SEX RATIOS AND MEASUREMENTS OF MIGRANT GOSHAWKS

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In a recent paper (Mueller and Berger, 1967) we showed that it is the younger members of the population of Goshawks (*Accipiter gentilis*) that invade areas south of the breeding range during autumn and winter. We are now able to report that there also appears to be a differential migration of the sexes. For some years we have been confident that an experienced worker could determine the sex of a living Goshawk simply by noting the relative size of the bird. We were reluctant to publish our findings based on sex determinations made by size alone because data from museum specimens usually indicated considerable overlap between the measurements of the sexes. Storer (1966) has recently provided an independent confirmation of the validity of our techniques of sex determination by showing that considerable sexual dimorphism exists in the size of Goshawks and that museum collectors often err in determining the sex of hawks.

In the autumns of 1951 through 1964 we live-trapped, examined, and measured 105 Goshawks at the Cedar Grove Ornithological Station in southeastern Wisconsin. Wing chord was measured by placing the carpal joint of the closed wing on a metric rule placed on a table edge and pivoting the wing downward until the tip of the longest primary touched the rule. Pressing the wing flat provided a measurement of wing arc. The length of the tail was measured by inserting a thin metal rule between the central rectrices and sighting across the tips of the two longest rectrices. The birds were placed head downward in upright metal cylinders of appropriate diameter and weighed to the nearest gram on a triple-beam balance calibrated to 0.1 g. The weight of the contents of the esophagus ("crop") was estimated and subtracted from the gross weight.

An examination of the plumage permitted us to place birds into three age classes: (1) Juvenals, (2) Adult I, including birds more than one but less than two years old, and (3) Adult II, including all birds more than two years old (see Storer, 1966; Mueller and Berger, 1967).

We determined the sex of each bird by a series of approximations. All but seven birds were tentatively assigned to a sex class by qualitative judgment at the time of capture. The measurements of wing chord and tail length for all Goshawks handled, irrespective of age class, were graphed. For both measurements the resulting distribution resembled two normal curves. The curve with the smaller mean was composed of birds qualitatively judged to be males; the larger, females. The seven undetermined birds fell largely into the zone of overlap. These seven birds were somewhat arbitrarily assigned to one or the other of the sexes, and the

TABLE 1
MEASUREMENTS OF WING ARC OF GOSHAWKS

Age	*Sex*	*n*	*Extremes*	*Mean + standard error*	*Standard deviation*	*Coefficient of variation*
Juvenal	♂	39	315–338	325±0.9	5.6	1.72
Juvenal	♀	18	342–365	353±1.6	6.6	1.87
Adult I	♂	15	325–344	333±1.2	4.5	1.35
Adult I	♀	11	350–376	357±2.4	8.0	2.24
Adult II	♂	12	320–343	329±1.5	5.3	1.61
Adult II	♀	9	351–370	362±2.4	7.1	1.96
Adult	♂[1]	25	309–338	323±1.6	7.8	2.42
Adult	♀[1]	42	339–374	354±1.3	8.6	2.44

[1] Data from Storer (1966).

mean and variance was calculated for each sex. A normal curve calculated for each distribution did not differ significantly from the actual distribution (chi-square test). The normal curves were ended arbitrarily where the calculated ordinal value became less than 0.05 (bird) units. The two curves for wing chord overlapped between 329 and 339 mm; the measurements of 10 hawks fell into this interval. The two curves for tail length overlapped between 246 and 254 mm; the measurements of five birds occurred in this interval. Nine of the birds with wing measurements in the overlap zone had tail measurements that were not in the overlap zone, and these were accordingly assigned to sex on the basis of tail measurement. Four of the birds with tail measurements in the overlap zone had wing measurements that were not in the overlap zone, and these were accordingly assigned to sex on the basis of the wing measurement. Only one bird had both wing and tail measurements that fell in the overlap intervals; it was classed a male because both measurements were more within the calculated normal curve for the male distribution than that for the female.

The measurements of wing arc for the six age and sex classes as determined by our techniques are given in Table 1, along with data from museum specimens from Storer (1966). Museum specimens appear to have a shorter wing than live birds, presumably from shrinkage in drying. Our measurements exhibit less variation than those of Storer (Table 1), possibly because we segregated two classes of adults whereas Storer combined them, and we obtained all our measurements at one locality during a 3-month calendar interval in contrast to the wide area and entire year over which Storer obtained his data. Our measurements otherwise are very similar to those of Storer, and it seems unlikely that we reduced variability by mistakenly assigning birds to the wrong sex class.

The sex ratio of adults does not differ significantly from a 1:1 ratio, although a few more males were taken than females (Table 2). The sex

TABLE 2
SEX RATIOS OF GOSHAWKS

Years	*Juvenal*		*Adult I*		*Adult II*	
	♂	♀	♂	♀	♂	♀
1950–60, 1964	19[1]	8	1	3	2	2
1961–63	20	10	14	8	10	7
Total	39[2]	18	15	11	12	9

[1] Significantly more birds of this sex than predicted by a 1:1 sex ratio; chi-square test, 95 per cent level.

[2] 99 per cent level.

ratio of the juvenals was 2.2 males to each female, which is significantly different from a 1:1 ratio. This unbalanced sex ratio of juvenals existed both in the invasion years of 1961 through 1963 (Mueller and Berger, 1967) and the non-invasion years (Table 2). Juvenal males begin southward migration much earlier in the autumn than do juvenal females; the earliest date we captured a male was 17 September, the first female was taken on 18 October, by which date 12 males had been taken. Juvenal males continue to occur at least as commonly as juvenal females through the remainder of the season; e.g. 5 males and 6 females were taken from 21 November through 16 December. It is possible, although we believe it unlikely, that southward movements of Goshawks continue on into late December and January and that females eventually dominate in the sex ratio. Limited observations suggest that little migration occurs after early December.

The median date of catch for juvenal males was 25 October; for females, 30 October. The median date of catch for Adult I males was 21 November; for females, 20 November. The median date of catch for both Adult II males and females was 13 November. Our data show no segregation of the sexes in the time of migration in either class of adults.

The preponderance of males among the migrating juvenals and their earlier southward movement may be due to nothing more than a sex-linked difference in migratory behavior. We have presented data and arguments (Mueller and Berger, 1967) that suggest the older, established birds displace younger, poorly established birds from a range that cannot support large wintering Goshawk populations, and similar behavioral mechanisms may be acting to displace the smaller males more often than the larger females. This hypothesis, and almost any other, does not offer an adequate explanation for the fact that among both classes of adults the sexes migrate in approximately equal numbers. It may be that once adults are established on an area both sexes remain unless the area is inadequate for any Goshawk. Also, displaced adult males might be able to compete more effectively with juvenal females than can the juvenal males, resulting

TABLE 3
MEASUREMENTS OF GOSHAWKS

Measurement	*Age*	*Sex*	*n*	*Mean*	*S.D.*	*Extremes*
Wing chord (mm)	Juvenal	♂	39	317	5.7	301–330
	Adult I	♂	15	325[2]	4.8	317–335
	Adult II	♂	12	322[1]	6.2	309–336
	Juvenal	♀	18	345	5.8	335–355
	Adult I	♀	11	352[1]	7.4	341–367
	Adult II	♀	9	354[2]	6.9	344–365
Tail (mm)	Juvenal	♂	39	238	6.3	221–252
	Adult I	♂	15	233	4.6	224–242
	Adult II	♂	12	227[2]	5.0	219–238
	Juvenal	♀	18	269	8.1	225–283
	Adult I	♀	12	265	6.4	254–273
	Adult II	♀	9	268	10.2	244–281
Weight (g)	Juvenal	♂	38	802	76.7	664–924
	Adult I	♂	15	906[2]	48.8	827–986
	Adult II	♂	12	915[2]	92.9	735–1035
	Juvenal	♀	18	1031	107.6	883–1285
	Adult I	♀	12	1127[1]	84.7	960–1247
	Adult II	♀	9	1189[2]	85.0	1035–1342

[1] Differs significantly from juvenal at the 95 per cent level (*t* test, two tailed).
[2] Differs significantly from the juvenal at the 99 per cent level.

in a somewhat greater movement of juvenal females and a reduced movement of adult males (Table 2).

Our data indicate that adult Goshawks are significantly longer winged and heavier than are juvenals (Table 3). Adult males also have shorter tails than Juvenal males. Storer (1955, 1966) has indicated that if body proportions remain the same an increase in wing-loading and more rapid flight is necessary for the bird to remain airborne. The more rapid flight would also presumably result in an increase in the impact of the hawk in striking its prey. These considerations are based on the observation that wing area is proportional to the square of the linear dimension. In our sample of Goshawks the ratio of Adult II weight to juvenal weight was 1.148 in males and 1.153 in females. The ratio of the cube of wing chord was 1.048 in males and 1.080 in females. The increase in weight thus seems to be greater than that expected merely on the basis of increase in size. Wing loading, flight speed, and force of impact are thus further increased in adults, presumably also increasing their competitive advantage over the juvenals. However, the greater than expected increase in weight may be largely the result of a seasonal increase in weight. On the average juvenals were caught earlier in the autumn than adults. Except for one sex and age class, the last 50 per cent of the Goshawks taken in the autumn averaged higher in weight than those taken earlier in the autumn (Table 4). This seasonal difference in weight was statistically significant in three of the six sex and age classes. It would thus appear that part of the dif-

TABLE 4
COMPARISON OF EARLY AND LATE FALL WEIGHTS OF GOSHAWKS

Age	Sex	*First 50% caught*		*Last 50% caught*	
		Mean	*S.D.*	*Mean*	*S.D.*
Juvenal	♂	772	74	823[1]	70
Adult I	♂	882	49	930	50
Adult II	♂	931	87	899	97
Juvenal	♀	962	57	1100[2]	102
Adult I	♀	1106	64	1144	94
Adult II	♀	1135	56	1240[2]	66

[1] Differs significantly from the weight of the first 50 per cent at the 95 per cent level (*t* test, two-tailed).

[2] Differs significantly at the 99 per cent level.

ference in weight between juvenals and adults is due to the fact that more juvenals are taken earlier in the season, when all birds are lower in weight.

Since massed southward flights of Goshawks are usually attributed to a shortage of food (see Bent, 1937: 137), it is of interest to compare the weights of Goshawks taken in invasion and non-invasion years. The mean weight of juvenal females taken in the invasion years of 1961–1963 was 92 g higher than the mean weight of those taken in non-invasion years. The juvenal males showed the opposite trend and were 34 g lighter during the invasion years than during the non-invasion years. Neither difference was statistically significant. The few adults taken during non-invasion years do not provide a sufficient sample for statistical comparison with invasion years. In all, it would seem that the interannual variation in Goshawk weights is no greater than the intraseasonal variation.

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SUMMARY

In the autumns of the years 1951 through 1964 we trapped 105 Goshawks at the Cedar Grove Ornithological Station in southeastern Wisconsin. The sex of each bird was determined by relative body size and wing and tail measurements. Significantly more juvenal males were taken than juvenal females. The sex ratio of the adults, however, did not differ significantly from 1:1. Juvenal males began autumnal migration before the females while both sexes of adults appeared to migrate simultaneously.

The means of wing measurements and weights of adults were greater than those of juvenals. The variation in weight within a season was at least as great as the variation in weight between invasion and non-invasion years. We hypothesize that the smaller juvenal males are more easily displaced from an inadequate winter range than either the larger, juvenal females or the adults of either sex.

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