Moth Diversity and Abundance between Habitats on a Shade Coffee Plantation in Western Jamaica

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Research Article

Moth diversity and abundance between habitats on a shade coffee plantation in western Jamaica

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Abstract. Habitat loss is the leading cause of wildlife decline worldwide. More prevalent than outright destruction, however, is habitat fragmentation, exhibited especially in tropical regions. Less well studied is the effect of these patchworks of habitats, and the subsequent effect on local invertebrate populations. A small-scale study assessing moth diversity and abundance between forest edges and crop interiors on a shade coffee plantation was conducted in western Jamaica in January 2009. Ornithologists use shade coffee as an example of sustainable agriculture that protects neotropical migratory birds, and shade coffee plantations have been shown to act as a buffer area ("halo") between fragmented habitats for insects. The patches of vegetation allow moths to disperse between areas without suitable vegetation for host plants. UV black light traps were used at the edge and interior of each site to sample local moth fauna. While there was no significant difference in morphospecies richness or abundance, there was a difference in diversity between sites, with very low overlap. The lack of significance suggests coffee habitat may act as a buffer between less disturbed forest and more disturbed human altered areas, but that some species may be restricted to certain habitats. Many moth species are host specific, and can serve as useful indicators for ecosystem and vegetative health and relative abundances. Studies of insects are important because of this group's extreme species diversity, and further research is necessary for assessing alpha, beta, and gamma diversity in rapidly disappearing forests in Jamaica and across the world's tropical regions.

Introduction

Habitat destruction is the leading cause of population declines of wildlife worldwide and is especially pronounced in sensitive tropical areas that harbor much of the earth's biodiversity (Groom et al., 2006). The tropical island of Jamaica is host to the fifth largest collection of endemic island plant species in the world but as of 1983, only 6% of undisturbed natural forests remained (McGinley, 2008). The remaining habitat is a patchwork of agricultural and human disturbed areas. Approximately 10,000 ha of Jamaica's agriculture is devoted to the production of coffee (*Coffea arabica*) (Kellermann et al., 2008). Coffee is the second most traded commodity worldwide after oil, and the large areas under cultivation in tropical areas make it especially relevant to conservation (Kellermann et al., 2008). The term "shade coffee" is used to denote coffee plants grown under the canopy of an overstory of trees, providing habitat for a variety of wildlife. In particular, neotropical migratory birds and insects derive a benefit from this practice (Johnson, 2000; Johnson et al., 2010).

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The theory of island biogeography provides a framework for investigating processes operating on islands of habitat in a "sea" of disturbed areas. Habitats, however, are rarely in an island/sea situation and consist in what has been termed "matrix," the complex patchwork of landscape conditions (Laurance and Bierregaard, 1997). Assessing management strategies in this matrix could yield more information on the implications of human altered habitats and effective conservation in a heterogeneous landscape (Ricketts et al., 2001; Summerville and Crist, 2004; Kellermann et al., 2008). This is especially true in tropical countries heavily modified by human activity and marked by the urgent need for people to obtain food and their livelihood from working landscapes. Conservation in these cases is difficult without taking into account the human impact on the environment and subsequent fragmentation of habitat.

In a study on moth fauna in a matrix in Costa Rica, Ricketts et al. (2001) discovered that species diversity and composition of Lepidoptera did not vary among agricultural habitats overall. At agricultural sites nearer to forest fragments however, there was greater richness and abundance than at sites further away. They suggested that "halos" of moth populations extended throughout a matrix of various habitats from forest patches. Moths should be able to disperse, depending on their abilities and requirements, between patches of suitable habitat, thus colonizing isolated forest fragments that contain suitable host plant species (Daily and Ehrlich, 1996). In particular, shade coffee habitat has been hypothesized to act as a buffer area for moths in fragmented forests (Dolia et al., 2007). The complex vegetation on shaded farms may act like a dispersal bridge between remnant forests for moth species.

Moths are insects in one of the largest orders, Lepidoptera, with over 160,000 described species in more than 120 families. Along with butterflies, they are some of the most recognizable insects in the world due to their striking wing patterns. The larvae are mainly plant feeders and often host-specific to one species or family of plants (Borror et al., 2005). This trait can be useful in assessing plant diversity in an area (Ricketts et al., 2001). The extreme diversity and abundance of moths underscore their extensive roles in pollination biology, herbivore ecology, and as prey items in a system. Their presence adds to ecosystem complexity and stability contributing to their significance as indicators of ecosystem health (Ricketts et al., 2001).

In this study the abundance and diversity of moths was compared between two habitat types: "coffee" and "forest edge" habitat. Studies by Carey (1994), Ricketts et al. (2001), and Summerville and Crist (2003) on moth abundance and habitat differences suggested that host species diversity is important for stable populations of some groups of Lepidoptera. Forest patches could act as sources for moth populations, helped in part by plant species diversity on shade coffee farms. Specifically, I tested the prediction that, if coffee habitat can serve as a buffer matrix between agriculture and forest communities through which moths can disperse, then moth species richness should be similar between the coffee and forest edge, and there should be significant community overlap.

Materials and Methods

The study was conducted on the Kew Park Farm near Betheltown from January 8-24, 2009, in Westmoreland, Jamaica. The Kew Park farm (18 ha) is a private shade coffee (*Coffea arabica*) plantation shaded by broadleaf plants such as *Ceiba, Hibiscis, Inga, Ficus,* and *Musa* in scattered clumps shading the rows of coffee. The farm is enclosed by densely forested limestone hills of native and alien vegetation bordered by a narrow road on one side. Across the road are pastures, farms, and homes with additional forest fragments and forested hills.

Moths were sampled at three forest edge and three coffee interior locations on the Kew Park farm. Each site was sampled for four nights total, not more than one night apart. Forest edge was defined as within 10 meters of a forest, and coffee interior was at least 75 meters away from forest edge. Sites were chosen using Geographic Information Systems with an aerial overlay map and located on the ground using handheld Global Positioning System units. Forest edge selection was based on sites nearest to intact forest fragments, while coffee site selection was based on the distance from edges and other sampling sites. All sampling was done pairwise, with one edge and one interior site sampled concurrently for 4 nights before progressing to the next pair of sites. Moths were attracted for sampling using a 15-watt ultraviolet black light per location powered by one 12-volt car battery, set up on a hanging white sheet (Borror, 2005; Gullan and Cranston, 2005). Black lights were set up on the side facing the forest on the edge sites, and facing the densest coffee groves in the interior in order to attract moths from those particular areas of interest and minimize species from the other habitats. At the first two locations, all moths were initially captured at site for later classification to morphospecies based on distinct external morphological characteristics. For later locations, unrecognizable moths were captured while recognizable moths were tallied by morphospecies. All captured morphospecies were pinned as type specimens for reference and archived at The University of West Indies in Mona, Jamaica. These methods are similar to those used by Barlow and Woiwod (1989) and Ricketts et al. (2001).

The tropics exhibit extreme biodiversity and as such it is not always possible to reliably identify insects below particular taxonomic groupings such as order or family without expert assistance. For these reasons it was most efficient to categorize moths as unidentified morphospecies based on distinct physical characteristics. Categorizing moths in this manner has been shown to correlate with actual species compositions where further identification was not feasible (Ricketts et al., 2001). Morphospecies abundance and richness was scored as the highest number of macromoths (greater than 1 cm in wing length) during a sampling and the number of morphospecies at a site in a sampling night. Moths smaller than 1 cm in wing length were grouped together as "microlepidoptera" and not included in comparisons because of difficulty in identification. Sites were sampled at least three times per night, at intervals between 45 and 60 minutes. Sampling began no earlier than 17:30 and ended no later than 21:30. Other variables recorded were moonrise time, moon phase, cloud cover, and sunset times. Elevation and temperature were probably not important factors in species distribution as the sites were near enough to not differ substantially.

The number of individual moths between sites, as well as the richness of moths between sites was compared with Student's t-tests. Simpson and Shannon indices were computed to compare diversity among individual sites and habitats. Finally, Jaccard's Indices were computed to compare community similarity between locations.

Results

A total of 1,700 individual moths were collected and observed across all sites. The coffee interior sites yielded 858 individuals and the forest edge sites had 842. There was no significant difference in average moth abundance between the two sites (coffee mean: 286 ± 60, edge mean: 281 ± 98, $t = 0.14$, df = 2, p = 0.90). The richness of morphospecies collected and observed at all sites was 202, with 70 unique species found in coffee and 52 unique species in edge. The average number of morphospecies detected at a site was not significantly different between habitats (coffee mean: 68 ± 11, edge mean 74 ± 17, $t = 0.70$, df = 2, p = 0.56) (Table 1).

Morphospecies diversity was not significantly different between habitats (coffee mean: 3.7 ± 0.2,

Table 1. Comparisons of mean (± 1 st. error) species richness and abundance between habitat sites, Kew Park Farm, Jamaica, West Indies, 2009.

Habitat	Mean Species Abundance	Mean Species Richness
Coffee	286 ± 60	68 ± 11
Edge	281 ± 98	74 ± 17

edge mean: 3.8 ± 0.1, t = 0.86, df = 2, p = 0.48, Shannon Index p = 0.68, Simpson Index p = 0.63). Jaccard index comparisons between paired coffee and edge paired sites gave community similarity levels between sites at 18%, 25%, and 24% shared composition of species. Community similarity within habitats was low, giving within-coffee similarity an 18% overlap, and within-edge similarity 14% overlap. Correlating distance between sites with the Jaccard's similarity indices showed no relationship between distance and species overlap (R^2 = 0.107) (Figure 1).

Discussion

Although moth morphospecies richness and abundance were similar in both habitats, the composition between the sites showed remarkably low overlap. Less than 25% of moth morphospecies were shared between edge and coffee sites overall. Between similar sites there were varying degrees of overlap from 18% to 24% in morphospecies composition. Similarly high richness and diversity may suggest that coffee habitats have the potential to act as a buffer for forest fragments, but the low overlap in composition suggests only a fraction of the forest moth community are able to use it. Certain moths may be confined to the forest edge, while others may readily occupy both habitats. It is also possible that diversity on the farm is high enough to obscure results from the sampling period. Sites often had morphospecies that were unique, even when only 100m away. Every site continually yielded new morphospecies at similar rates during the sampling period. A concurrent study at the Kew Park house 1 km away measured species accumulation over time. The number of macrolepidoptera morphospecies caught after four nights using similar methods was approximately 60% of the total identified at the end of 15 days, including many not seen on the farm (unpublished data).

The total abundance of moths by habitat was nearly identical (858 vs. 842), suggesting that abundance is not dependent on habitat type and that the matrix of forest and disturbed lands could be acting as a buffer or a transit corridor. Moths in the family Sphingidae are large, strong flyers capable of hummingbird-like flight, and were only found at lights in coffee habitat. The behavior of these moths suggests that they were attracted to the lights from above while in transit above the more open coffee rows. A sphingid moth was sighted during the study ovipositing eggs on vegetation in edge habitat, confirming

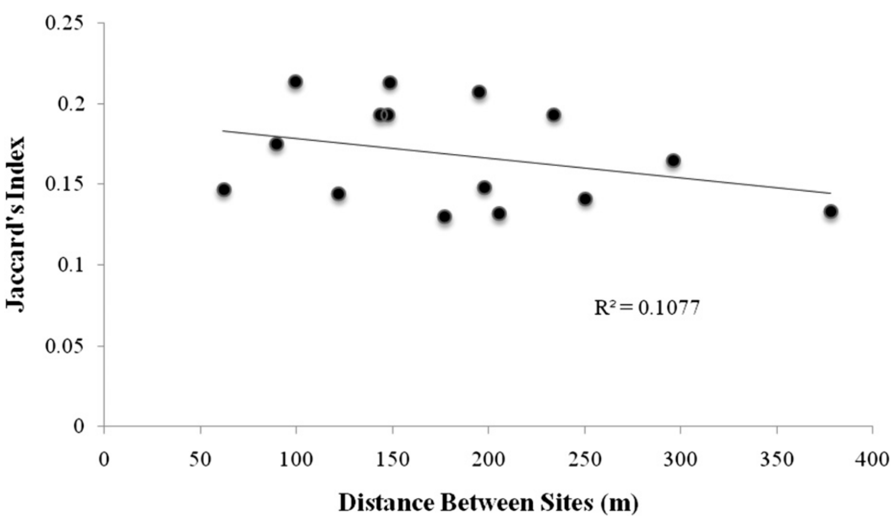

Figure 1. Trend in relationship between individual site Jaccard's diversity indices and distances between pairs of sites (n = 15). Each point represents a paired site against the relationship between distance between them (x-axis) and their diversity index (y-axis). Each site was paired to all other sites without repetition.

not only that they occur there, but that their larvae may associate with plant populations within that habitat.

It may also be that the patchwork of vegetation and habitat was too small to provide sufficient contrast and isolation of habitats. In the study by Ricketts et al. (2001), a larger area of homogenous habitat types was used, a feature difficult to find among the small farming plots in Jamaica. Therefore the described kilometer diameter "halo" extensions of moth ranges from forest patches would overlap and drown out significant differences. However, the "halo" effect may also vary among taxonomic groups (Ricketts et al., 2001). This may help explain the similarity in diversity between sites.

Invertebrate associations are one of the least understood aspects of ecology, and studies on moth-host plant relationships are especially incomplete (Ricketts et al., 2001; Choi, 2006). Although no family level plant associations were detected in Costa Rica, identifying moth species as generalists or specialists may be able to connect their relationships to habitat based on vegetative composition (Ricketts et al., 2001; Summerville and Crist, 2003). Generalist moths may also be more associated with disturbed sites, where forest has been altered or destroyed. In disturbed sites, herbaceous food plants are more common compared to forest-type foliage in undisturbed, possibly indicating habitat quality (Choi, 2006). The size of forest patches can also affect species richness more than vegetative composition where communities in smaller forests have closer relationships to the matrix (Summerville and Crist, 2004). These attributes may lend insight into whether moths are traversing the matrix, actively utilizing the matrix, or both. The mechanism behind moth "halos" is still unknown, and one possibility is that the matrix may act as a population sink for forest-based species (Ricketts et al., 2001).

In Jamaica, conservation efforts have been focused on migratory birds that provide ecosystem services (Kellermann et al., 2008; Johnson et al., 2010). Studies on migratory birds have shown that habitat selection is closely tied to food availability (Johnson and Sherry, 2001). These birds depend on invertebrates as an integral part of their diet, and the abundance of moths may factor into retaining birds to certain areas (Johnson, 2000). The lack of significance between coffee and edge sites suggests that they are equally attractive habitats for migratory birds. Further studies should be focused in agricultural or pastoral zones to discern the relative attractiveness and pull from coffee habitats, as well as to determine the extent of moth "halos" in Jamaican matrix. If moth "halos" correspond to a higher density of migratory birds, determining extent could be used as an indicator of optimal bird habitat, assisting in identifying potential sites to convince farmers to convert to shade methods. Research into identifying moth host-plant associations can also assist in deciding which plants to add or retain, as well as contributing to a poorly understood but integral aspect of ecology.

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