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Wild boar impact on forest regeneration in the northern Apennines (Italy)

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ABSTRACT

The foraging activities of wild boar (*Sus scrofa* L.) have been suggested to impact biodiversity and ecological processes in a wide array of ecosystems. Data indicate that wild boar affects forest vegetation by feeding on above- and belowground plant parts, as well as by soil disturbance causing plant mortality and influencing seedling recruitment. In this paper, we investigated wild boar impacts on forest regeneration within three different types of mixed deciduous woodlands, respectively dominated by chestnut (*Castanea sativa*), Turkey oak (*Quercus cerris*) and beech (*Fagus sylvatica*) occurring in the northern Apennines (Italy), a mountain area where wild boar numbers have increased rapidly in recent decades. The goal of our study was to present a robust procedure targeted towards estimating wild boar impact on fruits predation and seedling survival of tree species. We evaluated the impact comparing wild boar excluding plots with completely access free ones. Differently from the majority of other experiments, we used replicated exclosure plots (by means of an electro-welded iron grid) excluding wild boars without excluding all other large ungulates such as deer and native small vertebrates. This method, tested with camera trapping surveys, was effective in reducing time spent by wild boar on experimental plots in comparison with other animals. Nevertheless, the number of fruit was similar in the exclosure plots and completely access free plots. Our study demonstrated, however, that wild boar feeds preferentially with the bigger fruits that are visually more attractive and have higher energetic potentialities too. The proportion of seedlings survived at the end of the period studied was significantly higher in wild boar excluding plots compared to those completely access free. Moreover, the dominant species were not equally influenced by the exclosure method, with chestnut and beech more markedly affected with respect to Turkey oak. Finally, the seedling survival of subordinate tree species, compared to the one of dominant plants, was reduced by the activity of wild boars in all the woodlands studied. This impact could lead to reduced tree species richness of the woodlands under study with negative effects on the biodiversity of plants and animals within these ecosystems.

1. Introduction

Forest regeneration process is conditioned by several climatic, environmental and biotic factors. In particular, it is subject to the impact of ungulate herbivores, which could compromise the survival of tree seedlings. Indeed, the effects of ungulate browsing on tree regeneration (e.g. Ammer, 1996; Jorritsma et al., 1999; Reimoser, 2003) are well known, with particular focus on deer browsing (Cutini et al., 2011; Pépin et al., 2006; Ward et al.,

2008). The forest management programs should accordingly take into account the impact of ungulate herbivores, especially in mountain habitats (Côté et al., 2004; Reimoser, 2003; Vavra et al., 2007).

However, ungulate communities are not composed exclusively by deer and bovid species, but also by wild boar (*Sus scrofa* L.). This species is now one of the globally most widely distributed invasive ungulates, and may have pervasive impacts on ecosystem processes, biodiversity and regeneration in temperate forests and many other ecosystems (Barrios-Garcia and Ballari, 2012; Bevins et al., 2014; Campbell and Long, 2009). In its native range in mainland Europe, wild boar numbers have increased rapidly in recent decades (Massei and Genov, 2004); moreover, the species is expanding northwards beyond its preferred habitat of broadleaved forests (Haaverstad et al., 2014). An increasing occurrence pattern

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was documented in the last decades also from central and southern Italy (e.g. Apollonio et al., 2010; Boitani et al., 1995; Massolo and Mazzoni della Stella, 2006).

Population dynamics of wild boar in Europe are mainly determined by the life-history traits of the species, an habitat generalist with omnivorous diet and high fertility (Bieber and Ruf, 2005; Gethöffer et al., 2007), combined with the lack of predators in the more anthropized environments (Saez-Royuela and Telleria, 1986) and the reintroduction for hunting purposes (Long, 2003; Rollins et al., 2007). Winter harshness has a negative impact on wild boar number, whereas a warmer climate and resulting increased frequency of beech and oak mast years contribute to the recent increase in wild boar numbers across Europe (Bieber and Ruf, 2005; Melis et al., 2006). Given the high ecological and socio-economic impacts of the species (Pimentel et al., 2000), wild boar management is a growing concern for public administrations and conservation agencies (Bieber and Ruf, 2005; Monaco et al., 2010).

Wild boars are opportunistic omnivores feeding on all types of organic matter through four main feeding behaviours: browsing and grazing (grasses, herbs, stems, leaves), foraging on the ground (fruits, fungi, animal matter), rooting (rhizomes, roots, invertebrates), and predation (Ballari and Barrios-García, 2014 and references therein). Above-ground parts of plants comprise the higher percentage of organic matter ingested (Eriksson and Petrov, 1995; Herrero et al., 2005), whereas belowground plant parts are frequently of lesser importance as food (Eriksson and Petrov, 1995; Irizar et al., 2004). Indeed, rooting is frequently used when above-ground resources are scarce (e.g. in winter and early spring; Baron, 1982; Barrett, 1978; Scott, 1973). Among different above-ground plant matters, wild boars eat fruits and seeds (Herrero et al., 2005; Irizar et al., 2004), which are especially abundant in summer, but are available throughout the year (Baubet et al., 2004; Herrero et al., 2004), and provide a great source of energy during periods of food scarcity (Barrett, 1978; Belden and Frankenberger, 1990; Loggins et al., 2002). Moreover, wild boars consume large quantities of tree seedling and their rooting activities have been assessed to play a role in seedling removal (Gómez and Hódar, 2008; Lipscomb, 1989; Mayer et al., 2000). These remarks underline the need to quantify the influences of wild boar activities on forest regeneration process.

The results of a study conducted in Spain showed that energy resource for pigs reared in the wild derived for 90% from acorn crops and just for 10% from grass species (Rodríguez-Estévez et al., 2010). Moreover, the acorn quality and especially their seed vessel influenced the fruits digestibility and, consequently, the energy quality (Nieto et al., 2002). Therefore, in agreement with the optimal foraging theory, pigs prefer biggest acorn crops (Rodríguez-Estévez et al., 2008) and learn to recognize with visual stimulus bigger and better preserved acorns (Rodríguez-Estévez et al., 2009). If pigs reared in the wild are able to develop this selection system on acorn crops it is possible to hypothesise that also wild boars direct their foraging activities on high quality food.

The impact of wild boars on agricultural and productive lands is well known (Frackowiak et al., 2013; Geisser and Reyer, 2004; Saito et al., 2011) and many studies on the diet of this ungulate underlined the importance of crops species (Dardaillon, 1987; Herrero et al., 2006; Nores et al., 1999; Schley and Roper, 2003). The damages to tree species are, conversely, more poorly documented, even if, in the last years, some authors investigated wild boar impact on forest species, to increase knowledge about the delicate relationship between forest regeneration and ungulates, on which wild boars play a key role (Brunet et al., 2016; Fagiani et al., 2014; Gómez, 2004; Haaverstad et al., 2014; Kamler et al., 2016; Parkes et al., 2015; Siemann et al., 2009; Taylor et al., 2011). Many studies considered the impacts of ungulates on plants comparing different forest areas with free access or exclusion of

all ungulate species or of large terrestrial mammals in temperate and tropical regions (e.g. Cutini et al., 2011; Ickes et al., 2001; Rooke et al., 2004). Consequently, in these studies wild boar impacts were not separately evaluated, but within more general impacts of all ungulate or mammal species occurring in the area (Bergvall et al., 2006). In all the experiments, the exclosures were delimited by chain-link fences. Presently, we know only few experiments using replicated exclosures excluding wild boars without excluding all other large ungulates such as deer and native small vertebrates (Sweitzer and Van Vuren, 2002; Siemann et al., 2009; Taylor et al., 2011). Anyway, also in these experiments, the exclusion of wild boar was obtained by fences of different height.

The present study takes into consideration the relationship between wild boar and forest focussing on three tree species widely distributed and in the northern Apennines, where they form distinct woodland communities: chestnut (*Castanea sativa* Mill.), Turkey oak (*Quercus cerris* L.) and beech (*Fagus sylvatica* L.). Bearing in mind that wild boar predation on fruits coupled with rooting induced damages on seedlings could affect forest regeneration, the main goals of this study were:

(i) to assess the effectiveness of a new exclosure method, combined with camera trapping surveys;
(ii) to estimate wild boar impact on forest regeneration as fruit predation;
(iii) to verify the occurrence of a positive selection in relation to fruit quality;
(iv) evaluate wild boar impact on forest regeneration through seedling survival of dominant and subordinate tree species.

2. Materials and methods

2.1. Study area

The study was conducted within an area lying in the Massa-Carrara province (Tuscany region, Italy) (Fig. 1). The area spans about 377 km² and approximately extends from about 44°32′ to 44°29′N and from about 10°03′ to 10°13′E on the south-western slope of the Tuscan-Emilian Apennines. The elevation ranges from 160 to 1240 m above sea level.

The area has a temperate, sub-oceanic climate, with a mean annual temperature ranging from about 10 to 13 °C and a mean annual precipitation of about 1500 mm (Farina, 1980). Mixed deciduous woodlands with a high percentage of chestnut, Turkey oak and beech dominate the territory (Ferrarini, 1974).

2.2. Study design

Many studies used exclosures to investigate the impact of ungulates on forest regeneration without the opportunity of selecting a single species in relation to damages produced (Bergvall et al., 2006; Cutini et al., 2011; Rooke et al., 2004). In our study, we investigated the wild boar impact on forest regeneration by means of a new exclosure method developed specifically for reducing wild boar activity, using an electro-welded iron square grid of 1 × 1 m with a mesh size of 10 × 10 cm (Appendix A). This iron square grid was placed at 10 cm above the soil surface, so that the wild boar nose could not reach the fruits or other resources under the grid. However, the size of the mesh allowed other wildlife species (i.e. roe deer, badger, birds, etc.) to take resources even under the grid. Each grid was locked to ground with an iron hook at each corner.

At each site, we established two 1 × 1 m permanent plots, the first under the iron grid (from now on named WBE, wild boar excluding) and the second adjacent to the grid (from now on named CAF, completely access free) and marked with metal sticks. The choice of using two adjacent areas enabled us to exclude a