Assessing common birds' ecological requirements to address nature conservation in permanent crops: lessons from Italian vineyards.

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Running title:
Conservation of common bird species in vineyards.

Abstract

Viticulture contributed to shape "cultural landscapes" in several regions over all the continents. Recent farming intensification is causing landscape homogenization and biodiversity loss in several of those areas, but knowledge about the impacts on biodiversity in vineyards is still scarce.

Simplified agro-ecosystems resulting from intensification host mainly generalist and common species, which still play a key role in ecosystems' regulation and in the provision of ecosystem services.

We assessed the abundance of 11 common bird species at 47 linear transects in a vineyard-dominated landscape in Trentino (NE Italy), in both spring and winter, and analysed abundance variation in relation to three independent groups of predictors: landscape, management and topographic-climatic variables.

In the majority of species (7), abundance was primarily or considerably affected by landscape attributes. However, other 5 species were largely affected by management practices, often with conspicuous seasonal differences. Overall, landscape and management heterogeneity positively affected the abundance of 6 species.

Vineyard cover (and in particular the new *spalliera* trellising system) was negatively related to the abundance of 6 species, with the strongest impacts in winter. On the contrary, the cover of marginal habitats had major positive effects over 8 species.

Hedgerows, tree rows and dry stone walls, as well as traditional *pergola* vineyards and landscape and management heterogeneity should be conserved or restored in viticultural landscapes to promote the abundance of common bird species. This strategy would ensure the maintenance of the ecosystem services they provide, while promoting the general sustainability of the agroecosystem.

Keywords – abundance; commonness; hedgerows; marginal habitats; dry stone walls; Trentino.

1. Introduction

Agricultural-driven land-use intensification is the most important cause of the loss of terrestrial biodiversity at a global scale (Foley et al., 2011) and nowadays the reduction of this trend, instead of its stabilization, must be the actual goal for conservation (Butchart et al., 2010).

Agricultural intensification acts at two distinct but interconnected spatial scales. At the local (field) scale, it involves the intensification of farming practices (e.g. increasing fertilizer and pesticide inputs, deep ploughing, massive use of machinery). At the landscape scale, intensification causes homogenization and fragmentation through e.g. conversion of perennial grassland-like habitats into arable fields, increasing field size, removal of marginal habitats, resulting in highly simplified landscapes (Fahrig et al., 2011; Tscharntke et al., 2005).

Agri-environmental schemes (AESs) aim to counteract such negative effects of agricultural intensification on ecosystems, by providing financial incentives to farmers adopting farming practices with lower environmental impacts (Kleijn et al., 2006).

Landscape structure can explain much of the patterns of biodiversity in complex landscapes (i.e. those with >20% cover of semi-natural habitat, Batáry et al. (2011)), whereas in simpler landscapes management practices could have important effects on biodiversity (Chamberlain et al., 1999; Schmidt et al., 2005). As a consequence, general (and not specifically landscape-oriented) AESs could be poorly effective in complex landscapes, but pivotal in simpler ones (Batáry et al., 2011).

These simplified systems host mainly generalist and common species, defined as ‘those that are abundant and widespread’ (Gaston, 2010). Despite the low contribution to community richness, common species are exceptionally influential in determining many macroecological patterns and in providing ecosystem services (Gaston, 2011). As an example, birds provide fundamental services and economic benefits to humans, such as seed dispersal, pollination, biocontrol (Sekercioglu et al., 2004; Whelan et al., 2015).

A small proportional reduction in the abundance of a common species can result in the loss of a large number of individuals, then dramatically impacting on ecosystems.

A lot of natural and anthropogenic factors could suddenly change a common species into a rare or threatened one (Gaston and Fuller, 2008), and today common species actually 'lie at the very heart of the biodiversity crisis' (Gaston, 2011). In Europe, avian abundance and biomass are declining due to depletion of common species (Inger et al., 2014), with farmland birds being amongst the most threatened ones (Donald et al., 2006).

In temperate regions, permanent crops such as vineyards, olive groves and fruit orchards could host relevant populations of several common bird species (Brambilla et al., 2013; Rey, 2011). These crops are undergoing severe intensification (Caraveli, 2000), but there is limited knowledge about their impacts on biodiversity, including farmland common bird species (Balmford et al., 2012).

This is particularly concerning because permanent crops have been excluded from the 'greening' obligation introduced in the recent Common Agricultural Policy (CAP) 2013 reform, which aim to reduce the impact of EU agriculture. Such an exemption for permanent crops would hinder efforts to conserve biodiversity in these crops, which are often managed as highly intensive monocultures (Pe'er et al., 2014).

Vineyards are an example of permanent crops in which management practices have a direct effect on landscape structure and, in turn, on biological communities (Bruggisser, Schmidt-Entling & Bacher, 2010; Nascimbene *et al.*, 2013). In the past, viticulture had a preeminent role in creating impressive "cultural landscape" (Cohen et al., 2015; Kizos et al., 2012), characterised by extensive and traditionally terraced areas (Petit et al., 2012). Nowadays, viticulture intensification is resulting in homogeneous monocultures (Martínez-Casasnovas et al., 2010), determining a substantial reduction of natural habitats in the Mediterranean Biome (Viers et al., 2013). In this context, the landscape-mediated effect of viticulture on biodiversity is likely to be relevant for conservation (Hilty & Merenlender, 2004; Isaia, Bona & Badino, 2006; Gillespie & Wratten, 2012), but it is far from being fully understood.

Within this study, we explored the effect of landscape and management characteristics of vineyards on several common avian species, in an area largely dominated by viticulture. We investigated several landscapes across a gradient of progressive intensification to understand how landscape traits and management factors shape the abundance pattern of common birds.

We expected that some common species may be affected by the availability of marginal, natural and semi-natural habitat remnants. This could particularly apply to species which cannot nest on vines, or to species foraging mostly in other habitats, or feeding on resources not available in or below/above vines. Other species may be tied to traditional elements of agricultural landscapes, e.g. hedgerows, dry stone walls, isolated large trees, which provide nest-sites. Also management practices may be expected to affect bird abundance, by e.g. regulating food availability (e.g. via an effect of the intensity of phytosanitary treatment on insectivorous species) or detectability (e.g. creating patches of bare ground where prey detection is enhanced, e.g. Schaub et al. (2010)).

2. Materials and Methods

2.1. Study area

This study was carried out in Trento Province (South-eastern Alps, Northern Italy; Fig. 1a-b), a mostly mountainous area, where vineyards occur in the main valley floors and on the adjacent hilly sides, from 65 to 750 m asl. See Assandri et al. (2016a) for further details.

2.2. Model species, experimental design and bird counts

In this study we considered 11 common and widespread species in Italy (Nardelli et al., 2015). Three species are commonly found in the study area both in the breeding and wintering seasons: blackbird *Turdus merula*, great tit *Parus major* and chaffinch *Fringilla coelebs*. Four species are much more frequent in the breeding season: song thrush *Turdus philomelos,* blackcap *Sylvia atricapilla*, serin *Serinus serinus* and greenfinch *Carduelis chloris*. Four species occur exclusively or predominantly in winter: dunnock *Prunella modularis*, wren *Troglodytes troglodytes*, Eurasian robin *Erithacus rubecula* and rock bunting *Emberiza cia*.
We counted these species along forty-seven 200-m long linear transects distributed across the entire area covered by vineyards (Fig. 1c; Assandri et al., 2016) and within a 100-m buffer around the transect, thus each census plot covered 7.15 ha. To avoid double counting of the

same individuals, the minimum distance between neighbouring plots was 300 m. Further details on bird counts are given in supplementary materials.

2.3. Environmental variables collection

Following our previous approach (Assandri et al., 2016a), we measured landscape, management and topographic-climatic variables (Table 1) using the software QGIS (QGIS Development Team, 2016) and through an accurate field validation for some variables. Phytosanitary treatments are quite uniform as they are recommended by a central agricultural institute, but there are differences in the use of synthetic insecticides, fungicides, fertilizers and herbicides, which are allowed in conventional fields but not in organic ones. We then quantified the amount of vineyards under conventional and organic management for each plot. Certified organic agriculture in our study area is limited (<3% of vineyard area), but a specifically targeted design allowed us to include a mean (± SD) cover of organic vineyard equal to 13.9% ± 26.7 (range: 0-100 %).

We further distinguished vineyards according to two trellising systems occurring in the area: i) *pergola*, the traditional system (about 80% of vineyards in the Province; Chemolli et al., 2007), consisting of tall (up to >2 m) and spaced vines (up to 5 m between rows), supported by poles and beams; ii) *spalliera*, the standard global system, with lower vines supported by wires held between poles and with lower spacing (<2 m between rows).

Within these two systems, management is substantially the same, but mechanical harvesting and pruning are impeded by the *pergola* structure.

Topographic variables (mean elevation and slope) were derived from a 1-m resolution digital elevation model (DEM). We also calculated mean direct solar radiation for each plot on 21th June (for spring analysis) and 1st January (for winter) using r.sun function from software GRASS 7.0.2 (Neteler et al., 2012), taking into account the shadowing effect of the topography. We derived mean bioclimatic variables (BIO1-annual mean temperature; BIO12-annual precipitation) from WorldClim (www.worldclim.org, Hijmans, Cameron, Parra, Jones, & Jarvis, 2005) at a 30 arc-second resolution for each plot.

2.4. Statistical analyses

We grouped environmental variables into three categories of predictors: landscape, management and topographic-climatic variables (Table 1).

We considered the cover of vineyard within the management predictors, in order to: i) correct for vineyard cover into the plot when evaluating the effect of the management variables, ii) reduce collinearity among landscape variables.

We placed the length of hedgerows and tree rows among management variables, because in our study area their occurrence is fully determined by farmers' choices.

We applied the protocol for data exploration proposed by Zuur, Ieno, & Elphick (2010) for each group of predictors and applied log+1 transformation to apple, wood, urban and young plantations to reducethe weight of outliers. Topographic-climatic variables were highly collinear and elevation and BIO12 were consequently discarded.

We ended up with 16 environmental variables belonging to three groups (Table 1). We modelled separately their effect on each species/seasons. We used GLMs with a Poisson error distribution and a log-link function. Then, to evaluate whether Poisson distribution was appropriate for our data, we calculated the dispersion statistic on the residuals and, in case of overdispersion (> 1.5), we changed our distribution into a negative binomial one (Zuur et al., 2013) implemented with R package MASS (Venables and Ripley, 2002).

Our dataset showed a strong spatial structure, and spatial autocorrelation could affect the results of regression analyses (Beale et al., 2010), so we performed the Moran's I test on regressions' Pearson's residuals with R ape package (Paradis et al., 2004). In case of significant spatial autocorrelation we ran Poisson GLMMs with the R package glmmADMB (Skaug et al., 2015) using the geographical area (a factor with 9 levels grouping neighbouring plots, see Fig. 1c) as a random effect. Then we tested again for residuals' spatial autocorrelation and in all cases the GLMM procedure allowed us to remove it.

We worked within an information-theoretic approach (Burnham and Anderson, 2002) and we built all possible models for each species/season/predictor group with the *dredge* function in the R package 'MuMIn' (Barton, 2015).

We then performed model averaging across models with AICc<2 within each group, obtaining model-averaged coefficients, standard errors and relative variable importance (Johnson and Omland, 2004) for each explanatory variable. We used the full-average option, which is the most suited to determine which predictors have the strongest effect on the response variable (Grueber et al., 2011). We then compared the AICc value of the most supported model selected for each group to estimate the groups' relative importance.

For each species/season/predictor group, model validation and dispersion estimation were performed on single models including all the variables comprised in the most supported (ΔAICc < 2) models. All the analyses were performed with R version 3.2.0 (R Core Team, 2016).

3. Results

The comparison of the AICc values of the most supported models of each group of predictors (Table 2), allowed an assessment of the relative importance of each group of predictors for each species/seasons. Coherently with the diversity of the birds species here considered, the importance of different types of environmental variables varied among species and seasons. 4 species were mainly affected by landscape variables: blackbird (both seasons), chaffinch and blackcap (spring) and great tit (winter). Dunnock and serin were similarly affected ($\Delta AICc<2$) by landscape and by management, and by landscape and topographic-climatic variables, respectively.

The abundance of great tit (spring), chaffinch and rock bunting (winter) mostly varied according to management variables. Song thrush was affected similarly by management and topographic-climatic features. Topographic-climatic variables better explained the abundance patterns of 3 species: greenfinch (spring), robin and wren (winter).

Table 3 summarizes and tables S1, S2, S3 detail the effects of all the 16 environmental variables on the 11 species investigated.

Vineyard cover was the dominant habitat type and had negative effects on the abundance of 6 species; in winter, on robin (Fig. 2b), dunnock, wren and rock bunting and in spring on great tit and blackcap (Fig. 2a). Only for chaffinch (both seasons) and serin, vineyard cover promoted abundance.

Wood cover was selected in 10 out of 14 most supported models. In spring it had contrasting effects on species abundance, positive for blackcap, great tit and song thrush, and negative for blackbird, chaffinch, goldfinch and serin. In winter, wood cover effect was positive for dunnock, wren and rock bunting, negative for chaffinch.

The cover of herbaceous crops had a low importance, and its effect was negative for blackbird (both seasons), chaffinch and blackcap (spring), and positive for wren (winter); for great tit, the effect was positive in spring and negative in winter.

The cover of marginal habitats showed positive effects (and a relatively high importance) for 8 species, in particular in winter (e.g. Fig. 2c, e-f). As an example, when marginal habitat cover is above 15%, the predicted Eurasian robin abundance in winter displays values above the observed average abundance. Only song thrush was negatively affected by marginal habitats (spring), whereas a quadratic relationship (positive for intermediate values of habitat cover) was found for great tit (Fig. 2d).

The cover of intensive apple orchard showed positive effect on the abundance of both thrush species and greenfinch in spring; in winter, blackbird was the only species still positively affected, whereas great tit and chaffinch were negatively associated with apple orchards.

Urban cover showed a positive effect on 7 species, and a negative effect on song thrush (spring) and chaffinch and rock bunting (winter).

The number of habitat patches had a generally positive (5 species, e.g. Fig. 2j) or quadratic (serin) effect on bird abundance. As an example, when the number of habitat patches is above 3 per ha, the predicted great tit abundance in winter displays values above the observed average abundance. Some relevant exceptions occurred (the two thrushes in spring and rock bunting in winter, although for the latter the effect was secondary). The number of vineyard patches affected blackbird abundance (quadratically in winter, negatively in spring), and had a positive effect for great tit (both seasons), chaffinch (both seasons, see Fig. 2k for spring), serin and dunnock, negative for robin.

Hedge and tree rows had positive effects on most species (7) in both seasons (e.g. Fig. 2g), negative on song thrush (spring) and chaffinch (winter).

As an example, when hedge and tree rows length is above 400 m per plots (56 m/ha), the predicted great tit abundance in spring displays values above the observed average abundance. The cover of organic vineyards had negative effects on 4 species, and positive only in the case of greenfinch. The effects were consistent both in spring and winter.

The cover of *spalliera* vineyards had negative effect on 6 species and the effects were consistent across seasons. However, song thrush (spring) and rock bunting (winter) were positively affected by them.

The occurrence of dry stone walls along vineyard parcels had negative effects during the breeding period on blackbird, chaffinch and serin and positive on blackcap (Fig. 2h) and great tit. As an example, when more than 60% of vineyards have dry stone walls along at least one of their margins, the predicted blackcap abundance in spring displays values above the observed average abundance. In winter the effect was positive for all the 7 species considered (e.g. Fig. 2i).

The cover of young plantations had negative effects in spring on blackbird and positive on great tit, song thrush and chaffinch, negative effects in winter on blackbird, robin and dunnock and positive on chaffinch, wren and rock bunting.

Considering topographic-climatic variables, slope had negative effects in spring (on blackbird, chaffinch (Fig. 3b), serin and greenfinch) and positive for great tit and blackcap (Fig. 3c). In winter its effect was positive on robin, dunnock, rock bunting, wren and great tit.

Solar radiation had a lower relative importance than other variables and showed positive effects on serin and greenfinch (spring; Fig. 3a) and robin (winter), and negative effects on blackbird and chaffinch (spring) and on great tit and dunnock (winter).

The men annual temperature (BIO1) in spring had positive effect on blackbird, serin and greenfinch, negative on song thrush. In winter it had positive effect on the abundance of robin, blackbird and great tit.

4. Discussion

The species considered in this study are mostly habitat generalists, supposed to have broad ecological requirements, which allow them to dwell in different habitats and to be common also human-shaped habitats such as intensive vineyards. Nevertheless, our results suggested that not all vineyards are equally suitable for those species, and that different landscape and management characteristics definitely affect their abundances.

We showed that the abundance of common avian species inhabiting vineyard agroecosystems depends on a variety of environmental characteristics related to landscape characteristics, management practices and local topographic and climatic variables, with some important seasonal effects. This partially confirms previous findings at the community level in the same area (Assandri et al., 2016a), thus suggesting that common birds could be reliable biological indicators in this environmental system. Biodiversity patterns at the community level were primarily affected by landscape attributes, with management still playing a role and topographic-climatic variables having minor importance (Assandri et al., 2016a). Conversely, individual species abundance could be affected not only by landscape characteristics, but also by climatic-topographic traits and, especially, by management practices, which could have a significant or even predominant effect.

The cover of vineyard had a negative (or irrelevant) effect in determining bird abundances. Only two species, chaffinch and serin, were favoured by this kind of crop, being probably well adapted to it (they are able to nest on vines and forage under them). Both species also showed a positive relationship with the number of vineyard patches, this suggesting that they are favoured by heterogeneity at the field-scale. The largely negative effect of vineyard cover is consistent with the its effect on the richness of the whole avian community in spring (Assandri et al., 2016a).

In our study system, landscape and management heterogeneity in vineyards were positively related with the abundance of most species, with common species mirroring again the pattern reported at the community level (Assandri et al., 2016a).

The positive effect of heterogeneity on biodiversity in agricultural systems has been postulated for a long time (Benton et al., 2003; Fischer and Lindenmayer, 2007) and it has been reported also for vineyards (Barbaro et al., 2016; Gaigher and Samways, 2010; Steel et al., 2017; Verhulst et al., 2004). In fact,

the presence of habitats different from the vineyard and embedded into the matrix, allowed the occurrence of species less adapted to this kind of habitat, i.e. which are not able to nest or forage on (or under) the crop itself. This is the case of e.g. blackcap, which is favoured by woods, urban areas and hedgerows. Similarly, the greenfinch visits vineyards for feeding, but does not nest into them (Assandri et al., n.d.), and thus was favoured by the occurrence of urban areas (within which it breeds in gardens), hedgerows and apple orchards. Even in apple orchards, where greenfinches regularly nest, their abundance is enhanced by the presence of natural/semi-natural habitats, as for other common species (Brambilla et al., 2015).

In winter, the majority of the species considered occurs in vineyards only if other habitats or structures exist (and accordingly the negative effect of vineyards was particularly evident). Marginal habitats, such as hedgerows, tree rows and small abandoned areas with scattered shrubs, are particularly important for several individual species, as they are for the entire community (Assandri et al., 2016a).

There is a general consensus on the importance of hedgerows, which have a key ecological role in a variety of agroecosystems (Baudry et al., 2000), including permanent crops (Castro-Caro et al., 2015). As a consequence, incentives (provided by e.g. AESs) frequently promote the creation of hedgerow networks. However, the effect of hedgerows on biodiversity is context-dependent. Hedgerow networks (or other forms of tree and shrub restoration) created in areas or ecosystems where they never occurred may cause declines of open-habitat specialists (Assandri et al., 2016b; Besnard and Secondi, 2014; Pithon et al., 2016). Conversely, in systems like the one we investigated, where permanent crops occur and hedgerows have a traditional landscape value, such elements must be definitely preserved and possibly restored.

Dry stone walls, a distinctive and traditional element of several “cultural landscapes” shaped by viticulture (Petit et al., 2012) , hardly had any noticeable effect at the community level

(Assandri et al., 2016a). In the present work we showed that they could be important in determining abundance patterns of common species, probably because they were generally associated with marginal elements, as well as with weeds. This probably also explains the positive effect found in spring on blackcap and great tit abundance. The latter species can also use dry stone walls as nesting site (pers. obs.). In addition, dry stone walls occur on sloping valley sides, and in winter could be associated with a milder micro-climate.

Organic management have no or negative effects (in particular in spring) on the majority of species. This is a rather unexpected result considering previous findings in a variety of agricultural systems, e.g. Tuck et al (2014), but it is consistent with other studies in the same (Assandri et al., 2016a, n.d.) or in other viticultural areas (Brugisser et al., 2010; Rusch et al., 2015).

We believe that the local characteristics and spatial arrangements of organic wine farming play a key role in this sense. In Trentino organic farms cover a small extent and are isolated in a matrix of conventional farms and in an overall complex landscape (*sensu* Batary et al (2011), in which organic farming is less expected to have positive effects on biodiversity. Moreover, in the study area organic farming is quite intensive and phytosanitary treatments are generally more frequent than in conventional farming. Treatments are mostly based on the use of copper, sulphur and pyrethrins instead of other synthetic chemicals. Nonetheless, sulphur and copper had been reported to have negative effects on arthropods (Nash et al., 2010).

In the study area, the occurrence of two fairly different trellising systems allowed for a comparison of the effect of vineyard structure on species abundance. *Spalliera* vineyards, recently introduced in Trentino viticulture, are subject to an intensive management, with high mechanization levels. This probably led to the negative effect of this trellising system on several species here considered. In spring, this effect is due to the fact that the few common species breeding on vines (i.e. blackbird, chaffinch and serin) are favoured by the more complex "tree-like" structure of *pergola* vineyards, which offer a higher availability of potential breeding sites (Assandri et al., n.d.). In winter, *spalliera* vineyards are a "bare and poor" habitat, without any structures apart from poles, wires and single-branch wines. This could explain the general negative effect of this trellising system on most species in this season.

Rock bunting was an exception, as its abundance was promoted by *spalliera* cover. In winter this species exploits areas in proximity of rocky cliffs or dry stone wall-terraced systems, which, due to their harsh topography, are most suitable for *spalliera* vineyards. Moreover, it is the only open-habitat species considered in this study, and the more open appearance of *spalliera* probably better suited its needs.

The climatic-topographic models are generally less supported than the landscape and management ones, but for some species these factors could be of high relevance: the abundance of serin and greenfinch, as an example, were affected by both landscape and climatic-topographic variables (both species preferred warm and sunny areas at lower slopes). Song thrush showed important differences when compared with the other species, being negatively affected by the cover of marginal habitat, hedgerow length, dry stone walls and by the number of patches, and positively by vineyard cover. We hypothesize that such a distinct pattern was mainly driven by the strong positive preference of this species for apple orchards, which mainly occur in valley floors, in very intensive and simplified agroecosystem. The link with apple orchards was previously demonstrated in Trentino by Brambilla et al. (2013). Song thrush did not avoid intensive vineyards; on the contrary, an apparent process of “spillover” seems to occur in the northern part of the study area, where the species tends to colonize vineyards adjacent to apple orchards. This was also indirectly confirmed by the negative effect of temperature (which is higher in the southern part of the study area) on the species abundance.

5. Conclusions

Previous studies on biodiversity in vineyards were carried out at the community level (Bruggisser et al., 2010; Nascimbene et al., 2016; Pithon et al., 2016; Steel et al., 2017) or investigated the species-specific requirements of individual taxa of conservation concern (Arlettaz et al., 2012; Isenmann and Debout, 2000). Hence, this study is virtually the first attempt to investigate the basic ecological requirements of several common bird species in vineyards and to derive conservation implications from those results.

Initiatives to promote the environmental quality of the wider landscape matrix are fundamental to maintain naturally common species and the invaluable ecosystem services they provide (Kleijn et al., 2006). Protected areascan support only a limited amount of the populations of common species (Gaston and Fuller, 2008), and this implies that farmers have a great responsibility in conserving common bird species in agricultural ecosystems (Guillem and Barnes, 2013).

Unfortunately, the recent CAP reform does not help conserve biodiversity in vineyards and other perennial crops (Pe'er et al., 2014). Recent 'spot' initiatives oriented towards a more sustainable viticulture (e.g., Sigwalt *et al.*, 2012) are too week or interest too limited areas to produce substantial effects at a broader level, and consequently should be strengthened (Viers et al., 2013). At the same time, policy-makers should promote the environmental quality through well designed and scientifically sounding AESs, which should compensate for the lack of 'green' prescription in the European regulation.

In our study system, some key features appear of critical importance when considering at the same time both the different environmental factors and the relative effect on common species (this study) and on avian communities (Assandri et al., 2016a). The conservation or restoration of marginal habitats and hedgerows or tree rows, the maintenance of other traditional elements such as dry stone walls and *pergola* vineyards, and the increase of heterogeneity at both the landscape and the field scale should be the focus of conservation initiatives targeted at biodiversity conservation in vineyards.

If a synergy among farmers, policy-makers and conservationists working on viticultural systems will be achieved, broad positive effects on common bird species, and possibly on wider biodiversity, have to be expected.

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Figure captions

Fig. 1. Study area. A: Localization of Trento Province in Northern Italy. B: Vineyard cover in Trento Province (in violet). C: position of the 47 study plots in Trento Province viticultural district with the nine geographical areas used as levels in the GLMMs' random effect. Legend of Figure 1c: 1) Piana Rotaliana; 2) colline di Lavis-San Michele; 3) Val di Cembra; 4) colline di Trento; 5) Alta Vallagarina; 6) Mori; 7) Bassa Vallagarina; 8) Benaco; 9) Valle dei Laghi.

Fig. 2. Graphical representation of the effect of several landscape and management predictors on species abundance as predicted by the averaged models. Other predictors included in the models are kept constant at their mean value. Dashed lines represent the 95% confidence intervals of the mean. a) vineyard cover effect on blackcap abundance (spring); b) vineyard cover effect on Eurasian robin abundance (winter); c) marginal habitat cover effect on great tit abundance (spring); d) marginal habitat cover effect on great tit abundance (winter); e) marginal habitat cover on Eurasian robin abundance (winter); f) marginal habitat cover on dunnock abundance (winter); g) hedgerow length effect on great tit abundance (spring); h) vineyard with dry stone walls effect on blackcap abundance (spring); i) vineyard with dry stone walls effect on Eurasian robin abundance (winter); j) number of patches effect on great tit abundance (winter); k) number of vineyard patches effect on chaffinch abundance (spring).

Figure 3. Graphical representation of the effect of several topographic-climatic predictors on species abundance as predicted by the averaged models. Other predictors included in the models are kept constant at their mean value. Dashed lines represent the 95% confidence intervals of the mean. a) solar radiance effect on greenfinch abundance (spring); b) slope effect on chaffinch abundance (spring); c) slope effect on blackcap abundance (spring).

Table captions

Table 1. List of variables used in the analysis. Variables were measured in a GIS environment and then checked/validated in the field at the end of the breeding season.

Table 2. Type of model and relative AICc of the best model for each combination of groups of predictors and species/seasons. Type of model - GLM p: generalized linear model with a

poisson error distribution; GLM nb: generalized linear model with a negative binomial error distribution; GLMM p: generalized linear mixed model with a poisson error distribution. The most supported winter topographic-climatic model for the chaffinch was the null model.

Table 3. Synthetic representation of the effect of the environmental variables on species‛abundance. Legend: +: linear positive effect; -: linear negative effect; q: quadratic effect (positive for intermediate values, negative for low and high values). For more details on models output see tables S1, S2, S3 in supplementary materials online.

Table 1

Acronym	Description	Mean ± SD
	Landscape variables	
Woods	% cover of woodlands (large majority of broadleaved woodlands)	6.2 ± 8.9 %
Crops	% cover of croplands (mainly small fields and vegetable gardens; contain also extirpated wood crops)	2.3 ± 5.7 %
Marginal	% cover of marginal habitats (field margins, hedgerows and tree rows, abandoned areas with scattered shrubs, roads)	14.2 ± 6.1 %
Apple	% cover of intensive apple orchards	4.6 ± 9.4 %
Urban	% cover of urban areas	2.7 ± 4.3 %
Patches	Number of patches totally or partially overlapping with the plot	29 ± 11
	Management variables	
Vineyards	% cover of vineyards	64.0 ± 18.7 %
Hedgerows	Length of hedgerows and tree rows in the plot defined as is Assandri *et al.* (2016)	318.0 ± 285.7 m
Organic	% of organic vineyards into the plot (the remaining part is conventional)	13.9 ± 26.7 %
Spalliera	% of *spalliera* vineyards into the plot (the remaining part is *pergola* vineyards)	18.3 ± 29.7 %
Wall	% of vineyard into the plot with dry stone wall along at least one of their sides	46.9 ± 40.5 %
Vineyard patches	Number of vineyard patches totally or partially overlapping with the plot	20 ± 9
Young plantations	% of *young* vineyard plantation (<15 years) into the plot	30.2 ± 21.1 %
	Topographic-climatic variables	
Slope		8.9 ± 7.8 °
Solar radiance	Mean solar radiance on 1^{st} January and 21^{th} June	1774 ± 460 W/m^2; 8610 ± 240 W/m^2
BIO1	Mean annual temperature derived from Hijmans et al., 2005	11.6 ± 1.5 °C

Table 2.

	Landscape model		Management model		Topographic-climatic model	
	Type of model	AICc	Type of model	AICc	Type of model	AICc
Blackbird spring	GLM nb	243.29	GLM nb	249.64	GLM nb	250.21
Blackbird winter	GLM nb	251.22	GLM nb	262.13	GLM nb	263.29
Great tit spring	GLM p	139.41	GLM p	135.54	GLM p	141.43
Great tit winter	GLM p	186.16	GLM p	191.50	GLM p	200.05
Chaffinh spring	GLM p	194.67	GLM p	197.03	GLM p	201.60
Chaffinch winter	GLM nb	421.02	GLM nb	418.59	GLM nb	
Song thrush spring	GLMM p	148.69	GLMM p	132.66	GLMM p	132.64
Blackcap spring	GLM p	136.45	GLM p	151.92	GLM p	143.29
Serin spring	GLM p	178.80	GLM p	181.19	GLM p	177.79
Greenfinch spring	GLM nb	145.82	GLM nb	145.82	GLM nb	142.65
Eurasian robin winter	GLM p	188.51	GLM p	196.06	GLM p	186.18
Dunnock winter	GLMM p	151.39	GLMM p	150.52	GLMM p	152.85
Wren winter	GLMM p	147.28	GLMM p	144.17	GLMM p	139.37
Rock bunting	GLM nb	224.94	GLM nb	220.26	GLMM p	225.63

Table 3

	Blackbird spring	Blackbird winter	Great tit spring	Great tit winter	Chaffinch spring	Chaffinch winter	Song thrush spring	Blackcap spring	Serin spring	Greenfinch spring	Eurasian robin winter	Dunnock winter	Wren winter	Rock bunting winter
Woods	-		+		-	-	+	+	-	-		+	+	+
Crops	-	-	+	-	-			-					+	
Marginal		+	+	q			-	+	+		+	+	+	+
Apple	+	+		-		-	+			+				
Urban	+	+		+		-	-	+	+	+	+	+		-
Patches	-		+	+	+	+	-		q		+	+	+	-
Vineyards			-		+	+		-	+		-	-	-	-
Hedgerows	+	+	+	+		-	-	+	+	+	+	+		
Organic	-	-	-	-				-	-	+				
Spalliera	-	-			-	-	+		-	-	-	-		+
Wall	-	+	+	+	-	+		+	-		+	+	+	+
Young plantations	-	+	+		+	+	+				-	-	+	+
Vineyard patches	-	q	+	+	+	+			+		-	+		
Slope	-		+	+	+	-		+	-	-	+	+	+	+
Solar radiance	-			-	-	-			+	+	+	-		
BIO1	+	+		+	+		-		+	+	+			