

AGE AND SEX SIZE VARIATION IN GOLDEN EAGLES

BY GARY R. BORTOLOTTI

Although there has been much interest in the adaptive significance of sexual size dimorphism in birds of prey (see review by Newton 1979), quantification of the size differences between the sexes is lacking for many raptors. The Golden Eagle (*Aquila chrysaetos*) shows pronounced sexual size dimorphism, yet good criteria for differentiating between the sexes using morphological characters have not been determined. Recently, differences in size attributable to age have also become of interest in raptor biology from the viewpoint of their adaptive significance (Amadon 1980). Both sex and age size variation have been demonstrated for the North American accipiters (Mueller et al. 1976, 1979, 1981), Northern Harriers (*Circus cyaneus*; Bildstein and Hamerstrom 1980), Harris' Hawks (*Parabuteo unicinctus*; Hamerstrom and Hamerstrom 1978), and Bald Eagles (*Haliaeetus leucocephalus*; Bortolotti 1984a). My purpose is to quantify the size variability in North American Golden Eagles (*A. chrysaetos canadensis*) that is attributable to both age and sex, and to present criteria for sex determination that are suitable for use in field studies.

My data are measurements made on museum study skins. Specimens which are incorrectly labeled with respect to sex pose a problem in this kind of study. Few eagle skins are accompanied by any information on the label regarding the size or state of the gonads (only 7% in my sample), which is the only way of unequivocally identifying sex. Some specimens in fact have no sex label at all; if these must be ignored, the amount of material available for study would be considerably reduced. Therefore, objective criteria for correcting and/or determining the sex of museum specimens are much needed. The practices of removing questionably sexed birds, and/or subjectively correcting or adding to the sex label as an investigator sees fit, may bias samples by artificially enhancing the distinctiveness of the sex groups (also see discussion in Bortolotti 1984a). In this study all specimens I encountered were used in the analyses. I present a method which employs multivariate statistics to test in an objective fashion the accuracy of the sex data associated with a specimen. My results are compared to criteria for sex identification currently accepted by the U.S. Fish and Wildlife Service and Canadian Wildlife Service bird-banding offices.

METHODS

Study material.—I measured study skins regardless of date or location of collection. Of the 132 specimens included in analyses, 59 (45%) were from Alaska and Canada (excluding southern Ontario), 38 (29%) were from southern Ontario and the northern United States (Pacific northwest, northern Mid-west, and northeastern states), and 29 (22%) were from more southern states (Colorado, Kansas, Arkansas, California, A1

izona, Texas, and New Mexico). Six (4%) specimens lacked data on geographic origin but were labeled as *A. chrysaetos canadensis*. It is not particularly useful to describe the geographic extent of my sample more specifically because dates of collection for the specimens were not evenly distributed throughout the calendar year. Northern populations migrate south in winter, although little is known about the extent of these movements. Most of the specimens in my sample (91% of adult, and 93% of immature birds) were taken between September and April, a time when many northern birds might be found in southern latitudes (Boeker and Ray 1971). This collection bias is likely of little importance because geographic variation in size has not been documented for North American populations of Golden Eagles (although this may not have been adequately investigated). There was no obvious age or sex bias in date or location.

Variables.—I used dial calipers to measure length of the culmen without cere, depth of bill at the leading edge of the cere, and length of hallux claw. These measurements should be equally applicable to both museum study skins and living birds. Bill depth could frequently not be measured with accuracy because of the open mouths of some specimens, and thus I excluded it from multivariate analyses to minimize the use of estimates (see below). I also used calipers to measure the width of the bill at the point where feathers and cere meet at the top of the head, and length of bill from gape, although these should likely not be compared to live birds because of the nature of dried museum specimens. The measurement of culmen length, bill depth, bill width, bill length from gape, and hallux claw length, as they were done in the same manner for Bald Eagles, are diagrammed in Bortolotti (1984a).

For measurement of unflattened wing chord, I used a steel tape measure, and for all feather lengths I used a thin metal metric ruler. I measured tail length by inserting the ruler between, and guiding it along, the central rectrices to the point of their insertion. Similarly, I inserted the ruler between the 8th and 9th primaries, and between the first primary and first secondary, to obtain the lengths of the 8th primary and first secondary, respectively. I suspect that the wing chord and perhaps tail length measurements presented here are reasonably applicable to a field study. The 8th primary and first secondary measurements, however, may be strongly influenced by the drying of study skins after preparation and may thus not be directly comparable to live birds.

Because there is an uneven seasonal distribution to my sample, there could be a bias due to feather wear if feathers are more likely to be worn at one time of the year than another. The probability of this bias occurring is likely minimal as Golden Eagles do not undergo an annual molt (Jollie 1947) and so flight feathers may range in age from recently grown to over 2 years old. However, any feather or other body part which showed considerable wear, or that was broken or present in such a way as to make accurate measurement difficult, was considered missing.

To insure an adequate sample for the multivariate analyses, I used a missing value estimator computer program (Dixon and Brown 1979) to compute values for missing data. The estimate was obtained by regressing the variable of interest on all other variables. Only specimens with no more than 2 of the 9 variables missing were considered for analysis. Only 3% of the measurements involved missing data. For all univariate tests, as well as for all ranges and calculations of means and standard deviations, I used only the original data (estimates excluded). Sample sizes are thus somewhat variable among measurements.

Age classification.—Juvenile Golden Eagles are most strikingly different from adults in having a conspicuous white patch at the carpal joint of the wing (a product of basally white primaries and secondaries) and having rectrices whose proximal third is white and remaining distal portion dark brownish-black (Brown and Amadon 1968). The width of the dark terminal band on the tail increases with age through successive molts as an immature. The tail of an adult typically has a clouded gray-brown barred pattern sometimes with a small amount of white basally. The white wing patch decreases with increasing age, being replaced in the adult form by indistinct gray-brown bands. The age at which adult plumage is acquired has not been well documented; although it likely varies among individuals, it appears to be 3 to 4 years (Jollie 1947, Brown and Amadon 1968). Unequivocally-distinct plumages for all year-classes do not exist and I could thus only distinguish what I will refer to as immatures (young birds having large amounts of white on the rectrices), subadults (birds molting so that some rectrices were adult-like), and adults (possessing the plumage described above). Combining more than one plumage type as “immature,” although intuitively undesirable, may be most appropriate considering the complex molt of this species. Because individual Golden Eagles commonly have 2 (Jollie 1947) and possibly 3 (Spofford 1946) generations of feathers at one time, any description of age-related size variation should be considered conservative.

Sex determination of specimens.—The sex of Golden Eagles cannot be identified on the basis of plumage characters, and there are no published accounts of size differences that will permit absolute differentiation between the sexes. However, I found 2 non-overlapping distributions based on size and apparently reflecting sex. The methods used are similar to those developed for the Bald Eagle (Bortolotti 1984a).

RESULTS AND DISCUSSION

Statistical classification of sex.—For each of the 3 age classes, I entered all specimens into a principal component analysis (PCA). In each case the first 3 principal components explained between 78.9% and 85.9% of the variance in the entire data set, with the first component (PC1) accounting for 57.6% to 67.3% of the total variance. All variables were highly positively correlated with PC1. Therefore, PC1 is likely a “size”

factor, i.e., the major source of common variation in the data set is size and associated allometric shape change (Jolicoeur and Mosimann 1960, Gibson et al. 1976, Pimentel 1979).

Component scores for the individuals in each group were plotted along their respective PC1 axes (1 axis for each age class). For adults, 2 distinct groups appeared which, according to the sex on the labels, seemed to represent males and females (Fig. 1a). The distributions would have been non-overlapping except for 2 apparently anomalous individuals whose sex data on the label seemed doubtful to me. For example, the second largest bird in my entire sample was labeled a male. As an objective test of the hypothesis that these 2 birds were incorrectly sexed, I entered both into a discriminant function analysis (DFA) as "unknowns" to be classified by comparison with the other birds of "known" sex. Similarly, the specimens which lacked a sex identification on the label were also entered into the DFA as unknowns. A significant discriminant function ($P < .0001$) describing the differences between the sexes resulted. A classification phase associated with the DFA program used (Nie et al. 1970) checked the accuracy of the discriminant function generated. In this case, 100% of the individuals of known sex were correctly allocated to their group (i.e., male or female). The 2 birds of questionable sex were classified as opposite to what was listed on their labels. Birds without a sex on the label were assigned to one group or the other during the classification phase according to the highest probability of group membership as defined by the DFA. Given the distribution of birds was strongly bimodal and non-overlapping, I considered the sex assigned to each specimen by this DFA as the correct one for all subsequent analyses.

The results of PCAs of the subadult and immature classes also showed a bimodal ordination, except that the data on the labels failed to strongly identify these as male and female (Fig. 1b). This suggests that young birds were more frequently mis-sexed, as has been found for Bald Eagles (Bortolotti 1984a). Because the distributions of subadult and immature birds, unlike that of the adults, showed the sexes to overlap when represented one-dimensionally, an alternative method of assigning more reliable sex data than what was found on the labels was required. As described below, the size of the adults was used as a standard to sex younger birds.

The feathers of immature raptors of some species have been documented to be of different lengths than those of adult birds (Mueller et al. 1976, 1979, 1981, Amadon 1980, Bortolotti 1984a). Therefore in using adult morphology to sex immatures, I considered only the non-feather variables: culmen length, bill width, bill length from gape, and hallux claw. I assumed (erroneously, see below) that immatures were the same size as adults for these variables as has been found for the Bald Eagle (Bortolotti 1984a). I entered all adult males and females into a DFA as "knowns," and all subadult and immature birds as "unknowns" to be classified. The resulting function significantly ($P < .0001$) discrim-

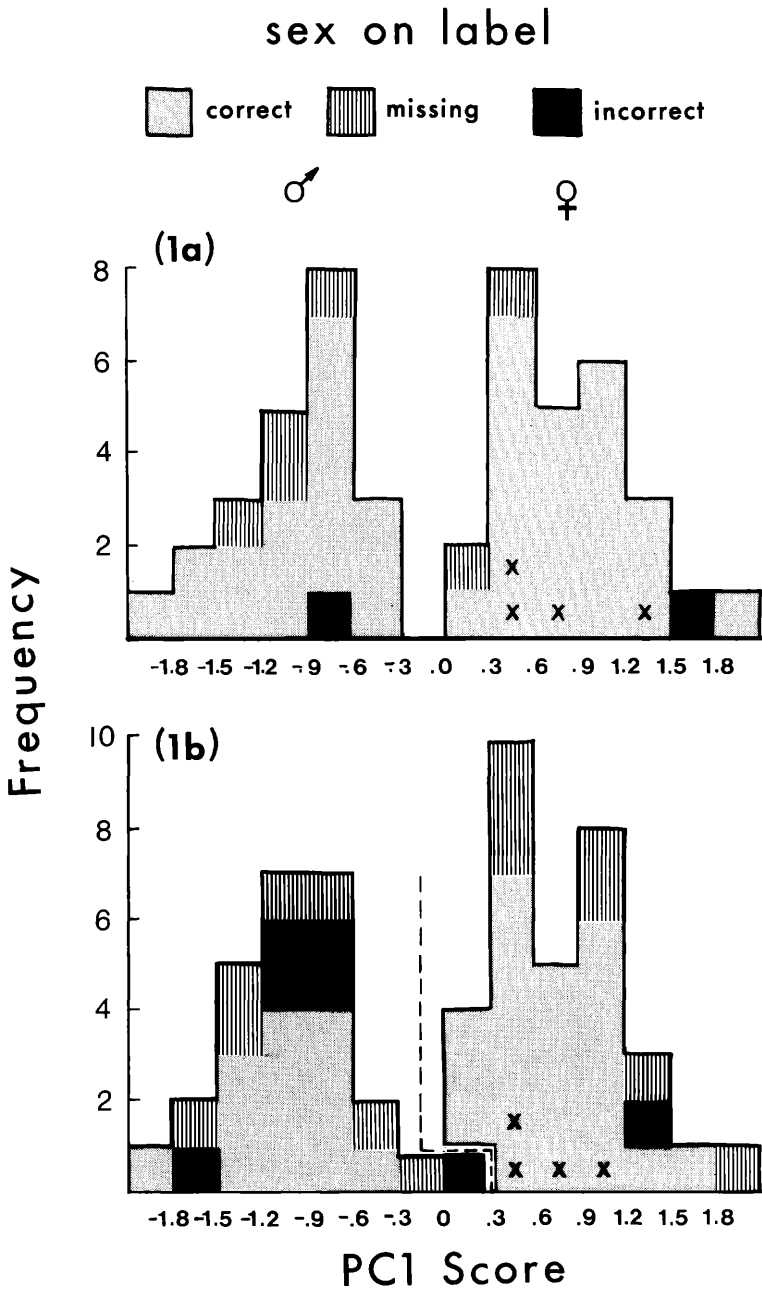


FIGURE 1. Distribution of museum specimens of (a) adult, and (b) immature Golden Eagles along their respective first principal component axes, showing sex information on labels. An x marks specimens for which a reference to the gonads was made.

inated between the sexes. By eliminating the feather-related characters, the number of variables in the DFA was reduced from 8 to 4. This, however, did not change the degree of accuracy in separating the sexes, since 100% of the adults were correctly sexed during the classification phase of the program. The sex assigned to all the non-adult birds by this method was then considered to be the correct one. When the sub-adult and immature eagles were subsequently analyzed in separate DFAs employing this a posteriori knowledge of the "correct" sex, using all variables, significant functions were produced ($P < .0001$). All 23 sub-adults and 58 immatures were correctly classified, thus confirming the validity of the original model.

Table 1 summarizes the morphological data for each sex in each age class. Within each age class, males were significantly different from females for all variables (t -tests, $P < .01$). Friedmann's (1950) mensural statistics for Golden Eagles (adults only) have commonly been used as a standard reference (e.g., used by Brown and Amadon 1968). If my measurements for wing chord and culmen length were taken in a manner comparable to that of Friedmann (1950), then the birds in my sample may be slightly larger (about 2% or less). Although the geographical breadths of the 2 are similar, my larger sample size includes proportionately more individuals from northern latitudes and this may partially explain the difference.

Age variation in size.—Analysis of variance (ANOVA) was used to test for statistical differences among age classes, and Gabriel's sum of squares simultaneous test procedure on ranked means was used as an a posteriori test for significant subsets. For bill width, bill depth, and bill length from gape there were no significant differences among age classes within a sex ($P > .05$). However, the culmen length of adult males was significantly longer than immature males ($F = 3.57$, $P < .05$), and culmen length for subadult females was significantly longer than that for the immature females ($F = 5.78$, $P < .01$). I do not know whether these age differences suggest that growth of the rhamphotheca (which continues throughout life, Stettenheim [1972]) exceeded wear, or whether they are artifacts of the sample. Coulter (1978) believed that the bills of Western Gulls (*Larus occidentalis*) did not attain full size until the birds were in adult plumage at 3 years old. Coulson et al. (1981) found the bill depth of Herring Gulls (*L. argentatus*) to increase in size for at least the first 9 years of life. Hallux claw also showed what could be interpreted as growth, but with a more convincing trend than culmen length. For both sexes there was an increase in hallux claw length with age, with the adult vs immature comparison for both males ($F = 5.94$, $P < .01$) and females ($F = 3.70$, $P < .05$) being significantly different, and subadult and immature females being nearly so ($P = .07$). Like the rhamphotheca, growth of the claws is continuous throughout life (Stettenheim 1972) again suggesting that growth exceeded wear for these birds. I have not found this change in culmen length or hallux claw with age in Bald Eagles (study skins or live birds). Perhaps because of different

TABLE 1. Sex and age class variation in size of Golden Eagles.

Variable	Age class	Males ^a			Females ^a		
		n	$\bar{x} \pm SD$	(Range)	n	$\bar{x} \pm SD$	(Range)
Wing chord	Adult	23	595.0 \pm 15.11	(569-619)	27	640.4 \pm 19.75	(601-674)
	Subadult	8	592.0 \pm 20.16	(566-632)	14	638.2 \pm 19.71	(608-685)
	Immature	26	585.9 \pm 16.63	(559-636)	31	632.2 \pm 16.00	(601-665)
Eighth primary length	Adult	23	437.0 \pm 12.54	(414-459)	26	466.0 \pm 13.80	(430-497)
	Subadult	7	438.7 \pm 10.08	(427-453)	15	461.1 \pm 15.01	(434-496)
	Immature	26	436.1 \pm 14.55	(412-456)	30	465.6 \pm 12.48	(442-490)
Tail length	Adult	22	286.5 \pm 10.03	(267-310)	24	307.2 \pm 9.69	(290-330)
	Subadult ^b	7	286.1 \pm 9.50	(275-303)	13	309.2 \pm 13.11	(293-321)
	Immature	23	297.7 \pm 17.95	(269-341)	30	322.0 \pm 21.09	(285-375)
First secondary length	Adult	19	359.1 \pm 10.48	(340-382)	25	384.0 \pm 13.10	(363-422)
	Subadult	8	359.2 \pm 12.96	(343-382)	13	381.0 \pm 11.06	(365-402)
	Immature	25	355.2 \pm 11.04	(334-373)	31	383.9 \pm 11.11	(368-422)
Culmen length	Adult	23	40.55 \pm 1.44	(36.9-43.5)	27	44.21 \pm 1.66	(41.7-47.5)
	Subadult	8	39.85 \pm 2.21	(37.1-43.2)	15	44.83 \pm 1.28	(43.2-47.5)
	Immature	26	39.36 \pm 1.44	(36.2-42.6)	31	43.34 \pm 1.36	(39.9-50.0)
Bill depth	Adult	19	27.48 \pm 0.81	(26.1-29.0)	22	29.37 \pm 0.71	(28.2-30.8)
	Subadult	8	27.39 \pm 1.38	(25.5-29.3)	13	29.39 \pm 0.91	(28.2-31.5)
	Immature	23	27.18 \pm 1.13	(25.2-29.2)	24	29.33 \pm 0.84	(27.6-31.8)
Bill width	Adult	22	27.42 \pm 1.73	(24.8-30.9)	25	29.09 \pm 1.78	(25.8-33.4)
	Subadult	7	26.83 \pm 1.54	(24.8-29.0)	15	28.53 \pm 1.44	(26.3-30.9)
	Immature	26	26.86 \pm 2.00	(22.8-30.6)	32	29.06 \pm 1.41	(26.4-33.1)
Bill length (gape)	Adult	23	58.27 \pm 2.44	(52.9-63.0)	26	63.24 \pm 2.13	(57.4-67.5)
	Subadult	8	57.48 \pm 4.26	(50.3-62.3)	14	63.43 \pm 1.66	(60.6-66.3)
	Immature	26	58.11 \pm 3.02	(51.2-63.1)	32	64.54 \pm 2.25	(59.5-69.0)
Hallux claw length	Adult	23	49.35 \pm 1.69	(45.9-52.9)	26	55.67 \pm 2.70	(49.8-63.4)
	Subadult	8	48.39 \pm 1.13	(46.1-49.7)	15	55.25 \pm 2.04	(51.6-60.5)
	Immature	24	47.75 \pm 1.62	(44.9-51.3)	30	54.01 \pm 2.15	(49.7-58.2)

^a All measurements are in millimeters.^b Includes specimens only with adult-like central rectrix (see text).

possibilities for wear given the species' habitat preferences, claws of the predominantly cliff-nesting mountain-dwelling Golden Eagle may grow faster than those of the tree-nesting Bald Eagle.

I had not anticipated the size variation with age. Since such variation is evident, the validity of using the size distribution of the adults to sex younger birds must be questioned. There is, however, considerable justification for employing this method of classifying the sex of non-adult eagles.

First, the differences between age groups were always much smaller than the differences between the sexes. Second, the age bias existed in only 2 of the variables and thus had relatively little effect on the final outcome. The discrimination of non-adult males and females, using adult size as a model, used 4 variables, and only 4 of the 24 age comparisons showed significant differences. To investigate how the sex classification of non-adult birds may have been influenced by the age variation, I performed discriminant analyses using adult dimensions to sex the immature and subadult birds, but eliminated culmen length and hallux claw. By removing culmen length from the analysis, the sex of only 1 immature bird was changed by the classification phase of the program. Likewise, the sex of only 3 birds was changed when hallux claw was removed. This suggests that if the entire removal of these variables causes little change, then a small increase in variability should have a relatively minor effect. Therefore, the age effect on culmen length and hallux claw has not likely affected the sex classification of the immature and subadult birds, and thus has not substantially altered the description of the differences between the sexes.

Since the subadult class was recognized on the basis of the presence of adult-like feathers, differences among age classes may be obscured when tested by ANOVA. Therefore in addition to ANOVA, I used *t*-tests (where stated below) to compare age classes. There were no significant differences in 8th primary or first secondary lengths among the age classes within a sex ($P > .05$). Wing chord showed an equivocal change with age as the probability level of the adult-immature comparison for males and females was $P = .051$ and $P = .08$, respectively (*t*-tests). What would appear to be a lack of concordance between the results for 8th primary and wing chord may be real. In contrast to the situation in Bald Eagles in which the 8th primary extends farthest from the folded wing, it is usually the 7th which is longest in Golden Eagles. Although data were not presented, Jollie (1947:569) stated that the wing feathers of "older birds" were "somewhat" longer than those of birds in juvenal plumage. It is possible that only in the juvenal plumage are wings shorter and thus my combination of more than 1 year of immature plumage masks such a change. Amadon (1980) suggested that the feathers of immature raptors are softer and therefore wear more rapidly. Although age differences in wing length therefore remain problematical, the differences, if they exist, are likely to be small.

Tail length was the only feather-related variable that showed pro-

nounced age-related differences. The tails of adult birds were significantly shorter than those of immature birds (males: $t = 2.59$, $P < .02$; females: $t = 3.17$, $P < .01$). The much higher standard deviation for the immature class (Table 1) suggests that the tail likely decreases in length annually, similar to that of the Bald Eagle (Bortolotti 1984a). The central rectrices of those subadults which were adult-like in appearance were also adult-like in size (Table 1). The few immature-like central rectrices (male: 292 mm; female: 336 and 330 mm) of subadults were longer than most of the adult-like ones.

There was no change in size of feather variables with age in Golden Eagles for 8th primary and first secondary, and relatively small changes for wing chord and tail, compared to the more substantial differences evident for the Bald Eagle (Bortolotti 1984a) for these same variables. For example, the juvenal to adult decrease in tail length for Bald Eagles is at least 4 times greater than that for Golden Eagles. It is unlikely that large age differences in the length of flight feathers could occur in Golden Eagles; since the wing molt is asymmetrical (between wings; Jollie 1947) and not all feathers are replaced annually, substantial age differences might result in an aerodynamic imbalance. The longer tails of immatures may be advantageous by enhancing maneuverability.

Field criteria for sex determination.—A predictive model for use in the field should be developed from a few variables which are (1) easily measured, (2) highly dimorphic, and (3) show a high degree of concordance between museum specimens and live birds. The variables which best satisfy these criteria for Golden Eagles are hallux claw and culmen length. Because of the age-related size differences for these measurements, the adult and subadult classes were combined (as no statistical differences were found between them) and examined separately from the immature class. A DFA of the adult/subadult birds using only hallux claw and culmen length, produced a significant ($P < .0001$) function: (culmen length $\times .393$) + (hallux claw length $\times .353$) - 35.142, whereby birds with positive values are females, and birds with negative values are males (Fig. 2a). In the classification phase, 97.2% of the specimens were correctly sexed. The 2 errors in classification involved females with small hallux claws. This could easily be attributable to wear. When the immatures were entered into a similar DFA the resulting significant ($P < .0001$) function: (culmen length $\times .405$) + (hallux claw length $\times .375$) - 35.818 classified 100% of the birds to their correct sex (Fig. 2b). This somewhat better classification for immatures would be expected if growth and wear of the culmen and hallux claw were involved in size determination, since older birds should show more variability in this respect (i.e., the adult class should be composed of birds of many ages). The line illustrating the plane which separates males from females for the adult/subadult and immature distributions, respectively, are parallel (compare Fig. 2a and 2b), indicating that the relationship between the sexes is similar for both age groups.

Comparison with other sex criteria.—Currently the bird-banding office

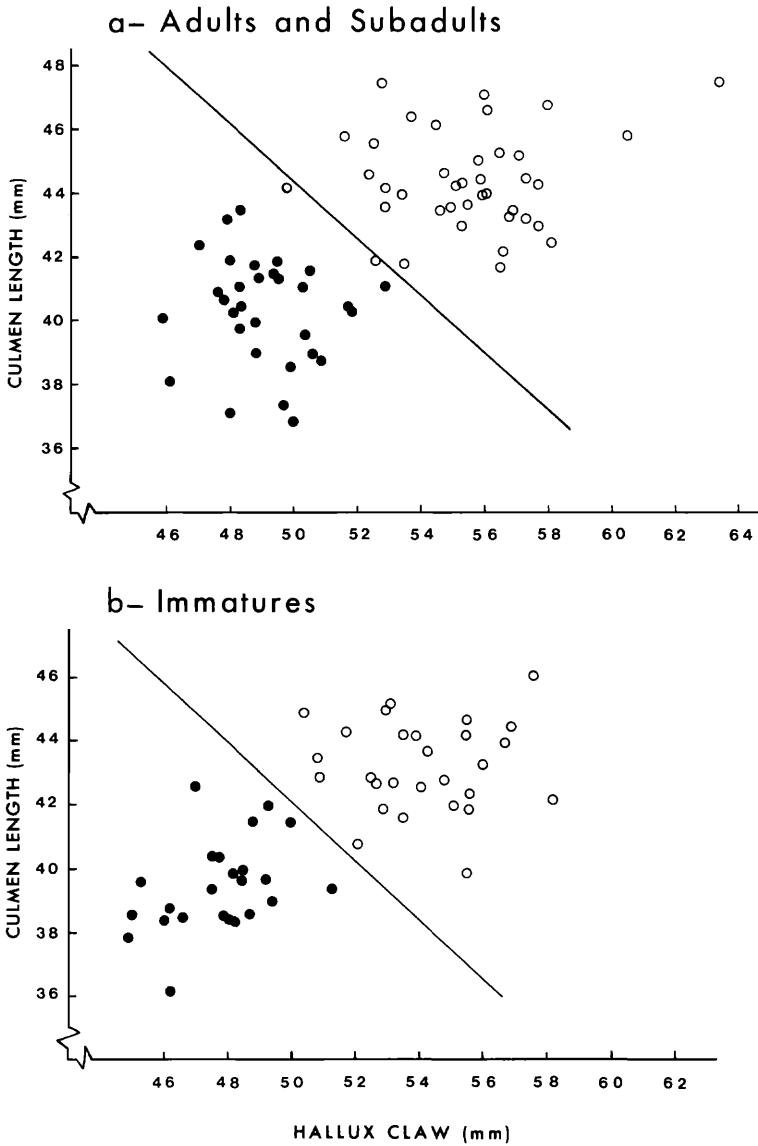


FIGURE 2. Distribution of male (solid circles) and female (open circles) (a) adult and subadult, and (b) immature Golden Eagles for the variables culmen length and hallux claw length. The line (representing combinations of the measurements for which the discriminant function equals zero) illustrates the plane which separates males from females.

uses a wing chord criterion for identifying the sex of Golden Eagles: males <625 mm, and females >660 mm (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1977). These values appear to be much larger than I would expect from my data (Table 1). However, as mentioned in the bird bander's manual (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1977), the wing chord of museum specimens may be 2–3% smaller than that of live birds because of the drying and shrinkage of prepared specimens. Therefore, for comparative purposes, I reduced the wing chord limits of males and females as defined by the banding office by 3%, and applied this adjusted criterion to my sample. Only 34.7% of the females and 82.5% of the males would have been sexed correctly. Although none of the males, and only 2.8% of the females would have been incorrectly sexed, 17.5% of the males and 62.5% of the females fell into the large zone in which sex could not be determined.

Sex ratio.—From the original data on museum labels for specimens used in this study, there appeared to be more females than males in the sample, particularly for non-adult birds. However, once the sex of these specimens had been corrected or determined for those that were unsexed, there were no statistically significant deviations from a sex ratio of 1:1. Most errors or lack of information regarding sex involved young birds (Fig. 1). Twenty-three percent of immature males were originally labeled as females, while only 3% of young females were labeled as males. Twenty-six percent of immatures, and 10% of adults were without sex data on the label. I believe these sex and age differences are most likely the result of difficulties in identifying immature gonads.

There was no a priori reason for me to assume a 1:1 sex ratio. Brown and Amadon (1968) suggested that possibly more female Golden Eagle chicks might be reared because the larger females might survive sibling aggression better than their brothers. Collopy (1980) found this to be true in Idaho, for the sex ratio deviated significantly from 1:1 in favor of females (1:1.44, mean for 10 years). As museum collections may be influenced by age and sex biases in mortality (for Golden Eagles see Bortolotti 1984b), they should not be assumed to be random samples of a population, and thus my results do not preclude the possibility of a sex bias in natural populations.

SUMMARY

Immature Golden Eagles appear to have slightly shorter culmens and hallux claws than adult birds. This suggests that growth of these parts has exceeded wear. There were no age-related differences in width of the culmen, length of the bill from gape, or depth of the bill. Immature birds have longer tails than adults, and may have slightly shorter wings, but are no different in length of the 8th primary or the first secondary feathers.

There were non-overlapping size distributions for the sexes of Golden

Eagles when analyzed multivariately. The sex of an individual can best be determined in the field by the use of a function describing the relationship of hallux claw length to culmen length. The accuracy of the function found in this study was 97.2% for adults and 100% for immatures.

After correcting assumed errors on museum labels I found that immature males were frequently mis-sexed, and that young eagles were most often unsexed. The sex ratio of the sample did not deviate from 1:1.

ACKNOWLEDGMENTS

I am grateful for the generous assistance of the curators and staff of the following museums where I measured specimens: Royal Ontario Museum, National Museum of Natural Sciences (Canada), Manitoba Museum of Man and Nature, Saskatchewan Museum of Natural History, University of Michigan Museum of Zoology, and the U.S. National Museum of Natural History, Smithsonian Institution. I also thank the staff of other museums who corresponded with me and provided me with information: Thomas Burke Memorial Washington State Museum, American Museum of Natural History, Provincial Museum of Alberta, and the Field Museum of Natural History. N. J. Flood kindly assisted in collecting some of the data. I thank N. J. Flood, J. C. Barlow, P. M. Fetterolf, M. N. Kochert, R. S. Palmer, and K. J. Szuba for their comments on the manuscript. The World Wildlife Fund (Canada), National Wildlife Federation, Department of Zoology University of Toronto, and the Natural Sciences and Engineering Research Council of Canada in a fellowship to myself and grant no. A3472 to J. C. Barlow, provided financial assistance.

LITERATURE CITED

- AMADON, D. 1980. Varying proportions between young and old raptors. Proc. Pan-Afr. Ornithol. Congr. 4:327-331.
- BILDSTEIN, K. L., AND F. HAMERSTROM. 1980. Age and sex differences in the size of Northern Harriers. J. Field Ornithol. 51:356-360.
- BOEKER, E. L., AND T. D. RAY. 1971. Golden Eagle population studies in the Southwest. Condor 73:463-467.
- BORTOLOTTI, G. R. 1984a. Sexual size dimorphism and age-related size variation in Bald Eagles. J. Wildl. Manage. 48:72-81.
- . 1984b. Trap and poison mortality of Golden and Bald eagles. J. Wildl. Manage. In press.
- BROWN, L. H., AND D. AMADON. 1968. Eagles, hawks and falcons of the world. Country Life Books, Feltham, Middlesex, U.K.
- COLLOPY, M. W. 1980. Food consumption and growth energetics of nestling Golden Eagles. Ph.D. dissertation, Univ. Mich., Ann Arbor, Michigan.
- COULSON, J. C., N. DUNCAN, C. S. THOMAS, AND P. MONAGHAN. 1981. An age-related difference in the bill depth of Herring Gulls, *Larus argentatus*. Ibis 123:499-502.
- COULTER, M. 1978. Growth in the Western Gull, *Larus occidentalis*: a summary of results. Colonial Waterbirds 3:84-91.
- DIXON, W. J., AND M. B. BROWN. 1979. Biomedical computer programs P-series. Univ. California Press, Berkeley, California.

- FRIEDMANN, H. 1950. The birds of North and Middle America. Part XI, U.S. Natl. Mus. Bull. No. 50.
- GIBSON, A. R., M. A. GATES, AND R. ZACH. 1976. Phenetic affinities of the Wood Thrush, *Hylocichla mustelina* (Aves: Turdinae). Can. J. Zool. 54:1679-1687.
- HAMERSTROM, F., AND F. HAMERSTROM. 1978. External sex characters of Harris' Hawks in winter. Raptor Res. 12:1-14.
- JOLICOEUR, P., AND J. E. MOSIMANN. 1960. Size and shape variation in the painted turtle. A principal component analysis. Growth 24:339-354.
- JOLLIE, M. 1947. Plumage changes in the Golden Eagle. Auk 64:549-576.
- MUELLER, H. C., D. D. BERGER, AND G. ALLEZ. 1976. Age and sex variation in the size of Goshawks. Bird-Banding 47:310-318.
- , ———, AND ———. 1979. Age and sex differences in the size of Sharp-shinned Hawks. Bird-Banding 50:34-44.
- , ———, AND ———. 1981. Age, sex, and seasonal differences in size of Cooper's Hawks. J. Field Ornithol. 52:112-126.
- NEWTON, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, South Dakota.
- NIE, N. H., C. H. HULL, J. G. JENKINS, K. STEINBRENNER, AND D. H. BENT. 1970. Statistical package for the social sciences. McGraw-Hill Book Co., New York, New York.
- PIMENTEL, R. A. 1979. Morphometrics: the multivariate analysis of biological data. Kendall/Hunt Publ. Co., Dubuque, Iowa.
- SPOFFORD, W. A. 1946. Observations on two Golden Eagles. Auk 63:85-87.
- STETTENHEIM, P. 1972. The integument of birds. Pp. 1-63, in Avian Biology, Vol. II, D. S. Farner and J. R. King, eds., Academic Press, New York, New York.
- U.S. FISH AND WILDLIFE SERVICE AND CANADIAN WILDLIFE SERVICE. 1977. North American bird banding techniques.

Department of Zoology, University of Toronto, Toronto, Ontario M5S 1A1, Canada. Received 3 Mar. 1983; accepted 1 Nov. 1983.