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Interchangeable sets of complementary habitat variables allow for flexible, site-adapted wildlife habitat management in forest ecosystems

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Abstract

Integrating biodiversity conservation into forest management is a major goal in sustainable forestry. Hence, target values for forest structural and compositional stand characteristics are required to ensure wildlife habitats of sufficient extent and quality. Yet, the possibility to meet these targets depends on the patch conditions, notably their initial state and future trajectory. Shaped by succession, site conditions and management regime, not all forest stands can be readily converted into a particular state, which calls for flexible management prescriptions. Using the example of two forest grouse species, capercaillie and hazel grouse, we sought complementary variable combinations – with quantitative thresholds for any given crucial habitat feature – which would likewise offer suitable habitat. Habitat variables were mapped in sampling plots within occupied and non-occupied 1 km^2 grid cells distributed across three Swiss mountain regions. Generalized linear mixed models (GLMM) were combined with conditional inference trees (CIT) to identify species-relevant variable combinations and variable thresholds. Important features for both species were the proportion of bilberry (*Vaccinium myrtillus*) and the number of basal-branched trees, as well as a low proportion of beech (*Fagus sylvatica*) in the canopy layer. Hazel grouse additionally favoured rowans (*Sorbus aucuparia*) as feeding trees and a high percentage of herbs in the ground layer, while the presence of inner forest edges was additionally important for capercaillie. Thresholds were not clear-cut: different values applied for a particular variable depending on other, functionally similar habitat variables present at the site. By delivering information about relevance, interactions and the required amount of crucial variables, we provide alternative options for flexible species habitat management which allows accounting for the prevailing stand conditions.

Zusammenfassung

Die Integration von Naturschutzzielsetzungen in die Waldbewirtschaftung ist wesentliches Ziel einer nachhaltigen Waldwirtschaft. Um Wildtierlebensräume in ausreichendem Umfang und Qualität zu gewährleisten werden waldstrukturelle Zielwerte benötigt. Die Möglichkeit diese Zielwerte zu erreichen hängt jedoch maßgeblich von den Ausgangsbedingungen und dem

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Entwicklungspotential eines Waldbestandes ab. Je nach Sukzessionsstadium, Standortsbedingungen und Bewirtschaftungsform können nicht alle Bestände gleichermaßen in einen gewünschten Zustand überführt werden. Dies macht flexible Managementvorgaben erforderlich. Am Beispiel von zwei sympatrischen Raufußhuhnarten, Auerhuhn und Haselhuhn, ermittelten wir Kombinationen komplementärer Habitatvariablen und zugehöriger Schwellenwerte, die gleichermaßen geeignete Lebensraumbedingungen bieten. Hierfür wurden Flächen mit und ohne Artvorkommen in drei Bergregionen der Schweiz verglichen und artrelevante Variablen, Variablenkombinationen sowie Schwellenwerte durch Generalisierte Lineare Gemischte Modelle und conditional inference trees (CIT) identifiziert. Wichtige Lebensraummerkmale für beide Arten waren der Anteil der Heidelbeere (*Vaccinium myrtillus*) sowie die Anzahl tiefbeasteter Bäume und ein geringer Anteil Buche (*Fagus sylvatica*) in der Baumschicht. Das Vorkommen des Haselhuhns wurde zusätzlich durch die Anzahl an Ebereschen (*Sobus aucuparia*) und einen hohen Anteil an krautigen Pflanzen in der Bodenvegetation bestimmt, Randlinien zu offenen Flächen im Wald waren ein wichtiger, zusätzlicher Habitatfaktor für das Auerhuhn. Die ermittelten Schwellenwerte für Habitatvariablen waren meist nicht klar definiert, vielmehr galten unterschiedliche Werte abhängig davon, welche anderen, funktional ähnlichen Habitatmerkmale in einer Fläche vorhanden waren. Neben der Identifikation artrelevanter Habitatvariablen kann die Bereitstellung alternativer Variablenkombinationen und kombinationsabhängiger Schwellenwerte eine wichtige Grundlage dafür liefern, Managementmaßnahmen flexibel an die in einem Waldbestand gegebenen Ausgangsbedingungen anzupassen.

Keywords: *Bonasa bonasia*; Complementary habitat variables; Conditional inference tree; Habitat management; Mountain forests; *Tetrao urogallus*; Thresholds

Introduction

In the human-dominated landscapes of Central Europe, where suitable wildlife habitat is limited, conservation management needs quantitative and spatially explicit prescriptions for biodiversity preservation and habitat restoration. In forest ecosystems, where species occurrence and diversity largely depends on characteristics of forest composition and structure (Bollmann et al., 2009), enhancing or restoring forest structural diversity is a prime goal of wildlife habitat management (Bergman, Jansson, Claesson, Palmer, & Milberg, 2012; Lindenmayer & Luck, 2005). Yet, evidence-based, quantitative targets with regard to the amount, size and configuration of crucial habitat features (e.g. Müller & Bütler, 2010) are still rare. Moreover, even if quantitative management prescriptions exist, they are often not equally applicable to all site conditions: Most forests are commercially used ecosystems, characterized by a slow vegetation succession. Stand composition and structure differ greatly depending on site conditions and mode of exploitation (Bürgi, 1998), and thus provide variable conditions for habitat management. Possibilities for habitat management are further constrained by the objectives of commercial forestry, which may interfere with habitat management goals (Bollmann & Braunisch 2013). While some measures can readily be implemented, e.g. removing trees to create gaps, alter light conditions and promote ground vegetation, other structural components such as tree species composition or age structure can only be modified within long time frames, and in strict consideration of the initial state and local site conditions. Given these limitations, achieving the multiple functionalities of forests through integrative management remains a big challenge. This is particularly true when the requirements of different species with diverging ecological needs have to be met within the same area. Yet, species rarely require similar habitat conditions throughout their range, but avail themselves of a mosaic of different habitat features and resources that offer complementary functionalities, such as food supply, cover against predators, roosting or breeding sites. Thereby, different habitat features may be interchangeable across a species' home range. Identifying sets of important and complementary variables is thus a key for a flexible multi-species habitat management.

In Europe, the hazel grouse (*Bonasa bonasia*) and the capercaillie (*Tetrao urogallus*) are two forest grouse species of conservation concern (Storch, 2007) which often occur sympatrically. Being considered as indicators for structural diversity of boreal and mountain forest ecosystems (Pakkala, Pellikka, & Lindén, 2003; Suter, Graf, & Hess, 2002), they have suffered from habitat loss and degradation during the last century mainly due to changes in forest management (Klaus, 1991). While qualitative habitat requirements for these two tetraonids have been well described (e.g. Glutz von Blotzheim et al., 1973; Müller, 1973), recent studies also provide quantitative target values for particular habitat features, including variable thresholds, which allow for targeted habitat management (Schäublin & Bollmann, 2011; Müller, Schröder, & Müller, 2009; Mathys, Zimmermann, Zbinden, & Suter, 2006; Suchant & Braunisch, 2004; Sachot, Perrin, & Neet, 2003). However, habitat recommendations vary considerably between studies and areas, providing evidence for their limited generality.

In this study we analyse the habitat requirements of the two species from a novel perspective: using multivariate classification and regression trees, we seek for different combinations of habitat variables as well as quantitative thresholds thereof that similarly promote species presence at the forest stand scale. In this context we explore if and to what