J. Field Ornithol., 55(3):336–342

A DESCRIPTION AND EVALUATION OF TWO TECHNIQUES FOR SEXING WINTERING SANDERLINGS

By J. L. Maron and J. P. Myers

Few wintering shorebirds have external characteristics that readily permit sexual identification even with bird in hand (Prater et al. 1977, Harrington and Taylor 1982, Skeel 1982). In this paper we compare two techniques, laparotomy and discriminant function analysis, for sexing adult wintering Sanderlings (*Calidris alba*). Laparotomy is a surgical procedure in which a small hole is made in a live bird's body cavity, enabling direct inspection of the gonads (Risser 1977). Discriminant function analysis is a statistical procedure in which several morphological variables are combined, in this case, to predict the likely sex of a measured individual (Cooley 1971, Reese and Kadlec 1982, Skeel 1982).

MATERIALS AND METHODS

Adult Sanderlings at Bodega Bay, California, were captured through the winter of 1982–1983 using mist nets placed around roosts on beaches at night (for a description of the study site see Connors et al. 1981). Birds were aged (sensu Prater et al. 1977), measured, and weighed the night of capture and kept overnight before release. Laparotomies were performed the morning after capture.

Laparotomies.—Laparotomies were performed in the standard way (Risser 1971) using an otoscope to help view the gonads. Laparotomies took 2 min or less and there was no need to sew the incision shut. Birds that were laparotomized were marked with unique combinations of plastic leg-bands and released within 30 min after surgery.

The survival of laparotomized birds in the wild was monitored by searching for these individuals one week and then 3 weeks after release. Laparotomized birds were resighted as part of a study examining Sanderling site fidelity at Bodega Bay (Myers 1980, in press).

Discriminant function analysis.—Laparotomized adult Sanderlings were measured for maximum wing chord, tarsus, and bill length (the latter measured from the tip of the bill to the proximal end of the nares). These variables were then used in a discriminant function analysis to determine the potential effectiveness of this statistical procedure for sexing Sanderlings.

Discriminant function analysis linearly weights and combines the morphometric characters to produce a multivariate function that maximizes statistical separation of the sexes. Its strength is that it pools information available from several morphometric variables rather than relying on one, as is usually the case in wader studies (Prater et al. 1977). Once discriminant functions are obtained, one can derive functions that classify cases of unknown sex. Stepwise discriminant function analysis was

TABLE 1. Mean (and standard deviation) bill, wing chord, and tarsus length for adult male and female Sanderlings (mm).

Sex	n	Bill length	Tarsus length	Wing chord
Male	42	22.4 (.88)	25.9 (.92)	123 (3.2)
Female	18	24.4 (.85)	26.8 (.82)	126 (3.6)

performed using the SPSS programs (Nie et al. 1975) at the University of California, Davis, computer center. Measurements from 15 adult females and 34 adult males were used in the analysis.

RESULTS

Laparotomies.—Of 34 Sanderlings laparotomized and color-banded, at least 97% were alive and behaving normally one week after release, and at least 90% were alive at least 3 weeks following surgery. Thus, only 10% were not seen at least 3 weeks post-surgery.

No difference was found between the survival of laparotomized birds and other adults caught at the same time but not surgically sexed, although the limited sample size for unsexed birds (n = 17) reduces the power of this comparison ($\chi^2 = .117$; df = 1; n = 52).

Discriminant function analysis.—The distributions for bill, maximum wing chord, and tarsus measurements overlap considerably for adult male and female Sanderlings (Table 1). The male : female ratios for these mean values are .93, .96, and .96, respectively. In the stepwise discriminant function analysis, bill length entered the equation first and contributed most to the discrimination. Maximum wing chord entered second and significantly improved the separation. Tarsus length did not improve the discrimination significantly after bill length and wing chord had been considered. Standardized discriminant function coefficients for bill, wing chord, and tarsus were .968, .478, and .467, respectively.

Individuals were statistically assigned to sex using classification functions,

$$C = 19.8\ B + 142.4\ W - 1101 \text{ (males)}$$

$$C = 22.3\ B + 144.7\ W - 1188 \text{ (females)}$$

where C is the classification score, B is bill length, and W wing length. In this classification procedure, 94% of 34 males and 87% of 15 females were correctly classified, or 92% of 49 overall. Using the pool of laparotomized birds, discriminant analysis assigned 91% of these individuals correctly. Figure 1 shows the distribution of males and females within this sample along the discriminant function axis.

The discriminant score, D, was calculated from the discriminant function:

$$D = 1.163\ B - .513\ W - 26.12$$

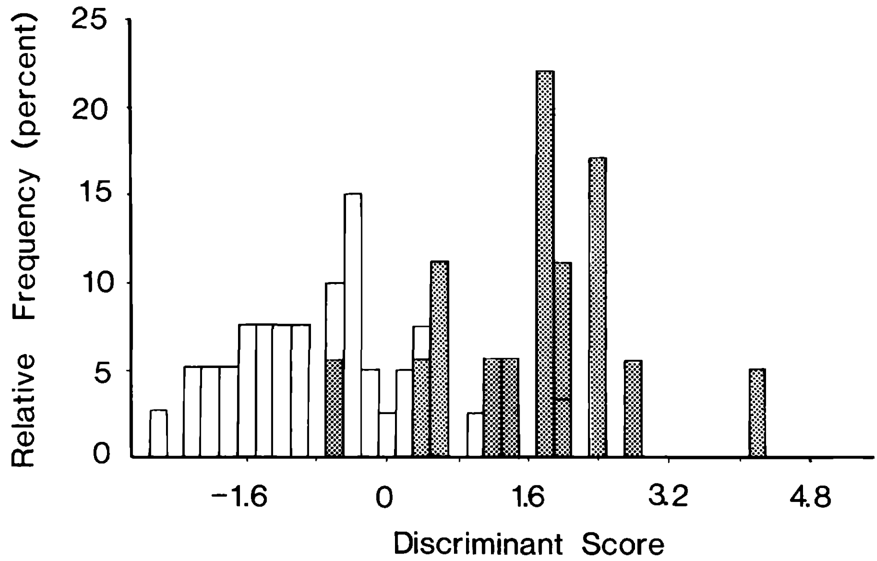

FIGURE 1. Frequency histograms of discriminant scores for males (open) and females (shaded). See text for discriminant function.

This represents the number of standard deviation units a given individual lies from the mean of all Sanderlings used in the analysis. The discriminant score allows an estimate of the probability that a particular individual of unknown sex is male or female (Fig. 2; Nie et al. 1975). Mean discriminant scores for males (n = 39) and females (n = 17) were −.733 and 1.682, respectively.

DISCUSSION

Detailed studies of wintering shorebirds reveal marked intrapopulational differences in individual behavior (Recher and Recher 1969, Myers et al. 1979, Myers 1984). Age and sex often contribute to these differences (Groves 1978, Johnson et al. 1981, Puttick 1981, Zwarts 1981, Goss-Custard et al. 1982). This makes accurate determination of sex vital. Laparotomies proved to be a quick, reliable, and safe method for sexing Sanderlings. The estimate of 97% survivorship after 1 week is conservative, since Sanderlings often move in and out of our local study area (Myers 1984).

Discriminant function analysis was also successful, certainly more so than any univariate approach, despite the common continued use of such methods. Discriminant function analysis ought to be the choice for those who must avoid surgery's potential effects on behavior.

Discriminant function analysis is not without problems, however. First, 91% correct classification does not imply that the likelihood of sexing

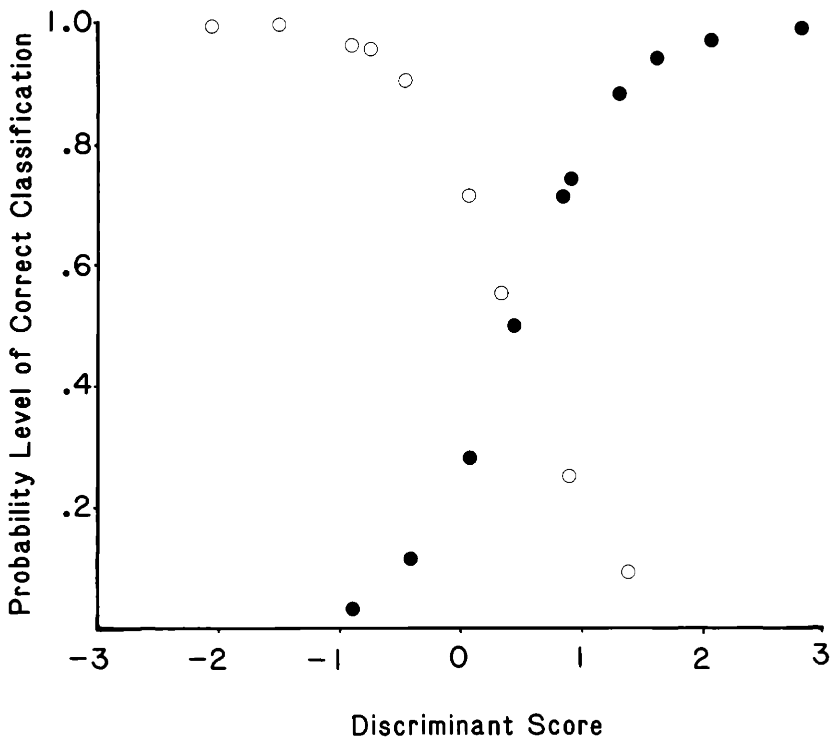

FIGURE 2. Probability of correct classification as a function of discriminant score. Open circles: probability of being male. Closed circles: probability of being female.

a particular individual is .91. This will depend upon where a bird lies along the discriminant axis (Fig. 1). The predictive power of discriminant function analysis is weakened considerably where the two distributions overlap (Fig. 2). Figure 3 illustrates the consequences of this for studies where certainty of sex is important. For example, if the study requires that the certainty of correct classification to male or to female exceeds .95, only 59% of birds classified will reach this criterion.

Second, the usual means of testing the effectiveness of a discriminant function analysis is to take the individuals of known sex used to generate the discriminant function and then ask what fraction is correctly classified in a retrospective test. Since the same individuals that are used to create the discriminant function are again used to test its accuracy, this procedure has a strong element of circularity. To examine this problem we used the discriminant function procedure to classify laparotomized birds that were not involved in generating the discriminant function. Of 11 individuals, 9 (82%) were correctly classified. Hence the utility of discriminant function analysis may be lower than suggested by typical studies, especially those with small samples.

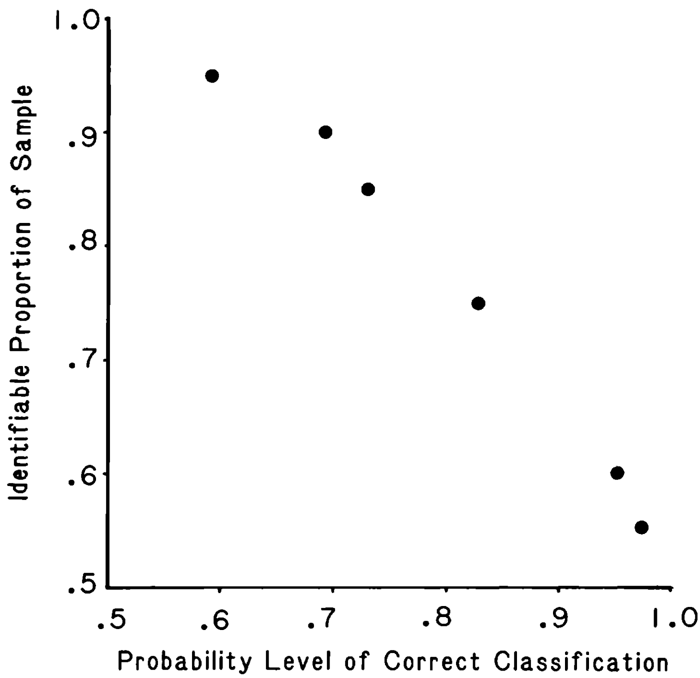

FIGURE 3. Proportion of sample exceeding a given minimum value of certainty of being one sex or the other.

A third source of error often creeps into the application of discriminant function analysis, one due not to the method itself, but rather the fact that users of discriminant function analysis sometimes take museum specimens as their reference series. These must be corrected for shrinkage when used to classify live birds. Our approach was the opposite: we used live birds to generate the classification scheme and then tested it on specimens. Using a pool of 20 adult Sanderling museum specimens of known sex (all collected in coastal northern California), discriminant analysis correctly classified 10 of 10 males and 5 of 10 females (75% overall correct). After correcting for 3% shrinkage (measured amount of bill shrinkage for Sanderling specimens, Myers, unpubl. data) we again classified these individuals using discriminant analysis. All 10 males were correctly classified as were 9 of 10 females (95% overall correct).

Finally, in widely distributed species such as the Sanderling, individuals may vary geographically in mensural characteristics (Prater et al. 1977). The applicability of discriminant functions to populations other than those from which they are derived should be assessed carefully.

In conclusion, we recommend that laparotomy and discriminant function analysis be used together to sex live birds. After a discriminant function is derived, many birds will not require laparotomy because they will exceed the necessary probability level, established by the investigator, of being male or female. For any given Sanderling this probability can be determined as we process the birds after capture: first by calculating the discriminant score based on measurements in the field with a hand-held programmable calculator, and then by examining Figure 2. Those not exceeding the required level can be laparotomized.

SUMMARY

Laparotomy and discriminant function analysis were compared as techniques for sexing wintering Sanderlings. No survivorship differences between laparotomized and non-laparotomized birds were detected after release to the wild. Discriminant function analysis proved effective for determining sex in over 90% of cases on which the DFA was based: 82% of cases in one independent sample, and 95% in a second. We recommend a combined approach: use DFA for cases falling in regions of the distribution where the probability of accurate sexing is high; use laparotomy for cases for which that probability is low.

ACKNOWLEDGMENTS

We thank V. Chow, J. B. Geller, I. K. Berzins, and L. W. Oring for comments on the manuscript. C. Hohenberger and T. Schick were of invaluable help in the field. J. Harris provided JLM valuable advice in laparotomy technique. F. A. Pitelka inspired this work and the staff at The Bodega Marine Laboratory greatly facilitated it. This work was funded by grants to the first author from Chapman Fund, NEBBA, the Graduate School and the Department of Biology at The University of North Dakota, and by grants from World Wildlife Fund-US, The Committee for Afternoon Projects, and Penn-Jersey Subaru to the second author. This paper is a contribution on the part of JLM from the Center for Ecological Education and Research.

LITERATURE CITED

Connors, P. G., J. P. Myers, and F. A. Pitelka. 1981. Interhabitat movements by Sanderlings in relation to foraging profitability and the tidal cycle. Auk 98:49–64.

Cooley, W. W. 1971. Multivariate data analysis. John Wiley and Sons, Inc., New York.

Goss-Custard, J. D., S. E. A. le V. dit Durell, and B. J. Ens. 1982. Individual differences in aggressiveness and food stealing among wintering Oystercatchers, *Haematopus ostralegus* L. Anim. Behav. 30:917–928.

Groves, S. 1978. Age-related differences in Ruddy Turnstone foraging and aggressive behavior. Auk 95:95–103.

Harrington, B. A., and A. L. Taylor. 1982. Methods for sex identification and estimation of wing area in Semipalmated Sandpipers. J. Field Ornithol. 53:174–177.

Johnson, O. W., P. M. Johnson, and P. L. Bruner. 1981. Wintering behavior and site-faithfulness of Golden Plovers on Oahu. 'Elepaio 41:123–130.

Myers, J. P. 1980. Sanderlings *Calidris alba* at Bodega Bay: Facts, inferences and shameless speculations. Wader Study Group Bull. 30:26–32.

———. 1984. Spacing behavior of nonbreeding shorebirds. Pp. 271–321, *in* Behavior of Marine Organisms, Vol. 6, Shorebirds, J. Burger and B. Olla, eds., Plenum Press, New York.

———, P. G. CONNORS, AND F. A. PITELKA. 1979. Territoriality in nonbreeding shorebirds. Stud. Avian Biol. No. 2:231–246.

NIE, N. H., C. H. HULL, J. G. JENKINS, K. STEINBRENNER, AND D. H. BENT. 1975. Statistical Package for the Social Sciences, 2nd ed. McGraw-Hill, New York.

PUTTICK, G. 1981. Sex-related differences in foraging behavior of Curlew Sandpipers. Ornis Scand. 12:13–17.

PRATER, A. J., J. H. MARCHANT, AND J. VUORINEN. 1977. Guide to the identification and ageing of Holarctic waders. British Trust for Ornithology Guide 17, Tring, Herts.

RECHER, H. F., AND J. A. RECHER. 1969. Some aspects of the ecology of migrant shorebirds. II. Aggression. Wilson Bull. 81:140–154.

REESE, K. P., AND J. A. KADLEC. 1982. Determining the sex of Black-billed Magpies by external measurements. J. Field Ornithol. 53:417–418.

RISSER, A. C. 1971. A technique for performing laparotomy on small birds. Condor 73: 376–379.

SKEEL, M. A. 1982. Sex determination of adult Whimbrels. J. Field Ornithol. 53:414–416.

ZWARTS, L. 1981. Intra- and interspecific competition for space in estuarine bird species in a one prey situation. Proc. XCII Int. Ornithol. Congr. (Berlin) pp. 1045–1050.

JLM, *Department of Biology, University of North Dakota, Grand Forks, North Dakota 58202*; JPM, *Academy of Natural Sciences, 19th and the Parkway, Philadelphia, Pennsylvania 19103*; JLM AND JPM, *Bodega Marine Laboratory, University of California, P.O. Box 247, Bodega Bay, California 94923.*
Received 19 Aug. 1983; accepted 16 May 1984.