PERSPEKTIVEN FÜR UMWELT & GESELLSCHAFT umweltbundesamt

HABITAT DISTRIBUTION AND CONNECTIVITY FOR THE BLACK GROUSE (*TETRAO TETRIX*) IN THE ALPS

Workpackage 5: “Corridors and Barriers”

Cemagref and UBA

Samuel DECOUT
Johannes SIGNER

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Contact:

Samuel Decout: samuel.decout@]cemagref.fr
Johannes Signer: j.m.signer@gmail.com

Katrin Sedy: katrin.sedy@umweltbundesamt.at

CONTENT

1 INTRODUCTION

The Alps are a region of high biodiversity in the middle of very densely populated central and western Europe. There are also old management regimes in the Alps that have evolved over several centuries and are slowly being changed. Many areas of the Alps are bound to extensive use by tourism. This naturally bring conflicts with wildlife and reduces the habitat available to wildlife. In this study the potential distribution, connectivity and barriers thereof for the black grouse (*Tetrao tetrix* L.) are modelled. For the species distribution model MaxEnt was used and connectivity was calculated with the Conefor Sensinode 2.2 and GUIDOS.

1.1 Black Grouse characterization

Black grouse occur in the Alps but also on moors and heaths. Lowland populations have disappeared in central Europe and are only found in Northern Europe and Scandinavia. Alpine populations migrate rarely to valleys, whereas in northern flat land population migrations rates of up to 20 km were observed. However, the mean distance was only 4.4 km (Bauer et al., 2005). Marjakangas and Kiviniemi (2005) found in Finland dispersal distances of up to 30 km. The preferred habitat of black grouse is the transition zone of forests, moors and heaths or the sub-alpine treeline in the Alps. The black grouse prefers structured habitat with *Vaccinium, Calluna, Erica* (Bauer et al., 2005). Males are black to dark blue and shiny and females are auburn with white bands (Grummt and Strehlow, 2009).

The diet of black grouse consists of buds, leaves and needles of *Latrix decidua* in spring and berries in autumn. During winter the main food is found on trees (Reimoser et al., 2000).

Until 2000 numbers of black grouse in the Alps have been more or less stable, with significant local fluctuations. However, at margins of its distribution the black grouse experienced decreases since 2000 (Bauer et al., 2005).

While in the lowland habitat loss and fragmentation is the main factor for decreasing black grouse numbers in the Alps habitat loss is only of a problem where treeline shifts due to the abandoned grazing (Bauer et al., 2005, Zbinden and Salvioni, 2003). Also wet and cold climatic condition during breeding seasons can be harmful (Zbinden and Salvioni, 2004) and increased use of habitats by humans (Patthey et al., 2008, Zeitler, 1995).

1.2 Spatial Extend and Resolution

The spatial extend of the study area was delimited by the alpine convention (Ruffini et al., 2004). This encompasses an area of approximately 190.000 km^2 . The resolution for the species distribution model was 30 seconds which roughly equals .

1.3 Selection of Observations

We agreed to make a selection from all observation and include in the first step of the model only recent sightings of females. For Austria we selected females of from 2000 to 2009 and for France females only from 2009 since previous samples may origin from the same locations. We had a dataset of approx. 700 observation. These 700 observations were reduced to 378 at a resolution of 1. We choose a random dataset of 30 % of the initial training dataset as test data. We did 50 replicates with a random seed of the test data.

We choose to use only female's presence location in relation with reproduction habitat selection and suitability for several reasons:

1. Most of the sightings collected with meta data available (in Austria and France) correspond to black grouse observations during the reproduction period (spring to summer – mating on lekking places and then breeding).
2. During summer, hens and cocks haven't the same habitat selection behaviour. Hens are very dependent on habitat structure and quality for breeding and protecting the chicks whereas cocks are less sensitive and should prefer dense shrub cover for moulting.
3. One of the main conservation priorities toward black grouse populations is the monitoring of sustainable reproduction habitats in order to insure local population viability by maintaining good reproduction success.

Data Sources:

Institutions	Obersvations for	n	Reference
Vogelwarte Sempbach	CHE	1040	(Schmied and Posse, 1998)
Nationpark Gesäuse	AUT	124	-
Haus der Natur	AUT,DEU	754	HdN (2010b), HdN (2010a)
Zoobodat	A	22	http://www.zobodat.at
Landesverwaltung Südtirol	ITA	89	-
Nationalpark Berchtesgaden	GER	757	-
-	FRA	15	(Caizergues et al., 2003)

1.4 Number of observations

Presence observations were very heterogeneous with a strong bias towards Switzerland. To avoid a region over fitting of the model (i.e. areas with a very high density of presence observation obtain very high occurrence probabilities and areas where presence observations are missing have low occurrence probabilities), not all observations were used to train the model. Different models were calculated with different number of points to train the model. Initially the model was calculated with 10 points. Constantly 10 points were added until 1000. For each run the points were selected at random. This process was repeated 10 times. For the final model 250 observation were used.

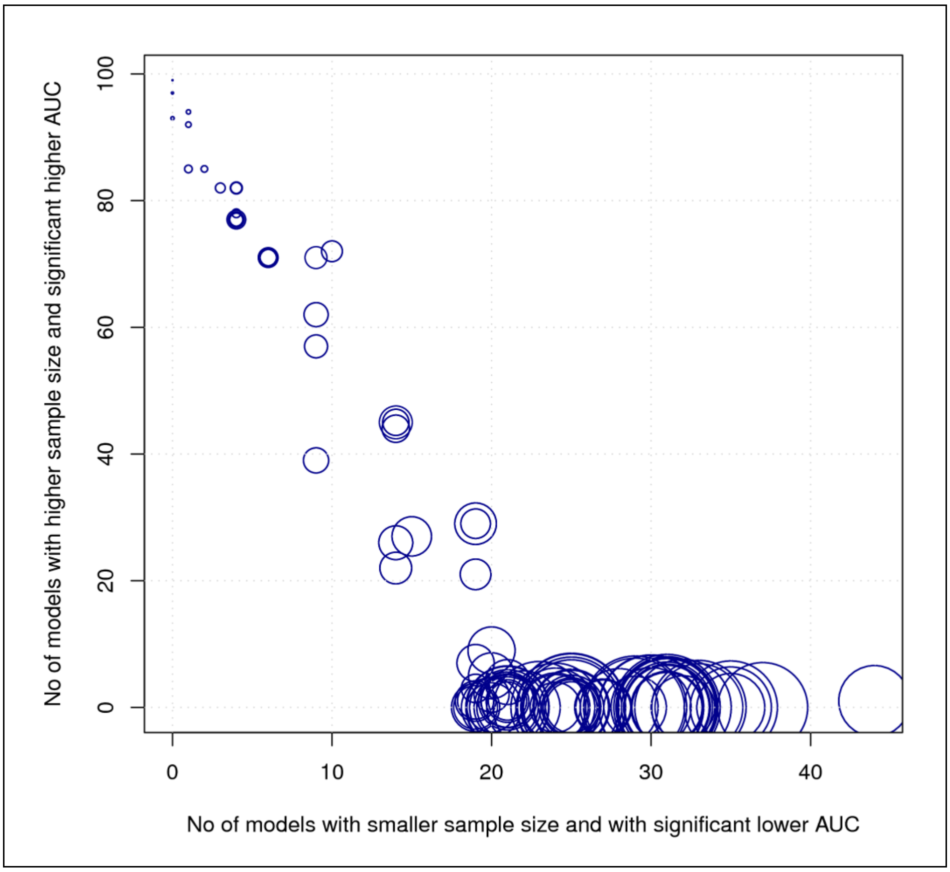

Illustration 1: shows the number of models with a significantly better AUC with lower and higher sample size. On the ordinate the number of models with more training observation and significantly higher AUC values are represented. On the abscissa number of models with less training observations and significantly lower AUC values are represented. The size of the circle represents the number of training observations used for one group (groups are training observation size n=10…1000. After a linear decline, the number of models with significantly better AUC and higher sample size is null, while the number of models with a lower sample size and significantly lower AUC still until a maximum of 40 (=400 training observations). However on the graph the highest density of circles is between 20 and 30 (2000-300 training observations). A sample size of 250 was chosen, as it is with the bent.

1.5 Environmental variables

We agreed to include the following environmental variables to the model:

- **Sub alpine heterogeneous agriculture land use** Density of CLC classes 321 322 323 324
- **Edge** Density of edge derived from a morphological spatial pattern analysis from the JRC forest map.
- **Edge-Jrc-CLC** It is the edge length density between forest (from the jrc forest map) and meadows and pastures from the CLC (classes 231 and 321).
- **Forest** Density of forest from CLC (classes 311 312 313)
- **Shrubs** Density of CLC classes 321 322 323 324
- **Mid-Slope** Mid-slope density, derived from a topographic index.
- **Elevation** Mean elevation per 1.

1.6 Models

The distribution of *T. tetrix* was modelled with maximum entropy distribution implemented in MaxEnt. MaxEnt, a statistical learning method (Phillips and Dudik, 2008, Franklin, 2010), that was given preference among many other methods to model the distribution of black grouse because of its ability to handle presence only data, small sample sizes (Wisz et al., 2008, Baldwin, 2009, Elith et al., 2006) and has successfully been applied to conservation biology in the past (Pearson et al., 2006, Yost et al., 2008).

Landscape connectivity can be modelled with regard to structural and functional connectivity Taylor et al. (2006). Where the former is orientated on landscape elements or a certain land cover type and the latter takes in account the resistance of the habitat matrix towards the migratory ability of an animal species. Within Econnect functional connectivity corridor models are desired.

The choice of the appropriate modelling technique will depend on the required detail of the output and the data available. Graph theoretic approaches can deliver a relatively accurate results, while requiring data of moderate quality (Calabrese and Fagan, 2004).

GUIDOS is an implementation of the morphological image processing algorithm. GUIDOS classifies a binary image (e.g. a forest map or a map of suitable black grouse habitat) in different categories. The different GUIDOS categories are described as follows:

- **Background (grey)** Pixel that are classified as forest or unsuitable for black grouse (*i.e.* predicted MaxEnt occurrence probability is below a threshold).
- **Core (green)** Pixels that are classified as forest or suitable black grouse habitat (*i.e.* predicted MaxEnt occurrence probability is above a threshold) and pixels are surrounded by habitat.
- **Branch (orange)** Branches of 1 pixel width that originate in core area and terminate in background (*i.e.* pixels that are unsuitable in the habitat matrix).
- **Edge (black)** Edges have on one side core area and on the other side background.

- **Islet (brown)** Suitable pixels that are surrounded by background.
- **Bridge (red)** Corridors that connect core areas.
- **Perforation (blue)** Pixels that are edges in forest wholes.
- **Loop (yellow)** One pixel wide corridor that originate in a core area and terminates in the same pixel.

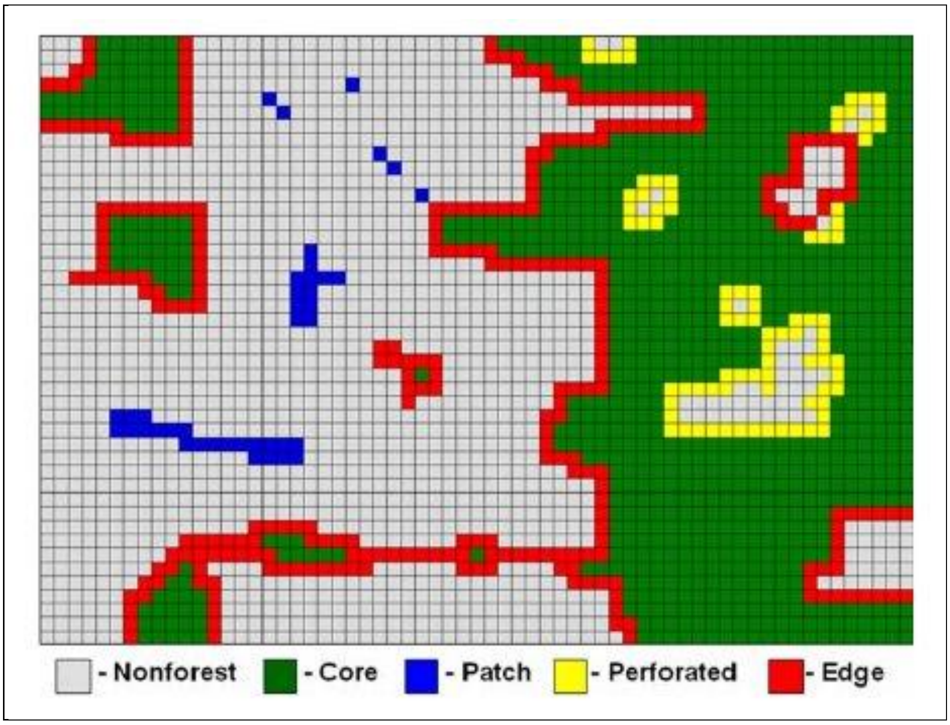

Illustration 2: Example of GUIDOS results by Vogt et al. (2007a) (remark: the colours differ to the ones used later in this report).

Here GUIDOS was used to identify regions which are highly fragmented. Within selected regions and (e.g. pilot region Berchtesgaden) the importance of each pixel for the overall connectivity was calculated. Similar studies have been conducted by Pascual-Hortal and Saura (2008) and Vogt et al. (2007b).

1.7 Model Selection

We choose the model with the lowest test omission rate (min=0.064, mean=0.1443 (+-0.039), max=0.255) out of 50 replicas, since the test AUC (mean=0.91,sd=0.0067) did not differ significantly among models.

1.8 Threshold Selection

The probability threshold computed by MaxEnt for the best model (10 percentile training presence) was 0.30. We agreed on to use the presence absence data set from Switzerland to obtain second validation. The validation with the Swiss data yielded an AUC of 0.78. From there we applied different methods to obtain a threshold. Finally we choose maximum percent correct classified (pcc). Max (ppc) was with a threshold of 0.05. 73 % of true positive (tp) and true negative (tn) where correctly identified. And in the remaining 27 percent false positive (fp) dominated (Also see Figure 3).

We propose three different maps as results.

1. Probability of female occurrence ranging from 0 to 1. This is the most "trust-able" outcome and should be used whenever possible (see Figure 3 in the appendix).
2. Threshold 1: potentially most suitable reproduction habitat. The threshold is based on 10 percentile from MaxEnt. This has been used in previous studies in the literature (see Figure 3 in the appendix).
3. Threshold 2: potential habitat range of black grouse. The threshold of 0.05 was derived from the pcc (see above). This threshold may overestimate the potential habitat of black grouse (false positive rate ≥ 20 %). (see Figure in the appendix).

It would be best to use the continuous probability distribution map and apply a local threshold after discussion with local experts. The thresholds here have been chosen for further work, but may not be the best ones.

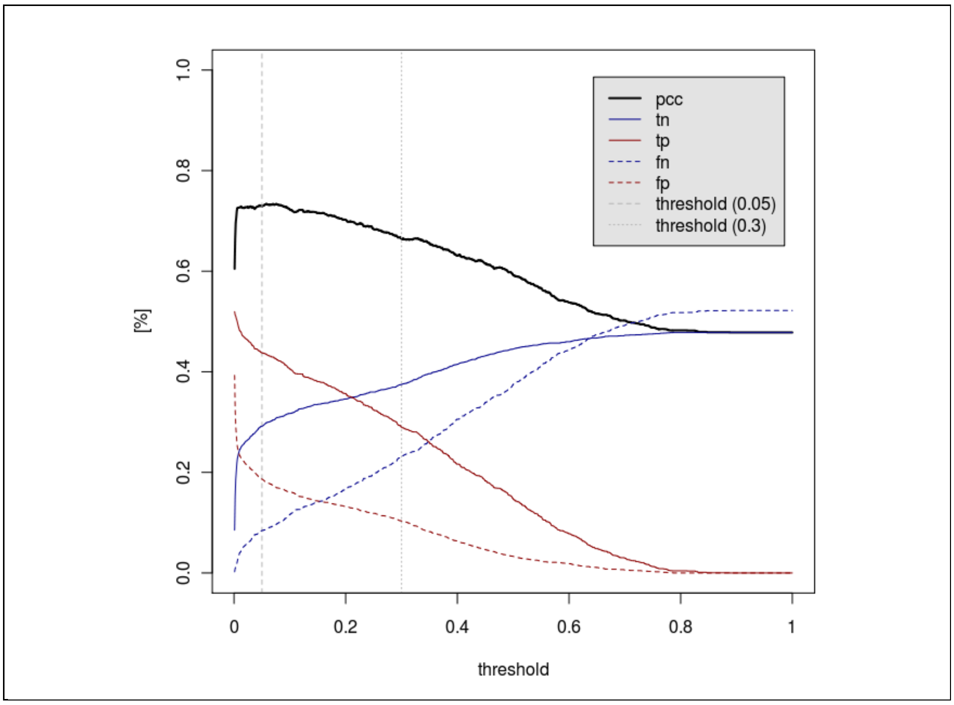

Illustration 3: Overview of the behavior of rates of tp, fn, fp, tn and pcc. The maps in Fig. 5, 6 and 7 are showing the continuous occurrence probability and the application of the thresholds for the whole alps.

1.9 Altitudinal Mask:

We also applied an altitudinal mask to the probabilities map output from MaxEnt in order to limit black grouse distribution predictions to its “common” altitudinal niche (1500 -2300 meters) (general altitudinal tendency observed in literature and with the distribution of presence data used). Also the distribution of black grouse probabilities suggest a habitat of 1500 to 2500 m, see also Figure 4. All the more, according to the French expert Yann Magnani (Observatoire des Galliformes de Montagne), the main natural barriers for black grouse dispersion are mountains tops and ridges whom the elevation is more than 2300m. All the more, black grouse is a good flyer bird and some individuals may be able to cross a valley but this is a particular case and nobody is able to quantify this pattern.

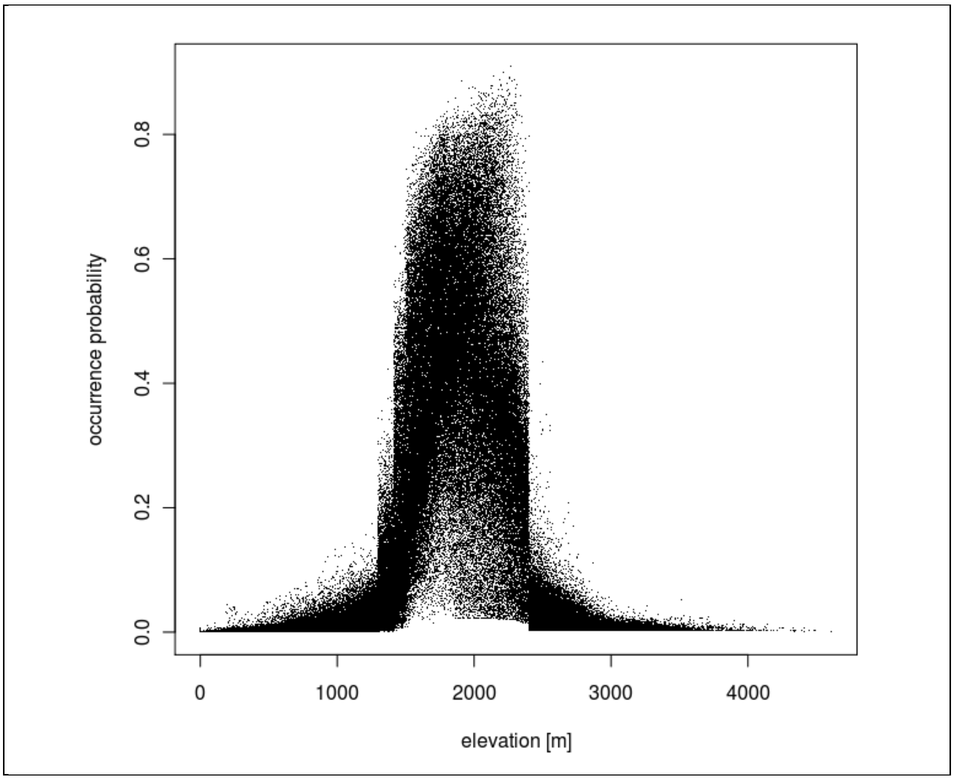

Illustration 4: Distribution of black grouse occurrence probabilities with regard to elevation

1.10 Results Black Grouse

In the following sections results from the black grouse distribution model are presented. In Figure 5, we show the contentious occurrence probability of black grouse for the whole Alps. The values vary between 0 (grid cells were black grouse is not expected to occurrence) to 1.

In Figures 6 and 7 the potential black grouse habitat is shown with application of a specific threshold value.

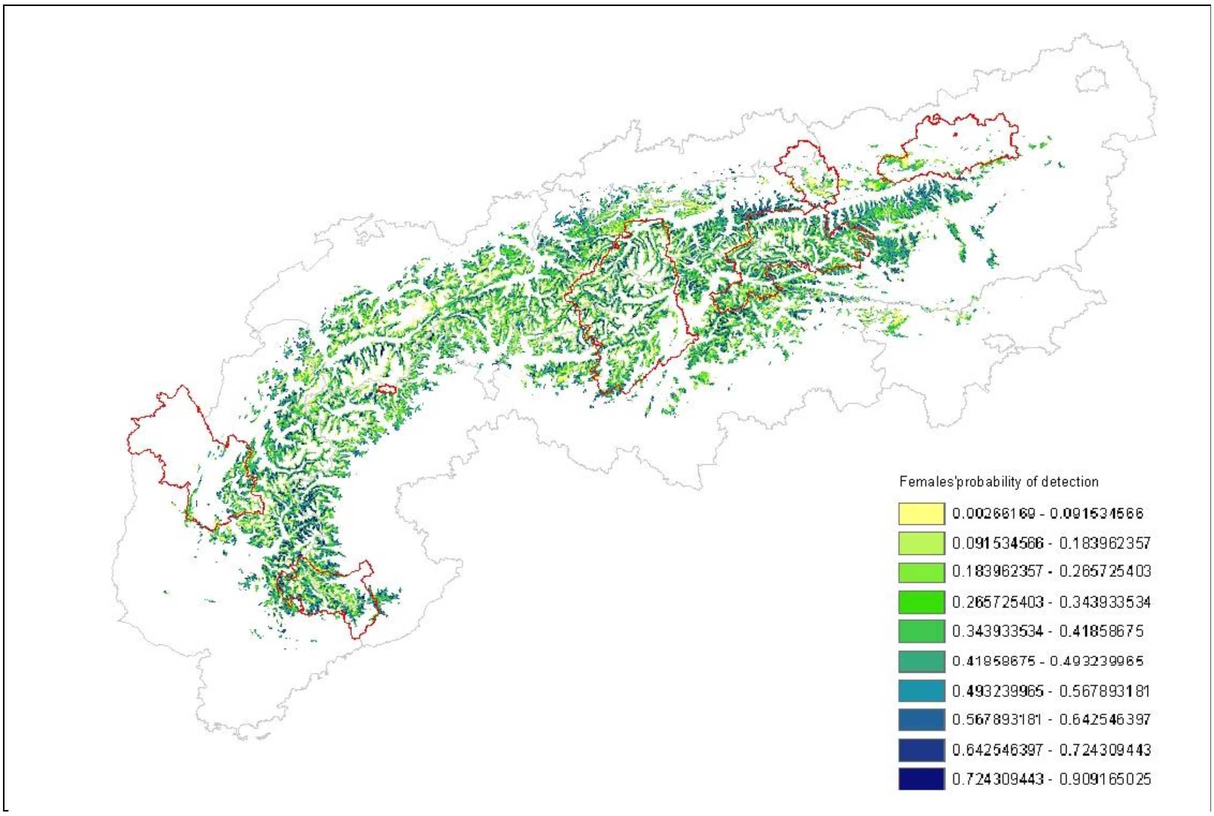

Illustration 5: Continuous occurrence probability of black grouse for the whole Alps at a resolution of 1 km

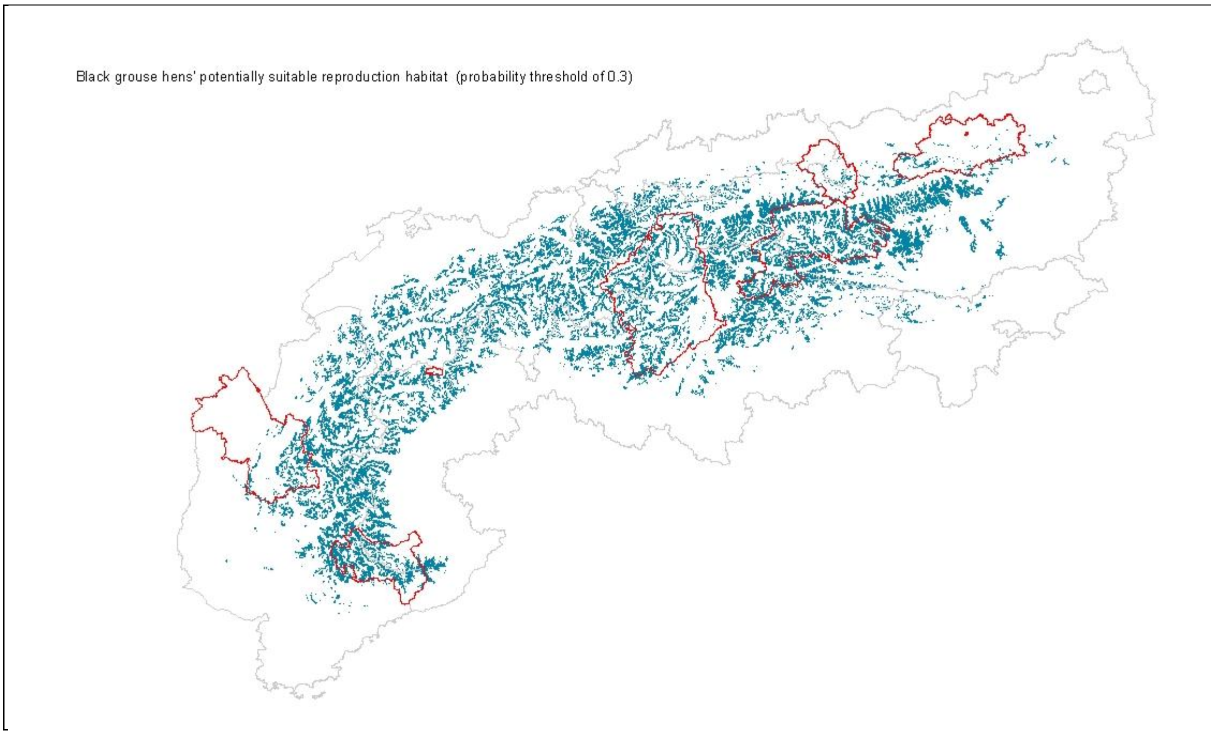

Illustration 6: Presence of black grouse for the whole Alps with a threshold of 0.3 at a resolution of 1 km

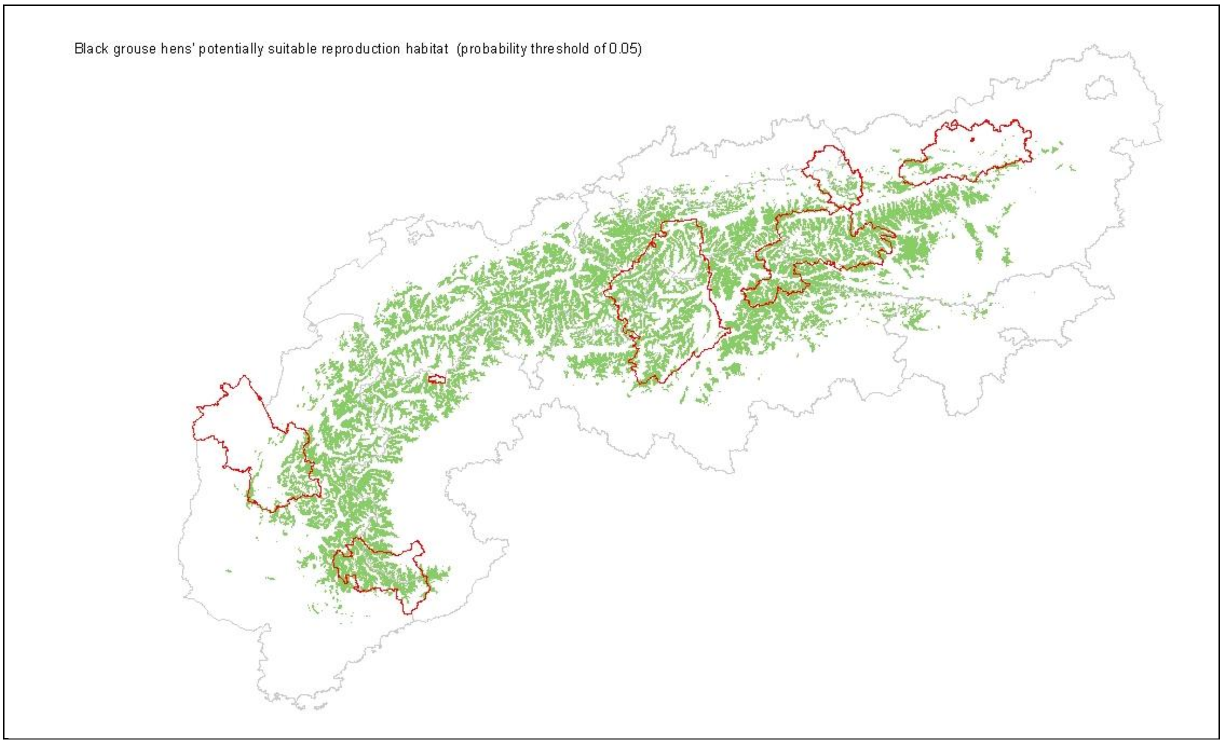

Illustration 7: Presence of black grouse for the whole Alps with a threshold of 0.05 at a resolution of 1km

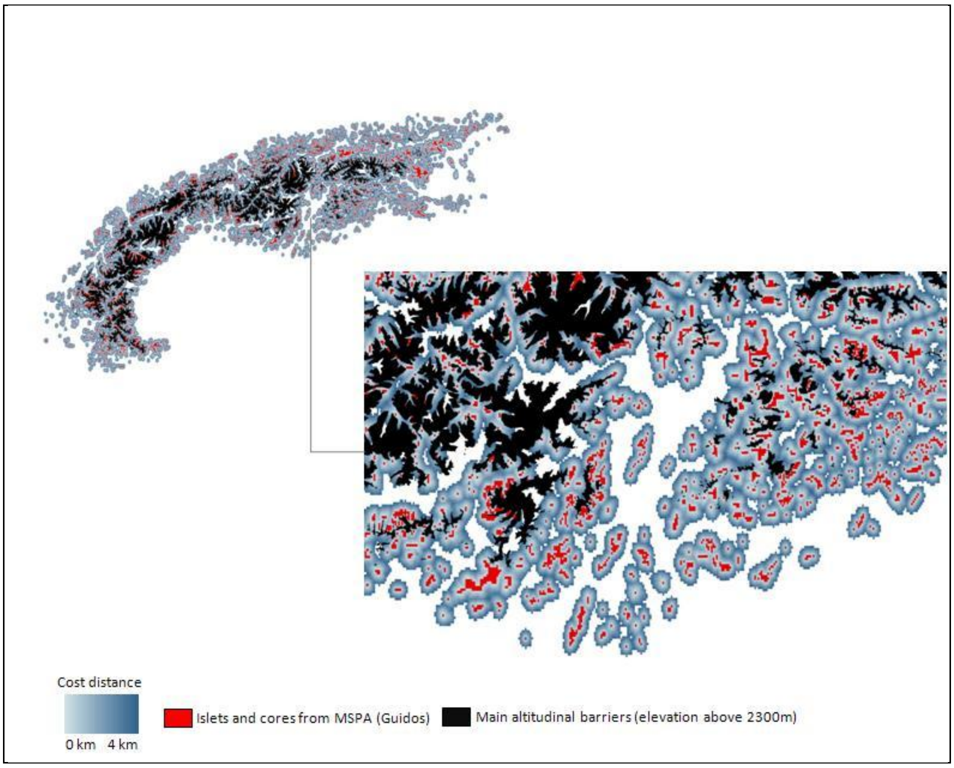

Illustration 8: Cost distance map of black grouse for Alps with a resolution of 1 km.

We applied the morphological spatial pattern analysis implemented in GUIDOS to potential black grouse habitat. The potential black grouse occurrence habitat was obtained by applying a threshold of 0.3 to the continuous occurrence probabilities. We then only used islets to see which islets are connected with each other using least cost surface. Results are shown in Figure 8.

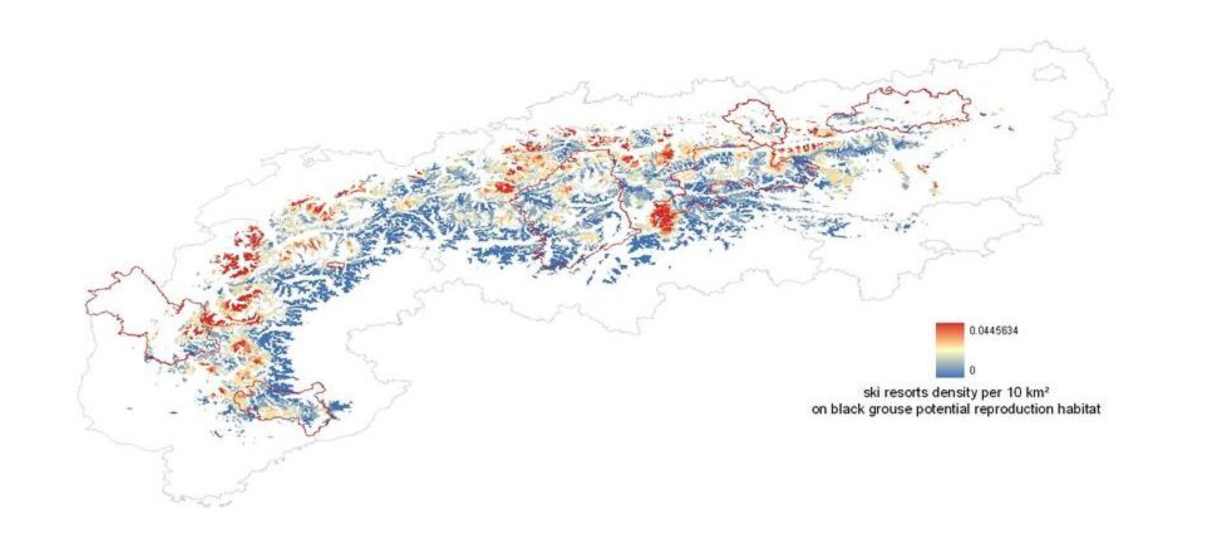

Illustration 9: Density of ski resorts in black grouse habitat for whole Alps with a resolution of 1 km

One of the main artificial disturbances for black grouse are ski lifts. We calculated the density of ski areas within black grouse habitat. Results are shown in Figure 9.

1.11 Validation

The distribution of black grouse has previously been modeled for Italy. This was done within the project Italian Ecological Networks (Boitani et al., 2002). Black grouse habitat predicted by the IEN had a significantly higher (p<0.001) MaxEnt occurrence probability than areas that were modeled as unsuitable for black grouse. A summary of the differences is shown in Figure 10.

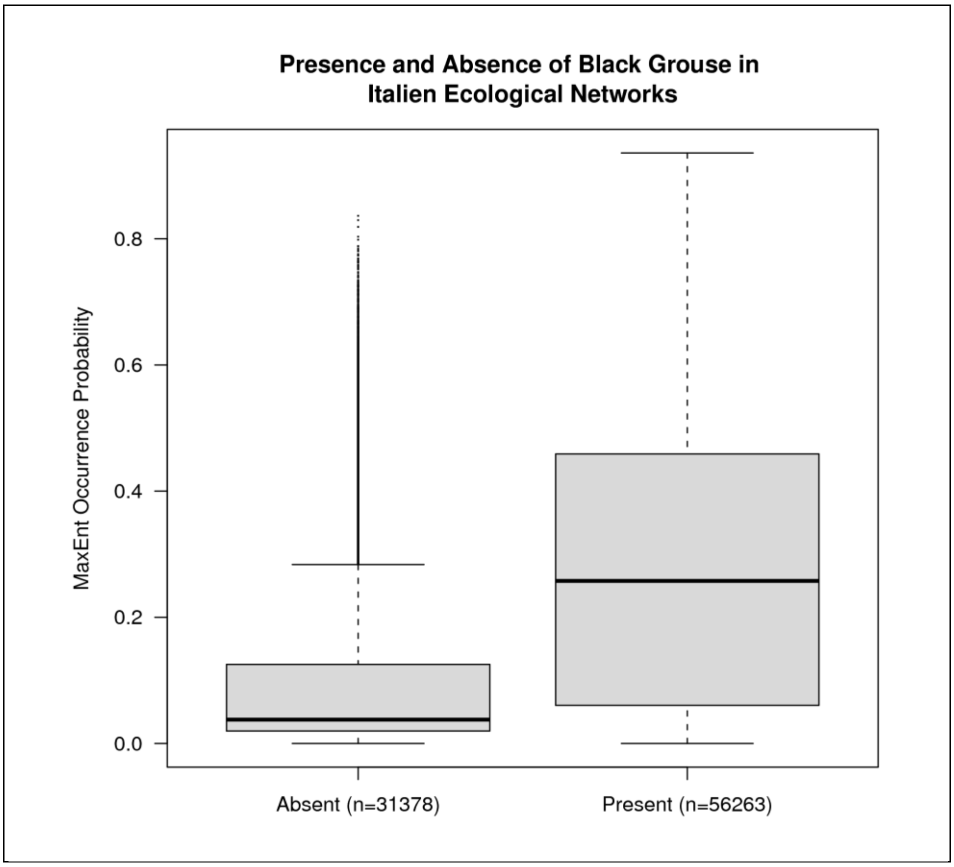

Illustration 10: Comparison of pixels of the MaxEnt model that are present or absent in the model of IEN (Absent n=31378,mean=0.11 +/-0.16; Present n=56263,mean=0.27 +/- 21; t-test p<0.001,t=127.983,df=80296.79)

1.12 GUIDOS and Conefore Sensinode, Berchtesgaden

In order to test connectivity indices with CONEFOR a test was run for the pilot region Berchtesgaden (see Figure 10). The integral index of connectivity (IIC) was used. A detailed description is provided by Saura et. al 2009.

In Figure 11 results from Conefor Sensinode are presented. Interpretation should be cautious because black grouse is a sedentary bird

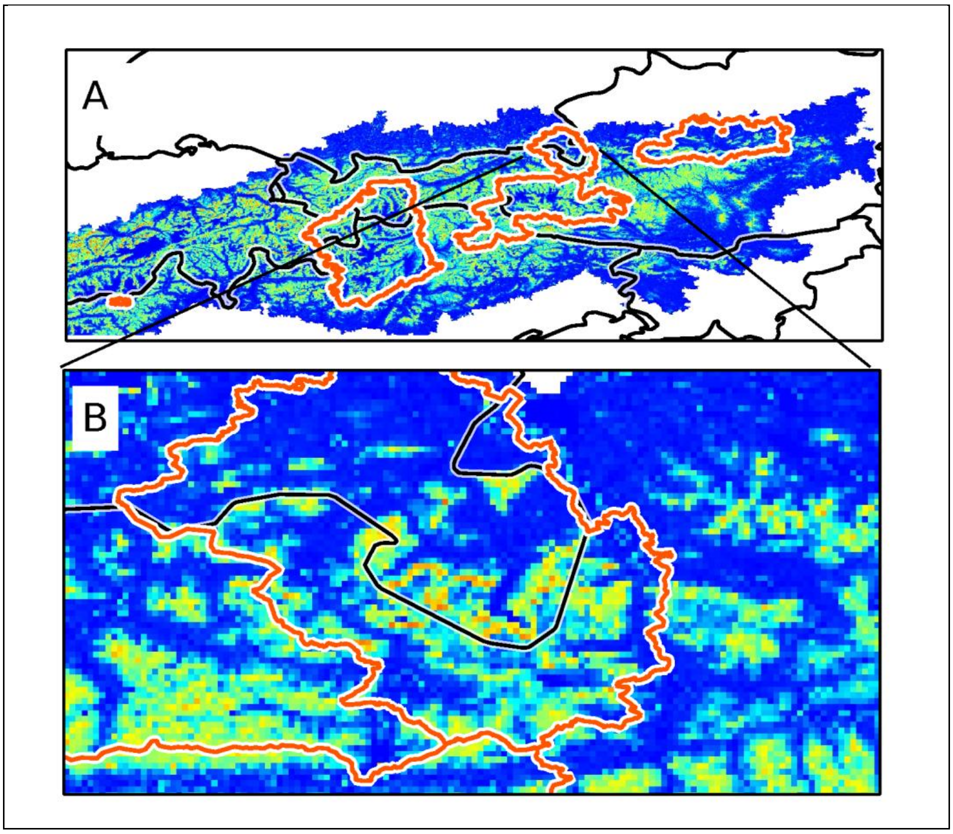

Illustration 11: Continuous occurrence probability from MaxEnt for the Pilot Region Berchtesgarden. Blue stands for a no occurrence probability and red for very high occurrence probability. The resolution of the map is 30 seconds (approximately 1 km).

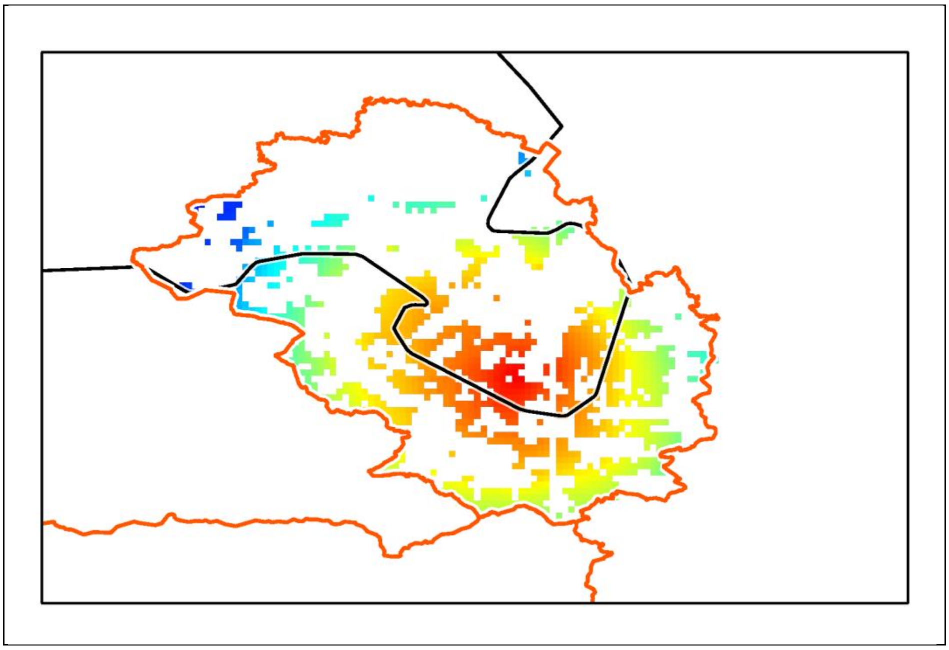

Illustration 12: Pixels with brighter colours (i.e. red) are of higher importance with regard to overall connectivity in the Berchtesgaden pilot regions. The resolution of the map is 30 seconds (approximately 1 km).

1.13 Conclusions for black grouse

- Main obstacles for large distance dispersal of black grouse are natural barriers (i.e. mountain ranges above 2500 m). The dispersal pattern of black grouse, given by its biology, is naturally very local and within a radius of 5 km. In France, according to expert knowledge, 80 % of juvenile hens disperse in a radius of 4 km from the potential breeding sites. Occasional long distance dispersal patterns may exist. It is impossible to quantify them without radio tracking of a dispersing individual or genetics studies. Human dominated landscape in valleys are no absolute barriers and are potentially permeable by flying over them.
- Nonetheless anthropogenic pressure acts on black grouse populations on a local scale and is impossible to consider at an alpine wide scale. Black grouse relies on several local habitat types during its annual cycle. Availability and **reachability** of these local habitat types are crucial – a ski resort, for example, can act as a barrier and also as a stress factor. Black grouse requires for breeding an area of approximately 20 ha of continuous habitat during summer according to experts. Fragmentation of these local breeding habitats by local disturbances (e.g. leisure activities and infrastructure) are seen as the main problem. For wintering habitat the frequency of perturbation is a bigger problem, this fact was also confirmed by experts. Frequent disturbance induces stress on the black grouse and imbalances its energy budget.
- We used least cost distance surface with a maximum distance of 4 km to test if all breeding patches can be reached. As friction map we used the inverse occurrence probability of MaxEnt. As a result we observed that black grouse may disperse among most patches in the core habitat of the central alps

(east-west range). There are few isolated patches, corresponding to peripheral alpine ranges where some populations already disappeared. This isolation is due to distance and only genetic studies can provide further insight. Additionally we run the analysis considering the islands and core habitat from the morphological spatial pattern analysis. We observed the same patterns of isolation by distance and we think that for the moment it is impossible to draw conclusion on connectivity and barriers on an alpine scale (see also Figure 8).

- We computed the density of ski resorts per 10 km² that falls in potential black grouse breeding habitat. This gives an idea of pressure of human activities on black grouse territories, but it is difficult to quantify the degree of perturbation (see also Fig. 9).
- With regard to Conefor Sensinode 2.2 it is possible to compute the importance of habitat patches towards connectivity.
- However, the ecological relevance of the results needs to be discussed also together with the expected changes in habitat due to climate change. Black grouse is a sedentary bird, therefore changes in its habitat are of high importance. Climate change will/might affect the ecosystems that shelter black grouse. Especially the species assemblage of plants that grouse is dependent on might change at certain altitudes and force this species to migrate to other, most probable higher habitats. To enable black grouse to migrate successfully it is crucial to reduce stressful and energy consuming anthropogenic influences that weakens the energy budget additionally. Such large scale disturbances like ski resorts and slopes, especially on higher altitudes, can interfere with the migratory behavior and have pronounced negative effects on settling of the birds. Therefore it is necessary to investigate the habitats, disturbances and potential barriers on a local scale. This analysis on the alpine scale will be a help for the identification of “hot spots” but the “spot check” can only be realized at the local level. This will also be necessary for the assessment of the effects of climate change.

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