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# Saproxylic beetles in three relict beech forests of central Italy: Analysis of environmental parameters and implications for forest management

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ABSTRACT

Three relict beech forest of central Italy were surveyed by different trap types: pitfall traps, and three different types of windows flight traps. Species richness and similarity of saproxylic beetles among the study areas were compared using Chao's indexes. Species composition and abundance were compared in order to test the influence of two trap factors on the catches of saproxylic beetles: the height effect and the colour effect (transparent or black panels). Redundancy Analysis was used to describe the factors affecting abundance and the occurrence of saproxylic beetles through some selected environmental variables at tree scale (tree diameter, canopy closure, tree cavity) and at plot scale (dead wood typology and decay class). The species richness and composition do not vary among the studied areas. The comparison among traps type showed changes in saproxylic beetle assemblages from the ground level to the canopy closure. On the contrary, trap colour did not influence the species composition. A combination of standardized and replicable pitfall and windows traps is suitable to compare the saproxylic fauna. The analysis performed at tree scale, revealed a different correlation between tree-dependent variables and saproxylic beetle richness and abundance for each trap type. Three dead wood variables at plot scale (the amount of standing dead trees, stumps and large branches on the ground) appeared to be good predictors of saproxylic beetle richness.



## 1. Introduction

Understanding the factors that affect species diversity is one of the most important challenges for conservation biology, especially in high diverse assemblages of saproxylic invertebrates in forest ecosystems, which are the most threatened animal assemblages in European forests (Grove, 2002; McLean and Speight, 1993; Nieto and Alexander, 2010; Stokland et al., 2012). Beetles make up the highest percentage of forest diversity among saproxylic organisms, and they act as a keystone in forest dynamics, as they contribute to the wood mass degradation, soil fertility and the incorporation of nutrients into the ecosystems (Buse et al., 2009; Grove, 2002; Micó et al., 2011). Stand structure, tree species composition, dead wood volume and arboreal microhabitats are important factors which affect forest biodiversity (Hunter, 1999; Lindhe and Lindelöw, 2004; Müller et al., 2012; Paillet et al., 2010; Regnery et al., 2013). Many species depend on tree microhabitats for food, shelter and breeding habitat (Michel and Winter, 2009; Vuidot et al., 2011; Winter and Möller, 2008). For example, dead branches are important food sources for saproxylic insects and fungi while tree cavities provide habitats for breeding birds, mammals and invertebrates but also lichens and bryophytes (Fritz and Heilmann-Clausen, 2010; Jonsell and Nordlander, 2002; Lučan et al., 2009; Parsons et al., 2003; Ranius, 2002; Vanderwel et al., 2006). Most saproxylic beetles are small, cryptic, and difficult to sample (Bouget et al., 2008). These features, together with the high number of species and trophic roles in saproxylic assemblages, makes their study challenging. Saproxylic insects have increasingly been studied over the past 20 years, especially in northern and central Europe, mainly because they make up one of the largest groups of red-listed species in many countries and have been particularly affected by forest management. On the contrary, ecological studies focused on the whole community of saproxylic beetles in southern Europe are scarce and restricted to some areas of Spain and south France (Bouget et al., 2008, 2009; Brin and Brustel, 2006; Dodelin, 2006; Micó et al., 2013; Quinto et al., 2013; Ricarte et al., 2009; Sirami et al., 2008). There are only two studies published on saproxylic beetle community in Italy, one dealt with some selected beetle families from a floodplain remnant forest in the Po Valley (Hardersen et al., 2012), another one on the taxonomical and

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functional biodiversity of saproxylic fungi and beetles in southern Italy (Persiani et al., 2010). As the majority of saproxylic insect diversity, in terms of species richness, is represented by beetles (Dajoz, 1980) and occurs in the southernmost regions of Europe (Nieto and Alexander, 2010), ecological studies on the saproxylic beetle communities in Italian woodlands are a priority objective for planning biodiversity conservation at European level.

Europe has the global responsibility to conserve forests dominated by *Fagus sylvatica* (Knapp and Spangenberg, 2007), which is endemic to Europe and is one of the major tree species of this continent, covering ca. 14–15 M ha of forest (Brunet et al., 2010). Increasing awareness of biodiversity loss in managed beech forests has resulted in considerable research efforts, e.g. the EU programme Nat-Man and other projects at national level within the framework of Natura 2000 (Brunet and Fritz, 2011; Heilmann-Clausen, 2011; Ódor et al., 2006; Tzonev, 2011; Vraska et al., 2011). In recent years the number of scientific papers on saproxylic organisms of beech forest in Europe is increased (Brunet and Isacsson, 2009a,b; Brunet et al., 2010; Lachat et al., 2012; Müller and Bussler, 2008; Müller et al., 2007, 2012; Schiegg, 2001).

The aim of the present work is to explore the saproxylic communities of three relict lowland beech forests of central Italy, with the following objectives: (1) to evaluate species richness and similarity of beetle assemblages among the study areas; (2) to compare the catchability of two pairs of traps combined respectively to evaluate the effects of their position (pitfall/single plane window flight traps) and colour (transparent/black cross window flight traps) in studying species composition and abundance of beetle assemblages; (3) to test the effect of variables at tree scale (diameter, canopy, cavity) and plot scale (dead wood volume, typology and decay class) on the species composition and abundance of beetle assemblages.

## 2. Materials and methods

### 2.1. Study areas

The study was carried out in three relict forest fragments consisting of old-growth forests dominated by beech trees (*F. sylvatica*), located in central Italy (Lazio Region): Allumiere (WGS84N 42°09′E 11°54′), Oriolo Romano (WGS84N 42°09′E 12°09′) and Monte Venere (WGS84N 42°21′E 12°11′). The three study areas are Sites of Community Importance (SIC) for the EU Habitats Directive: "Boschi Mesofili di Allumiere" (SIC IT 6030003), "Faggeta Monte Raschio e Oriolo" (SIC IT 6010034) and "Monte Fogliano e Monte Venere" (SIC IT 6010023). Moreover, Monte Venere and Oriolo Romano are located within two protected areas, namely the "Riserva Naturale Lago di Vico" and the "Parco Naturale Regionale Bracciano – Martignano", established respectively in 1982 and 1999.

Despite the long lasting history of human utilization that modified for millennia the Italian landscape, still nowadays it is possible to find patches of old-growth forests in Central Italy (Piovesan et al., 2010). An old-growth forest is dominated by old trees and may be or not a primary forest, i.e. never logged. In any case, it is considered to look like a primary forest because of a high degree of naturalness and a long time since the last major disturbance (Frelich and Reich, 2003; Spies, 2004). The three forest stands investigated are located at 400–800 m a.s.l (under the usual altitudinal range of beech forests in central Italy, 1000–1800 m a.s.l.). Their size varies from 60 ha (Allumiere and Oriolo Romano) to 170 ha (Monte Venere). Since 1994 they were left to develop under almost natural conditions, thanks to their status of Sites of Community Importance. Low-elevation beech forests (400–800 m a.s.l.) are typically located on fertile (e.g., volcanic) soils, in foggy areas near lakes or at short distance from the sea coast, where they may experience a surprisingly fast structural diversification (Piovesan et al., 2011); in our case, Monte Venere and Oriolo Romano are near to Vico and Bracciano lakes, while Allumiere is about 20 km from the Tyrrhenian coast.

An effect of low altitude is the rich composition of the tree and shrub layers, characterized by the coexistence of mesophilic (e.g. *F. sylvatica*, *Quercus cerris*, *Q. petraea*, *Carpinus betulus*, *Ostrya carpinifolia*, *Acer monspessulanum*, *A. pseudoplatanus*, *Ilex aquifolium*, *Castanea sativa*, *Ruscus aculeatus*) and Mediterranean species (e.g. *Quercus ilex*, *Erica arborea*, *Spartium junceum*).

### 2.2. Beetle trapping

A standardized method for sampling saproxylic beetle communities has yet to be developed, owing to the coexistence of many different guilds, each with own peculiarities in terms of dispersal activity, spatial and temporal distribution and microhabitat occupancy, which need specialized sampling techniques. A combination of sampling methods is usually required to obtain a comprehensive information on saproxylic communities (Alinvi et al., 2007; Bouget et al., 2008; Martikainen and Kouki, 2003; Ozanne, 2005).

Several trap types have been used to sample saproxylic beetles both in Europe and North America (Alinvi et al., 2007; Bouget et al., 2008; Hammond, 1997; Hammond et al., 2004; Jansson and Coskun, 2008; Langor et al., 2008; Økland, 1996; Ranius and Jansson, 2002; Ulyshen and Hanula, 2007; Webb et al., 2008). Beetle species are known to fly and disperse at different heights, in forest ecosystems (Speight, 1989). To obtain a comprehensive knowledge of beetle fauna in the three beech forests, we selected four different trap types that capture at different levels, i.e., at basal cavities (pitfall traps, PT) or at trunk and at the lower layer of the canopy closure (window flight traps, WFT). We used different types of window flight traps: single plane windows flight trap (PWFT), transparent cross windows flight trap (TCWFT) and black cross windows flight trap (BCWFT) (Bouget et al., 2008; Brustel, 2004).

Pitfall traps are transparent plastic glasses with a top diameter of 6.5 cm, and were placed in the cavity, so that their rims were at level with the wood mould surface. Window flight traps consist of a vertical barrier (usually transparent) to insect flight that is considered invisible to the insect. On hitting the barrier, most beetles drop down and fall into a plastic container with a liquid preservative. PWFT consisting of a $5 \times 15$ cm single transparent plastic panel, were hung on a branch and placed at the lower layer of the canopy, around 10 m above the ground. A comparison between PT and PWFT should show differences in species composition and abundance between the basal cavities and the lower layer of the canopy.

In TCWFT and BCWFT, analogous to the multidirectional Polytrap™ (EIP, Toulouse, France; Bouget et al., 2008; Brustel, 2004), the barrier is formed by two crossing plastic panels of $30 \times 60$ cm, transparent (TCWFT) or black (BCWFT) respectively. In the case of BCWFT the colour black of the panel has the function to imitate a cavity, to combine two principles: interception and shade attraction ("silhouette", according to Bouget et al., 2008). A comparison between these two trap types should obtain different proportions of true saproxylic species (higher in BCWFT). These traps were hung on a branch close to the trunk, at a height of 2–3 m above the ground. We usually placed TCWFT in front of a cavity entrance; in absence of the latter, the trap was placed in optional situations such as in front of beetle's emergence holes, woodpecker's holes or tree sectors severely attacked by fungi. Indeed, these situations represent a clear sign of the activity of saproxylic beetles. Beetles are the best-known group of invertebrates that live in decaying woody material of different kind, such as the inner surface of bark, or wood moderately or substantially decomposed by fungi