J. Field Ornithol., 57(2):155–167

ESTIMATION OF SEX RATIO FROM WING-LENGTH IN BIRDS WHEN SEXES DIFFER IN SIZE BUT NOT COLORATION

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Among avian species in which the sexes are similarly colored, sex can usually be distinguished during the breeding season by secondary sexual characteristics, such as brood patch or cloacal protuberance. In the non-breeding season such birds may be sexed by direct gonadal inspection by laparotomy. This procedure is difficult to apply when numbers of birds are large or when data are being collected in banding operations staffed with volunteers. In some of these species (e.g., many accipiters) sex can be determined by wing-length. In most species, however, overlap in wing-lengths prevents reliable sex determination of most individual birds (North American Bird Banding Manual, Volume II 1977, Craig and Manson 1981). Such overlap in wing-lengths also prevents reliable assignment of sex ratios in free-living populations (e.g., Ketterson and Nolan 1976).

Geographical and temporal variation of sex ratios in such look-alike birds are of substantial interest in physiological ecology and behavioral ecology (e.g., Ketterson and Nolan 1979, 1982; King et al. 1965). This led us to develop a method to estimate sex ratio from wing-length in sample populations of White-crowned Sparrows (*Zonotrichia leucophrys*). Our method reliably estimates the numbers of males and females in the sample (i.e., sex ratio). It also estimates mean wing-length, and permits determination of its variance, for each sex. We have found that the method may be applied to other species that have similar size dimorphism.

METHODS

By examining three series of racially distinct White-crowned Sparrows of known sex, we demonstrate that the distributions of wing-lengths (Tables 1–3):

1. Are bimodal, with peaks about 4 mm apart, when the sexes are displayed together.
2. Are normally distributed within each sex.
3. Have standard deviations in the order of ±2.0 mm within each sex.

To apply the method, the following characteristics of the sample should be present and conditions of measurement followed:

1. Birds considered together should usually be of the same taxonomic race.
2. HY-SY (<1 yr old) White-crowned Sparrows, have shorter wings than AHY-ASY (>1 yr old) sparrows (e.g., Mewaldt 1973). Hence, AHY-ASY birds should be analyzed separately from HY-SY birds.

TABLE 1. Wing-lengths of Gambel's White-crowned Sparrows 3–9 mo old collected in fall migration or wintering, both south of latitude 42°N in California, Nevada, Arizona, and Mexico.

Wing-length (mm)	Number				Estimated number		Wing-length (mm)
	M	F	M + F		M	F	
83	1		1		1		83
82	1		1		1		82
81			P	E			81
80	3		3	116	3		80
79	10		10		10		79
78	30	3	33		32	1	78
77	29	10	39		37	2	77
76	21	8	29		24	5	76
75	10	12	22—H		12	10	75
74	6	18	24		6	18	74
73	3	29	32	G	3	29	73
72	3	27	30	104	1	29	72
71	2	8	10			10	71
70	1	5	6			6	70
69		1	P 1			1	69
68		1	1			1	68
N	120	122	242		128	114	*N*
x̄	76.7	73.4	75.1		76.9	72.9	x̄
SD	±2.1	±2.0	±2.6		±1.7	±1.7	SD

Museum label: M:F::98:100 or 49.6% males.
Estimate: M:F::112:100 or 52.9% males.

3. Measurement technique should be standardized to reduce investigator caused variance.
4. Measurements should be made in the same few months of the year to reduce variance due to feather wear and should not bracket a period of flight feather molt.
5. Results improve if sample size is at least 100 individuals.

We have selected two ways to split the array of combined male and female wing-lengths. First, however, the extremes of the array of wing-lengths are combined, as at symbols P in Table 1, to make those extremes realistic. Then if the number of groups (accommodating combined extremes) in the array is odd (Table 1), a temporary division is made on the central group (H) and Procedure A is followed. If, however, the number of groups is even (Table 2), the temporary division is made between the central pair of groups (C–D) and Procedure B is followed.

Procedure A.—(See Data Set A and Table 1.) When the center of overlap in wing-lengths is judged to fall *on* a group (H), that group is divided into males (M) and females (F) in proportion to the number of wing-lengths above the H group (E = mostly males) and below the H group (G = mostly females). The number of males in the central group is determined thus:

TABLE 2. Wing-lengths of Gambel's White-crowned Sparrows 15+ mo old collected in fall migration and wintering, both south of latitude 42°N in California, Nevada, Arizona, and Mexico.

Wing-length (mm)	Number				Estimated number		Wing-length (mm)
	M	F	M + F		M	F	
85	1		P (1)		1		85
84	1		P (1)		1		84
83	5		P (5)		5		83
82	12	2	14	E'	14		82
81	25	2	27	253	27		81
80	41	3	44		43	1	80
79	44	1	45		43	2	79
78	59	11	70		64	6	78
77	39	7	46	—C	29—C'	12—C″	77
76	18	14	32	—D	17—D'	20—D″	76
75	15	34	49		8	41	75
74	3	33	36	G'	3	33	74
73	1	29	30	175	1	29	73
72		16	16			16	72
71	1	9	10			10	71
70	1		P (1)			1	70
69		1	P (1)			1	69
N	266	162	428		256	172	*N*
$\bar{x}$	78.5	74.5	77.0		78.8	74.3	$\bar{x}$
SD	±2.1	±2.3	±2.9		±1.9	±1.9	SD

Museum label: M:F::164:100 or 62.1% males.
Estimate: M:F::149:100 or 59.8% males.

$$M = \frac{E}{E + G} \times H$$

And the number of females:

$$F = \frac{G}{E + G} \times H \qquad \text{or} \qquad F = H - M$$

A normal curve with standard deviation of ±2.0 mm and with peak centering on a group diminishes in each direction from that peak (100%) to successively lower values of 88%, 69%, 54%, 42%, 32%, and 25% of each immediately higher value (see Appendix A, Table A). Because the difference in mean wing-lengths of males and females is about 4 mm (4 group intervals), the central group in the zone of overlap is assumed to be the second group from each of the peaks of the male and female curves, thus the 69% level. Fitting the normal curve for males in the zone of overlap then requires reductions in males in the next lower group to be 54% of the calculated central overlap number of males. To fit the normal curve further successive reductions are 42%, 32%, and 25% of the number in each immediately longer wing-length group.

Fitting the normal curve for females in that same zone of overlap requires reductions in females in the next higher group to be 54% of the calculated central overlap number of females. To fit the rest of the normal curve in the zone of overlap, successive reductions are then 42%, 32%, and 25% of the number in each immediately shorter wing-length group.

Procedure B.—(See Data Set B and Table 2.) When the center of overlap in wing-lengths is judged to fall between two groups, the numbers in these two groups (C and D) are combined and then redivided into male ($M = C' + D'$) and female ($F = C'' + D''$) portions in proportion to numbers above (E') and below (G') the split. The male portion (M) may be calculated thus:

$$M = \frac{E'}{E' + G'} \times (C + D)$$

The female portion (F) is then:

$$F = (C + D) - M$$

A normal curve with standard deviation of ±2.0 mm and with peak centering on two groups (and thus centering between those two class intervals), diminishes in each direction from the central pair, each 97% of the theoretical peak, to successively lower values of 78%, 61%, 47%, 37%, and 29% of each immediately higher value (see Appendix A, Table B). Because the difference in mean wing-lengths of males and females is about 4 mm (4 groups), the central pair of groups in the zone of overlap is assumed to center two groups from the central peak pairs of male and female curves, thus between the 78% and 61% levels. The male portion ($M = C' + D'$) is split with the down-slope value (D') 61% of the upper slope value (C') in accordance with:

$$C' + D' = M$$

Now solve for C' and D':

$$\text{Because } D' = 61C' \quad \text{then} \quad \begin{aligned} C' + 0.61C' &= M \\ 1.61C' &= M \\ C' &= \frac{M}{1.61} \end{aligned}$$

Then $D' = M - C'$

Numbers of males in the reconstructed series in the overlap zone are then further diminished to 47%, 37%, and 29% of each previous longer wing-length group.

The female portion ($F = C'' + D''$) is split similarly except D'' becomes the larger value and C'' is 61% of D'' thus:

$$C'' + D'' = F$$

Now solve for C'' and D'':

$$\text{Because } C'' = 0.61D'' \quad \text{then} \quad D'' + 0.61D'' = F$$
$$1.61D'' = F$$
$$D'' = \frac{F}{1.61}$$

Then $C'' = F - D''$

The numbers of females in the reconstructed series in the overlap zone are further degraded in numbers in successively larger wing-lengths to 47%, 37%, and 29% of each previous shorter wing-length group.

The balance of wing-lengths, E, above the central group in Procedure A, or E′, above the central pair of groups in Procedure B, are assigned as males except as reduced by numbers of females calculated for each of those groups. Similarly, the balance of wing-lengths, G, below the cental group in Procedure A, or G′, below the central pair of groups in Procedure B, are assigned as females except as reduced by numbers of males calculated for each of those groups.

RESULTS

Data Set A.—Included in Data Set A are Gambel's White-crowned Sparrows (*Z. l. gambelii*) 3 to 9 months of age (HY-SY) collected while in fall migration or wintering south of latitude 42°N in California, Nevada, Arizona, and Mexico (Table 1). Wing-lengths were taken as chord with dial caliper, all by Mewaldt, from museum skins in the Museum of Vertebrate Zoology, Berkeley, the California Academy of Sciences, San Francisco, and the Museum of Birds and Mammals, San Jose. Sex on the skin label was accepted as valid. Calculate numbers of males and females in H:

$$M = \frac{E}{E + G} \times H = \frac{116}{116 + 104} \times 22 = (0.527)(22) = 11.60 = 12$$
$$F = H - M_{75\text{ mm}} = 22 - 12 = 10$$

Calculate numbers of males (N_M) with wing-lengths less than 75 mm:

$$N_{M\ 74\text{ mm}} = 54\%\ N_{M\ 75\text{ mm}} = 0.54(12) = 6.48 = 6$$
$$N_{M\ 73\text{ mm}} = 42\%\ N_{M\ 74\text{ mm}} = 0.42(6.48) = 2.72 = 3$$
$$N_{M\ 72\text{ mm}} = 32\%\ N_{M\ 73\text{ mm}} = 0.32(2.72) = 0.87 = 1$$

Calculate numbers of females (N_F) with wing-lengths more than 75 mm:

$$N_{F\ 76\text{ mm}} = 54\%\ N_{F\ 75\text{ mm}} = 0.54(10) = 5.40 = 5$$
$$N_{F\ 77\text{ mm}} = 42\%\ N_{F\ 76\text{ mm}} = 0.42(5.40) = 2.26 = 2$$
$$N_{F\ 78\text{ mm}} = 32\%\ N_{F\ 77\text{ mm}} = 0.32(2.26) = 0.73 = 1$$

Calculate numbers of males with wing-lengths more than 75 mm:

$$N_{M\ 76\text{ mm}} = N_{M+F\ 76\text{ mm}} - N_{F\ 76\text{ mm}} = 29 - 5 = 24$$
$$N_{M\ 77\text{ mm}} = N_{M+F\ 77\text{ mm}} - N_{F\ 77\text{ mm}} = 39 - 2 = 37$$
$$N_{M\ 78\text{ mm}} = N_{M+F\ 78\text{ mm}} - N_{F\ 78\text{ mm}} = 33 - 1 = 32$$

$$N_{M\ 79\ mm} = N_{M+F\ 79\ mm} - N_{F\ 79\ mm} = 10 - 0 = 10$$
$$N_{M\ 80\ mm} = N_{M+F\ 80\ mm} - N_{F\ 80\ mm} = 3 - 0 = 3$$
$$N_{M\ 81\ mm} = N_{M+F\ 81\ mm} - N_{F\ 81\ mm} = 0 - 0 = 0$$
$$N_{M\ 82\ mm} = N_{M+F\ 82\ mm} - N_{F\ 82\ mm} = 1 - 0 = 1$$
$$N_{M\ 83\ mm} = N_{M+F\ 83\ mm} - N_{F\ 83\ mm} = 1 - 0 = 1$$

Calculate numbers of females with wing-lengths less than 75 mm:

$$N_{F\ 74\ mm} = N_{M+F\ 74\ mm} - N_{M\ 74\ mm} = 24 - 6 = 18$$
$$N_{F\ 73\ mm} = N_{M+F\ 73\ mm} - N_{M\ 73\ mm} = 32 - 3 = 29$$
$$N_{F\ 72\ mm} = N_{M+F\ 72\ mm} - N_{M\ 72\ mm} = 30 - 1 = 29$$
$$N_{F\ 71\ mm} = N_{M+F\ 71\ mm} - N_{M\ 71\ mm} = 10 - 0 = 10$$
$$N_{F\ 70\ mm} = N_{M+F\ 70\ mm} - N_{M\ 70\ mm} = 6 - 0 = 6$$
$$N_{F\ 69\ mm} = N_{M+F\ 69\ mm} - N_{M\ 69\ mm} = 1 - 0 = 1$$
$$N_{F\ 68\ mm} = N_{M+F\ 68\ mm} - N_{M\ 68\ mm} = 1 - 0 = 1$$

Data Set B.—Included in Data Set B are Gambel's White-crowned Sparrows (*Z. l. gambelii*) 15 and more months of age (AHY-ASY) collected while in fall migration or wintering south of latitude 42°N in California, Nevada, Arizona, and Mexico (Table 2). Wing-lengths were taken as in Data Set A and the sex on the label was accepted as valid. Calculate number of males (M) in C′ and D′ combined:

$$M = \frac{E'}{E' + G'} \times (C + D) = \frac{253}{253 + 175} \times (46 + 32) = 46.11 = 46$$

Calculate number of males in each of C′ and D′:

$$\begin{aligned} &\text{Males in } C' + D' = 46 \\ &\text{Model says } D' = 0.61C' \\ &\text{So: } C' + 0.61C' = 46 \\ &\qquad 1.61C' = 46 \\ &\qquad\quad C' = 28.57 \text{ or } 29 \text{ M with 77 mm wings} \\ &\text{And: } D' = M_{C'+D'} - C' = 46 - 29 = 17 \text{ M with 76 mm wings} \end{aligned}$$

Calculate number of females (F) in C″ and D″ combined:

$$F = (C + D) - M_{C'+D'} = (46 + 32) - 46 = 32$$

[It is strictly a matter of chance that known males and females with wing-lengths of 77 mm = 46 and in this specific application of the method the number of males with wings 77 mm plus 76 mm also = 46.]

Calculate number of females in each of C″ and D″:

$$\begin{aligned} &\text{Females in } C'' + D'' = 32 \\ &\text{Model says } C'' = 0.61D'' \\ &\text{So: } D'' + 0.61D'' = 32 \\ &\qquad 1.61D'' = 32 \\ &\qquad\quad D'' = 19.88 \text{ or } 20 \text{ F with 76 mm wings} \\ &\text{And: } C'' = F_{C''+D''} - D'' = 32 - 20 = 12 \text{ F with 77 mm wings} \end{aligned}$$

TABLE 3. Wing-lengths of Mountain White-crowned Sparrows ten or more months of age captured and sexed on breeding ground on Hart Mountain, Oregon from May to September 1972–1979.

Wing-length (mm)	Number			Estimated number		Wing-length (mm)
	M	F	M + F	M	F	
82	2		2	2		82
81	4		4	4		81
80	6		6	6		80
79	17		17	17		79
78	34	3	37	37		78
77	37	1	38	36	2	77
76	48	3	51	46	5	76
75	49	13	62	50	12	75
74	33	21	54	31	23	74
73	10	23	33	17	16	73
72	7	52	59	7	52	72
71	1	36	37	2	35	71
70		14	14	1	13	70
69		6	6		6	69
68		4	4		4	68
67		2	2		2	67
66		1	1		1	66
N	248	179	427	256	171	*N*
$\bar{x}$	76.1	72.1	74.5	76.0	72.1	$\bar{x}$
SD	±2.0	±2.0	±2.8	±2.1	±1.9	SD

Known sex: M:F::139:100 or 58.1% males.
Est. sex: M:F::150:100 or 60.0% males.

Calculate numbers of males with wing-lengths less than 76 mm:

$$N_{M\ 75\ mm} = 47\%\ N_{M\ 76\ mm} = 0.47(17) = 7.99 = 8$$
$$N_{M\ 74\ mm} = 37\%\ N_{M\ 75\ mm} = 0.37(7.99) = 2.96 = 3$$
$$N_{M\ 73\ mm} = 29\%\ N_{M\ 74\ mm} = 0.29(2.96) = 0.86 = 1$$

Calculate numbers of females with wing-lengths more than 77 mm:

$$N_{F\ 78\ mm} = 47\%\ N_{F\ 77\ mm} = 0.47(12) = 5.64 = 6$$
$$N_{F\ 79\ mm} = 37\%\ N_{F\ 78\ mm} = 0.37(5.64) = 2.09 = 2$$
$$N_{F\ 80\ mm} = 29\%\ N_{F\ 79\ mm} = 0.29(2.09) = 0.61 = 1$$

Calculate numbers of males with wing-lengths more than 77 mm:

$$N_{M\ 78\ mm} = N_{M+F\ 78\ mm} - N_{F\ 78\ mm} = 70 - 6 = 64$$
$$N_{M\ 79\ mm} = N_{M+F\ 79\ mm} - N_{F\ 79\ mm} = 45 - 2 = 43$$
$$N_{M\ 80\ mm} = N_{M+F\ 80\ mm} - N_{F\ 80\ mm} = 44 - 1 = 43$$
$$N_{M\ 81\ mm} = N_{M+F\ 81\ mm} - N_{F\ 81\ mm} = 27 - 0 = 27$$
$$N_{M\ 82\ mm} = N_{M+F\ 82\ mm} - N_{F\ 82\ mm} = 14 - 0 = 14$$
$$N_{M\ 83\ mm} = N_{M+F\ 83\ mm} - N_{F\ 83\ mm} = 5 - 0 = 5$$
$$N_{M\ 84\ mm} = N_{M+F\ 84\ mm} - N_{F\ 84\ mm} = 1 - 0 = 1$$
$$N_{M\ 85\ mm} = N_{M+F\ 85\ mm} - N_{F\ 85\ mm} = 1 - 0 = 1$$

TABLE 4. Wing-lengths of fall migrant and wintering Gambel's White-crowned Sparrows captured (1975–1976) for banding at Tucson, Arizona by C. E. Corchran, D. W. Lamm, and S. M. Russell.

Wing-length (mm)	Number HY-SY			Number AHY-ASY		
	M & F	Est. M	Est. F	M & F	Est. M	Est. F
84				1	1	
83				6	6	
82	2	2		15	15	
81	6	6		21	21	
80	21	21		49	48	1
79	39	38	1	49	46	3
78	70	65	5	76	67	9
77	81	66	15	61	40	21
76	100	63	37	66	28	38
75	115	47	68	90	15	75
74	125	25	100	93	6	87
73	99	11	88	81	2	79
72	113	3	110	65	1	64
71	68	1	67	25		25
70	39		39	8		8
69	19		19	4		4
68	2		2			
N	899	348	551	710	296	414
$\bar{x}$	74.5	76.8	73.0	75.7	78.4	73.8
SD	±2.7	±1.9	±2.0	±3.0	±2.1	±1.9

HY-SY: M:F::63:100 or 38.7% males.
AHY-ASY: M:F::71:100 or 41.7% males.
Age ratio: HY-SY:AHY-ASY::127:100 or 55.9% HY-SY.

Calculate numbers of females with wing-lengths less than 76.0 mm:

$$N_{F\ 75\ mm} = N_{M+F\ 75\ mm} - N_{M\ 75\ mm} = 49 - 8 = 41$$
$$N_{F\ 74\ mm} = N_{M+F\ 74\ mm} - N_{M\ 74\ mm} = 36 - 3 = 33$$
$$N_{F\ 73\ mm} = N_{M+F\ 73\ mm} - N_{M\ 73\ mm} = 30 - 1 = 29$$
$$N_{F\ 72\ mm} = N_{M+F\ 72\ mm} - N_{M\ 72\ mm} = 16 - 0 = 16$$
$$N_{F\ 71\ mm} = N_{M+F\ 71\ mm} - N_{M\ 71\ mm} = 10 - 0 = 10$$
$$N_{F\ 70\ mm} = N_{M+F\ 70\ mm} - N_{M\ 70\ mm} = 1 - 0 = 1$$
$$N_{F\ 69\ mm} = N_{M+F\ 69\ mm} - N_{M\ 69\ mm} = 1 - 0 = 1$$

Another data set of wing-lengths of known sex comes from our studies on the Mountain White-crowned Sparrow (*Z. l. oriantha*) on Hart Mountain National Wildlife Refuge in south central Oregon (King and Mewaldt, manuscript). Because our field work was done during the breeding season, sex was determined by cloacal protuberance in males and by readiness to lay or presence of incubation patch in females. Wing-lengths were taken as the chord with a steel rule, with a bend-of-wing stop, to the nearest mm. These are displayed along with results from application of the method in Table 3. A substantial portion of the higher

TABLE 5. Wing-lengths of fall migrant and wintering Gambel's White-crowned Sparrows captured (1969–1980) for banding at San Jose, California.

Wing-length (mm)	Number HY-SY			Number AHY-ASY		
	M & F	Est. M	Est. F	M & F	Est. M	Est. F
81	1	1		4	4	
80	1	1		14	14	
79	10	10		67	66	1
78	49	48	1	190	185	5
77	173	169	4	317	302	15
76	375	361	14	297	262	35
75	401	362	39	168	104	64
74	329	198	82	121	56	65
73	206	120	135	138	24	114
72	257	56	201	155	8	147
71	235	21	214	98	2	96
70	145	6	139	32		32
69	52	1	51	8		8
68	17		17			
N	2251	1354	897	1609	1027	582
x̄	73.8	75.1	71.8	75.2	76.6	72.9
SD	±2.3	±1.6	±1.7	±2.4	±1.5	±1.8

HY-SY: M:F::151:100 or 60.2% males.
AHY-ASY: M:F::176:100 or 63.8% males.
Age ratio: HY-SY:AHY-ASY::140:100 or 58.3% HY-SY.

proportion of males in the sample may be attributed to the higher catchability of males while females were incubating or brooding.

Application of method to data sets of unknown sex.—We have applied the method (Tables 4 and 5) to two blocs of data collected as part of the Western Bird Banding Association's White-crowned Sparrow Project of the mid-1970s (King and Mewaldt 1981, Mewaldt 1975, Mewaldt and King 1978). Here again we apply statistical tests for variance and confidence limits to help characterize the derived arrays of data. Several findings from these applications of the method follow:

1. Mean wing-lengths of AHY-ASY white-crowns were 0.8–1.6 mm longer (Tables 4 and 5) than those of HY-SY white-crowns (*t*-test $P < 0.001$ in the 6 possible comparisons). This compares favorably with Mewaldt's (1973) findings (1.1 to 1.5 mm longer) using individual case histories.

2. Males showed greater increases from HY-SY to AHY-ASY (1.5 mm and 1.6 mm) than females (1.1 mm and 0.8 mm) in samples taken at San Jose and at Tucson, respectively.

3. Greater percentages of males were present in the San Jose population (HY-SY = 60.2 and AHY-ASY = 63.8) than at Tucson (HY-SY = 38.7 and AHY-ASY = 41.7). This reinforces King et al. (1965) who found that males tend to winter farther north than females.

4. There were increases in male to female sex ratio (M:F) from the

HY-SY segment to AHY-ASY segment for the San Jose population (60.2:39.8 to 63.8:36.2) and for the Tucson population (38.7:61.3 to 41.7: 58.3). These suggest higher survival of males in the populations of Gambel's White-crowned Sparrows that winter in west central California and in southern Arizona.

DISCUSSION

The procedure we have used estimates distributions of wing-length accurately in sample populations of White-crowned Sparrows. Once these distributions have been charted it is possible to provide realistic estimates of mean wing-lengths by sex, and to estimate sex ratios. Confidence in the arrays of data derived by the method increase with the size of the sample.

Caution should be exercised in comparing data taken from museum study skins and data taken from living birds. Green (1980) working with shorebirds and Knox (1980) working with Rooks (*Corvus frugilegus*) have confirmed the generally held notion that wing-length measurements of freshly collected birds are greater than after they have been prepared as skins and have been allowed to dry for several months.

Wing-lengths, are easy to take and are commonly taken in field studies when birds are examined in the hand at the time of banding. However, such data suffer from investigator variability in technique. Such variability can be reduced substantially by carefully controlling the method of measurement and reducing the number of investigators taking wing measurements to as close to one as possible.

SUMMARY

A method is developed to separate distributions of wing-lengths by sex in White-crowned Sparrows. These distributions may then be used to estimate mean wing-lengths by sex and to estimate sex ratios. The derived distributions by sex compare well with known distributions from museum skins and from a field study when white-crowns were sexed from secondary sexual characteristics during the breeding season. When the method is applied to populations in southern Arizona and central coastal California it yields useful information on geographical variation in sex ratio on the wintering ground and changes in sex ratio with age useful in demography.

ACKNOWLEDGMENTS

We thank Charles E. Corchran, Donald W. Lamm, and Steven M. Russell for use of data collected at Tucson, Arizona. For permission to measure specimens in their care, we thank the curators of the Museum of Vertebrate Zoology, University of California, Berkeley, the California Academy of Sciences, San Francisco, and the Museum of Birds and Mammals, San Jose State University. We are grateful to the many persons who assisted us in the field on Hart Mountain in Oregon and at San Jose in California. We acknowledge with thanks review of our methods of estimation by the Washington State University Statistical Service Center and by Jonathan Bart, but take full responsibility for our presentation. R. Johnson prepared the computer program for application of the estimation procedures. These studies were supported logistically or fiscally by Hart Mountain National Wildlife Refuge, San Jose State University, Washington State University, and in part by a grant to King from the National Science Foundation [DEB 7909806].

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APPENDIX A

Diminution values for Procedures A and B were obtained by innovation of an extension to fitting the normal curve by the ordinate method (Arkin and Colton 1970). Here it is necessary to calculate deviations from the mid-point of a distribution in standard deviations. A table of normal curve ordinates (e.g., Arkin and Colton 1970:132–133) is then consulted to obtain decimal values of the maximum ordinate for each class interval, or group, in accordance with its deviation, in standard deviations, from the mid-point (Tables A and B). Our innovation is to calculate the second order percent, or diminution percent, that each per-

TABLE A. Calculation of normal distribution for a mean of 76.0 ± 2.0 and of applicable diminution percentages.

$\bar{x}$	Deviation	Deviation in standard deviations	Percent of maximum ordinate[1]	Diminution percents by steps[2]	Round off previous column[3]
82	6	3.0	1.11	25.28	25
81	5	2.5	4.39	32.45	32
80	4	2.0	13.53	41.68	42
79	3	1.5	32.46	53.52	54
78	2	1.0	60.65	68.72	69
77	1	0.5	88.25	88.25	88
76	0	0.0	100.00	100.00	100
75	−1	−0.5	88.25	88.25	88
74	−2	−1.0	60.65	68.72	69
73	−3	−1.5	32.46	53.52	54
72	−4	−2.0	13.53	41.68	42
71	−5	−2.5	4.39	32.45	32
70	−6	−3.0	1.11	25.28	25

[1] From table of normal curves ordinates as decimal of maximum ordinate.
[2] Percent by steps of each next higher value from the mid-point.
[3] These are the values actually used in the procedure.

cent of the maximum ordinate is of its next higher percent of the maximum ordinate. The necessary steps are tidy when the class intervals are in whole millimeters and when the standard deviation is also in whole millimeters. (Other units of measurement could also be used.) In this

TABLE B. Calculation of normal distribution for a mean of 76.5 ± 2.0 and of applicable diminution percentages.

$\bar{x}$	Deviation	Deviation in standard deviations	Percent of maximum ordinate[1]	Diminution percents by steps[2]	Round off previous column[3]
83	6.5	3.25	—[4]	—	—
82	5.5	2.75	2.28	28.64	29
81	4.5	2.25	7.96	36.80	37
80	3.5	1.75	21.63	47.25	47
79	2.5	1.25	45.78	60.65	61
78	1.5	0.75	75.48	77.88	78
77	0.5	0.25	96.92	96.92	97
76	−0.5	−0.25	96.92	96.92	97
75	−1.5	−0.75	75.48	77.88	78
74	−2.5	−1.25	45.78	60.65	61
73	−3.5	−1.75	21.63	47.25	47
72	−4.5	−2.25	7.96	36.80	37
71	−5.5	−2.75	2.28	28.64	29
70	−6.5	−3.25	—	—	—

[1] From table of normal curves ordinates as decimal of maximum ordinate.
[2] Percents by steps of each next higher value from the mid-point.
[3] These are the values actually used in the procedure.
[4] Outside the range of the source table, but could be extrapolated.

case a standard deviation of ± 2.0 mm is typical in our known distributions in the White-crowned Sparrow (Tables 1–3).

[Computer Program Available.—A computer program, applicable to birds of the approximate size and dimorphism as the birds considered in this report, has been prepared. Written for IBM compatible computers, you may obtain the program on a 5¼ inch diskette from the senior author for a reasonable charge.]