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The cost-effectiveness of using raptor nest sites to identify areas with high species richness of other taxa

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ABSTRACT

Given the limited resources available for conservation, it is important that the areas to preserve are selected in a cost effective manner. However, the cost effectiveness of the surrogate species strategy (the use of information on one or more species to identify areas of value for other species for which there is no, or more limited, available information) has seldom been evaluated.

In this study, we investigate the opportunity cost of setting aside breeding sites of two forest raptor species (the surrogate species) by evaluating their individual and combined contribution to preserve diversity of polypores (wood-decaying fungi) and birds against the contributions of previously established nature reserves. We use numeric optimization models to compare different reserve selection strategies.

Site selection based on nest sites of the dominant raptor species was more cost-effective than strategies using sites of the subordinate species or those processes previously used to select nature reserves in Finland. The inclusion of both raptor species in the reserve selection model further improved its performance relative to other approaches. This indicates that the means by which Finnish reserves are selected could be enhanced by including the breeding sites of these, and maybe other species, among the criteria used to select reserves in the future.

These results show that information on charismatic and well-surveyed species could be a cost-efficient add-on to help enhance conservation endeavours. Where there is inter-specific competition for biodiverse sites, and using multiple species is costly, basing reserve selection primarily on breeding sites of a dominant species may be the best strategy. However, further work is required to establish the extent to which dominant species are typically better indicators of conservation relevance.

1. Introduction

Protected areas are often established in an attempt to halt biodiversity loss. However, the global area currently protected is below the 17% of total land area proposed by the United Nations' International Convention on Biological Diversity (Convention on Biological Diversity, 2010). Moreover, nature reserves have often been established to secure populations of exceptionally rare or charismatic species and/or to protect areas that are actually of low natural resource value (Pressey, 1994). This practice has been criticized because it might fail to protect a substantial portion of the total biodiversity (Andelman and Fagan, 2000; Pressey et al., 1993). Consequently, algorithms designed to prioritize conservation action currently incorporate several aspects of biodiversity in a common framework and with an emphasis on environmental features (Kukkala and Moilanen, 2013; Margules and Pressey, 2000; Moilanen et al., 2009; Sutcliffe et al., 2015). Nevertheless, it is evident that charismatic surrogate species can be of strategic value to those wishing to protect biodiversity. For instance, such species can serve as flagship or 'poster child' species to divert funds towards conservation (Richardson and Loomis, 2009;

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Smith et al., 2012), they can make societal trade-offs in favour of conservation more publicly acceptable (Fischer and Vanderwal, 2007), and they can even make conservation action more affordable (Santangeli et al., 2012). These generalizations apply with particular force to predators, which tend to garner a marked share of conservation attention (Sergio et al., 2008; Smith et al., 2012).

Despite this history and evidence from several empirical studies, the use of surrogate species in conservation is controversial (Caro, 2010; Favreau et al., 2006; Lindenmayer et al., 2015). For example, it is not well known to what degree, if any, the surrogate efficiency of dominant species differs from that of subordinate guild members in cases when the species have similar habitat preferences. In the light of habitat selection (Clark and Shutler, 1999; Martin, 1998; Rosenzweig, 1981) and species interaction theory (Creel and Christianson, 2008) this could, however, be expected because dominant species may pre-emptively displace inferior competitors. Still, multiple surrogate species have commonly been assessed together under the rationale that several species combined may embrace more biodiversity than single species, as multiple species would encompass a wider range of habitats and ecological requirements (Lambeck, 1997; McKenzie et al., 1989; Nicholson et al., 2013; Schwenk and Donovan, 2011). Because subordinate surrogate species in a guild consisting of ecologically similar members are expected to be displaced to alternative habitats by dominant species (Byholm et al., 2012), competing species might complement each other as biodiversity indicators. However, the general applicability of this hypothesis is unclear.

A body of studies has examined the extent to which better-known taxa can act as a surrogate for biodiversity (see Caro 2010 for an overview). However, even a simple assessment of the biodiversity in areas inhabited by surrogate species together with that secured in adjacent already established reserves has seldom been attempted (but see, e.g., Marfil-Daza et al., 2013; Oldfield et al., 2004). Moreover, only a few studies effectively fulfill the requirement suggested by Roberge and Angelstam (2004), i.e., to evaluate the conservation performance of the network delivered by the surrogate species compared to that delivered by other conservation methods while simultaneously considering cost-efficiency aspects. This difficulty places limitations on a broader and more practical application of the surrogate species concept.

The aim of this study is to add to the understanding of the economic performance of surrogate species in conservation. We focus on predators because there is a theoretical rationale and empirical support for their use as surrogates of overall biodiversity (Burgas et al., 2014; Sergio et al., 2008, 2005) and because they often appeal to society. We apply a reserve selection framework that, for a given budget, maximizes the number of species included in the selected network using two widely distributed raptor species that have previously been shown to be consistently associated with high biodiversity (Burgas et al., 2014; Byholm et al., 2012). To evaluate the cost-efficiency of the surrogate species as opposed to other area-selection methods, three additional types of conservation approaches (i.e., existing protected areas, mature and random forest habitats) were compared with the raptor conservation approach. We hypothesize that (i) the two raptors known to be associated with biodiversity will enhance the effectiveness of other reserve selection criteria methods and that (ii) dominant raptor species will outperform subordinate species while (iii) the combined use of the competing species should deliver even more biodiversity.

2. Materials and methods

2.1. Study area, raptor species and inventory of surrogated taxa

Field work was conducted in the boreal biome of western Finland (ca. 4000 km^2, 62°50′N, 22°80′E) as part of a project investigating the links between raptors and biodiversity (Burgas et al., 2014; Byholm et al., 2012). Search and monitoring of nests of all raptor species has been actively carried out by a network of amateur raptor ringers and researchers for several decades. The extensive network of forest roads built to conduct forest management allows yearly inspection of nearly all tentatively suitable habitats in the study area. Approximately 75% of the land in the study region is covered by forest dominated by Norway spruce *Picea abies* L., Scots pine *Pinus sylvestris* L. and birches *Betula* spp. The forest in the area is heavily fragmented due to intensive forestry practices. As a consequence, the original tree species composition has largely been altered (pine has been preferred for regeneration) and most of the forest is in a young successional stage below 80 years (Muukkonen et al., 2012). Forest stands older than 140 years only represent approximately 1.7% of the study land area, while barely 0.5% of the land is covered by forest nature reserves. As a consequence, forest habitats and, in particular, mature forests, are a primary target for conservation efforts in the region (e.g., Lehtomäki et al., 2009).

Given this background, we investigated the biodiversity surrogate properties of two widely distributed raptor species, the Northern Goshawk *Accipiter gentilis* L. (hereafter Goshawk) and the Ural Owl *Strix uralensis* Pall. to test the cost efficiency of the two species for protection of forest habitats. Both species are common and widespread raptor species in Finland (Honkala et al., 2011) and have previously been shown to indicate areas with high biodiversity values of bird and wood-decaying fungi (polypores) in the study region (Burgas et al., 2014). While the Goshawk builds its own nest, the Ural Owl uses cavities or stick nests of diurnal raptors. The diurnal Goshawk preys mostly upon birds followed by middle to small sized mammals (Tornberg et al., 2006). The diet of the nocturnal Ural Owl is based on rodents but is complemented by birds and other small mammals during the low phases of rodent population cycles (Korpimäki and Sulkava, 1987). Both the Goshawk and the Ural Owl prefer the same type of mature mixed spruce forest (Mikkola, 1983; Tornberg et al., 2006), but due to interspecific avoidance and intra-guild predation effects the nest sites of the two usually do not overlap spatially (Mikkola, 1983; Byholm et al., 2012).

We evaluated how protecting raptor nest locations ($n = 29$ for each raptor species) could optimize the protection of other taxa, i.e., polypores and forest birds, using species number as a proxy for biodiversity. Both taxa have been closely linked with the ecological value of forests in Finland (e.g., Kotiranta and Niemelä, 1996; Virkkala and Rajasärkkä, 2007). Given that forest nature reserves are generally more homogeneous in habitat than the raptor nest sites and other potential spots for conservation in the heavily fragmented matrix, we sought to be more conservative with the complementarity analyses. Accordingly, we explored models that only included forest bird species, following the classification of Solonen (1994). In addition to raptor nest locations, we further surveyed biodiversity at three site types representing different hypothetical reserve selection approaches: (i) at mature forest sites subjectively chosen to resemble the characteristics of the raptor breeding sites (henceforth called genuine reference), (ii) at randomly selected forest habitat of any type (hence random reference) and (iii) at existing nature reserves targeting the conservation of any type of mature forest habitat in the study area. While there are different types of protected areas in Finland, we focused on reserves under nature conservation plans that, therefore, were selected primarily on the basis of conservation value and opportunity cost.