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Modelling habitat suitability for alpine rock ptarmigan (*Lagopus muta helvetica*) combining object-based classification of IKONOS imagery and Habitat Suitability Index modelling

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ABSTRACT

The maintenance and restoration of high-quality habitats of wildlife species in alpine ecosystems are key issues in conservation biology. The rock ptarmigan (*Lagopus muta helvetica*), which prefers open habitats above the treeline, is listed in Annex II of the EU Bird Directive. Large areas identified as potentially important for conservation and restricted financial resources for the implementation of conservation activities necessitate the development of tools supporting habitat monitoring and management. We developed a knowledge-based Habitat Suitability Index (HSI) model for rock ptarmigan and combined it with results of an object-based image analysis of very high resolution (VHR) satellite images (IKONOS) to create a rock ptarmigan habitat suitability map in the eastern Alps of Austria. The mechanistic habitat model contained 9 habitat variables, decisive for summer habitat use of rock ptarmigan (i.e., *slope*, *patchiness*, and land cover classes for: *rocks*, *rocks intermixed with vegetation*, *scree*, *dwarf shrubs*, *dwarf pine*, *alpine/subnival grassland*, and *forest*). We used Definiens Professional 5.0© software for the object-based image analyses, applying multi-resolution segmentation methods. We generated a classification hierarchy comprising the same variables used in the HSI model, each augmented by areas “in shadow”, and took into account clouds, water bodies and human infrastructures. We assessed classification accuracies, applying an Error Matrix based on TTA Mask. We reached an overall classification accuracy of 0.75 and a kappa statistic value of 0.70, the latter indicating good to very good agreement. The classification results indicated that the object-oriented image classification approach using VHR data was appropriately used to create an adequate thematic map for further habitat modelling. We calculated the habitat suitability maps using MapModels. Model output was validated with ptarmigan presence–absence data, using signs (droppings) as indicators of presence. We compared presence–absence data and results of habitat suitability classification employing contingency tables and non-parametric correlations. Frequencies of sample plots with rock ptarmigan signs significantly differed between the habitat suitability classes and significantly correlated with the HSI level. Combining the mechanistic HSI model with an object-base image analysis of VHR satellite images was an effective tool for the spatially explicit assessment of habitat suitability and could be useful in regional monitoring, planning and management activities for ptarmigan.

1. Introduction

In recent decades the focus of nature conservation and wildlife management has increasingly shifted from isolated, local projects to international large-scaled programs. The EU Birds Directive (Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds) and the FFH or Habitats Directive (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora) are the bases for the Natura 2000 network of protected areas. About 16% of Austria has been designated within Natura 2000 sites, encompassing some 13,417 km^2. Within these areas the maintenance of a favourable conservation status of species and habitats is a main target, which requires both an evaluation of the current status of habitats and monitoring of future changes on a large scale.

Grouse species listed in Annex II of the EU Bird Directive are indicators of ecosystem status and integrity (Storch, 2007). The alpine tetraonid rock ptarmigan (*Lagopus muta helvetica*), which prefers

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open subalpine and alpine habitats above the treeline (Glutz von Blotzheim et al., 1973), is an indicator species of habitat well-being within this vulnerable ecotone. Habitat loss, habitat fragmentation, increasing levels of human disturbance and climate change pose serious threats to grouse populations in Europe (Grabherr et al., 1994; Grabherr, 1995; Moen et al., 2004; Patthey et al., 2008; Storch, 2007; Watson and Moss, 2004). In the Swiss Alps, climate change is considered to be a potential cause of population decreases of rock ptarmigan over the last decade, and rising temperatures may result in distributional shifts of rock ptarmigan and consequently a decrease of habitat extent by up to two-thirds is predicted by 2070 (Revermann et al., 2012). Consequently, the maintenance or restoration of high-quality habitats in alpine ecosystems is a key issue in ptarmigan conservation. In order to evaluate changes in habitat quality and availability for rock ptarmigan, an assessment of the current status is required.

Faced with large areas of land that are of conservation concern and decreasing availability of the financial and human resources needed to implement conservation actions there is an obvious and urgent need for technical tools to support monitoring and management activities. Given the need for robust environmental monitoring to support conservation and land use planning, tools that allow useful information to be extracted from remote sensing data are urgently needed (Blaschke, 2010). Mapping wildlife habitats in mountainous terrain, and the lack of readily applicable automated methodologies mean that data extraction can be challenging (Nichol and Wong, 2008). Traditional methods for mapping and monitoring upland vegetation and biodiversity generally involve field surveys and/or the interpretation of aerial photographs, but both approaches are expensive and time consuming (Barrett and Curtis, 1999).

A powerful suite of tools and data exists within programs that sense global environmental conditions remotely, the value of which is enhanced by the spatial and temporal consistency of satellite data and its cost effectiveness. Moreover, such systems are the only practical ways to obtain data from locations, like alpine areas, that are difficult to access due to steep topography, snow cover, and danger of avalanches (Kobler et al., 2006). For decades satellite images have been used to classify land cover at large scales, and the spatial resolution of sensors suitable for earth resource studies has improved significantly during that time. Attempts to improve accuracy and reduce costs using satellite images have been limited by insufficient spatial resolution of medium-resolution sensors (Nichol and Wong, 2008). However, very high resolution (VHR) satellite images, such as IKONOS or Quickbird, have become available recently, and these offer improved conditions for classification of land cover.

In general, the classification of images from medium-resolution sensors was based on per-pixel approaches, where all pixels are automatically categorized into land cover classes or themes (Lillesand and Kiefer, 1994), but these are inappropriate for VHR images (Nichol and Wong, 2008). In contrast object-based segmentation methods yield more reliable classification results for VHR images and this approach has already been used in a range of recent habitat mapping projects (e.g. Bock et al., 2005; Kobler et al., 2006; Mallinis et al., 2008; van Lier et al., 2009; Weiers et al., 2004). One of the main advantages of object-based image analysis (OBIA) is the ability to fuse multi-source data and the classified image objects are a useful link upon which remote sensing and GIS integration can be built (Baatz and Schäpe, 2000).

Once a classification of land cover types of interest is available, species-specific habitat models are required for further modelling procedures. The ability to model spatial habitat suitability and distribution of species is of considerable importance in conservation biology and land use planning (Luoto et al., 2002). The mechanistic Habitat Suitability Index (HSI) modelling approach is a rapid and transparent habitat assessment tool, frequently applied in natural resource management (Storch, 2002). HSI models summarize the conceptual understanding of wildlife–habitat relationships of target species, based on literature reviews, expert opinion, or research studies (Morrison et al., 1992). They are planning tools to evaluate different conservation strategies and forest management scenarios in terms of habitat quality (O'Connor, 1986). Being introduced as a decision support tool in nature protection (U.S. Fish and Wildlife Service, 1981), HSI models have also been applied in the cases of individual target species (e.g., Angelstam et al., 2004; Larson et al., 2004; Storch, 2002). In contrast to advanced statistical models this expert-based approach does not rely on substantial presence–absence data. Moreover, HSI models are more general and realistic than statistical methods like GLM focussing on local precision (Guisan and Zimmermann, 2000).

Data about species' habitat requirements and land cover data can be combined using spatially explicit, i.e. raster-based, computer models, which result in habitat suitability maps that correspond to the probability of occurrence (Scott et al., 2002; Store and Jokimäki, 2003; Verner et al., 1986). Recently, habitat assessment and modelling for conservation purposes have been applied to forest-dwelling grouse species (e.g. Braunisch and Suchant, 2008; Braunisch et al., 2011; Graf et al., 2009; Manton et al., 2005), but not to alpine rock ptarmigan. Thus, we newly developed a general habitat suitability model for rock ptarmigan that might serve as a decision support tool in regional monitoring and planning. In this new approach we combined a novel conceptual HSI model with spatially-explicit land cover data derived from VHR IKONOS satellite images. To accommodate future variation in the environment due to changes in climate and land use, we developed a classification scheme that is transferable to satellite images in years to come. The small-scale approach presented in this paper should allow for regional habitat monitoring, considering the requirements of avian species according to the EU Birds Directive. Both the simplicity of this modelling approach and its applicability in case of limited data on species' distribution allows for regional-scale applications that are appropriate for the management of wildlife populations.

2. Study area

The study area is located in the Radstädter Tauern (47° 9′ N, 13° 23′ E) in the eastern part of the Austrian Alps (province of Salzburg). The modelled area comprises 100 km^2 with a north–south extent of 14.5 km and an east–west extent of 11.7 km. Elevation ranges from 985 to 2659 m above sea level (a.s.l.) and terrain slopes mainly range from level terrain to 65°. Some scattered steep slopes do occur but could not be deduced from the Digital Elevation Model (DEM). The bedrock is mainly composed of schist and limestone. Mean monthly temperature varies around 15.6 °C in July and −4.7 °C in January; mean annual precipitation is around 1135 mm (meteorological station in Radstadt at 858 m a.s.l.) (Central Institute for Meteorology and Geodynamics, Austria, 2000). The study area is dominated by Larch *Larix decidua*, Swiss pine *Pinus cembra* and Norway spruce *Picea abies*, with scattered patches of Dwarf pine *Pinus mugo*. The understorey is rich in dwarf shrubs including *Vaccinium myrtillus*, *V. vitis-idea*, *V. uliginosum*, *Rhododendron ferrugineum*, *R. hirsutum*, *Rhododthamnus chamaecistus*, *Juniperus communis nana* and *Empetrum hermaphroditum*. The alpine grassland above the treeline (around 1800 m a.s.l.) is dominated by dwarf shrubs including *V. vitis-idea*, *V. uliginosum*, *Salix reticulata* and *Helianthemum* sp. and grasses, intermixed with rocky areas.

3. Methods

The habitat suitability approach used in this study combined knowledge-based data on habitat requirements of rock ptarmigan