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Local Management and Landscape Use Intensity Associated with a Coffee Leaf-Chewing Beetle

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*Agroecological factors at local-management and landscape scales influence organisms residing in agriculture. Management for control of insect pests of agricultural commodities can be facilitated by our knowledge of these factors. We sampled for a minor coffee pest, a leaf-chewing beetle (*Rhabdopterus jansoni*), across sites that varied in coffee shade management and landscape land use composition. We show that* R. jansoni *abundance increased with higher local shade tree density, and the percentage of high-shade plantations and habitat diversity in the surrounding landscape. Sites at lower elevations also had more* R. jansoni *than at higher elevations. This study suggests that this minor pest prefers high-shade plantations, landscapes dominated by high-shade coffee land use, and lower elevations. These results will be useful for understanding this pest's population dynamics with continuing shade intensification and climate change occurring in the Mexican and Central American coffee growing region.*

KEYWORDS herbivore, Rhabdopterus, *pest control, scale, management*

INTRODUCTION

Diverse agroecosystems often have less pest damage, fewer herbivores, and more natural enemies in comparison to simplified systems (Letourneau

et al. 2011). In addition, at larger scales, heterogeneity in the surrounding landscape can promote diversity and abundance of natural enemies of crop pests within fields (Tscharntke et al. 2005; Bianchi et al. 2006; Letourneau et al. 2011). However, understanding pest responses to landscape complexity is more complicated. A quantitative synthesis of the literature showed that while pest population growth was found to decline with landscape complexity, pest richness increased, and no clear pattern was observed for the abundance of pests in relation to landscape complexity (Chaplin-Kramer et al. 2011). Hence, more studies are needed to better understand the importance of landscape complexity to pest communities and populations.

One crop, that is an ideal system to study crop pests, is coffee (*Coffea arabica* L.) because it is consumed by over 200 arthropod species in the Neotropics (Le Pelley 1973). Local factors, such as shade tree management, are important in maintaining predator communities that reduce pest populations in coffee agroecosystems (Perfecto et al. 2004). Landscape scale factors, such as the amount of forest in the surrounding landscape, can also be important in regulating pests, either through dispersal constraints or increased predator populations (Bianchi et al. 2006; Avelino et. al 2012). Only a few studies have investigated the impact of these factors on disease and pest abundance in coffee. One study observed effects of land use types in the surrounding landscape on the coffee leaf rust and the coffee berry borer (Avelino et al. 2012). Nonetheless, we know very little about how most of the herbivores that feed on coffee respond to multi-scale factors, therefore few generalizations can be made. Further, given the rapid climate and land use changes occurring in the Neotropical coffee growing region, we might see shifts in which pest species cause minor and major economic damage. For example, the coffee rust has only occasionally caused economic damage, but devastated the region in 2012–2013 (Cressey 2013).

The purpose of this study was to determine which local and landscape factors affect the abundance of *Rhabdopterus jansoni* (Jacoby) (Coleoptera: Chrysomelidae) a coffee leaf chewing herbivore. Little is known about the natural history and lifecycle of *R. jansoni,* known as *la tortuguilla* and *la vaquita*, in Mexico and Central America (Barerra et al. 2008). It consumes the leaves and fruits of coffee and is most abundant in May-July (Barerra et al. 2008). It is during this season that coffee leaves are maturing and thus the food source of *R. jansoni* is abundant. However, *R. jansoni* damage to coffee is not enough to consider it a major pest species by local agriculturalists (Barerra et al. 2008). We hypothesized that *R. jansoni* would be more abundant in coffee plantations with high coffee densities and low shade tree density, where food resources abound and predator abundance could be lowest (Root 1973; Perfecto et al. 2004). Additionally, we predicted that landscapes dominated by forests, high-shade coffee, and high habitat diversity should have fewer *R. jansoni* due to higher predator abundance or low dispersal through these habitats. By studying the dynamics of this beetle, we

hope to provide the scientific community with a model organism that can be used to aid in the understanding of the ecological factors that influence the entire pest complex.

METHODS

This study was conducted in the Soconusco region of Chiapas, Mexico, at elevations ranging from 600 to 1300 m above sea level. This landscape is largely dominated by coffee agriculture (94%) with small forest fragments interspersed within the agricultural matrix (6%) (Philpott, Lin, et al. 2008). We located 34 sites within nine coffee plantations that varied by management and landscape factors. We used a GPS (Garmin GPSmap76CSx) to map an approximate one-hectare circle around each site and documented the abundance and richness of tree species >10 cm dbh within that area. Abundance-based coverage estimators (ACE), in the program EstimateS (Colwell 2011), were used to approximate the total number of tree species within a site given that plot size varied. In order to get a measurement of the density of coffee bushes, we established a 15 × 15m subplot at the center of the 1-ha plot and counted all the coffee plants within it. We randomly selected five of the coffee bushes sampled and counted the number of foliated branches per bush to estimate the average bush size. To obtain landscape level features of the areas surrounding sampling sites, we used geographic information systems (GIS) and measured landscape heterogeneity by digitizing the borders of forests and plantations of varying shade tree management intensity using a basemap in ArcGIS 10. Plantation boundaries were used to define rough categorizations of landscape shade management intensity based on the average percentage of shade cover of plantations: high- (>70%), medium- (30–70%), and low- (<30%) shade management. Some plantations had large areas of more than one category of shade intensity level. We, therefore, delineated these areas and categorized each area into its appropriate level. With this categorization, we calculated percentage of forest, low-shade, medium-shade, and high-shade coffee land use types within 500 m radii surrounding each site. We also calculated the Shannon diversity index (Σ -ln(p)p) of the habitat types. The means and ranges for all variables measured are listed in Table 1.

Rhabdopterus jansoni beetles were collected by sweep netting 15 coffee bushes in transects on two occasions between May and July of 2012 between the hours of 7:00 and 14:00. Each bush received four upward sweeps of the net starting at the base of bush moving upward. We summed the number of *R. jansoni* per site across both sampling dates.

To determine the importance of local and landscape factors on *R. jansoni* abundance, we performed conditional inference trees (CIT) and generalized linear models (GLM). We chose to use two different methods

TABLE 1 Local and landscape factor mean and range

	Mean	Range
Local management factors		
Branches per bush	118	80–190
Coffee density (per 225 m^2)	71	23–154
Shade tree density (per hectare)	170	63–337
Shade tree richness (estimated per hectare)	29	10–74
*Landscape factors**		
Forest %	7	0–29
High-shade coffee land use (%)	28	0–100
Low-shade coffee land use (%)	28	0–100
Habitat diversity (Shannon's index)	0.50	0–1.21
Elevation (above sea level)	934	595–1273

*Landscape factors were measured at a 500-m radius surrounding site centers.

because CITs are nonparametric tests that are robust to collinearity and GLMs are a more traditional method. CITs use a binary recursive data-partitioning algorithm that first finds the independent factor that most explains the dependent factor, splits the independent variable in two partitions, then repeats the search and splitting algorithm (De'ath and Fabricius 2000). We constructed a CIT and included local factors (mean number of branches per bush, number of trees per hectare, estimated tree richness, coffee density) and landscape factors (percentage of forest, high-, medium-, low-shade coffee, and landscape diversity), as well as elevation as independent variables. To provide a more traditional method of multivariate analysis, we fitted a GLM with a Poisson error distribution (log = link). We ran GLM models with the inclusion of a random effect of plantation to control for pseudoreplication among plantations; however, we removed this factor because the estimated variance of the effect approached 0 and the factor did not improve model fit. In subsequent GLMs, we included the same local and landscape covariates as in the CIT and performed model selection to exclude non-significant factors using information criteria and residual deviance. We checked for overdispersion and collinearity using the program R (R Program 2011) and removed the percentage of medium-shade coffee due to collinearity with other factors.

RESULTS

The CIT and GLM revealed some consistent local and landscape level effects, but some differences between the outputs of the two approaches were observed. Both analyses showed that both local and landscape-level factors were important in predicting *R. jansoni* abundance. The CIT revealed that the density of shade trees was the most important factor explaining *R. jansoni* abundance, with plots containing more than 206 trees per hectare having

more *R. jansoni* than plots with fewer than or equal to 206 trees (Figure 1). Within plots containing fewer than 206 trees per hectare, the percentage of high-shade coffee within the landscape (500 m radius surrounding site) was the next most significant factor. Sites surrounded by greater than 10% high-shade coffee land use had more *R. jansoni* than sites that had less than 10% high-shade coffee land use in the landscape surrounding the site (Figure 1). The GLM found shade tree density and landscape level habitat diversity were significant factors positively correlated with *R. jansoni* abundance. It also
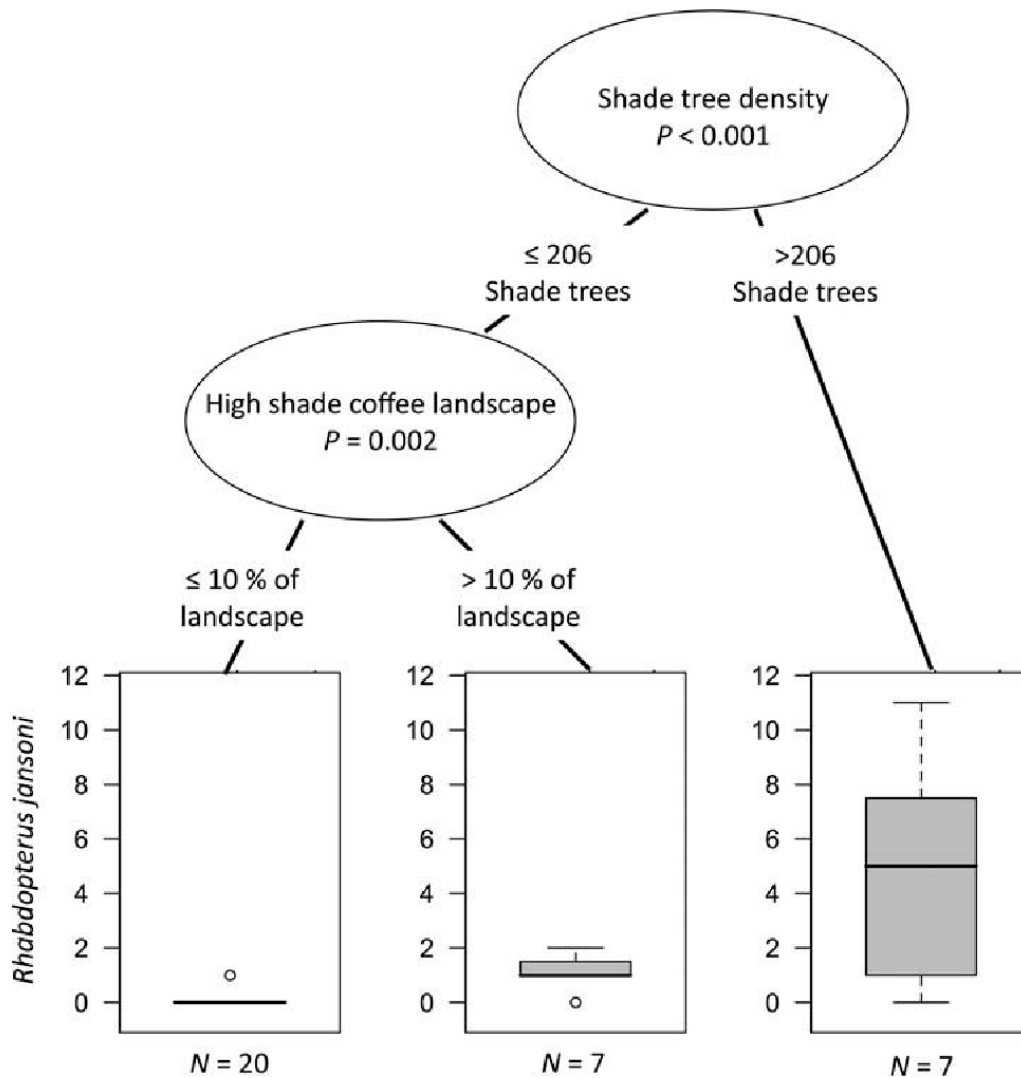

FIGURE 1 Conditional inference tree for *R. jansoni* abundance. The variables shown are those with the strongest association to *R. jansoni* abundance. *P* values reflect a test of independence between dependent and independent factors. Box plots (dark line = median, boxes = inner-quartile, whiskers = 1.5× inner-quartile range, circles = points outside range) at the base of the graphic show the distribution of *R. jansoni* abundance within each partition.

TABLE 2 Local and landscape factors explaining *R. jansoni* abundance in generalized linear model*

	Estimate ± SEM	Z	P value
Intercept	3.46 ± 1.388	2.5	0.0127
Shade tree density	0.005 ± 0.0026	2.0	0.0459
Low-shade coffee landscape (%)	−5.522 ± 2.106	−2.6	0.0087
Habitat diversity	2.963 ± 0.954	3.1	0.0019
Elevation	−0.007 ± 0.002	−4.0	< 0.0001

*Branches per bush, coffee density, shade tree richness, high intensity coffee (%), and forest (%) were excluded from the final model because these factors were not statistically significant and inclusion reduced model fit.

showed that the percentage of low-shade coffee in the landscape and elevation were negatively correlated with *R. jansoni* abundance (Table 2).

DISCUSSION

Contrary to our predictions, plots with high tree density, plots located in landscapes with high diversity habitat types, and plots with high percentages of high-shade coffee land use had higher abundance of *R. jansoni*. The use of two statistical tests reveals consistent patterns indicating that both local and landscape scale factors are important predictors of the abundance of *R. jansoni*. While the CIT and GLM were not entirely parsimonious, shade tree density was an important factor in both models. The results of the CIT showed that almost no *R. jansoni* individuals (19/20 sites contained zero *R. jansoni*) were found in sites with less than 206 shade trees (per hectare) and less than 10% high-shade coffee land use in the landscape. In other words, a high local tree density and/or a high percentage of high-shade farming in the landscape greatly influenced *R. jansoni* abundance. It appears that high shade plantations may act as a source of *R. jansoni* and *R. jansoni* disperses from these sources to nearby low-shade farms (sinks). *Rhabdopterus jansoni* might be more abundant under high-shade conditions because of favorable microclimatic conditions such as temperature and humidity. Similar results have been found for other beetles in coffee (Henderson and Roitberg 2006). It also could be that shade trees provide alternative or diverse food resources to this species, as high-shade farms typically have higher tree species diversity (Philpott, Arendt, et al. 2008). Shade could also be correlated with low levels of pesticide application. The main pesticides used in the region target another beetle species (the coffee berry borer) and may indirectly cause the mortality to *R. jansoni* (De la Mora et al. 2013). Further work could investigate the significance of these factors in explaining *R. jansoni* abundance.

The GLM also found that *R. jansoni* abundance was positively correlated with habitat diversity and negatively correlated with elevation. These results are surprising because a recent meta-analysis found that habitat complexity did not significantly explain pest abundance across agricultural studies (Chaplin-Kramer et al. 2011). It is unknown to what degree *R. jansoni* is a specialist, but *R. jansoni* could use multiple types of coffee plantations and forest fragments within its lifecycle. Thus, *R. jansoni* may need regional habitat diversity to maintain local populations in coffee plantations. Examples of herbivores using multiple habitat types are known in agriculture (Tscharntke et al. 2005). Further, natural history research could aid in our understanding of this pattern. In addition, we found support that *R. jansoni* favors lower elevations, which has important implications for climate change considering that species are known to migrate to high elevations as climatic conditions move. Similarly, other Chrysomelid beetles are sensitive to changes in elevation because of changes in microclimates (Flinte et al. 2011). This correlation may be driven by temperature differences at lower elevations, and understanding the factors that limit this leaf beetle may be useful in future years. The elevation at which these beetles are found may change. As climates at lower elevations are expected to shift up towards high elevations, we might expect that this species will soon become more prevalent in coffee plantations at higher altitudes.

Our study has outlined the local and landscape factors correlated with the abundance of *R. jansoni,* a coffee herbivore. Despite the fact that we show higher abundance in high-shade coffee plantations, *R. jansoni* is not considered a major pest in coffee and in agreement with Barerra et al. (2008) we currently do not recommend management changes to control for it. Other pests like the coffee berry borer, the coffee rust, and other fungal pathogens have recently, and in previous years, shown to be far more damaging and as such, pest management has focused on those species (Damon 2000; Cressey 2013). While some may argue that there is only value in studying the pest species that are of economic importance, others see the importance of studying herbivorous minor pests, like *R. jansoni,* as a preventative strategy. Before minor herbivores become major pests it is useful to understand their ecology while they coexist with crops and maintain stable population sizes below damaging densities. Knowing the factors limiting species like *R. jansoni,* will undoubtedly be useful later given that climates continue to shift and regional management across Mexico and Central America continues to intensify.

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