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Response of bat species to sylvo-pastoral abandonment

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ABSTRACT

We assessed the effect of abandonment of sylvo-pastoral practices in chestnut orchards (*Castanea sativa*) on bats in southern Switzerland to determine practical recommendations for bat conservation. We compared bat species richness and foraging activities between traditionally managed and unmanaged chestnut orchards, testing the hypothesis that managed orchards provide better foraging opportunities and harbour more bat species. Echolocation calls of foraging bats were sampled simultaneously at paired sites of managed and unmanaged orchards using custom made recorders. Vegetation structure and aerial insect availability were sampled at the recording sites and used as explanatory variables in the model. In a paired sampling design, we found twice the number of bat species (12) and five times higher total foraging activity in the managed chestnut orchards compared to the unmanaged ones. Bat species with low flight manoeuvrability were 14 times more common in managed orchards, whereas bats with medium to high manoeuvrability were only 5 times more common than in abandoned orchards. The vegetation structure was less dense in managed orchards. However, management did not affect relative insect abundance. Bats primarily visited the most open orchards, free of undergrowth. As a result of restricted access into the overgrown forests, the abandonment of chestnut orchards leads to a decline in bat species richness and foraging activities. Continued management of chestnut orchards to maintain an open structure is important for the conservation of endangered bat species in the southern Swiss Alps.

1. Introduction

Traditional forest clearing and agricultural practices in European landscapes have historically generated a mosaic of forests at different development stages, as well as permanent open stands and open agricultural areas. Although inadequate for forest specialists, this mosaic landscape favours species that prefer open habitats, and supports high species diversity (Blondel and Aronso, 1999). Recently, in the Swiss Alps, the combination of regional depopulation of rural areas and the abandonment of agriculture has lead to major changes in the ecosystem (Dirnböck et al., 2003). The subsequent renaturation of traditional landscape patterns into forests can lead to reduced biodiversity (Blondel and Aronso, 1999). However, although the effects of abandonment of traditional practices of cultivating and pasturing chestnut orchards are controversial, generally a mosaic of abandonment and active management seems favourable to biodiversity (e.g. McNeely, 1994; MacDonald et al., 2000; Benayas et al., 2007).

At present, chestnut orchards cover 0.4 million hectares in Europe or 17.7% of the total chestnut-growing area, with 80% concentrated in Italy and France (Conedera et al., 2004). In southern Switzerland, the area with chestnut orchard decreased from 9500 ha to 3000 ha in the last century (Stierlin and Ulmer, 1999). Since early medieval times traditionally managed sweet chestnut (*Castanea sativa* Mill.) orchards have formed a typical landscape element in the mountains of southern Europe (Conedera et al., 2004). The chestnut trees are grafted for fruit production and the orchards have a permanent open structure intercropped with cereals, hay or pasture (agro-sylvo-pastoral systems). With the rural depopulation of the last century and changes in human food consumption,

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this management scheme has become dramatically reduced. This trend has been further amended by the introduction and spread of chestnut diseases (Conedera and Krebs, 2008). Abandoned orchards are quickly invaded by other tree species, evolve into dense mixed forests and, within decades, disappear entirely (Conedera et al., 2000).

Since the late 1980s, an increasing interest in chestnut orchards as traditional landscape element has lead to a revitalization of orchards for their aesthetic value (recreation), as fire-break areas, and for economic reasons (tourism) (Conedera et al., 2004). However, the costs of orchard restoration and maintenance are high, and the impacts on biodiversity and species of special conservation concern have not yet been assessed. Restoration of traditional, small to medium sized chestnut orchards conserves large, old trees thereby providing shelter for many species that use cavities. Such moderate management may positively affect biodiversity as a whole, including endangered species that depend on old trees. Among the species that may potentially benefit from such restoration, insectivorous bats (Microchiroptera) constitute one of the most endangered taxonomic groups worldwide (Arita, 1993; Ceballos and Brown, 1995; Mickleburgh et al., 2002; Safi and Kerth, 2004; Schaub et al., 2007; Weller et al., 2008), and particularly in Europe where, of the 25 species on the red-list for southern Switzerland only *Pipistrellus pipistrellus* and *Pipistrellus kuhlii* were classified as not vulnerable (Duelli, 1994).

Many studies have investigated the relationship between bats and the structure and composition of forested habitat (Crome and Richards, 1988; Lumsden and Bennett, 2005) and forest management (Menzel et al., 2002; Patriquin and Barclay, 2003; Clarke et al., 2005b; Castro-Arellano et al., 2007; Presley et al., 2008). Hayes and Loeb (2007) present a comprehensive review of work done on the influence of forest management on bats in North America. With few exceptions (e.g. Jaberg et al., 2007; Duchamp and Swihart, 2008), most of these studies show higher bat activity and diversity in openings and in less dense forest stands, which are comparable to managed chestnut orchards. Studies from tropical regions indicate that management of forested areas with e.g. reduced impact logging and even tropical agroforestry systems can maintain species richness of bat assemblages with only small effects on species composition (Castro-Arellano et al., 2007; Harvey and Villalobos, 2007; Presley et al., 2008). Finally, Davy et al. (2007) emphasize the value of agriculturally cultivated olive groves as possible buffer to deforestation. In a fine-scale forest mosaic landscapes, as encountered in Switzerland, bat presence may be most influenced by changes in habitat quality or hampered accessibility for foraging in densely overgrown stands.

For bats, accessibility to spatially cluttered foraging habitat is largely governed by their flight manoeuvrability. These flight abilities and the type of orientation have coevolved in bats in adaptation to their main foraging environment (Neuweiler, 1984). Long and narrow wings (high wing loading) are associated with fast flight and foraging at higher altitudes away from acoustic obstacles (clutter) (sensu Fenton, 1990). Species with broad wings (low wing loading) fly slowly and are highly manoeuvrable within, or very close to, clutter (Fenton, 1990). Bats must be able to avoid obstacles, which affect flight and foraging efficiency (Schnitzler and Kalko, 2001). They efficiently do so as experimentally shown by Brigham et al. (1997). Some bats avoid regions of high structural clutter by commuting and foraging along open structures as trails, gaps and edges (Lloyd et al., 2006; Caras and Korine, 2009; Hein et al., 2009). In traditionally managed chestnut orchards, the understory is reduced, thus improving the accessibility for bats with higher wing loading. Clutter tolerant species with low wing loading should be less affected by reduced accessibility and prevail in unmanaged forests, while less clutter tolerant species with high wing loading should be biased towards more open, managed forests.

The aims of this study were (i) to investigate the effect of managing abandoned chestnut orchards on bat species diversity and activity (foraging, commuting and searching), (ii) to test the significance of management-induced changes in vegetation structure and food availability (aerial insect abundance), and (iii) to provide recommendations that may improve bat conservation in chestnut orchards. As management reduces undergrowth vegetation and thus enhances accessibility of orchards, we expected a higher number of bat species and higher activity in managed chestnut orchards, but lower relative insect abundance due to less available organic matter. Furthermore, as wing morphology and body weight define the flight performance of bats (Norberg and Rayner, 1987), and thus their spatial foraging niches (Neuweiler, 1984), we expected management to have a more profound effect on less manoeuvrable species.

2. Methods

2.1. Study area and orchard stands

The study was carried out along the sweet chestnut belt between 200 and 1000 m above sea level, on the southern slope of the Swiss Alps (45.9–46.5°N, 8.1°E and 9.2°E; Fig. 1), in the Canton Ticino. In this region, most of the formerly managed chestnut orchards are now abandoned and invaded by shrubs and trees.

Candidate orchards were evaluated by comparing chestnut distribution maps of 1959 and 2000, field assessment of management state, and interviews with orchard owners. Orchards were classed as unmanaged when management had ceased ≥30 years ago, while managed orchards were defined as those currently, or within the past 15 years, maintained by pruning, mowing, or grazing. The final set of paired sample sites consisted of 30 managed and 30 unmanaged chestnut orchards. Paired sites were of similar geography (average Euclidian distance between paired treatments: 916 m, range 110–3451 m), slope, exposition and elevation, and covered the major distribution area of chestnut orchards in the region (Fig. 1). Distance between sampling pairs was an average 23.2 km and distance to closest pairs an average 1.6 km with only two pairs being closer than 500 m to a second. Management area varied between orchards from less than 5 ha ($n = 17$) to more than 20 ha ($n = 5$) with 7 intermediate sites. Landscape characteristics around the sites were analysed for forested, open and built areas within ranges of 1, 2 and 5 km radius with GIS. Land use did not differ significantly between treatments within these ranges, with forested areas covering an average 50–60%, open areas 30–40% and built areas contributing with 8–10%. Forest canopy and undergrowth were generally more open and the grass more lush in managed chestnut stands, while unmanaged stands showed more closed canopies and were often invaded by other tree species and shrubs.

2.2. Bat recording and call identification

Bat activity was recorded from 02-June-2005 to 05-September-2005 during 30 full nights, one night per treatment pair. Two equivalent sets of recording equipment (Obrist et al., 2004b) were simultaneously placed in each paired site.

For optimal site-coverage, five custom-built microphones (frequency response ±3 dB from 20 to 120 kHz; Ultrasound Advice, London, UK) connected to a central recording unit were dispersed around the centre of each orchard, and ≥20 m away from its edge. Microphones were set 1 m above ground pointing 45° upwards, 20–150 m away from the recording unit and ≥20 m from each other. Obstruction by close leaves or branches in the recording direction was avoided. Bat echolocation was digitally recorded with PCMCIA data acquisition cards (PCCARD-DAS16/330, Measurement