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Habitat diversity promotes bat activity in a vineyard landscape

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ABSTRACT

Intensification of agricultural production has greatly limited the capacity of agricultural land to support other species. Maintaining landscape heterogeneity in and around agricultural landscapes can help conserve biodiversity and potentially natural pest control. Whereas bats (order: Chiroptera) are highly valued as natural predators of agricultural pests, little is known about the distribution and abundance of bat species across different types of agricultural landscapes. The objective of our study was to assess how local remnant habitat and surrounding natural areas influence bat activity levels within a vineyard landscape. To accomplish this, we conducted acoustic surveys at 21 vineyards within the North Coast wine-grape growing region of California. Using generalized linear mixed-models, we assessed the influence of local remnant habitat and surrounding natural areas to predict overall and species-specific activity patterns. A total of 14,613 bat passes were recorded, of which 80% were identified by a random forest classifier as either *Tadarida brasiliensis* the Brazilian free-tailed bat (25%), *Myotis yumanensis* the Yuma Myotis (24%), or *Eptesicus fuscus* the big brown bat (23%). The results of our models indicate that total bat activity, and the activity of each of the common bat species, was higher adjacent to remnant vegetation along the edges of vineyards as compared to within the vineyard, but that the effect of landscape-scale characteristics on bat activity was weak. This suggests that natural trees and shrubs should be conserved and restored throughout the vineyard landscape to enhance bat abundance for a win-win agricultural production and conservation solution.

1. Introduction

Intensification of agricultural production has greatly limited the capacity of agricultural land to support other species (Benton et al., 2003). Recent studies focused on quantifying the extent to which wildlife use agricultural landscapes have revealed that structurally simple agricultural systems support a limited numbers of species (Aue et al., 2014; Caudill et al., 2015). Retaining heterogeneous vegetation structure within the agricultural matrix, however, can increase species diversity (Frey-Ehrenbold et al., 2013; Medina et al., 2007; Mendenhall et al., 2014; Muñoz et al., 2013) as well as ecological services such as biological pest control (Veres et al., 2013).

Bats provide an important example of biological pest control, valued at 3.7 billion dollars in the United States alone (Boyles et al., 2012). Yet bats face myriad threats ranging from habitat loss and fragmentation, deforestation, environmental contaminants, to roost disturbance across the globe (Jones et al., 2009; Kunz et al., 2011; Weller et al., 2009). In light of the particularly widespread threat posed by habitat modification, several studies have examined the factors that serve to support bat populations in managed landscapes (Gert and Chelsvig, 2004; Lentini et al., 2012; Morris et al., 2010). Within managed landscapes, numerous features have been implicated to influence bat activity, from forested edges (Duff and Morrell, 2007; Ethier and Fahrig, 2011), tree lines (Fuentes-Montemayor et al., 2013; Kalda et al., 2015; Verboom and Spoelstra, 1999), and riparian buffers (Akasaka et al., 2012; Law and Chidel, 2002). Small local habitat remnants and linear landscape features, such as forested edges and riparian buffers provide a number of benefits to commuting and foraging bats, including greater insect abundance (Morris et al., 2010), protection from wind (Verboom and Spoelstra, 1999), potential

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cover from predators, and navigational landmarks (Verboom and Spoelstra 1999). Heterogeneity in urban areas is also related to bat activity rates; a lack of heterogeneity resulted in low activity in Illinois' agricultural lands (Gert and Chelsvig, 2004).

While agricultural expansion in particular is generally perceived as negatively affecting the distribution, abundance, and diversity of bats (Duchamp and Swihart, 2008; Gert and Chelsvig, 2004; Weller et al., 2009), individual species' abilities to exploit agricultural ecosystems (Wickramasinghe et al., 2003) vary significantly (Coleman and Barclay, 2011; Estrada and Coates-Estrada, 2002; Kalda et al., 2015). Characteristics of both individual farms (Wickramasinghe et al., 2003) as well as the larger agricultural landscape (Lentini et al., 2012) may influence on farm bat activity. Structural features such as remnant vegetation, hedgerows, and windbreaks have been shown to support increased bat activity within agricultural landscapes in Europe (Frey-Ehrenbold et al., 2013; Kalda et al., 2015; Wickramasinghe et al., 2003) and Australia (Lentini et al., 2012), arguing that heterogeneity in agricultural lands can enhance bat occupancy.

In new world Mediterranean-climate regions such as Chile and Northern California, the growth of the wine industry has led to extensive conversion of land to vineyard acreage (Viers et al., 2013). Given the importance of wine-grapes to regional economies, and the potential for continued expansion of viticulture, it is essential to integrate ecological and viticultural practices to produce landscapes that will sustain wine-grape production and species and habitat protection. Maintaining bat diversity in and around the vineyard landscape presents the possibility for a win-win solution for wine production and bat conservation.

There is little information about the diversity or activity of bats within California's agricultural landscapes (Long et al., 1996). While Long et al. (1996) confirmed agricultural pests in the diets of two common bat species; the extent to which these or other species use various agricultural landscapes remains poorly understood. The growth of the wine industry along the north coast of California has created a mosaic landscape, with much of the valley floor dominated by vineyard acreage. Despite vineyard expansion, riparian setbacks persist (Merenlender, 2000), and may serve to promote bat activity in this agricultural landscape, as well as promote connectivity between the remnant oak woodlands, grasslands, and hardwood forests that persist along hillsides and mountains (Hilty and Merenlender, 2004).

This study was designed to answer three questions regarding bat activity and distribution within these vineyard landscapes in northern California. Firstly, what is the relative activity and species composition in these landscapes? Secondly, how does maintaining natural vegetation that increases structural heterogeneity in and around individual vineyards affect bat activity within vineyards? Thirdly, to what extent do larger landscape-scale land cover patterns affect bat activity at specific sites?

To answer these questions, we conducted acoustic surveys within the North Coast wine-growing region along a gradient of natural land cover and compared bat activity in the middle of vineyards to sites immediately adjacent to remnant vegetation. We hypothesized that local and landscape scale habitat diversity influence bat activity within vineyards, and predicted that overall and species-specific bat activity patterns would be positively

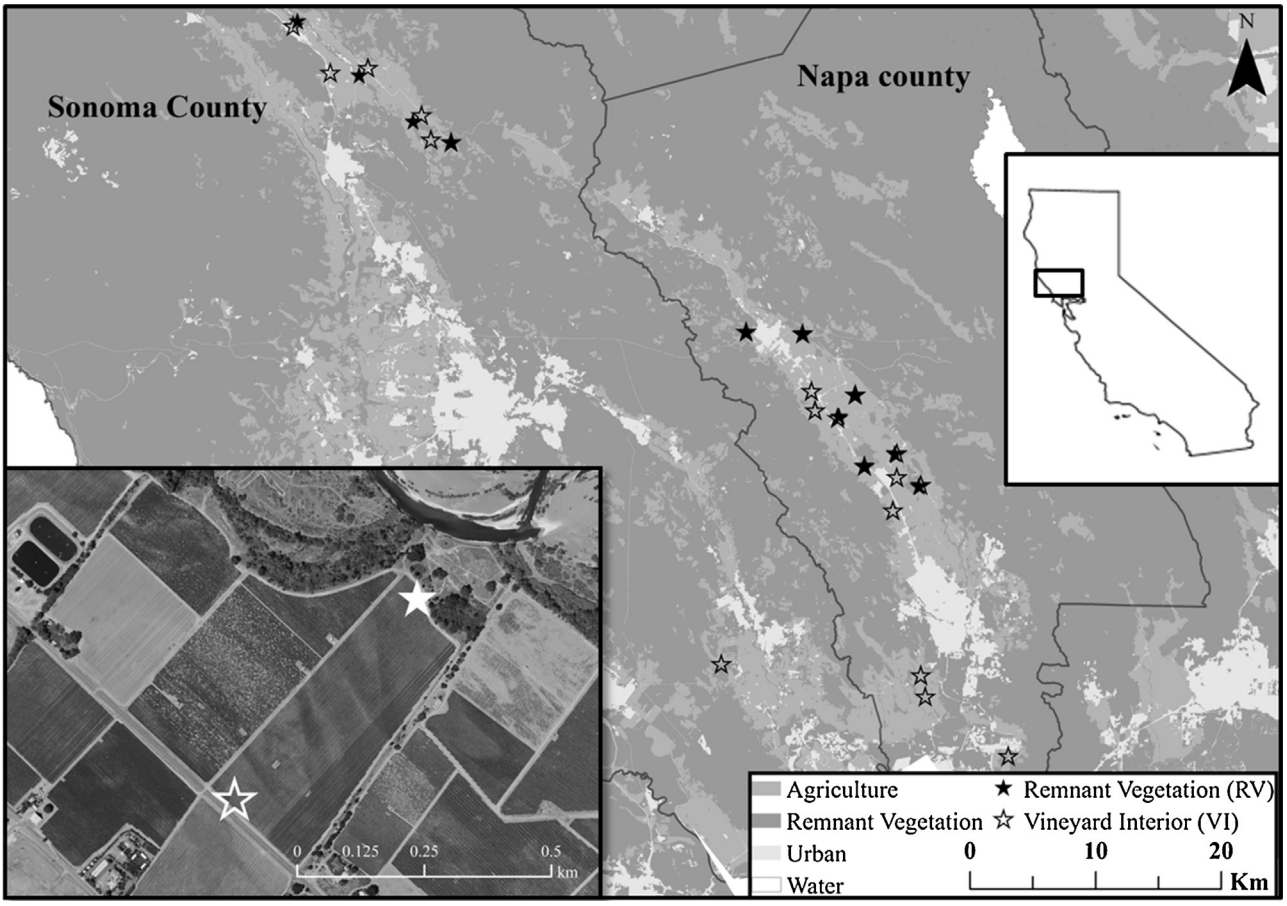

Fig. 1. Study area. "VI" indicates sites with 1 sampling point ($n = 10$). "RV" sites indicate the sites that had 2 nested sampling points, one in the vineyard interior (minimum of 70 m into vine rows), and vineyard edge (maximum of 35 m from edge of vineyard), adjacent to remnant natural vegetation ($n = 11$).