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Management systems may affect the feeding ecology of great tits *Parus major* nesting in vineyards

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ABSTRACT

The current intensification of agriculture is leading to growing concern about the sustainability of modern farming systems, since farmland biodiversity has severely declined. While several studies have shown that vineyard management systems (*i.e.* organic *vs.* conventional) are important factors determining biodiversity and influencing population trends, there is a paucity of studies focusing on the effects at finer levels, such as breeding behaviour, habitat selection and movements. Here, we examined the effects of vineyard management systems on the breeding ecology of great tits (*Parus major*) in north-western Italy. We used nest-boxes to video-record feeding efforts of parents, and radio-telemetry to detect the movements of the males. Habitat composition between the two management systems differed. Organic vineyards were characterized by a high grass cover and the presence of fruit trees, while the presence of bare ground and the use of herbicides were typical for conventional vineyards. The number of nestlings fed by parents per visit and the weight of nine day old nestlings were significantly higher in organic than in conventional vineyards. The diet of nestlings was unaffected by the management system, but depended on the landscape characteristics. Caterpillars were the favourite prey in forest-dominated areas, whereas other invertebrates increased in vineyard-dominated areas. Feeding home range was also independent of the management system, but depended on the age of males (larger in adults). Habitat selection of feeding parents within home ranges was non-random in relation to habitat availability and changed according to the distance from the nest: parents selected forests when they moved far from the nest and used vineyards when remaining in the surroundings of the nest-box. Our results suggest that management systems may affect parental feeding ecology of great tits nesting in vineyards. Differences in the number of nestlings fed per visit and in the weight of the nestlings suggest that conventional vineyards offer fewer feeding resources (and/or of lower quality) than organic vineyards, with potential negative effects on survival of juveniles.

1. Introduction

The expansion of agricultural land is widely recognized as one of the most significant anthropic environmental changes. The overall surface of cultivated land worldwide increased by 466% from 1700 to 1980 (Meyer and Turner, 1992). While the rate of expansion has slowed over the past three decades, the yield (*i.e.* the amount of food produced per unit area of cultivated land) has increased dramatically (Naylor, 1996), which has also been supported by economic and technological incentives to increase productivity. Agroecosystems are sustained by diverse inputs, such as human labour and petrochemical energy and products, which replace and supplement the functioning of many ecosystems. The current intensification of agriculture is leading to growing concern about the sustainability of farming systems, since farmland biodiversity has declined severely (Kleijn et al., 2011; Vickery et al., 2004; Woodcock et al., 2013). This is particularly important because modern agriculture has resulted in a loss of diversity (Aue et al., 2014) due to the homogenization in terms of crops grown and the increase of the yield per area on both animal (Donald et al., 2006; Vickery et al., 2004; Fuller et al., 2005; MacDonald et al., 2012; Assandri et al., 2017) and plant diversity (Buhk et al., 2017).

There is evidence that 19 out of 46 farmland bird species significantly declined throughout Europe as a consequence of agricultural practices and intensification (Donald et al., 2006).

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Organic farming systems are believed to have less environmental impact than conventional intensive agriculture, due to a reduced use of pesticides and inorganic nutrient application. Many studies have reported that organic farming increases biodiversity in the agricultural landscape, including, for example, carabid beetles (Caprio et al., 2015; Dritschilo and Wanner, 1980; Kromp, 1999; Pfiffner and Niggli, 1996), vascular plants (Hyvönen and Salonen, 2002) and birds (Freemark and Kirk, 2001).

Italy houses about 10% of the surface of vineyards in the world (Organisation Internationale de la Vigne et du Vin OIV). The Italian region with largest surface of vineyards is Sicily with over 110,000 ha, followed by Apulia with 96,000, Veneto, Tuscany, Emilia Romagna and Piedmont. The percentage of organic vineyards in Italy is about 5.8% (Istat, 2010). Several studies have shown that farming systems of vineyards are important factors determining biodiversity of plants and invertebrates (Bruggisser et al., 2010; Caprio et al., 2015; Costello and Daane, 2003; Di Giulio et al., 2001; Thomson and Hoffmann, 2007; Trivellone et al., 2012). For birds, most of the research has addressed the general effect of vineyard agroecosystems on communities (Assandri et al., 2016; Duarte et al., 2014) and populations. The hoopoe (*Upupa epops*), wryneck (*Jynx torquilla*), woodlark (*Lullula arborea*) and common redstart (*Phoenicurus phoenicurus*), for instance, are favoured by patches of bare ground (Arlettaz et al., 2012; Duarte et al., 2014; Schaub et al., 2010; Weisshaupt et al., 2011) within vineyards, indicating that a management that allows a patchy ground vegetation should be beneficial for these species. However, there is paucity of research assessing the effects at finer levels, such as breeding behaviour, habitat selection and movements.

The great tit (*Parus major*) is a hole-nesting, insectivorous species whose contribution to pest control in apple orchards has been demonstrated (Mols and Visser, 2002, 2007). At the same time, orchard management may affect its survival and breeding success, reducing food resources and increasing intraspecific competition (Bouvier et al., 2005). In the present study, we examined the effects of vineyard farming systems (*i.e.* organic *vs.* conventional) on the feeding ecology of great tits nesting in vineyards of the Langhe and Monferrato wine-producing region, which has been recently marked as an UNESCO World Heritage Site. Here, regional applications of Common Agricultural Policies have promoted the placement of nest-boxes in vineyards to favor hole nesting insectivorous species, which can reduce insect damage and support local biodiversity. We used video-recordings at the nest to assess the number of nestlings fed per visit and their diet, whilst we used radio-telemetry to calculate feeding home range size and habitat selection of male parents.

2. Material and methods

2.1. Study area

The study was carried out in the Langa and Basso Monferrato Astigiano (NW Italy), a rural region where vineyards are the dominant cultivation, covering 34% of the territory. Other land uses include oak (*Quercus robur*), chestnut (*Castanea sativa*) and black locust (*Robinia pseudoacacia*) woodland (26%), arable land (19%), grassland and pasture (9%) and urban areas (3%). Viticulture in this area is very intensive, and the resulting landscape is dominated by large patches of monoculture, surrounded by forests, crops and grasslands. Vineyards in the study area are kept using the "*Spalliera*" trellising system. It is characterized by low vines (generally <2 m) supported by wires held between wood or concrete poles. Hedgerows and isolated trees are often severely reduced. Organic vineyards are not abundant in the area and represent 1.86% of total vineyard area (246 ha of organic vineyards over a total cover of 16,860 ha of vineyards in the study area). The climate of this region belongs to type Cfa (Temperate, without dry season, hot summer), in terms of Köppen-Geiger's classification (Peel et al., 2007).

We focused on 14 vineyard patches (focal vineyards) in 2011. Vineyard patches were all similar in size, ranging from 7.42 to 9.23 ha (average size: 8.10 ± 0.83 ha). Seven vineyards were certified for organic production, whereby no chemical treatments except sulphur, copper sulphate and pyrethrin sprays were used. The organic vineyard patches were in general adjacent to conventional vineyards and were isolated from other organic vineyards due to the reduced distribution of this kind of management. The other seven vineyards were cultivated with conventional production methods. These involved chemical treatments with pre- and post-emergence herbicides (mostly glufosinate), insecticides (mostly against flavescence dorèe), anti-rot compounds, sulphur, copper and zinc sprays, products with esaconazol and copper oxiclorur sulphate against oidium and rots, carbamate pesticides and fungicide, and the use of mineral feeds with average concentration of P, K and N at 6.5 q/ha.

2.2. Vineyard and surrounding landscape description

Focal vineyards were described in terms of habitat composition and management characteristics by means of percentage of grass cover, percentage of soil rubble cover, use of herbicides and/or ploughing (as a presence/absence variable), presence of trees (such as peach, pear and apple) and/or presence of rural building. Habitat differences between the two management systems (*i.e.* organic *versus* conventional) were explored using Factor Analysis (FA) (Riitters et al., 1995). We used land cover data digitized from 1:10,000 aerial photographs to describe the landscape around the centroid of the focal vineyard patch both at a 500 m and a 1.5 km buffer radius. Seven local landscape variables were measured using a Geographical Information System (ESRI, 2006): the area of forests (FO), grasslands and pastures (PA), shrubs and bushes (BU), vineyards (VI), croplands and orchards (AG), garden patches (OT) and the aggregation index (AI). The AI quantifies the degree of fragmentation of a landscape and is calculated from a patch adjacency matrix, which shows the frequency with which different pairs of patch types appear side-by-side on the map (*i.e.* the buffer around the focal vineyard patch). Differences in land cover composition within the buffer around the focal vineyards regarding their management system (conventional or organic) were tested using a Kruskal-Wallis test due to non-normal distribution of the data.

2.3. Video-recording in nest-boxes

An artificial nest-box was installed as close as possible to the centroid of each vineyard (7 organic and 7 conventional). All nest-boxes were successfully occupied and were monitored by means of an infrared CCTV camera (Colour 420 line CCD high resolution camera) connected to a portable digital recorder (JXD990).

We recorded nest activity (for a minimum of 1 h to a maximum of 3 h per day) every two days during the morning, from egg hatching (day 0) for a total of 8–9 days recorded per nest. All recordings regarded the first clutch. Chicks were ringed and weighed at age 9 days. We recorded each parental visit to the nest-box, registering the sex of the parent and identifying the provisioned prey. Prey was classified as one of the following categories: butterfly's caterpillars (Lepidoptera), Spiders (Araneae) and other preys *i.e.* items that were brought less frequently, such as snails, or that were not identifiable based on the image analysis (*i.e.* other adult invertebrates and larvae). From the analysis of the videos, we estimated the time spent by the parents inside and outside the nest (in seconds). The average number of *pulli* fed per