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Can migrating Tengmalm's Owls *Aegolius funereus* be reliably sexed in autumn using simple morphometric measurements?

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I investigate whether three standard, easily-taken body measurements (wing length, tail length and mass) can be used in combination to determine accurately the sex of Tengmalm's Owls *Aegolius funereus* in autumn. A total of 135 migratory Tengmalm's Owls, caught in autumn 1999 on a small island between Sweden and Finland, were weighed, measured and accurately sexed using PCR-based molecular techniques. While females were on average larger than males, discriminant analysis using wing length, tail length and mass could not satisfactorily classify males and females. Ringers are advised not to use these common morphometric measurements to sex individual Tengmalm's Owls in autumn, as the degree of overlap is too great, and even the largest and smallest individuals might be incorrectly sexed.

Tengmalm's Owl *Aegolius funereus* (known as the Boreal Owl in North America) is a small, nocturnal hole-nesting species found in the boreal forests of Eurasia and North America (Mikkola 1983, König *et al* 1999). In Scandinavia, its numbers fluctuate with those of voles, its main prey (*eg* Hörnfeldt *et al* 1990, 2005). Tengmalm's Owls in Scandinavia are nomadic, and this itinerant behaviour is most predominant in juveniles and adult females and is related to cyclic vole abundance (Lundberg 1979, Korpimäki & Hongell 1986, Löfgren *et al* 1986, Korpimäki *et al* 1987, Sonerud *et al* 1988, Hipkiss *et al* 2002). There is currently no widely used and reliable sexing protocol for this species. However, as with other owls, Tengmalm's Owl is sexually size dimorphic, the female being larger than the male (*eg* Mikkola 1983 and references therein, Lundberg 1986, Korpimäki 1986). Differences between the sexes are greatest during the breeding season, when females weigh about 50% more than males (*eg* Korpimäki 1990), and are also easily distinguishable by their brood patch. During the breeding season, it is likely that mass alone is sufficient for determining the sex of Tengmalm's Owls. However, females lose a lot of weight after the breeding season, and in autumn they are on average only 4% heavier than males (Hipkiss 2002). Linear measurements reveal a small degree of sexual size dimorphism: females have wings that are up to 5% longer than males although there is an overlap between the sexes (*eg* Mikkola 1983, Korpimäki 1986, Hipkiss 2002).

The mobility of Tengmalm's Owls in autumn and their small size means that they are easily caught in mist nets, and are a frequent catch at bird observatories (*eg* Korpimäki & Hongell 1986, Hipkiss *et al* 2002), often well outside their normal breeding range. A reliable and easy method for sexing Tengmalm's Owls in autumn would be highly desirable to further the study of the interesting migratory behaviour of this species. Hayward & Hayward (1991) used a combination of four measurements (including wing, tail and bill measurements) to sex correctly Boreal Owls caught throughout the year in Idaho, USA. In this study I investigate whether a small number of standard, easily-taken body measurements (wing length, tail length and mass) can be used in combination to determine accurately the sex of Tengmalm's Owls in autumn. A PCR-based molecular technique was used to sex accurately Tengmalm's Owls migrating between Sweden and Finland, and a discriminant analysis was used to test the utility of body measurements for morphometric sexing.

METHODS

Capture and biometrics

Tengmalm's Owls were trapped during September–October 1999 at the bird observatory on Stora Fjäderägg, a small island in the Gulf of Bothnia between Sweden and Finland (63° 5'N 21° 0'E). Owls were trapped from dusk until dawn every night when weather permitted. Owls were caught using 16 mm mesh mist nets, and were attracted to the nets by continuously playing a recording of the male's territorial call. All owls caught were fitted with Swedish Bird Ringing Centre leg rings if unmarked, and aged by examining the moult patterns of the primary feathers (Hörnfeldt *et al* 1988). Owls were weighed to the nearest gram using a 300 g capacity Pesola spring balance, and wing length, measured from the carpal joint to the tip of the longest primary (after

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flattening and straightening the wing; *ie* maximum wing chord) and maximum tail length (both according to Baker 1993) were measured to the nearest millimeter using a ruler. Measurements were taken at least twice by two fieldworkers, to minimise error.

Molecular sexing

Determination of the sex of the owls relied on polymerase chain reaction (PCR) amplification of the sex-linked chromo-helicase-DNA binding genes CHD1W and CHD1Z, which map to the avian W and Z chromosomes respectively (Ellegren 1996, Griffiths *et al* 1996, Griffiths & Korn 1997). A 50 ml blood sample was taken from the brachial vein under the wing, and stored in Queens College buffer (20% DMSO, 0.25 M Na-EDTA, 100 mM Tris, pH 7.5, NaCl to saturation). Molecular sexing was essentially carried out as described in Fridolfsson & Ellegren (1999) and Hörnfeldt *et al* (2000), which can be referred to for a detailed protocol. Females were characterised by displaying both a CHD1W-specific fragment (1.2 kb in size) and a shorter CHD1Z-specific fragment (0.7 kb), while males showed only the shorter Z fragment.

Data analysis

Discriminant analysis was used to test whether the field measurements collected could be used to classify correctly the sex of owls caught. Analyses were carried out using SPSS version 14. Q–Q plots were used to confirm that the predictor variables (*ie* field measurements) were normally distributed, and Box's M tests were used to verify the homogeneity of group (*ie* sex) variances. Stepwise selection, using Wilks' lambda criterion, was used to select the most suitable predictor variables for discriminating between the two sexes.

RESULTS

A total of 135 Tengmalm's Owls were caught and successfully aged, measured and sexed, of which 48 were male and 87 female. Females were significantly larger than males for all measurements (Table 1: wing length, t = 4.6, $P < 0.01$; tail length, t = 2.3, $P = 0.02$; mass, t = 2.6, $P = 0.01$). However, and more importantly for this study, there was a high degree of overlap in the measurements of males and females, as is shown clearly in Fig 1.

Stepwise discriminant analysis identified wing length as the measurement that best discriminated between the two sexes (Wilks' lambda at first step: wing length = 0.86, tail length = 0.95, mass = 0.96). Tail length and mass did not significantly improve the model so the analysis contained no further steps and these two measurements were not included. The final discriminant model, including only wing length, correctly classified 70% of all individuals (65% of males and 72% of females). Dividing the owls into two age groups (juveniles and adults) and running separate stepwise discriminant analyses for each did not significantly change the results, *ie* wing length was still the only variable entered into the model, and classification accuracy was not better than for the model including both age groups together.

Table 1. Mean (and range) of wing length, tail length and mass of male (n = 48) and female (n = 87) Tengmalm's Owls.

	Male	Female
Wing length, mm	172.5 (159–185)	176.9 (162–187)
Tail length, mm	101.8 (93–112)	103.5 (93–115)
Mass, g	120.9 (93–146)	125.9 (100–151)

DISCUSSION

Mass, wing length and tail length are easily obtained field measurements frequently recorded by ringers of Tengmalm's Owls. During the breeding season, it is likely that mass alone is sufficient for determining the sex of Tengmalm's Owls. However, female Tengmalm's Owls decrease greatly in mass after breeding (Hipkiss 2002), so morphometric sexing methods involving mass used during the breeding season are unlikely to be of use in autumn. While mean mass, wing length and tail length were significantly larger for females than males, the degree of overlap was so great that they are not reliable for accurate sex determination in this species (Table 1, Fig 1). Even using these three measurements in a stepwise discriminant analysis did not reliably classify more than 70% of individuals, which is inadequate for scientific studies of this species. In the current popular literature (*eg* Mikkola 1983, König *et al* 1999), a fair degree of overlap in size between males and females is acknowledged, although ringers might be tempted to label individuals with a small wing length (*eg* < 165 mm) as 'males' and those with a larger wing length (*eg* > 176 mm) as 'females' (according to the data in König *et al* 1999). However, the data presented here from owls caught in autumn suggest that even these more 'extreme' individuals are difficult to sex, since the degree of overlap is greater than previously recorded. These earlier studies were based on a smaller sample of owls, which might have missed the more 'extreme' individuals (*ie* larger males and smaller females) found in this study.

While discriminant analysis failed to classify accurately males and females in this study, Hayward & Hayward (1991) successfully used this method on a larger number of body measurements for sexing Boreal Owls in Idaho,

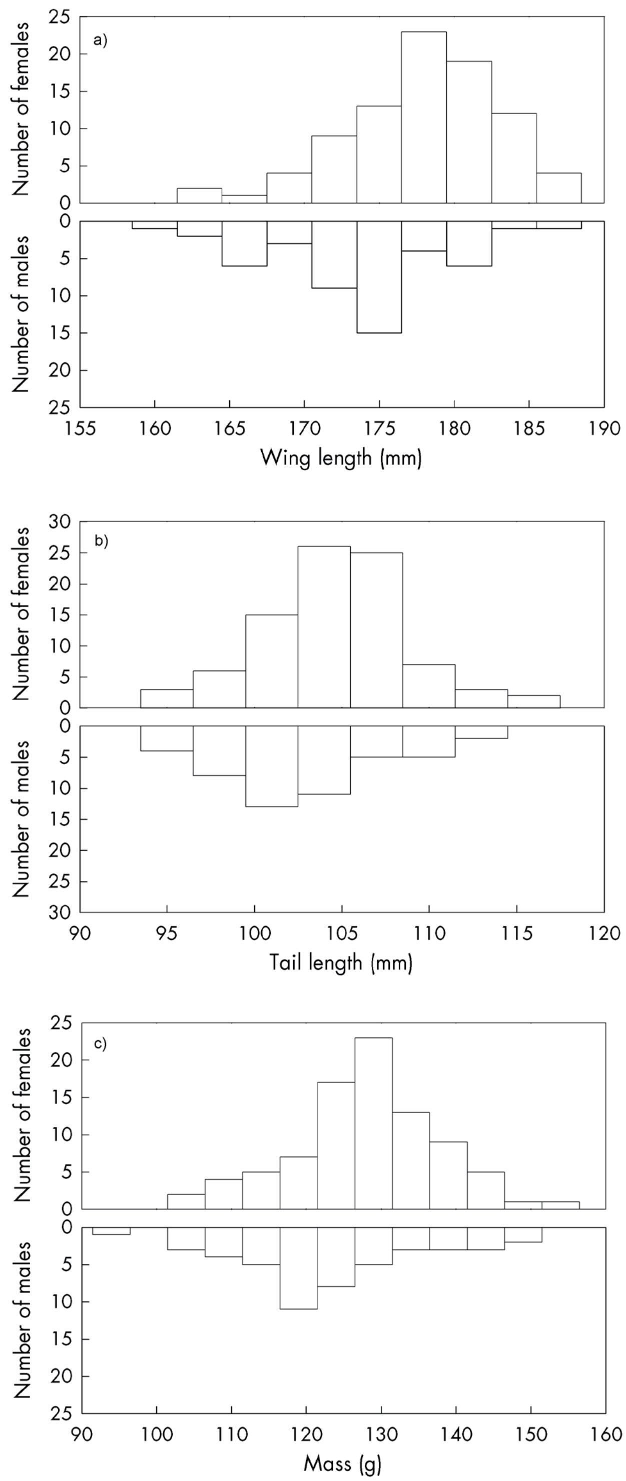

Figure 1. Distribution of (a) wing lengths, (b) tail lengths and (c) body mass of 48 male and 87 female Tengmalm's Owls caught in autumn 1999 on the Swedish island of Stora Fjäderägg in the Gulf of Bothnia. Bar interval width represents 3 mm for wing and tail length and 5 g for body mass.

USA. Their successful classification utilised several body measurements not taken in this study, and it is indeed possible that using more measurements, involving *eg* the bill and feet, might have improved the discriminant analysis used here. However, there are important differences between Hayward & Hayward's (1991) study and this one. Firstly their sample consisted of owls caught throughout the year, rather than exclusively in autumn. Secondly, the North American Boreal Owl *A. f. richardsoni* is a genetically distinct subspecies to the European *A. f. funereus* (Koopman *et al* 2005), and is generally larger (König *et al* 1999), so that conclusions drawn from a morphometric study of North American Boreal Owls may not hold for European Tengmalm's Owls.

The aim of this study was to investigate whether simple, commonly used measurements could be used to classify the sex of Tengmalm's Owls in autumn. However, the measurements taken overlapped too much between the sexes and proved to be of little use. It is therefore recommended that ringers and other fieldworkers do not attempt to sex Tengmalm's Owls in autumn using only wing length, tail length or mass. It is possible that other, more complicated morphometric measurements might prove useful for determining sex in Tengmalm's Owl, but until then molecular techniques provide the only reliable means of sexing this species outside the breeding season.

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