**Supplementary material to the paper "Home ranges, habitat and body mass: simple correlates of home range size in ungulates", DOI: 10.1098/rspb.2016.1234**

**S1: Data search for home range size in ungulates**

From literature, we gathered estimates on annual home range size (hectare) for adult individuals in species belonging to the taxa Perrisodactyla and Artiodactyla (table S1). The results included estimates of home ranges based on 90-95% contours of KDE or 90-100% MCP. If possible, we chose 90% and 95% contours over 100%, and KDE over MCP, as 90% and KDE show the least within population variation and are assumed to best represent home range size [1]. Estimates should also include an estimate uncertainty (standard error), as accounting for this may affect the results [2]. Only species with estimates of both sexes were included.

For each species we collected information on sex-specific mean body mass (gram), mean annual group size, habitat preferences for landscape openness (open, mixed or closed habitat), feeding type (grazer, mixed feeder or browser) and mating system (table S2). We acknowledge that mating systems are flexible traits that may vary according to local differences in resource distribution and population structure [e.g. 3], but assume that within-species variation in such characteristics is smaller than between-species variation. We thus categorized species as harem, tending, or territorial (including lek species) [4]. As both territorial and lekking males benefit from occupying a spatially restricted area [5] they coincide with regards to our predictions.

Collared peccary (*Tayassu pecari*) and wild boar (*Sus scrofa*) were excluded due to being the only promiscuous and omnivorous species, respectively, in this study. The lesser mouse deer (*Tragulus javanicus*) was an outlier with regard to body mass, weighing only 1300/1460 g (male/female), but omitting it from the analyses did not qualitatively affect the results and was included in all analyses. Of the original 257 estimates collected, 245 included species with estimates for both sexes, 195 included estimate uncertainty and 200 concerned species with a phylogeny according to Fritz, Bininda‐Emonds [6]. Accordingly, we kept 162 estimates from 22 species for the analyses, covering 90 unique areas on 7 continents (table S1). Of these, nine were studies of four non-ruminant species, and six studies and four species were the tropics, the remaining were studies of ruminants in temperate zones.

**Table S1 –** Studies with estimates of home range size and associated uncertainty in ungulates included in the analyses, from species with estimates on both sexes and a part of the phylogeny constructed by Fritz, Bininda‐Emonds [6]. The studies were found by literature search in Google Scholar and ISI Web of Science with the following search words: “home range”, “space use”, “area use” or “spatial variation” in combination with “ungulate” or “large herbivore”, and more studies were found from references within these and by identifying underrepresented parts of the phylogeny.

|  |  |  |
| --- | --- | --- |
| Species | Continent | References |
| Alces alces | Europe | [7-9]  |
|  | North-America | [10], [11], [12], [13], [14], [15] ,[16], [17], [18] |
|  |  | [19], [20], [21], [22] |
| Antilocapra americana | North-America | [23] |
| Axis axis | Asia | [24] |
| Bison bison | North-America | [25], [26] |
| Capra ibex | Europe | [27], [28], [29], [30], [31], [32] |
| Capra sibirica | Asia | [33] |
| Capreolus capreolus | Europe | [34], [35], [36], [37], [38], [39], [40], [41] |
| Cervus elaphus | Europe | [42], [43], [44], [45], [46], [47], [48] |
| Cervus nippon | Asia | [49], [50], [51] |
| Cervus nippon | North-America | [52] |
| Dama dama | Europe | [53], [54] |
| Dama dama | North-America | [55] |
| Dama dama | Oceania | [56], [57] |
| Diceros bicornis | Africa | [58], [59] |
| Equus caballus | Asia | [60], [61], [62] |
| Equus caballus | North-America | [63] |
| Equus hemionus | Asia | [61], [64] |
| Equus zebra | Africa | [65] |
| Giraffa camelopardalis | Africa | [66], [67], [68] |
| Muntiacus muntjak | Asia | [69] |
| Odocoileus hemionus | North-America | [70], [71], [72], [73] |
| Odocoileus virginianus | North-America | [74], [75], [71], [76], [77], [52], [78], [79], [80], [81], [82], [83], [84], [85], [86], [87] |
| Oreamnos americanus | North-America | [88], [89] |
| Ozotoceros bezoarticus | South-America | [90], [91], [92] |
| Rangifer tarandus | North-America | [93], [94], [95], [96], [97], [98] |
| Tragulus javanicus | Asia | [99] |

**Table S2** – Species’ characteristics used as explanatory variables in the analyses of home range size. BM = sex specific body mass (kg), GS = group size, H = habitat (O: Open, C: closed, I: mixed, [100]), D = diet (M = mixed feeder, B = browser, G = grazer, [101]), MS = mating system (T = tending, Tr = territorial, H = harem, [102]).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Species | ♂ BM  | ♀ BM  | GS | H | D | MS | References |
| Capra ibex | 95.00 | 45.00 | 11.50 | O | M | T | [101], [103], [104], [105], [27], [106] |
| Capra sibirica | 90.00 | 44.20 | 9.41 | I | G | T | [105], [107]  |
| Oreamnos americanus | 69.00 | 53.00 | 16.45 | O | G | T | [101], [104] |
| Bison bison | 469.90 | 274.75 | 22.20 | O | M | T | [108], [109], [105], [110], [111] |
| Alces alces | 440.00 | 330.50 | 1.35 | C | B | T | [112], [101], [113], [114], [115] |
| Capreolus capreolus | 27.68 | 26.73 | 4.00 | I | B | Tr | [116], [101], [117], [118], [105], [119] |
| Ozotoceros bezoarticus | 36.09 | 31.31 | 2.35 | O | M | H | [116], [120], [114], [91], [92], [121] |
| Odocoileus hemionus | 59.60 | 45.90 | 2.00 | I | B | T | [116], [101], [113], [114], [119], [122] |
| Odocoileus virginianus | 68.00 | 45.00 | 3.25 | I | B | T | [116], [101], [114], [119] |
| Rangifer tarandus | 136.67 | 88.87 | 3.40 | O | M | H | [123], [124], [104], [27], [114], [125] |
| Axis axis | 88.00 | 55.00 | 10.80 | I | M | T | [123], [116], [113], [114], [105] |
| Cervus elaphus | 160.00 | 107.50 | 5.50 | I | M | H | [126], [116], [101], [114], [105], [119] |
| Cervus nippon | 79.87 | 50.13 | 3.50 | I | M | Tr | [127], [101], [125], [114], [128], [105], [129]  |
| Dama dama | 71.00 | 41.20 | 4.35 | I | M | Tr | [130], [101], [119], [114], [131] |
| Muntiacus muntjak | 22.50 | 20.00 | 1.32 | C | M | Tr | [132], [124], [101], [114] |
| Antilocapra americana | 53.60 | 46.80 | 12.25 | O | M | Tr | [133], [101], [130], [105] |
| Giraffa camelopardalis | 1200.00 | 800.00 | 5.50 | O | B | T | [66], [134], [135], [136] |
| Tragulus javanicus | 1.30 | 1.46 | 1.06 | C | B | Tr | [132], [109] |
| Diceros bicornis | 1179.00 | 1179.00 | 2.33 | I | B | T | [137], [138], [139] |
| Equus zebra | 247.80 | 219.10 | 7.50 | O | G | H | [111], [62], [140] |
| Equus hemionus | 250.00 | 250.00 | 17.46 | O | G | H | [61], [64] |
| Equus caballus | 350.00 | 320.00 | 8.60 | O | G | H | [63], [141], [62], [61], BM: pers.comm. Kaczensky, P |

**Supplementary Material S2: Statistical procedures and methodological considerations regarding analyses of home range size variation in ungulates**

We considered home range size to follow a power law-like relationship with metabolic requirement, i.e. body mass and group size [142]. Home range size (hectare), body mass (gram), and mean annual group size were therefore ln-transformed. This also gave normal distributed residuals from the final models. Standard errors (se) of the home range size estimates were transformed using the delta method, i.e. the product of the derivative of the transformation ln(x) and the untransformed se(x). Because body mass and group size describe the realized metabolic requirements of an individual and their absence may confound the effects of the remaining variables [113], they were included in all models. The model including only body mass and group size served as the null model.

Testing effects of species’ traits (Supplementary Material, table S2) on home range size was done by adding them as main effects, whereas interactions between traits and body mass or group size were used to investigate variation in allometric slopes. Due to low sample size for some combinations of habitat and diet, we could not test for differences in allometric slopes between habitat and diet simultaneously. Furthermore, as these species’ traits are closely integrated with each other [100], and may therefore be prone to statistical collinearity. The absence of collinearity was ascertained through qualitatively stable parameter estimates [143,144] regardless of inclusion of several species traits. For instance, collinearity barred the possibility of including degree of polygamy in the analyses because its inclusion led to unstable parameter estimates. Hypotheses (see figure 1 in the article) were otherwise tested within the same model.

Species in Artiodactyla and Perrisodactyla are often considered ruminants and non-ruminants, respectively. The differences in energy intake of ruminants and non-ruminants may be balanced by increasing digesta retention and decreasing particle size, respectively [145,146]. However, ruminating limits movement, and it is not clear whether the time spent ruminating is balanced against the increased chewing time in non-ruminants [146]. Wider diet tolerance enables non-ruminants to utilize a larger range of habitat types [147], which in turn may decrease the home range size [148,149]. We assumed that these factors may balance each other with regard to home range sizes of ruminating and non-ruminating ungulates. This was ascertained by adding a term distinguishing ruminants from non-ruminants to the null model and highest ranked model (see table 1). There was no evidence for differences in home range size between ruminants and non-ruminants (βruminant vs non-ruminant = 1.10, CI: -4.13, 6.58, ∆DIC = 0.48, and βruminant vs non-ruminant = 1.24, CI: -3.59, 5.38, ∆DIC = 0.62, for null model and highest ranked model, respectively).

Using the studies including estimates from both sexes (n = 108) we also analysed the relationship between the ratios of home range size and body mass, defined as log2(male/female). A ratio of zero indicates absence of sex dimorphism, whereas a ratio of 1 indicates twice as large body mass or home range of males compared to females, and -1 indicates twice as large home range or body mass of females compared to males. We expected the slope between log2(HRMale/HRFemale) and log2(BMMale/BMFemale) to be larger than 1 as males were predicted to use larger home ranges than females for a given sexual size dimorphism.

Models were fitted using package MCMCglmm [150] in R version 3.2.2 [76], and ranked according to the Deviance Information Criterion [DIC, 151], where candidate models with ∆DIC < 2 were considered to receive similar support given the data. One could argue for more or less conservative thresholds [151], but given that subsequent models, ranked according to information criteria, only add one or few parameters to the highest ranked model it is limited how competitive they actually are [152]. In Gaussian models with relatively few effective parameters DIC behaves similar as AIC [153], but accounts for the parameter uncertainty, which is crucial in meta-analyses [154]. In addition, 95% credible intervals were used to assess parameters’ importance in explaining home range size variation.

Models were set to run for 1 000 000 iterations with a burn-in of 100 000 and thinning of 500, and average DIC values over three replicates were used to ensure convergence and consistency in ranking. Models were not sensitive to choice of priors. The priors for the variance components were half-Cauchy distributions with scale parameter 25 and variance and belief parameter to V = 1 and η = 1, respectively. Posterior medians were chosen as point estimates [155]. Priors for fixed effects followed a normal distribution with mean zero and large variances (V = 108), and an inverse-Gamma with ν=2\*shape, and V = shape/scale, with shape=scale=0.001 for the residuals. The model estimates were not sensitive to choice of prior, e.g. the estimated variance for species using half-Cauchy with a scale = 25, weak prior and weak improper prior were 1.65, 1.71 and 1.82, respectively. Following Gelman [156] we used half-Cauchy with scale = 25, as this is considered suitable for random predictors with < 5 groups. To improve mixing and confer less information with variances at small values we used parameter expanded parameters [alpha.mu=0,alpha.V=25^2, 156].

Methodological sources of variation, such as choice of method [157] and estimate uncertainty [2], may cause biased and anti-conservative estimates, and should be accounted for before drawing conclusions based on the results from the models. Furthermore, shared ancestry of species may affect the present observations, although this is less relevant for behavioural traits [158]. By considering phylogeny, estimate uncertainty and sampling method as nuisance terms we may ensure more correct estimates both in terms of a covariate’s effects size [119] and uncertainty [159], and predicted home range variance, respectively. As such, the effect of these considerations may alter apparent relationships (figure S2), and thus increase the understanding of how biological and methodological components may covary and make up the observed variation. We accounted for these challenges by the following analytical approaches:

Models were run in four parallel sessions with one of the following phylogenies as random effects [159]: 1) dated phylogeny [figure S1, 6], 2) Grafen branch length transformation [160], 3) random evolution since divergence [161], and 4) star phylogeny (i.e. no phylogenetic effects).

Estimate uncertainty, also called measurement error [159], includes both sampling noise (such as sample size and choice of methodology) and natural variation (such as behaviour and demography). Several measurements per species may account for some of the natural variation at the within species level. To account for repeated measurements, species and study area were added as random effects [159]. VHF-based estimates on home range size are often based on fewer locations, which may lead to smaller home range estimates [162]. Sampling method (GPS, VHF or visual observations) was therefore included as a random effect in the statistical models (see below for further details). Assuming that part of the within-species variation in home range size was caused by ecological differences, i.e. natural variation, rather than being simply an effect of number of animals tracked, we fitted a random-effect meta-analysis models with estimates not weighted and weighted according to their estimate uncertainty [159]. This implies that there is not one true effect size of e.g. diet across studies due to differences in forage availability, but overall the studies will converge to similar values. It also relaxes the assumption of no residual variation inherent in alternative phylogenetic analyses [e.g. 119] where species’ (non-phylogenetic) variation is confounded with residual variation [159].

Accounting for estimate uncertainty had only a small effect on the ranking of candidate models (table S3) and led to a small increase in parameter uncertainty (appr. 0.7%, Supplementary Material, table S4), but the five highest ranked models had similar fixed-effect structure regardless of estimate uncertainty (table S3). Similarly, the ranking of the top candidate models was similar for the four sessions with different phylogenetic random structure (table S3). This supports previous findings that behavioural traits show low phylogenetic signal compared to the effects of morphological and life history traits [158] and a low or no effect of branch length transformation [163]. The phylogenetic signal, H2 [similar to Pagel's lambda, 164] was slightly underestimated when not accounting for estimate uncertainty (0.21 to 0.18, Supplementary Material, table S4). The proportionate change in variance components [PCV, 165] to the null model, show that the fixed effects have phylogenetic dependencies (PCV = 0.16) which reduces the phylogenetic signal.

Accounting for the estimate uncertainty increased both parameter uncertainty and the power to detect the phylogenetic signal present, but had no qualitative effect on our conclusions.

The highest ranked model had a marginal R2 = 0.33 (accounting only for fixed effects), and a conditional R2 = 0.98 (also accounting for random structure). A large proportion of variance components (VC) explaining variation in home range size was attributed to sampling method (VC = 0.38, PCV = -0.22). In support of previous studies [1,166,167], the random structure suggested that home ranges derived from GPS locations were larger than those from VHF and visual observations (γ = random intercept: γGPS = 0.48 [-1.40, 2.23], γVHF = -0.74 [-2.66, 0.92], γVisual = -1.52 [-3.87, 0.37]). The larger estimates of home range size from GPS-based locations can be due to both increasing number of locations included, but also that GPS-data may capture excursions not observed using VHF or visual sampling [166]. However, any differences in effect size between sampling methods may depend on how the characteristics of the study area affect sampling strategy and the movement behaviour of the animal. For instance, differences in habitat structure may affect both the recorded locations and the movement characteristics of the animals [168]. The proportion of variance attributed to study area (VC = 0.29, PCV = 0.28) and species (VC = 0.10, PCV = 0.56) further supports usage of random effect meta-analysis.

**Figure S1** – Phylogeny [6] of species included in the analyses. A Grafen branch length transformation assumes increasing covariance between species with number of descendants from a shared node in the phylogeny, i.e. branch length increase with number of descendants [160], and one assuming random evolution where the variance is equal to time since divergence, i.e. branch length is set to one [161]. In the fourth session we ignored phylogeny (i.e. star phylogeny).



**Supplementary Material S3: Detailed presentation of results from a meta-analysis of home range size variation in ungulates**

Unless otherwise specified, estimate uncertainty and dated phylogeny has been accounted for in the results, and 95% credible intervals are given in square brackets.

Mean group size among species (see table S1) was 7.55 ± 1.56 SE (among studies 5.38 ± 0.42 SE), whereas mean body mass and annual home range size (mean of the within-species mean) among females and males were 185.2 ± 60.1 kg and 577.34 ± 364.3 km2, and 236.1 ± 71.5 kg and 210.6 ± 121.6 km2, respectively.

The highest ranked model included species habitat preferences and its interaction with body mass (∆DIC to the highest ranked model without habitat = 5.88, table S3). Species living in open habitats had overall largest home ranges after accounting for body mass and group size, whereas species living in mixed habitats had smallest home ranges (figure S2, table S4). The allometric relationship between body mass and home range size was steeper for species living in mixed habitats, and most shallow for species in open habitats (table S4, note that units have been changed for illustrative purposes in figure 1).

Candidate models including mating system, diet, and sex, either in interaction with body mass or group size, or as main effects, did not receive firm support. Although ΔDIC for some of these candidate models was quite low (e.g. ΔDIC = 0.13 for the model including diet as a main effect, table 1) they were extensions of the highest ranked. It is then important to keep in mind that despite apparent support they provide little additional information when not affecting the remaining variables and as such should not be presented as truly competitive [152,169]. Furthermore, the associated confidence intervals of the parameter estimates for these variables were very wide and included zero (e.g. diet: βGrazer vs βBrowser = -0.43 [-2.95, 2.56], βGrazer vs βMixed = -0.42 [-2.70, 2.18], βMixed vs βBrowser = -0.01 [-1.64, 1.86], mating system: βHarem vs βTending = -0.45 [-2.38, 1.53]; βHarem vs βTerritorial = -0.43 [-2.70, 1.64], βTending vs βTerritorial = -0.04 [-1.76,1.85], sex: βMales vs βFemales = 0.16 [-0.17, 0.52]). A further confirmation of the lack of sex-differences in home range size was that the relationship between log2-ratio home range size and log2-ratio body mass between males and females did not differ significantly from 1 (β = 0.55 [-0.29, 1.40]).

**Table S3 –** The highest ranked models (∆DIC < 2) and the null model (italic font) explaining the variation in annual home range size (ln-hectare) among ungulates. Model selection was run in four parallel sessions where phylogeny were accounted for either by dated branch lengths, transformed branch lengths [160,161] or without phylogeny (star phylogeny). ‘Grafen’ transformation implies that clades with more descendants are covary stronger than clades with fewer descendants, ‘One’ assumes a random evolution since divergence. $σ\_{m}^{2}$ indicates whether estimate uncertainty was accounted for or not. Abbreviations: H = habitat, BM = body mass (gram), D = diet, GS = group size, MS = mating system. K is the number of parameters. BM and GS were ln-transformed and included as main effects in all models. Note that for illustrative purposes, figure 2 show the predicted relationship with annual home range size and body mass expressed as km2 and kg, respectively.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Rank | H | BM × H | D | Sex | Sex × GS | MS |  | Dated | Grafen | One | Star |
| $$σ\_{m}^{2}$$ | K | DIC | DIC | DIC | DIC |
| Yes | 1 | × | × |  |  |  |  | 5 | 275.69 | 275.83 | 275.60 | 275.12 |
| 2 | × | × | × |  |  |  | 6 | 275.92 | 276.23 | 275.73 | 275.29 |
| 3 | × | × |  |  |  | × | 6 | 276.17 | 276.64 | 276.45 | 275.38 |
| 4 | × | × | × |  |  | × | 7 | 276.55 | 276.87 | 276.70 | 275.70 |
| *19* |  |  |  |  |  |  | *2* | *281.57* | *281.71* | *281.67* | *281.10* |
| No  | 1 | × | × |  |  |  |  | 5 | 265.25 | 265.31 | 265.14 | 265.11 |
| 2 | × | × | × |  |  |  | 6 | 265.42 | 265.64 | 265.51 | 265.29 |
| 3 | × | × |  |  |  | × | 6 | 265.70 | 266.02 | 265.91 | 265.38 |
| 4 | × | × | × |  |  | × | 7 | 266.08 | 266.36 | 266.24 | 265.78 |
| 5 | × | × |  | × | × |  | 8 | 266.60 | 266.43 | 266.52 | 267.42 |
| 6 | × | × | × | × | × |  | 9 | 266.65 | 266.40 | 266.59 | 267.42 |
| 7 | × | × |  | × | × | × | 9 | 266.81 | 267.05 | 267.20 | 267.49 |
| 8 | × | × | × | × | × | × | 10 | 267.04 | 266.79 | 267.39 | 267.77 |
| *32* |  |  |  |  |  |  | *2* | *277.83* | *278.00* | *277.95* | *277.24* |

**Table S4** – Parameter estimates and variance components from the highest ranked models explaining the variation in annual home range size (ln-hectare) in ungulates, with dated phylogeny (table 1), accounting for measurement error ($σ\_{m}^{2}) $or not. Allometric slopes (body mass, BM, ln-gram) and elevation estimates (95% confidence intervals) are given for each habitat, with pMCMC values (two times the probability that the β has the opposite sign, based on an effective sample size 1850) given for contrast estimates against the reference level (closed habitat). GS = ln-group size. Bottom rows show proportions of the variance component (VC) medians, and the proportion change in the variance (PCV) from the null model [165], where negative estimates indicates an increase in the variance attributed the given component from the null model. Note that for illustrative purposes, figure 2 show the predicted relationship for the model including $σ\_{m}^{2}$ with home range and body mass expressed as km2 and kg, respectively.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | $$Including σ\_{m}^{2}$$ | Not including $σ\_{m}^{2}$ |
|  |  | β | 95% CI | pMCMC | βm | 95% CI | pMCMC |
| Habitat | Closed | -6.09 | -14.56;1.65 | 0.150 | -5.92 | -13.40;1.43 | 0.140 |
|  | Mixed | -10.28 | -17.99;-3.19 | 0.401 | -11.67 | -18.82;4.90 | 0.248 |
|  | Open | 3.60 | -5.02;10.61 | 0.098 | 3.02 | -4.31;10.07 | 0.107 |
| BM × Closed habitat | 1.13 | 0.39;1.79 | 0.008 | 1.12 | 0.44;1.82 | 0.001 |
| BM × Mixed habitat | 1.44 | 0.88;2.03 | 0.499 | 1.55 | 0.97;2.03 | 0.323 |
| BM × Open habitat | 0.48 | -0.08;1.09 | 0.157 | 0.47 | -0.04;1.04 | 0.163 |
| GS |  | 0.30 | -0.82;1.36 | 0.596 | 0.26 | -0.82;1.47 | 0.640 |
|  |  |  | VCm | PCVm | VC | PCV |  |
| $$σ\_{Phylogeny}^{2}$$ |  |  | 0.21 | 0.16 | 0.18 | 0.08 |  |
| $$σ\_{Species}^{2}$$ |  |  | 0.10 | 0.56 | 0.11 | 0.58 |  |
| $$σ\_{Study area}^{2}$$ |  |  | 0.29 | 0.28 | 0.25 | 0.02 |  |
| $$σ\_{ Method}^{2}$$ |  |  | 0.38 | -0.22 | 0.33 | -0.25 |  |
| $$σ\_{ Residual}^{2}$$ |  |  | 0.03 | 0.10 | 0.02 | 0.05 |  |

**Figure S2 –** Variation in annual home range size (km2) of species belonging to Artiodactyla and Perissodactyla in relation to species’ a) habitat preference, b) mating systems, c) diet, and d) sampling method of locations. The central horizontal bar is the median, hinges represent the 25th and 75th percentile, whereas the whisker extends from the hinge until the most extreme value within 1.5 times the inter-quartile range.

**References**

[1] Börger L, Franconi N, De Michele G, Gantz A, Meschi F, Manica A, Lovari S, Coulson T. 2006 Effects of sampling regime on the mean and variance of home range size estimates. *J. Anim. Ecol.* **75**, 1393-1405. (doi: 10.1111/j.1365-2656.2006.01164.x)

[2] Morrissey MB, Hadfield JD. 2012 Directional selection in temporally replicated studies is remarkably consistent. *Evolution* **66**, 435-442.

[3] Carranza J. 1995 Female attraction by males versus sites in territorial rutting red deer. *Anim. Behav.* **50**, 445-453. (doi: 10.1006/anbe.1995.0258)

[4] Clutton-Brock T. 1989 Review lecture: mammalian mating systems. *Proc. R. Soc. Lond. B* **236**, 339-372. (doi: 10.1098/rspb.1989.0027)

[5] Shuster SM, Wade MJ. 2003 *Mating systems and strategies*. Oxfordshire, UK: Princeton University Press.

[6] Fritz SA, Bininda‐Emonds ORP, Purvis A. 2009 Geographical variation in predictors of mammalian extinction risk: big is bad, but only in the tropics. *Ecol. Lett.* **12**, 538-549. (doi: 10.1111/j.1461-0248.2009.01307.x)

[7] Cederlund G, Sand H. 1994 Home-range size in relation to age and sex in moose. *J. Mammal.* **75**, 1005-1012. (doi: 10.2307/1382483)

[8] Rolandsen CM, Solberg EJ, Bjørneraas K, Heim M, Van Moorter B, Herfindal I, Garel M, Pedersen PH, Sæther B-E, Lykkja ON*, et al.* 2010 Elgundersøkelsene i Nord-Trøndelag, Bindal og Rissa 2005 - 2010 Sluttrapport. *NINA Rapport* **588**, 1-146.

[9] Olsson MPO, Widen P. 2008 Effects of highway fencing and wildlife crossings on moose *Alces alces* movements and space use in southwestern Sweden. *Wildl. Biol* **14**, 111-117. (doi: 10.2981/0909-6396(2008)14[111:eohfaw]2.0.co;2)

[10] Ballard WB, Whitman JS, Reed DJ. 1991 Population dynamics of moose in south-central Alaska. *Wildl. Monogr.* **114**, 3-49.

[11] Courtois R, Crête M. 1988 Déplacements quotidiens et domaines vitaux des orignaux du sud-ouest du Québec. *Alces* **24**, 78-89.

[12] Courtois R, Labonte J, Ouellet JP. 1998 Movements and location of home range of Moose, *Alces alces,* in eastern Quebec. *Can. Field-Nat.* **112**, 602-610.

[13] Crête M, Courtois R. 1997 Limiting factors might obscure population regulation of moose (Cervidae: *Alces alces*) in unproductive boreal forests. *J. Zool.* **242**, 765-781.

[14] Crête M. 1989 Approximation of K carrying capacity for moose in eastern Quebec. *Can. J. Zool.* **67**, 373-380. (doi: 10.1139/z89-055)

[15] Demarchi NW. 2003 Migratory patterns and home range size of moose in the central Nass Valley, British Columbia. *Northwest Nat.* **84**, 135-141.

[16] Doerr JG. 1983 Home range size, movements and habitat use in two moose, *Alces alces*, populations in southeastern Alaska. *Can. Field-Nat.* **97**, 79-88.

[17] Gillingham MP, Parker KL. 2008 Differential habitat selection by moose and elk in the Besa-Prophet area of northern British Columbia. *Alces* **44**, 41-63.

[18] Laurian C, Ouellet JP, Courtois R, Breton L, St-Onge S. 2000 Effects of intensive harvesting on moose reproduction. *J. Appl. Ecol.* **37**, 515-531. (doi: 10.1046/j.1365-2664.2000.00520.x)

[19] Miller BK, Litvaitis JA. 1992 Habitat segregation by moose in a boreal forest ecotone. *Acta Theriol.* **37**, 41-50.

[20] Moen R, Nelson ME, Edwards A. 2011 Using cover type composition of home ranges and VHF telemetry locations of moose to interpret aerial survey results in Minnesota. *Alces* **47**, 101-112.

[21] Stenhouse GB, Latour PB, Kutny L, Maclean N, Glover G. 1995 Productivity, survival, and movements of female moose in a low-density population, Northwestern Territories, Canada. *Arctic* **48**, 57-62.

[22] Van Dyke F, Probert B, Van Beek G. 1995 Seasonal habitat use characteristics of moose in south-central Montana. *Alces* **31**, 15-26.

[23] Ockenfels RA, Alexander A, Ticer CLD, Carrel WK. 1994 Home ranges, movement patterns, and habitat selection of pronghorn in central Arizona, a final report. *Ariz. Game Fish Dep. Res. Branch Tech. Rep.* **13**, i-vi, 1-80.

[24] Moe SR, Wegge P. 1994 Spacing behavior and habitat use of axis deer (*Axis axis*) in lowland Nepal. *Can. J. Zool.* **72**, 1735-1744. (doi: 10.1139/z94-234)

[25] Larter NC, Gates CC. 1990 Home ranges of wood bison in an expanding population. *J. Mammal.* **71**, 604-607. (doi: 10.2307/1381800)

[26] Lott DF, Minta S. 1983 Home ranges of American bison cows on Santa-Catalina Island, California. *J. Mammal.* **64**, 161-162. (doi: 10.2307/1380770)

[27] Abderhalden W. 2005 Spatial behaviour and sexual segregation in the alpine ibex (*Capra ibex ibex*). *Natlpark-Forsch. Schweiz* **92**, 1-184.

[28] Grignolio S, Parrini F, Bassano B, Luccarini S, Apollonio M. 2003 Habitat selection in adult males of Alpine ibex, *Capra ibex ibex*. *Folia. Zool* **52**, 113-120.

[29] Grignolio S, Rossi I, Bassano B, Parrini F, Apollonio M. 2004 Seasonal variations of spatial behaviour in female Alpine ibex (*Capra ibex ibex*) in relation to climatic conditions and age. *Ethol. Ecol. Evol.* **16**, 255-264.

[30] Parrini F, Grignolio S, Luccarini S, Bassano B, Apollonio M. 2003 Spatial behaviour of adult male Alpine ibex *Capra ibex ibex* in the Gran Paradiso National Park, Italy. *Acta Theriol.* **48**, 411-423. (doi: 10.1007/Bf03194179)

[31] Pedrotti L. 1995 La reintroduzione dello Stambecco (*Capra ibex ibex*) nelle Alpi Orobie [PhD], Universita degli Studi di Milano.

[32] Scillitani L, Sturaro E, Menzano A, Rossi L, Viale C, Ramanzin M. 2012 Post-release spatial and social behaviour of translocated male Alpine ibexes (*Capra ibex ibex*) in the eastern Italian Alps. *Eur. J. Wildl. Res.* **58**, 461-472. (doi: 10.1007/s10344-011-0596-9)

[33] Reading RP, Amgalanbaatar S, Kenny D, DeNicola A, Tuguldur E. 2007 Siberian ibex (*Capra sibirica*) home ranges in Ikh Nart Nature Reserve, Mongolia: preliminary findings. *Mong. J. Biol. Sci.* **5**, 29-37.

[34] Bideau E, Gerard JF, Vincent JP, Maublanc ML. 1993 Effects of age and sex on space occupation by European roe deer. *J. Mammal.* **74**, 745-751. (doi: 10.2307/1382297)

[35] Focardi S, Aragno P, Montanaro P, Riga F. 2006 Inter-specific competition from fallow deer *Dama dama* reduces habitat quality for the Italian roe deer Capreolus capreolus italicus. *Ecography* **29**, 407-417. (doi: 10.1111/j.2006.0906-7590.04442.x)

[36] Jeppesen JL. 1990 Home range and movements of free-ranging roe deer *Capreolus capreolus* at Kalö Denmark. *Dan. Rev. Game Biol.* **14**, 1-14.

[37] Maillard D, Calenge C, Invernia N, Gaudin JC. 2002 Home range size and reproduction of female roe deer reintroduced into a Mediterranean habitat. *Zeitschrift Fur Jagdwissenschaft* **48**, 194-200. (doi: 10.1007/bf02192408)

[38] Pandini W, Cesaris C. 1997 Home range and habitat use of roe deer (*Capreolus capreolus*) reared in captivity and released in the wild. *Hystrix* **9**, 45-50.

[39] Rossi I, Lamberti P, Mauri L, Apollonio M. 2003 Home range dynamics of male roe deer Capreolus capreolus in a mountainous habitat. *Acta Theriol.* **48**, 425-432. (doi: 10.1007/bf03194180)

[40] San Jose C, Lovari S. 1998 Ranging movements of female roe deer: Do home-loving does roam to mate? *Ethology* **104**, 721-728.

[41] Zejda J, Bauerova Z. 1985 Home ranges of field roe deer. *Acta Sci. Nat. Acad. Sci. Brno* **19**, 3-44.

[42] Bocci A, Monaco A, Brambilla P, Angelini I, Lovari S. 2010 Alternative strategies of space use of female red deer in a mountainous habitat. *Ann. Zool. Fenn.* **47**, 57-66.

[43] Jeppesen JL. 1987 Impact of human disturbance on home range, movements and activity of red deer (*Cervus elaphus*) in a Danish environment. *Dan. Rev. Game Biol.* **13**, 1-42.

[44] Jerina K. 2012 Roads and supplemental feeding affect home-range size of Slovenian red deer more than natural factors. *J. Mammal.* **93**, 1139-1148. (doi: 10.1644/11-MAMM-A-136.1)

[45] Kamler JF, Jedrzejewski W, Jedrzejewska B. 2008 Home ranges of red deer in a European old-growth forest. *Am. Midl. Nat.* **159**, 75-82. (doi: 10.1674/0003-0031(2008)159[75:hrordi]2.0.co;2)

[46] Lovari S, Cuccus P, Murgia A, Murgia C, Soi F, Plantamura G. 2007 Space use, habitat selection and browsing effects of red deer in Sardinia. *Ital. J. Zool.* **74**, 179-189. (doi: 10.1080/11250000701249777)

[47] Pépin D, Morellet N, Goulard M. 2009 Seasonal and daily walking activity patterns of free-ranging adult red deer (*Cervus elaphus*) at the individual level. *Eur. J. Wildl. Res.* **55**, 479-486. (doi: 10.1007/s10344-009-0267-2)

[48] Schaefer JA, Morellet N, Pepin D, Verheyden H. 2008 The spatial scale of habitat selection by red deer. *Can. J. Zool.* **86**, 1337-1345. (doi: 10.1139/z08-122)

[49] Borkowski J, Furubayashi K. 1998 Home range size and habitat use in radio-collared female sika deer at high altitudes in the Tanzawa Mountains, Japan. *Ann. Zool. Fenn.* **35**, 181-186.

[50] Kawai Y, Ohtani S, Ishizuka Y, Ishii W, Matsushita Y. 2006 Spatial use of two sika deer (*Cervus nippon*) individuals which have overlapped home ranges. *Bull. Agric, Food Env. Sci. Res. Cent. Osaka Prefecture* **42**, 16-19.

[51] Nagata K. 2005 Home range characteristic of sika deer in Fudakake of Tanzawa Mountains. *Mamm. Sci.* **45**, 25-33.

[52] Eyler TB. 2001 Habitat use and movements of sympatric sika deer (*Cervus nippon*) and white-tailed deer (*Odocoileus virginianus*) in Dorchester County, Maryland. Maryland, University of Maryland, Eastern Shore.

[53] Borkowski J, Pudelko M. 2007 Forest habitat use and home-range size in radio-collared fallow deer. *Ann. Zool. Fenn.* **44**, 107-114.

[54] Davini S, Ciuti S, Luccarini S, Apollonio M. 2004 Home range patterns of male fallow deer *Dama dama* in a sub-Mediterranean habitat. *Acta Theriol.* **49**, 393-404.

[55] Morse BW, Nibbelink NP, Osborn DA, Miller KV. 2009 Home range and habitat selection of an insular fallow deer (*Dama dama* L.) population on Little St. Simons Island, Georgia, USA. *Eur. J. Wildl. Res.* **55**, 325-332. (doi: 10.1007/s10344-008-0245-0)

[56] Nugent G. 1994 Home range size and its development for fallow deer in the Blue Moutains, New Zealand. *Acta Theriol.* **39**, 159-175.

[57] Statham HL, Statham M. 1996 Movements of fallow deer (*Dama dama*) in Tasmania and the effects of population sampling on dispersal. In *12th Australasian Vertebrate Pest Conferences* (p. 55. Melbourne, Australia.

[58] Lent PC, Fike B. 2003 Home ranges, movements and spatial relationships in an expanding population of black rhinoceros in the Great Fish River Reserve, South Africa. *S. Afr. J. Wildl. Res* **33**, 109-118.

[59] Mukinya JG. 1973 Density, distribution, population structure and social organization of the black rhinoceros in Masai Mara Game Reserve. *Afr. J. Ecol.* **11**, 385-400.

[60] Bahloul K, Pereladova OB, Soldatova N, Fisenko G, Sidorenko E, Sempere AJ. 2001 Social organization and dispersion of introduced kulans (*Equus hemionus kulan*) and Przewalski horses (*Equus przewalski*) in the Bukhara Reserve, Uzbekistan. *J. Arid Environ.* **47**, 309-323. (doi: 10.1006/jare.2000.0714)

[61] Kaczensky P, Ganbaatar O, Von Wehrden H, Walzer C. 2008 Resource selection by sympatric wild equids in the Mongolian Gobi. *J. Appl. Ecol.* **45**, 1762-1769. (doi: 10.1111/j.1365-2664.2008.01565.x)

[62] Linklater WL. 2000 Adaptive explanation in socio-ecology: lessons from the Equidae. *Biol. Rev.* **75**, 1-20. (doi: 10.1017/s0006323199005411)

[63] Salter R, Hudson R. 1982 Social organization of feral horses in western Canada. *Appl. Anim. Ethol.* **8**, 207-223. (doi: 10.1016/0304-3762(82)90205-X)

[64] Shah N, Qureshi Q. 2007 Social organization and determinants of spatial distribution of khur (*Equus hemionus khur*). *Erforsch. Biol. Ressour. Mong.* **10**, 189-200.

[65] Penzhorn B. 1982 Home range sizes of Cape mountain zebras *Equus zebra zebra* in the Mountain Zebra National Park. *Koedoe-African Protected Area Conservation and Science* **25**, 103-108.

[66] Brand R. 2007 Evolutionary ecology of giraffes (*Giraffa camelopardalis*) in Etosha National Park, Namibia. Newcastle, Newcastle University.

[67] Ciofolo I, Le Pendu Y. 1998 Les Girafes du Niger: de l’ethologie au développement local. In *Rapport final - Project PURNKO. SNV.* (Niarney, Niger.

[68] Vander Wal E, Paquet PC, Messier F, McLoughlin PD. 2013 Effects of phenology and sex on social proximity in a gregarious ungulate. *Can. J. Zool.* **91**, 601-609. (doi: 10.1139/cjz-2012-0237)

[69] McCullough DR, Pei KCJ, Wang Y. 2000 Home range, activity patterns, and habitat relations of Reeves' muntjacs in Taiwan. *J. Wildl. Manage.* **64**, 430-441. (doi: 10.2307/3803241)

[70] Bender LC, Anderson DP, Lewis JC. 2004 Annual and seasonal habitat use of Columbian black-tailed deer in urban Vancouver, Washington. *Urban Ecosyst.* **7**, 41-53. (doi: 10.1023/b:ueco.0000020171.51193.62)

[71] Brunjes KJ, Ballard WB, Humphrey MH, Harwell F, McIntyre NE, Krausman PR, Wallace MC. 2009 Home-range size and overlap of sympatric male mule and white-tailed deer in Texas. *West. N. Am. Nat* **69**, 125-130. (doi: 10.3398/064.069.0105)

[72] Kie JG, Bowyer RT, Nicholson MC, Boroski BB, Loft ER. 2002 Landscape Heterogeneity at Differing Scales: Effects on Spatial Distribution of Mule Deer. *Ecology* **83**, 530-544. (doi: 10.2307/2680033)

[73] Ragotzkie KE, Bailey JA. 1991 Desert mule deer use of grazed and ungrazed habitats. *J. Range Manage.* **44**, 487-490. (doi: 10.2307/4002750)

[74] Bello J, Gallina S, Equihua M. 2004 Movements of the white-tailed deer and their relationship with precipitation in Northeastern Mexico. *Interciencia* **29**, 357-361.

[75] Brinkman TJ, Deperno CS, Jenks JA, Haroldson BS, Osborn RG. 2005 Movement of female white-tailed deer: effects of climate and intensive row-crop agriculture. *J. Wildl. Manage.* **69**, 1099-1111. (doi: 10.2193/0022-541X(2005)069[1099:MOFWDE]2.0.CO;2)

[76] Cooper SM, Owens MK, Cooper RM, Ginnett TF. 2006 Effect of supplemental feeding on spatial distribution and browse utilization by white-tailed deer in semi-arid rangeland. *J. Arid Environ.* **66**, 716-726. (doi: 10.1016/j.jaridenv.2005.11.015)

[77] Cornicelli L, Woolf A, Roseberry JL. 1996 White-tailed deer use of a suburban environment in southern Illinois. *Trans. Ill. State. Acad. Sci* **89**, 93-103.

[78] Hellickson MW, Campbell TA, Miller KV, Marchinton RL, DeYoung CA. 2008 Seasonal ranges and site fidelity of adult male white-tailed deer (*Odocoileus virginianus*) in Southern Texas. *Southwest. Nat.* **53**, 1-8. (doi: 10.1894/0038-4909(2008)53[1:srasfo]2.0.co;2)

[79] Hernandez S, Locke SL, Cook MW, Harveson LA, Davis DS, Lopez RR, Silvy NJ, Fraker MA. 2006 Effects of SpayVac (R) on urban female white-tailed deer movements. *Wildl. Soc. Bull* **34**, 1430-1434. (doi: 10.2193/0091-7648(2006)34[1430:eosouf]2.0.co;2)

[80] Humphreys GG, Nelson TA. 2000 Home ranges and movements of adult deer on Fort Chaffee, Arkansas. *J. Ark. Acad. Sci.* **54**, 59-63.

[81] Kilpatrick HJ, Spohr SM, Lima KK. 2001 Effects of population reduction on home ranges of female white-tailed deer at high densities. *Can. J. Zool.* **79**, 949-954. (doi: 10.1139/cjz-79-6-949)

[82] Quinn ACD, Williams DM, Porter WF. 2013 Landscape structure influences space use by white-tailed deer. *J. Mammal.* **94**, 398-407. (doi: 10.1644/11-mamm-a-221.1)

[83] Rhoads CL, Bowman JL, Eyler B. 2010 Home Range and Movement Rates of Female Exurban White-Tailed Deer. *J. Wildl. Manage.* **74**, 987-994. (doi: 10.2193/2009-005)

[84] Walter WD, VerCauteren KC, Campa H, III, Clark WR, Fischer JW, Hygnstrom SE, Mathews NE, Nielsen CK, Schauber EM, Van Deelen TR*, et al.* 2009 Regional assessment on influence of landscape configuration and connectivity on range size of white-tailed deer. *Landsc. Ecol.* **24**, 1405-1420. (doi: 10.1007/s10980-009-9374-4)

[85] Webb SL, Hewitt DG, Hellickson MW. 2007 Effects of permanent water on home ranges and movements of adult male white-tailed deer in southern Texas. *Tex. J. Sci* **59**, 261-276.

[86] Webb SL, Demarais S, Zaiglin RE, Pollock MT, Whittaker DG. 2010 Size and fidelity of home ranges of male white-tailed deer (*Odocoileus virginianus*) in Southern Texas. *Southwest. Nat.* **55**, 269-273. (doi: 10.1894/tal-doi: 10.1)

[87] Williams SC, Denicola AJ. 2002 Home range increase of lactating female white-tailed deer following herd reduction. *Northeast Wildl.* **57**, 29-38.

[88] Poole KG, Stuart-Smith K, Teske IE. 2009 Wintering strategies by mountain goats in interior mountains. *Can. J. Zool.* **87**, 273-283. (doi: 10.1139/z09-009)

[89] Singer FJ, Doherty JL. 1985 Movements and habitat use in an unhunted population of mountain goats, *Oreamnos americanus*. *Can. Field-Nat.* **99**, 205-217.

[90] Lacerda ACR. 2008 Ecologia e estrutara social do Veado-Campeiro (*Ozotoceros bezoarticus*) no pantanal, Universidade de Brasília.

[91] Rodrigues FHG, Monteiro-Filho ELA. 2000 Home range and activity patterns of pampas deer in Emas National Park, Brazil. *J. Mammal.* **81**, 1136-1142. (doi: 10.1644/1545-1542(2000)081<1136:HRAAPO>2.0.CO;2)

[92] Vila AR, Beade MS, Lamuniere DB. 2008 Home range and habitat selection of pampas deer. *J. Zool.* **276**, 95-102. (doi: 10.1111/j.1469-7998.2008.00468.x)

[93] Courtois R, Ouellet JP, Breton L, Gingras A, Dussault C. 2007 Effects of forest disturbance on density, space use, and mortality of woodland caribou. *Ecoscience* **14**, 491-498. (doi: 10.2980/1195-6860(2007)14[491:Eofdod]2.0.Co;2)

[94] Hazell ME, Taylor ME. 2011 Movements of boreal caribou in the James Bay lowlands. *Rangifer* **31**, 63-73.

[95] Mosnier A, Ouellet JP, Sirois L, Fournier N. 2003 Habitat selection and home-range dynamics of the Gaspe caribou: a hierarchical analysis. *Can. J. Zool.* **81**, 1174-1184. (doi: 10.1139/z03-065)

[96] Ouellet JP, Ferron J, Sirois L. 1996 Space and habitat use by the threatened Gaspe caribou in southeastern Quebec. *Can. J. Zool.* **74**, 1922-1933. (doi: 10.1139/z96-217)

[97] Rettie WJ, Messier F. 2001 Range use and movement rates of woodland caribou in Saskatchewan. *Can. J. Zool.* **79**, 1933-1940. (doi: 10.1139/cjz-79-11-1933)

[98] Schindler D. 2005 Determining Woodland Caribou Home Range and Habitat Use in Eastern Manitoba - Preliminary Analysis and Interim Report. (ed. Committee TEMWCA), pp. 1-71.

[99] Matsubayashi H, Bosi E, Kohshima S. 2003 Activity and habitat use of lesser mouse-deer (*Tragulus javanicus*). *J. Mammal.* **84**, 234-242. (doi: 10.1644/1545-1542(2003)084<0234:aahuol>2.0.co;2)

[100] Jarman P. 1974 The social organisation of antelope in relation to their ecology. *Behaviour* **48**, 215-267. (doi: 10.1163/156853974X00345)

[101] Hofmann RR. 1989 Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system. *Oecologia* **78**, 443-457. (doi: 10.1007/Bf00378733)

[102] Plard F, Bonenfant C, Gaillard J-M. 2011 Revisiting the allometry of antlers among deer species: male–male sexual competition as a driver. *Oikos* **120**, 601-606. (doi: 10.1111/j.1600-0706.2010.18934.x)

[103] Niethammer J, Krapp F. 1986 Handbuch der Säugetiere Europas, Band 2/II, Paarhufer− Artiodactyla (Suidae, Cervidae, Bovidae). *Aula, Wiesbaden*,

[104] Schaller GB. 1977 *Mountain monarchs. Wild sheep and goats of the Himalaya*. Chicago, USA: University of Chicago Press.

[105] Nowak RM, Paradiso L. 1999 *Walker's mammals of the world*. Baltimore, USA: John Hopkins.

[106] Clauss M, Lechner-Doll M, Streich J. 2002 Faecal particle size distribution in captive wild ruminants: an approach to the browser/grazer dichotomy from the other end. *Oecologia* **131**, 343-349. (doi: 10.1007/s00442-002-0894-8)

[107] Fedosenko AK, Blank DA. 2001 *Capra sibirica*. *Mamm. Species* **675**, 1-13. (doi: 10.1644/1545-1410(2001)675<0001:CS>2.0.CO;2)

[108] Lott DF. 1979 Dominance relations and breeding rate in mature male American bison. *Zeitschrift für Tierpsychologie* **49**, 418-432.

[109] MacDonald D. 1984 *The encyclopedia of mammals*. New York, USA: Facts on File.

[110] Larter NC. 1988 Diet and habitat selection of an erupting wood bison population. Fairbanks, University of British Columbia.

[111] Kaiser TM, Müller DW, Fortelius M, Schulz E, Codron D, Clauss M. 2013 Hypsodonty and tooth facet development in relation to diet and habitat in herbivorous ungulates: implications for understanding tooth wear. *Mammal Rev.* **43**, 34-46. (doi: 10.1111/j.1365-2907.2011.00203.x)

[112] Alados CL. 1986 Aggressive-behavior, sexual strategies and their relation to age in male spanish ibex (*Capra pyrenaica*). *Behav. Process.* **12**, 145-158. (doi: 10.1016/0376-6357(86)90053-7)

[113] Owen-Smith N. 1992 *Megaherbivores: the influence of very large body size on ecology*. Cambridge, UK: Cambridge University Press.

[114] Scott K. 1987 Allometry and habitat-related adaptations in the postcranial skeleton of Cervidae. In *Biology and management of the Cervidae* (ed. Wemmer CM), pp. 65-80. Smithsonian Institution, Virginia, USA: Smithsonian Institution Press.

[115] Waser PM, Jones WT. 1983 Natal Philopatry among Solitary Mammals. *Q. Rev. Biol* **58**, 355-390. (doi: 10.1086/413385)

[116] Clutton-Brock T. 1987 Sexual selection in the Cervidae. In *Biology and Management of the Cervidae* (ed. Wemmer CM), pp. 110-122. Smithsonian Institution, Virginia, USA: Smithsonian Institution Press.

[117] Loison A, Gaillard J-M, Pélabon C, Yoccoz NG. 1999 What factors shape sexual size dimorphism in ungulates? *Evol. Ecol. Res.* **1**, 611-633.

[118] Linnell JDC. 1994 Reproductive tactics and parental care in Norwegian roe deer. Cork, National University of Ireland.

[119] Mysterud A, Perez-Barberia FJ, Gordon IJ. 2001 The effect of season, sex and feeding style on home range area versus body mass scaling in temperate ruminants. *Oecologia* **127**, 30-39. (doi: 10.1007/s004420000562)

[120] Eisenberg JF, Redford KH. 1992 *Mammals of the Neotropics, Volume 2: The Southern Cone: Chile, Argentina, Uruguay, Paraguay*. Chicago, USA: University of Chicago Press.

[121] González S, Cosse M, Goss Braga F, Vila A, Merino ML, Dellafiore C, Cartes JL, Maffei L, Gimenez-Dixon M. 2010 Pampas deer *Ozotoceros bezoarticus* (Linnaeus 1758). *Neotropical cervidology* **1**, 119-132.

[122] Relyea RA, Lawrence RK, Demarais S. 2000 Home range of desert mule deer: testing the body-size and habitat-productivity hypotheses. *J. Wildl. Manage.* **64**, 146-153. (doi: 10.2307/3802984)

[123] Bunnell F. 1987 Reproductive tactics of Cervidae and their relationships to habitat. In *Biology and management of the Cervidae* (ed. Wemmer CM), pp. 145-167. Smithsonian Institution, Virginia, USA: Smithsonian Institution Press.

[124] Child G. 1964 Growth and ageing criteria of impala, *Aepyceros melampus*. *Occas. Pap. Natl. Mus. Rhodesia, B.* **27**, 128-135.

[125] Fuller TK, Keith LB. 1981 Woodland caribou population-dynamics in northeastern Alberta. *J. Wildl. Manage.* **45**, 197-213. (doi: 10.2307/3807887)

[126] Blaxter KL, Hamilton WJ. 1980 Reproduction in farmed red deer. *J. Agric. Sci.* **95**, 275-284. (doi: 10.1017/S0021859600039290)

[127] Balmford A, Bartos L, Brotherton P, Herrmann H, Lancingerova J, Mika J, Zeeb U. 1993 When to stop lekking - density-related variation in the rutting behavior of sika-deer. *J. Zool.* **231**, 652-656. (doi: 10.1111/j.1469-7998.1993.tb01946.x)

[128] Zejda J, Horakova M. 1988 Three kinds of weight in Sika deer (*Cervus nippon*). *Folia. Zool* **37**, 289-299.

[129] McCullough DR, Takatsuki S, Kaji K. 2009 *Sika deer: biology and management of native and introduced populations*. Tokyo, Japan: Springer.

[130] Mitchell GJ. 1980 *The pronghorn antelope in Alberta*. Alberta, USA: Alberta Department of Lands and Forests, Fish and Wildlife Division.

[131] Villerette N, Helder R, Angibault J-M, Cargnelutti B, Gerard J-F. 2006 Sexual segregation in fallow deer: are mixed-sex groups especially unstable because of asynchrony between the sexes? *C.R. Biol.* **329**, 551-558.

[132] Barrette C. 1987 The comparative behavior and ecology of chevrotains, musk deer, and morphologically conservative deer. In *Biology and management of the Cervidae* (ed. Wemmer CM). Smithsonian Institution, Virginia, USA: Smithsonian Institution Press.

[133] Barrett MW. 1982 Distribution, behavior and mortality of pronhorns during a severe winter in Alberta. *J. Wildl. Manage.* **46**, 991-1002. (doi: 10.2307/3808232)

[134] Du Toit J. 1990 Home range—body mass relations: a field study on African browsing ruminants. *Oecologia* **85**, 301-303. (doi: 10.1007/BF00319416)

[135] Le Pendu Y, Ciofolo I, Gosser A. 2000 The social organization of giraffes in Niger. *Afr. J. Ecol.* **38**, 78-85. (doi: 10.1046/j.1365-2028.2000.00214.x)

[136] VanderWaal KL, Wang H, McCowan B, Fushing H, Isbell LA. 2013 Multilevel social organization and space use in reticulated giraffe (*Giraffa camelopardalis*). *Behav. Ecol.* **25**, 17-26. (doi: 10.1093/beheco/art061)

[137] Estes RD. 1991 *The behavior guide to African mammals.* Berkeley, USA: University of California Press.

[138] Conway AJ, Goodman PS. 1989 Population characteristics and management of black rhinoceros (*Diceros bicornis minor*) and white rhinoceros (*Ceratotherium simum simum*) in Ndumu game-reserve, South-Africa. *Biol. Conserv.* **47**, 109-122. (doi: 10.1016/0006-3207(89)90094-3)

[139] Goettert T, Schoene J, Zinner D, Hodges JK, Boeer M. 2010 Habitat use and spatial organisation of relocated black rhinos in Namibia. *Mammalia* **74**, 35-42. (doi: 10.1515/Mamm.2010.012)

[140] Shultz S, Dunbar RIM. 2006 Both social and ecological factors predict ungulate brain size. *Proc. R. Soc. Lond. B* **273**, 207-215. (doi: 10.1098/rspb.2005.3283)

[141] Smith C, Valdez R, Holechek JL, Zwank PJ, Cardenas M. 1998 Diets of native and non-native ungulates in southcentral New Mexico. *Southwest. Nat.* **43**, 163-169.

[142] Lindstedt SL, Miller BJ, Buskirk SW. 1986 Home range, time, and body size in mammals. *Ecology* **67**, 413-418. (doi: 10.2307/1938584)

[143] Crawley MJ. 2012 *The R Book*: John Wiley & Sons.

[144] Kenny DA. 1979 Correlation and causation. (New York, USA, Wiley.

[145] Müller DWH, Codron D, Meloro C, Munn A, Schwarm A, Hummel J, Clauss M. 2013 Assessing the Jarman-Bell Principle: Scaling of intake, digestibility, retention time and gut fill with body mass in mammalian herbivores. *Comp. Biochem. Phys. A* **164**, 129-140. (doi: 10.1016/j.cbpa.2012.09.018)

[146] Clauss M, Nunn C, Fritz J, Hummel J. 2009 Evidence for a tradeoff between retention time and chewing efficiency in large mammalian herbivores. *Comp. Biochem. Phys. A* **154**, 376-382.

[147] Cromsigt JPGM, Prins HHT, Olff H. 2009 Habitat heterogeneity as a driver of ungulate diversity and distribution patterns: interaction of body mass and digestive strategy. *Divers. Distrib.* **15**, 513-522. (doi: 10.1111/j.1472-4642.2008.00554.x)

[148] Saïd S, Servanty S. 2005 The influence of landscape structure on female roe deer home-range size. *Landsc. Ecol.* **20**, 1003-1012. (doi: 10.1007/s10980-005-7518-8)

[149] Morellet N, Bonenfant C, Börger L, Ossi F, Cagnacci F, Heurich M, Kjellander P, Linnell JDC, Nicoloso S, Sustr P*, et al.* 2013 Seasonality, weather and climate affect home range size in roe deer across a wide latitudinal gradient within Europe. *J. Anim. Ecol.* **82**, 1326-1339. (doi: 10.1111/1365-2656.12105)

[150] Hadfield JD. 2010 MCMC methods for multi-response generalized linear mixed models: the MCMCglmm R package. *J. Stat. Softw.* **33**, 1-22.

[151] Spiegelhalter DJ, Best NG, Carlin BP, Van Der Linde A. 2002 Bayesian measures of model complexity and fit. *J. R. Stat. Soc. B Stat. Methodol.* **64**, 583-639. (doi: 10.1111/1467-9868.00353)

[152] Arnold TW. 2010 Uninformative parameters and model selection using Akaike's Information Criterion. *The Journal of Wildlife Management* **74**, 1175-1178.

[153] Hooten MB, Hobbs NT. 2015 A guide to Bayesian model selection for ecologists. *Ecol. Monogr.* **85**, 3-28.

[154] Ward EJ. 2008 A review and comparison of four commonly used Bayesian and maximum likelihood model selection tools. *Ecol. Modell.* **211**, 1-10. (doi: 10.1016/j.ecolmodel.2007.doi: 10.030)

[155] Hazelton ML, Gurrin LC. 2003 A note on genetic variance components in mixed models. *Genet. Epidemiol.* **24**, 297-301. (doi: 10.1002/gepi.10242)

[156] Gelman A. 2006 Prior distributions for variance parameters in hierarchical models (comment on article by Browne and Draper). *Bayesian anal.* **1**, 515-534.

[157] Nilsen EB, Pedersen S, Linnell JDC. 2008 Can minimum convex polygon home ranges be used to draw biologically meaningful conclusions? *Ecol. Res.* **23**, 635-639. (doi: 10.1007/s11284-007-0421-9)

[158] Blomberg SP, Garland T, Ives AR. 2003 Testing for phylogenetic signal in comparative data: behavioral traits are more labile. *Evolution* **57**, 717-745. (doi: 10.1111/j.0014-3820.2003.tb00285.x)

[159] Hadfield J, Nakagawa S. 2010 General quantitative genetic methods for comparative biology: phylogenies, taxonomies and multi‐trait models for continuous and categorical characters. *J. Evol. Biol.* **23**, 494-508. (doi: 10.1111/j.1420-9101.2009.01915.x)

[160] Grafen A. 1989 The phylogenetic regression. *Phil. Trans. R. Soc. B* **326**, 119-157. (doi: 10.1098/rstb.1989.0106)

[161] Paradis E. 2011 *Analysis of phylogenetics and evolution with R*. New York, USA: Springer.

[162] Hebblewhite M, Haydon DT. 2010 Distinguishing technology from biology: a critical review of the use of GPS telemetry data in ecology. *Phil. Trans. R. Soc. B* **365**, 2303-2312. (doi: 10.1098/rstb.2010.0087)

[163] Münkemüller T, Lavergne S, Bzeznik B, Dray S, Jombart T, Schiffers K, Thuiller W. 2012 How to measure and test phylogenetic signal. *Methods Ecol. Evol.* **3**, 743-756. (doi: 10.1111/j.2041-210X.2012.00196.x)

[164] Nakagawa S, Santos EA. 2012 Methodological issues and advances in biological meta-analysis. *Evol. Ecol.* **26**, 1253-1274. (doi: 10.1007/s10682-012-9555-5)

[165] Nakagawa S, Schielzeth H. 2013 A general and simple method for obtaining R2 from generalized linear mixed‐effects models. *Methods Ecol. Evol.* **4**, 133-142. (doi: 10.1111/j.2041-210x.2012.00261.x)

[166] Kochanny CO, Delgiudice GD, Fieberg J. 2009 Comparing global positioning system and very high frequency telemetry home ranges of white-tailed deer. *J. Wildl. Manage.* **73**, 779-787. (doi: 10.2193/2008-394)

[167] Pellerin M, Saïd S, Gaillard J-M. 2008 Roe deer *Capreolus capreolus* home-range sizes estimated from VHF and GPS data. *Wildl. Biol* **14**, 101-110. (doi: 10.2981/0909-6396(2008)14[101:rdcchs]2.0.co;2)

[168] Frair JL, Fieberg J, Hebblewhite M, Cagnacci F, DeCesare NJ, Pedrotti L. 2010 Resolving issues of imprecise and habitat-biased locations in ecological analyses using GPS telemetry data. *Phil. Trans. R. Soc. B* **365**, 2187-2200. (doi: 10.1098/rstb.2010.0084)

[169] Burnham KP, Anderson DR. 2002 *Model selection and multi-model inference a practical information-theoretic approach*. 2nd ed ed. New York, USA: Springer.