk's lambda = 0.74, $p < 0.01$, Squared Canonical Correlation $R_c^2 = 0.26$). The 37 SY birds (21 females and 16 males) randomly chosen to test the equation, were sexed with 81% reliability, highly significantly different from chance ($X^2 = 14.7$, $p < 0.01$), but similar to the pooled age birds.

SY Sex Score = (0.047 x CHRIS) + (0.507 x CULMEN) + (0.948 x MOUTH) + (0.460 x TONGUE) + (0.134 x WING) - 27.673. The cutoff value is 0.01. Birds below this value are female, and birds above this value are male.

The TY⁺ Sex DFA used 193 TY⁺ birds (73 females and 120 males) and derived an equation that correctly sexed 80% of the equation-generating birds (Wilk's lambda = 0.64, $p < 0.01$, Squared Canonical Correlation $R_c^2 = 0.36$). The 18 TY⁺ birds (4 females and 14 males) randomly chosen to test the equation were sexed with 94% reliability ($X^2 = 14.2$, $p < 0.01$, highly significant, but the X^2 has to be taken with caution because of the low female sample size).

TY⁺ Sex Score = (0.062 x CHRIS) + (0.818 x MOUTH) + (0.086 x TAIL) + (0.449 x TONGUE) + (0.175 x WING) - 31.951. The cutoff value is 0.03. Birds below this value are female, and birds above this value are male.

RESULTS: *Age*

Aging a pooled sample of males and females with DFA – All 535 determinantly aged and sexed birds were used for deriving or testing the equation. The equation was derived from 480 birds (287 SY and 193 TY⁺) and correctly classified 92% of the birds used to derive the functions (Wilk's lambda (0.37, $p < 0.01$, Squared Canonical Correlation $R_c^2 = 0.64$). The equation reliably classified 82% of the 55 randomly chosen test birds, 37 SY and 18 TY⁺, highly significantly different from chance ($X^2 = 24$, $p < 0.01$). These results are statistically similar to previous results, 88.5% in Suthers and Suthers (1990), and 83% in Fritze (2002) ($X^2 = 2.66$, $p = 0.2651$).

Pooled Age Score = (0.024 x CRIS) - (0.104 x CORTIP) + (0.136 x IRIS) - (0.11 x NINETEN) + (0.052 x TAIL) + (0.39 TONGUE) + (0.097 x WING) + (0.15 x WINGDIF) + (0.087 x WINGTIP) - 18.545. The cutoff value is - 0.22. A lower score designates SY, a higher score TY⁺.

Aging known sexes with DFA – Can birds of known sex be aged more accurately? The equation for females was derived from 172 SY and 68 TY⁺ females, and 88% of the birds used to derive the functions were aged correctly (Wilk's lambda = 0.49, p <0.01, R_c^2= 0.50). The test birds, 15 SY and 9 TY+ females, were aged with 83% reliability (X^2 =12, p <0.01), highly significant, but not different from that of the pooled sex DFA for age.

Age score for females = (0.046 x CHRIS) - (0.105 x CORTIP) + (0.303 x MOUTH) + (0.522 x TONGUE) + (0.205 x WINGDIF) - 10.26. The cutoff value is - 0.08. Birds below this value are classified as SY, birds above as TY+.

The equation for males was derived from 123 SY and 110 TY+ males, and 91% of the birds used to derive the functions were aged correctly (Wilk's lambda = 0.31, p <0.01, R_c^2 = 0.69). The test birds, 14 SY and 24 TY+ males, were aged with 100% reliability.

Age score for males = - (0.105 x CORTIP) - (0.155 x NINETEN) + (0.083 x TAIL) + (0.369 x TONGUE) + (0.13 x WING) + (0.157 x WINGDIF) + (0.147 WINGTIP) - 23.67. The cutoff value is 0.05. Birds below this value are SY, birds above are TY+.

The four comparative methods of aging a sample of 25 SY and 25 TY+ birds were statistically indistinguishable (X^2 = 3.96, df 4, p = 0.411). However, the *discriminant function analysis* was the most reliable determinant of age with 86% reliability, 0 defaults to AHY, 7 errors. Methods using the *mean, standard error of the mean, and confidence intervals* (Table 1), were more laborious than the discriminant function equation and were not as reliable (82%, 76%, 74%). These methods had 10-14% defaults to AHY, 2-7 errors. *Aging in hand* by descriptions was the least reliable, with 72% reliabililty, 12% in default, and 16% in error. Six female TY+ birds were in error in all the methods because of retained greater secondary coverts. A SY male with replaced greater secondary coverts was called ASY. Other errors in hand were caused by high CORTIP count and low TONGUE score in TY+ individuals. Hand-aged birds must, therefore, match all criteria (Table 1) to be aged more reliably, otherwise the birds need to be called AHY.

DISCUSSION

Sex DFA – The pooled analysis, with more TY+ available, was an improvement over Suthers and Suthers (1990). The TY+ males were sexed more reliably than SY males, possibly because of influences of brood age still making a difference in the second year. The soft part colors of late brood males would not be as dark as the colors of the earlier brood males, resulting in classification as females.

Aging by various methods – DFA was the most reliable method of aging catbirds. In the comparison of four methods, 70% of the errors were in the females. They have lower tongue color scores than males and more incidents of retained feathers. Six out of the seven incidences of TY+ birds aged erroneously, with retained greater secondary coverts, were female. It is as though late-brooding females bringing off fledglings in August or September did not have physiological time to molt completely before migration and, therefore, returned the next spring with retained

Table 1. Mean values for the age characteristics of the Gray Catbird with standard errors and 99% confidence intervals for possible use in the field.

		Cortip	Iris	Nineten	Tail	Tongue	Wing	Wingdiff	Wingtip	Sum
SY	N=434	4.32	5.58	25.50	91.40	2.57	87.19	36.79	13.38	266.73
	±SE	0.10	0.05	0.12	0.20	0.03	0.15	0.14	0.10	0.89
	±CI	0.26	0.13	0.31	0.52	0.08	0.39	0.36	0.26	2.31
In thefield use		≤ 4	≤ 6	≤ 26	≤ 92	≤ 3	≤ 87	≤ 37	≤ 13	≤ 268
ASY	N=192	3.31	6.25	26.36	95.20	3.02	90.44	39.85	14.88	279.31
	±SE	0.10	0.05	0.15	0.32	0.05	0.18	0.17	0.16	1.18
	±CI	0.26	0.13	0.39	0.82	0.13	0.46	0.44	0.41	3.04
In thefield use		≥ 3	≥ 6	≥ 26	≥ 95	≥ 3	≥ 90	≥ 40	≥ 15	≥ 278

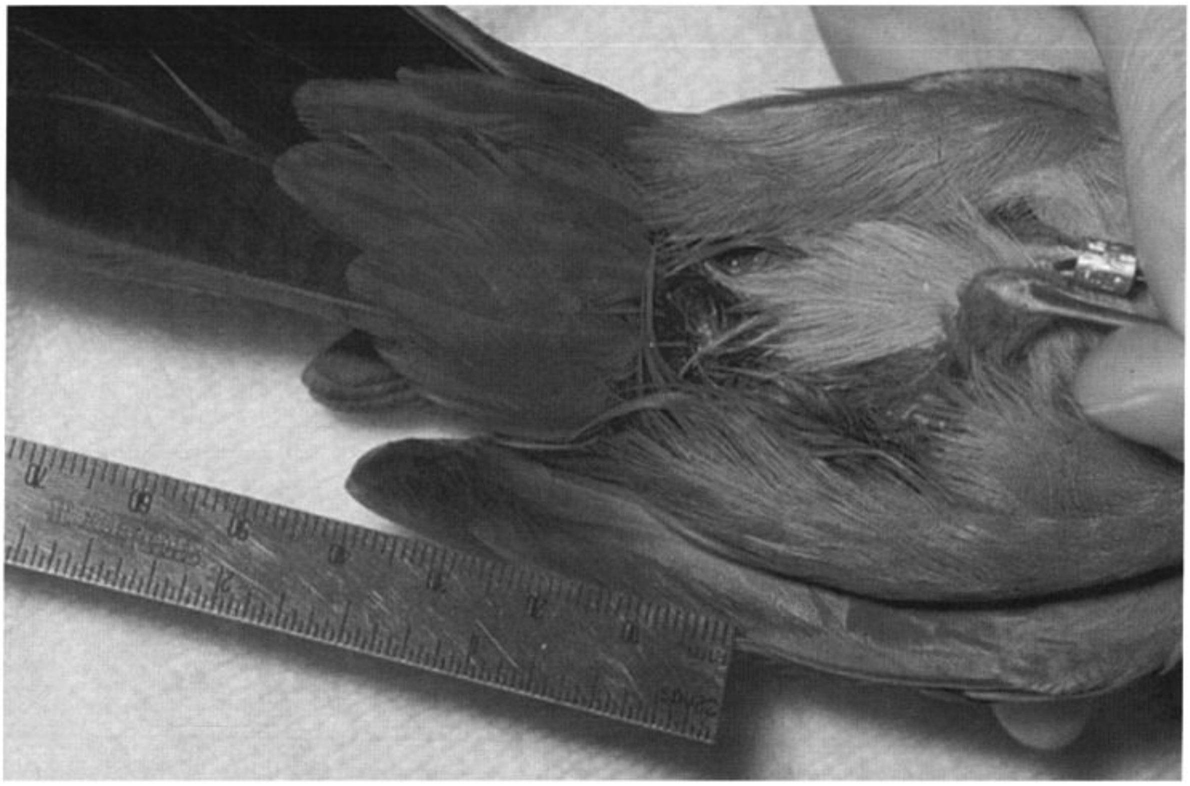

Fig. 1. NINETEN and WINGDIFF. Nineten is the distance between the tips of primary #10 and primary #9, measured on the underside, wing partially unfolded. This Nineten reads 29 mm (mm scale on the right edge of the ruler). Wingdiff is the distance between the tips of primary #10 and the longest primary (#6), measured on the underside, wing partially unfolded. This Wingdiff reads 41 mm.

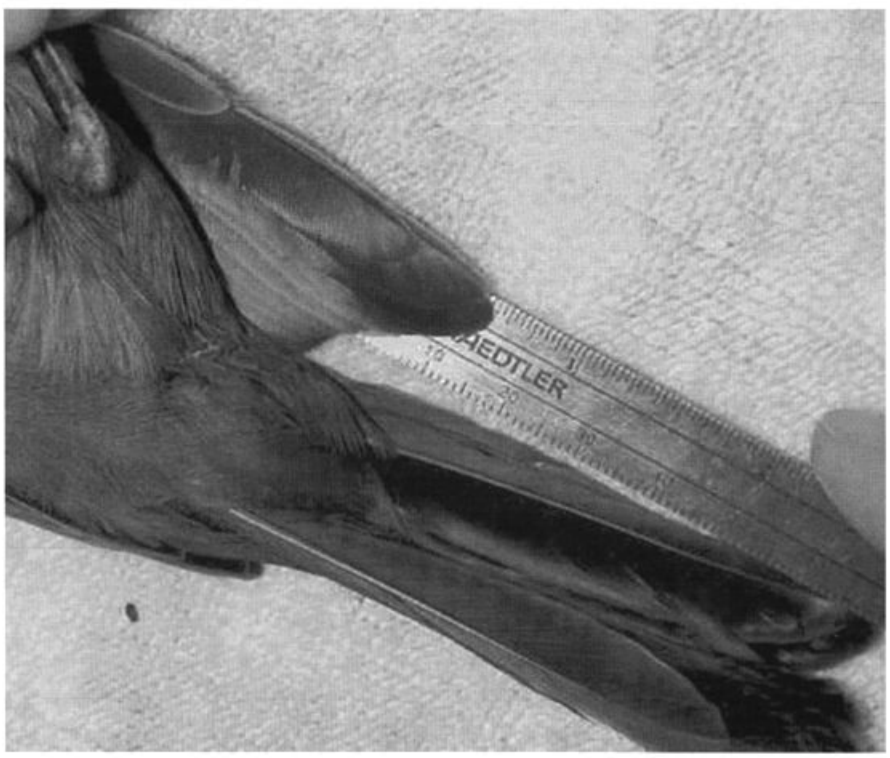

Fig. 2. WINGTIP is the difference between the longest primary and the longest secondary, with the wing slightly unfolded, looking from the underside. This Wingtip reads 14 mm (mm scale on the left edge of the ruler).

feathers. Another possible explanation is that the feather quality of old birds may not be as strong as that of young adults and will fade and wear more. Retained coverts have also been seen by the authors in other multibrooded birds, e.g. the Common Yellowthroat (*Geothlypis trichas*); therefore, caution is recommended in using molt limits for aging multi-brooded females. See also Mulvihill (1993) on molt limits.

Items for further study – To date there are 25 HY returns of known sex, 19 of which are males, not enough to run an analysis on sexing HYs of the same brood age in the fall. Some fledglings have dark edges on the yellow or pink tongue. Does this mean something?

ACKNOWLEDGMENTS

Our gratitude to patient helpers who understood the importance of years of detailed field data collection to accumulate adequate sample sizes: Lou Beck Sr., Jean M. Bickal, Emmerson Bowes, Susan Callegari, Tom Greg, Alan Goldberg, Elizabeth A. Graham, Janet L. Huie, Eileen Katz, Laurie Larson, Dan Longhi, Sharyn Magee, Michael Miles, Arlene Oley, Connie Sprague and Paul Wedeking. Many thanks to Rahul M. Dodhia, Statistical Consultant, who ran the most recent statistical tests. We gratefully acknowledge grants from the Washington Crossing Chapter of National Audubon Society for mist nets and statistical analysis. Our gratitude to landowners of what has come to be known as Sommer Park: The Delaware and Raritan Greenway, State of New Jersey, and Mercer County, NJ. Suggestions from D. W. Winkler for improving the manuscript are acknowledged gratefully.

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APPENDIX: DESCRIPTION OF VARIABLES

AGE: Birds with juvenal characteristics though fall migration were aged hatching year (HY). Spring birds with retained, faded juvenal primaries and coverts and/or with retained juvenal greater secondary coverts that were brown edged and shorter in contrast to the new coverts were aged second year (SY).Gray plumaged spring birds with iris and mouth scores of 5 or less were aged SY. Adult-looking birds with dark or blackberry irides, black mouth, and gray plumage were aged after hatching year (AHY). Returns were aged according to age at banding. In the DFA analyses, the TY$^+$ category consisted of all returned birds known to be at least in their third year, by being originally aged "determinately" as HY or SY.

CORTIP: the number of pairs of tail feathers with pale gray corners or tips.

CRISHORT: the length of the chestnut coloring along an edge of a center feather of the crissum (under tail coverts) as measured along the shorter chestnut edge, from the proximal inception of the chestnut coloring to the tip of the feather.

CULMEN: the length of the exposed culmen.

IRIS: iris color, scored from 1 to 7 as it progressed from fledgling's gray through brown to reddish black in steps of Munsell neighbors of (1) gray (10YR 5/1, 4/1), (2) brownish gray (7.5YR 5/2, 4/2), (3) grayish brown (5YR 5/4, 4/4), (4) reddish brown (2,5YR 4/4, 3/4), (5) reddish brown with lighter ring (10R 3/2 with 10R 5/4), (6) dark brown (7.5R 3/2), (7) reddish black (5R 1/1). This is an elaboration of Wood's (1973) method of separating AHY from HY by iris color, using the Munsell (1969) color ratings. We used the preferred system of letter-number notations (ASTM 1969), and we renumbered the 2.5-unit hue steps with a more manageable scale from 1 to 7, where 1 unit = 2.5 Munsell units.

MOUTH: mouth color, scored 1 to 7 as it progressed from fledgling's yellow through pink and gray to black in steps of Munsell neighbors of (1) yellow (10YR 8/8), (2) mostly yellow with some pink (7.5YR 9/2, 8/4) and/or gray (5YR 5/1), (3) mostly pink (5YR 9/2, 8/4), with some yellow, often at the folds of the mouth, and/or gray, (4) pink (2.5YR 8/4, 7/4), (5) mostly gray (10R 5/1) with pink (10R 8/4, 7/4), and/or black, (6) mostly black with some gray (7.5R 5/1) and/or pink (7.5R 8/4, 7/4), (7) black. We renumbered the 2.5-unit hue steps with a more manageable scale from 1 to 7, where 1 unit = 2.5 Munsell units.

NINETEN: the distance between the tips of primary #10 and primary # 9, measured on the underside of the slightly unfolded wing (Fig. 1).

PLUMAGE: scored from 1 to 5 as it progressed from (1) juvenal, (2) hatching year molting, (3) HY with retained greater secondary coverts, (4) HY or SY with retained primaries and primary coverts to (5) all new feathers; and the additional category (6) for AHY in molt.

SEX: by brood patch or cloacal protuberance (Bird Banding Manual II) scored 0 to 4 for none, small, medium, maximum, or receding, respectively (DeSante et al. 2002).

TAIL: tail length, taken by inserting a ruler vertically between the center pair of tail feathers until it touches the base of these feathers.

TAILDIFF: the difference in length between the longest, innermost tail feather #1 and the shortest, outermost #6.

TONGUE: tongue color, scored 0 to 4 as it progressed from fledgling's yellow through pink and gray to black in steps of Munsell neighbors of (0) yellow (10YR 8/8, 9/2), (1) pink (5YR 8/4, 7/6) with faded yellow remaining at the tip, (2) pink (10R 7/4) or a mix of pink, gray (10R 6/1) and/or black, (3) gray (5R 5/1) and black, or dark gray (5R 3/1), (4) black. We renumbered the 5-unit hue steps to a more manageable scale of 0 to 4, where 1 unit = 5 Munsell units.

WING: wing chord, with the wing folded naturally, unflattened.

WINGDIFF: the length, from the underside, between the tip of the shortest, outermost primary #10, and the tip of the longest primary #6, measured on the underside of the slightly unfolded wing (Fig.1).

WINGTIP: the difference between the longest primary and the longest secondary, with the wing slightly unfolded (Fig. 2).