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Nest density, nest-site selection, and breeding success of birds in vineyards: Management implications for conservation in a highly intensive farming system

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ABSTRACT

Increasing intensification in vineyards has detrimental effects on biodiversity. Although several studies addressed this topic, the reproductive outcomes of model organisms in vineyards received little attention.
We carrie d out the first study on birds nesting in natural nests on vines, focusing on nest density, breeding performance and nest-site selection in organic and conventional systems and in two contrasting trellising systems, *pergola* (taller, with more spaced rows and a denser canopy) vs. *spalliera*.
We surveyed 228 nests of six species and analysed nest densities and final fates as a function of vineyard management and trellising system by means of GLM(M)s.
51% of nests were abandoned before egg-laying and the probability of early abandonment was positively related to the amount of access farmers had for management activities. The number of nests was four times higher in *pergola* than in *spalliera* vineyards, likely due to *pergola*'s complex and tree-like structure. Organic or conventional management did not affect nest density, probably due to reduced differences in terms of management practices between them. Breeding success was low and marginally affected by the interaction of the management and trellising systems, being higher in conventional *pergola*.
Nests were preferentially built on larger vines and were placed at an increasing height on the vine as the season progressed. Nests built at greater heights had greater success.
We provide some management recommendations for bird conservation in vineyards: promoting *pergola* and maintaining older vineyards, limiting grass mowing in April and May, and in compatibility with agricultural management, optimising the amount of farmers' access to vineyards.

1. Introduction

The detrimental impact exerted by intensive agriculture on ecosystems and the environment is widely recognised and is predicted to further increase through the 21st Century (Norris, 2008).

In Europe, agricultural intensification resulted in severe depletion of farmland bird populations (Donald et al., 2006, 2001), avian abundance and biomass are still severely declining, and the trend for many common and widespread farmland species is particularly concerning (Inger et al., 2014).

Nevertheless, agroecosystems could still harbour rich biodiversity (Perrings et al., 2006), and there is a requirement for adequate knowledge that lead to effective agricultural policies in which biodiversity conservation is effectively addressed (Rands et al., 2010).

Permanent crops (e.g. orchards and vineyards) are the third largest farming system by area in Europe (Iglesias et al., 2011) and have experienced strong intensification (Caraveli, 2000), with detrimental effects on biodiversity (Plieninger et al., 2006; Brambilla et al., 2015) as is the case with many other crops. Intensification in permanent crops may impact biodiversity at both the landscape and the field scale and is usually associated with increased fertilizer and pesticide inputs, deep ploughing, homogenization of biotic communities, and habitat fragmentation (Tscharntke et al., 2005).

Notwithstanding, the biodiversity of vineyards and orchards in Europe has received scarce attention from ecologists and conservationists; as a consequence of this, the factors affecting plants and animals in these agroecosystems are poorly known (Balmford et al., 2012; Batáry et al., 2011), preventing the formulation of adequate management recommendations. This critical situation is exacerbated by the exemption

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of permanent cultivations from the 'greening' measures introduced with the recent 2013 reform of the Common Agricultural Policy, specifically designed to reduce the negative impact of agriculture on the EU environment (Pe'er et al., 2014).

Vineyards are among the most widespread permanent crops in the Mediterranean region. In the last few decades, vineyards have been subjected to severe intensification, with consequent substantial loss of habitats and biodiversity (Viers et al., 2013). Now, wine producers are increasingly aware that environmental quality is also perceived by consumers as important for wine quality (Tempesta et al., 2010). As a consequence, landscape and biodiversity are acquiring a new economic value, and in this context, organic viticulture is increasingly regarded as a way to accommodate the rising consumers' demand for healthier and sustainable products (Zucca et al., 2009).

Organic agriculture, indeed, has been reported to reduce the environmental impacts of agriculture (Lynch et al., 2012; Tuomisto et al., 2012), with only limited loss of yields (Seufert et al., 2012). The organic management system is also associated with the quality and healthiness of products (Smith-Spangler et al., 2012) and is perceived as providing more ecosystem services than the conventional regime (Sandhu et al., 2010). The effects of organic agriculture on biodiversity are highly debated and system-dependent. The organic regime has been reported to have positive effects on biodiversity compared with conventional systems (Tuck et al., 2014); however, the effects are highly variable and depend upon scale, crop type, taxa considered, and especially landscape complexity with greater effects at field scale, on arable lands, on poorly mobile species, and in homogeneous landscapes (Fuller et al., 2005; Gabriel et al., 2010; Lorenz and Lal, 2016; Winqvist et al., 2012).

In viticulture, some authors claimed positive effects of organic agriculture both on the diversity and abundance of plants (Nascimbene et al., 2012) and arthropods (Isaia et al., 2006; Sabbatini Peverieri et al., 2009). Conversely, other studies found no effects using the same or similar indicators (Bruggisser et al., 2010; Rusch et al., 2015).

Although birds are valuable biodiversity indicators (Gregory et al., 2005), very few studies have assessed the impact of viticulture on this taxon. Those available deal mainly with avian diversity (Assandri et al., 2016; Pithon et al., 2015; Sierro and Arlettaz, 2003), but analyses on whole communities at coarse scales cannot consider the fine-scale ecological requirements of individual species, which have been investigated by only a few studies (Arlettaz et al., 2012; Isenmann and Debout, 2000; Swolgaard et al., 2008). Assessments of the effects of organic viticulture on birds are even scarcer, with no effects detected on communities (Assandri et al., 2016) and negative effects reported for woodlarks, *Lullula arborea*, due to the dense swards found in organic fields which are unsuitable for the species (Arlettaz et al., 2012).

Reproduction is the most critical phase in the life cycle of most bird species (Lofts and Murton, 1973), and during it birds experience a variety of stressors, which affect fitness (Hanssen et al., 2005).

Studying the reproductive performance of bird species in vineyards with different management regimes is urgently needed to understand their impact on avian populations.

To the best of our knowledge, no study has considered birds nesting in vineyards in natural nests (i.e. not in nest-boxes). We aim to provide a pilot study in that sense, and again stress the importance of investigating the reproductive outcomes of model organisms in this intensive and highly managed habitat. Specifically, with this study, we aim to: i) evaluate the effect on bird nest density and breeding success of organic and conventional farming in two different vineyard systems; ii) evaluate the effect of management activities on nest survival; iii) describe the nest-site selection, the nesting phenology, and the factors affecting them in this human-shaped landscape; iv) propose best-practices and practical management recommendations to promote bird conservation in vineyards.

2. Materials and methods

2.1. Study area and experimental design

The study was carried out in the Piana Rotaliana lowland (200–230 m a.s.l.), located at the confluence of the Non Valley into the Adige Valley, in Trento Province (Northern Italy; Fig. 1a–b).

The alluvial soil of the area and the relatively warm climate are particularly favourable for viticulture, which is by far the dominant land use, along with apple orchards and urban areas and infrastructures.

Viticulture in this area is very intensive (large usage of chemicals, high levels of mechanisation, and water supplementation), and the resulting landscape is dominated by large patches of monoculture and considered "simple" (sensu Batáry et al., 2011), since the semi-natural habitats that remain account for <10% of the overall area and are mostly limited to river banks. Even hedgerows and isolated trees, which characterise other agroecosystems in the neighbouring areas (Assandri et al., 2016), are also severely reduced, with mean estimated densities of 18 m/ha and 0.2 tree/ha, respectively.

Two vineyard trellising systems occur: *pergola* and *spalliera* (Fig. 2). *Pergola* consists of tall vines (up to 2.5 m considering the secondary branches and grow into a dense leaf "roof"), supported by a robust structure of poles and beams. *Spalliera* is similar to a number of row-based trellising systems with lateral cordons occurring in most vine production areas worldwide (also known as espalier). It is characterised by low vines (generally <2 m) supported by wires held between poles. *Pergola* implies a greater distance among vine rows (up to 5 m) than the *spalliera* arrangement (generally <2 m). In *pergola* vineyards, some mechanical activities (e.g. mechanical harvesting and pruning) are not allowed, but in general the management practices do not differ between the two trellising systems. *Pergola* is the traditional and predominant form in the region (80% of the vineyard surface in Trentino; Chemolli et al., 2007). At least in the last few years, recent trends in regional viticulture led to a progressive replacement of *pergola* by *spalliera*, which can also successfully be grown at higher altitudes on steeper slopes, allows a higher degree of mechanisation and is apparently more suitable for the production of several renowned white vines (Chemolli et al., 2007).

Vines in the area are managed according either to conventional or organic regimes, but the latter is very rare (although increasing) in Trentino and accounts for <3% of the entire area covered by vineyards (our estimation based on unpublished public data). In organic viticulture, synthetic fungicides, insecticides, fertilizers and herbicides are not allowed, whereas sulphur, copper (as fungicides) and pyrethrins (as insecticides) are used.

Within the study area we selected 21 vineyards accounting for total 15.64 ha, subdivided as follow: 4.09 ha of organic *spalliera* (3 vineyards), 3.53 ha of conventional *spalliera* (3), 3.72 ha of organic *pergola* (8), 4.30 ha of conventional *pergola* (7) (Fig. 1c). Organic vineyards were all certified as such for at least four years. The different number of plots per category was imposed by the fact that the two trellising systems also differ in their average vineyard extension (smaller parcels in *pergola* than in *spalliera*), but we tried to sample a similar overall extent per each category.

It was not possible to choose study plots randomly or with perfectly homogeneous landscape surroundings (e.g. with the same amount of urban or semi-natural habitats in a determined radius from the plot) especially due to the scarce and uneven distribution of organic vineyards in the study area. Thus, we selected eight farms which supported the project and agreed to provide some data about agricultural activities carried out in each vineyards, allowing us to conduct specific analyses (otherwise impossible) on the effect of management practices on bird reproduction. However, excluding the differences explicitly determined by the design, all the plots were quite uniform and representative of the typical intensive vineyard found in the Piana Rotaliana.