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

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1. Introduction

The maintenance and restoration of high-quality habitats for wildlife species in alpine ecosystems are key issues in conservation biology. 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*), preferring open subalpine and alpine habitats above the treeline, is an indicator species within this vulnerable ecotone.

Traditional methods for mapping and monitoring upland vegetation and biodiversity generally comprise field surveys or interpretations of aerial photographs, but both approaches are expensive and time consuming (Barrett and Curtis 1999). Addressing large areas of conservation concern and decreasing availability of the financial resources urgent need for technical tools supporting monitoring and management activities becomes obvious. 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 high cost effectiveness. Very high resolution (VHR) satellite images like IKONOS or Quickbird have become available recently, offering improved conditions for classification of land cover. Contrary to per-pixel approaches, 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. Kobler et al. 2006). Once a classification of land cover types of interest is available, species-specific habitat models are required for further modelling procedures.

We newly developed a general habitat suitability model for rock ptarmigan that might serve as a decision support tool in regional monitoring and planning (Zohmann et al. 2013). 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 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. Methods

The habitat suitability approach combined knowledge-based data on habitat requirements of rock ptarmigan with spatially explicit land cover data derived from satellite imagery to model the habitat suitability for the target species. The approach comprised the following steps (Figure 1): 1. Knowledge-based habitat modelling, 2. Object-based image analysis of IKONOS imagery, 3. Combining steps (1) and (2) for final habitat suitability model, 4. Model validation.

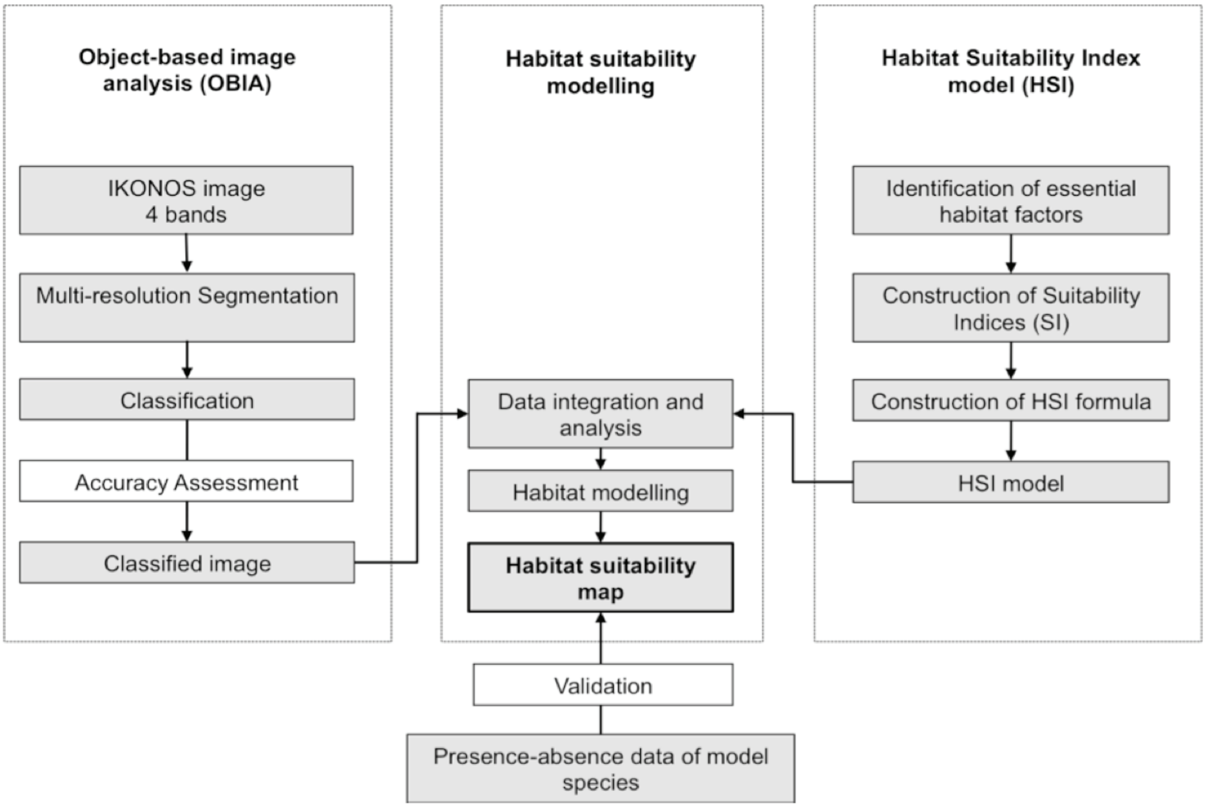

Figure 1. Workflow of the habitat modelling approach.

We applied the Habitat Suitability Index (HSI) approach (U.S. Fish and Wildlife Service 1980) to calculate summer habitat suitability for rock ptarmigan in terms of terrain and vegetation characteristics, representing food supply, cover and demands for rearing of offspring.

We used Definiens Professional 5.0© software for object-based image analyses, applying multi-resolution segmentation methods (Baatz and Schäpe 2000). This bottom-up, region-merging procedure using singlepixel segments (Definiens 2006) has successfully been applied to other mountainous regions (e.g. Dragut and Blaschke 2008).

We generated a classification hierarchy comprising the same variables of the HSI model. Image classification training for the nearest neighbour function was performed by labelled samples for each subset, respectively. For each class we selected representative sample image objects and an iterative classification process was performed.

We used accuracy measures to compare and evaluate the classification with respect to its suitability to specific applications. We assessed classification accuracies by Error Matrix based on TTA Mask, where test areas are used as a reference to check classification quality.

For final habitat suitability modelling, we used MapModels (Riedl et al. 2000, Riedl and Kalasek 1998), a flowchart-based modelling-tool implemented in Arc View® (ESRI 1996).

The model’s key feature is the calculation of habitat suitability for rock ptarmigan within each grid cell using fuzzy membership-functions (Zadeh 1965). The scoring of habitat suitability between 0 and 1 was approached by Fuzzy Logic. For model validation, we compared presence–absence data and results of habitat suitability classification employing contingency tables and non-parametric correlations.

3. Results and discussion

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 producer’s accuracy of individual classes varied from 0.64 for scree to 0.89 for alpine to subnival grassland. The highest values for user’s accuracy were assigned to clouds (0.95), dwarf pine (0.92) and alpine to subnival grassland (0.91). 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.

The habitat suitability model for rock ptarmigan yielded HSI values between 0.7 and 0.84; grid cells situated below 1400 m a.s.l. were assigned to the class of lowest suitability. In total, 20% of the grid cells were assigned to the class of “very high suitability” and 21% of the grid cells to the classes of “high” and “medium” suitability. 38% of the grid cells were assigned to the category “no/low suitability” (Figure 2).

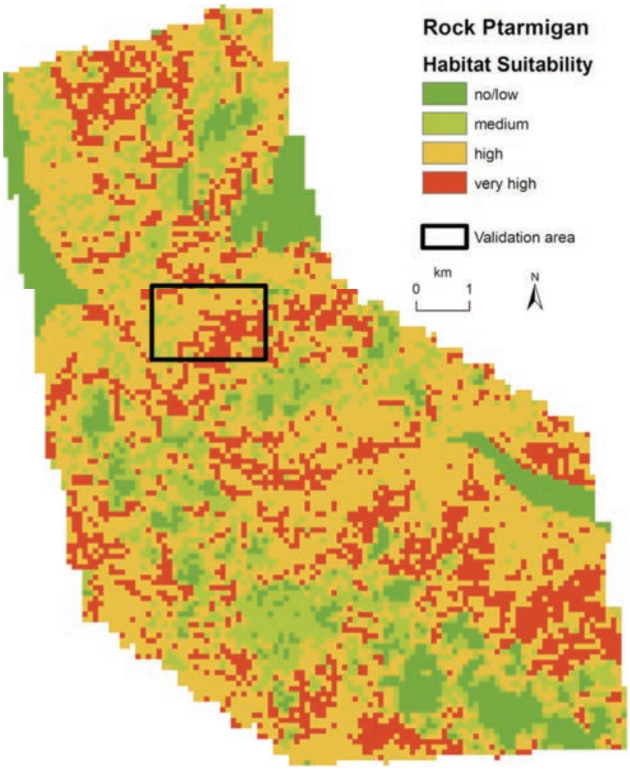

Figure 2. Map of habitat suitability (no/low, medium, high, very high) for rock ptarmigan.

To validate our habitat model we compared the model output with existing presence–absence data from the study area (Schweiger et al. 2012). Within this delimited validation area, HSI values ranged between 0.4 and 0.9. Re-standardized proportions of sample plots with rock ptarmigan signs significantly increased with increasing HSI class (Kendall’s $\tau = 1.000$, $p < 0.01$). There were highly significant differences in the re-standardized proportions of presence or absence plots over the HSI classes ($\chi^2 = 13.816$, df = 2, $p < 0.001$). Rock ptarmigan habitat use was closely related to habitat suitability**.**

The model approach we used is an effective tool for spatially explicit habitat suitability assessment and is well suited for regional monitoring, planning and decision support. Although being non-dynamic in structure, it can be used to assess temporal changes using spatial data of land characteristics collected at different points of time. Combining the modelled habitat suitability with presence–absence data of rock ptarmigan for different points of time, changes in habitat suitability and distribution can be evaluated over larger time periods.

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