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The tragedy of the science-policy gap – Revised legislation fails to protect an endangered species in a managed boreal landscape

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ABSTRACT

Unsustainable use of forest resources poses a serious threat to biodiversity worldwide. This threat is particularly important in boreal biomes, where intensive production-oriented forestry is widely applied. Legislation is one of the key tools for preserving nature from anthropogenic damage. Designation of environmental legislation should be grounded on sound scientific evidence in order to be effective. We assess the impact of guidelines enforcing the Finnish ad-hoc legislation aimed at preserving breeding sites and resting places of the Siberian flying squirrel (*Pteromys volans*), a protected species in Finland and in the European Union under the Habitats Directive. Its habitat is under pressure from widespread forest clear-cutting practices. We collected data on site occupancy by breeding female flying squirrels from 81 sites spanning 12 years (2005–2016) and on relevant habitat variables around the site. Using generalized linear mixed models we quantified the predicted occupancy of breeding female flying squirrels in relation to the cover of breeding habitat around a site. We then compared the resulting habitat requirements of breeding females with the habitat that would be retained according to the initial national legislation guidelines and their proposed first revision. We show that both the initial and the proposed revision of the habitat protection guidelines allow the retention of breeding habitat patches of minimal size, which would yield a very low (less than 5%) predicted occupancy by a breeding flying squirrel female. The current revised guidelines are not science-driven and remain ineffective in safeguarding the species habitat from expanding forestry. These results expose the wide gap between science and policy for the implementation of environmental legislation, in this case the Habitats Directive, to protect species of conservation concern. There is an urgent need to fill the science-policy gap in order to achieve the preservation of biodiversity in a world under rapid transformation.

1. Introduction

The biodiversity in forest environments worldwide is under increasing pressure from anthropogenic resource extraction resulting in habitat loss, fragmentation and the deterioration of extant habitats (Pimm et al., 2014). The boreal forests currently form a third of the earth's woodland cover but are under imminent and increasing pressure from intensive industrial-oriented resource extraction (Bradshaw et al., 2009). This poses a threat to the persistence of boreal species (Schmiegelow and Mönkkönen, 2002). Boreal forests are fundamental not only for ensuring the persistence of boreal biodiversity but also for preserving the important services this ecosystem provides, including carbon sequestration and clean water provision (Moen et al., 2014).

Beginning after World War II industrial-scale forestry has been practiced throughout the Circumboreal regions. This practice is based on even-aged forest stand management, clear cut harvesting and thinning (Kuuluvainen et al., 2012). In Fennoscandia, industrial type of forestry has caused a progressive deterioration of the ecological value of forests and resulted in many forest habitats becoming endangered or near threatened (e.g. Raunio et al., 2008). Forest living species are disproportionately represented on the Red Lists of threatened species of Finland, Sweden, and Norway (Rassi et al., 2010; Westling, 2015; Henriksen and Hilmo, 2015).

Effective nature protection is often achieved by means of regulatory top-down approaches, such as the establishment of protected areas and the enforcement of legislation based on scientific evidence (Watson et al., 2014; Santangeli et al., 2016). A good understanding of species habitat requirements across their different life-stages (Courchamp et al., 2015) is imperative to define ad-hoc species-level protection measures, which can then be updated as new evidence becomes available within an adaptive management framework (McCarthy and Possingham, 2007).

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One of such species that has been the focus of ad-hoc legislation is the Siberian flying squirrel (*Pteromys volans*), hereafter flying squirrel. The flying squirrel is one of those boreal forest species heavily threatened by modern age intensive forest management regimes in the boreal region owing to its association with old-growth forests which are under strong pressure from widespread commercial forestry (Santangeli et al., 2013a). As a result the species is listed in Annex IV of the Habitats Directive (92743/EC), which means its habitat should be protected by the law within its range of occurrence in the European Union (EU). In Finland the flying squirrel was given protection status according to the National Conservation Act (§ 49). Flying squirrel breeding sites and resting places are legally protected since 1.1.1997 from destruction and deterioration. A guidance document, for implementing the above legislation during forest logging operations, was published in 2004 (Anon., 2003). However, those guidelines proved to be ineffective (Santangeli et al., 2013a; Jokinen et al., 2015). One main reason for that failure was that the initial habitat protection guidelines were not based on science. Instead, an arbitrary and minimal forest area (size 0.03–0.07 ha), was defined as the breeding site and resting place to be retained during forest logging operations in compliance with the Nature Conservation Act (§ 49). In 2014 the Finnish Ministry of Environment initiated a revision of the old guidance document from 2004. Through this revision process an enquiry regarding an updated guidance document, suggesting 0.1–0.3 ha as a sufficient area for a flying squirrel breeding site and resting place, was distributed among stakeholders (Anon., 2015). However, the resulting guidance document (Anon., 2016a) contained no science-based guidelines regarding the required size of a breeding site and resting place to be protected. Consequently the issue was surpassed by referring to high court decisions establishing 0.18 ha as too small and 3.7 ha as too large areas for the species (Korkein Hallinto-oikeus, 2014, 2015). During the revision process the only scientific studies preliminarily addressing the issue of required habitat area were ignored (Hanski et al., 2001; Jokinen et al., 2015). The lack of specific guidelines resulting from revised legislation leaves stakeholders in a situation where they are taking conservation decisions in the dark. Ultimately this leaves the species at the mercy of largely unregulated forestry, as most of the breeding sites and resting places are protected according to the judgement of forest harvesters and forest owners (Jokinen et al., 2015, Anon., 2016a). Therefore, there is a need for providing robust scientific evidence on the habitat requirements of the species that can then be used to inform decisions. Without this evidence, conservation measures are likely to fail (Cook et al., 2010).

Here we aim to fill the above mentioned gap in ecological knowledge of flying squirrel habitat requirements in Finland. We quantify the habitat requirements of breeding female flying squirrels using a unique study design composed of forest patches along a gradient of different size and fragmentation. Specifically we aim to quantify possible thresholds in the effect of cover of habitats of different suitability for breeding female flying squirrels. In doing so, we consider different spatial scales that are biologically relevant. We then compare the habitat requirements with the initially enforced legislation, the proposal for its revision and the current regulations (Anon., 2003; Anon., 2015; Anon., 2016a). Finally, we discuss the implications of the study results with regards to implementing effective, sustainable and publicly acceptable conservation measures for the species in privately owned boreal forests.

2. Methods

2.1. Study species and enforced conservation guidelines

The flying squirrel is a small nocturnal tree squirrel widely spread throughout the Eurasian taiga. Within the European Union, the vast majority of the species population occurs in the southern part of Finland (Santangeli et al., 2013b). Here flying squirrels are declining due to destruction of their primary habitat, layered mature spruce dominated mixed forests (Koskimäki et al., 2014; Liukko et al., 2016). These forests provide key elements such as food, nesting places and shelter. The flying squirrel is a herbivore and mainly feeds on leaves, buds, catkins, flowers and seeds of deciduous trees. Large spruces are perceived to provide cover against predators and are used for storing catkins as winter food (Mäkelä, 1996). Litters are reared in cavities built by the Great spotted woodpecker (*Dendrocopus major*) but nest boxes are readily used (Lampila et al., 2009; Koskimäki et al., 2014). Dreys are mostly used by females outside the breeding season. A female typically has one litter per year. Adults have a strong site fidelity, with males' home range being about 60 ha while that of females is about 8 ha (Hanski et al., 2000).

The flying squirrel is globally classified as Least Concern according to the IUCN Species Red List, but is classified as Near Threatened in Finland (Liukko et al., 2016). In the "State of Nature in the EU" the status of the population of flying squirrels in Finland, despite enforced conservation guidelines, was reported as unfavourable (Anon., 2013). The density of flying squirrels in the study area was estimated to be 0.01–0.02 females/ha (Wistbacka et al., 2009, 2010).

2.2. Study area and forest management

The study area (Fig. 1) is about 7000 ha (70 km^2) and located on the coast of the Baltic Sea in central-western Finland. The area is largely covered by boreal forests dominated by Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*), the majority of which are intensively managed using a rotational tree-growing cycle usually lasting 60–100 years and terminating with the clear-cutting of all the standing trees (see more details of the study landscape in Santangeli et al., 2013a). Other more environmentally sustainable means of wood harvesting, i.e. continuous cover silviculture or clear cuts smaller than 0.3 ha, are still rarely used in the region (Sjölind, M., personal communication 5.12.2016). Since 1.1.2014 there is no regulation of the minimum dimension of diameter at breast height below which trees cannot be clear-cut in the Finnish Forest Act. Only 2.8% of the forests in the region are strictly protected (National Reource Institute Finland, 2014).

2.3. Site occupancy and landscape variables

We classified habitats in the study area in three classes according to Selonen et al. (2001), Santangeli et al. (2013a) and Jokinen et al. (2015). Habitat suitable for breeding females (hereafter "breeding habitat") is defined as layered spruce dominated mixed forests, containing trees of different size and age (Table 1). The trees have a mean diameter at breast height > 18 cm (i.e. mature forests) and the amount of deciduous trees is over 5%. Semi-suitable habitat is defined as mono specific (typically pine plantations) forests with mean tree diameter at breast height > 8 cm, where flying squirrels can move but cannot breed because of lack of some resources (such as food provided by deciduous trees or shelter provided by spruce trees; Table 1). The semi-suitable habitats were further split into two categories: pine dominated plantations i.e. areas where flying squirrels can move and thinned even-aged deciduous tree forests where flying squirrels can move and feed. Unsuitable habitat is represented by open areas covered by young sapling stands or clear-cuts, roads, fields, water or built up areas i.e. areas unusable for flying squirrels for moving, feeding and breeding (Table 1).

We established 81 study sites (hereafter sites) by placing 1–5 nest boxes at a short distance to each other (within 100 m radius) in homogeneous patches of spruce-dominated forest (breeding habitat). Patches were clearly separated from the others by intermittent unsuitable habitat for breeding (e.g. open areas, pine-dominated forest or saplings). In six occasions, the forest fragment considered was very large and had multiple groups of nest boxes separated by at least 200 m. We considered each of these groups as independent sites following