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BIOMETRIC DIFFERENCES BETWEEN AGE AND SEX CLASSES OF THE LEVANT SPARROWHAWK *ACCIPITER BREVIPES* ON MIGRATION AT EILAT, ISRAEL

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ABSTRACT

The Levant sparrowhawk (*Accipiter brevipes*) is a typical raptor with reversed sexual size dimorphism wherein the female is larger than the male. Here, we present the factors contributing to biometric differences between the age and sex classes. Starting from 1984, 1164 Levant sparrowhawks were captured and banded in the area immediately to the north of Elat, Israel. Comparing mean values, feather-dependent characters were 6.6–7.3% larger in adult females than in adult males, and 6.2–6.8% larger in second year females than in second year males. Differences were greater for culmen and hallux length and for body mass. We found wing cord and body mass to be the parameters most efficient in separating sex or age classes. Upon performing discriminant analyses on our data set, we found that hallux length varied independently between males and females, irrespective of the age of the bird. Our data establish that the Levant sparrowhawk is the least dimorphic of the European *Accipiter* species but has a sex-specific hallux size.

INTRODUCTION

The Levant sparrowhawk (*Accipiter brevipes*) is a typical raptor with reversed sexual size dimorphism wherein the female is larger by 9–10% than the male (Cramp and Simmons, 1980; Clark and Yosef, 1997; Gorney et al., 1999). Males have blue-gray upper parts and darker flight feathers, under parts are buff or pinkish on the breast and underwing coverts, and the underwing is white with black ends to the primaries (Cramp and Simmons, 1980; Forsman, 1998; Clark and Yosef, 1998). In contrast, females have brown-gray upper parts. Juveniles are usually described with upper parts a darker brown than females and heavily streaked with tear-shaped elongated spots on the chest. Underwing coverts of juveniles are narrowly barred, and only the tips of the primaries

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are darker than in adult females. Males have a pale throat divided by a dark line, and the tail is paler than in females (Cramp and Simmons, 1980).

Levant sparrowhawks are considered scarce (Cramp and Simmons, 1980; Wallace, 1983) and are one of the three raptor species whose breeding distribution is limited to the Western Palearctic region (Hagemeijer and Blair, 1997). Recent studies have illustrated that in spring, Levant sparrowhawks concentrate in the Elat–Aqaba region in great numbers (e.g., 45,000–55,000; Safriel, 1968; Shirihai and Christie, 1992; Yosef, 1995; Shirihai et al., 2000) and migrate north along the rift valley towards Syria and Lebanon (Frumkin et al., 1995), heading for Syria, Romania, Ukraine, and Russia (Yosef, 1998).

Elat is situated at the northern edge of almost 2000 km of continuous desert regions of the Sahara and Sinai. Hence many birds land here to rest after crossing the deserts (Safriel, 1968). In the framework of the only migratory raptor banding program of the Old World, we attempted to capture and band a maximum number of Levant sparrowhawks from mid-April till early May between the years 1996–1998. In addition, we included data from previous raptor banding programs conducted at Elat between the years 1984 and 1988 (Clark, 1995; Gorney et al., 1999).

Little has been published on the Levant sparrowhawk on its breeding grounds (Cramp and Simmons, 1980), and most researchers (e.g., Clark and Yosef, 1997; Gorney et al., 1999) and field guides (Clark 1999; Forsman, 1999) report that the adult sexes are dimorphic and that age classes are easily identified by plumage. As pointed out by Clark and Yosef (1997), in the Levant sparrowhawk differences between age and sex classes are smaller than those in similar species. Feather-dependent characters (wing cord, tail length) in other European *Accipiter* species are 10–20% longer in females than in males, while culmen and hallux lengths are 14–27% longer, (Cramp and Simmons, 1980). Moreover, females are heavier than males by 40–50% in *Accipiter badius*, 60% in *Accipiter gentilis*, and 80% in *Accipiter nisus* (Cramp and Simmons, 1980). However, we and Shirihai (pers. comm.) have observed overlap between classes in the field for Levant sparrowhawk. Hence, the aim of this paper is to present the main parameters that contribute to the biometric differences between the age and sex classes and to suggest a method to help separate the four age and sex classes.

MATERIALS AND METHODS

Levant sparrowhawks were captured and banded in the area immediately to the north of Elat, Israel. A fixed raptor banding station was set up in the agricultural fields of Kibbutz Elot that consisted of bow-nets, mist nets, and dho-gazas operated from a blind (cf. Clark, 1970, 1981; Clark et al., 1986; Gorney et al., 1999). In addition, two sets of mist nets 120 m long were set parallel to tree lines (Fornasari, 1987), bal-chatri traps (Berger and Mueller, 1959) were used from a mobile vehicle to capture perched or low-flying raptors, and box traps were placed in the date palm plantations (Clark and Yosef, 1997).

All Levant sparrowhawks captured were fitted with appropriate-sized aluminum bands. The species, age (either second-year or after-second-year), sex, wing cord (unflattened), and body mass of each raptor were noted on a banding form. The aging of

Levant sparrowhawks was based on plumage and molt (Clark and Yosef, 1998). Length of culmen, hallux, and tail were also taken from a smaller subset of birds. Our reference to the word hallux pertains specifically to the hind claw; this is to better understand our forthcoming arguments with Mueller and Meyer (1985), who describe the same just as "claw" and also relate to the toe separately.

We performed one-factor ANOVA on each of the biometric parameters measured, and age and sex differences were tested by means of the Tukey multiple range test (Zar, 1984). Based on Fischer F estimates, we decided upon the major discriminating factors that separate sex and age classes in the Levant sparrowhawks. We performed discriminant analysis to identify a linear function that would explain the overall data variability according to the age and sex class biometrics measured (Manly, 1994). Unless otherwise stated, all measured data are presented as mean ± SE, N, and range. We chose $p = 0.05$ as the minimum acceptable level of significance.

DATA COLLECTION

The data included in this study were collected between the years 1984 and 1988 (cf. Clark and Yosef, 1997; Gorney et al., 1999) in the framework of a joint raptor trapping and ringing project of the Society for Protection of Nature in Israel and the International Birding & Research Centre in Eilat (IBRE). The project was reinitiated in 1996 by the IBRCE (Clark and Yosef, 1997) and continues to date. Data up to May 1999 are reported here.

RESULTS

During the nine spring raptor banding seasons a total of 1560 Levant sparrowhawks were captured and ringed, of which 462 were between the years 1984–1988 (Gorney et al., 1999) and 1098 between the years 1996–1999 (1996—Clark and Yosef, 1997; 1997–1999—unpubl. data). From these two data sets, 340 and 381 individual Levant sparrowhawk measurements, which included all the parameters we required for our analyses, were selected (Fig. 1). An additional 15 birds were not included in the analyses as obvious outliers (mistaken identity) for the parameters included in our study.

As reported by Clark and Yosef (1997) and Gorney et al. (1999), all of the measured parameters show a significant difference between sexes, with females being larger than males and adults larger than juveniles (Table 1). In all of the multiple comparisons between the age and sex classes, we found a significant difference, except for hallux size between adult and juvenile females.

Comparing mean values, wing cord was 7.3% larger in adult females than in adult males, 7.8% larger in second year females than in second year males: similar values were found for tail length and hallux (7.9% vs. 7.8% and 8.0% vs. 8.8%, respectively). These differences were higher for culmen (10.2 and 11.2%) and even higher for body mass (23.4% in adult birds and 24.1% in second year birds).

Age-related differences within sexes were comparatively small when compared to sex-related differences. Body mass was greater (7.2% in females and 7.8% in males) and

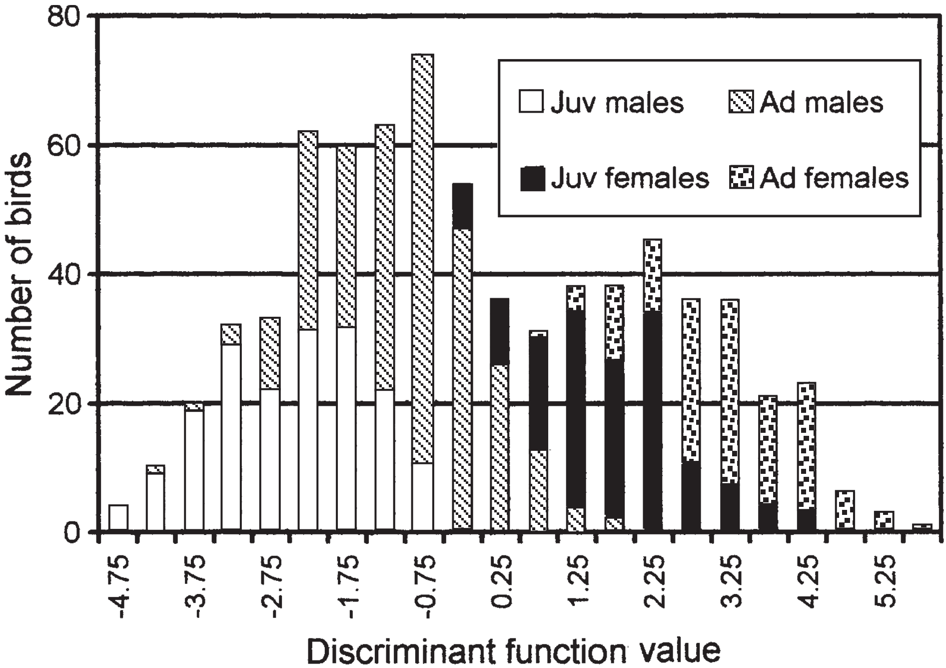

Fig. 1. Distribution of Levant sparrowhawks measured on migration at Elat, Israel, according to their discriminant function values (see text for further details). Juv = juvenile; Ad = adult.

Table 1
Biometrics of Levant sparrowhawks (*Accipiten brevipes*) trapped at Elat, Israel. Data are presented as mean ± SE, *N*, and range in parentheses

Parameter	Adult female	Juvenile female	Adult male	Juvenile male
Wing cord, mm	234.9 ± 0.4, 267 (224–247)	226.4 ± 0.4, 248 (212–243)	218.9 ± 0.3, 370 (200–232)	209.9 ± 0.4, 270 (195–224)
Tail, mm	168.6 ± 0.5, 102 (155–193)	163.5 ± 0.5, 115 (139–179)	156.3 ± 0.3, 142 (141–172)	151.7 ± 0.4, 143 (134–167)
Culmen, mm	14.1 ± 0.05, 68 (11.9–15.6)	13.9 ± 0.04, 94 (12.8–15.2)	12.8 ± 0.03, 123 (10.3–14.6)	12.5 ± 0.04, 128 (10.0–14.4)
Hallux, mm	14.9 ± 0.05, 68 (13.2–16.8)	14.8 ± 0.05, 96 (13.1–16.8)	13.8 ± 0.04, 124 (11.0–15.8)	13.6 ± 0.04, 129 (11.8–15.2)
Body mass, g	207.0 ± 2.2, 263 (110–290)	193.3 ± 1.6, 248 (150–243)	167.9 ± 1.1, 362 (108–268)	155.8 ± 1.3, 270 (115–205)

Table 2
Pooled within-group correlations between discriminating variables and canonical discriminant functions (variables are ordered by size of correlation within function). All variables were retained in the analysis. The symbol "*" denotes largest absolute correlation between each variable and any discriminant function. The percent of variability explained by each function is also shown

Variable	Function 1	Function 2	Function 3
Cord	0.783*	–0.592	–0.121
Tail	0.526*	–0.062	0.416
Mass	0.455*	0.085	0.415
Culmen	0.547	0.554*	0.072
Halux	0.435	0.444	–0.632*
% Variance	95.87	3.99	0.15

wing cord (3.8% and 4.3%) and tail length (3.1% and 3.0%) were longer in adults in comparison to the juveniles of the same sex. Age-related differences within sexes were small for hallux (0.7% in females, 1.5% in males) and culmen (1.4% in females and 2.4% in males); this was possibly due to the direct relationship of these parameters with hunting behavior (cf. Mueller and Meyer, 1985) that might be consistent among all birds of the same sex (Selander, 1966; Storer, 1966), such as in the merlin, *Falco colombarius*, (e.g., Newton, 1979; Wiklund, 1996). In effect, as a general statement on the Falconiformes of the Western Palearctic, Mueller and Meyer (1985) indicated that bill length and hind claw are the greatest sexually dimorphic characters.

We found the highest F values in wing cord (652.3, p <<0.01). Culmen (323.2, p <<0.01), tail (287.1, p <<0.01), and body mass (215.6, p <<0.01) had lower values, and hallux (205.0, p <<0.01) had the lowest values. Since Fischer F is a ratio between two variances, related respectively to the parameter variability among classes and within classes, the higher the ratio, the higher the probability that the classes we are dealing with show different values, or may be distinguished on the basis of those values. This indicated that the wing cord is the most efficient univariate parameter in separating sex or age classes. We considered body mass to be a less reliable parameter, a conclusion borne out by the data, because this study pertained to the migratory stage of their lifecycle wherein the largest differences and fluctuations were to be expected.

The discriminant analyses helped identify three different functions with different correlates to the univariate parameters (Table 2). Wing cord, tail, and body mass had the highest correlation values, with function 1 indicating that all of the measured variables were consistent with the others and varied in the same manner. On the other hand, culmen and hallux were best correlated with functions 2 and 3, respectively (Table 2). This substantiated our findings that culmen varied mainly with age and hallux with sex.

Function 1 explained 95.9% of the total variability in the data set. This allowed us to retain this single function to assign each individual to its inferred sex or age class.

Table 3
Classification results of the discriminant analysis applied to the overall sample of Levant sparrowhawks. Percent of "grouped" cases correctly equals 76.56%. 1 denotes adult female, 2 denotes juvenile female, 3 denotes adult male, and 4 denotes juvenile male

		Inferred class membership			
Age/Sex class	N	1	2	3	4
Group 1	132	101 76.5%	29 22.0%	2 1.5%	0 0.0%
Group 2	146	27 18.5%	104 71.2%	15 10.3%	0 0.0%
Group 3	264	0 0.0%	12 4.5%	216 81.8%	36 13.6%
Group 4	179	0 0.0%	0 0.0%	48 26.8%	131 73.2%

The full function is expressed as follows:

$$Vs = 0.074B + 6.978W + 1.604T + 32.247C + 28.028H - 1399.462$$

where Vs is the value of the discriminant function for the specimen "s" on the basis of its measurements, B = body mass, W = wing cord, T = tail, C = culmen, H = hallux. Based on this, the percent of "grouped" cases correctly classified was 76.6% (Table 3).

To improve our ability to discriminate between the sex and age classes, we classified all specimens into categories of 0.5 width along the axes identified by the discriminant function values (Fig. 1). The four classes displayed zones of overlap which explain the 23.4% discrepancy in correct classification for each individual. However, our ability to separate the juveniles from the adults based on the retained "tear-drop" juvenile feather increased our ability to correctly separate the sexes within age classes by 100% in juveniles and >95% in adults. Hence, it is evident that there was no overlap between the juvenile sex classes and almost no overlap between the adult sex classes (Fig. 1); males are under the threshold values, females are over, with discriminant values at –0.5 for juvenile birds and 1.0 for adult birds (2.3% of errors in males, 4 individuals out of 264, and 1.5% in females, 2 individuals out of 151). Conversely, if only univariate analyses were performed on the data set (see Table 1), all the variables showed a distinct overlap.

DISCUSSION

Owing to the fact that the Levant sparrowhawk undertakes the longest migration of the Palearctic *Accipiter* species (see Cramp and Simmons, 1980; Shirihai et al., 2000), the environmental pressures exerted have resulted in a wider "uniformity" of biometric parameters among the sex and age classes. In fact, feather measurements and body mass vary together. Wyllie and Newton (1994) also reported strong correlations between hand-wing and other characters in a large sample of female Eurasian sparrowhawk. The exception we found to this rule was hallux length, which varied independently between males and females irrespective of the age of the bird.

We concur with Mueller and Meyer (1985) that culmen length is a “trophic structure” in the sense that it does not vary with the different trophic attitudes of the two sexes, but with the size of the bird; in fact, according to our data, it depends mainly on the age. Bill length is usually regarded as a measurement of a trophic appendage, but in Accipitridae, its importance is questionable since prey is seized by the feet, and the beak is used merely to dismember prey (Mueller and Meyer, 1985).

Further, we agree with Mueller and Meyer (1985) that the hallux is a reliable measure indicative of sexual dimorphism. Our data suggest that the lifestyle and hunting habits of the Levant sparrowhawk have resulted in a consistent sexual dimorphism, which varies independently of all the other biometric parameters. On the other hand, based on behavioral observations, Mueller and Meyer (1985) stated that three *Accipiter* species (*A. striatus*, *A. cooperii*, *A. gentilis*) do not necessarily use the hallux to immediately kill prey, which are almost exclusively avian (Cramp and Simmons, 1980). However, our findings do not necessarily contradict Mueller and Meyer (1985), because the Levant sparrowhawk differs from the species they studied in that it has a very diverse prey base, which also includes mammals, possibly due to its long-distance seasonal migrations. Proof of this can be found in the fact that the above three *Accipiter* species are caught almost exclusively on bird lure, while the majority of the Levant sparrowhawk are trapped at Elat on bal-chatri traps containing laboratory mice.

In conclusion, our data concur with Mueller and Meyer (1985) who stated that the most dimorphic species specialize on birds, while mammalian predators are dimorphic to a lesser extent. The Levant sparrowhawk is the least dimorphic of the European *Accipiter* species. The species shows a different morphological pattern in males and females, which becomes evident when several biometric variables are analyzed together. The method used in this study allowed us to separate the different age and sex classes with greater accuracy than previously published studies wherein biometric comparisons were made (e.g., Clark and Yosef, 1997, Gorney et al., 1999). Discriminant analysis may allow the identification of those individuals that are either misidentified in the field or the identification of possible hybrids (RY, unpublished data) that do not fit into either of the categories evaluated.

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