Ecography

E7291
Van Moorter, B., Visscher, D., Herfindal, I., Basille, M. and Mysterud, A. 2012. Inferring behavioural mechanisms in habitat selection studies – getting the null-hypothesis right for functional and familiarity responses. – Ecography 35: xxx–xxx.

Supplementary material

Appendix 1: Supplementary figures

Fig. A1

The probability of use as a function of the proportion available on a linear and logit-scale for simultaneous and hierarchical multi-item choice in a landscape with two habitat types. The change in probability of use of a habitat type is shown for different preferences (0.01, 0.1, 0.2, 0.3, …, 0.9, and 0.99) when the proportion available of a habitat type changes from 0 to 1, for simultaneous choice (in blue) and hierarchical choice (in green) mechanisms. At equal availability of both habitat types (the black line at: prop(available) = 0.5), both approaches give the same probability of use, which equals the preference. The left panel shows the probability of use on a linear scale, whereas in the right panel both the probability of use and the proportion available are transformed to a logit-scale. The relationship has become linear for both the simultaneous and hierarchical approach. The simultaneous approach has a slope equal to 1, whereas the hierarchical approach has a slope equal to 0 and the intercept equals the logit of the preference (see Supplementary material Appendix 4 for proof).

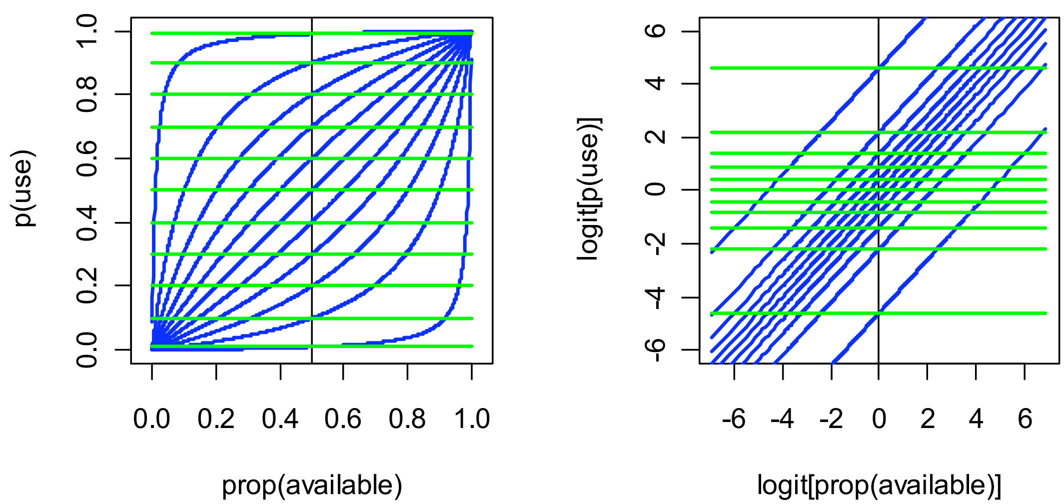


Fig A2
The estimated regression-coefficient from an ordinary logistic regression as a function of availability for each habitat layer in both landscape types. Panels a, b and c are the functional responses for the random landscape, respectively variable or layer LS1, LS2 and LS3. Panels d, e and f are the functional responses for the clumped landscape, respectively variable or layer LS1, LS2 and LS3. The full black line depicts the regression line between the beta-coefficients and proportion availability, the dotted line is the preference in the simulation.

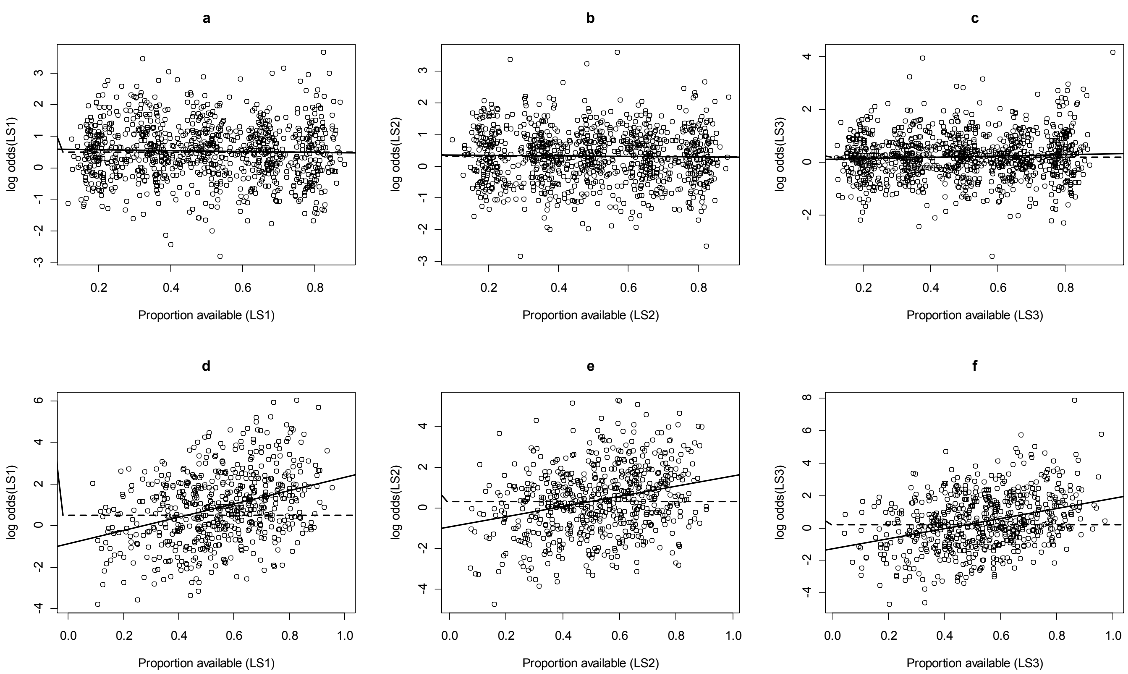


Fig A3

The relative use of each habitat layer as a function of availability for both landscape types on a logit-scale. Panels a, b and c are the functional response in the random landscape (respectively: LS1, LS2 and LS3), and panels d, e and f in the clumped landscape (respectively: LS1, LS2 and LS3). The full black line represents the fitted relationship, the dotted line represents the null-hypothesis.

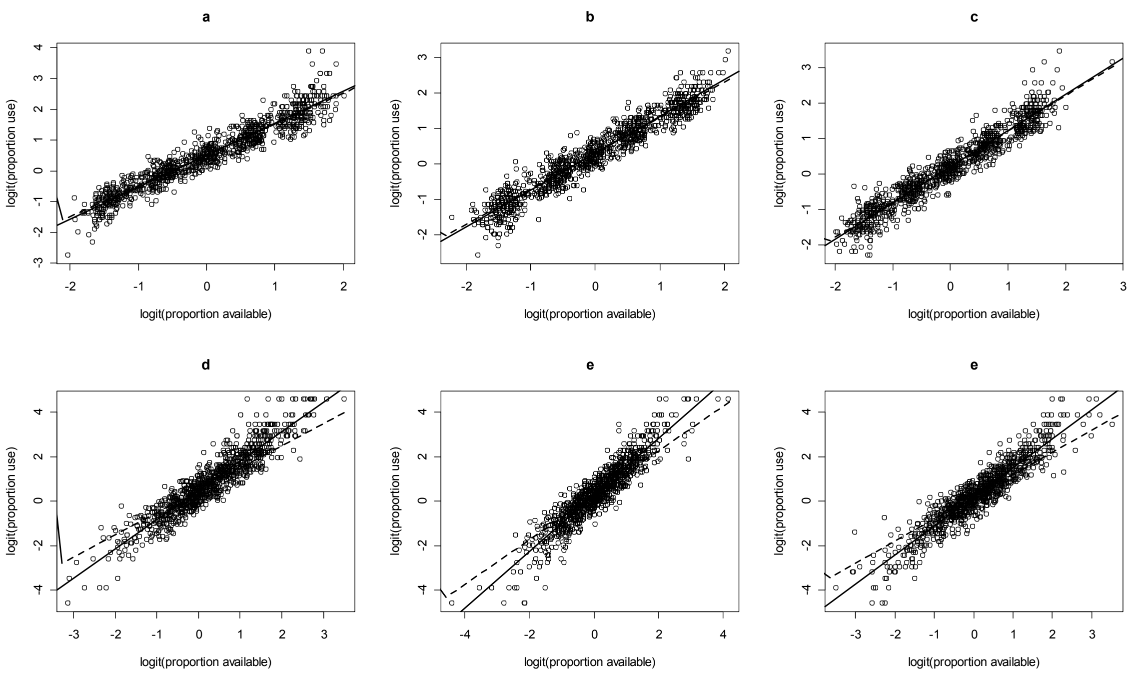
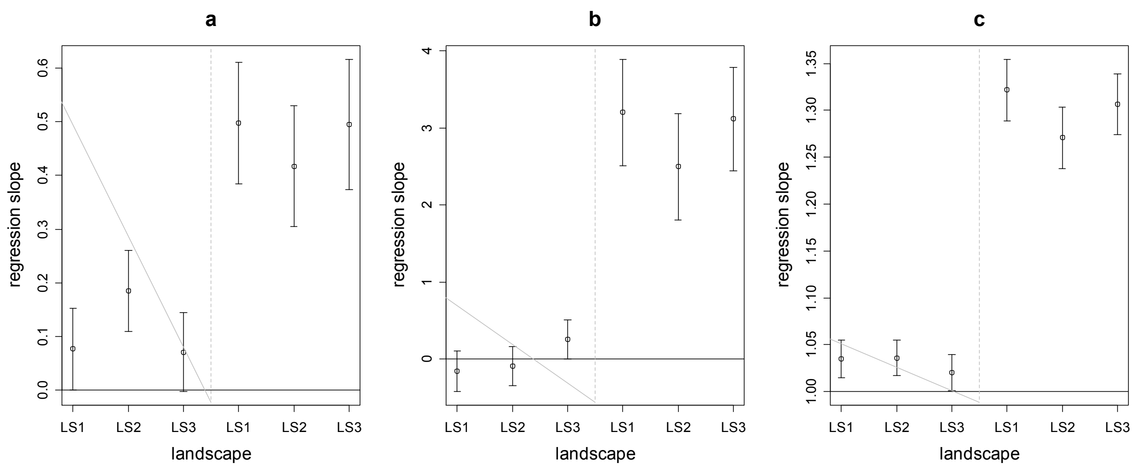


Fig A4

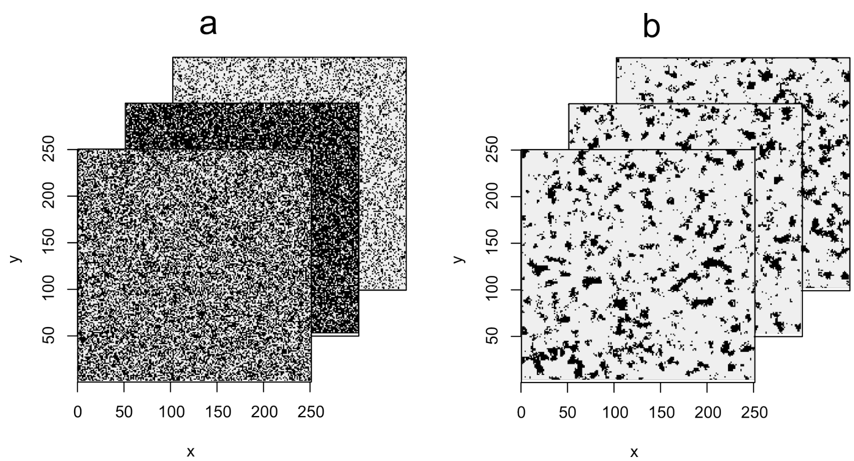
Comparison of the slope of the estimated linear relationship between habitat selection and availability for three statistical approaches.   Panel a is the regression slope with 95%CI for the conditional logistic regression, panel b for the ordinary logistic regression, and panel c for the logit-transformed relative use versus proportion available. Each panel has on the left side the results for random landscapes and on the right those for clumped landscapes; for each of those landscape types the three habitat variables (LS1, LS2 and LS3) are shown from left to right. The black horizontal line shows the expected value under the null-hypothesis. Note the different scales of the y-axes.



Appendix 2: Details of the landscape simulation

We explain in detail the simulation of the random and clumped landscape types used in our study.

General procedure – each landscape was simulated on a 250x250 pixel grid. The simulated landscapes consist of 3 binary habitat variables or layers. Such a 3-D binary landscape can code $2^3 = 8$ different habitat types. These binary variables were obtained by applying a threshold to continuous variables. Two types of landscapes were simulated:



Random landscapes (panel a) – We simulated random landscapes by drawing each pixel independently from a uniform distribution (range: [0, 1]). We increased range of variation in available habitats between animals by applying a range of thresholds (0.1 to 0.9 by 0.1 intervals) for the binarization of the first two variables (the thresholds between both variables varied independently, whereas for the third variable this threshold was kept constant at 0.5).

Clumped landscapes (panel b) – Autocorrelated or clumped landscapes were Gaussian random fields generated with autocorrelation. The variogram (γ) was spherical between points at lag (h):

$$\gamma(h) = \begin{cases} c_0\left[\frac{3}{2}\frac{h}{a_0} - \frac{1}{2}\left(\frac{h}{a_0}\right)^3\right], & \text{for } h \le a_0 \\ c_0, & \text{for } h > a_0 \end{cases}$$

with a_0 the scale or range and c_0 the sill or asymptotical value of the autocorrelation function. We use the package “RandomFields” (Schlather 2010) from the R-project (R Development Core Team 2010) to simulate these landscapes. The landscape mean was 1 and standard deviation 1, the scale for the autocorrelation function was 10 without a nugget-effect. These landscapes where binarized with a threshold of 0 (all pixels above 0 were set to 1 and those below to 0). The resulting landscapes have the 1’s and 0’s clumping together into patches.

REFERENCES

R Development Core Team. 2010. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Schlather, M. 2010. RandomFields: Simulation and Analysis of Random Fields. R package version 1.3.45.

Appendix 3: Additional analysis

Sensitivity assessment

We investigated the sensitivity of our results to the values used in the main text by testing different sets of parameter values ($b_{LS1} = 0.40$, $b_{LS2} = 0.25$, $b_{LS3} = 0.15$ and $b_{LS1} = 0.30$, $b_{LS2} = 0.30$, $b_{LS3} = 0.30$ and $b_{LS1} = 0.60$, $b_{LS2} = 0.20$, $b_{LS3} = 0.10$). We presented only the results from the first set, because each of these different sets led to the same conclusions.

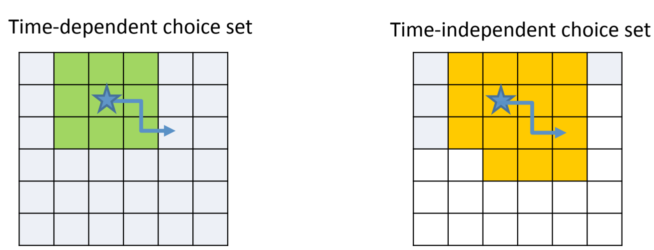
Different approaches for the functional response analysis

METHODS

We complemented the conditional logistic regression analysis with both ordinary logistic regression (e.g. Manly et al. 2002) and the approach advocated by Mysterud and Ims (1998), *i.e.* the change in use with availability.

For these additional analyses, we defined availability not separately for each time step (as for the conditional logistic regression), but independently of time (see figure).

Figure: The choice sets defined dependent and independent of time.
The blue line shows the trajectory of an animal moving over a landscape. For the time-dependent choice set (on the left), only the pixels immediately surrounding the animal are considered available at the starting point (i.e. the green area). Whereas, for the time-independent choice set (on the right), all pixels that appeared once in the choice set of the whole movement path are considered available at the starting point (i.e. the yellow area). Note that such a time-independent choice set is similar to considering the whole home range as available at any given time.



Thus, for the whole trajectory of each animal we considered only one single choice set, instead of one choice set for each movement step. All used pixels together with their direct neighbours (king-style) were available in the choice set, i.e. all pixels that appeared at least once in the choice sets for the simulated steps contributed on an equal basis to the available set for the analyses. This second approach for defining availability is more common in empirical studies and is analogous to defining habitat availability within an animal's home range (i.e. order 3 according to Johnson's [1980] habitat selection hierarchy).

For the comparison of used and available pixels with ordinary logistic regression (e.g. Johnson et al. 2006), we measured used pixels as those 100 that were visited by an animal and available pixels as a random sample of 100 pixels from all those available (i.e. the aforementioned time-independent available pixel set). The functional response analysis followed Eq. 9 in the main text, however, with the proportion available of a habitat characteristic, $prop(A_{LSc})$, defined as the average from the sampled available pixels.

Mysterud and Ims (1998) investigated the proportion used of a landscape characteristic, $prop(U_{LSc})$, as a function of proportion available of that characteristic, $prop(A_{LSc})$, on a logit scale, this relationship is expected to be linear:

$$logit(prop(U_{LSc})) = \alpha + \psi_{LSc} \times logit(prop(A_{LSc})) + \varepsilon \qquad \text{Eq. S1}$$

We quantified proportion available of a characteristic, $prop(A_{LSc})$, from the aforementioned time-independent available pixel set. The proportion use, $prop(U_{LSc})$, is measured by the proportion of all pixels used. Here, we expected slope $\psi_{LSc} = 1$ in Eq. S1, because no functional response was present in the process generating the data.

RESULTS

The difference between the results from the random and clumped landscapes was more pronounced using the ordinary logistic regression (Supplementary material Appendix 1, Fig. A2) than using the conditional logistic approach (main text, Fig. 2, and Supplementary material Appendix 1, Fig. A4). In random landscapes, there were hardly any changes in log odds with availability, i.e. no statistically significant functional responses (φ_{LS1} ± SE: -0.16 ± 0.14, $p > 0.1$; φ_{LS2} ± SE: -0.09 ± 0.13, $p > 0.1$; φ_{LS3} ± SE: 0.25 ± 0.13, $p < 0.05$). In clumped landscapes functional responses were stronger and statistically significant for all three habitat layers, with a positive relationship between the beta-coefficient and availability (φ_{LS1} ± SE: 3.2 ± 0.4, $p < 0.001$; φ_{LS2} ± SE: 2.5 ± 0.4, $p < 0.001$; φ_{LS3} ± SE: 3.1 ± 0.3, $p < 0.001$).

In the statistical approach advocated by Mysterud and Ims (1998), the relationship between use and availability was small, but statistically significantly different from one, indicating a functional response (Supplementary material Appendix 1, Fig. A3). Again, this functional response was stronger in the clumped landscape ($\psi_{LS1} \pm$ SE: 1.32 ± 0.02, $p < 0.001$; $\psi_{LS2} \pm$ SE: 1.27 ± 0.02, $p < 0.001$; $\psi_{LS3} \pm$ SE: 1.31 ± 0.02, $p < 0.001$) than in the random one ($\psi_{LS1} \pm$ SE: 1.03 ± 0.01, $p < 0.001$; $\psi_{LS2} \pm$ SE: 1.04 ± 0.01, $p < 0.001$; $\psi_{LS3} \pm$ SE: 1.02 ± 0.01, $p = 0.041$).

REFERENCES

Johnson, D. H. 1980. The Comparison of Usage and Availability Measurements for Evaluating Resource Preference. – Ecology 61: 65–71.

Johnson, C. J. et al. 2006. Resource selection functions based on use–availability data: theoretical motivation and evaluation methods. – J. Wildl. Manage. 70: 347–357.

Manly, B. F. J. et al. 2002. Resource selection by animals: statistical analysis and design for field studies, 2nd ed. – Chapman and Hall.

Mysterud, A. and Ims, R. A. 1998. Functional responses in habitat use: availability influences relative use in trade-off situations. – Ecology 79: 1435–1441.

Appendix 4: Mathematical proof

The relationship between relative use and availability, when multi-item choice is simultaneous on a landscape with two habitat types (A and B):

$$\text{logit}(prop.useA) = \text{logit}\left(\frac{useA}{useA+useB}\right)$$
$$\text{logit}(prop.useA) = \log\left(\frac{useA}{useA+useB}\right) - \log\left(1-\frac{useA}{useA+useB}\right)$$
$$\text{logit}(prop.useA) = \log(useA) - \log(useA+useB) - \log\left(1-\frac{useA}{useA+useB}\right)$$
$$\text{logit}(prop.useA) = \log(useA) - \log(useA+useB) - \log\left(\frac{useA+useB}{useA+useB}-\frac{useA}{useA+useB}\right)$$
$$\text{logit}(prop.useA) = \log(useA) - \log(useA+useB) - \log\left(\frac{useB}{useA+useB}\right)$$
$$\text{logit}(prop.useA) = \log(useA) - \log(useA+useB) - \log(useB) + \log(useA+useB)$$
$$\text{logit}(prop.useA) = \log(useA) - \log(useB)$$
$$\text{logit}(prop.useA) = \log(prefA * avaA) - \log\left((1-prefA)*(1-avaA)\right)$$
$$\text{logit}(prop.useA) = \log(prefA) - \log(1-prefA) + \log(avaA) - \log(1-avaA)$$
$$\text{logit}(prop.useA) = \text{logit}(prefA) + \text{logit}(avaA)$$

Hence,
logit use is isometric with logit available, with the intercept equal to the logit of the preference.