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Using hedgerows as model linkages to examine non-native plant patterns

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ABSTRACT

Non-native plant distribution and community composition, along with an array of environmental factors, were examined in 31 hedgerows, an archetypal class of conservation linkage, in the northern part of California's Central Valley. Row crop, orchard, and vineyard agriculture dominate this area, and hedgerows have been popular for well over a decade. Seven groups of explanatory data (environmental, historical, landscape, management, spatial, structural, and biological) were used to determine the strongest correlates of spatially-explicit patterns of non-native plants within and immediately surrounding hedgerows. In 15 hedgerows, a field experiment tested the effect of degree of shading on non-native plant diversity and cover.

The results of this project showed that: (1) Hedgerows harbored a flora of non-native plants richer than the surrounding matrix and that invasion was spatially structured. (2) Edges were more invaded than interiors in terms of both non-native richness and percent cover. (3) Differences between edges and interiors were likely due to shade. (4) Community-level patterns were most strongly correlated with the environmental, historical, structural and/or landscape explanatory variables. (5) Matrix types affected the non-native plant community in different ways, and the direction of those relationships was influenced by plant dispersal mode.

This research revealed that hedgerows can function as barriers to plant invasion if managed appropriately. Results supported the idea that these features may function as invasion conduits but perhaps not as major sources for invasion into agricultural fields. Specific recommendations are made regarding key factors (management, site, and species characteristics) influencing invasion, with particular emphasis on the role of shade, matrix characteristics, and plant dispersal mode.

1. Introduction

Conservation linkages, also known as habitat or wildlife corridors, are connective lands designed to allow native species (plants and animals) to move, thus negating some of the negative effects of pervasive habitat fragmentation and climate change (e.g., Hilty et al., 2006; Schippers et al., 2009; Beier, 2012). Agricultural hedgerows were chosen as the model linkages for this study because they embody basic structural characteristics of conservation linkages of particular interest (high perimeter: area ratio). Hedgerows are linear plantings or remnants of shrub or low tree species which run along edges of agricultural fields. They can provide or support ecosystem services (e.g., pollinator services) and native species habitat (Marshall and Moonen, 2002; Donald and Evans, 2006; Roy and de Blois, 2008) and may also enhance landscape connectivity for native species (Sitzia, 2007; Schippers et al., 2009; Van Geert et al., 2010).

Conversely, because they are typically embedded in working landscapes, hedgerows can be a source of concern for many agriculturalists because of their potential to harbor economically harmful non-native plant species (Sosnoskie et al., 2007; De Cauwer et al., 2008; Brodt et al., 2009). Several studies have examined spatial and compositional distribution of non-native plants in field margins, hedgerows, and windbreaks and have found that these linear features can function as refugia for non-native plant species (Sosnoskie et al., 2007; Boutin et al., 2008; Liira et al., 2008; Petit et al., 2013). Deckers et al. (2008) detailed the potential conduit function of hedgerows by showing that an invasive tree species' movement through a hedgerow system is mediated through the perching behavior of its main dispersal agents, birds.

This research used a blend of observation and experimentation to examine potential major influences on non-native plant communities within the context of model landscape linkages, a novel

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approach. Data collection and analysis focused on key aspects of the matrix, linkage, and species ecology, essential elements for an evaluation of invasive plant patterns in linkages (Wilkerson, 2013). The specific research questions were:

1. Are there differences in non-native plant distribution patterns between the different spatial axes of the hedgerow (edge vs. interior and ends vs. middles)?
2. If such differences exist, are they attributable to differences in light availability?
3. How do differing matrix types and other site variables relate to non-native plant richness and abundance patterns within the hedgerow and the immediately adjacent matrix?
4. Do non-native plant patterns in hedgerows differ depending on dispersal mode?

2. Methods

California's Central Valley, a large, mostly flat valley that dominates the interior of the state, is a mosaic of agricultural fields and rangeland interspersed with restored or remnant natural habitat. Non-native plants are pervasive throughout the landscape, and hedgerows are well distributed throughout the northern part of the Valley. Private landowners, NGOs, and government agencies have actively encouraged agriculturalists to maintain or restore hedgerows with native woody and herbaceous species (Earnshaw, 2004; Brodt et al., 2009; Long and Anderson, 2010).

Thirty-one hedgerows were chosen for the descriptive study. Of those, 15 were used in the experimental shade study. Hedgerows were selected based on similarity of management methods and planted native species and also based on a diversity of ages, from just-planted to 15 years old. All fell within three contiguous counties (Yolo, Solano, and Colusa) that have similar topography and land use/land cover types, and most non-native plants were annual grasses or forbs. The entire agro-ecological study area was 1400 km^2. The selected hedgerows ran along active field and/or orchard edges and had a farm road on one side. They ranged between 2–7 m in width and 120–800 m in length. All the study hedgerows ended sharply in either agricultural fields, or more often, dirt roads.

Selected hedgerows had generally the same planted shrub and tree species, most commonly *Sambucus nigra*, *Heteromeles arbutifolia*, *Cercis occidentalis*, *Baccharis pilularis*, *Ceanothus* spp., and *Quercus lobata* and occasionally native grasses *Stipa pulchra*, *Elymus glaucus*, *Elymus triticoides*, and *Muhlenbergia rigens*. Site preparation and management of the hedgerows were largely similar, including tilling, pre-planting herbicide, weed removal, seasonal watering via drip lines, and continued weed management.

2.1. Data collection

In the height of the spring flowering season (mid April–early June) of 2009 and 2010, observational data was collected from 31 hedgerow sites. The sampling design differentiated between middle vs. ends and interior vs. edges (Appendix 1A). "Edge" was defined as the outer 1 m of a hedgerow and "interior" the center line of the planting, at least 2 m from either edge. There were no "interior" quadrats in narrow (<3 m wide) hedgerows. Hedgerows "ends" were clearly demarcated by the cessation of hedgerow plantings. Five sampling sites were delineated along evenly spaced portions of each hedgerow. At each sampling site, a 10 m-long transect and a 1 m^2 quadrat imbedded within the transect were surveyed, and the frequency and aerial percent cover, respectively, of all native and non-native plant species was recorded. Fifteen transects and quadrats were surveyed for each of the 15 wider hedgerows, and five transects and quadrats for each of the 16 narrower ones. All focal species were non-native to California and usually to North America and are referred to only as non-native because not all have been classified as invasive by local evaluation sources (e.g., Cal-IPC, 2006).

Data was also collected at three matrix sampling sites: the two ends and the midpoint of the hedgerow (Appendix 1A). All species' frequencies were recorded along transects perpendicular to the hedgerow up to 27 m into the matrix (e.g., if the hedgerow ran N-S, matrix transects ran E-W). At each of the two end collection areas, additional transects were run to capture that edge type (e.g., if the hedgerow ran N-S, these transects would also run N-S.) For baseline data, six hedgerows were located that had been planted the winter prior to data collection (referred to as 0-year-old hedgerows). Presence–absence data was collected in the same way as described below (5 sampling sites with 10 m transects).

Explanatory data were grouped into seven categories (Table 1) and were chosen based on the research questions above and their usefulness for land managers, as well as on similar multivariate plant community analyses (e.g., Deckers et al., 2004; Hyvönen et al., 2005; Bassa et al., 2011). Historical and management data were collected via surveys sent to each grower about the hedgerow(s) on their property. Soil environmental data came from SoilWeb, an online tool using U.S. Department of Agriculture and National Council for the Soil Studies soil survey data (http://casoilresource.lawr.ucdavis.edu/soilweb/). Landscape, structural, and biological variables were collected with vegetation data. Definitions for all matrix land-use types are included in Appendix 1B. To account for spatial autocorrelation, spatial variables were derived from a cubic trend surface regression equation based on x and y coordinates: $z = b_1x + b_2y + b_3x^2 + b_4xy + b_5y^2 + b_6x^3 + b_7x^2y + b_8xy^2 + b_9y^3$ (Borcard et al., 1992).

Each non-native plant species was placed into one or more dispersal mode categories (cf. Cal-IPC, 2006; DiTomaso and Healy, 2007; Hintze et al., 2013). Because many species had more than one major mode of dispersal, wind vs. animal/bird vs. water vs. gravity-dispersed species could not be compared in one analysis.

2.2. Experimental set-up

To complement the observational study and delve more into the mechanics of this spatial phenomenon, a shading study was designed to test the direct effects of shade on non-native plant diversity and cover. Three mesh weights of shade cloth made of black knitted polypropylene were chosen to create different light levels that resembled levels found within existing hedgerows. Light level data was measured using a PAR (photosynthetically active radiation) ceptometer which measures the portion of the light spectrum that plants use for photosynthesis. All light measurements under the shade cloths and within hedgerows were made between hours of 13:00 and 15:00 within a three-week period in early winter. Light levels beneath the 90% cloth (meant to block 90% of sunlight) were closest to the mean light level found in the interiors of mature hedgerows (40 $\mu mol\, m^{-2}\, s^{-1}$). The 60% (285 $\mu mol\, m^{-2}\, s^{-1}$) and 30% (660 $\mu mol\, m^{-2}\, s^{-1}$) cloths spanned the range of light levels found along the edges of mature and within the interior of younger (narrow) hedgerows. Based on the results from preliminary analysis, it was hypothesized that the 90% and 60% shade cloths would decrease the diversity and cover of non-native plants whereas 30% shade would actually increase those metrics through a facilitative effect (e.g., Baumeister and Callaway, 2006; Semchenko et al., 2012).

In November 2011, after the first heavy rain of the 2011–2012 "rain year", shade cloth-covered sample plots were erected in 15 hedgerows where observational data had previously been