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Spatial and Temporal Diversity in Ground Level Fruit Feeding Butterflies

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Abstract

Butterfly diversity has long been proposed as an indicator of habitat disturbance. Rapid assessment of fruit feeding butterflies is often used to predict disturbance impacts and so can aid in the development approval process in Trinidad. However, such an approach makes several assumptions about the relationship between butterfly diversity and habitat disturbance. This study reports on an investigation of these relationships. Ground level fruit feeding butterflies were trapped within forest, agricultural, and cocoa plots in Grande Riviere. Seven sampling stations were used in each plot, and trapping was replicated 6 times each month from May to September, 2010. Shannon's Diversity (H) was calculated for each plot to determine if $H_F > H_A > H_C$. H was also calculated monthly across all plots to examine temporal changes in diversity. H for the three plots was found to be 2.48, 1.56, and 2.00, respectively. H for the months of May to September was found to be 1.72, 1.98, 1.05, 1.99, and 2.15, respectively. Comparison with another study in Trinidad suggests that the guild of ground level fruit feeding butterflies may be used as biological indicators of disturbance, but not for rapid assessments. Areas dominated by *Caligo eurilochus minor* are less disturbed, and a dominance of *Euptichia penelope* and *E. hermes* are reflective of disturbance.

Key words: butterflies, *Caligo minor,* disturbance, *Euptchia hermes, Euptchia penelope*, indicator, Shannon diversity

Introduction

The Certificate of Environmental Clearance Rules (2001) is generally considered the most effective mechanism for regulating development in Trinidad and Tobago. For developments that may have significant environmental impacts, the regulating agency, the Environmental Management Authority (EMA), typically requires an Environmental Impact Assessment (EIA), before issuing or denying a CEC. They issue Terms of Reference (TOR) which are a blueprint for completing the EIA. These TORs provide developers with an indication of what studies are required for an EIA.

Typically, developers can satisfy the TOR by undertaking rapid ecological assessments (EMA, 2010). Such assessments provide a snapshot of the biological diversity in the area earmarked for development. TOR studies usually call for a description of the species richness and diversity from major taxonomic groups such as trees, birds, fish, and benthic macro fauna, at sites proposed for development

(EMA, 2010). This quantification of biodiversity helps to paint a portrait of the level of disturbance already experienced at the development site. From a development perspective, the logic is that the more disturbed a site is found to be, the easier it would be to obtain a CEC, and the CEC itself should not require intensive conservation efforts to protect the biological resources at the site.

However, while that the most diverse taxa on earth are insects (Wilson, 1988), it is notable that this taxon has never been identified as objects for study in appropriate TORs by the EMA (EMA, 2010). Insects are probably just as overlooked on the local stage as they are on the international level (Meyers et al, 2000; Clark and May, 2002; and Leather, Basset, and Hawkins, 2008).

If this taxon was to be considered in the future by the EMA, one key question would be to determine which group of insect should be used as indicators of habitat disturbance. Termites (Vasconcellos et al, 2010; Lawton et al, 1998; Eggleton et al, 1995), beetles (Scheffler, 2005; Rainio and Niemelä, 2002; Davis et al, 2001) and ants (Philpott, Perfecto, and Vandermeer, 2006; Watt, Stork, and Bolton, 2002; Roth, Perfecto, and Rathcke, 1994) are examples of arthropod groups that have been used in habitat disturbance studies.

Butterflies are another well studied group that has thepotential to serve as indicators of disturbance (Sundufu and Dumbuya 2008). They have been used in habitat disturbance studies in several areas of the world (Beck and Schulze 2000; Wood and Gillman 1998; DeVries et al. 1997; Hill et al. 1995; Sparrow et al. 1994; Spitzer et al. 1993; Kremen 1992; Brown 1991; Lovejoy et al. 1986;). They have also been suggested as particularly good environmental indicators due to their sensitivity to microclimate and light intensity changes (Wood and Gillman, 1998; Erhardt, 1985), and also because of their complex life history (Kremen, 1992; Ehrlich, 1984). Butterfly taxonomy is also well known compared with other tropical insect groups and many species can be reliably identified in the field (Wood and Gillman, 1998). In addition, their distribution and natural history are relatively well known (Brown, 1997).

This paper seeks to examine the applicability of this group as indicators of disturbance in Trinidad, and by extension their suitability for use in rapid ecological assessments for the local EIA process. This study's approach was to compare butterfly diversity under different land-use types, which included natural forest, cocoa plantations and open field agriculture.

Methods

Study Site

This study was conducted at Grande Riviere, a remote rural area situated in northeast Trinidad (Figure 1). Here, three treatments of varying human disturbance were chosen: (undisturbed) forest; cocoa plantations; and open field agriculture. Forest (F) study areas were selected based on having >70% canopy cover and being dominated by tall trees of several species. Cocoa plantations (C) were defined as areas having >70% canopy cover, but with approximately 90% dominance of *Cacao* spp. Finally, open field agriculture (A) referred to areas with <30% canopy cover, having very few trees, and dominated by agricultural short crops and grass (Figure 1). The agricultural plot and the cocoa plot were adjacent to each other, and the forest plot was located 1.5 km away from these two.

Collection

Butterflies were collected at the study sites, during the months May to September, which have been previously documented as the best times for collecting these insects (Barcant 1970). Butterflies were sampled during six days of each month (three days each at the start and end of each month).

Baited fruit traps were used to sample butterfly communities at each site (Mendéz and Funes 2007). Twenty one inverted cone butterfly traps were used in this study. Seven traps were set up in each of the three disturbance treatments (F, C, and A). On each day, traps were baited from 8 am to 12 pm, and checked approximately 24 hours thereafter. All specimens were removed for later identification, and bait was added if needed. The bait consisted of a fermented mixture of over-ripe/rotting bananas, brown sugar, and cane juice.

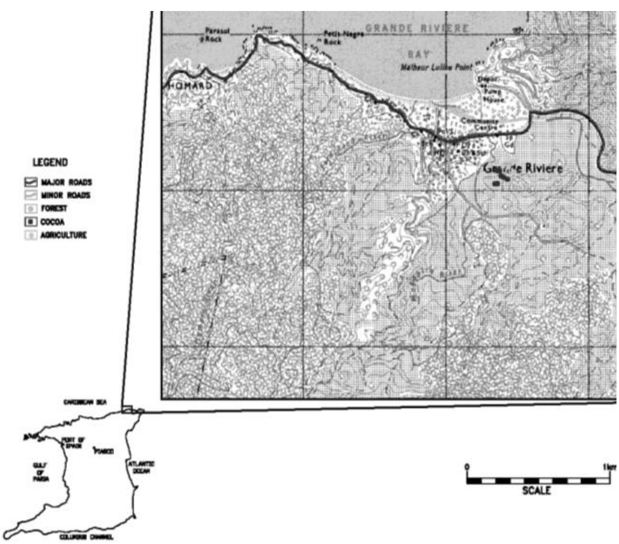

Figure 1: Locations of forest (F), agriculture (A) and cocoa (C) disturbance areas and sampling stations in Grand Riviere, Trinidad.

Analysis

Differences in butterfly diversity in the different habitats (F, A, and C), were estimated using Shannon's Diversity (H), Shannon's Equitability (E_H), Number of Individuals (N), and Species Richness (S). These diversity indices were calculated using the total results from F, A, and C for each month from May to September to examine monthly changes in diversity. Non-metric multidimensional scaling (nMDS was also used to search for differences in the diversity of butterflies among the three disturbance types. MDS analysis of the top five species from each area was also used to investigate possible indicator species for both least and more disturbed areas.

Results

Two thousand two hundred and forty five (2245) individuals of 45 species of butterfly were captured from 609 trap-days in Grande Riviere. Diversity indices by disturbance area for the sampling period are presented at Table 1, and Table 2 provides these monthly.

Table 1: Butterfly diversity indices for forest, agriculture and cocoa areas in Grand Riviere, Trinidad.

Disturbance Area	**Diversity Indices**			
	H	**E_H**	**N**	**S**
Forest	2.48	0.76	443	26
Agriculture	1.56	0.44	1048	35
Cocoa	1.99	0.61	754	26

These data suggest that the highest value of H was recorded in the Forest, with H being intermediate for the Cocoa plantations and lowest in the agricultural areas. However, both the greatest number of species and individuals were observed from the agricultural area, which also had the lowest E_H value.

Table 2: Monthly butterfly diversity indices for forest, agriculture and cocoa areas in Grande Riviere, Trinidad.

MONTH	**DIVERSITY INDICES**			
	H	**EH**	**N**	**S**
May	1.72	0.67	116	13
June	1.98	0.70	144	17
July	1.05	0.29	674	37
August	1.99	0.58	396	30
September	2.15	0.64	913	27

H values for the months of June, August and September were similar, with a slight decrease noted in May, and July showing the largest decrease. July also recorded the highest species richness with an intermediate number of individuals, and the lowest E_H value (0.29).

The MDS analysis of the mean number of species for each sampling station is presented graphically at Figure 2. This figure suggests that there is a distinction between butterfly diversity at the three habitat types. Here, forest sampling stations were clustered on the left of the plot, agricultural sampling stations were to the right, and cocoa in the centre. These data suggest that the disturbance level may be related to changes in the butterfly diversity.

The top five most abundant species for the three habitat types are presented at Table 3. While the MDS analysis suggests that there were clear differences between the butterfly communities at each site, there were two agricultural stations (A2 and A3) that clustered with the cocoa plots.

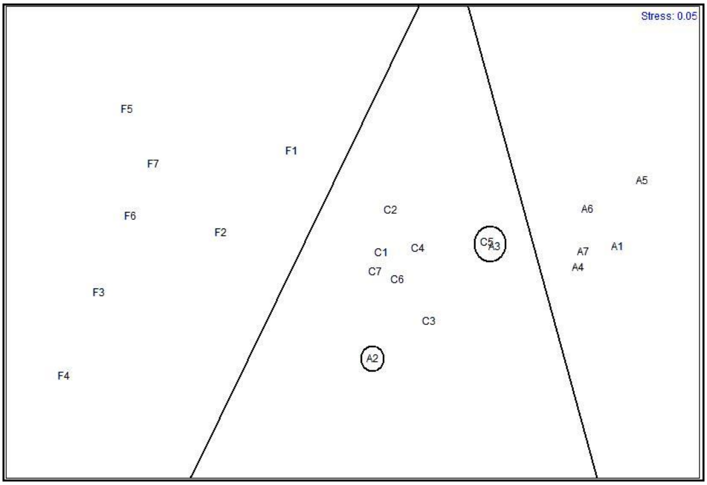

Figure 2: MDS plot of butterfly species richness at each sample station.

Table 3: The five most abundant butterfly species found in forest, agriculture and cocoa areas in Grand Riviere, Trinidad.

Forest		**Agriculture**		**Cocoa**	
Species Name	Number	Species Name	Number	Species Name	Number
Euptchia Penelope	105	*E. Penelope*	574	*E. Penelope*	353
Taygetis virgilia	55	*E. hermes*	272	*E. hermes*	81
Morpho peleides insularis	49	*E. palladia*	27	*E. palladia*	70
Caligo eurilochus minor	48	*T. virgilia*	23	*C. dirce*	64
Colobura dirce	33	*C. dirce*	21	*T. penela*	38
Pierella hyalinus fusimaculata	33			*T. virgilia*	38

E. penelope, T. virgilia, and *Colobura dirce* were the species that occurred in the top five for each of the study areas. *E. hermes* was ranked second in the

Agriculture and Cocoa areas, but did not feature among the dominant Forest species. *M. insularis*, *C. minor*, and *P. fusimaculata* appeared only in Forest sites.

Wood and Gillman (1998) examined the effects of disturbance on forest butterflies in the Victoria Mayaro Reserve in southern Trinidad. They studied butterflies in disturbed (D) and undisturbed (U) areas of evergreen (E) and semi evergreen (SE) forest. To allow comparison with their work, diversity indices were computed from their understory data, to enable a comparison with the undisturbed areas in the present study (F to UE and USE). Similarly, a comparison between the disturbed areas in their data sets (C and A to DE and DSE), and the data in the current study (F, UE and USE to C, A, DE, and DSE). Diversity estimates for the Wood and Gillman (1998) study are presented Table 4. This table suggests that that H for undisturbed evergreen forest (UE) was higher than its disturbed counterpart (DE), while in undisturbed semi-evergreen forest (USE), it was lower than its disturbed counterpart (DSE).

Table 4: Butterfly indices calculated from Wood and Billman (1998).

AREA	DIVERSITY INDICES			
	H	E_H	N	S
D E	1.78	0.81	66	9
U E	2.01	0.87	34	10
D SE	2.24	0.78	133	18
U SE	1.68	0.65	86	13

DE – Disturbed Evergreen Forest
UE – Undisturbed Evergreen Forest
DSE – Disturbed Semi-Evergreen Forest
USE – Undisturbed Semi-Evergreen Forest

Discussion

This study set out to investigate the hypothesis that for tropical butterflies, species richness is positively correlated to vascular plant species richness, or $H_F > H_A > H_C$ (Simonson et al, 2001, Nyamweya and Gichuki, 2000). However, in this study it was found that for butterflies at the Grande Riviere sites that $H_F > H_C > H_A$.

This may be the result of landscape-scale pattern effects of the cocoa sampling stations. The study area was nestled in a landscape of secondary forest with greater flora diversity than the cocoa area, while the agricultural sampling area was located just north of the cocoa area. The proximity of the cocoa area traps to areas richer in flora diversity may have acted to lure butterflies from these richer surrounding areas.

Perhaps, if Pollard Walks were used instead of baiting the species richness and diversity in the cocoa sites would have been different. In addition, if the cocoa sample site was of a larger size, perhaps the source/sink dynamics would have had less of a confounding effect on the results

However, the clear pattern of Shannon diversity (H) in the three disturbance treatments cannot be easily overlooked, and suggests that there was an effect of degree of disturbance on species richness and eveness.

With the exception of *Euptychia* spp., no other species caught in the agricultural sampling stations were observed feeding on the rotting agricultural produce. Disturbance of floral composition, height canopy cover, and the timing and intensity of physical alteration of the landscape may all contribute to changes in butterfly diversity.

Interestingly 2 agricultural plots could not be differentiated from forest plots using nMDS. This suggests that these polts may have been confounded by their relative position on the landscape relative to the other treatment types. With regard to seasonal patterns in diversity, the H for each month from May to September shows no clear pattern. The lowest H value belongs to the month of July, which records the highest S and lowest equitability. The most abundant species captured in all months, were *E. penelope* and *E. hermes*. July was also the month that experienced the heaviest and longest period of rainfall.

Barcant (1970) lists the host plant of the *Euptychia* genus as "grass", and notes that butterflies were more abundant following an extreme dry season (as was experienced in 2010). These conditions were realised in the agricultural area during the month of July, and this may account for July having the highest species richness, and a population boom of the commonest species (*E. penelope* and *E. hermes*).

In decreasing order of abundance, the top five most abundant species for the forest sites were *E. penelope*, *T. Virgilia*, *M. peledies*, *C. minor*, with *C. dirce* and *P. fusimaculata* tying for fifth. With the exception of *M. peledies*, *C. minor* and *P. fusimaculata*, all the other species also featured in the top five species for the more disturbed areas. These three species were recorded for each of the trapping months mainly from the forest, but they were also caught in lesser numbers in the cocoa. This makes these species ideal as indicators of least disturbed sites (Sparrow et al. 1994).

The most noticible difference between the forest and the other two areas are the presence of a tall canopy. This may well be the defining factor affecting the distribution of these three butterfly species. Yet, during the time spent in the field, it was not unusual to observe *M. peleides* flying across the agricultural areas. However, none were caught in traps in this agricultural treatment. Based on this it may be said that *M. peleides* prefers to feed under the canopy.

Similarly, while the food plant for the larve of *C. minor* is the *Musa spp.* (Barcant, 1970), none were ever observed flying in the agricultural area where the host plant was available and free from chemicals and pesticides, and only five individuals (N = 69) were captured from this area. This is because the genus is both crepuscular and its eyes are sensitive to bright light (Frederiksen and Warrant, 2008). Despite this, when the conditions were right for flight at dusk or at dawn, the baited traps in the agricultural area still did not attract *C. minor*. It may therefore be said that this species also prefers to feed under the forest canopy.

P. fuscimaculata was exclusively caught and observed from canopy enclosed areas. This species is perhaps truly indicative of areas with closed canopies, and the increased flora density of the forest appears responsible for their presence there in higher numbers.

E. penelope was the most abundant species in all of the sampling areas, and this was also found to be the case for each month of capture. This species was found to exhibit an affinity for the disturbed areas (A and C), more so than the undisturbed areas (F). However, due to its commonness in all areas, relative abundance in sampling areas and not presence/absence data should be considered if using *E. penelope* as in indicator. So, in two areas where *E. penelope* is found, the area with the a relatively higher number of individuals may be the least disturbed of the two areas. The nMDS plot for the mean number of this species caught at each sampling station provides a visual aid to this statement.

T. virgilia and *C. dirce* were also found to be abundant in all of the disturbed areas. However, *C. dirce*, showed no meaningful pattern in its use of disturbed areas. Even though its host plant – *Cecropia peltata* (Barcant, 1970) favours disturbance areas (such as the agricultural and cocoa plots), comparitaviley high numbers of *C. dirce* were found in the forest plot (see Table 3). *T. virgilia* exhibited a preference for disturbed areas, and was more dominant in the cocoa. However, this species was not present in the dry season month, and 71 % (N = 118) of the individuals were captured in September. These findings do not make *T. virgilia* a suitable indicator species.

E. hermes was the most abundant species for both of the disturbed areas (C and A), and exhibited a clear preference for the agricultural area, accounting for 69 % (N = 359) of the total individuals. Based on this and its presence during the entire sample period, this species is typical of disturbed areas. In particular, *E. hermes* may also be indicative of recently altered sites.

T. penela was recorded only in the last three trapping months, and July and September peak population periods for the species. For these reasons, *T. penela* is not an appropriate indicator species.

In Grande Riviere the least disturbed area (F) produced the highest H value (2.48), and the more disturbed areas had lower H values. However, this was not the case for both undisturbed areas used by Wood and Gillman (1998).

The traps in their undisturbed evergreen sites (UE) produced an H of 2.01, and traps in the disturbed evergreen (DE) sites produced an H of 1.78. This followed the findings at Grande Riviere where least disturbed areas have a higher H value than disturbed areas. In contrast, traps in the undisturbed semi evergreen (USE) area produced an H value of 1.68, which was lower than the 2.24 value for H in the disturbed seasonal evergreen (DSE) area. This finding does not conform to the trend for the previous two findings.

Wood and Gillman (1998) conducted a relatively rapid assessment of butterfly diversity, given that their 10 days of sampling occurred over a twenty day period. Since their H results did not consistently show that undisturbed areas have higher H value than disturbed areas, it can be said that rapid assessment of butterfly diversity using Shannon's Index alone, was not suitable to identify areas of disturbance.

When the results from Wood and Gillman's (1998) rapid assessment are compared to Barcant's list of proposed indicators (Table 5), three of the five proposed indicators appear effective for analysis.

For both forest types, undisturbed areas had higher numbers of *C. minor* than in their disturbed areas. In this case, the sensitivity of this species to light (Frederiksen and Warrant, 2008) may play a key role in limiting their numbers at disturbed sites. However, almost the same number of *M. peleides* occurred in either area, and too few *P. fusimaculata* were caught to make any inferences. On the other hand, *E. penelope* and *E. hermes* were more common in disturbed areas. This lends weight to the inconclusiveness of rapid assessment of butterfly indicator species for assessing undisturbed areas.

Table 5: Occurrence of proposed butterfly indicator species modified from Wood and Gillman (1998) and Barcant (1970).

SPECIES NAME		NUMBER OF INDIVIDUALS			
		Disturbed Area		Undisturbed Area	
Barcant (1970)	**Wood and Gillman (1998)**	**SE**	**E**	**SE**	**E**
INDICATORS OF LEAST DISTURBANCE					
P. fusimaculata	*P. hyalinus*	0	1	0	0
M. peleides		3	9	6	5
C. minor	*C. eurilochus*	2	0	6	2
INDICATORS OF MORE DISTURBANCE					
E. penelope	*Cissia Penelope*	51	16	43	10
E. hermes	*C. hermes*	6	1	1	0

The present study was limited by the time available to complete the study. In this regard it was not possible to obtain data for a full wet season and a full dry season, which would have allowed for a more complete analysis. It was also limited to areas in the landscape that were generally safe and accessible. Ideally, larger areas of cocoa and the agricultural should have been sampled. This would reduce the contribution of the source/sink dynamics from nearby habitats affecting the results. Finally, due to manpower limitations it was not possible to include Pollard Walks as part of this study.

Conclusions

It was found that $H_F > H_C > H_A$, and that H is greater in less disturbed areas than in more disturbed areas in long term studies such as at Grande Riviere. Variation in the monthly H was observed from May to September, although the results from this study should not be taken as conclusive from a seasonal or annual cycle. Where *C. minor* is relatively more abundant, such area(s) may be considered least disturbed, while areas where *E. penelope* and *E. hermes* are relatively more abundant may be considered more disturbed. Rapid assessment of butterflies, even when coupled with the use of indicator species, cannot be used to fully determine disturbance levels in an area.

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