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„Habitat use of black grouse (*Tetrao tetrix*) at the Natura 2000 site "Niedere Tauern" (Austria)"

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Habitat use of black grouse (*Tetrao tetrix*) at the Natura 2000 site "Niedere Tauern" (Austria)

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ABSTRACT

Modeling habitat suitability has become increasingly popular in conservational science and wildlife management in recent years. For a species of conservation interest as the black grouse this approach gives researchers and conservationists the opportunity to acquire a helpful management tool. In this study we used incidence data from black grouse surveys conducted in July-August 2011 along 51 point-stop transects (mean length: 5.10 km) at the Natura 2000 site "Niedere Tauern" in Styria (Austria) to construct a habitat suitability model. Of 45 measured or estimated environmental variables only 16 variables, which proved to significantly affect black grouse occurrence, were further considered. After accounting for multi-collinearity, 10 variables remained for subsequent modeling. Effects of variables on black grouse occurrence were evaluated using a stepwise-forward and stepwise-backward model selection approach. Five explanatory variables significantly affecting occurrence of black grouse remained in the final generalized linear model: dwarf shrub cover, mean perimeter-area ratio (quantifying habitat heterogeneity within a 100 m radius), steepness of slope, topographical heterogeneity and distance to huts. Only for the last four variables GIS layers covering the whole study area were available. Therefore only these variables were subsequently used to calculate a habitat suitability map, which can be used as a preliminary tool to evaluate to what extent high quality habitat areas are covered by the currently designated area of the Natura 2000 site "Niedere Tauern".

Key words: alpine landscapes, black grouse, ecotones, habitat heterogeneity, habitat model, habitat suitability, logistic regression, *Tetrao tetrix*

INTRODUCTION

Alpine landscapes are increasingly influenced by tourism such as winter sports and hiking (Patthey et al. 2008), and the abandonment of traditional agricultural use like grazing and cutting of mountain pine (*Pinus mugo*) changes the landscapes composition (Dullinger et al. 2003, Pearce-Higgins et al. 2007). This combination of circumstances makes survival difficult for animals adapted to mountainous habitats, which in the past were characterized by extensive traditional land use and only slight human disturbance. Therefore, monitoring measures documenting changes in distribution patterns and population density have to be implemented to quantify the impact on alpine species. Additionally, habitat requirements of endangered species have to be identified to develop effective conservation strategies.

When Austria became a member of the European Union in 1995, a significant data deficit regarding the national distribution and the conservation status of endangered species has led to several condemnations by the EU. Since borders of conservation areas were designated only based on literature not necessarily reflecting a species' current distribution status, and the practiced hunting seasons were not in accordance with the Natura 2000 guidelines, conservation measures for endangered species proved to be insufficiently implemented, particularly in the remote alpine regions (Praschk 2004). This also holds for the black grouse (*Tetrao tetrix*). Most black grouse populations in Central Europe decreased in the last decades (Baines et al. 2000, BirdLife International 2011). Common reasons for the decline are habitat degradation, habitat loss, small population sizes, disturbance and predation (Storch 2000a). Especially human activities in winter months like skiing and snowshoe hiking aside of trails can be a serious threat (Patthey et al. 2008).

In Austria the black grouse is included in the bird directive with the current IUCN Red List category of Least Concern (LC) (BirdLife International 2011). However, to maintain stable populations nature reserves have to be designated and adequate conservation measures (e.g. visitor management, wild sanctuary zones, hunting plans and adequate forest management) have to be implemented for endangered species, such as the black grouse, listed in Annex 1 of the bird directive (Ostermann 1998, Storch 2002).

The black grouse is a species of ecotones such as transition zones between forest and steppe, moor, heath or mountain thicket. In alpine areas it inhabits larch and spruce dominated loose forests and alpine meadows with a high amount of dwarf shrub cover (Klaus et al. 1990, del Hoyo et al. 1994, Grant and Dawson 2005). As an umbrella species of alpine timberland ecosystems its survival can be seen elementary for the whole area (Glutz et al. 1973, Patthey et al. 2011).

Several studies on habitat requirements of the capercaillie (*Tetrao urogallus*) were conducted in the last decade, inter alia to develop habitat suitability models for alpine populations of the species (Segelbacher and Storch 2002, Storch 2002, Graf et al. 2006)(Segelbacher and Storch 2002). By contrast, to our knowledge, so far only one profound habitat model for an alpine population of black grouse was published (Schweiger et al. 2011).

According to Morrison et al. (2006 p.10) a “Habitat... is an area with the combination of resources (like food, cover, water) and environmental conditions (temperature, precipitation, presence or absence of predators and competitors) that promotes occupancy by individuals of a given species (or population) and allow those individuals to survive and to reproduce”. In reality, it is impossible to measure or estimate all of the abiotic and biotic factors that potentially affect the occurrence of species, including the black grouse. For this reason habitat models based on a certain subset of such factors are used as tools in ecology, nature conservation and management. They establish relationships between a species occurrence and measured and estimated habitat variables and allow predictions of a species’ potential distribution as a function of current environmental conditions (Schröder and Reinecking 2004, Schweiger et al. 2011). According to Van Horne and Wiens (1991) a useful habitat model should satisfy three criteria: (1) It should be based on assumptions and mathematical functions that are logically sound and biologically relevant (2) it should be general and (3) simple and useable.

The objective of this study was to identify habitat variables that best explain the occurrence of black grouse at the Natura 2000 site “Niedere Tauern”, embedded in the Important Bird Area “Niedere Tauern”, which contains a black grouse population with a minimum of 2,050 estimated males (BirdLife International 2011). A more detailed knowledge about the species’ habitat requirements in the area of „Niedere Tauern“ is an important precondition to evaluate its local conservation status according to the Natura 2000 framework. Furthermore, this case study may contribute a brick to our general understanding of the conservation needs for protecting the species’ alpine populations.

Recent studies demonstrated that several habitat variables (e.g. dwarf shrub cover, alder, ground vegetation height) appear to affect the occurrence of grouse species (capercaillie and black grouse) on large spatial scales up to 1,000 m (Storch 2002, Angelstam et al. 2004, Graf et al. 2005). However, the focus of this study was on habitat parameters potentially affecting the occurrence of black grouse on smaller spatial scales of up to 200 m. We particularly tested to what extent variables which proved to be important predictors for the occurrence of black grouse in other regions are useful for modeling the species’ local distribution at the Natura 2000 site “Niedere Tauern”. For example, in other studies occurrence probability of black grouse was shown to be affected by habitat heterogeneity, the amount of dwarf shrub cover (especially blueberry) and the presence of anthills (Baines 1995, Ludwig et al. 2000, Etzold 2005, Grant and Dawson 2005, Patthey et al. 2011, Schweiger et al. 2011).

METHODS

Study area

The Natura 2000 site "Niedere Tauern" is situated in Styria, Austria and has a size of 120.000 ha (Figure 1). Elevation ranges between 600 m a.s.l. at the major valley bottoms and 2,862 m a.s.l. at the summit of Mount Hochgolling. The study area is embedded between the Enns valley in the north and the upper Mur valley in the south. The area is spread over the mountain ranges Schladminger Tauern, Rottenmanner and Wölzer Tauern as well as the Seckauer Tauern (from west to east) (Praschk 2004). Annual precipitation ranges from 1,000-1,800 mm and rises towards higher altitudes (Pilger et al. 2010). A total of 30% of the study area is covered by forest which corresponds to 36,000 ha. Main tree species are the Norway spruce (*Picea abies*), European larch (*Larix decidua*), Swiss pine (*Pinus zembra*), Mountain pine (*Pinus mugo*) and Green alder (*Alnus viridis*). The understory vegetation in the forested parts is beside dwarf shrubs dominated by grasses and ferns (own observation). The whole area is rich in dwarf shrubs like blueberry (*Vaccinium myrtillus*), lingonbeery (*Vaccinium vitis-idea*) and two species of alpine roses (*Rhododendron ferrugineum*, *Rhododendron hirsutum*). While in the forested parts browsing keeps the vegetation small, above the tree line dwarf shrubs are naturally much smaller and assorted with rocky patches (Dullinger et al. 2003). In the whole area extensive pasturing is pursued, mainly with cattle and horses during the summer months (Galaun et al. 2006).

The "Niedere Tauern" used to be a poor region in the last centuries. Having not much industry and infrastructure, tourism is relatively new and the density of hiking trails and huts in the area is lower than in other parts of the Central Alps. Nevertheless, cross country skiing is becoming a big problem especially for grouse in the winter months (Arlettaz et al. 2007, Patthey et al. 2008, Nopp-Mayr and Grünschachner-Berger 2011). There is also an intensive forestry usage and many forest roads dissect the area. Furthermore, hunting activities are very high, in particular for red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and chamois (*Rupicapra rupicapra*). Black grouse are hunted in small numbers during mating season. The numbers vary for each hunting district (Praschk 2004).

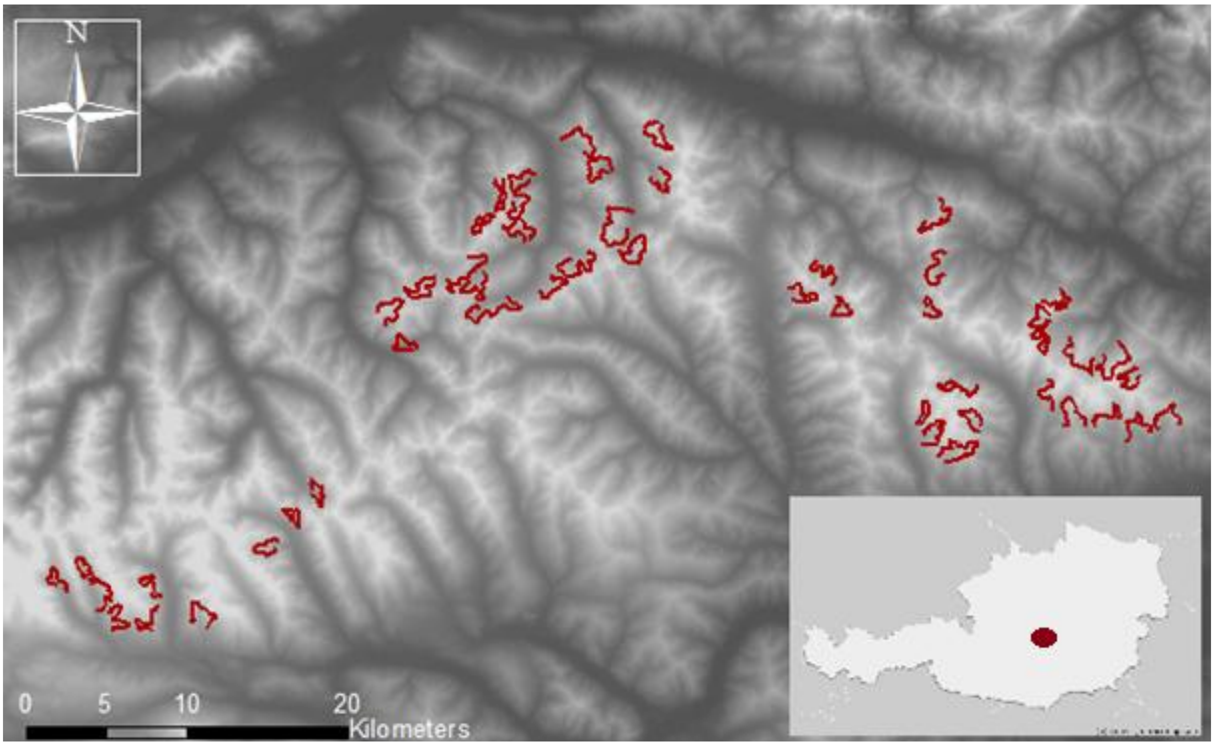


Figure 1: Maps showing the location of the Natura 2000 site "Niedere Tauern" in Styria, Austria (small box) and the position of black grouse transects (red lines).

Black grouse survey

Black grouse were surveyed along a total of 51 transects (Figure 1) of 3.2-8.6 km length (mean ± SD = 5.150±1.019 km) using the point stop method (Bibby et al. 1998, Storch 2002). Transects were selected to cover a substantial part of the study area between 1,600 and 2,100 m a.s.l. reflecting the major altitudinal distribution range of the species at Niedere Tauern (own data, unpublished). Furthermore, transects and survey points were situated to consider all habitat quality categories of an existing expert model which will not be further considered in this study (for more information see Galaun et al. 2006). Variables classified as important for black grouse by the expert model, were half open landscapes, hilly terrain with wide hillsides, well developed dwarf shrub cover dominated by Ericaceae, softwood for winter feeding and snow cover (Galaun et al. 2006).

Each transect connected about 9-19 points (mean±SD = 14±5 points) with a minimum distance of 300 m between points. Besides considering the habitat quality categories of the existing expert model (Galaun et al. 2006), points were randomly placed with the restriction of topographic accessibility.

Each transect point was visited once between dawn and dusk in the period from July to August inclusive (02.07.–30.08.2010). A point survey lasted 15 min. All visual and acoustic records were noted up to a distance of 100 m. We searched for faeces and feathers within a radius of 5 m. The survey was conducted in July and August due to moulting of black grouse cocks and hens without chicks, which increases the chance to find feathers (Novatschin 2007). Because capercaillie and ptarmigan (*Lagopus muta*) also occur and signs of both species can be similar, it was important to document all signs for later verification of species identification. We therefore took photos from feaces and collected feathers for a subsequent expert evaluation in case of doubt. Additionally, all birds as well as signs and tracks were recorded when encountered between transect points.

Habitat variables

For each of our selected transect points as well as for points where black grouse was recorded between those, we measured or estimated a total of 28 habitat parameters within a 20 m radius and extracted information on further 18 variables from a geographic information system (GIS) (see Appendix Table A).

As a bird of ecotones and transition zones we hypothesize that black grouse would prefer habitats having a high patchiness i.e. a distinct vertical and horizontal heterogeneity of vegetation layers (number of tree layers, gaps) (del Hoyo et al. 1994). We therefore developed variables including information about vegetational heterogeneity. We quantified the number of tree layers by counting the number of dominant and subdominant tree species. We also used GIS data provided by the Johanneum Research company in Graz, Styria (Johanneum Research 2011). Digital terrain models (DGM) exist for the whole area in a 10 m resolution and were provided by GIS Steiermark (GIS Steiermark 2011). Parameters like elevation, slope, exposition and human facilities were extracted. For all GIS analyses we used ArcGIS (ArcGIS version 9.3. ESRI Redland California www.esri.com). Using the Euclidian distance tool in Spatial Analyst, for each point we exported the distance from roads, hiking trails, water bodies and huts. A land covers layer was used to calculate the mean perimeter area ratio index MPAR which is the mean perimeter-area ratio of habitat patches (Moser et al. 2002). MPAR can be seen as a measure of habitat heterogeneity (Helzer and Jelinski 1999, Lukasch et al. 2011). We calculated the MPAR index for different spatial scales. Therefore, transect mapping points were buffered with a 50, 100 and 200 meter radius and then intersected with the land cover layer.

STATISTICAL ANALYSES

Data reduction

Transects and survey points were selected to cover areas of different habitat suitability according to the expert model (Galaun et al. 2006). Spacing between mapping points on transects was at least 300 m in this design. For the purpose of model building we had to consider black grouse records between

selected mapping points. However, this increased spatial autocorrelation, hence redundancy in our data. We therefore reduced the data set such that the distance between two points was at least 150 m.
For points and additional signs less than 150 m apart we had to decide which of the two to retain. We therefore applied the following procedure: If the selected survey point did not contain a sign, it was excluded, otherwise we retained the one with the higher ranking, i.e. direct observation > feather > faeces. If the records were of equal ranking, we retained the original mapping point.
However, even when including records between selected survey points, absence points predominated the data set. To account for this imbalanced ratio of presence and absence, we subsequently reduced the number of survey points without black grouse records. Since we only collected data during one season and each transect was mapped only once, the chance to fail detecting black grouse signs was high. Black grouse are sedentary birds with relatively small home ranges during summer and their activity rate is not very high. Males stay near to the leks while females stay close to breeding places (Caizergues and Ellison 2002) especially when having chicks. We therefore made the assumption that habitat suitability exceeds the area close to a point with a black grouse sign. According to the literature, we assumed a mean home range size of 65 ha for males and females in summer (Novatschin 2007, BirdLife International 2011). This corresponds to a circle with a radius of 455 meters. We excluded all absence points within this radius around presence points. With this procedure we attempted to reduce false absences and to improve the balance between presence and absence data.

Model building

With having the response variable "incidence" in a binary form "1- 0" we chose a binary logistic regression model to evaluate effects of habitat parameters on the occurrence of black grouse. Logistic regression models are widely used in habitat modelling (Brooks 1997, Guisan and Zimmermann 2000, Pearce and Ferrier 2000, Menard 2002, Dormann et al. 2003, Schröder and Reineking 2003, Brotons et al. 2004, Graf et al. 2005, Schweiger et al. 2011).
To avoid overestimation of the habitat model, we reduced the number of habitat variables used for modeling. We only considered variables that had a $p < 0.1$ in binary logistic regressions testing for effects on the likelihood of black grouse occurrence (Hosmer and Lemeshow 2000). In all of our modeling, we included untransformed variables, since normality is not required, and errors terms are allowed to have non Gaussian distribution (Guisan and Zimmermann 2000). All the statistical analyses were calculated with SPSS (PAWS Statistics Version 18.0.0 www.spss.com).
Because multicollinarity of explanatory variables can cause problems in logistic regression models (Harrell 2001, Menard 2002) the second step was to test for relationships between all remaining variables in a correlation matrix. For this purpose we chose the two sided Spearman rank-correlation test. If two variables were highly correlated $|r_s| > 0.7$ we excluded the one with a lower *p*- value

regarding the response variable “incidence” (for correlation matrix see Appendix Table B) (Fielding and Haworth 1995, Dormann et al. 2003).

The last step in model building was to check for quadratic relationships. Variables that model incidence with a quadratic term suggest an optimum or pessimum regarding black grouse presence probability.

For model validation we used the random sample function in SPSS to have a data set for calibration (66% of points) and one set for the validation (34% of points) of the best model. With the remaining variables we built a GLM with a logit link function and the binary response variable incidence 1/0. In a first try we reduced variables with the stepwise backwards selection and then a forward selection (Manel et al. 2001). We build two models, one including also the quadratic relations and one which only included the variables that had had a p value < 0.1. We chose the final model using the Akaike information criterion (Akaike 1973), which indicates the goodness of the fit. AIC values have to stay low with the basic assumption that if AIC value is at 0, 100% of the model is explained. Additionally we calculated the Hosmer-Lemeshow goodness-of-fit statistics (Hosmer and Lemeshow 2000) and the Nagelkerke R^2 (Nagelkerke 1991). We ended modeling when all remaining variables had a $p < 0.05$. Finally we checked for spatial autocorrelations using the Moran´s Index in ArcGIS.

Model evaluation

Evaluation of the performance in presence-absence models is based on the confusion matrix (see Table 1). This is an approach that faces the actual incidences 1/0 to the predicted incidences 1/0. The matrix identifies true positive presences (a), false positive presences (b), false negative absences (c) and true negative absences (d) that were predicted by the GLM (Fielding and Bell 1997, Manel et al. 2001).

Table 1: Confusion matrix that faces the actual incidences to the predicted incidences being (+) the presence and (–) the absence data, (a) the true positive, (b) the false negative, (c) the false negative, and (d) true negative cases that were predicted by the GLM.

		Actual	
		+	-
Predicted	+	a	b
	-	c	d

Subsequently, we applied the *SimTest* developed by Zimmermann (2001) to test for the predictive power of our habitat model. Most of the measures used are described in Fielding and Bell (1997) and Zimmermann (2001). The *SimTest* calculates different quality criterions at their best thresholds.

The prevalence (*Prv*) indicates the proportion of observed presences P = (a+c) (for a and c see Table 1). The overall diagnostic power (*ODP*) on the other hand stands for the proportion of observed absences. The positive predictive power (*PPP*) estimates the probability of the accordance between the observed "presence" and the "presence" calculated by the model. The negative predictive power (*NPP*) is the opposite of the (*PPP*) comparing the absences. Where *NPP* and *PPP* are maximized an optimized threshold can be obtained. Sensitivity can be seen as the probability that a true "presence" is classified correctly. Two measures picture the simulation errors – type 1 and type 2. Type 1 errors are falsely predicted "presences" of black grouse when in reality there are "absences". Type 2 errors are the inversion of the former - falsely predicted "absences" (Zimmermann 2001). The *SimTest* calculates additional values like the Cohen's kappa coefficient. According to (Landis and Koch 1977) kappa values over 0.4 indicate moderate to good results.
The model was also evaluated by the Receiver Operating Characteristic (ROC) curve. This curve is achieved by plotting the sensitivity vs. 1-specificity for varying probability thresholds. In this case sensitivity is the true positive rate predicted by the model whereas the specificity describes the true negative rate. A good model performance is characterized by a curve that maximizes sensitivity with having on the other site low values of 1-specificity. High performance models are indicated by large area under the curve (AUC) values (Manel et al. 2001). AUC values range between 0.5 and 1.0. AUC values of 0.5–0.7 indicate low accuracy, while values of 0.7–1.0 indicate useful applications (Fielding and Bell 1997, Manel et al. 2001). The AUC is considered to be acceptable if it is larger than 0.7. That means that 70% of the random selection from the positive group will have scored greater than a random selection from the negative class (Fielding and Bell 1997). Because we have partitioned the data we have values for both data sets.

Habitat suitability map

The habitat suitability map was produced in ArcMap with the spatial analysis tool "map algebra" connecting the modeled probability of occurrence *P* with the available GIS layers using the following formula:

$$\boldsymbol{P = 1/(1 - exp\big(-(constant + beta_1 * \ x_1 \ldots + beta_n * x_n)\big)}$$

Beta values represent the Beta coefficients of the habitat variables remaining in the habitat model.

RESULTS

Black grouse could be recorded at a total of 8.41% of the 452 selected transect points, corresponding to 38 points. Additionally, birds or signs were found at 45 locations between selected transect points, resulting in a total of 83 "presence" points. After data reduction 482 points remained for model building and model validation. The calibration data set (N=318) consists of 39 points with grouse records and 279 without records. For the validation data set (N=164) the relation between points with presences and absences was 27 to 137. A total of 16 environmental variables remained after univariate statistics (see Table 2).

Table 2: Variables significantly affecting black grouse occurrence. HUTS and CCLOSURE are still included since they showed significant p values in quadratic relationships.

Variable	Code	p unvaried	R^2 Nagelkerke
Elevation	**ELEV**	**<0.001**	**0.057**
Steepness of slope	**SLOPE**	**0.002**	**0.037**
Topographical heterogeneity	**TPHETG**	**0.044**	**0.015**
Open/Gap	**GAP**	**0.015**	**0.031**
number of vaccinium	**VACNUMB**	**0.008**	**0.024**
MeanPerimeterAreaRatio Index	**MPAR50**	**0.015**	**0.022**
MeanPerimeterAreaRatio Index	**MPAR100**	**<0.001**	**0.067**
MeanPerimeterAreaRatio Index	**MPAR200**	**0.002**	**0.034**
Count 50	**C50**	**0.003**	**0.032**
Count 100	**C100**	**<0.001**	**0.055**
Count 200	**C200**	**0.002**	**0.033**
Distance to huts	**HUTS**	**0.048**	**0.016**
Distance to huts^2	**HUTS^2**	**0.392**	**0.003**
Succession	**SUCC**	**0.063**	**0.017**
Canopy/Crown closure	**CCLOSURE**	**0.992**	**0.006**
Canopy/Crown closure^2	**CCLOSURE^2**	**0.044**	**0.020**
Dwarf shrub cover	**DWCOVER**	**0.005**	**0.031**
Blueberry cover	**BLCOVER**	**0.020**	**0.020**

The evaluation of multicollinarity of these remaining variables by Spearman rank correlations showed that the explanatory variables MPAR50, MPAR100, MPAR200, C50, C100, C200 where highly related as well as DWCOVER and BILBCOVER with $|r_s|> 0.7$ (see Appendix Table B). For the final model we retained MPAR100, C200 and DWCOVER having a stronger influence on the response variable incidence. For two variables, CCLOSURE and HUTS, effects on black grouse occurrence were best explained by a quadratic regression. Because of inhomogeneous distribution among the categories we excluded Succession (SUCC).

Finally ten explanatory variables remained for the final model building: SLOPE, ELEV, TPHETG, GAP, VACNUMB, MPAR100, C200, $HUTS^2$, $CCLOSURE^2$ and DWCOVER.

Final model for black grouse

The best results gave the model which included quadratic relations. The five explanatory variables that were contained in the final calibration model were SLOPE, TPHETG, MPAR100, DWCOVER and $HUTS^2$. The final model showed a Nagelkerke R^2 of 0.29. The AIC for the null model was 238.7 and 197.7 for the final model, i.e. deviation explained was 17% (238.7-197.7= 41; 41/238=0.172). An AUC value of 0.813 indicated good discrimination ability for the calibration data. The accuracy 0.682 for validation data was relatively low (Figure 2). The *p*-value of the Hosmer-Lemeshow goodness-of-fit statistic of 0.151 indicated good model fit, i.e. the model was not significantly different from a logistic curve. Results of the *SimTest* (Table 3) showed a prevalence of 0.12 which is very low what influences all other results from this test (Zimmermann 2001). The overall diagnostic power (ODP) 0.88 is very high. Best Kappa values were at 0.424 which indicating a good predictive power of the habitat model.

Which threshold to take and what value to prefer depends on the data and the goal the study has in the end. The *SimTest* suggests a value of 0.37 as the cut for best classification rate.

Table 3: Accuracy Assessment of the SimTest by Zimmermann 2011. Numbers in [] indicates the optimized threshold. Threshold ranges from 0.0 to 1.0

ACCURACY ASSESSMENT	Values	
Prevalence:	0.12	
Overall diagnostiv power:	0.88	
Area under the curve (AUC):	0.809	
Optimal correct classification rate(CCR):	0.896	
Optimal Kappa:	0.424	
Commission of best CCR (=false pos.):	0.018	
Omission of best CCR (=false neg.):	0.718	
Cut for best classification rate:	0.37	
Minimum acc. error (90% of positives):	0.54	
Minimum acc. error (75% of positives):	0.38	
Cross-over of misclassification rates:	0.14	
At optimized threshold:		At 0.50 threshold:
Correct classification rate (CCR):	0.896 [0.37]	0.889
Kappa statistics:	0.424 [0.26]	0.196
Misclassification rate (MCR):	0.877 [<0.01]	0.110
Positive predictive power (PPP):	1.000 [0.51]	0.833
Negative predictive power (NPP):	1.000 [0.01]	0.891
Odds-ratio (OR):	5.176 [0.04]	40.883

A high spatial autocorrelation was found for the calibration data (Moran's Index = 0.06; z-scores = 2.68; p = 0.007; N=318) as well as the whole data set (Moran's Index = 0.15; z-scores = 5.50; p < 0.001; N=482).

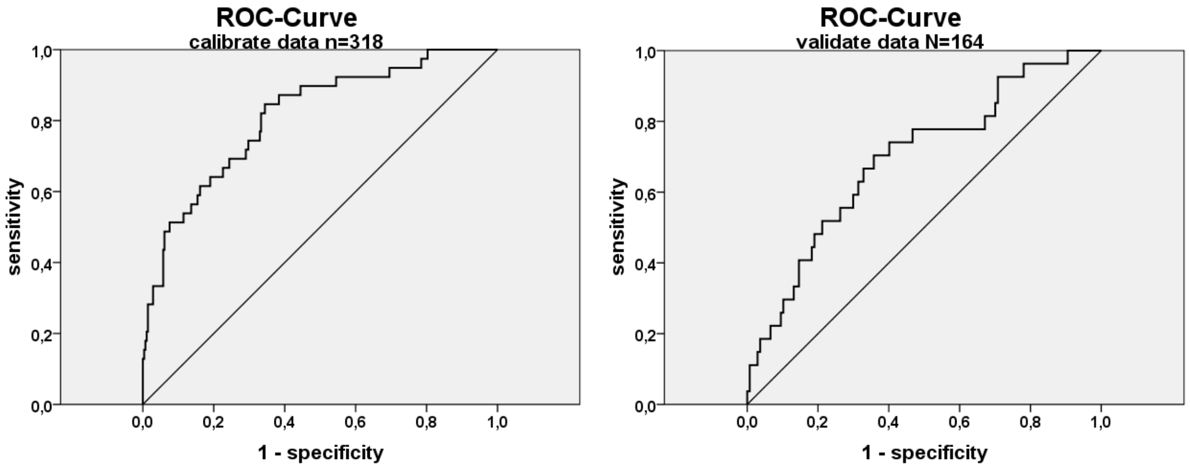


Figure 2: Receiver operator curve for the calibration data set (N=318) and the validation data set (N=164) with an AUC value of 0.813 and 0.682, respectively.

Variables for black grouse

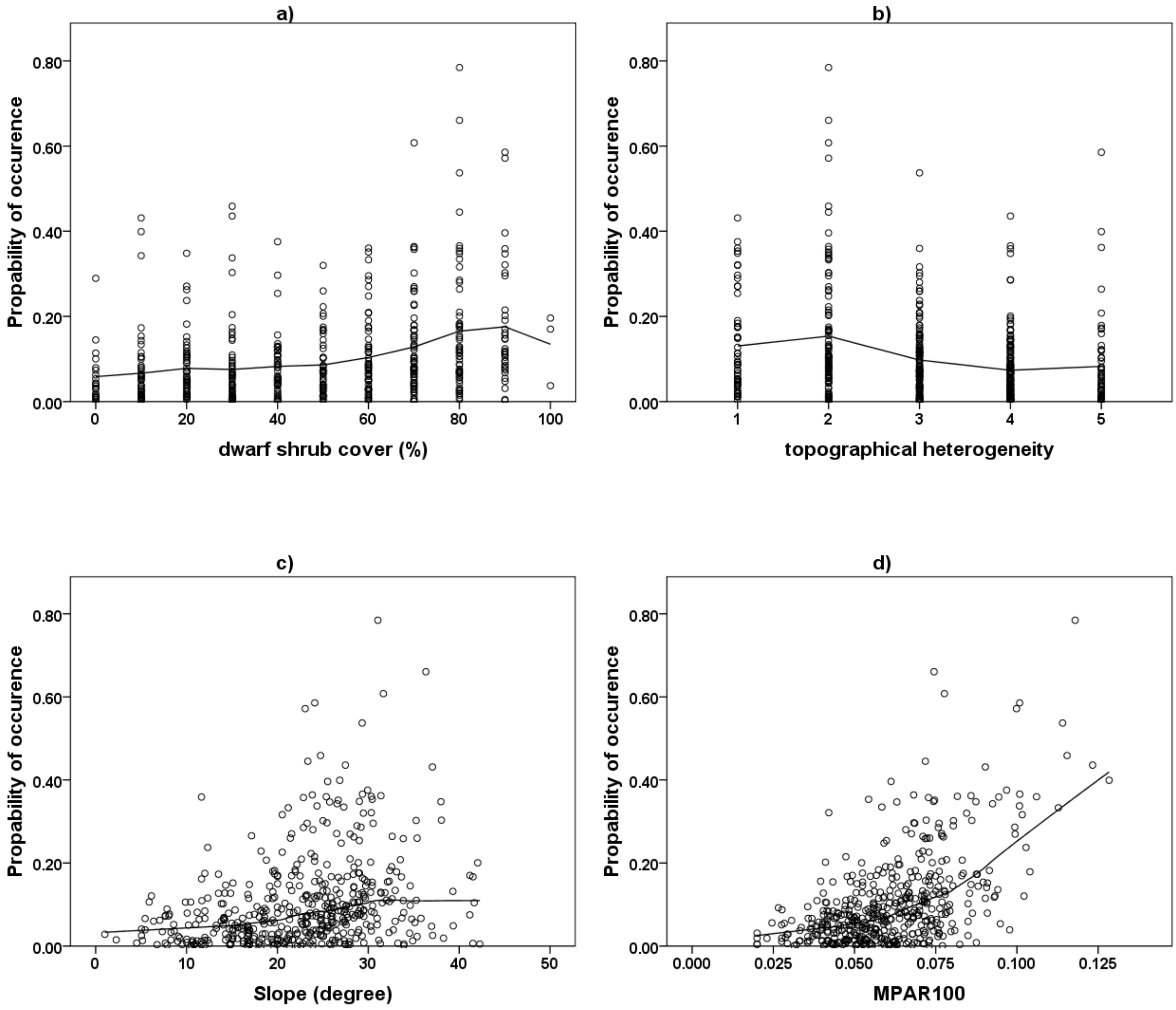
Table 4: Variables included in the final model of the calibration data (N=318).

variables	coefficient of the parameters	Standard error	Wald	Sig.	Exp(B)
SLOPE	0.064	0.030	4.520	0.033	1.066
TOPHETG	-0.480	0.162	8.796	0.003	0.619
MPAR100	53.323	11.469	21.617	<0.001	1.438E23
DWCOVER	0.022	0.008	8.226	0.004	1.023
HUTS	0.004	0.001	10.266	0.001	1.004
$HUTS^2$	<0.001	<0.001	9.074	0.003	1.000
Constant	-10.295	1.846	31.099	<0.001	<0.001

The final model included five variables (see Table 4 and Figure 3) of which only dwarf shrub cover was mapped in the field - all other explanatory variables were extracted from available GIS layers.
All categories of dwarf shrub cover (0-100%) where recorded on the mapping points. Black grouse occurrence increased with the amount of cover and was highest between 80-90% (Figure 3; a)).
Highly represented in the final model were the topographic explanatory variables. Two of them slope and topographical heterogeneity contributed significantly to the models information content. Topographic heterogeneity was classified in five categories from 1 (very high) to 5 (very low). The negative regression coefficient indicated what can be seen in Figure 3, b) - if the topographical heterogeneity is too high, black grouse occurrence will decrease.
On the mapped points slope varied between 0-40^o degrees. The influence of slope regarding the response variable was quite low (Table 4). Nevertheless the probability of occurrence for black grouse increased slightly with the steepness of slope (Table 4; Figure 3 c)).
Because of intercorrelation only one variable reflecting the habitat heterogeneity remained in the final model. The mean perimeter area ratio index with a spatial resolution of 100 meter showed the

strongest positive influence on black grouse occurrence (Table 4) and black grouse occurrence increased drastically with higher MPAR values (Figure 3 d)).

The only quadratic relation included in the final model was the mean distance to huts. The distances to huts ranged from 500 m to 5 km. Black grouse occurrence was at its peak in a mean distance to huts at around 2000 m (Figure 3 e)).



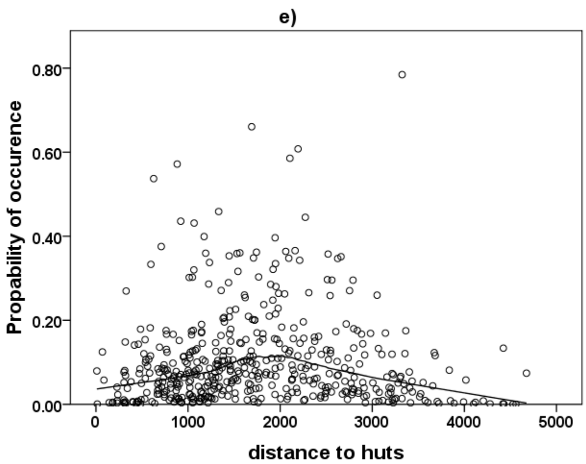


Figure 3: Probability of black grouse occurrence predicted by the final habitat model plotted against (a) dwarf shrub cover (b) topographical heterogeneity, (c) slope, (d) MPAR (measured within r = 100m), and (e) the Euclidean distance to huts. Lines visualising the relationships between probabilities and the five variables are fitted using the Loess function.

Habitat suitability map for black grouse

An important part of habitat modelling is the visualisation of the results. For further management such as the designation of core zones or habitat improvement measures, they can serve as a practical tool. To build a proper habitat suitability map all variables influencing the occurrence probability of black grouse have to be available in a GIS shapefile. For our data this was not the case for dwarf shrub cover. Therefore, Figure 5 shows a preliminary map considering all variables included in the final model (SLOPE, TPHETG, MPAR100 and HUT^2) except DWCOVER. The map shows five different categories of habitat suitability from green (probability of black grouse occurrence ~ 80-100%) to red (probability of black grouse occurrence 0 to ~ 4%). The map shows large areas of good habitat suitability especially in the core zones of the Natura 2000 area. Areas with low and moderate habitat suitability are mainly situated at the boundaries reflecting the existing borders of the Natura 2000 site. Green zones in the centre of the study area are partly overestimated because they include major valleys where no data was collected. The formula used to create the map in "map algebra":

P=1/(1+exp(-(-7.007+[SLOPE]*0.064-[TPHETG]*0.31+[MPAR100]*38.775+
[HUTS] * 0.003 - [$HUTS^2$] *0.00000060563)))

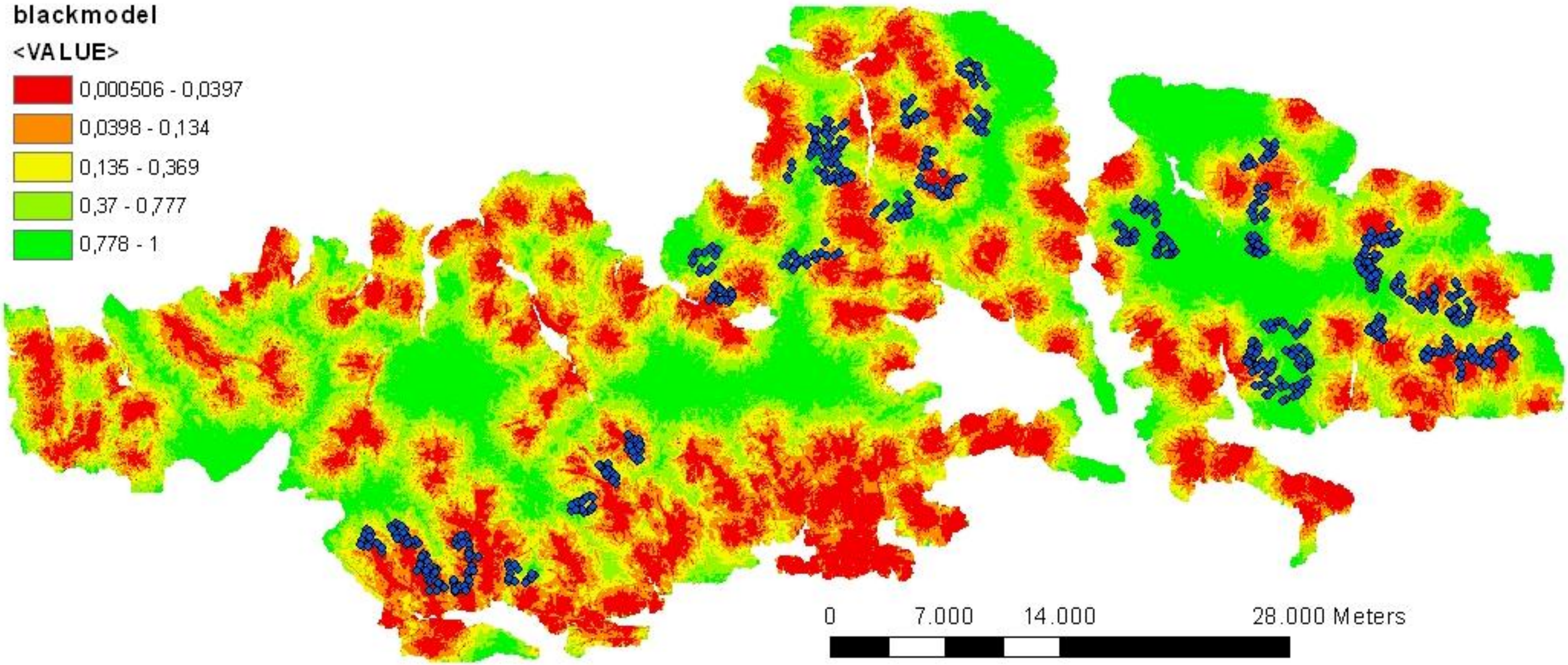


Figure 5: A map showing the habitat suitability with a spatial resolution of 10 m for black grouse in the study area. Colors indicate different probabilities of occurrence ranging from a high probability (>77%; green) to a low probability (< 4%; red).The map is based on all variables included in the final habitat model except dwarf shrub cover, for which no GIS data were available.

DISCUSSION

Habitat modeling has become very popular in recent years, partly because new technical tools improved and simplified data acquisition (Store and Jokimaki 2003). Results should help conservationists to understand habitat requirements of (endangered) species and should facilitate the development of effective habitat management strategies aiming to maintain or even increase existing populations (Bissonette and Storch 2003). Since financing and available time for field work are often the limiting factors, and predictions of habitat suitability can be limited regarding spatial and temporal scale (Kleyer et al. 1999). Due to the large size of our study area and the relatively short field season, we also could only account for a relatively small number of factors potentially influencing the occurrence of black grouse. Our habitat model for the occurrence of black grouse at the Natura 2000 site "Niedere Tauern" was based on data collected during the summer months July and August and our transects only covered a relatively small part of the entire study area. Additionally to the low density of transects and survey points, the number of absences and presences was very imbalanced towards points without grouse records.

The absence of a species can have three causes (Hirzel et al. 2002): (1) The species was present but could not be detected, (2) the habitat is suitable, but the species is not present or (3) the habitat is currently not suitable for the species. The failure to record the species' presence can be given due to our low survey effort of only one 15 min visit per point and the difficulty to detect the species. During the post-breeding season the black grouse is a highly secretive bird due to its sedentary habits, particularly during moulting when birds spend most of the day preening (del Hoyo et al. 1994). The main time for dispersal starts in late autumn and has its peak in the end of October (Caizergues and Ellison 2002, Warren and Baines 2002). As it was neither dispersal nor mating season and the species action radius most likely is very small during this time of the year (July-August) it can be rather difficult to detect. Another possibility for potentially false absences could be that molted feathers had been blown away before our survey.

The second reason for the absence of a species is given when the habitat is suitable, but the species is not yet/no more present in the study area. Northern populations of black grouse have pronounced population cycles (Ludwig et al. 2006), which can have a profound effect for modeling habitat suitability. When the population size is at its minimum the suitability of an area for black grouse can be underestimated, while in years when black grouse numbers peak, habitat suitability can be overestimated (Nopp-Mayr and Grünschachner-Berger 2011). However, while population cycles are typical for northern populations they seem to be largely absent at the species´ more central and southern distribution range, including the Alps (Glutz von Blotzheim et al. 1973, Cattadori and Hudson 1999). Additionally, habitat fragmentation can lead to the absence in otherwise suitable habitats due to low reproductive success and dispersal ability of black grouse (Bissonette and Storch 2002, Graf et al. 2005).

A falsely predicted presence for points where the species does not occur can be also the result of a failure to consider important habitat variables. For example we were not able to measure the real impact of tourism because we had no information about the disturbance regime caused by hiking trails and forest roads. Furthermore, our habitat model did not consider effects of predators such as the red fox (*Vulpes vulpes*), common raven (*Corvus corax*), carrion crows (*Corvus corone*) or the golden eagle (*Aquila chrysaetos*) (Angelstam 1986, Nopp-Mayr and Grünschachner-Berger 2011). A total of ≥25 breeding pairs of the Golden Eagle are estimated to occur at the Niedere Tauern (BirdLife International 2011). Grouse represent an important prey (up to 13.8%) for alpine populations of the Golden Eagle (Glutz von Blotzheim 1989). While the effect of the carrion crow should be moderate above the tree line (Klosius 2008), red fox and raven can play an important role as black grouse predators especially during breeding season (Angelstam 1986). Furthermore, the importance of predation seems to be increased in fragmented habitats or small and therefore more vulnerable populations (Klaus et al. 1990, Baines 1996, Storch 2000b).

Predictive ability of the model

Our final model contained five variables explaining the small-scale occurrence of black grouse at the Natura 2000 site "Niedere Tauern". The AUC of 0.813 indicates a good performance of our final habitat model based on the calibration data. Unfortunately, the AUC value 0.692 of the model based on the validation data is just below the threshold of 0.7, therefore indicating a relatively low accuracy of our resulting habitat model (Fielding and Bell 1997). The *SimTest* by Zimmermann (2001) builds a new optimized threshold for datasets where the chance of overlooking incidences is high. Because our model should serve to determine areas of a high conservation relevance for black grouse in the Natura 2000 site "Niedere Tauern", a high number of falsely predicted presences will be more costly in terms of conservation than a high number of falsely predicted absences (Fielding and Bell 1997, Reineking B, Schröder B 2003). Another weakness of our habitat model is that Moran's autocorrelation coefficient indicates a high spatial autocorrelation for the whole data set as well as for the calibration data of the final model. High spatial autocorrelation can increase prediction errors in the model because the key assumption of statistical analyses that residuals should be independent and homogenously distributed is violated. Spatial autocorrelation can occur because of environmental and historical factors. The spatial distribution of a species depends on its dispersal mechanism and other behavioral factors. Especially lekking behavior of black grouse males can cause spatial aggregation of records. Because spatial autocorrelation can be found at different spatial scales it is rather hard to avoid autocorrelation in unexplored areas (Legendre 1993, Dormann et al. 2007).

The predictions of our final model have so far been restricted to the summer months since we did not collect presence and absence data for black grouse during breeding season and winter months where habitat requirements can be different. During breeding season the presence of shelter against predators and weather conditions would be more important, whereas in the winter months the presence of conifers as an important food source, drive the distribution of black grouse (Klaus et al. 1990, Baines 1995, Baines et al. 1996, Grant and Dawson 2005).

Variables selected by the model and their biological relevance

Our final habitat model for black grouse included the variables SLOPE, MPAR 100m, TPHETG, DWCOVER, HUT and HUT^2. Of all variables quantified by ground surveys, only DWCOVER remained in the final model. Our data indicate that black grouse positively respond to an increased dwarf shrub cover. Dwarf shrubs represent an important food source and offer protection against predators and harsh weather conditions (Glutz et al. 1973, del Hoyo et al. 1994, Schweiger et al. 2011). Other variables such as ground vegetation height, which has proven to be an important explanatory variable in previous studies (Klaus et al. 1990, Baines 1996, Schweiger et al. 2011), did not show a significant effect on black grouse occurrence. Vegetation height can be particularly important during the breeding season when chicks need to feed on insects and also reduces predation risk through increased cover (Angelstam 1986, Klaus et al. 1990). However, ground vegetation height only varied slightly in our study area. At >90% of our survey points vegetation height was between 10 and 30 cm and it did not differ between points with (mean vegetation height ± SD = 20.91±10.34 cm) and without black grouse records (21.75±9.65 cm; t-test considering all data: $t = 0.631$, $p = 0.530$).
Another explanatory variable, which did not contribute to explaining black grouse occurrence, is the availability of anthills, although it appeared to strongly affect the black grouse occurrence in other alpine populations (Schweiger et al. 2011). Ants present an important protein resource for black grouse chicks in the first weeks after hedging (Glutz v. Blotzheim et al. 1973). In our study area ant hills were recorded at 33% of our survey points, but black grouse were not recorded with a significantly higher frequency at survey points with ant hills compared to survey points without ant hills (Chi-square test: $\chi^2 = 2.10$, $p = 0.1472$).
Of the variables measured in ArcMap, MPAR100 most strongly affected black grouse occurrence, which emphasizes the importance of high habitat heterogeneity. Structural heterogeneity already proved to be an important habitat variable for black grouse occurrence in other studies (e.g. Patthey et al. 2011). In our study the MPAR Index was found to significantly affect black grouse occurrence on different spatial resolutions (50, 100 and 200m radius), but due to a high multicollinarity only MPAR100m was considered for modelling.

TPHETG also remained in the final model but only weakly affected black grouse occurrence showing a weakly decreasing probability of occurrence with increasing topographical heterogeneity. The relief can have a strong influence on the soil and thereupon on the vegetation (Etzold 2005). Variation of topographical heterogeneity paired with differences in vegetation structure can lead to differences in snow cover and the capacity to retain water. Topographical heterogeneity can also affect the extent of insolation and wind exposure which again both can affect the duration of snow cover (Link and Marks 1999). Also the steepness of slope, another variable remaining in our final habitat model, can influence the snow cover duration. Additionally, the variable can have an impact on human activities such as skiing and hiking (Braunisch et al. 2011).

Our habitat model also indicates an effect of hut distance on black grouse occurrence. In the "Niedere Tauern" huts are often run during the summer months, attracting local visitors, tourists and cattle farmers, which keep their cattle grazing on alpine meadows in the vicinity. Therefore, the surroundings of huts may represent "hotspots" of human disturbance decreasing the habitat quality for black grouse. Although disturbance levels may not necessarily have an impact on fecundity, at least not until disturbance frequencies exceed a certain level (Baines and Richardson 2007). Pasturing in vicinity of huts can be even positive for black grouse due to reduced Mountain Pine cover (Ludwig, personal communication). An increased density of predators around huts can have a further negative effect on black grouse. Particularly potential predators such as carrion crows and ravens appear to be attracted by huts, which can have a negative effect on breeding success (Storch and Leidenberger 2003). The significant effect of the squared term of hut distance could be explained through an optimum distance to huts. This could be achieved when black grouse still benefit from pasturing around huts but are not exposed to higher human disturbance levels and predator density in the immediate vicinity to huts.

CONCLUSIONS

When compared to other studies from different regions of the Alps (e.g. Patthey et al. 2011, Schweiger et al. 2011), our results identified partly identical habitat requirements for black grouse at the Natura 2000 site "Niedere Tauern". This is an indication that habitat use of different alpine populations is shaped by similar habitat requirements. A major weakness of all studies on habitat use of black grouse in the Alps is that existing data do not cover all seasons of the year. Although seasonal differences may exist concerning the importance of environmental variables for predicting the small and large scale habitat quality. Furthermore, the application of other modeling tools such as the *ecological niche factor analysis* (ENFA) (Hirzel et al. 2002) may help to understand to what extent predictions of the spatial distribution of black grouse can be generalized. An ENFA additionally would have the advantage of only considering presence data, thereby avoiding false absences, which may have a major impact on model performance particularly in species such as the black grouse with rather cryptic habits during most of the year.

Beside the mentioned weaknesses, our habitat model makes some first preliminary predictions of the spatial distribution and size of high quality habitat areas at the Natura 2000 site “Niedere Tauern, which should be validated by subsequent ground surveys. Although minor spatial adaptations may be necessary, large areas of high quality habitat appear to be located in the core area of the Natura 2000 site “Niedere Tauern”, emphasizing that at least a substantial part of the black grouse population is situated within the currently designed borders of the Natura 2000 site.

Beside the designation of protected areas and the development of adequate management strategies (e.g. to reduce human disturbance) aiming to maintain existing black grouse populations, long-term monitoring schemes should be established to detect a potential prospective population change. Such monitoring schemes are necessary to evaluate the effectiveness of conservation actions and the mid- to long-term impact of land-use and climate change. While first negative effects of climate change on the survival and population size of northern black grouse populations were reported (Ludwig et al. 2006), such data are not available for alpine populations, which could suffer by a reduction of suitable habitat due to an upward shift of the current tree line as demonstrated for other bird species (Graf 2009).

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APPENDIX

Table A: List of all Variables tested in logistic regressions.

Variable	**shortcut**	**Definition**	**Source**	**Data type**
Elevation	ELEV	m above sea level	GIS Steiermark[1]	metric
Steepness of slope	SLOPE	Degree	GIS Steiermark	metric
Topographical heterogeneity	TPHETG	in categories 1..very high, 2..high, 3..mean, 4..low, 5..very low	GIS Johanneum[2]	ordinal
Dead wood standing	DWOODS	3 categories; 1..single,2..groups,3..covered	From data sheet	ordinal
Dead wood laying	DWOODL	3 categories; 1..single,2..groups,3..covered	From data sheet	ordinal
Anthills	ANTS	Number of Anthills	From data sheet	metric
Open/Gap	GAP	2 categories 0..no,1..yes wider than stand is high	From data sheet	nominal
Needles	NEEDL	2 categories 0..no,1..yes absence or presence of pine or fir	From data sheet	nominal
Ground cover height	GCOVERH	Vegetation height in 10cm intervals	From data sheet	metric
Wet soil	WETSOIL	2 categories 0..no,1..yes	From data sheet	nominal
Stone	STONE	2 categories 0..no, 1..yes	From data sheet	nominal
Cattle	CATTLE	2 categories 0..no, 1..yes	From data sheet	nominal
Number of vaccinium	VACNUMB	number Vaccinium	From data sheet	ordinal
Vertical heterogeneity	VERTHETG	number tree layer	From data sheet	ordinal
MeanPerimeterAreaRatio Index 50m	MPAR50	Relation of Perimeter and Area in a radius of 50m	GIS	metric
MeanPerimeterAreaRatio Index 100m	MPAR100	Relation of Perimeter and Area in a radius of 100m	GIS	metric
MeanPerimeterAreaRatio Index 200m	MPAR200	Relation of Perimeter and Area in a radius of 200m	GIS	metric
Count 50	C50	Number of Land cover types in a radius of 50m	GIS	ordinal
Count 100	C100	Number of Land cover types in a radius of 100m	GIS	ordinal
Count 200	C200	Number of Land cover types in a radius of 200m	GIS	ordinal
Huts	HUT	Euclidean distance to huts	GIS Johanneum	metric
Forest roads	ROAD	Euclidean distance to roads	GIS Johanneum	metric
Distance to hiking trails	HIKING	Euclidean distance to hiking trails	GIS Johanneum	metric
Distance to water bodies	WATER	Euclidean distance to water bodies	GIS Johanneum	metric
Distance to OEAV huts	OEAV	Euclidean distance to OEAV huts	GIS Johanneum	metric
Succession	SUCC	8 categories 1..young/rejuvenation, 2..thicket, 3..polestage, 4..medium	From data sheet	nominal

		age,5..old forest, 6..single tree treat, 7..treeline, 8..not forested		
Canopy/Crown cover	CCOVER	percentage of floor covered by trees in10 percentage interval	From data sheet	metric
Main Tree species	MTREE	By name of the two dominant species; spruce, beech, fir, pine, alder, mugo, uncinata, zembra	From data sheet	nominal
Subdominant Tree species	SUPTREE	By name of the two subdominant species; spruce, beech, fir, pine, alder, mugo, uncinata, zembra	From data sheet	nominal
Alder all	ALDALL	Presence of alder on points with incidence 0/1	GIS	ordinal
Alder 50	ALDER50	Percentage of alder in a radius of 50 meters	GIS	ordinal
Alder 100	ALDER100	Percentage of alder in a radius of 100 meters	GIS	ordinal
Alder 200	ALDER200	Percentage of alder in a radius of 200 meters	GIS	ordinal
Rejuvenation cover	REJCOVER	percentage 1<25, 2<50, 3<75, 4>75	From data sheet	ordinal
Ground Vegetation	GVEG	By name of the two dominant species; none, grass, moss, fern, blackberry, raspberry, blueberry, lingonberry, alpine rose, rocks, other	From data sheet	nominal
Dwarf shrub cover	DWCOVER	percentage of ground cover	From data sheet	metric
Blueberry cover	BLCOVER	percentage of ground cover	From data sheet	metric
Vaccinium vitis-idea	VVIDEA	2 categories 0..no,1..yes	From data sheet	nominal
Vaccinium uliginosum	VLIGINOSUM	2 categories 0..no,1..yes	From data sheet	nominal
Vaccinium oxycoccus	VOXY	2 categories 0..no,1..yes	From data sheet	nominal
Juniperus comunes	JUNIPER	2 categories 0..no,1..yes	From data sheet	nominal
Caluna vulgaris	CALUNA	2 categories 0..no,1..yes	From data sheet	nominal
Rhododendron ferruginium/hirsutum	RHODO	2 categories 0..no,1..yes	From data sheet	nominal
Field of *Pinus mugo*	MUGFIELD	2 categories 0..no,1..yes	From data sheet	nominal

[1] GIS Steiermark. 2011. Geographisches Informationssystem - Land Steiermark. Downloaded July 13, 2011, from http://www.gis.steiermark.at/.
[2] Johanneum Research. 2011. http://www.joanneum.at/jr.html. Downloaded July 13, 2011, from http://www.joanneum.at/jr.html.

Table B: Correlation matrix showing the regression coefficients and *p* values of the two sided Spearman rank testing for correlation of habitat variables.

		C50	C100	C200	TPHETG	GAP	VACNUMB	SLOPE	CCOVER	MPAR50	MPAR100	MPAR200	DWCOVER	BLCOVER	HUT	ELEV
C50	Correlation Coefficient	1.000	0.666	0.422	0.120	0.113	-0.028	-0.022	0.064	0.819	0.755	0.505	0.003	-0.038	-0.124	0.006
	Sig. (2-tailed)	.	<0.001	<0.001	0.008	0.013	0.546	0.635	0.158	<0.001	<0.001	<0.001	0.949	0.399	0.006	0.903
C100	Correlation Coefficient	0.666	1.000	0.610	0.084	0.068	-0.044	0.004	0.024	0.546	0.817	0.672	-0.052	-0.065	-0.039	0.036
	Sig. (2-tailed)	<0.001	.	<0.001	0.064	0.136	0.333	0.926	0.602	<0.001	<0.001	<0.001	0.253	0.157	0.397	0.426
C200	Correlation Coefficient	0.422	0.610	1.000	0.050	0.059	-0.042	0.017	0.029	0.339	0.560	0.915	0.014	-0.105	-0.085	0.161
	Sig. (2-tailed)	<0.001	<0.001	.	0.271	0.193	0.358	0.714	0.532	<0.001	<0.001	<0.001	0.751	0.021	0.063	<0.001
TPHETG	Correlation Coefficient	0.120	0.084	0.050	1.000	0.003	-0.048	-0.038	0.023	0.058	0.072	0.063	0.018	-0.032	0.047	-0.020
	Sig. (2-tailed)	0.008	0.064	0.271	.	0.951	0.297	0.407	0.612	0.202	0.116	0.166	0.688	0.482	0.308	0.662
GAP	Correlation Coefficient	0.113	0.068	0.059	0.003	1.000	0.035	-0.016	-0.023	0.153	0.106	0.082	0.083	0.093	-0.129	-0.052
	Sig. (2-tailed)	0.013	0.136	0.193	0.951	.	0.443	0.721	0.615	0.001	0.020	0.074	0.067	0.040	0.005	0.254
VACNUMB	Correlation Coefficient	-0.028	-0.044	-0.042	-0.048	0.035	1.000	0.029	0.045	-0.083	-0.075	-0.047	0.428	0.353	0.057	0.090
	Sig. (2-tailed)	0.546	0.333	0.358	0.297	0.443	.	0.529	0.324	0.067	0.099	0.303	<0.001	<0.001	0.213	0.048
SLOPE	Correlation Coefficient	-0.022	0.004	0.017	-0.038	-0.016	0.029	1.000	0.088	-0.026	-0.054	-0.007	0.143	0.045	-0.163	0.080
	Sig. (2-tailed)	0.635	0.926	0.714	0.407	0.721	0.529	.	0.054	0.569	0.238	0.880	0.002	0.327	<0.001	0.078
CCLOSURE	Correlation Coefficient	0.064	0.024	0.029	0.023	-0.023	0.045	0.088	1.000	0.058	0.024	0.054	0.062	0.162	-0.056	-0.049
	Sig. (2-tailed)	0.158	0.602	0.532	0.612	0.615	0.324	0.054	.	0.202	0.603	0.238	0.172	0.000	0.222	0.287
MPAR50	Correlation Coefficient	0.819	0.546	0.339	0.058	0.153	-0.083	-0.026	0.058	1.000	0.753	0.450	-0.035	-0.053	-0.132	-0.001
	Sig. (2-tailed)	<0.001	<0.001	<0.001	0.202	0.001	0.067	0.569	0.202	.	<0.001	<0.001	0.440	0.244	0.004	0.989
MPAR100	Correlation Coefficient	0.755	0.817	0.560	0.072	0.106	-0.075	-0.054	0.024	0.753	1.000	0.703	-0.068	-0.073	-0.053	0.045

	Sig. (2-tailed)	<0.001	<0.001	<0.001	0.116	0.020	0.099	0.238	0.603	0.000	.	<0.001	0.136	0.107	0.248	0.322
MPAR200	Correlation Coefficient	0.505	0.672	0.915	0.063	0.082	-0.047	-0.007	0.054	0.450	0.703	1.000	0.023	-0.070	-0.051	0.145
	Sig. (2-tailed)	<0.001	<0.001	<0.001	0.166	0.074	0.303	0.880	0.238	<0.001	<0.001	.	0.608	0.124	0.266	0.001
DWCOVER	Correlation Coefficient	0.003	-0.052	0.014	0.018	0.083	0.428	0.143	0.062	-0.035	-0.068	0.023	1.000	0.731	0.081	0.138
	Sig. (2-tailed)	0.949	0.253	0.751	0.688	0.067	<0.001	0.002	0.172	0.440	0.136	0.608	.	<0.001	0.077	0.002
BLCOVER	Correlation Coefficient	-0.038	-0.065	-0.105	-0.032	0.093	0.353	0.045	0.162	-0.053	-0.073	-0.070	0.731	1.000	0.032	-0.128
	Sig. (2-tailed)	0.399	0.157	0.021	0.482	0.040	<0.001	0.327	<0.001	0.244	0.107	0.124	<0.001	.	0.482	0.005
HUT	Correlation Coefficient	-0.124	-0.039	-0.085	0.047	-0.129	0.057	-0.163	-0.056	-0.132	-0.053	-0.051	0.081	0.032	1.000	0.302
	Sig. (2-tailed)	0.006	0.397	0.063	0.308	0.005	0.213	<0.001	0.222	0.004	0.248	0.266	0.077	0.482	.	<0.001
ELEV	Correlation Coefficient	0.006	0.036	0.161	-0.020	-0.052	0.090	0.080	-0.049	-0.001	0.045	0.145	0.138	-0.128	0.302	1.000
	Sig. (2-tailed)	0.903	0.426	<0.001	0.662	0.254	0.048	0.078	0.287	0.989	0.322	0.001	0.002	0.005	<0.001	.

ZUSAMMENFASSUNG

Modellierung von Habitateignung hat in den letzten Jahren zunehmend an Bedeutung für Naturschutz und Wildtiermanagement gewonnen. Durch die Weiterentwicklung technischer Werkzeuge wie Geoinformationssysteme (GIS) kann die Datenerfassung und Darstellung vereinfacht werden. Habitatmodelle können somit einen wertvollen Beitrag zur Beurteilung von Lebensräumen und Habitatpräferenzen liefern. Mit gewonnenen Daten können artspezifische Schutzgebiete eingerichtet und geeignete Managementmaßnahmen ergriffen werden. In Rahmen dieser Masterarbeit konnten wir mit Hilfe von Freilanddaten und Daten aus dem GIS die Habitat Präferenzen des Birkwildes im alpinen Lebensraum des Natura 2000 Gebietes „Nieder Tauern“ Steiermark modellieren. Hierfür wurden in einem Untersuchungszeitraum vom 1. Juli bis 30 August 2010 entlang von Transekten mittels erweiterter Punkt-Stopp Methode Daten erhoben. Mit der Information über Präsens/Absenz an verschiedenen Punkten als abhängige Variable und aufgenommenen und errechneten Habitat Parametern als Prädiktorvariablen waren wir in der Lage ein Habitatmodell für diese Art zu berechnen. Um die Rolle von Habitat Heterogenität und räumlicher Auflösung zu berücksichtigen, berechneten wir den *Mean perimeter area ratio index (MPAR)* sowie verschiedene Variablen auf unterschiedlichen räumlichen Maßstäben/Radien. Fünf Prädiktorvariablen zeigten im finalen Model einen signifikanten Einfluss auf die Vorkommenswahrscheinlichkeit von Birkwild im Untersuchungsgebiet: Zwergstrauchdeckung, der *Mean perimeter area ratio index* in einem Radius von 100 m, die Neigung des Geländes, die Reliefenergie/Kammerung sowie der Quadratische Zusammenhang der mittleren Distanz zu Hütten. Unsere Ergebnisse zeigen, dass es heute möglich ist wichtige Habitatparameter aus dem GIS zu generieren, die die Feldarbeit zukünftig unterstützen können. Unsere Ergebnisse zeigten zudem, dass die Heterogenität der Habitatstrukturen ein wichtiges Indiz für das Vorkommen von Birkwild im alpinen Lebensraum ist und auch zukünftig eine große Bedeutung in Habitatmodelierung und Managementmaßnahmen besitzen sollte. Unser Modell kann somit dazu beitragen schutzwürdige Gebiete für Birkwild zu identifizieren und Verbesserungsmaßnahmen im Habitat vorzunehmen.

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Juni-August 2010	**Ziviltechnikkanzlei Dr. Hugo Kofler: Kartierung von Birkwild in den Niederen Tauern Steiermark** Suche nach indirekten und direkten Nachweisen entlang von Transekten
Mai- August 2009	**Aufenthalt in Kanada (British Columbia, Yukon Territories)** mit Besuch diverser Nationalparke
März 2009	**Forschungsanstalt für Waldökologie und Forstwirtschaft (FAWF) Rheinland Pfalz: Mitarbeit an einer Kartierung** Sammeln von Rotwildlosung zur Genotypisierung
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