Footpad Dimorphism as a Possible Means to Determine Sex of Adult and Juvenile Northern Spotted Owls (*Strix occidentalis caurina*)

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INTRODUCTION

Determination of sex in monochromatic species is often difficult without the aid of behavioral clues or sex- determination models that are based on morphometrics. Behavioral clues to gender, such as vocalizations, are considered one of the most reliable means to determine sex of adult Spotted Owls (*Strix occidentalis*) (Forsman et al. 1984). Recent research indicates that female Spotted Owls have significantly greater weight, wing length, tail length, bill length, bill depth, number of tail bars, and tarsus length than males (Blakesley et al. 1990). However, none of these measures reliably determines sex of juveniles. For example, 6 of 8 juveniles that had been sexed based on a count of tail bars were found as adults to have been sexed incorrectly (Blakesley et al. 1990).

A reliable method to determine sex, particularly of juveniles, will enhance understanding the demography of Spotted Owls. Footpad measurements have been used to determine sex of several other raptor species (Table 1). Here, we describe the potential for footpad measurements to aid sex determination of juvenile Spotted Owls. We also describe the proper method to record this measure, and recommend various other morphological measurements that may be useful for sex-determination models.

METHODS

We captured, measured and banded adult (n = 40) and juvenile (n = 20) Spotted Owls in the Wenatchee National Forest, Washington, between 18 June and 28 August in 1989-90. All adult owls occurred as pairs and were sexed by factors including behavior (e.g. vocalizations), size (weight, wing length), and presence of a brood patch. In all cases, these factors resulted in accurate sex determination of adults.

Footpad Measurement.--With the owl in hand, we measured (to the nearest 0.1 mm) the total length from the tip of the middle toe to the tip of the hallux with dial calipers (Figure 1; see also Bortolotti [1984], Figure 1). This measure differs from, and should not be confused with, foot measures reported by Baldwin et al. (1931). The foot must be fully open when this measurement is taken; measurements of even slightly clenched footpads will result in inaccurate measurement and a greater likelihood of misidentification of sex (Edwards and Kochert 1986). It is best to have one person extend the talons while a second person makes the measurement. To minimize error, several readings (by one or more individuals) should be taken for each footpad, until multiple readings indicate the foot is fully relaxed (Henny et al. 1985, Edwards and Kochert 1986). We observed slight differences between left and right footpads on some individual birds; we used the largest of the two measurements whenever this occurred.

RESULTS AND DISCUSSION

We found that 21 adult males had a significantly smaller footpad than 19 adult females (mean = 67.46, s.d. = 1.33 vs. 70.97, 0.84, respectively; one-tailed t-test, t = 9.83, $P < 0.001$). The frequency distributions of footpad lengths for males and females are illustrated in Figure 2. Of 21 males, 18 (85.7%) had footpad lengths < 69 mm, while 17 of 19 females (89.5%), had footpad lengths $\geq$ 70 mm. Thus 35 of 40 (87.5%) adult owls had footpad lengths < 69.0 or $\geq$ 70.0 mm, representing a narrow range of overlap (12.5%). In comparison, 17 of 20 (85%) juveniles had footpad lengths of either < 69 or $\geq$ 70 mm.

Analyses of morphometric data for 18 juveniles banded in a 16-day period (20 June-5 July 1990) indicate positive correlations between date and both weight (r^2 = 0.38, F-ratio = 9.82, P = 0.006) and wing chord (r^2 = 0.55, F-ratio = 19.75, P = 0.001). Because growth rates are asymptotic (O'Connor 1984) and evaluation of the plotted data revealed linear relationships in both instances, it was evident that these physical features had not reached the asymptote (i.e. weight and wing length were still increasing during this period). Conversely, we found no correlation between footpad length and date (r^2 = 0.007, F-ratio = 0.103, P = 0.75), indicating that footpad growth had already stabilized. Such differential growth patterns have been recorded for raptors (Olendorff 1974, Moss 1979; see also O'Connor [1984] for review of growth rates and patterns in birds). In fact, footpad and tarsal growth have been documented to exceed growth rates of other physical features (Moss 1979, Bednarz and Hayden 1991). These results suggest that (1) footpads of juvenile Spotted Owls attain full size before fledging (some time before we initiated banding in June); and (2) given the size of juvenile footpads, a level of sexual dimorphism similar to that for adults likely will be found in a larger sample of juveniles.

Our ability to verify the sex of juvenile Spotted Owls in our sample is currently limited, pending recapture of measured and banded birds. Development of a statistical model (using one or more variables) for sex determination may require a large sample of sexed owls (e.g. the sample in Blakesley et al. [1990] was 133 birds). Because the mortality rate of juvenile Spotted Owls is high (Gutiérrez et al. 1985, Miller 1989), a considerable number of birds would be required in a typical banding operation to ensure an adequate number of recaptures. However, verification of sex can be accomplished by other means, such as chromosomal sampling (Biederman and Lin 1982, Delhanty 1989, Tiersch et al. 1991). Such procedures would expedite the process of collecting a sample suitable for model development because sex verification would be rapid and all birds captured could be used.

Sex-determination models (e.g., discriminant function analysis) are more powerful when morphometric variables are added to the model that increase the rate of correct classification (see Brennan et al. 1984). For this reason, we suggest that banders record the measurements reported by Blakesley et al. (1990) as well as fourth primary length (Peterson and Thompson 1977, Bechard et al. 1985, Poole 1989), tarsal width (Olendorff 1972, Moss 1979) and maximum width of head (Olendorff 1972). Given the potential importance of the footpad and other parameters, we encourage Spotted Owl researchers to record these measurements during the course of regular banding operations.

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REFERENCE COMMENTS

Table 1. Results from studies where footpad measurement was used to determine sex of various raptors.

Henny and Clark (1982)	No overlap between sexes of Peregrine Falcons *(Falco peregrinus)* of two age classes (n=11 males, 71 females).
Bortolotti (1984)	Footpad was one of 3 "repeatable" measurements that were used to distinguish presumed sex of Bald Eagle *(Haliaeetus leucocephalus)* nestlings.
Henny et al. (1985)	In adults, no overlap between sexes of Northern Goshawk *(Accipiter gentilis)* (n=23 males, 37 females), Cooper's Hawk *(A. cooperi)* (n=42 males, 23 females) and Sharp-shinned Hawk *(A. striatus)* (n=11 males, 7 females).
Edwards and Kochert (1986)	In a one-variable discriminant function analysis model, the footpad length variable correctly identified all Golden Eagles *(Aquila chrysaetos)* (n=31 males, 18 females).
Bednarz and Hayden (1991)	Range of toe-pad of nestling male (n=34) and female (n=47) Harris' Hawk *(Parabuteo unicinctus)* did not overlap after reaching growth curve asymptote.

Figure 1. Photograph illustrating proper measurement of footpad (see front cover photo).

Figure 2. Frequency distribution of footpad lengths of adult male, adult female, and juvenile Spotted Owls in the Wenatchee National Forest, Washington.