Effect of Landscape Structure on Biological Control of Vineyard Pests in Northern California

Efecto de la Estructura del Paisaje en el Control Biológico de Plagas en Viñas del norte de California

ROGÉ, Paul, UC Berkeley – ESPM, proge@berkeley.edu; VIELI, Lorena, UC Santa Barbara - Bren School of Environmental Science and Management, lvieli@bren.ucsb.edu; MILES, Albie, UC Berkeley – ESPM, afmiles@nature.berkeley.edu; WILSON, Houston, UC Berkeley –ESPM, houston@nature.berkeley.edu

Abstract
Non-crop patches of habitat in agricultural matrices play an important role in maintaining biodiversity, including natural enemies which in turn play a role in natural pest regulation. This research focused on the effect of landscape structure on insect populations. The results of this research suggest that there is an important relationship between landscape structure indices and insect populations associated with vineyards. Predator diversity increased with landscape complexity and with distance to riparian habitat from the sampling point. Positive response was exhibited by Orius spp. populations and negative by Syrphidae species. The complexity of the landscape favors Coccinelidae and Syrphidae species. Leafhopper (Erythroneura elegantula) densities populations were higher at larger distances from riparian habitat and increased landscape complexity. These results suggest that conservation planning at a regional scale is crucial to the regulation of pests.

Keywords. *Agroecosystem, natural enemies, pest regulation.*

Resumen
Hábitat de parches no cultivados en la matriz agrícola juegan un rol importante en la mantención de biodiversidad y enemigos naturales. Este estudio busca clarificar la relación entre la estructura y composición del paisaje y poblaciones de insectos en viñedos. Los resultados muestran que existe una relación importante entre la complejidad del paisaje y poblaciones de insectos. La diversidad de predatores aumenta con la complejidad del paisaje y con la distancia respecto de hábitat ripario. Ésta última afecta positivamente las poblaciones de Orius spp. y negativamente a los sírfidos. La complejidad del paisaje afecta positivamente la densidad de coccinélidos y sírfidos. Las poblaciones Erythroneura elegantula mostraron un aumento al incrementarse la distancia respecto de hábitat ripario y la complejidad del paisaje. De esta forma, los resultados sugieren que la planificación de hábitat no cultivado a escala regional es crucial para proveer regulación de plagas.

Palabras claves: *Agroecosystema, enemigos naturales, regulación de plagas.*

Introduction
The intensification of agricultural production reduces biodiversity and undermines ecosystem services, which are sets of ecosystem functions that directly or indirectly enhance human wellbeing. Since intensification aims to maximize the output of agricultural commodities, the biodiversity of agroecosystems has increasingly been reduced to only those species with the greatest productive response under ideal environmental conditions. Technological progress coupled with social and economic bias towards large-scale production has resulted in the dominance of entire regions by single crops (ALTIERI and NICHOLLS, 2002). Agricultural patches have come to dominate the landscape mosaic.

The regulation of agricultural pests by natural enemies can be enhanced by diversification and the conservation of non-crop habitats within agricultural matrices. Non-crop habitat patches in many cases contribute positively to pest regulation services. This may be due to the differential movement patterns of natural enemies and pests between patches. It is important to maintain environments that ensure the survival of natural enemies, since the risk of extinction at local levels is generally greater for natural enemies than for their hosts (CRONIN and REEVE, 2005). At landscape level, natural enemies may spill over between crops and surrounding habitats. Many natural enemies have adapted to the problem of local extinction by using non-crop habitat for alternate hosts, nutrient supplementation, shelter, or overwintering habitat (JONSSON et al., 2008). Non-crop habitats that contribute to pest regulation should be of high conservation priority and value (BIANCHI et al., 2008) since insect services to agriculture have an estimated worth of $57 billion per year worldwide (LOSEY and VAUGHAN, 2006).

Our research explores whether landscape complexity (i.e. the quality, geometry, and persistence of non-crop patches within an agricultural matrix) is responsible for increasing the abundance of pests and natural enemies. Since spaces between productive fields, such as fallows, naturalized pastures, wooded areas, and field margins act as biodiversity reservoirs (OLSON and WACKERS, 2007), we hypothesize that indices of landscape complexity can explain the abundance of pests and natural enemies in vineyard agroecosystems. The results shown here represent the first year of a three year study.

Methods

We analyzed the abundance of western grape leafhopper (*Erythroneura elegantula*), its parasitoid (*Anagrus spp.*), and predators (Asilidae, Cantharidae, Carabidae, Chrysopidae, Coccinellidae, Coenagrionidae, Geocoris, Hemiptera, Memerobidae, Nabidae, Odonata, Orius, Raphidiidae, Reduviidae, Spiders, Staphylinidae, Syrphidae, large wasps) in eight different vineyards within different landscape structures in Sonoma and Napa Counties, California. All vineyards are located within a Mediterranean climate.

We performed five measurements during the 2008 growing season using yellow sticky traps that were left for two weeks within each vineyard. Insect abundances were counted in the laboratory using microscopes when needed. A stepwise linear regression was conducted to identify the set of variables that are significant in explaining the abundance and diversity of predators. We used the total accumulated means of insect abundances and predators diversity, which were added to 1 and log-transformed before data analysis to compensate for the skewness and/or kurtosis of the data.

In order to control for climate differences between the vineyards, we used elevation, accumulated degree days (starting from January 1, 2008) and accumulated rainfall corresponding to the closest weather station and date of measurement. Regarding specific agronomic management, there were no significant differences among the sites of this study. The landscape structure was described by (1) landscape complexity measured as the fraction of non grape vegetation cover at a radius of 500m from the center of the sample fields (in the study areas almost all crops are grape vines) and (2) distance to riparian habitat.

Results

Predator diversity, estimated based on presence-absence criteria, was affected by all the variables used in the model at a p-value less or equal to 0.055 (Table 1). As the distance to riparian habitat increased so did the diversity of predators, but this relationship is probably non-linear and the ranges of distances used in this study were probably not large enough (97 to 790m). However, predator diversity increased with landscape complexity (represented by fraction of non-grape vegetation) which is consistent with ecological theory (BENNETT et al., 2006), which contends that landscape complexity increases insect diversity.

TABLE 1. Results on linear multiple regression using predators diversity as the response variable (R^2=0,45).

[redacted]

In order to asses predators densities we analyzed separately three groups of predators: *Orius spp*, *Coccinellidae* species and *Syrphidae* species. As expected, the distribution in the landscape of each group of species was affected by different variables in the landscape (Table 2). The distance to riparian habitat affects positively *Orius spp*. and negatively *Syrphidae* species, whereas fraction of non-grape vegetation affects positively *Coccinellidae* and *Syrphidae* densities, but not *Orius spp*. , which is a less mobile insect when compared to coccinellids and syrphid flies.

TABLE 2. Summary of variables affecting predator density.

[redacted]

Anagrus spp. and its obligate host, *Dikrella cruentata*, are found on *Rubus spp*. (which grows on riparian habitats) throughout the year Doutt and Nakata (1973, apud CATE, 1975). On grapes, western grape leafhopper (WGLH) is an alternate host to *Anagrus spp*. during the spring and summer. Results of this study show that WGLH increased with distance to riparian habitat (p-value 0,002) (Table 3). Also, the complexity of the landscape increases WGLH densities (p-value 0,0577). The WGLH spends the winter in a diapausing state and begins to lay their eggs on grape vines two weeks after their leaves appear (CATE, 1975). Before grape vines begin to produce leaves, the WGLH has been observed in alternate food plants such as *Rubus sp*., almond trees, forbs and numerous grasses, which apparently serve as food host from the time WGLH begin to become active in the spring until the oviposition host (grape) is available (CATE, 1975). Therefore, it seems plausible that as the fraction non-grape vegetation cover is larger in the landscape the

WGLH populations have more alternate food when they begin their activity. Consequently, the landscape structure and composition might favor or not WGLH population, depending on the type of vegetation cover, whether it is riparian or not, and whether such vegetation also supports WGLH enemies.

TABLE 3. Regression variables determining the WGLH population densities, their estimated value, F-Ration and significance. Model R^2= 0,77

[redacted]

Conclusions

This study corroborates that landscape structure and composition are important in determining WGLH densities and diversity of predators within vineyard agroecosystems. Over the next two years our study will continue to document the potential for non-crop habitat to provision the ecosystem services of natural pest regulation. More studies are needed to develop thresholds of landscape indices beyond which provisioning of ecosystem services, such as natural pest regulation are lost. As our understanding of ecosystem services improves, we can develop regional strategies for pest management based on the conservation of non-crop habitats in the agricultural matrix.

References

ALTIERI, M.A.; NICHOLLS, C.I. The simplification of traditional vineyard based agroforests in northwestern Portugal: some ecological implications. *Agroforestry Systems*, Dordrecht, v.56, p.185-191, 2002.

BENNETT, A.F.; RADFORD, J.Q.; HASLEM, A. Properties of land mosaics: Implications for nature conservation in agricultural environments. *Biological Conservation*, Essex, v. 133, p. 250-264, 2006.

BIANCHI, F., GOEDHART, P.; BAVECO, J. Enhanced pest control in cabbage crops near forest in The Netherlands. *Landscape Ecology*, Dordrecht, v. 23, p. 595-602, 2008.

CATE, J.R. *Ecology of Erythroneura elegantula Osborn (Homoptera: Cicadellidae) in grape agroecosystems in California*. 1975. (PhD dissertation) - University of California, Berkeley. 1975.

CRONIN, J.; REEVE, J. Host-parasitoid spatial ecology: a plea for a landscape-level synthesis. *Proceedings of the Royal Society B - Biological Sciences*, v. 272, p. 2225-2235, 2005.

JONSSON, M. et al. Recent advances in conservation biological control of arthropods by arthropods. *Biological Control*, Orlando, v. 45, p. 172-175, 2008.

LOSEY, J.E.; VAUGHAN, M. The Economic Value of Ecological Services Provided by Insects.

BioScience, Washington, v. 56, n. 4, p. 311-323, 2006.

OLSON, D.; WACKERS, F. Management of field margins to maximize multiple ecological services. Journal of Applied Ecology, Oxford, v. 44, p. 13-21, 2007.