Ecological Engineering 100 (2017) 107–119

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Searching the right tie—Expert-based vs. statistical niche modeling for habitat management at the alpine treeline ecotone

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ARTICLE INFO

Article history:
Received 11 May 2016
Received in revised form
24 November 2016
Accepted 10 December 2016
Available online 24 December 2016

Keywords:
Logistic regression
GLM
Expert system
Habitat suitability index
HSI
Tetrao tetrix
Austria

ABSTRACT

Understanding of wildlife-habitat relationships is a fundamental issue in conservation ecology allowing for the formulation of specific management demands. As habitats of various species are shifting and contracting in the course of global change, ecological niche models (ENMs) have to provide more than distributional maps. Rather, applicability of models for practitioners, conservationists and land managers should be prioritized, providing guidelines for management decisions. We developed correlative ENMs (*cENMs*, logistic regression) for alpine Black grouse (*Tetrao tetrix* L.) for five different study areas in Austria. We further propose one expert-based ENM (*xENM*) and a new hybrid approach (*xcENM*). We validated the models with independent test data sets and compared them in terms of discriminatory power, calibration, and parsimony. *The xcENM* reached an intermediate position between *cENMs* and *xENM* in terms of accuracy and calibration power. The *cENM* for the entire data pool had the best performance of all approaches in terms of accuracy, but showed a weaker transferability and a lower parsimony than the *xENM*. All models highlighted the importance of well-structured habitats for Black grouse, providing resources for feeding, resting, and rearing chicks. We further show the importance of habitat patches without anthropogenic disturbances for habitat suitability and provide recommendations for habitat management and habitat creation.

1. Introduction

Improving our understanding of wildlife-habitat relationships is a key question in ecological research allowing for a delineation of conservation needs and referring environmental management demands. Better understanding of species-habitat ties is of particular interest in the case of indicator species as they are used for monitoring of environmental changes, for formulating conservation targets and for proving the efficiency of management measures (Siddig et al., 2016). Indicator species by definition should be easy to monitor and they should reflect environmental conditions in terms of their status such as presence/absence, population density, reproductive success etc. (Landres et al., 1988; Siddig et al., 2016).

In the past, a variety of modeling approaches have been established to derive ties between speciesí occurrences or abundance and environmental characteristics (e.g. Byrne et al., 2014; Ottaviani et al., 2004; Özesmi and Mitsch, 1997; Pedersen et al., 2014; Store and Jokimäki, 2003; Zurell et al., 2012). Ecological niche models (ENMs) are based on the assumption that they catch at least a subset of environmental conditions, which allow for survival and reproduction of species (Warren, 2012). Basically, such models either rely on (i) empirical phenomenological data of species occurrences, or (ii) functional traits and physiological constraints of species (see Kearney et al., 2010). As models being independent of current speciesí distribution would be beneficial, they should be based on the fundamental niche concept rather than on realized niches demanding for mechanistic, knowledge-based modeling approaches.

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http://dx.doi.org/10.1016/j.ecoleng.2016.12.009

Table 1
Characterization of the five study areas (Climate characterization based on the mean values from 1971 to 2000.

Study area (Province of Austria)	Geographic position	Geological substratum	Mean annual precipitation [mm]	Mean temperature July [°C]	Altitude [m a.s.l.]	Spatial extent [ha]	Plots with Black grouse signs [%]	Human disturbance	Grazing
Gleinalm (Styria)	47°15′ N 15°06′ O	Silicate	1065	11	1473–1844	191	39	low	low
Kasberg(Upper Austria)	47°48′ N 14°01′ O	Limestone	1846	11	1250–1747	251	34	high	high
Loser (Styria)	47°40′ N 13°47′ O	Limestone	1959	11	1500–1650	100	32	high	high
Pleißling (Salzburg)	47°14′ N 13°28′ O	Limestone and silicate	1788	9	1763–2153	180	42	medium	medium
Vorarlberg(Vorarlberg)	47°16′ N 9°50′ O	Limestone and silicate	1914	11	1413–2010	290	41	high	medium

Source: Hiebl et al., 2011).

Several studies showed that habitat models might provide valuable support for decision processes in nature conservation (e.g. Geary et al., 2013; Immitzer et al., 2014; Lindenmayer et al., 1991; Mladenoff et al., 1999; Zohmann et al., 2014). Gaining of basic ecological knowledge on the one hand and transferability of scientific findings into a practical context and concrete environmental engineering actions pose specific challenges to modelers. E.g., concurrently maximizing model premises of generality, realism and precision in the course of model building is not feasible, but only two of the three characteristics might be optimized at the same time (Levins, 1966). In their review on predictive habitat distribution models, Guisan and Zimmermann (2000) depict three groups of models based on trade-offs between the three premises: (i) empirical (phenomenological/ecological/statistical) models optimizing the premises of reality and precision at the expense of generality; (ii) mechanistic (physiological/fundamental/process-based) models yielding maximum reality and generality at the expense of precision; (iii) analytical (mathematical/theoretical) models favoring generality and precision while subordinating reality. As a fourth premise, model parsimony reduces overfitting, balancing goodness of fit of models against model complexity (Vandekerckhove et al., 2014). While overfitting leads to excellent adaption of models to underlying data sets, the performance for out-of-sample applications might become poor (Vandekerckhove et al., 2014). Depending for example on geographic dimension, spatial resolution, and the share of realized niche covered by empirical data (Guisan et al., 2013), correlative ENMs are assumed to be more prone to overfitting than mechanistic approaches. Consequently, benefits and constraints of different modeling techniques as well as specific management and conservation goals for a target species have to be considered when choosing an appropriate modeling approach (Guisan and Zimmermann, 2000). For environmental engineering purposes, aspects of applicability of ENMs in a practical context (e.g. use of an ENM by land manager, technical bureau, forester) as well as highest possible transferability in time and space seem to be particularly important as these features allow for the design of concrete management actions on the one hand and for monitoring and proving efficiency on the other hand.

Changing quantity and quality of speciesí habitats and resulting management demands pose particular challenges for nature conservation planning. To support management decisions with respect to national and international nature conservation strategies and laws (e.g. the Habitats Directive – Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, the Birds Directive – Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds), both precise and general *ENM*s and guidelines are needed (see Guisan et al., 2013). As habitats of various species are shifting and contracting in the course of global change (Ehrlén and Morris, 2015; Morin and Lechowicz, 2008; Gelviz-Gelvez et al., 2015), models have to provide more than distributional maps. Rather, applicability of models for practitioners, conservationists and land managers should be prioritized, providing guidelines for management decisions. Thus again, mechanistic and correlative *ENM* approaches compete depending on the context of application.

Model validation or evaluation (sensu Guisan and Zimmermann, 2000) should ideally be based on independent data. If independent data from previous studies are not available or supplemental data collection is limited by financial or time constraints, *ENM*s should at least be applied to semi-independent data sets derived from data partitioning or resampling procedures (cross validation, jack-knife, bootstrapping etc.).

In this paper, we contrast an expert-based *ENM* approach to correlative *ENM*s for Black grouse (*Tetrao tetrix* L.), searching for ecological predictors to which the species responds distinctly