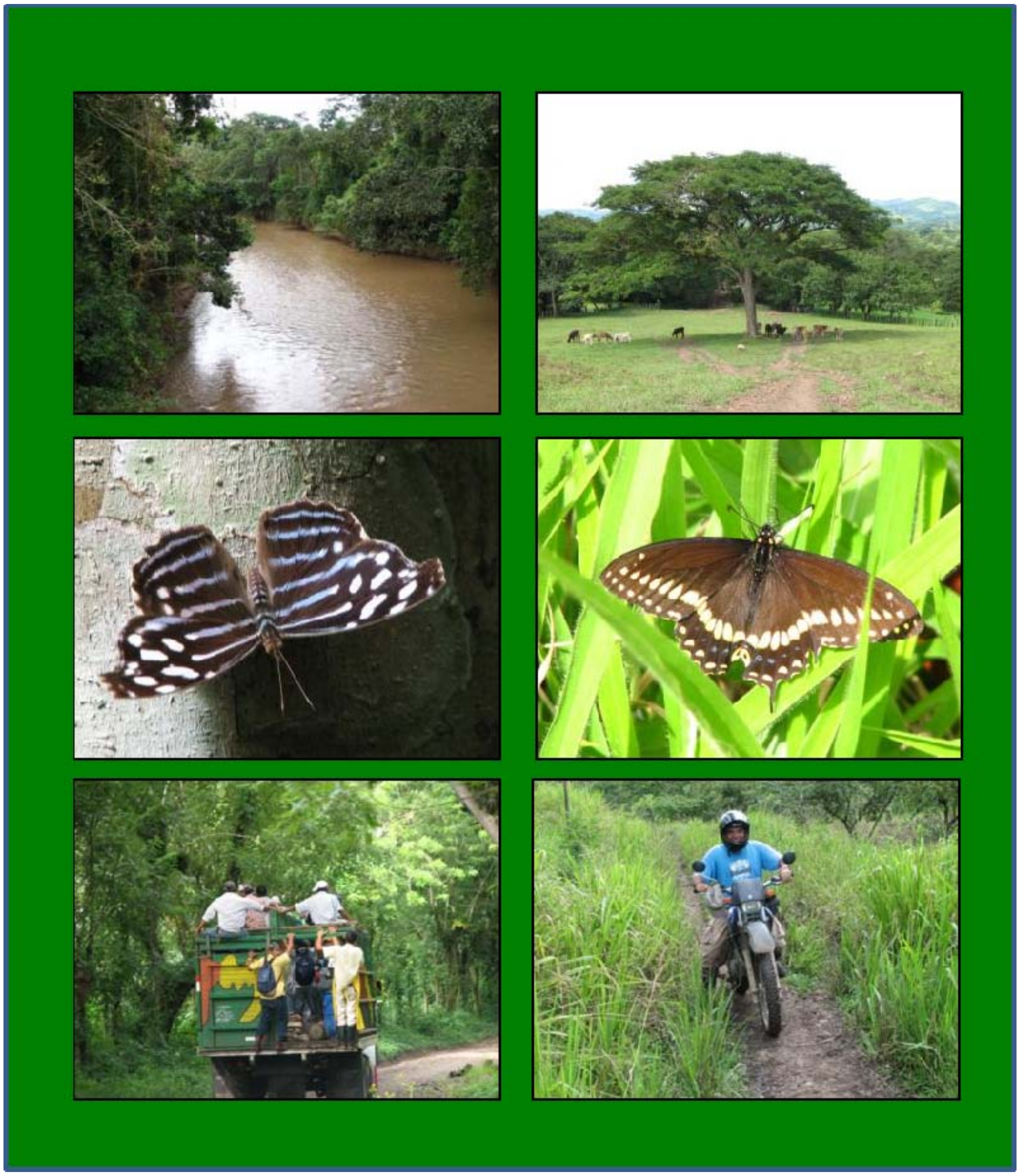
Conserving butterfly diversity in agricultural landscapes in Copán, Honduras and Matiguas, Nicaragua

Final Report

According to a Maya legend, when a warrior died, his soul transformed into a butterfly



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Contents

1. Introduction

Over the past century, Central American natural areas have been extensively cleared and fragmented for coffee plantations, cattle pastures, and other agricultural land uses. Pastures now comprise 20-60% of the total land area of each of the seven Central American countries, and are considered an important cause of biodiversity loss in the region (Restrepo, 2002; Szott et al., 2000). In response to this threat, there is now growing interest in promoting silvopastoral systems (SPS) as a way to conserve biodiversity, maintain ecosystem services, and improve the agro-ecological resilience of pasture-dominated landscapes. SPS incorporate various forms of tree cover into cattle farms, creating systems that are generally more diverse and structurally complex than traditional grass monocultures. Previous studies have shown that SPS retain moderate to high levels of native biodiversity, yet the specific type, extent, and spatial configuration of silvopastoral systems needed to support such diversity remains poorly understood (Tobar & Ibrahim 2008, Harvey et al. 2008a)..

In this study, we seek to elucidate these relationships by studying the composition and abundance of butterfly species in two pasture dominated landscapes in Central America: one in Honduras and one in Nicaragua. We used butterflies as the focus of our work because they are widely recognized as a useful indicator taxon and because they commonly respond to environmental heterogeneity on the scale of tens to hundreds of meters—the same scale at which small farmers make management decisions. The goal of this study was to improve our understanding of the conservation value of SPS and of how cattle farms could be managed to better conserve butterfly biodiversity in pasture dominated landscapes. To do so, we characterized the butterfly and woody plant communities present in different SPS land uses including secondary forest, riparian forest, live fences, forest fallow, pasture with high tree density (>25 trees per hectare), and pasture with low tree density.

The goals of this study were threefold. First, we sought to improve the knowledge base about butterfly diversity, distribution, ecology, and natural history in two landscapes where it is currently poorly known. This information can be used to understand the role of butterflies in performing key ecological services (such as pollination) in agricultural landscapes. Second, since butterflies are a commonly-used indicator species, we sought to examine how butterfly sampling could be used to monitor the effects of agricultural management practices on native plant and animal diversity. Third, we sought to identify the agricultural land uses and practices that support rich butterfly assemblages. This information, in turn, can be used to inform policies and incentives for conservation-friendly agricultural management.

This information is used to clarify the contribution of silvopastoral systems (pasture with trees, live fence) to the conservation of butterfly communities. Specifically, we want to understand how silvopastoral systems increase habitat quality, quantity and connectivity in pasture dominated landscapes. To do so, we characterized butterfly assemblages in different land uses within tree typical pasture-dominated landscapes: Copán, Honduras and Matiguas, Nicaragua. The analysis of this study are use to understand the patterns of butterfly diversity in agricultural land use.

2. Study Areas

2.1 Honduras

The Honduras study area was an agricultural landscape (800 km^2) in the Copán River watershed (Table 1, Annex 1), municipalities of Cabañas, Copán Ruinas, San Jeronimo and Santa Rita, in northwestern Honduras (14°43’ - 14°58’ N, and 88°53’ - 89°14’ W). Altitudes range from 600 to 1800 meters above sea level. The life zone is Tropical Wet Forest (Holdridge 1978). The average annual temperature is 21°C; average humidity is 45%; and annual rainfall ranges between 500 and 1800 mm. There are two seasons: the rainy season (May-December) and dry season (January-April).

The principal agricultural production systems in this landscape are shade-grown coffee and livestock production, while subsistence farming of corn, beans, rice, tomatoes, onions, cabbage, and other crops occurs on a smaller scale (Otero 2002; MANCORSARIC 2006). The cattle production is dual-purpose (milk and meat), with large, extensively grazed pastures (primarily *Hyperrhenia rufa*, *Cynoden nlemfuensis* and *Brachiaria brizantha*) and little use of fertilizers and supplementary feed. Livestock production has increased since the removal of tobacco plantations in the region since 1995, but this shift has brought environmental problems such as deforestation for pasture establishment, loss of wildlife, soil degradation, and water and fuelwood extraction for subsistence (Otero 2002; MANCORSARIC 2006).

The current landscape is dominated by pastures but retains a diverse and heterogeneous tree cover. According to a land use map based on a 2007 IKONOS satellite image, pastures cover 39.8% of the landscape. Other important land uses include coffee plantations (23.7%), pine forest (7.2%), secondary forests (11.6%), forest fallows (7.7%), riparian forests (6.3%), crops (0.8%), and other land uses (3.0%) (Sanfiorenzo 2008).

2.2 Nicaragua

The Nicaragua study area was an agricultural landscape (353 km^2) in the Bulbul watershed, municipality of Matiguas, department of Matagalpa (Table 1, Annex 1), in north-central Nicaragua (85°27' N, 12°50' W). The life zone is locally classified as semi-deciduous forest (Salas 1993), and falls within Holdridge's Tropical Moist Forest life zone (Holdridge 1978). The annual temperature is 24°C and annual rainfall ranges between 1200 and 1800 mm, with most rainfall occurring in the rainy season between May and December. Altitudes range from 200 to 900 meters above sea level (Laurent *et al.* 2001). The region is one of the main cattle producing regions of Nicaragua and is typical of cattle-dominated landscapes throughout the Pacific and central regions of Central America. Most cattle production is dual-purpose (milk and meat), with large, extensively grazed pastures (primarily *Hyperrhenia rufa*, *Cynoden nlemfuensis* and *Brachiaria brizantha*) and little use of fertilizers and supplementary feed (Betancourt *et al.* 2003).

It is not clear when the region was first colonized; however, permanent settlements are known to have been present from the 1920s onwards. The most recent period of deforestation occurred from the 1950s to present. However, some natural regeneration occurred in the region in the 1980s as the area was largely abandoned during the Nicaraguan civil war. The current landscape is dominated by pastures, but retains a diverse and heterogeneous tree cover. According to a land use map based on a 2002 Quickbird satellite image, pastures cover 68.2% of the landscape. Other important land uses include tree plantations (including fruit trees and live fences; 8.5% of area), secondary forests (6.8%), forest fallows (6.8%), riparian forests (1.4%), crops (1.2%), and other land uses (7%) (Harvey *et al.* 2008).

Table 1. Location and characteristics of project landscapes.

Landscape	m asn	Landscape Size (km^2)	Life zone	Dominant Land Uses
Matiguas, Nicaragua	200-1000	353	Transition from tropical dry forest to humid forest	Cattle pasture, pasture with trees, small areas of agricultural crops
Copan, Honduras	1000-1800	800	Tropical wet forest (Atlantic slope)	Cattle pasture, pasture with trees, oak/pine forest, coffee

3. METHODS

3.1 Field Sampling

We sampled butterflies in the six main types of tree cover present in the landscape: (1) secondary forests; (2) riparian forests; (3) forest fallows (young secondary regrowth on former pastures, locally known as “charrals”); (4) Multi strata live fences dominated by *Bursera simaruba* trees; (5) pastures with high tree cover (>25 trees/ha), and (6) pastures with low tree cover. We selected two types of pastures (with different levels of tree cover), because previous studies have suggested a relationship between tree density and animal diversity (*e.g.,* Estrada & Coates-Estrada 2002, Lumsden & Bennett 2005, Medina et al. 2007, Harvey et al. 2008, Tobar et al. 2007). All tree cover types were open to entry by cattle and the forest habitats had been affected by firewood and timber extraction. No surveys were conducted in either continuous or fragmented primary forests, as these are not present in the agricultural landscape.

Using satellite images for each landscape, we identified candidate sample plots, with the goal of establishing six plots per land use per landscape. Each of these plots was visited in the field to ensure that it was of sufficient size for the monitoring protocol. This required a minimum of 1 ha for secondary forests, forest fallows, and pastures, a minimum length of 300 m for riparian forests and live fences, and a minimum width of 15 m for riparian forests. In addition, secondary forests had to have a minimum canopy height of 15 m and a well developed understory, and forest fallows had to have a canopy height of between 2 and 10 m. Plots that did not fulfill these criteria were replaced with another randomly chosen plot. In the Matiguas landscape, we were able to identify only three suitable forest fallow plots because many fallows had recently been cleared and put back into crop or livestock production. Accordingly, the study included 36 plots in Copán and 33 plots in Matiguas. At each plot selected, vegetation structure and composition were characterized by surveying all trees greater than 5 cm diameter at breast height (Sanchez Merlo *et al.* 2005; 2008).

At each sample point, we established 100-meter long transects for butterfly sampling. Each transect was sampled six times: three times in the morning (0800-1200) and three times in the afternoon (1200-1600) on different days. For each sample, we walked the transect for 45 minutes and recorded all butterflies observed. Butterflies were identified by reference to to D'Abrera (1981, 1984, 1987a, 1987b, 1989, 1995), DeVries (1987, 1997) and Lamas (2004). Individuals that could not be identified in the field were collected for later identification. This method is considered the most effective and rapid sampling technique for butterflies (Pollard 1977). Sampling excursions occurred between September 2008 and May 2009. In each sampling excursion, we sampled one plot of each habitat type, with plots being sampled in random order. The total sampling effort was 26 hours per habitat for a total of 156 hours per landscape.

Additional details on the vegetation structure and composition of each type of tree cover can be found in Sanchez Merlo *et al.* (2005; 2008). Each transect per landscape was sampled three times, for two days during the study period. Each time, we walked the transect for 45 minutes between 08:00 and 16:00 on days with optimum climate conditions. We recorded all butterflies observed during the transect walks; All butterflies present in each transect were observed or captured, registered and identified by reference to D'Abrera (1981, 1984, 1987a, 1987b, 1989, 1995), DeVries (1987, 1997) and Lamas (2004). Individuals that could not be identified in the field were collected for later identification. This method is considered the most effective and rapid sampling technique for butterflies (Pollard 1977). Sampling excursions occurred between September 2008 and May 2009. In each sampling excursion, we sampled one plot of each habitat type, with plots being sampled in random order. Butterflies were sampled using a transect method (100 m long). The total sampling effort will be 26 hours per habitat for a total of 156 hours per landscape.

4. Data analysis

4.1 Diversity and composition in the agricultural landscape

For each transect, we summarized the number of individuals per species, species richness, and the Brilloun D index (Magurran 2003).). We used the Brilloin index because it is a more appropriate measure of diversity, it is more sensitivity more sensitive to species abundance (Magurran 2003). Using InfoStat 2008 software, we compared mean values using analysis of variance (ANOVA) and post-hoc Fisher´s LSD tests. For analysis and interpretation of results, species were grouped based on relative abundance per plot (abundant [>30%], common [10-29%], and rare [<10%]), and habitat requirements (forest species and generalists) following DeVries (1987).

We evaluated sampling intensity at the land use and landscape levels using the parametric Clench equation to estimate total species richness (Soberon & Llorente 1993). For the comparisons of species richness, we developed species accumulation curves curves for the whole dataset for each of the two landscapes using Ecosim 5.0 software with 1,000 randomisations (Gotelli & Entsminger 2006). We considered the average number of species to differ between landscapes if the 95% confidence intervals did not overlap (Gotelli & Entsminger 2006).

Compositional variation was evaluated with a cluster analysis carried out using Sørensen´s similarity index and the Flexible Beta linkage method, using PC-ORD 4.0 software (McCune & Mefford 2002). Indicator Species Analysis (Dufrene McCune & Mefford 1999) was used to determine which species were statistically associated with transect groups subjectively-delimited on the basis of the cluster analysis. Species with indicator values (IV) of at least 60% and for which the indicator value for a transect group was matched or exceeded fewer than 50 times by randomised values in a Monte Carlo simulation were considered statistically associated with that group, equivalent to $\alpha=0.05$.

5. Results

5.1 Variation of numbers of observations and species diversity among tree cover types in each agricultural landscape

Honduras

A total of 5285 individuals were observed, belonging to 120 butterfly species (Annex 3). The number of individuals (P = 0.0111), species richness (P = 0.0128) and Brilloun index (p=0.0248) all varied significantly among the tree cover types evaluated (Table 2). The mean number of individuals was greater in multiestrata live fence, followed riparian forest, pastures with low tree cover than forest fragment and forest fallow. Mean butterfly species richness per plot was greater in riparian forests and multistrata live fence than in pastures with low tree cover; butterflies species richness per plot was intermediate in all other tree cover types. Brilloun D index was greatest in riparian forest and lowest pasture with low tree cover; Brilloun D index per plot was intermediate in all other tree cover types.

Table 2. Comparison of mean species richness, abundance and diversity of butterflies per plot (± SE) in six types of tree cover (N = six replicate per treecover type) in the agricultural landscape of Copán, Honduras. Different letters within a row indicate statistical differences between habitats, LSD Fisher test (P < 0.05).

Habitat	Pastures with low tree cover	Secondary forests	Forest fallows	Pastures with hight tree cover	Multistrata Live fences	Riparian forests
Number of species	19.7±1.9a	20.5±3.9a	21.8±0.4a	24.3±3.2ab	30.8±4.4b	32.7±2.5b
Number of individuals	177.3±12.6ab	87.8±20.65c	95.3±11.3c	157.3±30.9a	183.2±26.5c	179.8±28.5bc
Brilloun D index	1.9±0.1a	2.01±0.18ab	2.29±0.06bc	2.13±0.16ab	2.29±0.12bc	2.51±0.1c

The Clench richness estimator indicated that in landscapes 92.3% of species were found by our sampling (Fig. 1) and that the number of butterfly species would increase in all tree cover types with additional sampling (Table 3). The richness estimator indicated that riparian forests were the richest habitats in species, followed by multi-strata live fences. The least species-rich habitat was pasture with low tree cover.

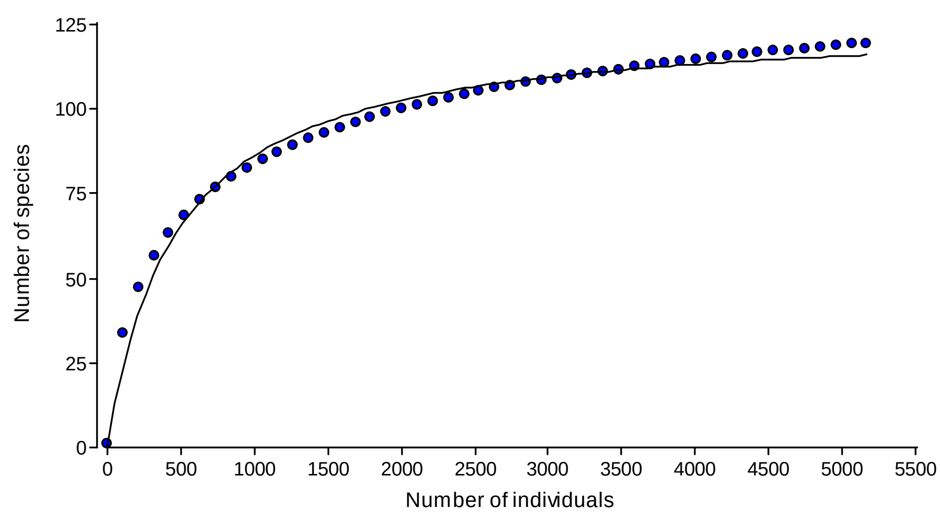

Figure 1. Species accumulation curve of butterflies in the agricultural landscape in Copan Honduras. Observed species (Continuous line) and estimated species using the Clench richness estimator (dotted line).

Table 3. A comparison of butterfly species richness in Copán, Honduras, showing observed species richness, estimated species richness using the Clench model (Soberón & Llorente 1993), and inventory level (observed richness as a percentage of estimated richness).

Habitat	Pastures with low tree cover	Secondary forests	Forest fallows	Pastures with high tree cover	Multistrata Live fences	Riparian forests
Observed species	53	64	65	67	79	87
Estimated species	64	81	80	79	94	100
Inventory level (%)	82	79	81	85	84	87

The cluster analysis separated butterfly assemblages at the 36 transects into two distinct groups (G1 and G2; see Figure 2). Group G1 was made up exclusively of transects from forest fragments, riparian forest and forest fallow, while G2 consisted of all of the live fence and pasture transects, together with one of the riparian forest transects. The indicator species analysis identified 12 butterfly species that were significantly associated with one or the other group of transects (Table 4). Five species were significantly associated with disturbance forest area (G1:secondary forest, riparian forests and forest fallow), while the indicators of live fences and pastures (G2) were *Anartia Fatima, Danaus plexipus, Eurem daira, Pyrisitia dina, P. nise*, *Hermeuptychia hermes* and *Hemmiargus hanno*, species typical of open and even semi-urban habitats (DeVries 1987; Table 4).

Table 4. Indicator species for each of the groups of transects delimited by the cluster analysis for the agricultural landscape in Copán, Honduras. Indicator groups are G1 (forest fragment, riparian forest and forest fallow) and G2 (open habitats).

Species	Group	Indicator value (IV) observed	Mean of IV	p-value
Greta oto	G1	65,7	23,8±7,23	0.002
Itaballia demophile	G1	61,5	18,6±6,28	0,001
Mechanitis polymnia	G1	82,2	36,8±8,87	0,001
Morpho peleides	G1	53,8	27±7,67	0,005
Pareuptychia metaleuca	G1	65,1	28±7,05	0,001
Anartia fatima	G2	75,1	47,7±6,27	0,002
Danaus plexippus	G2	60,9	28±7,02	0,001

Eurema daira	G2	95,3	46,2±7,93	0,001
Hemiargus hanno	G2	91,3	38,3±7,89	0,001
Hermeuptychia hermes	G2	75	54,5±3,68	0,001
Pyrisitia dina	G2	69	45,4±7,2	0,009
Pyrisitia nise	G2	86	48,4±5,66	0,001

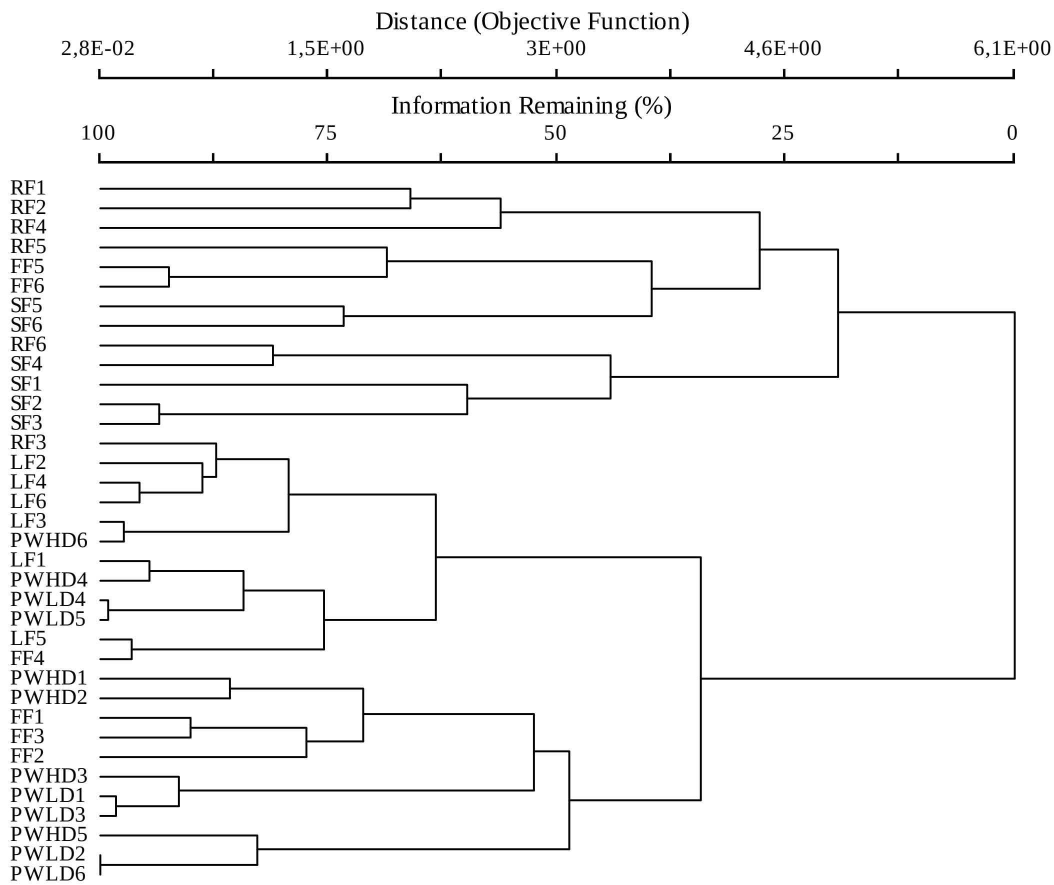

Figure 2. Cluster analysis dendrogram grouping the 36 transects established in the agricultural landscape in Copán, Honduras into two groups, G1 and G2. Abbreviations are as follows: SF=secondary forest, RF=riparian forest, FF=forest fallow, PWHD=pasture with high tree cover, PWLD=pastures with low tree cover, LF=multi-strata live fence.

G1

Nicaragua

A total of 4552 individuals were observed, belonging to 64 species of butterflies (Annex 4). The mean number of individuals was not statistically different among habitats (P = 0.2297), species richness (P = 0.05) and Brilloun index (p=0.028) both varied significantly among the tree cover types evaluated (Table 5). Mean butterfly species richness was greatest in forest fallow, followed by riparian forest, secondary forest. Brilloun index were greatest in secondary forests and riparian forest than life fence and pastures.

Table 5. Comparison of mean species richness, abundance and diversity of butterflies per plot (± SE) in six types of tree cover (N = six replicates per tree cover type, except three replicates for forest fallow) in the agricultural landscape of Matiguas, Nicaragua. Different letters within a row indicate statistical differences between habitats, LSD Fisher test (P < 0.05).

Habitat	Pastures with low tree cover	Pastures with high tree cover	Multistrata Live fences	Secondary forests	Riparian forests	Forest fallows
Total # species	19.5±1.2a	20.33±1.3ab	20.3±1.1ab	22.67±1.05abc	24±1.03bc	25±3.51c
Total # of individuals	136.5±10.16a	155.83±17.89a	159.33±19.97a	116±11.89a	118.5±15.07a	145±11.24a
Brilloun D index	2.22±0.03a	2.22±0.07a	2.2±0.06a	2.45±0.04b	2.43±0.08b	2.35±0.17ab

The Clench species richness estimator indicated that our sampling found 94% of species present (Figure 3) and that the number of butterfly species would increase in all tree cover types with additional sampling (Table 6). The secondary forests were the richest habitats in species, followed by riparian forests, forest fallows, and pastures with high tree cover. The least species-rich habitat was pasture with low tree cover.

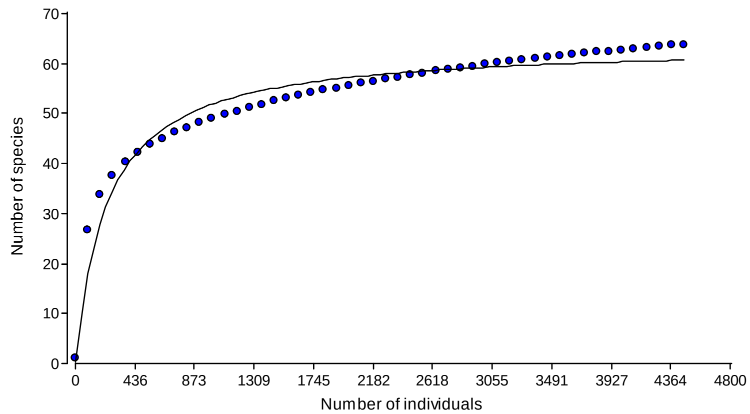

Figure 3. Species accumulation curve of butterflies in the agricultural landscape in Matiguas, Nicaragua: observed species (continuous line) and estimated species using the Clench richness estimator (dotted line).

Table 6. A comparison of butterfly species richness in Matiguas, Nicaragua. Observed species richness, Estimated species richness using the Clench model (Soberón & Llorente 1993), inventory level, observed richness as a percentage of estimated richness.

Habitat	Pastures with low tree cover	Multistrata Live fences	Pastures with high tree cover	Forest fallows	Riparian forests	Secondary forests
observed species	34	38	39	42	43	46
Estimated species	37	41	41	49	46	54
Inventory level (%)	92	93	95	86	93	85

The cluster analysis butterfly assemblages at the 33 Matiguas transects into two distinct groups (G1 and G2; Figure 4). The G1 was made up exclusively of transects from forest fragments, riparian forest and forest fallow, while G2 consisted of all of the live fence and pasture transects, together with three of the riparian forest, secondary forest and forest fallow transects. The indicator species analysis identified 22 butterfly species that were significantly associated with one or the other group of transects (Table 4), 12 species were significantly associated with conserved forest area (G1: secondary forest, riparian forests and forest fallow), while the indicators of live fences and pastures (G2) were 10 species typical of open and even semi-urban habitats (DeVries 1987; Table 4).

Table 4. Indicator species for each of the groups of transects delimited by the cluster analysis. Indicator groups are G1 (forest fragment, riparian forest and forest fallow) and G2 (open habitats) from the agricultural landscape, Matiguas, Nicaragua.

Species	Group	Indicator value (IV) observed	Mean of IV	p-value
Caligo memnon	G1	64,7	21,9±6,96	0,001
Callicore pitheas	G1	87,4	43,6±7,17	0,001
Heliconius erato	G1	60,7	40,7±7,35	0,019
Hermeuptychia harmonia	G1	60,2	26,7±7,32	0,001
Itaballia demophile	G1	75,5	46,2±6,57	0,002
Mechanitis lysimnia	G1	87,3	32,3±7,75	0,001
Mechanitis polymnia	G1	64,2	26,1±7,58	0,001
Morpho peleides	G1	94,7	36,4±7,42	0,001
Pareuptychia ocirrhoe	G1	99,3	28,7±7,48	0,001
Parides arca	G1	68,5	30,8±7,94	0,001
Pierella luna	G1	70,8	26,9±7,31	0,001
Siproeta stelenes	G1	63	53,8±3,31	0,01
Anartia fatima	G2	74,6	51,2±4,61	0,001
Aphrissa boisduvalii	G2	65,3	46,1±6,57	0,009
Danaus plexippus	G2	71,4	32,6±7,92	0,001
Dryadula phaetusa	G2	66,7	30,8±7,64	0,001
Eurema daira	G2	80,7	51,1±4,67	0,001
Junonia evarete	G2	70,4	39,8±7,88	0,003
Phoebis philea	G2	80,1	45,1±5,82	0,001
Pyrisitia nise	G2	79,6	47,1±6,13	0,001
Pyrisitia proterpia	G2	74,6	50,2±6,25	0,001
Rhabdodryas trite	G2	80,7	47,8±6,73	0,001

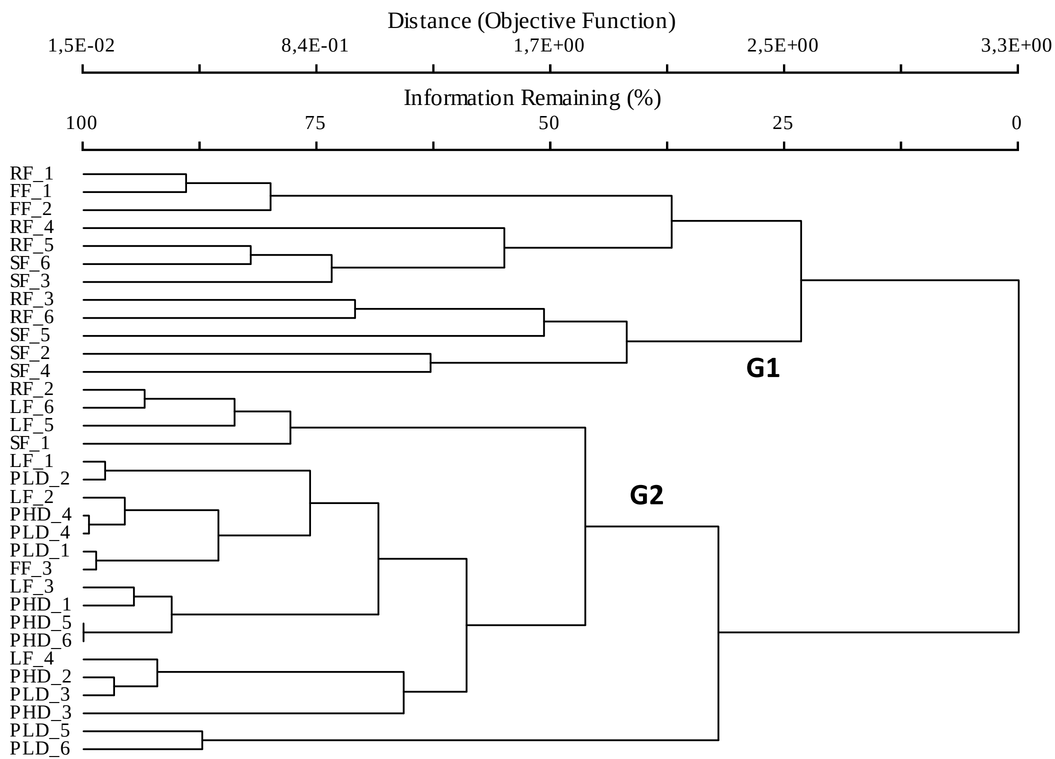

Figure 4. Cluster analysis dendrogram grouping the 33 transects established in the agricultural landscape in Matiguas, Nicaragua. Abbreviations are as: SF= Secondary forests, RF= riparian forests, FF= forest fallow, PHD= Pastures with high tree cover, PLD= Pastures with low tree cover, LF= Multistrata live fences.

6. Discussions

Our study suggests that Neotropical agricultural landscapes containing a heterogeneous on-farm tree cover may conserve a diverse butterfly fauna, as butterflies could readily be moved within the agricultural matrix and take advantage of the habitats and resources present. Despite the fact that both agricultural landscapes (Copan, Honduras; Matiguas, Nicaragua) were dominated by pastures and retains less than 15 percent of their original forest cover, they have a high butterfly species richness (120, 64 species, respectively).

In addition to their high species richness, both agricultural landscapes contained several butterfly species of conservation interest. In Copan these included *Memphis oenomais* (captured in life fences), a species that has been considered an indicator of conserved secondary forest (Devries 1987). Another species have been associated of conserved areas such as: *Dynamine postverta, Marpesia petreus, Parides arcas, Phantiades bathildis.* In Matiguas, *Dynamine postverta, D. paulina, Epiphile adrasta, Myscelia cyaniris, Satyrotaygetis satyrina, which were registered in very low abundances and observed in different tree cover types, indicating the potential value of those landscapes for butterfly conservation.*

Butterfly assemblages in different types of tree cover within the agricultural landscape, Butterfly diversity and species richness were clearly associated with diferrent types of tree cover present in each landscape. In Copán, The high species diversity of butterflies in riparian and multistrata life fences, in Matiguas, riparian forests and forest fallow, may reflect the fact the greater tree diversity and nectar and fruit availability in these habitats relative to other types of tree cover (Sanchez Merlo *et al.* 2005), which make these sites good foraging areas.

Secondary forests had the lowest butterfly abundances in both landscapes, but had the highest aggregate species richness in Matiguas and intermediate aggregate species richness in Copán, suggesting that these forests are still important habitats even though butterflies are less abundant. Studies of the vegetation in secondary forests in the region indicate that these habitats are less floristically and structurally diverse than the riparian forests (Sanchez Merlo *et al.* 2005), which may account for the lower butterfly abundance observed in this tree cover type.

Butterflies were abundant in live fences, despite the narrowness of these habitats (most consist of only a single row of trees and have canopies less than 5 m wide), their limited tree species diversity (mainly *Bursera simaruba*) and their frequent disturbance by management (Harvey *et al.* 2006). Butterflies appear to use live fences and other linear features to orientate their flights across agricultural landscapes and to cross open pasture areas(Tobar et al. 2007; Tobar & Ibrahim *in press,* Harvey et al 2006; 2008b).

Our study suggests that conservation policies designed to conserve butterflies within agricultural landscapes need to focus on conserving suitable habitats within the landscape and ensuring that the landscape composition surrounding these habitats is appropriate for lepidoptera conservation. However, the patterns and types of tree cover within agricultural landscapes are determined by the farmers who own and manage the land, any conservation efforts must actively work with farmers to management landscapes that meet both conservation

7. Conclusions

Our results suggest that Neotropical agricultural landscapes containing a heterogeneous and diverse tree cover can maintain diverse butterfly assemblages, and underscore the importance of conserving forest and tree cover within human-dominated landscapes. While efforts to conserve neotropical butterflies should focus foremost on the retention and protection of riparian forests and any remaining forest patches, our results indicate that integrating tree cover within pastures and multistrata life fence may also contribute to butterfly conservation. For example, diversifying live fences with species that serve as food for butterflies may be beneficial, as butterflies frequently visit and use live fences. Since the use of live fences is readily compatible with existing farming systems (Harvey *et al.* 2005; Tobar & Ibrahim, in press), it may therefore be possible to design and manage farming landscapes in ways which allow both productive and conservation goals to be achieved.

Although our study underscores the important role of on-farm tree cover for butterfly conservation, additional studies are needed to ascertain the exact status of the butterfly assemblages within agricultural landscapes and to obtain detailed information on other butterflies species present in the landscape that might be observed using other methods such as baited butterfly traps or Van Someren Rydon traps (DeVries & Walla 2001). In addition, while this study presents evidence that butterflies use different tree cover types in an agricultural landscape, further work is needed to understand exactly how butterflies use these habitats—in conjunction with other complementary habitats—throughout their life cycles. It will also be critical to determine whether there are thresholds of tree cover within agricultural landscapes below which butterfly conservation is substantially compromised.

8. Acknowledgments

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10. Annex

Annex 1 Location of transect in agricultural landscape in Copán, Honduras. 2008.

ID	Land Uses	transects	X	Y
1	Riparian Forest	RF_01	279469	1645222
2	Riparian Forest	RF_02	278704	1645147
3	Riparian Forest	RF_03	276067	1645113
4	Riparian Forest	RF_04	267767	1643454
5	Riparian Forest	RF_05	269717	1641143
6	Riparian Forest	RF_06	274283	1640878
7	Secondary Forest	SF_01	275952	1644647
8	Secondary Forest	SF_02	275318	1643108
9	Secondary Forest	SF_03	275531	1643496
10	Secondary Forest	SF_04	269271	1641255
11	Secondary Forest	SF_05	269442	1641027
12	Secondary Forest	SF_06	269532	1642564
13	Multiestrata Life Fence	LF_01	279401	1644947
14	Multiestrata Life Fence	LF_02	275105	1644091
15	Multiestrata Life Fence	LF_03	275150	1643604
16	Multiestrata Life Fence	LF_04	274863	1641365
17	Multiestrata Life Fence	LF_05	274957	1642713
18	Multiestrata Life Fence	LF_06	274459	1642365
19	Pastures with high tree cover	PHD_01	277771	1638133
20	Pastures with high tree cover	PHD_02	278403	1638415
21	Pastures with high tree cover	PHD_03	279424	1645564
22	Pastures with high tree cover	PHD_04	275930	1640096
23	Pastures with high tree cover	PHD_05	274754	1641433
24	Pastures with high tree cover	PHD_06	274879	1643678
25	Pastures with low tree cover	PLD_01	279160	1646967
26	Pastures with low tree cover	PLD_02	273082	1648438
27	Pastures with low tree cover	PLD_03	278379	1638036
28	Pastures with low tree cover	PLD_04	273752	1641748
29	Pastures with low tree cover	PLD_05	274648	1641884
30	Pastures with low tree cover	PLD_06	269611	1642648
31	Forest Fallow	FF_01	278371	1645001
32	Forest Fallow	FF_02	278229	1644978
33	Forest Fallow	FF_03	276312	1644874
34	Forest Fallow	FF_04	271102	1641287
35	Forest Fallow	FF_05	270189	1641971
36	Forest Fallow	FF_06	269975	1641596

Annex 2. Location of transect in agricultural landscape in Matiguas, Nicaragua. 2008.

ID	Land Uses	transects	Farmer	X	Y
1	Riparian Forest	RF_01	Juan Pastor Gonzalez	665450	1414523
2	Riparian Forest	RF_02	Guillermo Garcia	665997	1413917
3	Riparian Forest	RF_03	Julio Zeledon	673245	1416145
4	Riparian Forest	RF_04	Isidro Leon	673163	1415996
5	Riparian Forest	RF_05	Simeon Sosa	674118	1415463
6	Riparian Forest	RF_06	Nazario Gutierrez	671249	1413931
7	Secondary Forest	SF_01	Manuel Urbina	665606	1413664
8	Secondary Forest	SF_02	Isidoro Martinez	667149	1413118
9	Secondary Forest	SF_03	Fermin Vega	684788	1424700
10	Secondary Forest	SF_04	Fortunato Robles	685709	1423794
11	Secondary Forest	SF_05	Pilar Campo	672770	1415227
12	Secondary Forest	SF_06	Nazario Gutierrez	672552	1414813
13	Multiestrata Life Fence	LF_01	Jorge Blandon	693301	1418715
14	Multiestrata Life Fence	LF_02	Francisco Calero	665453	1413332
15	Multiestrata Life Fence	LF_03	Napoleon Zeledon	668446	1415371
16	Multiestrata Life Fence	LF_04	William Robles	670997	1412632
17	Multiestrata Life Fence	LF_05	Isidro Leon	673048	1416046
18	Multiestrata Life Fence	LF_06	Nazario Gutierrez	671440	1414033
19	Pastures with high tree cover	PHD_01	Jose R Castillo	665698	1416850
20	Pastures with high tree cover	PHD_02	Juan Pastor Gonzalez	665584	1414639
21	Pastures with high tree cover	PHD_03	Guillermo Garcia	665915	1414094
22	Pastures with high tree cover	PHD_04	Francisco Calero	666203	1413985
23	Pastures with high tree cover	PHD_05	Napoleon Zeledon	668480	1415019
24	Pastures with high tree cover	PHD_06	Gloria Elda Lopez	673280	1415843
25	Pastures with low tree cover	PLD_01	Jorge Blandon	667087	1417538
26	Pastures with low tree cover	PLD_02	Jorge Blandon	666867	1417698
27	Pastures with low tree cover	PLD_03	Juan Pastor Gonzalez	665467	1414180
28	Pastures with low tree cover	PLD_04	Francisco Calero	665556	1413504
29	Pastures with low tree cover	PLD_05	Cristobal Rayo	669257	1415347
30	Pastures with low tree cover	PLD_06	Tomas Sosa	668574	1415674
31	Forest Fallow	FF_01	Francisco Calero	665791	1413155
32	Forest Fallow	FF_02	Julio Zeledon	673416	1415956
33	Forest Fallow	FF_03	Pilar Campo	672785	1415118

Annex 3. A list of the butterflies observed in agricultural landscape, Copan, Honduras, and a total number of individual.

Especie	Riparian forests	Secondary forests	Forest fallows	Multistrata Live fences	Pastures with high tree cover	Pastures with low tree cover	Total general
Papilionidae							
Papilioninae							
Battus polydamas					X		1
Heraclides thoas	X		X	X	X		10
Papilio lycophron					X		1
Papilio polyxenes				X	X		11
Papilio thoas			X		X		2
Parides arcas		X	X	X			5
Parides sp.				X			1
Pieridae							
Dismorphiinae							
Dismorphia amphiona	X	X				X	7
Dismorphia sp.		X					1
Enantia licinia	X						1
Coliadinae							
Aphrissa boisduvalii					X		3
Eurema albula	X	X	X	X	X	X	29
Eurema arbela			X		X	X	23
Eurema daira	X	X	X	X	X	X	402
Eurema elathea					X	X	40
Eurema proterpia	X		X	X	X	X	18
Eurema sp.				X			4
Eurema xanthoclora	X						2
Pyrisitia dina	X	X	X	X	X	X	206
Pyrisitia lisa	X		X	X	X	X	30
Pyrisitia nise	X	X	X	X	X	X	306
Phoebis argante	X		X	X	X		12
Phoebis philea	X	X	X	X	X	X	42
Phoebis sennae			X	X	X	X	19
Phoebis statira			X		X	X	4
Pierinae							
Appias drusilla		X	X				9
Ascia monuste		X					5
Itaballia demophile	X	X	X				126
Itaballia pandosia		X					9
Melete isandra	X	X	X	X	X	X	62
Pieriballia viardi	X	X	X	X			45
Nymphalidae							
Nymphalinae							
Anartia fatima	X	X	X	X	X	X	605
Anartia jatrophae	X		X	X	X	X	45

Annex 3. ***Continued***

Especie	Riparian forests	Secondary forests	Forest fallows	Multistrata Live fences	Pastures with high tree cover	Pastures with low tree cover	Total general
Anthanassa ardis	X			X		X	5
Anthanassa tulcis				X		X	4
Castilia myia	X	X	X	X	X	X	35
Castilia ofella	X			X	X		7
Chlosyne hippodrome			X			X	2
Chlosyne sp						X	1
Historis odius	X	X	X	X	X	X	27
Junonia evarette				X	X	X	8
Siproeta stelenes	X		X	X			10
Tegosa anieta	X		X	X	X	X	72
Temesis laothoe				X	X		3
Thessalia theona	X			X			4
Biblidinae							
Biblis hyperia		X					1
Catonephele mexicana	X	X		X			13
Diaethria astala				X			1
Dynamine postverta	X		X	X			5
Hamadryas feronia	X	X	X	X	X	X	56
Mestra amymone				X	X		2
Nica flavilla	X		X		X		4
Vanessa virginensis					X		2
Cyrestinae							
Marpesia petreus		X					1
Charaxinae							
Memphis oenomais				X			1
Zaretis ellops					X		1
Morphinae							
Caligo erilochus		X					1
Caligo memmon	X	X					2
Morpho peleides	X	X	X	X	X		60
Limenitidinae							
Adelpha celerio	X	X	X	X	X	X	19
Adelpha iphiclus	X						4
Heliconiinae							
Actinote thalia		X					1
Actinote guatemalena	X			X			5
Agraulis vanillae					X		3
Dryadula phaetusa			X		X	X	3
Dryas iulia	X	X	X	X	X	X	127
Eueides aliphera	X	X		X			4
Euptoieta hegesia	X						1
Heliconius charitonius	X	X	X	X	X	X	49

Annex 3. ***Continued***

Especie	Riparian forests	Secondary forests	Forest fallows	Multistrata Live fences	Pastures with high tree cover	Pastures with low tree cover	Total general
Heliconius erato	X	X	X	X	X		52
Heliconius hecalesia	X	X	X				28
Heliconius ismenius	X	X	X		X		27
Heliconius sp.	X						1
Danainae							
Danaus eresimus	X		X	X	X	X	34
Danaus gilipus	X		X	X		X	6
Danaus plexippus				X	X	X	49
Dircenna jemina	X	X	X	X	X		21
Dircenna klugii	X		X	X	X		5
Godyris zavaleta	X		X	X			11
Greta oto	X	X	X	X			27
Hyalyris excelsa	X						5
Hypothyris euclea	X	X					9
Hypothyris lycaste	X	X					9
Mechanitis lysimnia	X	X		X	X	X	57
Mechanitis menapis	X	X		X	X		26
Mechanitis polymnia	X	X	X	X	X	X	273
Melinaea ethra	X						2
Napeogenes cranto				X			1
Napeogenes peredia	X						4
Oleria paula		X					1
Oleria rubescens	X				X		8
Tithorea harmonia	X	X					6
Tithorea tarrisina		X					1
Satyrinae							
Cepheuptychia glaucina			X				1
Cissia pompilia	X	X	X	X	X	X	45
Cissia similis		X		X	X	X	31
Euptychia sp. 1				X			4
Hermeuptychia hermes	X	X	X	X	X	X	1247
Megeuptychia antonoe	X	X	X	X	X		26
Pareuptychia hesionides	X	X	X	X	X	X	232
Pareuptychia metaleuca	X	X	X	X			37
Pierella luna	X	X					13
Satyrinae sp.					X		4
Taygetis andromeda	X	X	X	X			7
Taygetis virgilia	X	X					4
Yphthimoides renata	X			X			2

Annex 3. Continued

Especie	Riparian forests	Secondary forests	Forest fallows	Multistrata Live fences	Pastures with high tree cover	Pastures with low tree cover	Total general
Riodinidae							
Euselasinae							
Euselasia sp. 1	X	X	X	X			14
Riodininae							
Emesis sp.		X	X	X	X		5
Eurybia sp.	X	X					3
Leucochimona lagora	X	X		X			5
Melanis electra					X		1
Mesosemia sp. 1	X	X	X	X			29
Metacharis sp.	X	X	X	X	X	X	40
Nymphidium sp. 1	X		X	X	X	X	20
Lycaenidae							
Theclinae							
Arawacus phaenna	X			X			7
Electrostrymon sp.				X			1
Phantiades bathildis	X					X	3
Polyommatinae							
Hemiargus hanno	X		X	X	X	X	189
Leptotes cassius			X	X	X	X	24

Annex 4. A list of the butterflies observed in agricultural landscape, Matiguas, Nicaragua, and a total number of individual.

Species	Riparian forests	Secondary forests	Forest fallows	Multistrata Live fences	Pastures with high tree cover	Pastures with low tree cover	Total general
Papilionidae							
Papilioninae							
Battus polydamas					X	X	2
Heraclides thoas				X			1
Parides arca	X	X	X	X	X	X	35
Parides montezuma	X			X	X	X	12
Pieridae							
Dismorphiinae							
Pseudopieris nehemia	X	X	X	X	X	X	58
Coliadinae							
Aphrissa boisduvalii	X	X	X	X	X	X	132
Eurema daira	X	X	X	X	X	X	674
Pheobis philea	X	X	X	X	X	X	145
Phoebis sennae		X	X	X		X	13
Pyrisitia nise	X	X	X	X	X	X	188
Pyrisitia proterpia	X	X	X	X	X	X	235
Rhabdodryas trite	X	X	X	X	X	X	150
Pierinae							
Itaballia demophile	X	X	X	X	X	X	91
Nymphalidae							
Nymphalinae							
Adelpha cocala	X	X	X	X	X		6
Anartia fatima	X	X	X	X	X	X	803
Anartia jatrophae					X	X	3
Anthanassa tulcis			X				1
Chlosyne hippodrome	X						2
Colobura dirce	X	X	X	X	X		16
Janatella leucodesma						X	1
Junonia evarete	X	X	X	X	X	X	134
Siproeta epaphus	X			X	X		6
Siproeta stelenes	X	X	X	X	X	X	223
Smyrna blomfildia	X						1
Thessalia theona	X		X	X	X	X	19
Biblinae							
Callicore pitheas	X	X	X	X	X	X	114
Dynamine postverta		X					1
Dynamine paulina	X						1
Epiphile adrasta	X	X	X				4
Hamadryas feronia	X	X	X	X	X	X	74
Hamadryas glauconome		X					1

Annex 4. ***Continuation***

Species	Riparian forests	Secondary forests	Forest fallows	Multistrata Live fences	Pastures with high tree cover	Pastures with low tree cover	Total general
Mestra amymone					X		3
Myscelia cyaniris		X	X		X		3
Myscelia ethusa		X					1
Nica flavilla	X	X	X	X	X		14
Temenis laothoe		X	X				2
Charaxinae							
Prepona omphale	X	X	X				5
Siderone marthesia			X			X	2
Heliconius							
Agraulis vanillae						X	2
Heliconius charitonius	X	X	X		X	X	18
Heliconius erato	X	X	X	X	X	X	108
Dryas iulia	X	X	X	X	X	X	55
Dryadula phaetusa		X		X	X	X	63
Euptoieta hegesia					X		3
Danainae							
Mechanitis lysimnia	X	X	X	X		X	111
Mechanitis polymnia	X	X	X	X	X	X	48
Danaus gilippus		X	X	X	X	X	18
Danaus plexippus	X			X	X	X	43
Dircenna dero			X				1
Morphinae							
Caligo memnon	X	X					20
Morpho peleides	X	X	X	X	X	X	78
Satyrinae							
Chloreuptychia arnaca	X	X					6
Cyllopsis rogersi		X		X			9
Euptychia westwoodi	X	X	X		X		44
Hermeuptychia harmonia	X	X	X	X	X		30
Hermeuptychia hermes	X	X	X	X	X	X	464
Pareuptychia metaleuca	X	X	X	X			26
Pareuptychia ocirrhoe	X	X	X			X	83
Pierella luna	X	X	X	X			43
Satyrotaygetis satyrina	X	X		X	X		18
Taygetis andromeda	X	X	X	X	X		34
Riodinidae							
Riodininae							
Melanis electron	X	X	X	X	X	X	48
Mesosemia lamachus		X					2
Thisbe lycorias			X				1