Article:

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Figure 1 Examples of individual species-energy relationships of varying strengths, for (a) nightingale *Luscinia megarhynchos*, (b) blackbird *Turdus merula*, (c) grasshopper warbler *Locustella naevia* and (d) black grouse *Tetrao tetrix*. Open squares with values of either zero or one represent real data, and filled grey symbols represent the probability of occurrence predicted by a logistic model. Deviance is the change in deviance of the logistic species-energy model, relative to a null model, and slope is the slope of that relationship. [Negative values indicate that a species is less likely to occur in high-energy areas.]

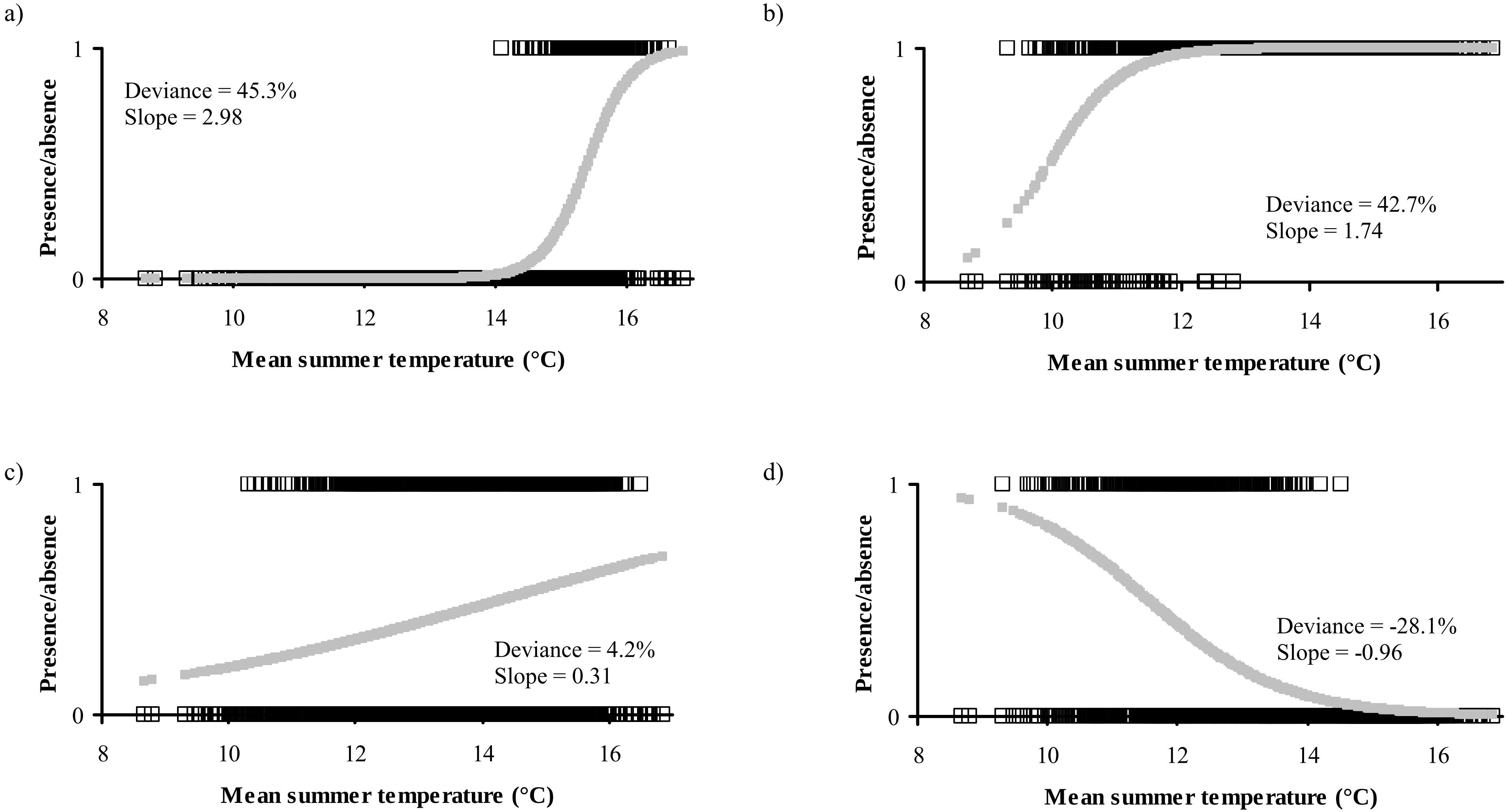


Figure 2 Histograms of the strength of individual species-energy models measured as the change in deviance, relative to a null model, of (a) logistic species-temperature, (b) logistic species-NDVI regressions, and the slopes of (c) logistic species-temperature, (d) autologistic species-temperature, (e) logistic species-NDVI and (f) autologistic species-NDVI regressions (each of the following bins contain one species but are not visible on the plot: -12.45 to -12.15; -3.75 to -3.45; 6.75 to 7.05; 16.35 to 16.65). Note the change in the scale of the axes.

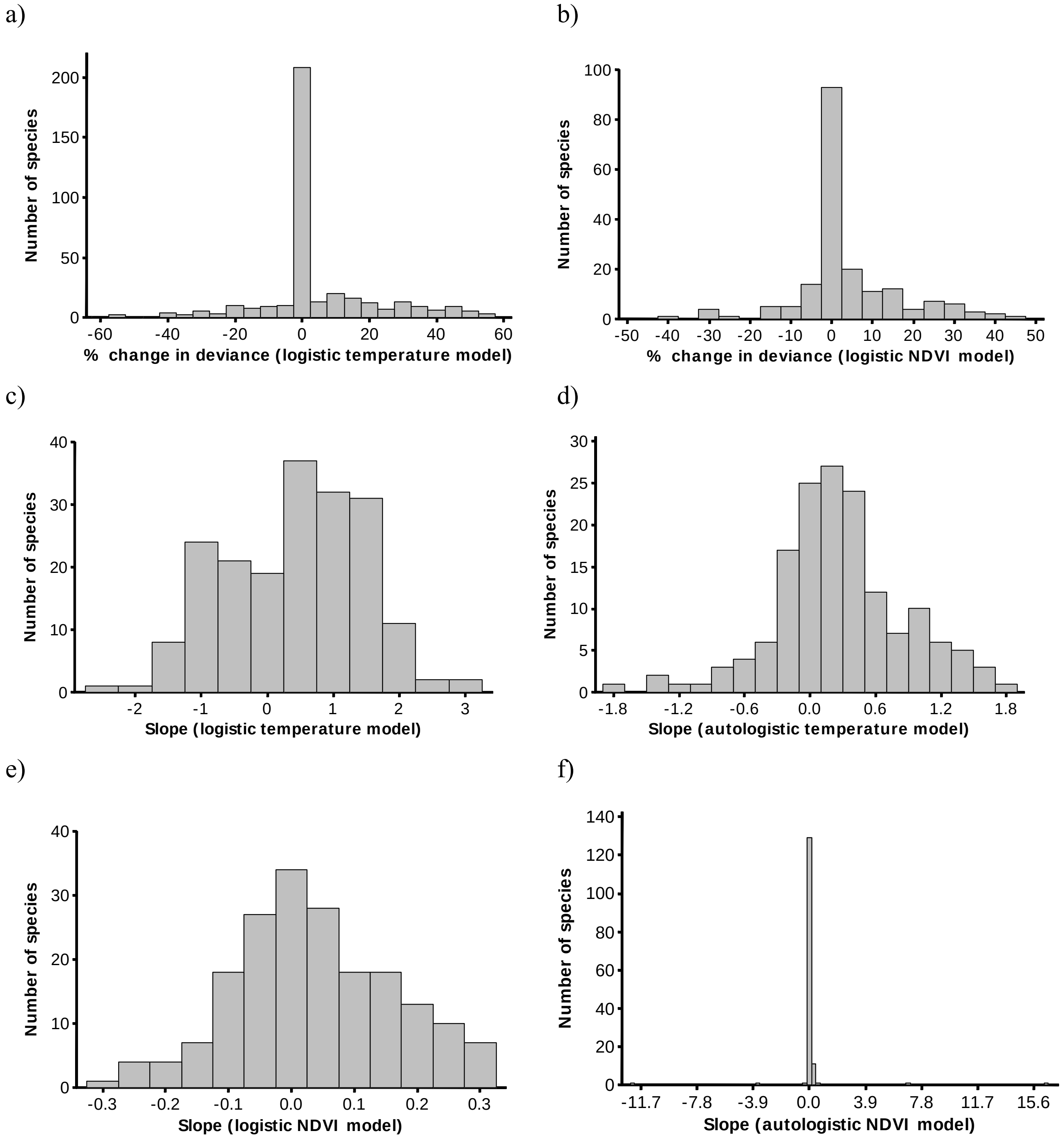
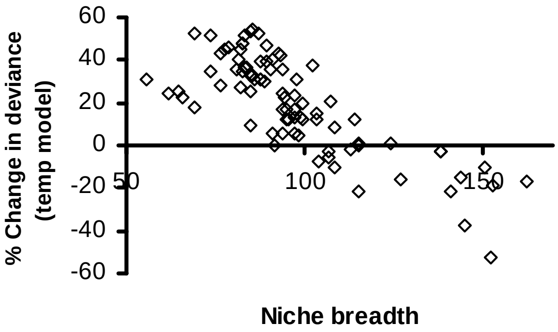
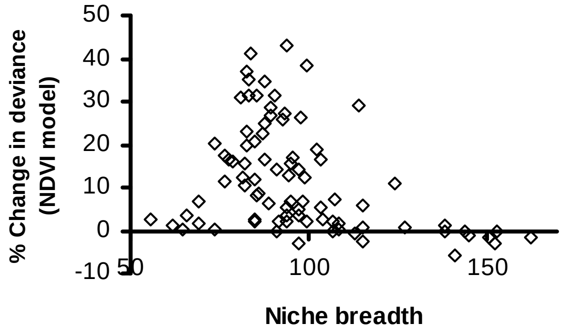


Figure 3 Relationships between the strength of individual species-energy relationships, constructed using logistic regression, and niche breadth (a-d) or population size (e-h).

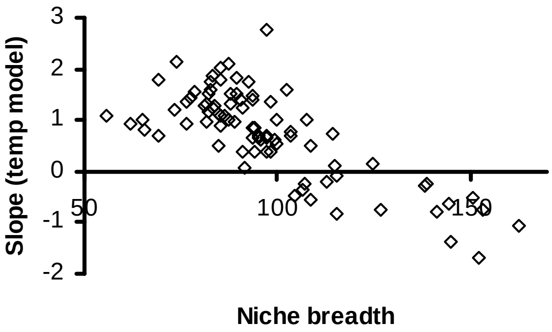
a)



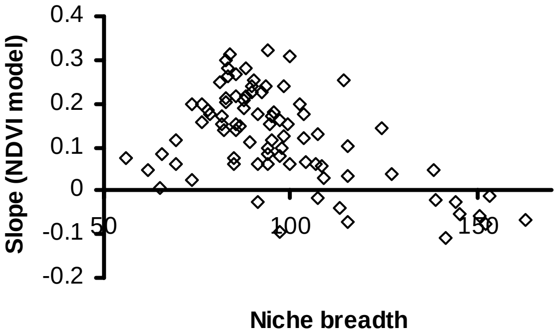
b)



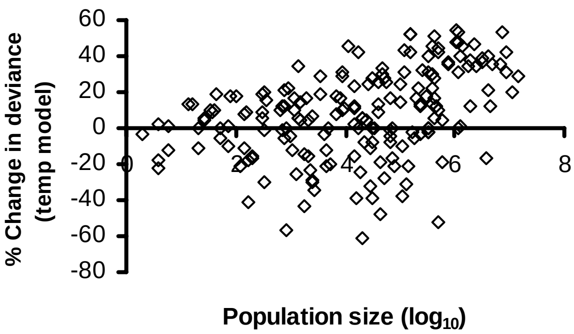
c)



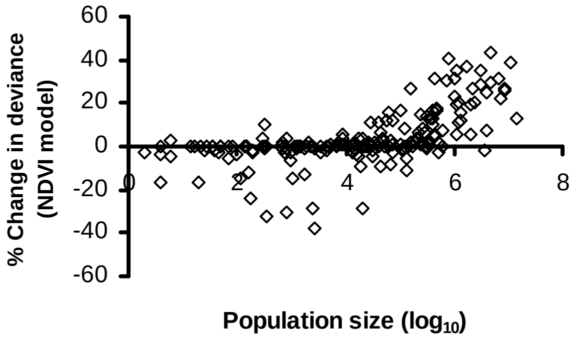
d)



e)



f)



g)

h)

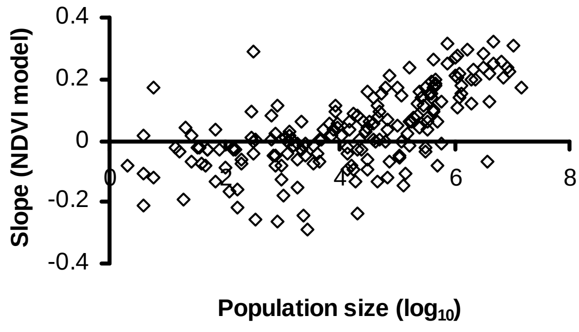


Table 3. Relationships between the strength of species-energy relationships and niche breadth in cases where the latter is retained in the best fitting multiple regression models (see Table 1). Akaike Information Criterion values (AIC) are given for comparison with those presented in Table 1, smaller values indicate a better fit. Negative effects ---- *P*<0.0001

species-energy model			predictor	fit of model of species energy relationship strength	
strength metric	energy metric	model type	niche breadth	AIC	r^2
slope	temp	logistic	---- $F_{1,82}$=119.4	154.3	59.3%
"	"	autologistic	---- $F_{1,73}$=23.4	115.9	23.8%
"	NDVI	logistic	---- $F_{1,82}$ =31.4	-143.1	27.7%
deviance ch.	temp	logistic	---- $F_{1,82}$= 139.5	-73.9	63.0%

Appendix

Markov Chain Monte Carlo-Stochastic Approximation

Three main methods have been developed to account for spatial structure within binary logistic regression models namely, Maximum Pseudo-Likelihood Estimation (MPLE), Markov Chain Monte Carlo Likelihood (MCMCL) and Markov Chain Monte Carlo Stochastic Approximation (MCMC-SA). For this paper, we initially used both the MCMCL and MCMC-SA methods developed by He *et al.* (2003), however given that the MCMCL method failed to converge for a large proportion of the models (>50%), we provide results based on the MCMC-SA method only. In this instance presence/absence data are recorded at *M* locations (sites) forming a subset *D* of a rectangular lattice. Each site in *D* is described by coordinates (*k*,*l*) specifying the row and column of the lattice at which it is located. At each site (*k*,*l*), we observed a binary response $y_{k,l}$ and a *p* x 1 vector of covariates $x_{k,l}$ where $y_{k,l} = 1$ if a site is occupied by a given avian species, otherwise 0. Taken altogether, the *M* binary responses $Y = \left(y_{k,l}, (k,l) \in D\right)$ constitute a map of the distribution of that particular species.

The second-order (taking account of the eight neighbouring cells to the north, northeast, east, southeast, south, southwest, west and northwest) autologistic regression model specifies the conditional probability $P_{k,l}(\theta)$ that $y_{k,l} = 1$ given all other values $y_{m,n}\left((m,n) \neq (k,l)\right)$ as follows

$$Pk,l(\theta) = P(y_{k,l} = 1 \mid \text{all other values}) = \frac{\exp\left(f_{k.l}(\theta)\right)}{1 + \exp\left(f_{k,l}(\theta)\right)}$$

where $f_{k,l}(\theta) = \beta_0 + x_{k,l}^T \beta_1 + \gamma_1 y_{k,l}^{(1)} + \gamma_2 y_{k,l}^{(2)} + \gamma_3 y_{k,l}^{(3)} + \gamma_4 y_{k,l}^{(4)}, \theta = \left(\beta_0, \beta_1^T, \gamma_1, \gamma_2, \gamma_3, \gamma_4\right)^T \in \Theta$ (a parameter space for (θ)), $y_{k,l}^{(1)}$ is the number of occupied sites in $\{(k, l+1), (k, l+1)\}$, $y_{k,l}^{(2)}$ is the number of occupied sites in $\{(k,-1,l), (k+1,l)\}$, $y_{k,l}^{(3)}$ is the number of occupied sites in $\{(k,-1,l-1), (k+1,l+1)\}$ and $y_{k,l}^{(4)}$ is the number of occupied sites in $\{(k,-1,l+1), (k+1,l-1)\}$. Thus, $\gamma_1, \gamma_2, \gamma_3$ and γ_4 are the parameters for describing various spatial correlation structures (respectively 1st order north-south, 1st order east-west, 2nd order northeast-southwest, 2nd order northwest-southeast).

For each species individually the estimation procedure was stopped using a two stage process in which the first stage uses a sequence of large gain constants to force estimates into a small range of the maximum likelihood estimate using a maximum of 50,000 iterations. The second stage further refines the likelihood estimate to within an accuracy of 0.001 using the methodology of Zhou & Zhu (2003).

References

He, F., Zhou, J.L. & Zhu, H.T. 2003 Autologistic regression model for the distribution of vegetation. *Journal of Agricultural, Biological and Environmental Statistics* **8**, 205-222.

Zhou, J.L. & Zhu, H.T. 2003 Robust estimation and design procedures for random effect model. *Canadian Journal of Statistics* **31**, 99-110, 2003.