From the World of Theses

The section provides a forum for the students of geography to present the content of their theses in brief. The writings discuss for example the research frames in general or research results, possible themes for further studies and the practices of research processes in more detailed ways.

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Spatial modeling in biogeography: finding suitable habitats for endangered raptors

Introduction

Habitat loss and fragmentation constitute the main threats to biodiversity and species survival (Hanski 2007). Effective conservation of species requires detailed data about the location of suitable habitats and the environmental factors affecting them (Guisan & Thuiller 2005, Hanski 2007). With the help of spatial modeling it is possible to meet these needs in order to clarify the effects of different environmental factors and landscape structure on species and make predictions concerning wider areas (Turner & Gardner 1990, Hirzel & Le Lay 2008). Habitat models are often considered as an ecological niche application, as they relate the occurrence or abundance of species to environmental variables (Hirzel & Le Lay 2008). Consequently, they can be used to produce predictions of suitable habitats (Guisan & Zimmermann 2000, Araújo & Guisan 2006). Identifying factors affecting suitable breeding habitats is of primary concern for effective planning and targeting protection. Recent studies reveal that, at broad regional level, climate is the most important factor explaining species distribution. At the local level, topography, land use and land cover related factors as well as habitat availability determine distribution (e.g. Pearson et al. 2004, Luoto et al. 2007, Luoto & Heikkinen 2008). Adding fine scale variables, such as land cover to climatic models improve the accuracy of habitat models (Pearson et al. 2004, Seoane et al. 2004). However, hierarchical modeling has not yet been used very often to identify suitable habitats (cf. MacKey & Lindenmayer 2001), although it may reveal how different factors affect the model performance more precisely (Pearson et al. 2004). Endangered raptors are well suited to habitat modeling, because they are often closely monitored and reported, require large areas to maintain populations and are quite sensitive to changes in land use (Austin et al. 1996). According to previous studies, important factors explaining bird distribution and habitat besides climate are land use (Luoto et al. 2007), vegetation

(Seoane et al 2004), topography (Bustamante & Seoane 2004) and landscape structure (Virkkala et al. 2004). The Golden Eagle (*Aquila chrysaetos*) and the Peregrine Falcon (*Falco peregrinus*) are long-lived raptors that require large territories. Due to its low population size, the Golden Eagle is classified as vulnerable and the Peregrine Falcon as endangered in Finland according to IUCN classification (Rassi et al. 2001). Although species status in the near future is estimated to be successful with growing populations, the level of protection is still unfavorable due to low population sizes and disconnected distributional areas (Ollila & Koskimies 2008). Several previous studies have shown, that with the help of modeling, it is possible to find suitable habitats for the Golden Eagle (López-López et al. 2007, Tapia et al. 2007) and the Peregrine Falcon (eg. Wightman & Fuller 2006). For these raptors, suitable habitat models extending to the whole area of Finland have as yet not been created.

Material and methods

The study area consisted of Finland at the resolution of 2 x 2 km (n = 83 468). Resolution is assumed to represent core areas in breeding habitats of the Golden Eagle and the Peregrine Falcon, and therefore enables the modeling of fundamental environmental factors affecting breeding habitats (McGrady et al. 2002). Nest site information of the study species' was derived from the unique long-term monitoring scheme conducted by the Finnish Ministry of the Environment.

The study was performed using binary nest site information as response variables and 14 environmental variables at a 4 km2 resolution. Habitat models were built in hierarchical manner using five sets of predictive environmental variables: C) climate only, CT) climate and topography, CTL) climate, topography and land cover, CTLH) climate, topography, land cover and human impact and CTLHK) climate, topography, land cover, human impact and habitat connectivity. Variables were selected based on previous studies on raptors (e.g. Bustamante & Seoane 2004, Sergio et al. 2004, Brambilla et al. 2006). In order to identify the main environmental correlates for nest occurrences and locate the most suitable breeding sites for the Golden Eagle and the Peregrine Falcon generalized additive models (GAMs) were used. Environmental factors selected for the models and the hierarchical partitioning of the data is examined to draw conclusions about key features of raptor breeding habitats.

Results

The Golden Eagle and the Peregrine Falcon nest distributions were successfully predicted with generalized additive modeling (Figure 1). Golden Eagle breeding habitats could be explained and predicted the best with all the parameters. In the case of the Peregrine Falcon, the model including climate, topography and land cover reflected the best predictions. For the most part, models became more accurate while adding parameters hierarchically. Results are in great concordance with many previous studies (Bustamante & Seoane 2004, Pearson et al. 2004, Seoane et al. 2004, Venier et al. 2004, Luoto et al. 2007), and support the idea, that

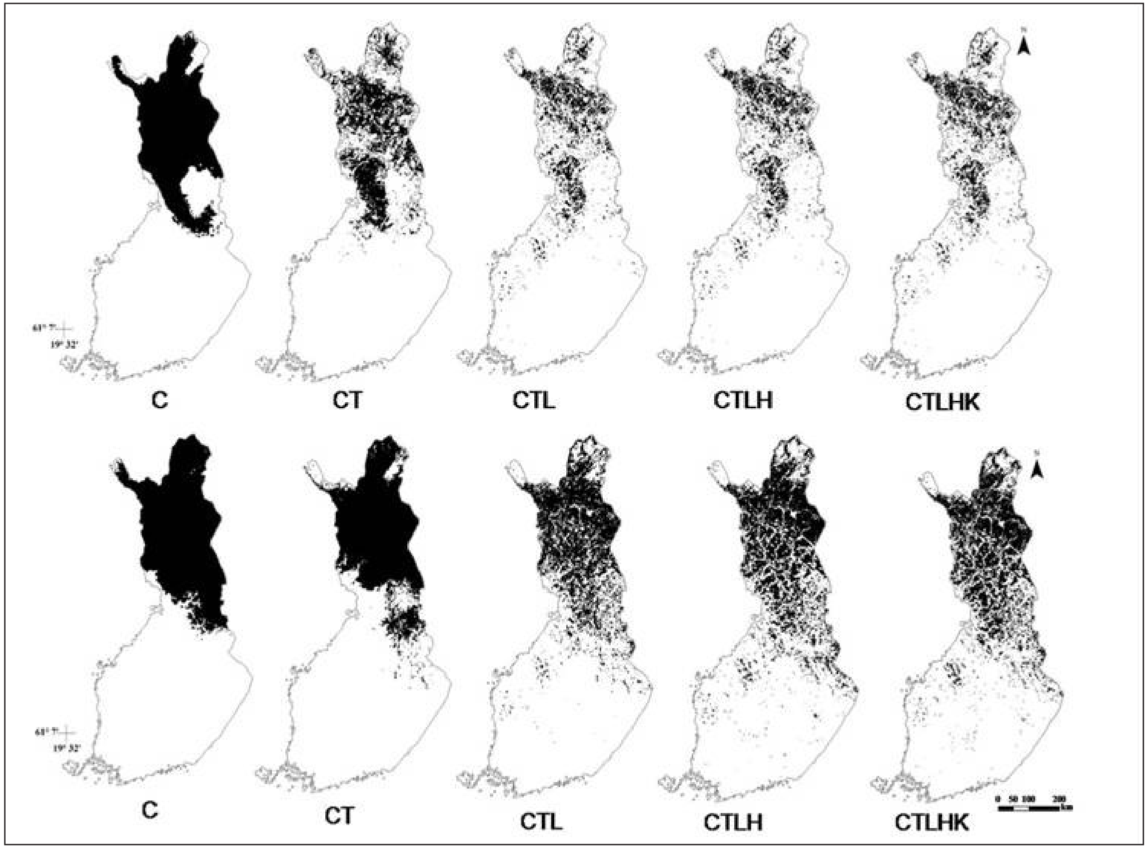

Figure 1. Predicted breeding habitats of the Golden Eagle (lower maps) and the Peregrine Falcon (upper maps) in Finland based on five GAM-models. Black areas represent suitable breeding habitats for the species. Abbreviations below the maps are C= climate, T = topography, L = landcover, H = human impact and K = connectivity of habitats. Models are built in hierarchical manner; the first models are based on climatic factors, and the last models (CTLHK) are based on hybrid models including all variables.

hierarchical modeling reveals the complexity of natural systems and helps to clarify the effects of several environmental factors on species distributions simultaneously (Pearson et al. 2004). The Golden Eagle habitats seem to be topographically heterogeneous and disturbance-free, extending across central and northern Finland. The results support previous studies about the Golden Eagle breeding commonly in habitats, which have some steady nest trees, but also open foraging lands (Sergio et al. 2006). Landscape diversity should be taken into account in all future efforts to preserve the Golden Eagle. In the case of the Peregrine Falcon, open peatlands and their connectivity had the greatest contribution on nest site distribution. In southern Finland, management of deteriorated open peatlands is a prerequisite for the expansion of the species. However, there may be several environmental factors and their various interactions behind the spatial structure of bird habitat, in which case one should draw conclusions from single predictors especially cautiously (Heikkinen et al. 2004). Modeling indicates extreme fragmentation of suitable habitats for both species. Although mobile species are able to move easily between habitat patches, raptors that require large territories cannot survive if habitats become too small in size. Results show that habitat models can be efficient tools when predicting habitat loss and fragmentation effects. Species distributions will probably change in the future, so estimates about suitable habitats should be treated with caution, and temporal and spatial extrapolation of models should thus be avoided. Biotic interactions, such as competitive species, might have a strong impact on the breeding environment. The Golden Eagle's and the Peregrine Falcon's responses to habitat loss are not unambiguous, and new studies concerning climate and land cover dynamics are needed. Ollila and Koskimies (2008) have noted, that climate change effects on the Golden Eagle and the Peregrine Falcon are difficult to assess. However, by modeling the distribution of these species with several environmental variables the possible effects could be estimated more accurately. Climate change may turn out to be critical for distribution of raptors, because human activity restricts mobility of both species in southern Finland, and population density and nest availability are limiting factors in the North. The peat industry also poses a challenge to the survival of the Peregrine Falcon population. Consequently, these topics need some further investigation, for which the hierarchical approach can provide some valuable information. This master`s thesis demonstrates, that when certain restrictions are taken into account, habitat models can be used to locate suitable habitats for raptors. Identification and demonstration of suitable habitats cartographically enables protection and inventories to be focused on areas, where the probability of occurrence is high (García-Ripollés et al. 2005). Furthermore, habitat models of indicator species, such as the Golden Eagle and the Peregrine Falcon, can also provide valuable information for the purposes of larger ecosystem protection. The reality is that habitat models are not merely objects of study, but are also important tools to make further hypotheses and to deepen the understanding of the distribution of species (Sergio et al. 2004).

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