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DIFFERENCES BY AGE AND SEX IN THE SIZE OF SAW-WHET OWLS

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In most species of birds the male is larger than the female. However, in many birds of prey the female is larger than the male. Earhart and Johnson (1970) review this reversal in Falconiformes. Work on North American accipiters confirmed this reversal and also showed that adults have longer wing chords than juveniles, although the magnitude of the difference is much less than that between the sexes in each age class (Mueller et al. 1976, 1979, 1981a,b).

Earhart and Johnson (1970), analyzed 32 forms of owls from museum collections and concluded that owls usually show reversed size dimorphism, and when wing length is used as the criterion, the smaller North American species of *Strix, Otus,* and *Aegolius* are less dimorphic than the larger species.

For the Saw-whet Owl (*Aegolius acadicus*), wing chords of males and females apparently show substantial overlap thereby causing difficulty in assigning sex for owls in this group when this taxonomic character is used alone. Mueller and Berger (1967) confined their analysis of 213 Saw-whets trapped in Wisconsin to 2 age classes (immature and adult) and did not report numbers of males or females. In the work by Weir et al. (1980), with 1128 Saw-whets captured and released, birds with wing chords ≤ 134 mm were considered males and ≥ 141 mm as females (Sheppard and Klimkiewicz 1976, Anon. 1977). Those with wing chords from 135 to 140 mm were classed as sex unknown. It was expected that this procedure must result in more identified males than identified females (Edwards et al. 1982) because of the area of overlap in the Gaussian distributions of their wing chords and the different standard deviations for males and females reported by Earhart and Johnson (1970).

In this paper, we apply an established statistical method to the separation of the superimposed normal distributions of wing chords of unsexed Saw-whet Owl populations and report decision boundaries for the assignment of sex based on the wing chord of any individual Saw-whet.

METHODS

Source of data.—Our banders trapped and released 2671 Saw-whet Owls during autumn migration at Prince Edward Point, Ontario (43°57′N, 76°54′W) in 1975–1981. Weir et al. (1980) described the area and trapping methods. In 1975 we did not age the 83 birds trapped, so these are excluded from the analysis. The remaining 2588 were weighed and examined for molt. The right and left wing chords were measured on 1727 of the owls. For the remainder, only the right wing chord was

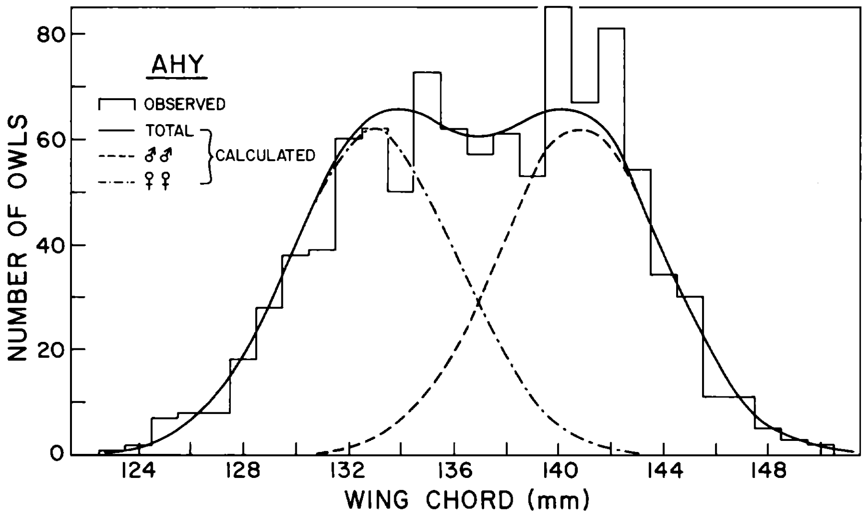

FIGURE 1. Wing chord–frequency histogram for 1011 AHY Saw-whet Owls at Prince Edward Point, Ontario.

measured. The wing chord was measured by placing the bend of the wing, closed in its natural position, against the vertical stop at the zero point of the scale and pivoting the wing until the longest primary touched the scale. No portion of the wing was pressed down against the rule. The measurements were made by about 15 different banders over the years. As a consistency test, 50 owls were measured independently by each of 3 banders. Measurements usually agreed within ±1 mm, with occasional differences of up to 2 mm.

Age criteria.—Owls were aged by color of primary and secondary feathers. Presence of both dark (unworn) and paler (worn) flight feathers indicated the partial postbreeding remex molt typical of an after-hatching-year (AHY) bird. Flight feathers of dark uniform color without wear denoted hatching-year (HY) birds. Ten birds that showed pale uniform color in flight feathers accompanied by worn tips were also assigned as AHY. Some birds showed 3 shades of color, suggesting 3 feather generations. Examination in good light is needed to detect this third paler shading, which could be easily overlooked under the propane lighting used. No attempt is made here to distinguish between second-year (SY) and after-second-year (ASY) birds. One bird identified initially as AHY in 1977 had all dark feathers when recaptured in 1978, indicating that at least some of the AHY birds have a complete postbreeding molt by October. Thus our classification of birds as either HY or AHY was not error-free.

Correlation between left and right wing chords.—A consistency test was done between the left and right wing measurements on each of the 1727

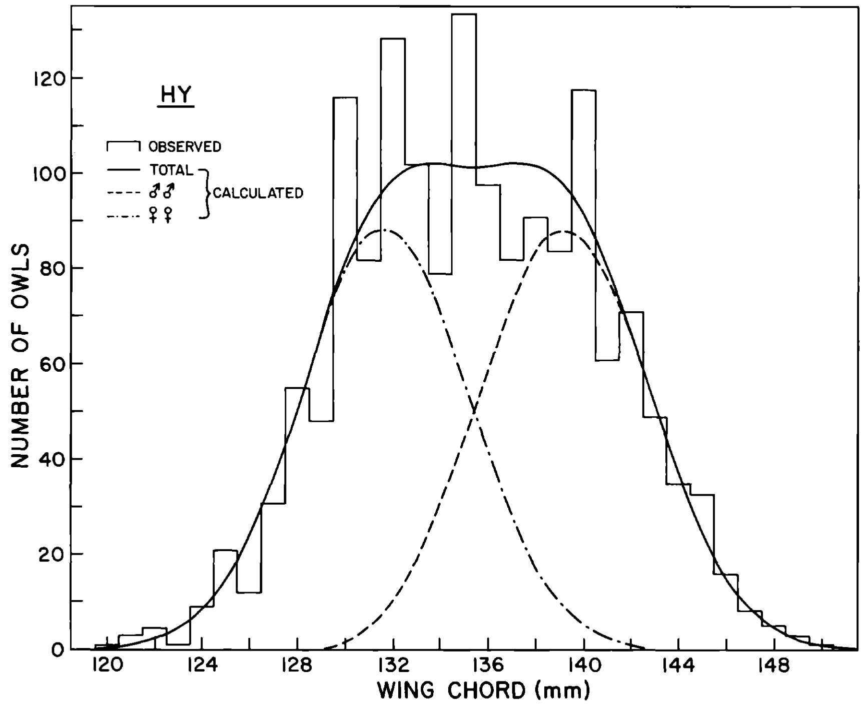

FIGURE 2. Wing chord–frequency histogram for 1577 HY Saw-whet Owls at Prince Edward Point, Ontario.

owls. For the AHY subpopulation, the correlation coefficient (r) was found to be .94 with a slight bias to a longer right wing chord by .21 mm (n = 716). This bias is significant at the $P \leq .0001$ level. For the HY group, $r = .94$ and the right chord exceeded left by .19 mm (n = 1731), also significant at the $P \leq .0001$ level. This bias is probably a result of the "right-handedness" of most of the measurers rather than real differences between the lengths of right and left wings.

Sex criteria.—The statistical method adopted for the analysis does not require the assignment of sex a priori for each bird. We tested for a bimodal distribution of wing chords and conclude, consistent with earlier work (Earhart and Johnson 1970), that the larger subpopulation is female and the smaller is male.

MacDonald and Pitcher (1979) developed an interactive computer program for estimating group parameters from size frequency data. Their method allows dissection of a distribution mixture into its components, including those in the overlapping region that cannot be clearly seen in plotted data. The program gives the means, standard deviations, and proportions to describe each component. MacDonald provided us

TABLE 1. Mean wing chords of Saw-whet Owls.

	Unconstrained SD		Constrained SD	
	♂	♀	♂	♀
AHY fraction of subpopulation	0.50 ± 0.08	0.50 ± 0.08	0.50 ± 0.08	0.50 ± 0.08
Wing chord,[a] mm	133.27 ± 3.59 (±0.34[c])	141.02 ± 3.03 (±0.24[c])	133.06 ± 3.30 (±0.12[c])	140.84 ± 3.30 (±0.12[c])
χ^2 (df)[b]	26.0 (22)		34.4 (23)	
HY fraction of subpopulation	0.50 ± 0.10	0.50 ± 0.10	0.50 ± 0.03	0.50 ± 0.03
Wing chord,[a] mm	131.71 ± 3.47 (±0.29[c])	139.19 ± 3.71 (±0.34[c])	131.76 ± 3.58 (±0.12[c])	139.27 ± 3.58 (±0.12[c])
χ^2 (df)[b]	82.4 (25)		84.6 (26)	

[a] Right hand side.
[b] Degrees of freedom.
[c] Standard error of estimate.

with the program which produces a computed frequency as a function of some measurement character, for our purpose wing chord, for comparison with actual data.

The population of Saw-whets was divided into AHY and HY subpopulations separated by color of flight feathers as described above. Each subpopulation was considered to contain two components: males and females. Birds were not sexed at the outset of the analysis. To begin the computer calculation, initial estimates of wing chord means, variances, and proportions were needed. These were obtained from a plot of frequency against right wing chord (Figs. 1 and 2).

RESULTS AND DISCUSSION

Numerical results.—The MacDonald program gave estimates of the mean wing chord and its standard deviation for both the male and female components of each subpopulation. In addition, the program gave estimated sex ratios for each subpopulation. For the AHY group, the program yielded fractions of male and female at .55 ± .08 (SD) and .45 ± .08 respectively, which in a null test do not differ significantly from 1:1. Therefore, the program was rerun, constrained to have a 1:1 sex ratio, thereby reducing by one the number of parameters to be estimated and obtaining $\chi^2_{22} = 26.0$ (Table 1). The standard deviation of the standard deviation (standard error of estimate) in the wing chords is also given and is such that the wing chords of the two sexes show overlapping standard deviations. A null test shows the differences in standard deviations to be insignificant. Thus, by constraining these standard deviations to be equal, the parameters to be estimated are further reduced by one and the variance on the estimated parameters is also

TABLE 2. Comparison of wing chords of Saw-whet Owls.

			Means and standard deviations		
		n	Males	Males and females	Females
This study:					
	HY	1577	131.8 ± 3.58	135.6 ± 5.18	139.3 ± 3.58
	AHY	1011	133.1 ± 3.30	137.0 ± 5.07	140.8 ± 3.30
HY	AHY	(2588)	(132.3 ± 3.53)	(136.1 ± 5.19)	(139.9 ± 3.53)
Earhart and Johnson (1970):					
HY	AHY	57	132.2 ± 3.83	135.6 ± 4.68	139.0 ± 2.46
Mueller and Berger (1967):					
	HY	?	—	136.5 ± 5.5	—
	AHY	?	—	138.5 ± 4.6	—
HY	AHY	213	—	(137.3 ± 5.3)[a]	—

[a] The bracketed numbers represent data calculated by us based on sex fraction given by Mueller and Berger (1967).

reduced, thereby giving tighter estimates of the parameters. The resulting change in the mean chord is −.2 mm and $\chi^2_{23} = 34.4$.

A similar treatment of the HY group is also given in Table 1. The run with constrained standard deviations produces parameters whose standard deviations show less variance. However, for both the constrained and unconstrained runs, the fit of the frequency curve using the calculated parameters to the experimental data is worse than that for the AHY subpopulation, with χ^2 values of 82.4 and 84.6 respectively.

Shown in Figs. 1 and 2 are the wing chord-frequency histograms for AHY and HY groups respectively, with the calculated frequency curve superimposed. The bar steps represent the experimental data and the continuous smooth curves the estimated frequencies calculated using the calculated MacDonald program parameters. This continuous curve has been resolved into the male and female components in each figure.

Comparison with previous workers.—Earhart and Johnson (1970) considered sexual size differences only. Mueller and Berger (1967) analyzed the birds by two age classifications but not by sex. To allow comparison, our data have been put in the form shown in Table 2.

By grouping our HY and AHY chords for either sex separately, agreement with Earhart and Johnson is excellent (viz., 132.3 to 132.2 mm and 139.9 to 139.0 mm). When the sexes are lumped, agreement is still good (136.1 to 135.6 mm). Their slightly shorter wing measurements are consistent with shrinkage in museum specimens (W. E. Godfrey pers. comm., Mueller and Berger 1968). To compare our study with that of Mueller and Berger, the sexes in our data were lumped for each age class. Their wing chords are slightly greater than ours (viz., 136.5 to 135.6 mm and 138.5 to 137.0 mm). This may be a result of systematic

TABLE 3. Estimated individual probability of sex of Saw-whet Owls given wing length.

Wing chord (mm)	AHY		HY	
	P(♂)	P(♀)	P(♂)	P(♀)
120	1.000	0.000	1.000	0.000
121	1.000	0.000	1.000	0.000
122	1.000	0.000	1.000	0.000
123	1.000	0.000	0.999	0.001
124	1.000	0.000	0.999	0.001
125	1.000	0.000	0.998	0.002
126	1.000	0.000	0.996	0.004
127	0.999	0.001	0.993	0.007
128	0.998	0.002	0.988	0.012
129	0.996	0.004	0.978	0.022
130	0.993	0.007	0.961	0.039
131	0.986	0.014	0.932	0.068
132	0.971	0.029	0.885	0.115
133	0.943	0.057	0.812	0.188
134	0.890	0.110	0.707	0.293
135	0.799	0.201	0.574	0.426
136	0.662	0.338	0.430	0.570
137	0.491	0.509	0.296	0.704
138	0.322	0.678	0.191	0.809
139	0.190	0.810	0.116	0.884
140	0.103	0.897	0.069	0.931
141	0.054	0.946	0.040	0.960
142	0.027	0.973	0.022	0.978
143	0.014	0.986	0.013	0.987
144	0.007	0.993	0.007	0.993
145	0.003	0.997	0.004	0.996
146	0.002	0.998	0.002	0.998
147	0.001	0.999	0.001	0.999
148	0.000	1.000	0.001	0.999
149	0.000	1.000	0.000	1.000

differences in the measuring technique between different groups of banders. The pooled mean of 137.3 mm was calculated assuming the proportion by age of the 213 owls to be the same as that for the 168 owls given in their Table 2.

Probability of sex given wing length.—The probability of assigning the correct sex to an individual owl from its measured wing length was calculated using the heights of the two normal distributions for male and female in each age class with the parameters shown in Table 1. The results are the probabilities shown in Table 3 and are identical for either the constrained or unconstrained parameters listed in Table 1. For example, for the AHY (HY) subpopulation, a wing chord of exactly 134 mm indicates an 89.0% (70.7%) probability that the bird is male and of exactly 141 mm a 94.6% (96.0%) probability a female.

The data in this form, while giving the probability of correct sex assignment of an individual owl, do not indicate (1) what fraction of the

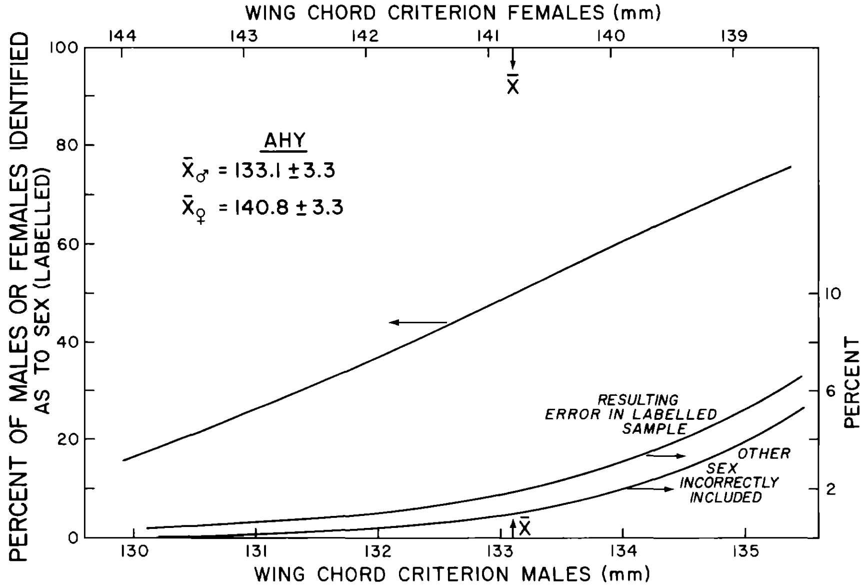

FIGURE 3. Percent of males or females identified as to sex (labelled), resulting percent error in labelled sample, and other sex incorrectly included as a function of wing chord criterion for sex determination in AHY Saw-whet Owls.

entire sample has its sex assigned, (2) percent of the other sex incorrectly included in the sex assignment, (3) percent error in sex assignment. To obtain these answers, it is necessary to consider all the birds included above or below a given wing length. Suppose that for the AHY group we use the criterion that all birds with a wing chord ≥ 141 mm are considered females and "labelled" as females. From Fig. 1, it is evident that a large fraction of the female population is excluded with only 47.6% to the right of 141 mm included and "labelled" as female. At the same time, a small area of the curve for males is included which amounts to .84% of the male population being incorrectly identified or "mislabelled" as females. Hence, out of a sample of 100 birds, .84 males will be misidentified as female, and $(100 - .84) \times .476 = 47.2$ identified correctly as females. This gives an error in the female (labelled) sample of $.84/(47.2 + .84) = .0175$ or 1.8%.

Similar results for the various possible wing chord criteria are shown in Fig. 3 (AHY) and Fig. 4 (HY) from which the expected errors for any wing criterion chosen can be read. For example, if the wing chord criterion for AHY males is taken to be ≤ 133 mm, the upper curve in Figure 3 shows that 50% of the total number of males in a large sample will be correctly labelled as males. The bottom curve shows that 1% of the females in a large sample will be mislabelled as males, giving (middle

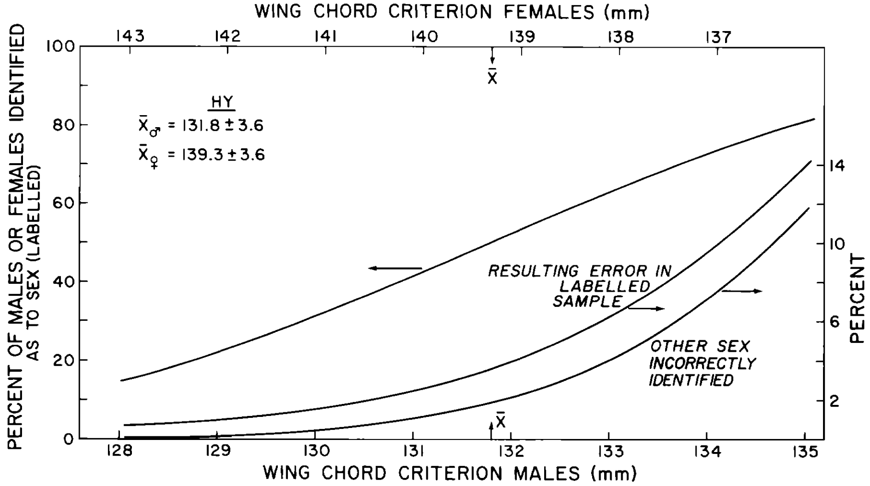

FIGURE 4. Percent of males or females identified as to sex (labelled), resulting percent error in labelled sample, and other sex incorrectly included as a function of wing chord criterion for sex determination in HY Saw-whet Owls.

curve) a 2% error in the labelled sample. That is, although half of the males will be identified as males, 2% of those identified as males will actually be females.

Current and recommended new sexing criteria.—To assess the current criteria recommended for banding, i.e., ≤131 mm for males and ≥143 mm for females without regard for age (Anon. 1980) we see from Fig. 3 that for AHY birds, only 26% of the male population and 25% of the female population are included, respectively. The misidentifications for ≤131 mm are .8%, and for ≥143 mm .5%, respectively. For the HY birds, 41.2% of the males and 15.2% of the females are included, respectively, with errors in labelled samples for ≤131 mm at 1.1% and 2.6%, and for ≥143 mm at 0.1% and .7%.

We recommend for AHY that banding criteria be shifted to ≥140.8 mm for females and ≤133.1 mm for males. These will result in correct identification of 50% of each sex and misidentification of only 1% of the other sex, producing a 2% error in the labelled sample. Similarly, we recommend for HY that the banding criteria be ≥139.3 mm for females and ≤131.8 mm for males. These will result in correct identification of 50% of each sex and misidentification of only 1.9% of the other sex, producing a 3.6% error in the labelled sample. We believe these criteria can be applied safely in the autumn. Since we do not know the timing of the year-to-year growth in either longer feathers or greater length of bone in the wing, we cannot know whether the criteria can be applied to an SY Saw-whet in winter and spring preceding its wing molt. We have no evidence of geographic variation for this species, but the usual care should be taken in comparing measurements for separate populations.

As a practical matter, since measurements are normally only made to the nearest mm, these criteria would become: AHY female ≥141 mm, male ≤133 mm, HY female ≥139 mm, male ≤132 mm, and for unaged samples, female ≥140 mm, male ≤132 mm.

SUMMARY

Based on the assumption of sexual dimorphism, the distribution of wing lengths of the Saw-whet Owl for the separate HY and AHY age classes has been resolved into two subpopulations corresponding to sex. The wing chord of females is greater than that for males. In addition, adult birds in each sex class have longer wings than the respective immatures. Probabilities are presented for correct assignment of sex based on wing chord for any individual Saw-whet Owl. Also presented are the fraction of the entire sample that may be identified as to sex and the percent errors in the labelled samples. Recommendations for new sexing criteria are also given.

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LITERATURE CITED

ANONYMOUS. 1977. North Am. bird banding techniques. Vol. 2, Pt. 6. Ageing and sexing. Can. Wildl. Serv. and U.S. Fish and Wildl. Serv.

———. 1980. North Am. bird banding techniques. Vol. 2, Pt. 6. Ageing and sexing. Can. Wildl. Serv. and U.S. Fish and Wildl. Serv.

EARHART, C. M., AND N. K. JOHNSON. 1970. Size dimorphism and food habits of North American owls. Condor 72:251–264.

EDWARDS, M. H., R. D. WEIR, AND R. B. STEWART. 1982. Comments on sexing Saw-whet Owls by wing chord. Wilson Bull. 94:555–557.

MACDONALD, P. D. M., AND T. J. PITCHER. 1979. Age-groups from size frequency data: A versatile and efficient method of analyzing distribution mixtures. J. Fish. Res. Board Can. 36:987–1001.

MUELLER, H. C., AND D. D. BERGER. 1967. Observations on migrating Saw-whet Owls. Bird-Banding 38:120–125.

———, AND ———. 1968. Sex ratios and measurements of migrant Goshawks. Auk 85: 431–436.

———, ———, 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 size of Sharp-shinned Hawks. Bird-Banding 50:34–44.

———, ———, AND ———. 1981a. Age and sex differences in wing loading and other aerodynamic characteristics of Sharp-shinned Hawks. Wilson Bull. 93:491–499.

———, ———, AND ———. 1981b. Age, sex and seasonal differences in size of Cooper's Hawks. J. Field Ornithol. 52:112–126.

SHEPPARD, J. M., AND M. K. KLIMKIEWICZ. 1976. An update to Wood's bird bander's guide. North Am. Bird Bander 1:25–27.

WEIR, R. D., F. COOKE, M. H. EDWARDS, AND R. B. STEWART. 1980. Fall migration of Saw-whet Owls at Prince Edward Point, Ontario. Wilson Bull. 92:475–488.

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