J. Field Ornithol., 61(3):320-327

# SEXUAL DIMORPHISM IN NORTHERN SPOTTED OWLS FROM NORTHWEST CALIFORNIA

JENNIFER A. BLAKESLEY, ALAN B. FRANKLIN,
AND R. J. GUTIÉRREZ
*Department of Wildlife, Humboldt State University*
*Arcata, California 95521 USA*

Abstract.-We measured weight, wing length, tail length, bill length, bill depth, and tarsus length and counted the number of complete tail bars of live adult and subadult Northern Spotted Owls *(Strix occidentalis caurina).* All variables showed significant differences between mean values for females and males (*n* = 65 females, 68 males). There was no significant correlation between male and female sizes of mated Spotted Owl pairs for any measurement variable (*n* = 64 pairs; 57 females and 56 males). We determined that weight was a better predictor of sex than the number of complete tail bars or any other measurement variable. Adding additional variables to weight in a discriminant analysis did not improve the original correct classification rate of 90.2%. Mean weights of female and male owls were 663 g ± 42.8 (SD) and 579 g ± 34.9, respectively. Dimorphism Indices were highest for the cube root of weight (4.51), tail length (3.30 ) and wing length (2.47). Determining sex of an owl in the field by the owl's vocalizations and behavior remains the most reliable sexing technique. Field measurements may be used to estimate the sex of a captured owl when behavioral cues are not available.

## DIMORFISMO SEXUAL EN UNA POBLACIÓN DE *STRIX OCCIDENTALIS CAURINA* DEL NOROESTE DE CALIFORNIA

Sinopsis-Tomamos datos sobre el peso, tamaño del ala, rabo, largo y profundidad del pico, tarso y además contamos el número de las barras completas en el rabo de individuos adultos y subadultos de *Strix occidentalis caurina.* Todas las variables mostraron diferencias significativas entre los valores promedios tanto para las hembras como para los machos *(n* = 65 hembras, 68 machos). No hubo correlación significativa entre los tamaños de las hembras y los machos apareados *(n* = 64 parejas; 57 hembras y 56 machos). Determinamos que el peso es mejor indicador para determinar el sexo que el número de barras completas en el rabo o cualquier otra medida variable. El añadir variables adicionales al peso de las aves en un análisis discriminativo, no mejoró la clasificación original de 90.2%. El peso promedio de las hembras resultó ser de 663 g ± 42.8 (SD) y el de los machos de 579 g ± 34.9. El índice de dimorfismo resultó mayor para la raiz cúbica del peso (4.51), largo del rabo (3.30) y largo del ala (2.47). No obstante, la técnica más confiable para determinar el sexo de estas aves en el campo resulta ser la vocalización y conducta de éstas. El determinar el sexo a través de medidas puede ser utilizado cuando el elemento de conducta no pueda ser utilizado.

We attempted to find the most reliable method for sexing Spotted Owls based on several morphological characteristics including tail bars. Using data from 38 museum specimens and live-trapped Northern Spotted Owls (Strix *occidentalis caurina),* Barrows et al. (1982) reported that the sex of Spotted Owls may be determined by counting the number of complete tail bars.

Reversed sexual dimorphism in body weight and wing chord length is well documented for owls and other raptors (Earhart and Johnson 1970). Hypotheses attempting to explain evolution and adaptive advantages of such dimorphism in owls and other raptors are often based upon the differing magnitude of sexual dimorphism in related species (Lundberg 1986, Mueller 1986, Pleasants 1988). Measurement data for many species are limited to small samples of field data or museum specimens. Measurements of live birds taken from a large sample of owls of known sex during field studies may clarify some of the relationships between size dimorphism and life history patterns.

## METHODS

We measured the following characteristics of live-trapped Northern Spotted Owls (modified from Baldwin et al. 1931) in the field from April through August, 1982 through 1988: weight; wing length (from the bend of the wing to the tip of the longest flattened primary); tail length (from the base to the tip of the longest retrix); bill length (from the forehead to the tip of the bill); bill depth (at the base of the bill); tarsus length (from the intertarsal joint to the joint at the base of the third toe); and the number of complete tail bars (Barrows et al. 1982). Weight was measured to the nearest 10 g with a 1000 g Pesola scale; wing and tail length were measured to the nearest mm using a ruler; bill and tarsus were measured to the nearest 0.1 mm with dial calipers.

Owls were aged as adult ($\geq$ 3 yr old) or subadult (<3 yr old) by the shape and color pattern of the tips of the retrices (Forsman 1981). The sex of each adult and subadult owl was determined from vocalizations and behavior (Forsman et al. 1984). Preliminary analyses using Mann-Whitney U-tests (Zar 1984) showed no significant difference for any variable between adult and subadult age classes of either sex ($n = 47$ adult and 25 subadult females, 61 adult and 8 subadult males; $P > 0.05$). Therefore, age classes were combined in subsequent analyses.

Owls were captured using primarily noose poles and mist nets (Forsman 1983). All owls captured were banded and released unharmed. Mice (*Perumyscus* and *Mus* spp.) were sometimes fed to the owls before capture to assess whether the owls were nesting or were caring for young (Forsman 1983). We subtracted 20 g (the average mouse weight) for each mouse eaten by an owl before it was weighed. Fifty-four percent of the owls were measured on two or more occasions, 1 mo-5 yr apart. Multiple measurements were averaged for each individual owl.

Each measurement variable was tested for univariate normality and homoscedasticity (Zar 1984). Extreme outliers believed to reflect measurement or recording errors were removed ($n = 5$ owls). Complete information was taken from 65 females and 68 males. We used t-tests (Zar 1984) to test differences between female and male owls for each measurement variable. We used a subsample of the data to compare sizes of mated pairs of Spotted Owls ($n = 64$ pairs; 57 females and 56 males) using linear correlation with each variable.

We calculated dimorphism indices ($DI$) for all variables except tail bars (Earhart and Johnson 1970), where $DI = 100(\text{mean female size} - \text{mean male size})/0.5(\text{mean female size} + \text{mean male size})$. The cube root of weight was used for more direct comparison with other, linear, measurements (Earhart and Johnson 1970).

We calculated linear correlation coefficients between all pairs of measurement variables (both sexes combined). Discriminant analysis with jackknifing was used to find the best field predictor of sex (Huberty 1984). Cohen's Kappa (Titus et al. 1984) was calculated from un-jackknifed results to provide chance-corrected classification rates.

Juvenile Spotted Owls were also captured and measured between June and August ($n$ = 52 complete and 81 incomplete sets of measurements). The sex of juveniles was not known at the time of capture. Juvenile measurements were compared to adult measurements, but were not included in statistical analyses.

## RESULTS

All seven morphological variables were significantly different between female and male Northern Spotted Owls ($P < 0.01$; Table 1). Differences in weights of individual owls measured ≥two times over 2-4 yr had a mean range of 47 g (8% of mean weight) for males ($n$ = 42) and 80 g (12% of mean weight) for females ($n$ = 29). Dimorphism indices ranged from 1.80 for bill depth to 4.51 for weight (Table 1). There was no significant correlation between male and female sizes of mated Spotted Owl pairs for any measurement variable ($P > 0.05$, Table 1). Linear correlation coefficients were significant ($P < 0.05$) for 13 of 21 variable combinations (Table 2).

Weight had the highest correct jackknifed classification rate in l-variable discriminant analysis (90.2%, $K$ = 80.4; Table 3). Adding additional variables to the model did not increase the correct classification rate and no combination of other variables resulted in a correct jackknifed classification rate higher than 82.7%. The best 2-variable discriminant model, Discriminant Score ($DS$) = 33.55206 – (0.15366 x tail length) – (0.97687 x no. tail bars), resulted in 81.2% correct jackknifed classification ($K \pm$ 95% $CI$ = 62.4 ± 13.6). The best 3-variable model, $DS$ = 102.24475 – (0.20191 x wing length) – (0.59057 x bill depth) – (0.39046 x tarsus length), resulted in 82.7% correct jackknifed classification ($K \pm$ 95% $CI$ = 65.4 ± 13.1). The best 4-variable model, DS = 104.80955 – (0.16447 x wing length) – (0.08617 x tail length) – (0.25287 x bill length) – (0.41151 x tarsus length), resulted in 79.7% correct jackknifed classification ($K \pm$ 95% $CI$ = 65.4 ± 13.1). For the multi-variable models, an owl was classified as female if $DS < 0$ and male if $DS > 0$.

The tail bar method of sexing Spotted Owls (Barrows et al. 1982) correctly classified 76.7% of our sample (61.5% of females and 91.2% of males). While few males had >3 tail bars, 38.5% of females had <4 tail bars (Fig. 1).

Of the 133 juveniles banded from 1985 through 1988, sex was later determined for nine owls (five recaptured as subadults and/or adults, four recovered dead). We had previously counted tail bars on eight of these juveniles (six males, two, females); six of the eight (five males, one

TABLE 1. Statistical comparisons of morphological characteristics of female and male Northern Spotted Owls from northwest California.

| Variable | Female[a] | | Male[b] | | Female vs. male[a,b] | | | Correlation of mated pairs[c] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | $t$ | $P$[d] | $DI$[e] | $r$ | $F$ | $P$ |
| Weight | 663 | 42.8 | 579 | 34.9 | 12.45 | <0.001 | 4.51 | −0.01 | 0.01 | 0.93 |
| Wing length | 328 | 6.9 | 320 | 6.1 | 6.99 | <0.001 | 2.47 | 0.08 | 0.40 | 0.53 |
| Tail length | 201 | 6.6 | 195 | 7.5 | 4.80 | <0.001 | 3.03 | 0.09 | 0.47 | 0.49 |
| Bill length | 37.7 | 1.54 | 36.8 | 1.52 | 3.50 | <0.001 | 2.42 | 0.19 | 2.38 | 0.12 |
| Bill depth | 22.4 | 0.91 | 22.0 | 1.04 | 2.57 | 0.006 | 1.80 | 0.00 | 0.00 | 0.99 |
| Tarsus length | 61.6 | 2.06 | 60.2 | 2.22 | 3.99 | <0.001 | 2.30 | 0.14 | 1.29 | 0.26 |
| Tail bars | 3.9 | 1.63 | 2.4 | 0.95 | 6.29 | <0.001 | | | | |

[a] $n = 65$ females, [b] $n = 68$ males, [c] $n = 64$ pairs; 57 females and 56 males.
[d] $P$ = 1-tailed probability.
[e] $DI$ = Dimorphism Index = 100 × (mean female size − mean male size)/0.5 × (mean female size + mean male size) (Earhart and Johnson 1970).

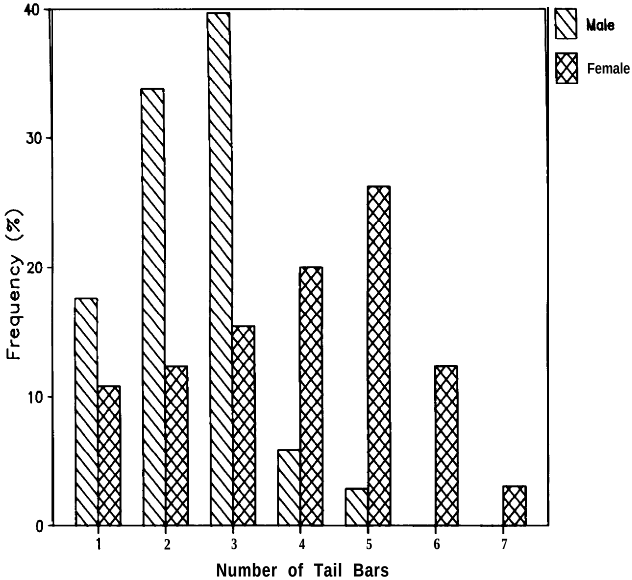


FIGURE 1. Percent frequency distribution of the number of tail bars found on adult and subadult Northern Spotted Owls in northwest California ($n$ = 65 females, 68 males).

female) were incorrectly sexed by the tail bar method as juveniles. All three of the males recaptured as subadults had five or six tail bars as juveniles and 1-3 tail bars as subadults. The female recaptured as a subadult had five tail bars as a juvenile and four as a first year subadult.

## DISCUSSION

Weight was the most accurate predictor of sex among standard field measurements of Northern Spotted Owls. Furthermore, among the variables, weight was the easiest to measure and probably least subject to observer error. Mueller believed that (1986:401) "weight is the best

TABLE 2. Linear correlation coefficients for pairs of measurements of Northern Spotted Owls from northwest California ($n$ = 133). All $r > 0.18$ are significant ($F > 3.92$, $P < 0.05$).

| | Wing length | Tail length | Bill length | Bill depth | Tarsus length | Tail bars |
|---|---|---|---|---|---|---|
| Weight | 0.45 | 0.48 | 0.32 | 0.29 | 0.26 | 0.34 |
| Wing length | | 0.41 | 0.26 | 0.07 | 0.11 | 0.28 |
| Tail length | | | 0.27 | 0.24 | 0.00 | 0.03 |
| Bill length | | | | 0.14 | 0.06 | 0.19 |
| Bill depth | | | | | 0.01 | 0.15 |
| Tarsus length | | | | | | 0.24 |

TABLE 3. Sex classification of Northern Spotted Owls from northwest California using single-variable discriminant analysis (*n* = 65 females, 68 males).

| Variable | Classify as female if | % Correctly classified | Cohen's Kappa ± 95% CI | Wilk's Lambda |
|---|---|---|---|---|
| Weight | >621 g | 90.2 | 80.4 ± 23.2 | 0.458 |
| Wing length | >323 mm | 75.9 | 52.0 ± 14.8 | 0.728 |
| Tail length | >198 mm | 72.2 | 44.3 ± 23.1 | 0.850 |
| Bill length | >37.2 mm | 63.9 | 27.9 ± 18.3 | 0.914 |
| Bill depth | >22.1 mm | 60.2 | 20.2 ± 19.0 | 0.952 |
| Tarsus length | >60.9 mm | 68.4 | 36.9 ± 20.3 | 0.829 |
| Tail bars | >3 | 76.7 | 53.1 ± 21.6 | 0.768 |

measure of body size" for owls although Lundberg (1986) indicated that weight of European owls was highly variable throughout the year. Hirons et al. (1984) found that weights of male Tawny Owls (*Strix aluco)* varied little throughout the year, whereas female weights were highest in February/March and declined until August/September. Mean live weights for male and female Tawny Owls were most similar from June-September. Assuming a similar pattern for Spotted Owls, our discriminant analysis using weight (developed for April-August) would apply throughout the year if male weights remain relatively constant and female weights are higher between September and March. Although multi-variable discriminant functions were not as accurate as using weight alone, we included them because they may be useful for sexing emaciated owls or when weight data are not available.

Although Barrows et al. (1982) reported that the tail bar method could be applied using binoculars without handling the owls, we found this to be very difficult in most situations. Furthermore, we found the number of complete tail bars to be inconsistent between and within molts (adult tail feathers molt in alternate years; Forsman 1981). The tail bar method was particularly unreliable for sexing juveniles.

We were unable to use measurements to determine the sex of juveniles because growth curves were not available for juvenile Spotted Owls. Juvenile Spotted Owl remiges were fully developed between 12 June and 24 July and retrices between 22 June and 3 August (Forsman 1981, Forsman et al. 1984). However, only 17% and 6% of the juveniles we sampled were captured after 24 July and 3 August, respectively. In addition, Hirons et al. (1984) reported that fledgling Tawny Owls exceeded adult weights before independence; thus weight probably will not be useful as a predictor of sex in juvenile Spotted Owls.

Dimorphism indices for the cube root of weight *(DI = 4.51)* and wing length *(DI* = 2.47) were similar to those reported for Spotted Owls by Earhart and Johnson (1970:Table 3; *DI = 3.02* and 2.23, respectively, = 10). Solis (1983) found that female Spotted Owls in our study area Foraged in areas with higher densities of conifers >90.0 cm dbh, lower densities of hardwoods, and more decayed snags than males, supporting the idea that sexual dimorphism may be related to differential habitat use by the sexes (Earhart and Johnson 1970).

Earhart and Johnson (1970:261) suggested examination of the sizes of mated pairs to "clarify what sizes of mates are able to form proper pair bonds." We found no significant linear relationships between the sizes of mated pairs (i.e., the largest males were not necessarily paired with the largest females).

Sexing Spotted Owls by vocalizations and behavior remains the most reliable technique. This method is nearly 100% accurate, assuming the owls are responsive to a biologist's calls or mousing efforts and the biologist is experienced in recognizing Spotted Owl calls. However, morphological measurements mav be used to estimate an owl's sex when behavioral cues are not available.- Knowledge of the morphological characteristics best able to distinguish between the sexes also may be useful to scientists examining the possible causes and implications of sexual dimorphism in owls and other raptors.

## ACKNOWLEDGMENTS

We are grateful to T. J. Evans, W. S. LaHaye, C. A. Moen, J. P. Ward and K. E. Young for their long hours of field work. Thanks also to J. P. Ward and J. R. Waters for helpful discussions regarding data analysis. We appreciate the comments of C. W. Barrows, E. D. Forsman and J. P. Ward on a previous draft of this manuscript and reviews by C. T. Collins and H. C. Mueller. This study was funded by California Department of Fish and Game, Federal Aid in Wildlife Restoration Project W-65-R-3 and **4,** and California Environmental License Plate Funds; USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Cooperative Agreement No. PSW-87-0011 CA; and McIntire-Stennis Project HSU No. 85.

## LITERATURE CITED

**BALDWIN,** S. P., H. C. **OBERHOLSER, AND L. G. WORLEY.** 1931. Measurements of birds. Cleveland Mus. Nat. Hist. Sci. Publ., Vol. II. 165 pp.

**BARROWS,** C. W., P. H. **BLOOM, AND** C. T. **COLLINS.** 1982. Sexual differences in the tail barring of Spotted Owls. N. Am. Bird Bander 7:138-l 39.

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

**FORSMAN,** E. D. 1981. Molt of the Spotted Owl. Auk 98:735-742.

———. 1983. Methods and materials for locating and studying Spotted Owls. U.S. For. Serv. Gen. Tech. Rep. PNW-162. 8 pp.

——— E. C. MESLOW, AND H. M. WIGHT. 1984. Distribution and biology of the Spotted Owl in Oregon. Wildl. Monogr. 87:l-64.

HIRONS, G. J. M., A. R. HARDY, AND P. I. **STANLEY.** 1984. Body weight, gonad development and moult in the Tawny Owl *(Strix aluco).* J. Zool., Lond. 202:145-164.

**HUBERTY,** *C.* J. 1984. Issues in the use and interpretation of discriminant analysis. Psychol. Bull. 95:156-171.

**LUNDBERG,** A. 1986. Adaptive advantages of reversed sexual size dimorphism in European owls. Ornis Scand. 17: 133-l 40.

**MUELLER, H. C. 1986.** The evolution of reversed sexual dimorphism in owls: an empirical analysis of possible selective factors. Wilson Bull. 98:387-406.

PLEASANTS, J. M. 1988. Reversed size dimorphism in raptors: evidence for how it evolved. Oikos 52:129-135.

SOLIS, D. M., JR. 1983. Summer habitat ecology of Spotted Owls in northwestern California. M.S. thesis, Humboldt State Univ., Arcata, California. 169 pp.

TITUS, K., J. A. MOSHER, AND B. K. WILLIAMS. 1984. Chance-corrected classification for use in discriminant analysis: ecological applications. Am. Midl. Nat. 111: 1-7.
ZAR, J. H. 1984. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Received 19 May 1989; accepted 5 Dec. 1989.