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Effects of forest management on density and survival in three forest rodent species

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ABSTRACT

Several studies have shown that small mammal communities are influenced by silvicultural activities, possibly because these affect the quality of wildlife habitats. Previous research mainly focused on community parameters and abundance of target species, however the most robust way to study the impacts of forestry on wildlife is to follow a demographic-response approach. Investigating multiple demographic measurements is essential to understand how populations respond to forest management, nevertheless studies focusing on multiple demographic parameters are lacking. Our analyses targeted individual survival and population density, to understand the demographic mechanisms by which forest management exerts its effects on small mammals. We focused on the populations of *Apodemus flavicollis*, *A. sylvaticus* and *Myodes glareolus*, constituting the guild of forest- and ground-dwelling rodents in central Italy. Populations were monitored for three years in a continuous forest subject to different management practices (mainly coppicing activities and conifer afforestation). We identified four forest management types (three coppice stands logged in different years and a conifer plantation) where we selected 12 sampling areas. We sampled a total of 31,752 trap-nights capturing more than 1350 individuals. We also gathered quantitative data on the amount of trophic and cover resources in each area to better interpret the response of populations to silvicultural activities. For all the three species, coppicing activities had strong positive effects on population density, which were, in some cases, matched by similar effects on individual survival whereas afforestation of conifer plantations negatively affected populations of *A. flavicollis* and *M. glareolus*. We found that different types of forest management, such as the recently coppiced stands, did not create high-density sinks but, rather, enhanced the carrying capacity of the habitats by increasing the availability of cover and food resources. On the contrary, the high forest resulted to be less preferred habitat for *A. sylvaticus* and *M. glareolus*, possibility due to its lack of food and cover resources. Our analyses encompassing multiple population parameters allowed us to highlight the mechanisms by which forest management affects small mammal populations.

1. Introduction

Forests cover more than 200 million ha in Europe, however only less than 3% of this area is covered by natural forests (FAO, 2015). European forests have been altered by humans over the last 6000 years and are amongst the most intensively managed forests in the world (Jactel et al., 2009). During the last decades, environmental, social and cultural functions of forests have gained increasing importance (Spiecker, 2003) consequently forest managers have started focusing on sustainable forest management rather than on timber production only. Likewise, a more ecologically-oriented approach has been applied by forest managers and biodiversity protection has become one of the main objectives of a sustainable forest management (Bengtsson et al., 2000; Lindenmayer et al., 2000). To manage forests in an ecologically sustainable manner, however, we need a detailed mechanistic understanding of *how* silvicultural activities affect biodiversity.

The amount and availability of key resources such as food and shelter determine habitat quality and have thus a crucial effect on wildlife populations (Johnson, 2007; Mortelliti et al., 2010). Forest management targeting wood production directly affects

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wildlife habitat quality by modifying the structure of vegetation and stand composition. It is not surprising therefore that mammal communities are affected by forest management and, consequently, responses of small mammals to forestry practices have been studied extensively (e.g. Bogdziewicz and Zwolak, 2014; Paillet et al., 2010; Zwolak, 2009). Previous research on small mammals mainly focused on community parameters (i.e. species richness and composition, e.g. Bowman et al., 2001; Carey and Harrington, 2001; Panzacchi et al., 2010) and abundance of target species (e.g. Gorini et al., 2011; Savola et al., 2013), nevertheless investigations focusing on other demographic parameters such as survival are lacking (Manning and Edge, 2004).

If, as suggested above, forest management modifies the quality of wildlife habitats, the most robust approach to study the impacts of forest management is to follow a demographic response approach (i.e. to investigate multiple demographic parameters) (Gaillard et al., 2010; Johnson, 2007; Mortelliti et al., 2010). Density alone may be a misleading indicator of habitat quality, because high-density habitats may be sinks (Van Horne, 1983). However, simultaneous measurements of density and survival will allow researchers to establish if a habitat has a higher carrying capacity or if it may potentially act as a sink. Several studies have followed a demographic response approach, i.e. targeting multiple demographic parameters, to investigate the response of small mammals to forestry activities in North America (e.g. Klenner and Sullivan, 2009; Ransome et al., 2009; Sullivan and Sullivan, 2014a, 2014b). However to the best of our knowledge few studies have followed this approach in Europe and have focused on single species (e.g. Sozio et al., 2015) thus it is difficult to make generalizations about the response of small mammal populations to forestry.

To contribute in filling the knowledge gap on the demographic mechanisms determining the response of small mammal populations to forest management, we conducted a three-years study focused on the guild of forest- and ground-dwelling rodents in central Italy: *Apodemus flavicollis*, *A. sylvaticus* and *Myodes glareolus*. We chose to use these three species because they lie on a gradient of specialization to forest habitats and thus may act as useful model species to study population responses to silvicultural activities. More specifically, *A. sylvaticus* is the most generalist (i.e. it may inhabit open areas) whereas *A. flavicollis* and *M. glareolus* are more strictly associated with forest habitats.

To evaluate the mechanisms by which different management practices (i.e. conifer plantations and three types of coppice logged in different years) affect demographic parameters of the target small mammals, we tested the two following alternative hypotheses:

(H_1) silvicultural practices create source-sink habitats, with high rodents population density and low quality habitats and lower density and higher quality habitats (Van Horne, 1983);

(H_2) alternatively we predict that silvicultural practices will affect the carrying capacity of habitats by creating high quality habitats characterized by high population density and high survival. With this regard we were particularly interested to explore the dynamics in areas where silvicultural practices create a contrasting availability of resources (e.g. high food abundance and low cover to protect from predators).

2. Methods

2.1. Study area

The study was conducted in *La Selva* Forest (43°13′N, 11°4′E), located 45 km from Siena, in central Italy (Fig. 1). The altitude ranges from 350 to 700 m a.s.l. The climate is Mediterranean, with warm dry summers (mean monthly temperature about 23 °C) and cool wet winters (mean monthly temperature about 4 °C) and an average annual rainfall of about 750–1600 mm per year. The area (approximately 8000 ha) is characterized by deciduous woodland dominated by *Quercus cerris*, with a mixture of *Q. pubescens* and other deciduous woody species (Tognetti et al., 2007). Coppice management has been widespread in this area during the last centuries, mainly for charcoal production and firewood. Silvicultural activities have been reduced during the last decades as the demand for timber production decreased. Furthermore, starting from 1920s up to 1970s several conifer plantations (dominated by *Pinus nigra*) have been established on uncultivated and poor-quality fields for the main purpose of making them productive (Angiolini et al., 2011). As a consequence, the area is now a mosaic of different silvicultural practices.

2.2. Study design

We identified four forest management types: three coppiced stands of forests dominated by *Q. cerris*, logged in different years, and conifer plantations. Recent coppices were logged 5–10 years ago and are characterized by low stand density; old coppices were logged around 20 years ago and are characterized by a higher tree density. The high forest is the most mature oak forest having been logged at least >30 years ago and it is dominated by high and relatively old trees. Finally, conifer plantations, which are densely spaced similarly to the old coppice, were established during the 1970s and are dominated by *P. nigra*. We selected three spatial replicates per forest management type for a total of 12 sampling areas (Fig. 1). In each sampled area we used a trapping grid with 49 traps (7 × 7 with traps spaced 10 m apart). To minimize the edge effect from neighbouring habitats we placed the grids at least 100 m apart from the habitat border.

2.3. Trapping protocol

Demographic data were collected following a capture-mark-recapture protocol. Each of the 12 grids was trapped every other month for three years, starting from September 2011 to July 2014 for a total of 18 trapping sessions. During each session traps were active for three consecutive nights. Live traps (Sherman and L.O.T traps) were baited with a mixture of sunflower seeds, peanut butter and apple, and provided with bedding for thermoregulation. Traps were checked daily early in the morning. Captured individuals were identified at species level, and were subsequently sexed, aged, weighed and marked by toe-clipping. Toe-clipping is a commonly-used method to mark small mammals. Pavone and Boonstra (1985) have noted its potential drawbacks on survival, but several studies found that its effects on vital parameters (such as body weight, survival, etc.) or recapture rate were negligible (e.g. Braude and Ciszek, 1998; Fisher and Plomberg, 2009; Wood and Slade, 1990). Animals were released at the place of capture. Furthermore, since field identification of *A. flavicollis* and its sister species *A. sylvaticus* is particularly challenging in southern Europe, molecular analyses were performed in order to correctly identify the mice species (for details see Bartolommei et al., 2015).

All the procedures of trapping and manipulation of animals took place in compliance with the European Council Directive 92/43EEC (Italian law D.Lgs 157/92 and LR 3/1994) and with the European Council Directive 86/609/EEC (Italian law D.Lgs 116/92).

2.4. Resource assessment

We measured the availability of key resources in each trapping area. Key resources include fruits and acorns (trophic resources) and cover of shrubs (critical for cover and protection from predators) (Amori et al., 2008; Harris and Yalden, 2008).