Ornis Fennica 90:203–210. 2013

Sex discrimination in the Savi's Warbler (*Locustella luscinioides)* using morphometric traits

Izabela Kulaszewicz*, Dariusz Jakubas & Katarzyna Wojczulanis-Jakubas

*University of Gdańsk, Department of Vertebrate Ecology and Zoology, ul. Wita Stwosza 59, 80-308 Gdańsk, Poland. *Corresponding author's e-mail: izak998@gmail.com*

Received 12 October 2012, accepted 10 April 2013

Determining an individual's sex is often difficult in species with monomorphic plumage, but it is important in many ecological studies. This study proposes a logistic function for sexing the Savi's Warbler, *Locustella luscinioides*, based on standard body measurements. Nine measurements (wing length, tail length, head to bill length, bill length, bill width, bill height, tarsus width in two dimensions and hind-claw length) were selected via logistic regression using AIC_c (Akaike's information criterion for small sample size), with sex (determined by molecular analysis) as the dependent variable. In total, 224 Savi's Warblers (161 immatures and 64 adults) caught in northern Poland during autumn migration in 2010 and 2011 were examined. The function applied to immatures identified wing length, bill length, head to bill length and hind-claw length as the best measurements for sexing, with 91% of birds correctly classified (90% of females and 92% of males). A second function, applied to adults, included only wing length and bill length as the best predictor variables to identify sex, and it correctly classified 94% of individual (93% of females and 94% of males).

1. Introduction

Behavioral and ecological studies often require knowledge of the sex of individuals being studied. However, field identification of sex may be difficult in species where males and females show no plumage dimorphism. Sexing by cloacal protuberance (Svensson 1992), the presence of a brood patch (Green 1982, Reese & Kadlec 1982) or breeding behavior (Baeyens 1981) may be useful in such cases, but these features are only for sexually active individuals during the breeding season (Coulson *et al.* 1983). Other methods of sex identification include genetic analysis (Griffiths *et al.* 1998), hormone analysis (Eason *et al.* 2001) and/or laparoscopy (Risser 1971); however, these techniques are expensive, time-consuming, sometimes highly invasive, and require trained workers and specialized equipment (Edgington 1989). Thus, alternative, quick and non-invasive but reliable techniques for sexing birds are of great value to field researchers. Logistic regression analysis applied to morphometric data is a statistical method that can provide a simple method of producing a logistic function for predicting the sex of birds. It has previously been used in some monomorphic bird species (e.g. Ellrich *et al*. 2010, Ong *et al*. 2011).

In this study, a logistic function for sexing the Savi's Warbler, *Locustella luscinioides*, based on standard body measurements was proposed. The Savi's Warbler is a cryptic, territorial, migratory passerine. It breeds in marshlands in Europe and Asia and winters in sub-Saharan Africa (Cramp 1998). The intra-specific variation in morphometrics is relatively poorly known, and the morphometric characteristics are based on a limited set of measurements (Nowakowski 2002). Significant differences in wing length between adult males and females have been found in several populations (reviewed in Cramp 1998, Nowakowski 2002), which suggests that body size measurements may be useful for sex identification. However, these sex differences have not been studied in detail prior to this study. Here, external measurements of molecularly sexed individuals migrating through northern Poland in autumn were used to derive a function for sex identification.

2. Material and methods

2.1. Field and laboratory work

Data were collected in the southern part of the Druzno Lake reserve (54°05' N, 19°27' E) in N Poland. Lake Druzno is a big, shallow lake that is largely overgrown by reedbeds and swampy vegetation. It is a good breeding and resting place for birds associated with wet biotopes, including the Savi's Warbler. Data were collected during autumn migration in 2010 (25 July–3 October) and 2011 (25 July–28 August). Birds were captured in 20 nets situated in reedbeds.

Captured Savi's Warblers were ringed, measured and weighed. Wing length and tail length were measured with a ruler (1 mm accuracy). Head-bill, bill length, bill width and height, leg width in two dimensions (1: the wide and 2: the narrow diameter of the tarsus bone, just above the upper ring edge when the ring was resting on the tarsus normally) and hind claw length were measured using calipers (0.1 mm accuracy; all measurements after Svensson 1992). Birds were weighed using electronic balance (OHAUS, with 0.1 g accuracy). All measurements were taken by the same person (IK). The birds were aged as adults or immatures, according to external characters (Svensson 1992). A small amount of blood (10–20 μl) was taken from the brachial vein according to standard procedures (Owen 2011) and immediately preserved in 70% ethanol. Each individual was sampled only once.

DNA was extracted following evaporation of the ethanol and using a Blood Mini kit (A&A Biotechnology, Gdynia, Poland). Sexing was performed by amplification of a 390-bp fragment of the CHD gene on the W chromosome (in females only), and a 370-bp fragment on the Z chromosome (in both sexes), using the primer pair P2 and P8 (Griffiths *et al.* 1998). The primer pair is universal for birds and has been proven to work in the closely related genus *Acrocephalus* (Jakubas & Wojczulanis-Jakubas 2010, Wojczulanis-Jakubas & Jakubas 2011). PCR was performed according to the protocol of Griffiths *et al.* (1998) with 50°C for annealing the primers. The size difference in PCR products was clearly visible on a 2% agarose gel.

In total, 226 Savi's Warblers, including 65 adults (32 females and 33 males) and 161 immatures (60 females and 101 males) were measured and sexed.

2.2. Data analysis

All morphological variables were tested for normal distribution with Kolmogorov–Smirnov tests. Then a multiple logistic regression was used to establish the best morphological predictor variables for sex discrimination (separately for adults and immature). The best function has been selected using Akaike's information criterion for small sample size (AIC_c) (Burnham & Anderson 2002, Mazerolle 2006, Hegyi & Garamszegi 2011). To compare the relative performance of the models, the difference (ΔAIC_c) between the AIC_c value of the best model and the AIC_c value for each of the other models and Akaike's weights (Burnham & Anderson 2002) were calculated. Models that were selected have $\Delta AIC_c < 4$. Models with $\Delta AIC_c < 2$ have substantial support, those in which $4 < \Delta AIC_c < 7$ have considerably less support, and models having $\Delta AIC_c > 10$ have essentially no support. The support refers to the relative capacity of a model to describe the information present in the data. Akaike's weights (w) can be interpreted as the probability that model is the best model for the observed data given the candidate set of models. The sum of all Akaike's weights is 1 (Mazerolle 2006). The procedure was accomplished by the stepAIC function from the package MASS of the program R version 2.1.0 (R Development Core Team 2007, package MASS; Venables & Ripley 2002). The stepAIC function does both forward and backward selections and selects models with lower AIC_c scores. The AIC_c allows one to compare and rank multiple competing models and to estimate which of them best approximates the "true" process underlying the biological phenomenon under study (Symonds & Moussalli 2011).

The sex assigned by molecular analysis was used as the dependent variable, and morphological measurements were predictors in the logistic regression. The sexes were coded "1" for male and "0" for female. The goodness-of-fit of the logistic regression was tested with a Hosmer–Lemeshov test (Hosmer & Lemeshov 1989).

The model produced a linear logistic function of the form:

$$D = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n \quad (1)$$

where α was a constant and $\beta_{1, 2, \ldots, n}$ were regression coefficients of the predictor variables $x_{1, 2, \ldots, i}$. An individual bird, given its specific measurements, was classified as being male if $P_{male} > 0.5$ or female if $P_{female} \leq 0.5$. The probability that a bird with a given morphology was male was estimated according to:

$$P_{male} = \frac{e^D}{1 + e^D} \quad (2)$$

where D was the logistic function and e was the base of the natural logarithm.

The probability of being female was:
$P_{female} = 1 - P_{male}$

The effectiveness of the logistic function for identifying sex was assessed in two ways. First, we calculated the proportion of adults of known sex that were classified correctly, using all individuals in the analysis. Second we performed cross-validation by jackknife procedure (i.e., each individual was classified by the function derived from all other individuals except for the given one). Due to unequal sample sizes for males and females, a chance-corrected procedure (Cohen's kappa statistic) was used to determine if the classification was better than random (Titus *et al.* 1984, Berg *et al.* 2004). To estimate precision of the proposed functions, the standard error of Nagelkerke R^2 value was estimated using jackknife procedure (Efron 1982). Data did not exhibit multicollinearity ($r < 0.14$ for all pairwise correlations).

Due to the different moulting strategies of adult and immature Savi's Warblers (Cramp 1998) and to reported age differences in wing length (Alatalo *et al.* 1984, Tiainen & Hanski 1985, Norman 1997, Nowakowski 2002), separate analyses were performed for adults and immatures.

Studies on some passerines show that sexual size dimorphism varies geographically (Ellrich *et al.* 2010). Individuals of the same species originating from different latitudes may have different wing morphologies as an adaptation to different migration strategies and/or local conditions (Leisler & Winkler 2003). Also wing length in the Savi's Warbler varies geographically (Cramp 1998), with an increase from west to east and from south to north in Europe (Müller 1981, Flint & Stewart 1983). Since birds migrating through the study area originate from more northern latitudes, they may have a different wing morphology compared to the local population. To check whether geographical variation in the measurements of birds occurred in the present study, all morphometrics were compared among pentads using Kruskal–Wallis test. No significant differences were revealed (Table 1).

Table 1. Variation in morphometric measurements among pentands in immature (N = 161) and adult (N = 65) Savi's Warblers *Locustella luscinioides* (results of Kruskal–Wallis tests).

	Immatures		Adults	
	H	P	H	P
Wing length	2.809	0.902	10.955	0.089
Tail length	8.813	0.266	13.986	0.096
Head to bill bill length	7.729	0.357	10.476	0.106
Bill length	6.546	0.465	6.314	0.389
Bill width	9.314	0.231	12.956	0.053
Bill height	6.637	0.468	6.314	0.389
Leg width 1	10.457	0.176	13.065	0.063
Leg width 2	9.887	0.964	3.599	0.731
Claw length	3.356	0.850	12.476	0.076

Table 2. Body measurements (W – wing length, T – tail length, BTH – bill to head length, B – bill length, BW – bill width, BH – bill height, LW1 – leg width 1, LW2 – leg width 2, C – claw length) of immature and adult males and females of Savi's Warblers *Locustella luscinioides* caught in northern Poland during autumn migration in 2010–2011.

	Immatures Me, Q_1–Q_2 (*N*)		Adults Me, Q_1–Q_2 (*N*)	
	Males	Females	Males	Females
W	70[a], 70–71 (98)	69[a], 68–69 (60)	71[b], 70–72 (33)	69[b], 68–69 (28)
T	57[d], 55–58 (87)	56[d],54–57 (59)	59[c],56–61 (28)	56[c], 55–57 (28)
HTB	33.3[a], 32.8–33.5 (101)	32.1[a], 31.8–32.5 (60)	33.5[b], 33.2–33.8 (33)	32.1[b], 32.2–33.6 (32)
B	11.2[a], 10.5–11.8 (101)	10.2[a], 10.1–10.6 (60)	11.6[b], 10.8–12.2 (33)	10.2[b], 10.3–11.3 (32)
BW	3.6[a], 3.4–3.9 (101)	3.3[a], 3.2–3.4 (60)	3.7[b], 3.6–3.9 (33)	3.3[b], 3.3–3.5 (32)
BH	2.8[a], 2.6–2.9 (101)	2.4[a], 2.3–2.8 (60)	2.8[d], 2.8–3.1 (33)	2.4[d], 2.3–2.9 (32)
LW1	1.4[a], 1.4–1.6 (101)	1.4[a], 1.3–1.5 (60)	1.5[c], 1.4–1.6 (33)	1.4[c], 1.3–1.5 (32)
LW2	1.2, 1.1–1.2 (101)	1.2, 1.1–1.2 (60)	1.2, 1.1–1.2 (33)	1.2, 1.1–1.2 (32)
CL	7.4[a], 7.0–7.6 (101)	6.6[a], 6.5–7.0 (60)	7.3[b],6.9–7.4 (33)	6.6[b],6.5–7.0 (32)

Mann–Whitney *U*-tests: a,b = $P \leq 0.001$, c = $P \leq 0.003$, d = $P = 0.03$

All statistical analyses were performed in SPSS 17.0 for Windows (SPSS Inc., Chicago), R package (R Development Core Team 2007) and STATISTICA 8.0 (StatSoft, Inc., Tulsa, Oklahoma). The accepted significance level was $P < 0.05$.

3. Results

Both adult and immature males were on average bigger than females in all measurements except for leg width in the second (narrow) dimension (Table 2).

The largest sex differences ($P < 0.001$) were found in wing length, bill length, bill width and claw length (both adults and immatures) and head-bill length, bill height (only immatures).

Adults were on average bigger than immatures in five of the nine measurements (tail length, bill-head length, bill length, bill width and claw length; Table 3).

When logistic regression was applied to the nine morphological measurements of the immature birds, one equation has been selected as the best in separating the sexes (Table 4). This function (D_1) identified wing length, bill length, head-bill length and hind claw length (Nagelkerke R^2 = O.79, SE= 0.0431; Hosmer-Lemeshow GOF test:

Table 3. Body measurements of immature and adult of Savi's Warblers *Locustella luscinioides* caught in northern Poland during autumn migration in 2010–2011, with results of Mann–Whitney *U*-tests (M–W *U*-test) for intersexual comparisons.

Variables	Me, Q_1–Q_2 (*N*)		M–W *U*-test	
	Immatures	Adults	*Z*	*P*
Wing length	70, 69–71 (161)	70, 68–72 (61)	0.486	0.626
Tail length	56, 55–58 (161)	57, 55–57 (61)	2.144	0.032
Head to bill length	32, 32–33 (161)	33.3, 32.4–33.7 (61)	2.847	0.004
Bill length	10.7, 10.1–11.3 (161)	11.0, 10.6–11.8 (61)	2.873	0.004
Bill width	3.5, 3.3–3.8 (161)	3.6, 3.3–3.8 (61)	0.858	0.391
Bill height	2.7, 2.4–2.8 (161)	2.8, 2.4–2.9 (61)	2.249	0.024
Leg width 1	1.4, 1.3–1.6 (161)	1.4, 1.3–1.6 (61)	0.549	0.582
Leg width 2	1.2, 1.1–1.2 (161)	1.2, 1.1–1.2 (61)	1.129	0.258
Claw length	7.1, 6.7–7.5 (161)	6.9, 6.5–7.3 (61)	2.217	0.026

Table 4. Rank of linear models for sex discrimination in the Savi's warbler *Locustella luscinioides* using morphological parameters (W – wing length, T – tail length, BTH – bill to head length, B – bill length, BW – bill width, BH – bill height, LW1 – leg width 1, LW2 – leg width 2, C – claw length) in adult and immature birds based on Akaike's Information Criterion corrected for small sample size (AIC_c). Akaike's weight (*w*) is calculated from the set of models with $\Delta AIC_c < 4$. Bold models are proposed by the authors to sex the Savi's Warblers.

Rank	Model	ΔAIC_c	Akaike's weights (*w*)
Immatures			
1	**Intercept + W + BTH + B + C**	**0.00**	**0.46**
2	Intercept + W + T + BTH + B + BW + C	0.76	0.31
3	Intercept + W + T + BTH + B + BW + LW2 + C	2.18	0.15
4	Intercept + W + T + BTH + B + BW + LW1 + LW2 + C	3.76	0.07
Adults			
1	**Intercept + W + B**	**0.00**	**0.41**
2	Intercept + W + T + BTH + B	0.70	0.29
3	Intercept + W + T + BTH + B + BW	1.60	0.19
4	Intercept + W + T + BTH + B + BW + BH	2.69	0.11

$P = 0.987$) as the best measurements to identify the sexes in immatures (Table 4).

$D_1 = -172.396 + (1.407 \times \text{wing length}) + (1.192 \times \text{head-bill length}) + (1.559 \times \text{bill length}) + (2.796 \times \text{claw length})$

This function correctly classified 92.5% of the Savi's Warbler immatures of known sex (90.3% females and 93.9% males). The cross-validation test produced the same classification results – 92.5% correct. Chance-corrected procedure showed that classification was 84% (kappa = 0.842, $SE = 0.083$, $P < 0.001$) better than chance.

Similarly, when regression was applied to the nine morphological measurements in adult birds, one equation separated the sexes best (Table 4). This function (D_2) identified wing length and bill length (Nagelkerke $R^2 = 0.78$, SE = 0.0314; Hosmer-Lemeshow GOF: $P = 0.15$) as the best measurements to identify the sexes in adults (Table 4).

$D_2 = -143.2366 + (1.762 \times \text{wing-length}) + (1.806 \times \text{bill-length})$

This function correctly classified 93.8% of the adults Savi's Warbler of known sex (93.5% females and 93.9% males). The cross-validation test produced the same classification results. Chance-corrected procedure showed that classification was 87.5% (kappa = 0.875, SE = 0.125, $P < 0.001$) better than chance.

When sex was assigned only if P_{male} or $P_{female} \geq 0.80$, the functions correctly classified 95.2% of immatures and 96.2% of adults, with 18.0% and 24.0%, respectively, left unsexed. When the probability criteria were set to $P \geq 0.90$, the functions correctly classified 98.3% of immatures and 97.4% of adults, with 33.0% and 27.0%, respectively, left unsexed (Table 5).

Using only wing and bill length measurements to estimate sex in immatures (as it was in adults) reduces the efficiency of the function from 92.5% to 65.0%.

4. Discussion

The present study revealed significant differences in body size between males and females of the Savi's Warbler. Males had longer wings, tails, head-bills, and hind claws, and wider tarsi and taller bills compared to females. Intersexual differences in wing length have also been reported for German, Russian and Polish populations (Bub & Dorsch 1988, Nowakowski 2002). All this provides another example of subtle size dimorphism

Table 5. Probabilities of being male or female in relation to wing length and bill length in adult Savi's Warblers *Locustella luscinioides*. Bold areas indicates the probability of being male [or female (P_{female} = 1 – P_{male})] P > 0.90.

	Wing length [mm]							
Bill length [mm]	67	68	69	70	71	72	73	74
9.5	**0.000**	**0.002**	**0.011**	**0.063**	0.280	0.694	**0.930**	**0.987**
9.6	**0.000**	**0.002**	**0.014**	**0.074**	0.318	0.731	**0.941**	**0.989**
9.7	**0.000**	**0.003**	**0.016**	**0.088**	0.359	0.765	**0.950**	**0.991**
9.8	**0.001**	**0.003**	**0.020**	0.103	0.401	0.796	**0.958**	**0.993**
9.9	**0.001**	**0.004**	**0.023**	0.121	0.445	0.824	**0.965**	**0.994**
10.0	**0.001**	**0.005**	**0.028**	0.142	0.491	0.849	**0.970**	**0.995**
10.1	**0.001**	**0.006**	**0.033**	0.165	0.536	0.870	**0.975**	**0.996**
10.2	**0.001**	**0.007**	**0.040**	0.192	0.580	0.890	**0.979**	**0.996**
10.3	**0.001**	**0.008**	**0.047**	0.221	0.624	**0.906**	**0.983**	**0.997**
10.4	**0.002**	**0.010**	**0.056**	0.254	0.665	**0.920**	**0.985**	**0.997**
10.5	**0.002**	**0.012**	**0.066**	0.290	0.704	**0.933**	**0.988**	**0.998**
10.6	**0.002**	**0.014**	**0.078**	0.329	0.740	**0.943**	**0.990**	**0.998**
10.7	**0.003**	**0.017**	**0.092**	0.370	0.774	**0.952**	**0.991**	**0.999**
10.8	**0.004**	**0.020**	0.109	0.413	0.804	**0.960**	**0.993**	**0.999**
10.9	**0.004**	**0.024**	0.127	0.457	0.831	**0.966**	**0.994**	**0.999**
11.0	**0.005**	**0.029**	0.149	0.502	0.855	**0.972**	**0.995**	**0.999**
11.1	**0.006**	**0.034**	0.173	0.548	0.876	**0.976**	**0.996**	**0.999**
11.2	**0.007**	**0.041**	0.201	0.592	0.894	**0.980**	**0.997**	**0.999**
11.3	**0.009**	**0.049**	0.231	0.635	**0.910**	**0.983**	**0.997**	**1.000**
11.4	**0.010**	**0.058**	0.265	0.676	**0.924**	**0.986**	**0.998**	**1.000**
11.5	**0.012**	**0.069**	0.302	0.714	**0.936**	**0.988**	**0.998**	**1.000**
11.6	**0.015**	**0.081**	0.341	0.75	**0.946**	**0.990**	**0.998**	**1.000**
11.7	**0.018**	**0.096**	0.383	0.782	**0.954**	**0.992**	**0.999**	**1.000**
11.8	**0.021**	0.112	0.427	0.811	**0.962**	**0.993**	**0.999**	**1.000**
11.9	**0.025**	0.132	0.472	0.837	**0.968**	**0.994**	**0.999**	**1.000**
12.0	**0.030**	0.154	0.517	0.861	**0.973**	**0.995**	**0.999**	**1.000**
12.1	**0.036**	0.179	0.562	0.881	**0.977**	**0.996**	**0.999**	**1.000**
12.2	**0.043**	0.207	0.606	0.899	**0.981**	**0.997**	**0.999**	**1.000**
12.3	**0.051**	0.238	0.648	**0.914**	**0.984**	**0.997**	**1.000**	**1.000**
12.4	**0.061**	0.273	0.688	**0.927**	**0.987**	**0.998**	**1.000**	**1.000**
12.5	**0.072**	0.310	0.726	**0.938**	**0.989**	**0.998**	**1.000**	**1.000**
12.6	**0.085**	0.350	0.760	**0.948**	**0.991**	**0.998**	**1.000**	**1.000**
12.7	**0.100**	0.392	0.792	**0.956**	**0.992**	**0.999**	**1.000**	**1.000**
12.8	0.117	0.436	0.820	**0.963**	**0.994**	**0.999**	**1.000**	**1.000**
12.9	0.137	0.481	0.845	**0.969**	**0.995**	**0.999**	**1.000**	**1.000**

in passerines. Differences in body size in passerines are usually much less pronounced than in other bird taxa, such as raptors (e.g., Pitzer *et al.* 2008), shorebirds (e.g., Meissner & Pilacka 2008) and seabirds (Niizuma *et al.* 1999, Tickell 1968). The sex differences in body size of the Savi's Warbler strongly suggest that sex of the birds should be considered in future work, as it might affect the birds' behavior, habitat use, niche portioning and migration.

The results of the regression analysis clearly indicate that sexes can be distinguished based on their morphometrics. The efficiency of the proposed functions, exceeding 90%, is high compared to those proposed for other passerine monomorphic species. For example, Ellrich *et al.* (2010) proposed functions based on logistic regression to determine sex of four passerines using several measurements, with the correctness ranging from 77.6% to 89.4%. Functions proposed for sexing the Savi's Warbler were not able to determine all birds correctly (9.0% and 6.0% incorrect classifications in immatures and adults, respectively), but the likelihood of erroneous sex determination can be reduced by leaving individuals with probability values 0.1–0.9 unsexed. Such a solution has been also suggested for the Sedge Warbler *Acrocephalus schoenobaenus* (Wojczulanis-Jakubas & Jakubas 2011). This might be particularly important when using the functions with new data sets. Classification efficiency might be lower in new data sets because the data may be distributed differently.

In the present study, immatures were smaller than adults in some measurements (tail length, head-bill length, bill length, bill width and claw length, Table 3). This was also reported in other studies on the Savi's Warbler (Alatalo *et al.* 1984, Tiainen & Hanski 1985, Norman 1997, Nowakowski 2002). The reason for the differences between the age groups may be that immatures are undersized. Immatures may be smaller than adults because they are still growing (Norman 1997). For that reason, the functions presented here should only be used for the same age cohort for which they were developed.

The average wing length of the Savi's Warbler varies geographically (Cramp 1998), increasing from west to east and from south to north in Europe (Müller 1981, Flint & Stewart 1983). However, no temporal variation in any of the studied morphometrics was found in the present study. This may suggest that all birds originated from the same population and/or from various populations with undetectable differences in the studied measurements. The function proposed in the present study therefore may be useful for the birds from at least central and northern part of Europe. In any case, caution should be used in applying the proposed functions for sexing individuals from other, e.g., more southern regions.

Acknowledgements. We are grateful to ringers, Dr Czesław Nitecki, Dr Beata Michno, Jakub Typiak, Brygida Manikowska-Ślepowrońska and other volunteers for their contribution to field work. We thank to Dr Jacek Nowakowski and Dr Andreas Lindén for critical comments of the manuscript. We appreciate the improvements in English usage made by Becky Cramer through the Association of Field Ornithologists' program of editorial assistance. The study was performed under permission of local Animal Research Authority and Provincial Nature Protection Bureau.

Ruokosirkkalinnun (*Locustella luscinioides*) sukupuolen määrittäminen morfometristen mittojen perusteella

Monissa ekologisissa tutkimuksissa tieto yksilön sukupuolesta on tärkeätä, mutta monomorfisilla lajeilla sukupuolen määrittäminen on usein myös vaikeata. Tässä tutkimuksessa esitetään logistinen funktio, jolla ruokosirkkalinnun sukupuolen voi määrittää perustuen tavanomaisiin morfometrisiin mittoihin. Yhdeksän mittaa (siiven pituus, pyrstön pituus, pään + nokan pituus, nokan pituus, nokan leveys, nokan korkeus, nilkan leveys kahdessa ulottuvuudessa, sekä takavarpaan kynnen pituus) toimivat selittävinä muuttujina logistisessa regressiossa, jossa molekylaarisesti todettu sukupuoli on selitettävänä muuttujana.

Tärkeimmät selittävät muuttujat seulottiin informaatioteoreettisella mallivalinnalla, perustuen AIC_c-suureeseen (Akaiken informaatiokriteeri korjattu pienelle otannalle). Aineisto sisältää kaikkeaan 224 lintua (161 nuorta ja 64 aikuista), jotka pyydystettiin syysmuutolla Pohjois-Puolassa vuosina 2010 ja 2011. Nuorten sukupuolen tunnistamiseksi siiven, nokan, pään + nokan, sekä takavarpaan kynnen pituudet osoittautuivat parhaiksi tuntomerkeiksi, joita yhdistämällä 91 % linnuista luokiteltiin oikein sukupuolelleen. Aikuisilla linnuilla vastaavat parhaat tuntomerkit olivat siiven ja nokan pituus, joiden avulla peräti 94 % luokiteltiin oikein.

References

Alatalo, R., Gustaffson, L. & Lundberg, A. 1984: Why do young passerine birds have shorter wings than older birds? — Ibis 126: 410–415.

Baeyens, G. 1981: Functional aspects of serial monogamy: the magpie pair-bond in relation to its territorial system. — Ardea 69: 145–166.

Berg, A., Gardenfors, U. & Proschwitz, T. 2004: Logistic regression models for predicting occurrence of terrestrial molluscs in southern Sweden – importance of environmental data quality and model complexity. — Ecography 27: 83–93.

Bub, H. & Dorsch, H. 1988: Kennzeichen und Mauser europäischer Singvögel. Teil. Cistensänger, Seidensänger, Schwirle, Rohrsänger (*Cisticola, Cettia, Locustella, Acrocephalus*). — A. Ziemsen Verlag, Wittenberg Lutherstadt.

Burnham, K. P. & Anderson, D. R. 2002: Model Selection and Multimodel Inference: A Practical Information.Theoretic Approach. — (2nd ed.), New York Springer-Verlag.

Coulson, J.C., Thomas, C.S., Butterfield, J.E.L., Duncan, N., Monaghan, P. & Shedden, C. 1983: The use of head and bill length to sex live gulls *Laridae*. — Ibis 125: 549–557.

Cramp, S. 1998: The complete birds of western Palearctic on CD-ROM. — Oxford University Press, Optimedia.

Eason, D., Cree, A., Halverson, J. & Lambert, D.M. 2001: A comparison of five methods for assignment of sex in the Takahe *Porphyrio mantelli*. — Journal of Zoology 253: 281–292.

Edgington, D.G. 1989: Behavioural and morphological sexing of the Humboldt Penguin *Spheniscus humboldti*. — Spheniscid Penguin Newsletter 1: 14–20.

Efron, B. 1982: The Jackknife, the Bootstrap and Other Resampling Plans. CBMS-NSF Regional Conference Series in Applied Mathematics, Monograph 38, SIAM, Philadelphia.

Ellrich, H., Salewski, V. & Fiedler, W. 2010: Morphological sexing of passerines: not valid over larger geographical scales. — Journal of Ornithology 151: 449–458.

Flint, P. & Stewart, P. 1983: The Birds of Cyprus B.O.U. Check list No. 6. — British Ornithologists' Union.

Green, P.T. 1982: Sexing rooks *Corvus frugilegus* by discriminant analysis. — Ibis 124: 320–324.

Griffiths, R., Double, M.C., Orr, K. & Dawson, R.J.G. 1998. A DNA test to sex most birds. — Molecular Ecology 7: 1071–1075.

Jakubas, D. & Wojczulanis-Jakubas, K. 2010: Sex- and age-related differences in the timing and body condition of migrating Reed Warblers *Acrocephalus scirpaceus* and Sedge Warblers *Acrocephalus schoenobaenus*. — Naturwissenschaften 97: 505–511.

Hegyi, G. & Garamszegi, L. 2011: Using information theory as a substitute for stepwise regression in ecology and behavior. — Behavioral Ecology and Sociobiology 65: 69–76

Hosmer, D. & Lemeshov, S. 1989: Applied Logistic Regression. — John Wiley and Sons, New York.

Leisler, B. & Winkler, H. 1991: Ergebnisse und Konzepte ökomorphologischer Untersuchungen an Vögeln. — Journal für Ornithologie 132: 373–425.

Mazerolle, M. J. 2006. Improving data analysis in herpetology: using Akaike's Information Criterion (AIC) to assess the strength of biological hypotheses. — Amphibia-Reptilia 27: 169–180.

Meissner, W. & Pilacka, L. 2008: Sex identification of adult Dunlin *Calidris alpina alpina* migrating in autumn through Baltic region. — Ornis Fennica 85: 135–139.

Müller, H. 1981: Altersbestimmung, Mauser und einige biometrische Daten von Rohrschwirlen. — Der Falke 28: 258–265.

Niizuma, Y., Takahashi, A., Kuroki, M. & Watanuki, Y. 1999: Sexing by external measurements of adult rhinoceros auklets breeding on Teuri Island. — Japanese Journal of Ornithology 48: 145–150.

Norman, S. 1997: Juvenile wing shape, wing moult and weight in the family *Sylviidae*. — Ibis 134: 617–630.

Nowakowski, J. 2002: Variation of morphometric parameters within the Savi's Warbler (*Locustella luscinioides*) population in eastern Poland. — Ring 24: 49–67.

Ong, H.K.A., Chinna, K., Khoo, S.K., Ng, W.L., Wong, B.Y., Chow, K.L., Chong L.K., Pillai, K. & Vellayan, S. 2011: Morphometric sex determination of Milky and Painted storks in captivity. — Zoo Biology 30: 1–10.

Owen, J.C. 2011: Collecting, processing, and storing avian blood: a review. — Journal of Field Ornithology 82: 339–354.

Pitzer, S., Hull, J., Ernest, H. B., & Hull, A.C. 2008: Sex determination of three raptor species using morphology and molecular techniques. — Journal of Field Ornithology 79: 71–79.

Reese, K.P. & Kadlec, J.A. 1982: Determining the sex of black-billed magpies by external measurements. — Journal of Field Ornithology 53: 417–418.

Risser, A.C. 1971: A technique for performing laparotomy on small birds. — Condor 73: 376–379.

Svensson, L. 1992: Identification Guide to European Passerines. — Fingraf AB, Stockholm.

Symonds, M. & Moussalli, A. 2011: A brief guide to model selection, multimodel inference and model averaging in behavioural ecology using Akaike's information criterion. — Behavioral Ecology and Sociobiology 65: 13–21.

Tiainen, J. & Hanski, I. 1985: Wing shape variation of Finnish and Central European Willow Warblers *Phylloscopus trochilus* and Chiffchaffs *P. collybita*. — Ibis 127: 365–371.

Titus, K. Mosher, J. & Williams, B. 1984: Chance-corrected Classification for Use in Discriminant Analysis: Ecological Applications. — American Midland Naturalist 111: 1–7.

Tickell, W.L.N. 1968: The biology of the great albatrosses, *Diomedea exulans* and Diomedea epomophora. — Antarctic Research Series 12: 1–55.

Venables, W. & Ripley, B. 2002: Modern applied statistics with S. Springer-Verlag — New York, New York, USA.

Wojczulanis-Jakubas, K. & Jakubas, D. 2011: Predicting the sex of the Sedge Warbler (*Acrocephalus schoenobaenus*) by discriminant analysis. — Ornis Fennica 88: 90–97.