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Reactive forest management can also be proactive for wood-living beetles in hollow oak trees

Leonie A. Gough *, Tone Birkemoe, Anne Sverdrup-Thygeson

Norwegian University of Life Sciences, Department of Ecology and Natural Resource Management, P.O. Box 5003, NO-1432 Ås, Norway

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ABSTRACT

The debate about whether proactive (focused on irreplaceable species) or reactive (focused on vulnerable species) conservation is more effective usually focuses on the global or multinational scale and knowledge of how these principles interact on-the-ground is lacking. Here we use the first long-term dataset on an entire oak-living beetle community in hollow oaks (*Quercus spp.*) to ask whether policy-driven conservation actions aimed at vulnerable species can also be proactive for unthreatened, but irreplaceable species. Hollow oaks are vital keystone structures that are rich in both vulnerable and irreplaceable wood-living beetles. We sampled in excess of 23,000 individuals from 307 species over four seasons, across the oak range in Norway. We assessed the importance of key environmental variables for vulnerable, irreplaceable and generalist species. We show that simple management actions taken to benefit vulnerable species in hollow trees could also contribute to preventing the decline of important, irreplaceable species. Clearing regrowth is predicted to increase vulnerable species richness by 75–100%, specialist richness by 65%, and to benefit two generalist species. Regrowth clearance is likely to be similarly beneficial in all oak-based habitats with hollow trees across Europe and North America. Increased oak circumference and local habitat quantity were also beneficial for species richness and influenced species composition. Based on this we provide advice for targeting conservation action. We suggest economic, carbon and recreational benefits of clearance that could increase the attractiveness of conservation for policy-makers. We show the importance of examining large-scale conservation planning principles at a local scale to elicit how they work on the ground where conservation actually happens.

1. Introduction

Current species extinction rates are among the highest ever observed (Barnosky et al., 2011; Naeem et al., 2012). In the face of this daunting scale of loss, it is important to target conservation resources as effectively and efficiently as possible to achieve greatest biodiversity benefit (Wilson et al., 2007). One approach is to focus conservation action on hotspots of biodiversity, areas where many species co-occur (Brooks et al., 2006; Myers et al., 2000; Redford et al., 2003). Hotspots can be designed to be reactive, focusing on highly vulnerable (threatened) species to prevent their extinction, or proactive focusing on highly irreplaceable (rare, but unthreatened) species to prevent them becoming threatened in the future (Brooks et al., 2006).

There has been much debate about the merits of implementing proactive vs. reactive conservation, mainly in the field of conservation planning related to global or multinational priority-setting (Brooks et al., 2006; Margules and Pressey, 2000; Wilson et al., 2007). In reality much current conservation action and spending on the ground is reactive regardless of this debate, as it is determined by policy at a variety of levels from international to local. Policy makers can be reluctant to act to protect biodiversity until there is a clear threat to it, because of the perceived costs of intervention and conflicting interests (Drechsler et al., 2011). Conservation often therefore focuses on actions targeted to slow threatened species' decline and prevent their extinction.

Oak (*Quercus spp.*) based systems are global hotspots of biodiversity (Buse et al., 2010; Sverdrup-Thygeson, 2009) and are considered as one of the most important habitats in a variety of ecosystems across the temperate zone from boreonemoral woodland (Andersson et al., 2011), lowland European wood-pasture and woodland (Bouget et al., 2014; Vera, 2000) and Mediterranean forests (Buse et al., 2013) to North American savannah (Brawn, 2006) and American and European agricultural lands (Gibbons et al., 2008). Ancient, hollow oak trees are an integral component of these systems. They are keystone structures, their great size and age conferring vital ecological roles that cannot be replicated

* Corresponding author. Tel.: +44 79 80 45 78 27.
E-mail addresses: leonie.gough@nmbu.no, leonie.gough@oxon.org (L.A. Gough).

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by younger, smaller trees (Lindenmayer et al., 2014). Hollow oaks are 'habitat trees' (Bouget et al., 2014) that contain varied microhabitats including cavities, wood mould, dead wood, and fissured bark which support a multitude of different species (Ranius et al., 2011; Stokland and Siitonen, 2012) including fungi, lichens, birds, small mammals and insects (Bergman et al., 2012; Siitonen, 2012). Oak ecosystems are suffering a drastic decline due to direct removal, a lack of traditional forest management in areas where it historically occurred, intensive forestry and climate events such as severe drought (Bjorkman and Vellend, 2010; Horak et al., 2014; Paillet et al., 2010; Vera, 2000) and large, hollow trees are often disproportionately affected (Lindenmayer et al., 2014). Hollow oak trees are incredibly rich in wood-living beetles, a group of animals with one of the highest proportions of threatened species in Europe (Davies et al., 2008; Grove, 2002; Nieto and Alexander, 2010; Speight, 1989). In Norway over 60 red-listed wood-living beetle species are found exclusively on hollow trees, primarily oak, and many hundreds more are associated with other microhabitats in veteran oaks (Kålås et al., 2010). The vulnerability of hollow oaks and their importance for red-listed species has been recognized by the Norwegian government and hollow oak trees are designated as a 'selected habitat type' ('utvalgt naturtype') under the Regulation on Selected Habitats 2011 (associated with the Nature Diversity Act 2009). A key aim of the Regulation is to ensure that hollow oaks are managed appropriately to halt their decline, increase oak recruitment and benefit red-listed species. There is a national Action Plan which sets out the need for action (Norwegian Environment Agency, 2012).

This protection of hollow oaks in Norway is a reactive approach (prioritizing high vulnerability) to conservation as defined by Brooks et al. (2006), as it focuses on red-listed species that are in need of urgent action to prevent a slide towards extinction. Most existing research into conservation of hollow oak trees and wood-living beetles has been reactive, attempting to determine how best to conserve red-listed species associated with the oaks. However, there are hundreds of beetle species associated with hollow oak trees that are not currently threatened but are highly irreplaceable due to rarity through endemism or limited distribution. A proactive conservation approach (prioritizing high irreplaceability) aiming to prevent further species from reaching the red list could also be taken.

Whether conservation is proactive or reactive, it usually occurs in the context of limited resources and requires targeted on-the-ground action. Conservation managers in Norway are currently in need of advice on how to target their resources most efficiently to fulfil the aims of the Action Plan. Hollow oak trees in Norway therefore provide an ideal system to investigate the potential of reactive conservation actions to benefit other species. In order to advise landowners and managers on how best to selectively target trees for management, we need to know how actions taken influence beetle species richness. Ecological knowledge is growing about wood-living beetle requirements. We know that increasing the amount of dead wood in the wider surroundings can benefit species richness (Sverdrup-Thygeson et al., 2010), and that a landscape-level approach to habitat restoration is required to increase oak recruitment, reduce fragmentation and facilitate insect dispersal (Franc et al., 2007). We also know that various tree factors influence beetle species richness, including amount of wood mould, age and size of the tree, and whether a tree is in a forest or open landscape (Ranius et al., 2009a,b; Sverdrup-Thygeson et al., 2010). However, it is often hard to draw inferences from these existing studies about how to specifically and immediately manage the existing trees and immediate area around them on-the-ground to improve the prospects of associated biota. Most studies have taken a reactive view, focused on red-listed species. It is not clear whether the conclusions drawn about red-listed species also apply to other species.

The studies providing the most practical management advice have focused on only one (Ranius, 2002; Ranius et al., 2009b) or a few species (Vodka et al., 2009), which due to their restricted geographical distribution (such as *Osmoderma eremita*, a focus of research in Sweden but known from only one location in Norway) or specialist ecology makes it hard to generalize recommendations for a whole community. Another shortcoming of existing studies is the short time frame (one or two seasons) used for sampling (Koch Widerberg et al., 2012; Ranius et al., 2010,2009b; Sverdrup-Thygeson et al., 2010). Long-term wood-living insect sampling designs are non-existent for hollow oaks, although there are examples from birch (Martikainen and Kaila, 2004) and mixed forests (Grove and Forster, 2011; Hjalten et al., 2012; Parmain et al., 2013). Beetles are known to experience large population fluctuations between years and wood-living species are elusive, with limited detection probability. In addition, the very high number of rare species associated with oaks are likely to have stochastic occurrence or patchy distribution, meaning a high proportion of the community may be missed in one year's sampling (Engen et al., 2008; Jansson et al., 2009; Thompson, 2004). Rare beetles accumulate in samples slowly over years (Martikainen and Kaila, 2004), but just one extra sampling year (two years total instead of one) vastly increases the number and diversity of species caught (Parmain et al., 2013). For these reasons conclusions based on one year's sampling, particularly of rare species, may not be robust.

In this study we use the first, to our knowledge, long-term dataset on an entire oak-living beetle community in hollow oak trees to investigate whether reactive conservation actions aimed at vulnerable species in a hotspot habitat can also be proactive for currently unthreatened, but highly irreplaceable species. It is a large-scale study, with samples from across the whole oak range in Norway. We use the results to provide management recommendations for species conservation and explore the policy implications of the recommendations.

2. Materials and methods

2.1. Data collection

The data set used in this study is a part of an ongoing study of hollow oaks under the National Program for Surveying and Monitoring Biodiversity – Threatened Species in Norway (ARKO project (ARKO, 2011)). The study contains data from 50 hollow oak (*Quercus robur* and *Q. petraea*) trees in 10 sites, spread across the geographical range of oak in Norway (Fig. 1). All sites had at least five hollow oaks close to each other (6–250 m). A hollow oak was defined as a tree of at least 95 cm circumference with a visible cavity in the trunk, in line with the Regulation on Selected Habitats 2011, although one tree with a visible cavity included in the analysis was slightly smaller.

Five environmental variables were included in the analysis – Circumference, Regrowth, Cavity Stage, Number of Big and Hollow Oaks and Amount of Forest (Table 1). These were selected from an initial larger set of measured variables after assessing collinearity between variables through calculation of correlation coefficients and inspecting Variance Inflation Factors (VIFs). We prioritized variables that were ecologically meaningful and could either be directly influenced by management or easily measured by conservation managers at new sites.

Each tree was sampled for beetles in four years between 2004 and 2011. Two flight interception traps (20 cm × 40 cm windows, traps with ethylene glycol and detergent) were used per tree, one directly in front of the cavity opening and one in the canopy, and they were emptied once a month between May and August.