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Patterns of bird diversity and habitat use in mixed vineyard-matorral landscapes of Central Chile

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ABSTRACT

The Mediterranean climate region of central Chile is rich in biodiversity and contains highly productive agricultural lands, which creates challenges for the preservation of natural habitats and native biodiversity. Ecological data and studies for the region are also limited, making informed conservation in agricultural landscapes difficult. The increasing availability of remotely sensed data provide opportunities to relate species occurrences to measures of landscape heterogeneity even when field measures of habitat structure are lacking. When working with such remotely sensed data, it's important to select appropriate measures of heterogeneity, including common metrics of landscape composition as well as frequently overlooked shape metrics. In this contribution we combine bird surveys with multispectral satellite imagery to develop boosted regression tree models of avian species richness, and of habitat use for 15 species across a mixed vineyard-matorral landscape in central Chile. We found a range of associations between individual species and land cover types, with the majority of species occurring most frequently in remnant habitats and ecotones rather than the interiors of large vineyard blocks. Models identified both metrics of landscape composition and patch shape as being important predictors of species occurrence, suggesting that shape metrics can complement more commonly used metrics of landscape composition. Vineyards that include corridors or islands of remnant habitat among vine blocks may increase the amount of area available to many species, although some species may still require large tracts of intact natural habitat to persist.

1. Introduction

The coincidence of high levels of biodiversity in areas of dense human population and areas of high agricultural value is a well-studied phenomenon (Cincotta et al., 2000; Imhoff et al., 2004; Myers et al., 2000; Williams, 2013). In places where such overlap occurs, agricultural priorities often take precedence over conservation. Chile in particular, has had limited success in efforts to promote and incorporate conservation measures within the context of an agricultural sector that enjoys strong economic influence and policy support (Armesto et al., 2010; Budds, 2013; Carruthers, 2001; Valdes and Gnaegy, 1996). Even where conservation policies within agricultural areas are in place, the outcomes are mixed (Kleijn and Sutherland, 2003), as is the case in many of the world's Mediterranean-type ecosystems (Underwood et al., 2009).

Given this backdrop, it is valuable to consider how the design or restoration of agricultural landscapes can aid in supporting regional conservation strategies. Strategies such as the incorporation of hedgerows, riparian buffers, and/or the conservation of remnant vegetation patches may successfully provide adequate habitat for diverse species, especially when informed by a scientifically-based understanding of species-habitat relationships (Kremen et al., 2012; Perfecto and Vandermeer, 2008; Viers et al., 2013). While continued efforts to protect and set aside natural habitat will be critical for many conservation efforts, a complementary approach that focuses on mechanisms and incentives to achieve conservation

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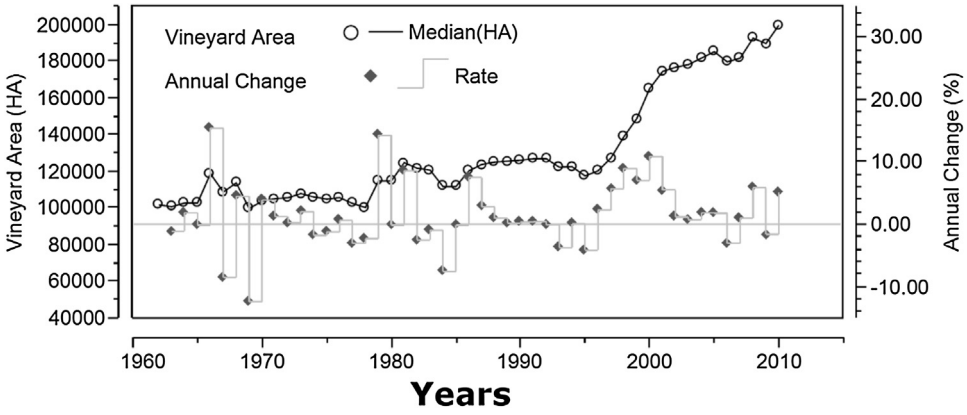

Fig. 1. Estimated vineyard footprint and trends for Chile between 1962 and 2010. Partial Figure from Viers et al., 2013 (Viers et al., 2013). Data sources: CWI (http://www.wineinstitute.org/files/WorldVineyardAcreagebyCountry.pdf); FAO (http://faostat.fao.org); OIV (http://www.oiv.int/oiv/info/frstatoivextracts2).

within the context of existing and expanding agricultural footprints is feasible and can also have broad impacts (Cox and Underwood, 2011; Rosenzweig, 2003). Identifying opportunities for conservation within agricultural landscapes is especially relevant to Chile's central valleys, where only 1–3% of the Mediterranean-type ecosystems (depending on how they are defined) fall within the National Protected Areas System (Cox and Underwood, 2011; Wilson et al., 2007). Among the dominant pressures on these ecosystems is the presence and continued expansion of vineyard plantations (Fig. 1), which fuel the country's thriving wine industry but also reduce the extent of matorral and sclerophyll forest habitats, reduce remnant patch size, and facilitate the spread of invasive species (Aguayo et al., 2009; Fuentes et al., 2013; Scherson et al., 2014).

There is a long history of ecological research demonstrating the correlation between habitat heterogeneity and animal species diversity (Tews et al., 2004a and citations therein), which has been extended both theoretically and empirically to agricultural systems (Bennett et al., 2006; Fahrig et al., 2011; Weibull et al., 2003). Remotely sensed imagery – which has become increasingly accessible and affordable – can be used to quantify heterogeneity of existing land cover, even in areas where there is limited field data. Through the use of flexible statistical analyses (e.g., boosted regression trees), one can model complex relationships between these agricultural landscape patterns and species occurrence information to develop spatially explicit habitat suitability models. In turn, these models can be used to predict how landscape features may affect biodiversity or individual species occurrences. These models can be especially valuable for conservation planning in areas where detailed biological data and ecological studies are scarce (Armstrong and McCarthy, 2007; Gossa et al., 2015).

Selecting appropriate metrics to describe the heterogeneity of a landscape is essential in leveraging remotely sensed data to create habitat suitability models, and in this case to ultimately inform efforts towards making vineyard landscapes more biodiversity-friendly. Often habitat heterogeneity is characterized by the number or variance of different habitat patches within a landscape (Tews et al., 2004a). Such metrics describe the composition of land cover types and are insensitive to spatial attributes such as patch shape. However, spatially explicit measures of landscape heterogeneity are also readily available (McGarigal et al., 2012) and may complement compositional metrics in describing wildlife diversity and habitat use (Schindler et al., 2013).

The aim of this paper is to examine the relative importance of spatially explicit shape metrics in describing the relationship between habitat heterogeneity, and both Chilean bird species richness and habitat use in a vineyard-dominated landscape. We also evaluate the utility of boosted regression trees for integrating a variety of landscape metrics to quantify species-habitat relationships from limited field data. We believe this approach can inform future research in agricultural areas, as well as provide useful insight and guidance for increased accommodation of biodiversity in working landscapes. This can be particularly important for areas such as Chile's Mediterranean region where agricultural development is proceeding rapidly, and where local research informing sustainable agriculture and conservation practices is sparse.

2. Methods

2.1. Study area

Study sites were located in the Colchagua Valley (34.68° S, 71.14° W), a recognized wine region in the sixth region of central Chile (Fig. 2). The climate is Mediterranean with warm, dry summers and cool, wet winters (Di Castri and Hajek, 1976). Chile's Mediterranean region makes up only 19% of the country's land area, and yet supports 77% of the human population and encompasses 39% of the area devoted to agriculture, grazing and timber (Barbosa and Villagra, 2015; Instituto Chileano Nacional de Estadisticas, 2007, 2011). We focused on three vineyards, all of which abut the undeveloped Rucatalca or Alto del Huique hills and thus contain a matrix of remnant and vineyard habitats within their properties. The vineyard management strategies of the three properties range from conventional (Montes – Apalta estate), to certified organic and biodynamic (Emiliana – Los Robles estate) with Caliterra's Colchagua estate containing both conventionally and organically managed vineyard blocks. All work was conducted on private property with the owners' approval. Surveys were non-invasive and no additional permitting or permissions were required.

2.2. Bird surveys

Avian point count surveys were conducted at 48 points within the three properties between September 27th and December 3rd, during the breeding season of 2011. Sites were stratified across three habitat categories: natural remnant (nine survey points in forest habitats and seven points in shrubland habitats), vineyard, and their ecotone (ecotone points were located within 50 m of the habitat boundary; Fig. 3). Each point was surveyed three times during the breeding season for bird species occurrence. At each point a 5-min survey was conducted, where an experienced observer identified as many individuals by sight or sound as possible (Ralph et al., 1995). Surveys were completed within four hours of sunrise when birds were most active. Points were located along transects and spaced at a minimum of 250 m apart. In surveys conducted