wood-warblers (Parulinae) following spring migration over the Gulf of Mexico. Oecologia 74:47–54.

PASZKOWSKI, C. A. 1984. Macrohabitat use, microhabitat use, and foraging behavior of the Hermit Thrush and Veery in a northern Wisconsin forest. Wilson Bull. 96:286–292.

PIENKOWSKI, M. W. 1983. Surface activity of some intertidal invertebrates in relation to temperature and the foraging behaviour of their shorebird predators. Mar. Ecol. Prog. Ser. 11:141–150.

RAND, A. L. 1956. Foot-stirring as a feeding habit of Wood Ibis and other birds. Amer. Midl. Nat. 55:96–100.

SIMMONS, K. E. L. 1961. Further observations on foot-movements in plovers and other birds. Brit. Birds 54:418–422.

SMITH, J. N. M. 1974. The food searching behaviour of two European thrushes. II. The adaptiveness of search patterns. Behaviour 49:1–61.

WILLIS, E. O. 1966. The role of migrant birds at swarms of army ants. Living Bird 5:187–231.

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A nonparametric aid in identifying sex of cryptically dimorphic birds. — Discriminant function analyses (DFA) have been used to sex birds from external morphometric characters (e.g., Shugart 1977, Ryder 1978, Rising and Shields 1980, Wooller and Dunlop 1981, Hanners and Patton 1985, Blohm 1987, Edwards and Kochert 1987). In some species, subtle nonmetric plumage characters may aid in sexing hand-held birds, but their inclusion in discriminant function models statistically is inappropriate. Here we present an alternative method (multiple logistic regression, MLR) for sexing birds based upon suites of morphometric and categorical plumage characteristics. We apply the method to a sample of White-throated Sparrows (*Zonotrichia albicollis*), a species difficult to sex based upon external characters outside the breeding season. MLR relates a dichotomous dependent variable (sex in this case) to several explanatory variables (i.e., morphological characters) (Harrell 1986). MLR has the advantage over other classification algorithms, such as discriminant function analysis (DFA), since its use is appropriate when assumptions of multivariate normality are violated (Press and Wilson 1978). Thus, it is possible to include categorical and dummy variables as explanatory variables. A step-wise procedure can be employed whereby a morphological variable is included in the regression model if its significance is less than a critical value (e.g., 0.05) and is removed if its significance falls above a critical value (e.g., 0.10) in order to identify those morphological characters most important in differentiating the sexes. The probability (P) of a specimen's belonging to a group (in this case the probability of a bird's being male, $Y = 1$) is then $P(Y = 1) = 1/(1 + \exp(-L_x))$ where L_x is the logistic function. The fraction of concordant pairs of observations (c) indicates the predictive ability of the model and is a better indicator than the percentage of correctly classified cases (Harrell 1986). This concordance is calculated by pairing all observations with different values of the dependent variable (Y) and then counting the number of cases where the individual with the larger Y has a higher estimated P than the individual with the smaller Y. Ties are counted

as one-half rather than given a full rank of one (Harrell 1986). Since DFA and MLR give similar results when samples are normally distributed and covariance matrices are equal (Neff and Marcus 1980), the predictive ability of DFA and MLR can be compared indirectly by examining the fraction of concordance of MLR models containing only wing length and those containing wing length and categorical variables.

In order to examine the utility of MLR in sexing the cryptically dimorphic White-throated Sparrow, we measured wing-chord length and five plumage characters of 462 museum specimens (302 males and 160 females) and 40 live specimens (25 males and 15 females). The White-throated Sparrow demonstrates a range of plumage characteristics in both males and females (Lowther 1961, Thorneycroft 1975), and there apparently is a relationship between sex, size, and morph (Rising and Shields 1980). During the non-breeding season, when cloacal protuberance and brood patch are not available as indicators of sex, determining sex of hand-held birds generally is by wing chord length (Atkinson and Ralph 1980, North American Bird Banding Manual 1984, Watt 1986). Males and females demonstrate considerable overlap in size, however, and there is disagreement as to the extent of this overlap (Atkinson and Ralph 1980, North American Bird Banding Manual 1984). Due to evidence for clinal variation in morphology (Lowther 1961), we restricted our measurements to birds collected in the eastern United States and Canada, from South Carolina north to Newfoundland and west to West Virginia. Only birds of known sex with a right wing chord free of feather damage or tip wear were included in the sample, and wing chord length was measured to the nearest mm. Museum specimens were assumed to be sexed correctly. Birds in juvenal plumage (here designated as juveniles) were excluded from the analysis. Live birds were measured at the time of capture and sexed later by laporotomy.

Plumage scores were adapted from Lowther (1961), Vardy (1971), Atkinson and Ralph (1980), and Watt (1986). Birds were considered white-striped (WS) or tan-striped (TS) based on the color of the median crown-stripe. Lateral stripes were scored as all black (B), mixed black and brown (BBr), or all brown (Br). A single crown-stripe value was then assigned to each bird based on the increased presence of brown feathering on both median and lateral stripes (i.e., WS/B = 1, WS/BBr = 2, WS/Br = 3, TS/B = 4, TS/BBr = 5, and TS/Br = 6). Superciliary stripe color was assigned values of: (1) no apparent yellow, (2) small dull yellow stripe, (3) large dull yellow stripe, or (4) large bright yellow stripe. Throat lines (malar marks) were assigned values of 1 to 5 as illustrated by Lowther (1961). An index of throat patch brightness was modified to reflect the contrast of throat color with chest color and extent of streaking of the chest: (1) a dull gray streaked throat with no contrast with the streaked breast, (2) a dull gray non-streaked throat with slight but apparent contrast with the streaked breast, (3) a fully white throat and complete contrast with a light gray breast without a marginal border of black feathering, and (4) a fully white throat separated from a fully dark gray breast by a discrete bordering of black feathers. These five categorical characters were chosen since they are easily and rapidly scored under field conditions (see Watt 1986). All measurements were performed by BAS in order to eliminate variance associated with multiple participants (Nisbet et al. 1970). For the logistic regression procedure, we chose entry and retention criteria of $P < 0.05$ and $P < 0.10$, respectively.

Mean wing chord length (± 1 SD) of males (N = 327) was 73.3 mm $\pm$ 2.1 and of females (N = 175) was 69.8 mm $\pm$ 2.4 and differed statistically between sexes ($t = 16.95$, $P < 0.0001$). Few males (<5%) had wing chord lengths of less than 70 mm, while few females (<8%) had wing chord lengths >73 mm (Table 1). In this sample, >80% of birds at each wing chord length <71 mm or >73 mm were females and males, respectively. The greatest area of overlap occurred at 71 and 72 mm, where roughly half of all birds were of either sex.

Two variables (wing length and throat lines) entered and were retained in the following

TABLE 1
PERCENTAGES OF MALE AND FEMALE WHITE-THROATED SPARROWS AT EACH MEASURED
WING-CHORD LENGTH AND THE PERCENTAGE OF MALES IN THE SAMPLE[a]

Wing length (mm)	Females (%)	Males (%)	All birds (% male)
62	0.57	0.00	0.0
66	2.29	0.00	0.0
67	13.70	0.92	6.3
68	13.70	2.80	16.7
69	20.60	1.83	8.2
70	17.70	3.67	17.2
71	8.60	8.56	50.0
72	7.40	10.10	57.7
73	7.40	22.00	74.8
74	3.40	18.70	84.5
75	2.30	20.50	90.0
76	1.10	7.30	86.6
77	1.10	3.40	74.7
78	0.00	0.31	100.0

[a] N = 502.

stepwise logistic regression model (χ^2 = 215.03, P < 0.0001): L_x = −41.10 + 0.59 wing length − 0.28 throat lines. The fraction of concordance for this model was 0.87, whereas with only wing length in the model c was 0.86. Similarly, wing length combined with crown-stripe color also resulted in a model with predictive ability (χ^2 = 213.03, P < 0.0001). Thus, L_x = −37.88 + 0.60 wing length − 0.54 crown stripe. The fraction of concordance again was 0.87 with both variables in the model.

White-throated Sparrows demonstrate seasonal and age-related differences in plumage characteristics (Atkinson and Ralph 1980) and also may experience wear on primary feathers affecting the use of these characters to identify sex. Accordingly, we divided our sample into summer and winter samples. Birds collected from May through July comprised a summer sample (N = 161), while birds collected from October through March comprised a winter sample (N = 167). This regrouping did not appreciably affect either model. The model which included wing length and throat lines had a c of 0.84 for winter birds. With only wing length considered, the model for winter birds had a c of 0.83 and for summer birds a c of 0.90. Throat lines did not enter the model for summer birds.

The North American Bird Banding Manual (1984) recommends that White-throated Sparrows with wing lengths ≤67 mm be classified as females and that those birds with wing lengths ≥74 mm be classified as males. Atkinson and Ralph (1980) found that all birds with wing-chord lengths >72 mm were males and those with wing lengths <68 mm were females. In our study, one-half of all birds with wing-chord lengths of 71 or 72 mm were either male or female. When MLR was applied to this sample, throat lines alone entered the model (χ^2 = 5.22, P < 0.05), but this model had a modest fraction of concordance (c = 0.66).

In this study, we combined a continuous metric variable (wing chord length) with several categorical plumage variables in an effort to predict sex of White-throated Sparrows. The
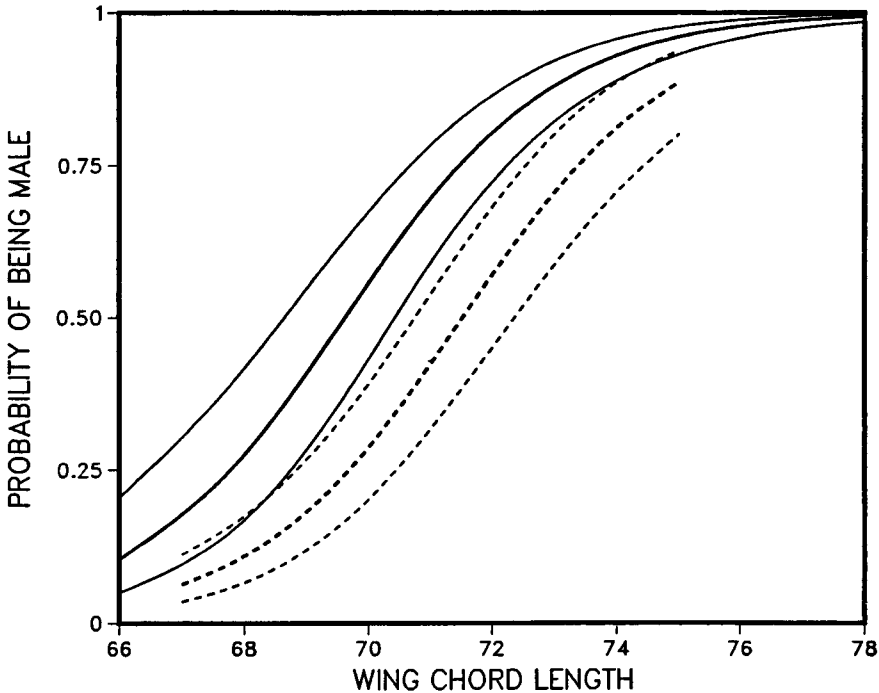
THROAT LINES

FIG. 1.   Probability curves derived from a multiple logistic regression model of wing length and throat lines. The solid lines represent throat line values of one and the dashed lines represent throat line values of five. Both probability curves (thick lines) are bounded by 95% confidence limits (thinner lines). We included values for each curve only within the range of wing lengths observed in this study. The form of the probability curves of wing chord length and crown-stripe color are similar and are not illustrated.

logistic regression model supported the supposition that males were larger than females. Two related characters (crown-stripe color and throat lines) contributed to the predictive strength of the resulting models, thereby increasing the number of individuals in the sample which could be sexed accurately. However, the improvement in classification over wing length alone was slight. Nevertheless, the increased presence of brown feathering on median and lateral crown stripes or increased number and darkening of throat lines moved the probability curve to the right (Fig. 1), thereby decreasing the region of overlap between sexes. Similarly, the shift in the probability curve to the left by the presence of a white median crown stripe together with increased black feathering on lateral crown stripes or a lack of throat lines increased the probability of an individual's being a male. The improvement in classification was greatest for birds of intermediate size where wing-chord length alone was useless for determining sex. While we included only one continuous variable in

our analysis, the use of other continuous variables (e.g., tarsal length or beak dimensions) may enhance the predictive ability of logistic regression models.

Categorical plumage variables contributed a high degree of statistical significance to the MLR models. In practical terms, however, these plumage variables provided only a modest gain in the ability to sex White-throated Sparrows accurately, although it is possible that predictive ability may be improved if birds could be segregated by age or status of their molt or if additional morphological variables can be included. MLR, using a combination of metric and categorical variables, corroborated previous results for White-throated Sparrows in which only wing length was examined and further substantiated the results of Rising and Shields (1980) in that certain plumage morphs of the White-throated Sparrow may be more specific to one sex than to the other. MLR thus resulted in a slight improvement over other methods (North American Bird Banding Manual recommendation and DFA) of sexing individuals of a species as notoriously difficult to sex outside of the breeding season as the White-throated Sparrow. Although there was still overlap in size and plumage characters between the sexes, the region of uncertainty was reduced by logistic regression. We emphasize that, while MLR resulted in a statistically significant though very modest gain in predictive ability in White-throated Sparrows, application to other species may provide substantial improvement over other traditional (parametric) methods. We suggest that multiple logistic regression may be widely applicable to avian studies where combinations of metric morphological and categorical plumage characters might be useful indicators of sex or taxonomic status. Under conditions of multivariate normality, however, we still recommend the use of DFA since computationally it is more efficient (Efron 1975).

LITERATURE CITED

ATKINSON, C. T. AND C. J. RALPH. 1980. Acquistion of plumage polymorphism in White-throated Sparrows. Auk 97:245–252.

BLOHM, R. J. 1987. Reliability of morphological measurements in sexing newly hatched wild Gadwall ducklings. J. Field Ornithol. 58:144–147.

EDWARDS, T. C., JR. AND M. N. KOCHERT. 1987. Use of body weight and length of footpad as predictors of sex in Golden Eagles. J. Field Ornithol. 58:317–319.

EFRON, B. 1975. The efficiency of logistic regression compared to normal discriminant analysis. J. Am. Stat. Assoc. 70:892–898.

HANNERS, L. A. AND S. R. PATTON. 1985. Sexing Laughing Gulls using external measurements and discriminant analysis. J. Field Ornithol. 56:158–164.

HARRELL, F. E., JR. 1986. The LOGIST procedure. Pp. 269–293 *in* SUGI supplemental library user's guide, Version 5 Edition (R. P. Hastings, ed.). SAS Inst., Inc., Cary, North Carolina.

LOWTHER, J. K. 1961. Polymorphism in the White-throated Sparrow, *Zonotrichia albicollis* (Gmelin). Can. J. Zool. 39:281–292.

NEFF, N. A. AND L. F. MARCUS. 1980. A survey of multivariate methods for systematics. Privately published, New York, New York.

NISBET, I. C. T., J. BAIRD, D. V. HOWARD, AND K. S. ANDERSON. 1970. Statistical comparison of wing-lengths measured by four observers. Bird-Banding 41:307–308.

North American Bird Banding Manual. 1984. Canadian Wildlife Service Publ. Vol. 2, Ottawa, Ontario, Canada.

Press, S. J. and S. Wilson. 1978. Choosing between logistic regression and discriminant analysis. J. Am. Stat. Assoc. 73:699–705.

Rising, J. D. and G. F. Shields. 1980. Chromosomal and morphological correlates in two new world sparrows (Emberizidae). Evolution 34:654–662.

Ryder, J. P. 1978. Sexing Ring-billed Gulls externally. Bird-Banding 49:218–222.

Shugart, G. W. 1977. A method for externally sexing gulls. Bird-Banding 48:118–121.

Thorneycroft, H. B. 1975. A cytogenetic study of the White-throated Sparrow, *Zonotrichia albicollis* (Gmelin). Evolution 29:611-621.

Vardy, L. E. 1971. Color variation in the crown of the White-throated Sparrow, *Zonotrichia albicollis*. Condor 73:401–414.

Watt, D. J. 1986. Plumage brightness index for White-throated Sparrows. J. Field Ornithol. 57:105–113.

Wooller, R. D. and J. N. Dunlop. 1981. The use of a single external measurement for determining sex in a population of Silver Gulls, *Larus novaehollandiae*. Aust. Wildl. Res. 8:679.

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Brown-headed Cowbird parasitism on Golden-winged and Blue-winged warblers.—The Golden-winged Warbler (*Vermivora chrysoptera*) has been expanding its range northward for about the last 150 years (Gill 1980). It simultaneously has declined and even disappeared in much of its southern range. This pattern has been well documented in, for example, Massachusetts and Connecticut (Gill 1980), southern Michigan (Will 1986), and central New York (Frech and Confer 1987). The decline in southern portions of its range is correlated temporally and spatially with the expansion of a closely related congener, the Blue-winged Warbler (*V. pinus*). Hypotheses that attempt to explain the decline of the Golden-winged Warbler in the south with expansion in the north include the following: (1) Suitable habitat. The Golden-winged Warbler, at least in central New York, nests in successional fields about 20 years old. Reforestation of abandoned farmland occurred about 100–150 years ago in the southern and eastern portions of the recent Golden-winged Warbler range, such as Connecticut and Massachusetts. In the more northern portions of the Golden-winged Warbler range, farmland abandonment occurred more recently and still is occurring. Therefore, large amounts of suitable habitat are still available in the northern expanding portions of the Golden-winged Warbler range. (2) Competition with the Blue-winged Warbler. Expansion of the Blue-winged Warbler into Golden-winged Warbler range is well documented (e.g., Gill 1980, Confer and Knapp 1981, Will 1986). Will (1986) observed that the Blue-winged Warbler dominated the Golden-winged Warbler in central Michigan. However, our observations in Central New York suggested that Golden-winged Warblers dominated Blue-winged Warblers. (3) Expansion of the Brown-headed Cowbird (*Molothrus ater*) into the Golden-winged Warbler range. No sample of significant size has been examined for an effect