Ecography

E7200
Zurell, D., Grimm, V., Rossmanith, E., Zbinden, N., Zimmermann, N. and Schröder, B. 2011. Uncertainty in predictions of range dynamics: black grouse climbing the Swiss Alps. – Ecography 34: xxx–xxx.

Supplementary material

Supplementary material. Appendix 1.

Submodels of individual-based model

Carrying capacity

Carrying capacity is a function of habitat area and suitability (Keith et al. 2008), and is updated at the beginning of each time step. Habitat suitability is defined as black grouse occurrence probability determined by the statistical species distribution models. Suitable habitat is defined by a threshold minimum value of habitat suitability. This threshold is given by the present-day prevalence of black grouse (Liu et al. 2005). We assumed that habitat suitability was a direct surrogate of carrying capacity whenever the modelled habitat suitability exceeded this threshold (for examples see Anderson et al. 2009, Araújo et al. 2002, Keith et al. 2008). Maximum carrying capacity was defined as the maximum density of black grouse per km^2 that can be expected in Switzerland given the home range requirements of the species.

Individuals may persist for some time under suboptimal conditions. This is realised by a simple memory effect incorporated in the habitat suitability index. If the SDM prediction for a cell is lower than the cell's habitat suitability of the preceding time step, then habitat suitability of the actual time step is the mean of the preceding habitat suitability and the current SDM prediction. This simple memory effect prevents too abrupt shifts in habitat suitability.

Reproduction

The probability of a hen to reproduce successfully and lead young is *pleadYoung*. Some may fail to reproduce because eggs do not hatch or nests are predated or deserted. We calculated these probabilities from empirical data (Zbinden and Salvioni 2003, Zbinden unpublished data).

Fledging

Upon successful reproduction the probability of a hen to lead a certain number of young birds is *p(x)Fledglings*. Probabilities were calculated from empirically observed distribution of brood sizes (Zbinden and Salvioni 2003, Zbinden unpublished data). The probability for a fledgling to be female is *pYoungFemale*, otherwise it is a male and is subsequently ignored.

Natal dispersal

In autumn, first-year hens disperse from their natal patch with a probability *pDispersal* (Caizergues and Ellison 2002). Dispersal is assumed to be equally likely in eight directions, and subsequently each dispersing individual is assigned a random direction (N, NE, E, SE, S, SW, W, and NW). The expected mean natal dispersal distance of female black grouse *meanDist* and the range of dispersal distances *rangeDist* were compiled from Caizergues & Ellison (2002). These two values were used to draw the individual dispersal distances from an empirical model for natal dispersal distances in birds which was proposed by Sutherland et al. (2000, Equ. 2) and is based on the negative exponential distribution. In our model, individual birds perceive the environment as heterogeneous and avoid to settle in or to traverse wide stretches of unsuitable habitat (Zbinden, unpublished data). Hence, they will not settle in cells without any resources available. This is the case when habitat suitability is so low that carrying capacity $K < 1$, or when the cell is crowded and $N \geq K$. Dispersers will then search the (eight) nearest neighbour cells for better suited habitat or, if this search is of no avail, will make a second dispersal attempt. Individuals will not cross widely unsuitable areas, i.e. more than ten cells (i.e. max. 10 km) with carrying capacity $K < 1$. If they encounter such a stretch of unsuitable habitat, they will sidestep it and resume their original direction as soon as possible (cf. Graf et al. 2007).

Mortality and density dependence

All sources of mortality are subsumed under an annual survival probability (*pSurv*), the probability of an individual hen to survive until early spring (Zbinden and Salvioni 2003). Mortality and emigration may increase with density due to increased predation risk or simply due to shortage of resources. As no information is available for density dependence in Alpine black grouse populations, we assumed carrying capacity K to have a ceiling effect on the local population. If the number of adults in a cell exceeds K, random individuals are removed from this cell according to two rules: (1) Individuals will be randomly assigned to the (eight) nearest neighbour cells, if these are not crowded ($N < K$). Thereby, we accounted for some adaptability of home ranges. Then, (2) if local population size N still exceeds K, random individuals will be removed from the cell until the local population size is equal to K (Grimm and Storch 2000).

References

Anderson, B. J. et al. 2009. Dynamics of range margins for metapopulations under climate change. - Proc. R. Soc. B 276: 1415-1420.

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Zbinden, N. and Salvioni, M. 2003. Verbreitung, Siedlungsdichte und Fortpflanzungserfolg des Birkhuhns Tetrao tetrix im Tessin 1981-2002. - Der Ornithologische Beobachter 100: 211-226.

Supplementary Figures and Tables

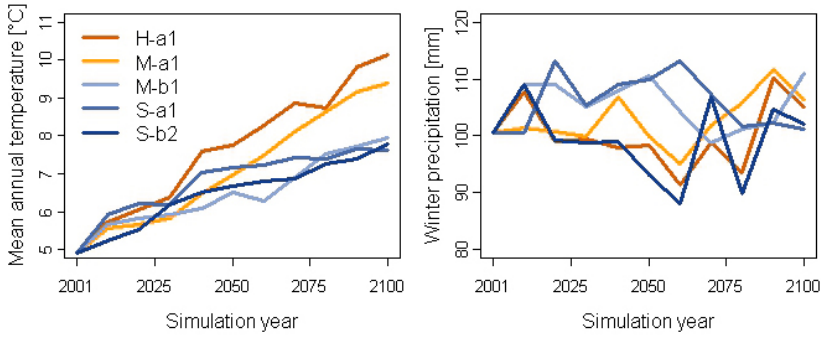

Figure A1. Predicted mean temperature and precipitation changes for scenarios of climate change. For abbreviations see Table 1 in journal article.

Table A1: Table showing SDM evaluation statistics (mean ± SD of 100 split-sample runs).

Performance criterion	BRT	GAM	GLM
AUC	0.950 ± 0.01	0.949 ± 0.01	0.946 ± 0.01
Explained deviance R^2	0.590 ± 0.02	0.583 ± 0.03	0.572 ± 0.03
TSS	0.785 ± 0.02	0.784 ± 0.02	0.782 ± 0.02
Sensitivity (True presences)	0.926 ± 0.01	0.939 ± 0.01	0.947 ± 0.01
Specificity (True absences)	0.859 ± 0.01	0.845 ± 0.01	0.836 ± 0.01
Calibration slope (Spread)	1.005 ± 0.07	0.975 ± 0.10	0.955 ± 0.13
Calibration intercept (Bias)	0.003 ± 0.14	0.006 ± 0.14	0.013 ± 0.14

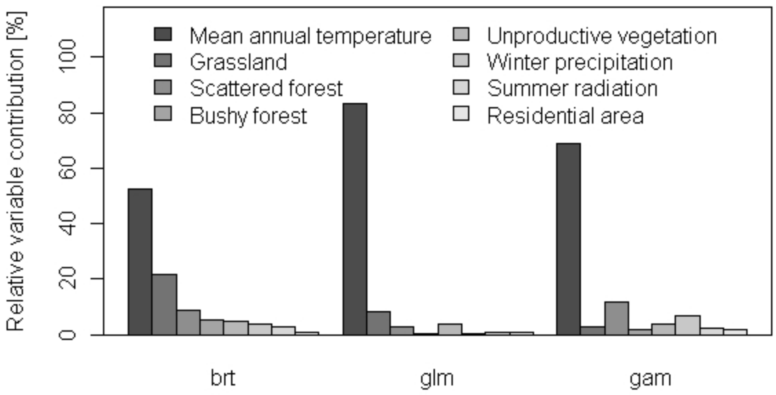

Figure A2. Relative variable contribution in SDMs.

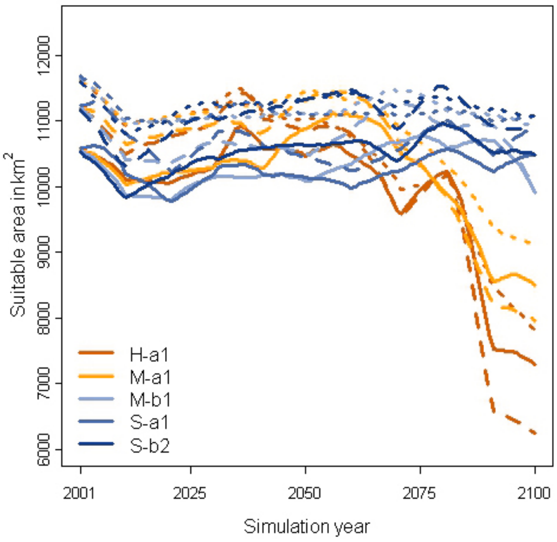

Figure A3. Predicted suitable area size for scenarios of climate change and different SDM algorithms. Solid lines indicate predictions made by BRT, dashed lines GAM and dotted lines GLM. Suitable area is defined as the sum of all 1 km^2 cells with habitat suitability exceeding the prevalence threshold. For abbreviations see Table 1 in journal article.

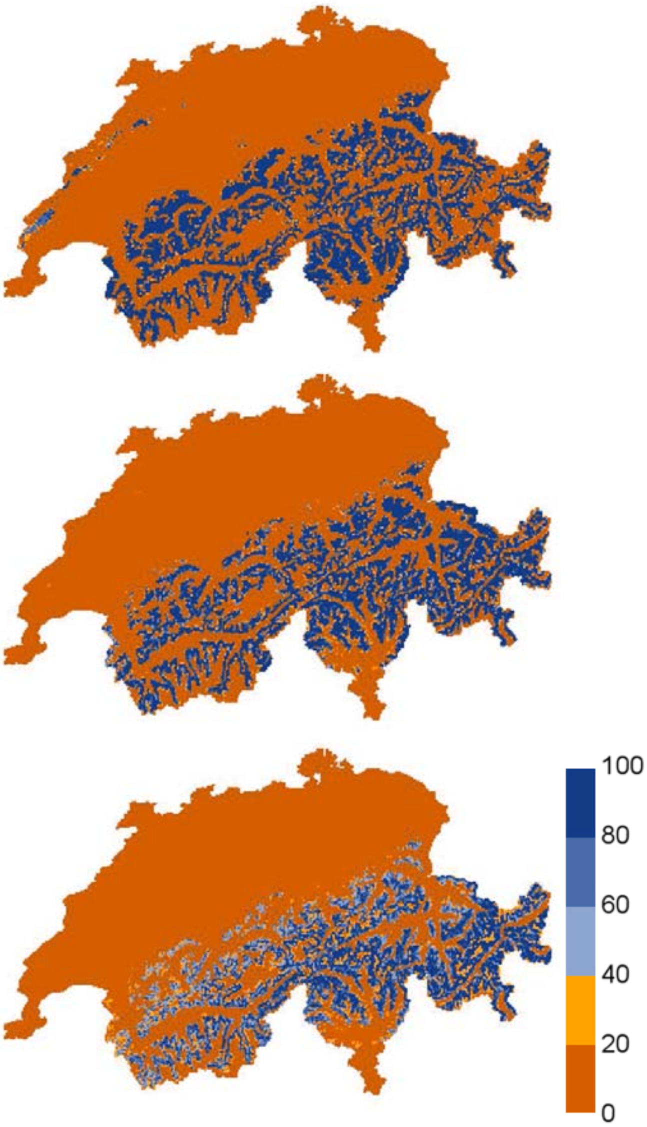

Figure A4. Consensus on black grouse presence across different SDMs and climate scenarios for years 2001, 2050 and 2100 (from top to bottom), calculated as fraction of simulations (*n* = 15) predicting black grouse to be present. IBM was run with default parameterisation. (Note that zero percent consensus on presence equal 100 % consensus on black grouse absence).

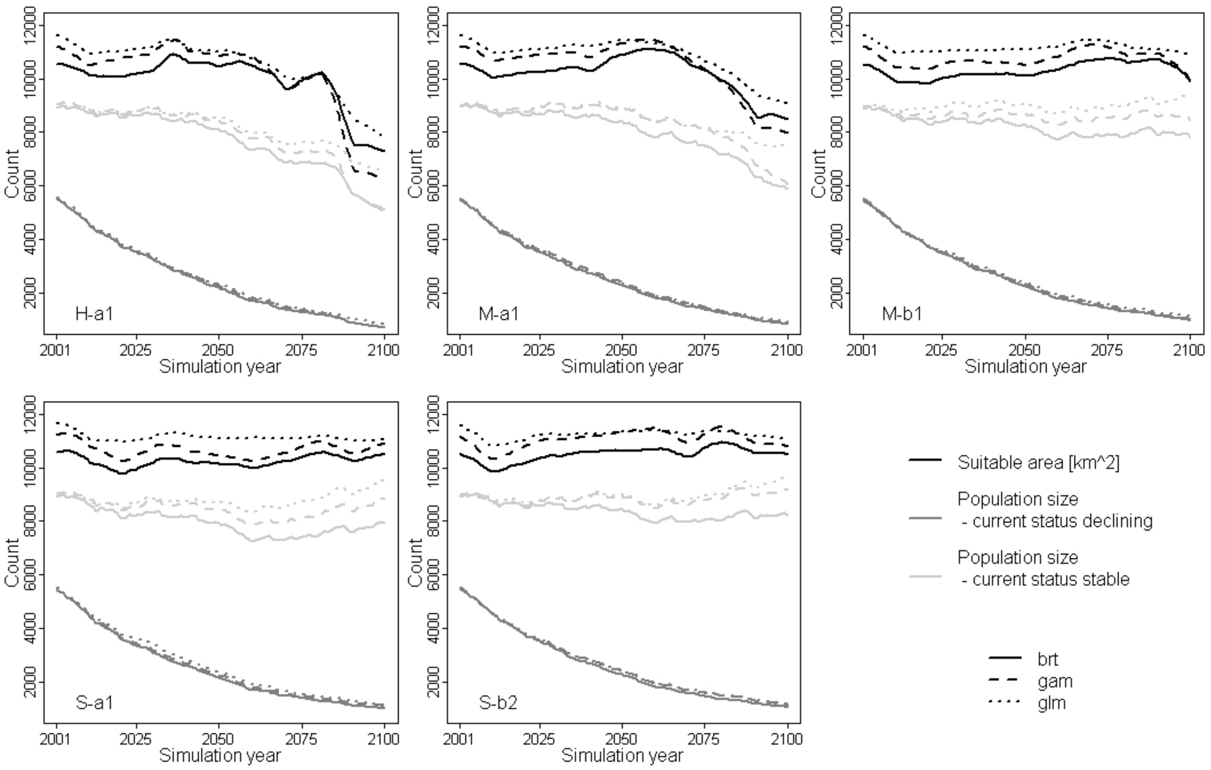

Figure A5. Predicted suitable area size and population size for scenarios of climate change, different SDM algorithms and different IBM parameterisations. Suitable area is defined as the sum of all 1 km^2 cells with habitat suitability exceeding the prevalence threshold. Population size with current status 'declining' is predicted by running the IBM with default parameterisation. Population size with current status 'stable' is predicted by increasing survival probability in IBM (*pSurv*=0.51). For abbreviations of climate scenarios see Table 1 in journal article.