Bird friendly wine country through diversified vineyards

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Contributed Paper

Bird-friendly wine country through diversified vineyards

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Abstract: Vinecology, the integration of ecological and viticultural practices, focuses on the working landscapes of the Mediterranean-climate biomes to make wine-grape production compatible with species conservation. We examined how maintaining remnant native vegetation and surrounding natural areas in and around vineyards, two primary practices of vinecology, may influence bird community richness and composition across a vineyard landscape. We conducted bird surveys over spring and summer (October–January) at 120 sites across a wine-grape growing region in central Chile. The sites were equally divided across vineyards with and without remnant native vegetation, and sites had varying amounts of adjacent natural land cover. We used generalized linear mixed models to examine individual species responses to remnant vegetation in the vineyard at plot scale (within a 50-m radius) in the surrounding natural area (within a 500–1000 m radius). We used the Horn similarity index to explore overall community differences to quantify variations in endemic species, guild detection levels, and species richness between site types. At the plot scale, 9 out of 30 species were positively associated with the proportion of remnant vegetation and 3 species were negatively associated. Six were positively influenced by the proportion of native vegetation in the surrounding landscape and 3 species were negatively associated with proportion of native vegetation. Although overall total detections and richness were significantly greater in continuous mixed Mediterranean forest, 84.9% of these species were also detected in forest remnants within vineyards. Endemics, insectivores, granivores, and omnivores were all more abundant in vineyards with remnant native vegetation than in vineyards without remnant native vegetation. Our results show the value of maintaining and restoring natural vegetation remnants in vineyards as a tool for bird conservation that can be applied in working landscapes of the New World Mediterranean climate regions.

Keywords: agroecosystems, Aves, biodiversity hotspot, central Chile, working landscapes

Campos Vitivinícolas Amigables con las Aves mediante Viñedos Diversificados

Resumen: La vinecología, la integración de prácticas ecológicas y vinícolas, se enfoca en los paisajes productivos de los biomas pertenecientes al clima mediterráneo para lograr que la producción de uvas sea compatible con la conservación de especies. Analizamos cómo la conservación de la vegetación nativa remanente y las áreas naturales vecinas dentro y alrededor de los viñedos, dos prácticas primordiales de la vinecología, pueden influir sobre la riqueza y composición comunitaria de aves en todo un paisaje vinícola. Realizamos censos de aves durante la primavera y el verano (octubre - enero) en 120 sitios a través de una región en la que se cultivan uvas en la zona central de Chile. Los sitios estuvieron divididos de manera igualitaria en viñedos con y sin vegetación nativa remanente. Los sitios también tuvieron cantidades variables de cobertura natural de suelo adyacente. Usamos modelos lineales mixtos generalizados para examinar las respuestas individuales por especie a la vegetación remanente en el viñedo a escala de parcela (dentro de un radio de 50m) en el área natural vecina (dentro de un radio de 500–1000m). Usamos el índice de similitud de Horn para explorar las diferencias comunitarias generales para cuantificar las variaciones en las especies endémicas, los niveles de detección de gremios y la riqueza de especies entre los tipos de sitio. A escala de parcela, nueve de cada 30 especies estuvieron asociadas positivamente con la proporción

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de vegetación remanente y tres especies estuvieron asociadas negativamente. Seis especies fueron influenciadas positivamente por la proporción de la vegetación nativa en el paisaje vecino y tres especies estuvieron asociadas negativamente con la proporción de vegetación nativa. Aunque el total general de detecciones y de la riqueza fueron significativamente mayores en el bosque mediterráneo mixto continuo, el 84.9% de estas especies también fue detectada en los bosques remanentes dentro de los viñedos. Las especies endémicas, insectívoras, granívoras y omnívoras fueron más abundantes en los viñedos con vegetación nativa remanente que en los viñedos sin ésta. Nuestros resultados muestran la importancia de la conservación y restauración de los remanentes de vegetación nativa en los viñedos como herramientas para la conservación de aves que pueden ser aplicadas en paisajes funcionales en las regiones con clima mediterráneo del Nuevo Mundo.

Palabras Clave: agroecosistemas, Aves, Chile Central, paisajes productivos, puntos calientes de biodiversidad

摘要: 葡萄园生态学是生态学与葡萄栽培实践的结合, 它聚焦于地中海气候生物群落的工作景观, 旨在使酿酒葡萄生产与物**种**保护相兼容。我们研究了葡萄园生态学中的两种主要做法—维持葡萄园内部及周边的残存原生植被及自然区域, 将如何影响整个葡萄园景观中鸟类群落的丰富度和组成。我们在春季和夏季 (十月至一月) 对智利中部一个葡萄产区的 120 个位点进行了鸟类调查。这些位点平均分布在葡萄园中, 有些包含残存原生植被, 另一些没有, 且位点周围也有不同数量的自然土地覆盖。我们使用广义线性混合模型分析了葡萄**园**地块尺度上 (半径在 50 米以内) 周围自然区域 (半径为 500-1000 米) 中**每种**鸟类对残存植被的反应。我们使用 Horn 相似性指数来探索群落的整体差**异**, 以量化不同位点类型之间特有种、观测到的鸟群数量和物种丰富度的变化。在样方尺度上, 30 **种**鸟类中有 9 **种**鸟的数量与残存植被比例呈正相关, 3 **种**呈负相关。 6 **种**鸟类的数量与周围景观中原生植被比例呈正相关, 3 **种**与原生植被比例呈负相关。虽然在连续的地中海混交林中观测到的鸟类总量和丰富度显著更高, 但这些物种中有 84.9% 在葡萄**园**内的残存森林中也能发现。与没有原生植被的葡萄**园**相比, 有残存原生植被的葡萄**园**中特有**种**、食虫鸟类、食谷鸟类和杂食鸟类都更为丰富。我们的结果表明了维持和恢复葡萄园中残存自然植被的价值, 这可以作为鸟类保护的工具, 应用于新世界地中海气候区域的工作景观之中。**【翻译: 胡怡思; 审校: 聂永刚】**

关键词: 智利中部, 生物多样性热点地区, 鸟类, 工作景观, 农业生态系统

Introduction

Wine grapes are one of the most important crops in terms of economic returns and the extent of land they cover in Mediterranean ecosystems worldwide (Viers et al. 2013) and are estimated to cover 7.5 million ha globally (OIV 2017). Vineyard industry sales in Chile were valued at US$2,200 million in 2011 and projected to reach US$4,500 million in 2020 (Vinos de Chile 2010). Habitat conversion due to vineyard expansion has been widespread in the last 30 years (Viers et al. 2013). Vineyards are predicted to expand into new areas where climatic conditions will be favorable for wine-grape production to meet the demands of new markets (Hannah et al. 2013). Vineyard development poses a threat to biodiversity, particularly across the 4 Mediterranean-climate areas outside the Mediterranean Basin, collectively known as the New World Mediterranean (California, Chile, South Africa, and Australia). These areas still harbor much endemic biodiversity and many are biodiversity hotspots (Myers et al. 2000; Viers et al. 2013). This threat is well illustrated by the loss of plant species in patches of fynbos and renosterveld along the Cape of South Africa (Fairbanks et al. 2004). Likewise, in California vineyard development has led to extensive landscape conversion (Merenlender 2000). In Chile's Central Valley, wine grapes and other agricultural activities have replaced native matorral (shrubland) (Schulz et al. 2010), threatening what is left of this biodiversity hotspot (Alaniz et al. 2016).

Vinecology provides a useful approach for these Mediterranean-climate regions, where there is a clear need to undertake conservation across the working landscape (Viers et al. 2013). We examined the vinecology approach in considering the agricultural landscape in the context of the surrounding natural habitat, recognizing that the agricultural sector plays a primary role in managing much of the remaining portions of land in Mediterranean-climate biomes. Protecting native land cover in and around vineyards is central to vinecology practices (Viers 2013). However, a recent review of the effects of agricultural practices on multiple ecosystem services reveals limited evidence that biological corridors successfully connect natural areas in farmlands, seminatural areas in agroecosystems have value for wildlife, and hedgerows help conserve biodiversity in vineyards (Dicks et al. 2019; Shackelford et al. 2019). In a global meta-analysis of working landscapes (including croplands, rangelands, and forests), Prevedello et al. (2018) found nine studies that showed that scattered trees increased on-farm vertebrate richness and abundance, but they did not include any Mediterranean-type ecosystems . Thus, empirical evidence is needed to assess the value of remnant vegetation for biodiversity conservation across vineyard landscapes in the New World Mediterranean.

Increasing landscape complexity in an agroecosystem can increase habitat and thus increase biodiversity (Kremen & Miles 2012; Tscharntke et al. 2012; Barbaro et al. 2017). Bird richness and abundance can be improved by the presence of forest remnants (including isolated trees), forest edges, and riparian vegetation in agroecosystems (Martin et al. 2012; Bennett et al. 2014; Prevedello et al. 2018). Hence, the establishment and protection of small-scale patches of riparian and other natural vegetation in farmlands has been promoted in the literature as a useful conservation strategy (Bennett et al. 2006; Le Roux et al. 2018). The spatial configuration, composition, and extent of the natural vegetation surrounding agriculture can also significantly influence the occurrence and abundance of bird species (Radford & Bennett 2007; Lindenmayer et al. 2010). Bird guilds can be differentially affected by shape, composition, and extent of habitat, as well as level of anthropogenic landscape modification (Hall et al. 2018). It is important to assess the influence of different scales of habitat conservation on biodiversity conservation. Therefore, we considered whether small patches of native vegetation, distance to the nearest continuous forest, proportion of surrounding forest in the landscape, or a combination of these attributes influence bird detections and community composition. Finally, survey date can influence animal detectability and relative abundance due to environmental variables (Kelt et al. 2012).

We aimed to assess how local remnant vegetation and surrounding natural areas influence bird community richness and composition in a New World Mediterranean vineyard landscape. We surveyed birds across central Chile and used detailed land-cover measurements across vineyards with and without remnant native vegetation and adjacent large natural areas to investigate whether the bird communities (e.g., bird trophic guilds and endemic species) are distinct between continuous native vegetation, remnants, and vineyards; whether changes in the proportion of remnant native vegetation influence bird species; and whether the proportion of continuous native vegetation at the landscape scale influences bird species.

Assessing the influence of the natural land cover on biodiversity across the vineyard working landscape is vital for conservation of biodiversity hotspots associated with Mediterranean-climate biomes (Kremen & Merenlender 2018). Managing agroecosystems for biodiversity conservation is also one of the national biodiversity policies in Chile (Ministerio de Medio Ambiente 2018), but it is poorly understood in this region.

Methods

Study Area

Vineyard landscapes of central Chile have a Mediterranean climate (Viers et al. 2013). The native vegetation in the area is dominated by sclerophyllous forest and scrubland (Gajardo 1994) (hereafter matorral). We conducted this research in central Chile (i.e., the Metropolitan and O'Higgins regions), one of the country's most prominent wine-production areas. This area represents 36.9% of the national vineyard land area (ODEPA 2018) (Fig. 1).

Bird Surveys

We conducted 6 auditory and visual bird counts at 20 vineyards varying in the amount of surrounding native vegetation (total of 120 survey points) (see Supporting Information for details on amounts of native vegetation). At each farm, 2 survey points were in vineyard without remnants of native vegetation, 2 in remnant native vegetation in the vineyard, and 2 in native vegetation adjacent to the vineyard. There were 40 survey points in each land site type (matorral, remnant, vineyard). We refer to the survey points in large landscape-scale areas of continuous, predominantly native vegetation, at least 250 m from the nearest vineyard as *matorral*. Remnants sites were in small patches of native vegetation composed of trees and shrubs in the vineyards. Vineyard sites were inside vineyards without remnants of native vegetation and were at least 250 m from the nearest remnant or continuous native vegetation edge. All survey points were at least 250 m apart to avoid double counting of the same birds and at least 250 m from the edge between vineyard and native vegetation to avoid edge effects (Pfeifer et al. 2017). Exact survey locations in site types were selected randomly. Survey points in remnants surrounded by vineyard had an average distance to the nearest native vegetation of 1020 m (range 100–3900 m).

All the birds seen or heard were recorded in 10-minute, 50-m-radius point counts at 120 survey locations (Fig. 1) during spring and summer (October–January) of 2014 and 2015 (Ralph et al. 1995; Matsuoka et al. 2014). We conducted three point counts at each site, the first in 2014, the second in early breeding season in 2015, and the third during late breeding season in 2015 (360 total counts). The year 2015 was wet due to an El Niño Southern Oscillation (Santoso et al. 2017). The same observer (A.M.-S.) conducted all surveys from 0800 to 1200 under fair weather conditions with light to moderate winds (Ralph et al. 1995). We categorized the feeding behavior of all birds in the study (Supporting Information) based on Estades (1997) and Martinez and Gonzalez (2004). Scientific and common names were obtained from Remsen et al. (2014).

Land-Cover Analyses

We used recent satellite imagery (2013–2014) (ESRI 2017) with had a spatial resolution of $\leq$1 m^2 to classify landscape variables. Object-based image analysis

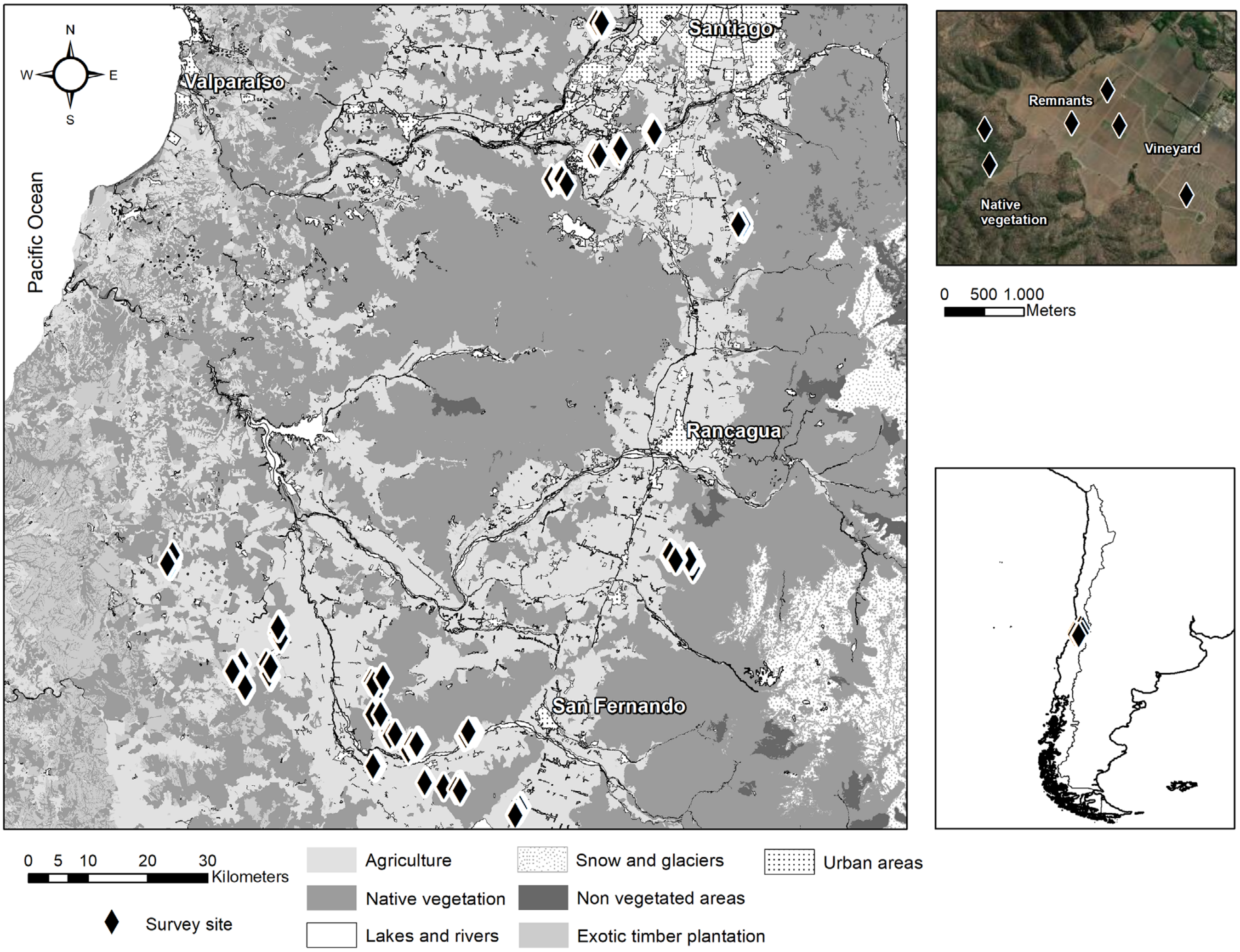

Figure 1. Study area in central Chile. Bird survey sites (n = 120) are in a gradient of vineyard influence.

allowed us to identify and quantify remnants, vineyards, and matorral site types with eCognition Developer (Trimble 2012) and ArcGIS 10.5 software (ESRI 2016). Object-based image classification (Yu & Gong 2012) resulted in in polygons for each feature. Manual classification of each polygon was done to distinguish among matorral, vineyard and other land-cover types, based on observations in the field, because manual classification can result in better accuracy than automated classification methods (Husson et al. 2016). We quantified the amount of matorral cover within annular areas (ring-shaped areas with hollow centers) at 4 scales surrounding each sample point: area radii were 50, 250, 500, and 1000 m around each bird survey station. The use of annular areas can reduce the potential for autocorrelation among the different scales (Aldinger et al. 2017). We used Pearson correlation analysis to estimate the correlation among the different scales of land cover and set a threshold of 0.65 for inclusion in the bird-detection prediction models (correlation analysis in Supporting Information) (Burnham & Anderson 2002; Kang et al. 2015). Based on this analysis, 2 scales were ultimately included as variables in the bird-detection prediction models (50-m radius corresponded to plot scale and 500–1000 m radii corresponded to landscape scale).

Bird Models

Generalized linear mixed models (GLMM) were developed to examine the influence of the proportion of matorral and remnant native vegetation on bird total detections, species richness, and detections of guilds (insectivores, granivores, omnivores) and on a group of individual endemic species (Supporting Information). To provide a clear comparison with other studies, we reported the relative total detections of birds per hectare for all land site types. To avoid problems related to modeling rare species, we restricted analysis to bird species that had >5 records in at least 5 different sites per season (Cunningham et al. 2008). We used Julian day (factor with 57 levels) and survey site (factor with 120 levels) nested by farm where the survey was conducted (factor with 20 levels) as random effects and site category (matorral, remnant, vineyard factor with 3 levels), year (factor with 2 levels: 2014, 2015), and proportion of native vegetation at landscape scale (continuous, landscape) as fixed effects. In addition, we tested the influence of the distance to the nearest continuous patch of native vegetation.

All continuous variables were first standardized to a mean of 0 and SD of 1 (to allow comparisons among explanatory variables). We considered a modeled bird response was significantly related to an environmental variable when the range of the 95% model-averaged confidence interval (95% CI) did not contain zero (Elsen et al. 2017). Model average was determined in models that presented ΔAICc <2 in the dredge command of the MuMIn package (Barton 2016), which allowed us to incorporate the uncertainty of several models instead of selecting only 1 best model and resulted in a more robust prediction (Burnham & Anderson 2002). Detections for all species (total detections), insectivores, Turkey Vulture (*Cathartes aurea*), and Harris Hawk (*Parabuteo unicinctus*) required the use of zero-inflated Poisson regression, and in these cases the best model is reported. The GLMM was performed using lme4 package (Bates et al. 2015) with a Poisson log-link distribution to model the relationship among species-guild detections and site covariates, and we used glmmTMB package for zero-inflated Poisson models (Brooks et al., 2017, 2019). We conducted these statistical analyses with R, packages unmarked (Fiske & Chandler 2011) and AICcmodavg (Mazerolle 2017), and used ggplot (Wickham 2016) for plotting. We also checked for overdispersion (ratio of summed Pearson residuals to residual df <1.15) and spatial autocorrelation with Moran's I test (Supporting Information). We did not detect significant overdispersion, and species total detections and richness, as well as guilds and individual model calculations, were not affected by the spatial distribution of survey sites (Supporting Information). A post hoc Tukey analysis was run with the package multcomp (Hothorn et al. 2008) to make pairwise comparisons among land site types (remnant, vineyard, matorral) in the full GLMMs.

To examine the relative similarity among community composition across land cover types (remnants, vineyard, matorral), we compared bird detections by using pairwise Horn equal- and size-weighted measures of percent similarity based on Shannon entropy (Jost et al. 2011). This percent similarity index provides a measure of the similarity in species composition among site types (range 0%, minimum similarity, to 100%, maximum similarity) and is more useful than other similarity indices (e.g., Morisita-Horn) when considering rare species (Jost et al. 2011). We pooled detections from all farms and both years to compare relative detections among the 3 land site types. We weighted species by their relative detections so as not to focus on dominant species (Chao et al. 2016). We used 10,000 bootstrap replications to obtain SE estimates (95% CIs). We did not include vineyards in comparisons of site types for endemic birds because detection rates were low in vineyards without remnants of native vegetation. We used the package SpadeR (Chao et al. 2016) in R 3.4.2 (R Development 2017) for this analysis. Data and code are available in Supporting Information.

Results

In total, we recorded 5068 individuals from 360 observations belonging to 48 bird species across 120 study sites (details in Supporting Information). The mean native vegetation remnant size in vineyards was 0.17 ha (SD 0.15) and the range was 0.004–0.54 ha (corresponding to 0.5–69% at the 50 m of the plot scale).

Thirty species were present in more than 5 survey stations, and out of these, 19 species had a significant relationship with proportion of native vegetation at either the plot or landscape scale or both (Fig. 2 & Supporting Information). Nine species were positively associated with the proportion of native vegetation at plot scale (50-m radius): Dusky-tailed Canastero (*Pseudasthenes humicola*), Dusky Tapaculo (*Scytalopus fuscus*), California Quail (*Callipepla californica*), Morning Sierra-Finch Finch (*Phrygilus fruticeti*), Chilean Flicker (*Colaptes pitius*), House Wren (*Troglodytes aedon*), Plain-mantled Tit-Spinetail (*Leptasthenura aegithaloides*), Tufted Tit-Tyrant (*Anairetes parulus*), and White-crested Elaenia (*Elaenia albiceps*). Three species had a negative relationship: Band-tailed Sierra-Finch (*Porphyrospiza alaudina*), Eared Dove (*Zenaida auriculata*), and Southern Lapwing (*Vanellus chilensis*). The proportion of native vegetation at the landscape scale was an important positive predictor for 6 species: Chilean Mockingbird, California Quail, Common Diuca Finch (*Diuca diuca*), Austral Blackbird (*Curaeus curaeus*), Long-tailed Meadowlark (*Sturnella loyca*), and Turkey Vulture. Three species were negatively influenced by vegetation at this scale: Chilean Swallow (*Tachycineta leucopyga*), Chimango Caracara (*Phalcoboenus chimango*), and Southern Lapwing. Distance from the nearest matorral edge to the center of the remnant had a negative effect on 8 species and a positive effect on 1 species (Supporting Information). Finally, year 2 of the survey (El Niño Year) revealed significantly higher abundance in that year for 4 species: Grassland Yellow-Finch (*Sicalis luteola*), Chilean Flicker, Austral Thrush (*Turdus falcklandii*), and Long-tailed Meadowlark and lower for 2 species (Band-tailed Sierra-Finch, and California Quail).

Total detections and richness were positively influenced by the proportion of native vegetation at both plot

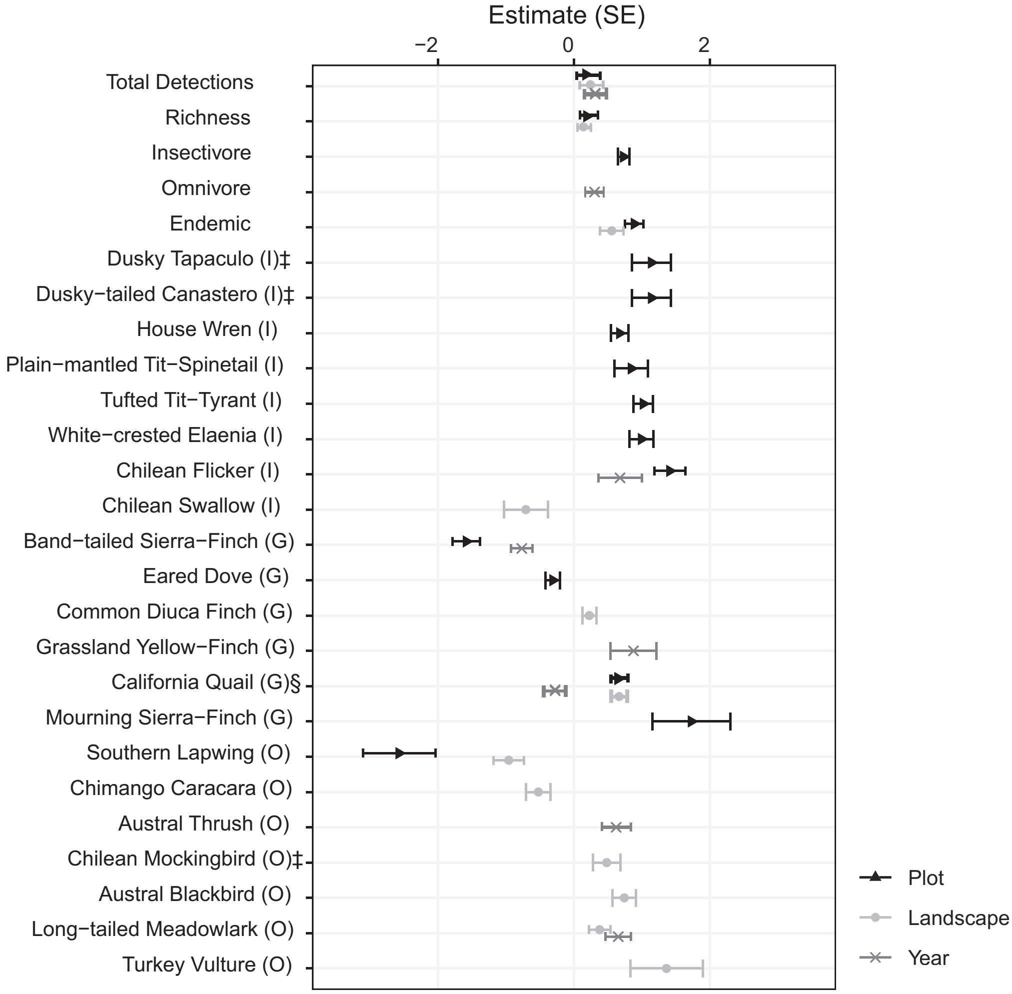

*Figure 2. Generalized linear mixed model results for the evaluation of the influence of landscape variables on bird community groups (species detected summed and grouped by guilds) and individual species (also classified by dietary guilds) I, insectivores; G, granivores; O, omnivores; ‡, endemic species; SS, non-native species; bars, 95% CIs; covariates are native vegetation at 50-m radii and 500- to 1000-m radii of point-count locations and year). Only significant effects (*p < 0.05*) are shown for each species model: negative effect below zero and positive effect above zero. Supporting Information contains a complete list of species analyzed.*

and landscape scales and by the year of the survey. Insectivores and endemics were positively associated with the proportion of native vegetation at plot scale. Endemics were positively associated with the presence of native vegetation at landscape scale. Year was positively associated with total detections and omnivores (Fig. 2 & Supporting Information).

The bird models revealed differences in community composition among matorral, remnant, and vineyard sites for all the bird guilds except for omnivores. Bird total detections (individuals per hectare) were significantly lower in vineyards (mean = 10.14 [SE 0.53]) than in remnants and matorral, whereas total detections were not different between remnants (mean = 15.79 [SE 0.53]) and matorral (mean = 16.44 [0.53]) (Fig. 3 & Supporting Information). Similarly, richness was significantly higher in remnants than vineyards ($p < 0.001$) and significantly higher in matorral than in vineyards ($p < 0.001$). The lowest values were in vineyards (mean = 4.18 [SE 0.22]), followed by remnants (mean = 7.75 [0.22]) and matorral (mean = 9.18 [0.22]) (Fig. 3).

Differences in bird detections among site types are illustrated in Fig. 3. Endemic bird detections were different among all site types, and lower in vineyards (mean = 0.03 [SE 0.14]) than in remnants (mean = 1.11 [0.14]) and matorral (mean = 3.02 [0.14]). Insectivore detections were lower in vineyards (0.45 [0.24]) than in remnants (mean = 2.98 [0.24]) and matorral mean = (6.81 [0.24]). Granivores had significantly ($p < 0.001$) more detections in remnants (mean = 7.35 [SE 0.40]) than in vineyards (mean = 5.51 [0.40]), but remnants were not significantly different from matorral (mean = 5.56

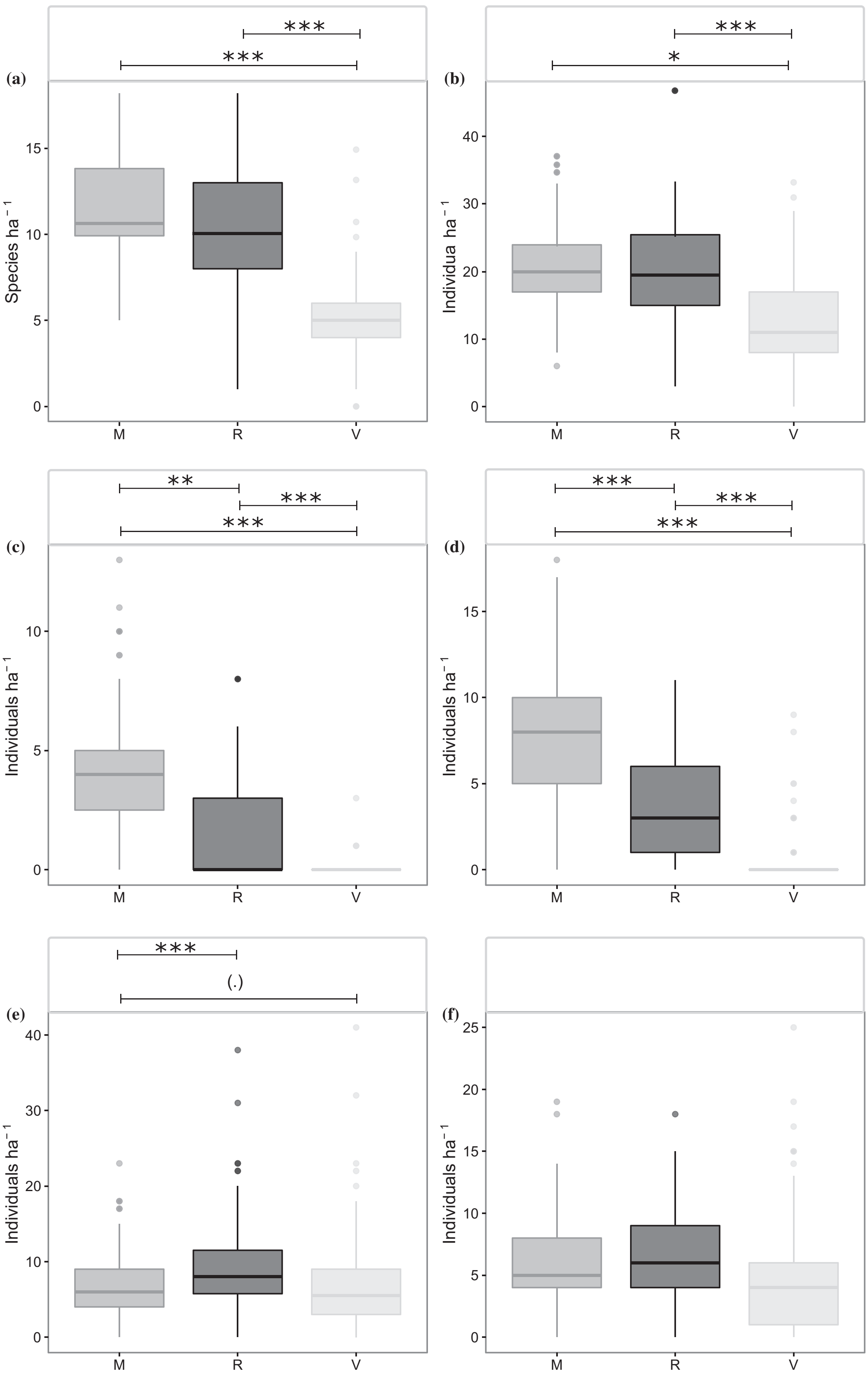

*Figure 3. Comparison (mean and SE) of the 3 site types (M, matorral; R, remnants; V, vineyards) for (a) species richness and (b) total detections of birds and summed (c) endemic, (d) insectivore, (e) granivore, and (f) omnivore species' detections (post hoc Tukey test on the generalized linear mixed model: ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$; (.), $p < 0.1$).*

Table 1. Pairwise similarity index (Horne equal weight measures) across bird communities in vineyard landscapes of central Chile.

Metric or guild	*Comparison*	*Index estimate*	*SE*	*95% CI*
Total detections	V-R	0.826	0.022	0.782–0.870
($n = 48$)	V-M	0.652	0.056	0.543–0.761
	R-M	0.849	0.012	0.827–0.872
Granivores	V-R	0.925	0.011	0.902–0.947
($n = 13$)	V-M	0.752	0.017	0.719–0.785
	R-M	0.865	0.014	0.839–0.892
Omnivores	V-R	0.721	0.024	0.675–0.768
($n = 7$)	V-M	0.494	0.023	0.449–0.539
	R-M	0.910	0.011	0.889–0.931
Insectivores	V-R	0.649	0.064	0.524–0.774
($n = 14$)	V-M	0.307	0.109	0.093–0.521
	R-M	0.855	0.017	0.821–0.888
Endemics[a]	R-M	0.843	0.028	0.788–0.898
($n = 6$)				

Landscape pairwise comparison (V, vineyards; R, remnants; M, matorral [native vegetation forest and scrubland]).
[a] *Endemics compared only between remnants and matorral.*

[0.40]). Total omnivore detections were not significantly different across the 3 site types: remnants (mean = 5.16 [SE 0.28]), vineyards (mean = 3.98 [0.28]), and matorral (mean = 4.65 [0.28]).

Similarities were observed between bird communities detected in remnants and matorral for all bird guilds, and granivores were the guild most evenly distributed across site types (Table 1). Out of all 48 species detected, we found 32 in vineyards, 37 in remnants, and 43 in the surrounding matorral, and 26 were shared across all the site types. Bird communities were most similar between remnants and matorral sites (33 species, 84.90% of species total detections). There was less similarity between remnants and vineyards (29 species, 82.65% species total detections) (Table 1). Vineyards and matorral shared only 28 species (65.20% of all species total detections).

Discussion

We found that retaining remnant native vegetation in Chilean vineyards provided local habitat for native birds; detections, richness, insectivores, and endemic species were significantly higher in remnants relative to vineyards. Bird communities detected in vineyards with remnants were more like those found in the surrounding native matorral forests than like those in vineyards without remnants of native vegetation. Total bird detections and richness were significantly higher where there was surrounding native vegetation at the landscape scale, and native vegetation at the landscape scale affected bird community composition, guilds, and species across the vineyard landscape.

These findings coincide with those of other researches who determined that native vegetation remnants, as well as hedgerow proportion and small woods, in vineyards support higher bird richness and abundance (Assandri et al. 2017; Steel et al. 2017). In particular, our observation of more insectivorous birds in large remnants than in other site types is consistent with other studies of vineyards (Jedlicka et al. 2014; Barbaro et al. 2017). Insectivores, such as House Wren, Plain-mantled Tit-Spinetail, and Tufted Tit-Tyrant, were more abundant in vineyards with remnants. These species may provide ecosystem services, such as pest control, in wine-grape production areas. This was observed by Jedlicka et al. (2014), who found that pest larval removal rates are 3.5 times higher in the presence of Western Bluebirds nesting in the vineyards than in vineyards where they are absent. Two-thirds of the endemic bird species we evaluated, Dusky-tailed Canastero and Dusky Tapaculo (the last one belonging to *Rhinocryptidae* family), presented a positive and significant association with remnants. Most of the endemic rhinocryptids feed on insects in the understory (De Santo et al. 2002). Rhinocryptids were restricted to matorral, indicating that these species are less likely to be found in anthropogenic environments, so the need for core native habitat may be key for their survival in central Chile.

Vineyards with no remnant native vegetation contained a subset of species associated with open habitat and with a relatively higher tolerance for anthropogenic environments. Southern Lapwing, Chimango Caracara, and Band-tailed Sierra-Finch are species commonly found in agroecosystems and urban areas (Silva et al. 2015; Muñoz-Sáez et al. 2017). Interestingly, Southern Lapwing detections were negatively related to the proportion of remnant at plot scale in vineyards and the proportion of native vegetation at landscape scale, indicating its preference for open areas (Muñoz-Sáez et al. 2017).

Our results agree with those of others that highlight the importance of small structural features, such as single trees or hedgerows, to increase birds in agroecosystems (Mendenhall et al. 2011) and the value of isolated trees for vertebrates in agroecosystems (Prevedello et al. 2018). The extent of the native vegetation remnants at plot scale, spatial configuration (e.g. linear strips vs. intersections), and floristic composition are also relevant components of the emergent properties of the landscapes that shape wildlife communities (Radford & Bennett 2007; Bennett et al. 2014; Hall et al. 2016). Indeed, our results showed that when the distance to the nearest edge of matorral was incorporated in the models, the significant influence of remnants persisted. Our results provide scientific evidence for maintaining native vegetation in vineyards to positively influence bird communities. These remnants take up relatively little arable land for an impressive impact on bird conservation. Furthermore, the presence of remnants can increase habitat connectivity (Polyakov et al. 2019) and help maintain riparian areas.

The use of native plants to reestablish native vegetation remnants (e.g. hedgerows) and as cover crops also increases biodiversity in agroecosystems (Muñoz-Sáez et al. 2017; Jiménez-Alfaro et al. 2020). Loss of crop production need not be an issue if remnant vegetation is strategically placed in less productive areas (e.g., poor soils) (Rey Benayas et al. 2019). Equally important, natural land cover at the landscape scale positively influenced one-fifth of the species analyzed (from various dietary guilds), emphasizing the importance of protecting continuous areas of natural vegetation. Further study of matorral specialist birds across habitat patches is warranted to understand their response to fragmentation associated with intensive agriculture. Finally, in the year 2015 a strong El Niño event occurred associated with high levels of precipitation (Santoso et al. 2017), and the effect of year of the bird survey could be related to the influence of this event on food resources (Kelt et al. 2012).

These results should be interpreted considering the following limitations. First, we did not measure all the characteristics of vineyards, such as inter-row cover crops or bare soil, that could shape bird communities in vineyards (Guyot et al. 2017). However, previous research shows that these variables could be more significant during winter than during the reproductive season in central Chile (Muñoz-Sáez et al. 2017). Second, we did not assess the influence of conventional versus organic agriculture. Recent studies reveal that highly mobile species, such as birds, are influenced more by the proportion of natural vegetation in the landscape than by whether management is conventional or organic (Gonthier et al. 2014; Assandri et al. 2016). Additional research is needed to assess the influence of agricultural management practices on bird communities.

Large vineyard monocultures without remnant native vegetation are common in Mediterranean-climate Chile, and remnants of native vegetation are not usually considered in conservation-planning or agricultural land-use policy. The exception is that strips of native vegetation along water courses are protected under Chilean law (Romero et al. 2014), although not always conserved. Considering the scarcity of protected areas in this region (Pliscoff & Fuentes-Castillo 2011) and the highly threatened status of its ecosystems (Alaniz et al. 2016), it is important to incentivize the retention and restoration of small remnants for bird conservation (Rey Benayas et al. 2019).

It is important to note that most sclerophyllous forest and Chilean matorral is privately owned, and most of the vineyards participating in this research own adjacent hills with native vegetation. Recently, laws approved by the Chilean parliament favor private conservation initiatives, but incentives for conservation of working landscapes are insufficient and lack legal recognition (Tecklin & Sepulveda 2014), leaving private land conservation dependent on landowner preferences (Zorondo-Rodríguez et al. 2014).

The main driver of the wine industry is international market demand (Vinos de Chile 2010). Hence, consumers could play a significant role in driving wine industry innovation toward more sustainable practices (Viers et al. 2013). Just recently a biodiversity criterion was added to the national sustainability codes used for certification in Chile, which will help inform consumers. Including the preservation and restoration of remnants of native vegetation, as well as conservation of surrounding natural areas, in sustainability certification programs could enhance biodiversity conservation across global New World Mediterranean regions.

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Supporting Information

Supporting information includes Appendix S1 that shows The gradient of native vegetation and vineyards around each survey site (Appendix S1), Spearman's rank correlation results among variables (Appendix S2), a complete list of the species recorded (Appendix S3), Moran's I correlograms of bird species total detections and richness models (Appendix S4), GLMM model average results (Appendices S5–S7), effects of native vegetation at plot scale on bird assemblages in vineyards (Appendix S7), post hoc Tukey test results for the comparison of bird communities at each study site (Appendix S8), and data and code (Appendix S9) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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