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An allometric function to fit leg-loop harnesses to terrestrial birds

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Harnesses are indispensable for a long-term attachment of instruments to animals, particularly birds. The exact fit is crucial for both the reliability of the tags and the animals' health and natural behaviour. Using data from 19 bird species ranging from 8–400 g, I present an allometric function to calculate the dimension of leg-loop harnesses for birds on the basis of body mass data. The model greatly facilitates determining the correct loop span for new species without time-consuming experiments. More importantly, the equation permits calculation of the excess span that is required for tagging juvenile, still growing birds.

The proper attachment of radio-tags and other instruments is of prime importance for avoiding adverse effects to study animals. Although few studies are specifically designed to assess possible effects of tagging, researchers are aware of the methodological problems and ethical responsibility. Many authors report no adverse effects (birds: e.g. Brigham 1989, Hill and Talent 1990, Neudorf and Pitcher 1997, Naef-Daenzer et al. 2001a, Sunde 2006), however, others indicate considerable impact, for example, on activity time allocation (Hooge 1991), foraging performance (Massey et al. 1988, Ackermann et al. 2004), and survival (Petty et al. 2004). Glue and tail-mounts are very suitable for short-term studies. Harnesses are indispensable for the long-term instrumentation of animals (reviewed by Kenward 2001). However, harness mounts pose the problem that they may inhibit, for example, the action of flight muscles or the deposition of fat if they are too snug. On the other hand, birds may entangle a wing, leg or the bill if harnesses are loose, which can result in immobilization and fatal harm. The fitting problems are particularly tricky when juvenile animals are tagged before their growth is completed (Sunde 2006).

The Rappole-type harness for birds fits around the thighs, and is an alternative to back-packs or underwing loop harnesses (Rappole and Tipton 1991). It proved very reliable for many bird species, except those with very short thighs (e.g. ducks). This type of harness leaves critical parts such as the flight muscles and major fat deposits untouched. Furthermore, there is little possibility of the bird becoming entangled. However, it is important that the loops fit accurately. If they are too large, the bird will step out in a short time, if they are too tight, hopping or walking will be restricted, and the bird is at risk of physical harm. Therefore, determining the appropriate loop size for a particular species requires some experimentation, which is difficult where keeping a few animals in captivity for a short period is impractical. Here, I present an allometric model for determining the appropriate loop span of leg-loop harnesses. Since body mass data are available for most bird species, such a function will allow predicting the correct loop span without extensive experimentation.

Methods

I used data from research conducted at the Swiss Ornithological Institute as well as information provided by foreign researchers in response to an inquiry to the Biotelem mailing list (biotelem@bgu.listserv.ac.il). Data on body mass and the empirically determined harness span for 19 species were used. These ranged from coal tit *Parus ater* (8–11 g) to grey partridge *Perdix perdix* (350–400 g). Each species provided one independent data point (average mass in g, and average span in mm), except species with large body mass variation or sex dimorphism. For one species, two independent estimates from different research projects were supplied (thus, total n = 24 data pairs). The list of sample species, raw data and data sources is given in Table 1. I measured loop dimensions using the span of the loops, including the width of the transmitter case, with the loops stretched but not extended (where elastic cords were used, Fig. 1). The number of individuals that were tagged was not included in the analysis.

Since no independent data were available to validate the model I used a cross-validation procedure. Each species was excluded from the calculation of the allometric function, and the residuals of the empirically determined harness span to the predicted span were used as a test value. Additional validation was obtained by testing calculated harness sizes in the field for two small passerine species and the bearded vulture *Gypaetus barbatus*, a species far out of the range of body mass for which the equation was calculated, and by comparing the calculated values with the empirically determined harness size.

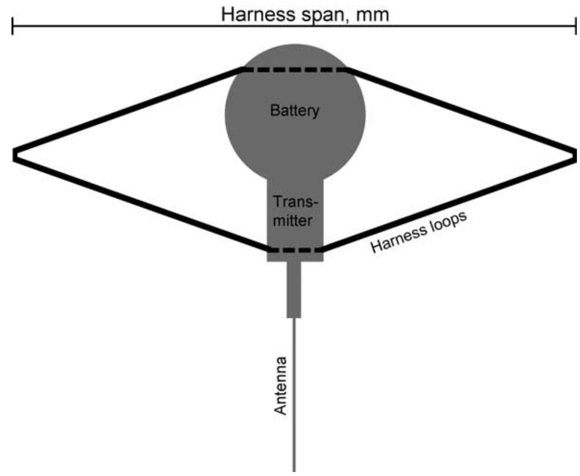

Fig. 1. Illustration of how harness loop span was measured for modelling the allometric relationship with body mass. The drawing shows a standard transmitter design (grey) with the two loops stretched out but unextended. The length of cord required for a specific span depends on the geometry and is best measured on a drawing.

Table 1. Raw data and data sources for the bird species included into the allometric model.

Species	No. in Fig. 2	Body mass, g	Loop span, mm	Data source
Coal tit *Parus ater*	1	8	34	Own data
Coal tit *Parus ater*	1	11	38	Own data
Blue tit *Parus caeruleus*	2	12	40	Own data
Kentucky warbler *Oporornis formosus*	3	13	42	Rappole and Tipton 1991
Barn swallow *Hirundo rustica*	4	18	42	Own data
Great tit *Parus major*	5	19	44	Own data
House finch *Carpodacus mexicanus*	6	22	44	E. Swarthout, Cornell Lab. es243@cornell.edu
Nightingale *Luscinia megarhynchos*	7	23	48	V. Amrhein v.amrhein@unibas.ch
Wood lark *Lullula arborea*	8	26	51	Own data
Bicknell's thrush *Catharus bicknelli*	9	28	49	K. McFarland kmcfarland@vinsweb.org
Alpine accentor *Prunella collaris*, female	10	36	54	L. Heer, pers. comm.
Alpine accentor *Prunella collaris*, male	10	40	56	L. Heer, pers. comm.
Wood thrush *Hylocichla mustelina*	11	40	58	Rappole and Tipton 1991
Wood thrush *Hylocichla mustelina*	11	43	56	Powell et al. 1998
White throated robin *Turdus assimilis*	12	61	60	E. Cohen emlcohen@hotmail.com
White throated robin *Turdus assimilis*	12	71	70	E. Cohen emlcohen@hotmail.com
Common grackle *Quiscalus quiscula*	13	100	80	Rappole and Tipton, 1991
Black stilt *Himantopus novezelandiae*	14	220	98	R. Maloney, Twizel NZ maloney@doc.govt.nz
Kestrel *Falco tinnunculus*	15	220	100	Own data
Woodcock *Scolopax rusticola*	16	230	110	Own data
Long-eared owl *Asio otus*	17	300	115	Own data
Grey partridge *Perdix perdix*	18	330	120	Own data
Barn owl *Tyto alba*	19	340	121	Own data
Grey partridge *Perdix perdix*, large	18	410	130	Own data
Bearded vulture *Gypaetus barbatus* (not in model)		5150	358	D. Hegglin, pers. comm.
Bearded vulture *Gypaetus barbatus* (not in model)		6000	385	D. Hegglin, pers. comm.
Bearded vulture *Gypaetus barbatus* (not in model)		8000	450	D. Hegglin, pers. comm.

Results

There was a very strong relationship between bird body mass and harness span following a power function ($y = 14.16 + 8.34 \times \text{body mass}^{0.437}$, $r^2 = 0.994$, $F_{23} = 1895.3$, $P < 0.001$, Fig. 2). Accordingly, the birds' body mass explains the major proportion of variance in loop span.

The cross-validation of the model confirmed the good fit. The average residual of the empirically determined harness span from the predicted value (for the species that was excluded from fitting the equation) was -0.12 ± 3.8 (SD) percent of the predicted loop span. The extremes were -8.6% (white throated robin *Turdus assimilis*) and 6.05% (kentucky warbler *Oporornis formosus*), hence no species deviated widely from the regression curve. Accordingly, the correlation of the observed versus the expected span (excluding the particular data point) was very high ($\text{observed} = 0.026 + 1.002 \times \text{predicted}$, $r^2 = 0.996$). To test the effect of the species on the resulting regression equation, I calculated the expected span for a 100 g bird for all cross-validation functions. The variance in the expected values was very small (expected loop span $= 76.7$ mm $\pm$ 0.29 SD, range 76.0–77.3 mm). This indicates that the allometric relationship is very robust against the effect of a single data point. Also, the 6 data sets from non-passerine species did not deviate significantly from the regression curve (ANOVA on residuals, effect of taxon: $F_{1,22} = 0.191$, $P = 0.67$).

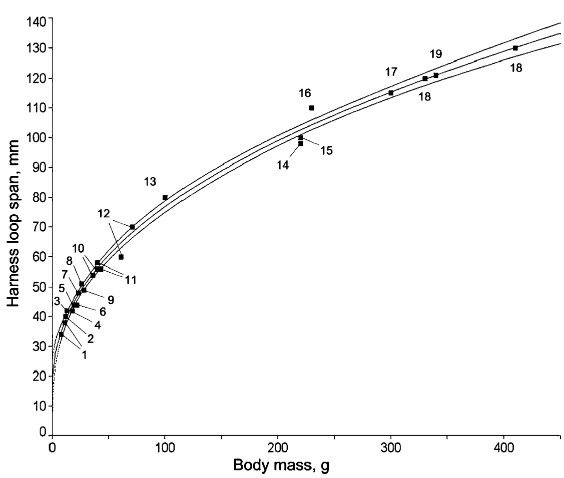

Fig. 2. The relationship of harness loop span (as measured according to Fig. 1) to body mass as calculated for 19 bird species. $\text{Span} = 14.16 + 8.34 \times \text{body mass}^{0.437}$, $r^2 = 0.994$, $P < 0.001$. The fitted curve and 95% confidence intervals for the fit are shown. Numbers refer to the species number given in Table 1.

Discussion

The strong allometric relationship between body mass and loop span of Rappole-type harnesses provides a useful tool to dimension the harnesses for bird species for which no field experience is available. Most of the example species were passerines, however, since the non-passerine species did not deviate from the equation, this model is likely to apply also to other taxa. Therefore, the model predicts the required span of leg-loop harnesses and minimizes the potential risk where tests with captive birds are impractical. Indeed, the calculated harness span for winchats *Saxicola rubetra* (18 g) and reed buntings *Emberiza schoeniclus* (20 g) proved to fit accurately and no further modifications were required (pers. comm: H. Schuler, winchat and G. Pasinelli, reed bunting).

Any attachment must allow for frequent and quick changes in body mass. The Rappole-type harness is less likely than e.g. body harnesses to cause problems in this respect because neither transmitter nor loops touch areas with large muscles or fat deposits. Experience from species in which large numbers individuals were tagged suggests that a standard span (as calculated from the equation) would fit for ca. 90% of the individuals. For example, in a study on great tit fledglings, a standard span of 44 mm proved reliable for birds of 14.5–20.0 g, i.e. a range of 85–125% of the average body mass (Naef-Daenzer et al. 2001b). I did not observe frequent losses in individuals of low mass, while there was still a slack of ca 1 mm between body and transmitter in the heaviest individuals. However, with extremely large or very small individuals, or in species that accumulate exceptionally large fat deposits, adjustments may be required.

Where juvenile birds have to be tagged, taking into account the expected growth to adult size is an important issue (e.g. Hill et al. 1999). The present equation allows the excess loop span to be calculated and therefore greatly facilitates the optimal harnessing of growing individuals. Similarly, species with a pronounced sex dimorphism require different loop spans (Kenward et al. 2001), which can be predicted using the present relationship. The use of elastic cords to account for future growth or for variation in body size is limited because a permanent extension of the loops causes pressure, and hence, the risk of injuries. On the other hand, elastic loops can considerably reduce short-term pressure on the animal's skin due to movements.

Although the data cover a range of about 10 to 400 g, the allometric relationship can probably be extrapolated to larger species. In context of a study of the bearded vulture in Switzerland, a few individuals were instrumented with ARGOS transmitters using leg-loop harnesses. The empirically fitted harness size (e.g. 380 mm for a 6 kg bird, D. L. Ohrmeyer pers. comm.) corresponded well with the predicted span of 387 mm using the above function.

Research implications

Despite the near-perfect fit of the allometric equation, researchers should carefully evaluate the calculated harness span when a particular species is to be equipped. A cautious approach to the perfect fit would be to begin with loops that are relatively large, that is, about 105% of the calculated span. Potential problems with fitting harnesses to a species not included into the above model may arise because the structural conformation rather than body mass is the critical issue for proper fit of the harness. Unfortunately, a standardized estimate of skeletal size was not available for a sufficient number of species. Species of similar size may differ in mass. For example, in a radio-tracking study of juvenile barn owls, the calculated harness span proved to be too loose, and various transmitters were lost (B. Almasi pers. comm.). The reason was, that the fledging mass of barn owls normally is considerably higher than the final mass as an adult bird, although the structural growth is completed. Recalculating the harness span according to average adult weights solved the problem satisfactorily.

Many bird species do not wear Rappole-type harnesses well because their thighs or pelvis is too short. Also behavioural peculiarities may be involved in the loss of instruments with such birds (Walker et al. 2006). In such species an alternative solution should be sought instead of tightening harnesses to a dangerous extent (e.g. Weimerskirch et al. 2006).

Harnesses may be attached to the transmitter in many different ways. As a result the length of cord required for a given harness size is larger than twice the loop span. I suggest that the required cord length is best measured using a drawing similar to Fig. 2.

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