



Short Communication

A unique Lepidopteran assemblage in primary forest understory of central Sri Lanka

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ABSTRACT

Sri Lankan Lepidopterans are diverse and increasingly inhabit areas undergoing rapid anthropogenic change. We examined butterfly assemblages in five habitat types in central Sri Lanka, an area with a mosaic of habitat types (primary and secondary forest, wetland margins, shrubland, and home gardens). Sixteen quadrats in each habitat type were repeat-sampled. Quadrats differed in proportional cover of different microhabitats and in microclimate. Butterfly abundance and richness were lowest in primary forests (PFs). Assemblages of butterflies were generally similar across all habitat types with the exception of PFs, which featured a unique assemblage. This study reinforces the importance of PFs in butterfly conservation as it harbors a unique and relatively low-abundance assemblage of species.

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Introduction

Butterflies drive key ecosystem services such as pollination and their role in food webs, yet they are declining in many areas (Belsky and Joshi 2018). Sri Lanka has a high diversity of butterflies, comprising 248 known species, of which 26 are endemic species (Jayasinghe et al 2016). They are esthetically appealing and contribute to the economically critical issue of the appeal of Sri Lanka to tourists, a country in which much tourism is related to wildlife (Van der Poorten 2014). Sri Lankan butterflies are also under conservation threat; about 40% of the butterfly species are threatened, and 8.5% are critically endangered (Van der Poorten 2014). The threats to Sri Lanka's butterfly diversity relate mostly to a growing human population driving habitat destruction for agriculture and urbanization (Van der Poorten 2014). In particular, once rural or remote areas, such as those around Wasgamuwa National Park in central Sri Lanka, are developing rapidly.

This study examines the distribution of butterflies across five prominent habitat types in a part of Sri Lanka which is experiencing

rapid development. We also document microhabitat and microclimate characters of these habitat types as these aspects influence butterfly occurrence, habitat suitability, and even population dynamics (de Schaetzen et al 2018; Mills et al 2017; Walsh 2017). Specifically, we investigate whether anthropogenic habitat change is likely to influence butterfly conservation by examining whether primary forest (PF) habitats are equivalent to a range of human-modified habitats. Although some information on butterfly assemblages and habitats is available in Sri Lanka (Peiris et al 2017), much information on distribution and habitat associations is lacking (Fernando et al 2017; Priyadarshana et al 2017).

Material and methods

Our study area borders the south-western part of the Wasgamuwa National Park, Central Province of Sri Lanka, in the intermediate climate zone. The prevailing climate is tropical, with a dry season extending from March to September and a rainy season from October to February. The mean temperature is 32°C, and the mean annual rainfall is 2250 mm (Peel et al 2007). The region is situated in lowland Sri Lanka, 125–300 m a.s.l. This zone has the highest biodiversity of butterflies in Sri Lanka and is characterized by a mixture of wet zone, dry zone, and hill country climates (Jayasinghe et al 2016). Butterfly diversity is highest in this region

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from late October until around April (Fernando et al 2017; Jayasinghe et al 2016). This study was conducted in late November until early December 2016.

Five distinct habitat types were evident: 1) primary forest, an area of forest that had been undisturbed for at least 100 years; 2) secondary forest, a forest where a disturbance such as fire or logging has affected the area recently (i.e., 5–10 years previously); 3) wetland margin, an open grassland area, within 150 m of a large body of water in an artificial pondage; 4) shrubland, a landscape dominated by shrubs and smaller trees no more than 15 m tall, and 5) home gardens, an area directly adjacent to a dwelling in an agricultural area. We sampled sixteen 5 × 5 m quadrats in each habitat type, with quadrats at least 300 m apart (Trappe et al 2017). Each quadrat was sampled (careful, thorough searching by two investigators) on two separate days. We acknowledge that individuals above head height were not sampled. Surveys did not commence for some time after quadrat markers were established. We used a “stopping rule” to surveys, such that surveys ended when 2 minutes had passed since the last butterfly detection; surveys typically lasted an hour. In each quadrat, a series of microhabitat cover estimates were collected, and microclimate (air temperature, wind speed, and humidity) was assessed using a shaded Kestrel weather station.

Statistical analyses

Microhabitat variables were normally distributed and analyzed by generalized linear models. Size class of butterflies (wingspans: < 30 mm, 30–60 mm, 60–100 mm, > 100 mm) were converted to a four-point ordinal scale and compared across habitats using a Kruskal–Wallace test (for identified species). Butterfly richness and abundance were Poisson-distributed and were analyzed using generalized linear models specifying a log-link (implemented in SPSS v 24). Butterfly occurrence in each quadrat was converted to a presence/absence measure to assess assemblages in each habitat type. We used multidimensional scaling (MDS), analysis of similarity (ANOSIM), and similar percentages (SIMPER), where appropriate, based on a zero-inflated Bray–Curtis resemblance matrix (implemented in PRIMER v 6). Percentage cover of microhabitat variables was analyzed using similar techniques, based on a Euclidean resemblance matrix.

Results

Unsurprisingly, microhabitat characteristics of the quadrats varied with habitat type (ANOSIM, $R = 0.578$, $p < 0.001$; Table 1) although an MDS revealed that all habitat types had overlapping

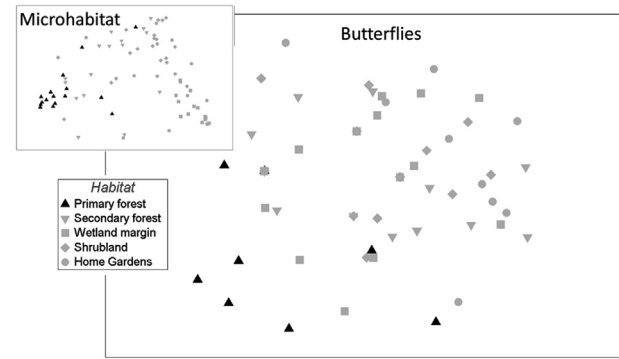


Figure 1. Multidimensional scaling plots of butterfly assemblage and microhabitat characteristics of quadrats (inset) of five habitat types in central Sri Lanka.

distributions in two-dimensional space (inset, Figure 1; stress 0.11). All pairwise comparisons were significant ($p < 0.001$) except for shrubland and home gardens ($R = 0.13$, $p = 0.07$). Air temperature also varied between habitat types ($F_{4,75} = 9.481$, $p < 0.001$), with Tukey's tests revealing that the homogenous subset of shrubland and wetland margins was about 2°C warmer than other habitats. Humidity followed a similar pattern ($F_{4,75} = 6.974$, $p < 0.001$), with home gardens and PF more humid than shrubland and wetland margins (secondary forest featured in both subsets; Table 1). Wind speed in wetland margins was almost double that in all other habitat types ($F_{4,75} = 9.412$, $p < 0.001$; Table 1).

A total of 379 butterflies of 30 species were encountered including 11 unidentified butterflies (4 species) (Table 2). Of these, 17 were classified as very common, and two, as rare. One species was endemic to Sri Lanka (Sri Lankan one-spot grass yellow, *Eurema ormistoni*). Butterfly species sampled were generally small (12 species with 30- to 60-mm wingspan) and least commonly large (2 species, >100 mm; Table 2). Abundance (counts) differed with habitat (Wald $\chi^2_4 = 57.227$, $p < 0.001$; Table 1); all habitats held different abundances of butterflies (Wald χ^2_1 's, 6.588–26.405; $p < 0.001$ –0.010) except for wetland margins and home gardens (Wald $\chi^2_1 = 2.608$, $p = 0.106$). Species richness differed with habitat (Wald $\chi^2_4 = 13.115$, $p = 0.011$; Table 1) although the only pairwise difference was that richness in PF was lower than all other habitat types (Wald $\chi^2_1 = 4.442$, $p = 0.035$). Species size ($n = 367$) differed between habitats (Kruskal–Wallace statistic = 21.363, $df = 4$, $p < 0.001$); the median size for PF was < 30 mm wingspan, whereas all other habitat types had median wingspans of 30–60 mm. Butterfly assemblages differed between habitat types (ANOSIM, $R = 0.108$, $p < 0.001$), with an MDS (2D stress 0.16) indicating that all habitat

Table 1. Overall survey results and habitat and microclimate characteristics of each habitat type.

Metric	Primary forest	Secondary forest	Wetland	Shrubland	Home garden
Butterfly species richness (overall abundance)	11 (36)	15 (58)	10 (98)	11 (65)	16 (122)
Habitat					
Grass cover—spreading (%)	0.0 ± 0.0	12.7 ± 22.3	81.9 ± 17.0	7.8 ± 18.3	35.6 ± 31.8
Grass cover—sedge—clumping (%)	11.6 ± 21.8	41.9 ± 27.8	3.6 ± 6.9	46.2 ± 21.3	27.8 ± 24.3
Sedge (%)	3.6 ± 5.9	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 1.3
Shrub (%)	20.3 ± 11.3	9.1 ± 13.8	4.1 ± 11.3	7.5 ± 12.8	22.8 ± 21.2
Leaf litter (%)	79.4 ± 24.3	52.5 ± 26.9	0.6 ± 1.7	15.9 ± 20.8	11.9 ± 21.5
Fallen log (%)	4.7 ± 6.9	3.5 ± 5.9	0.0 ± 0.0	2.8 ± 5.2	3.1 ± 7.9
Bare ground (%)	13.8 ± 21.1	27.8 ± 17.6	9.8 ± 12.4	38.8 ± 19.5	38.1 ± 26.8
Rock (%)	10.9 ± 13.4	0.3 ± 1.3	3.1 ± 8.9	0.9 ± 2.7	0.9 ± 3.8
Canopy cover (%)	72.5 ± 26.6	42.8 ± 34.7	0.0 ± 0.0	12.8 ± 25.4	24.4 ± 34.2
Microclimate					
Air temperature (°C)	28.7 ± 1.3 ^a	29.4 ± 1.0 ^a	31.9 ± 1.9 ^b	31.8 ± 1.5 ^b	29.9 ± 3.0 ^a
Wind speed (kph)	1.6 ± 1.5 ^a	1.9 ± 1.5 ^a	4.5 ± 1.8 ^b	1.3 ± 0.9 ^a	2.5 ± 2.2 ^a
Humidity (%)	71.5 ± 7.4 ^a	66.1 ± 5.1 ^{a,b}	61.0 ± 5.6 ^b	60.2 ± 8.2 ^b	68.4 ± 9.4 ^a

Means ± standard deviation presented. Superscripts define homogenous subsets defined by Tukey *post hoc* analyses.

Table 2. Species recorded in each habitat type (percentage of sites).

Species	Binomial nomenclature	PF	SF	WM	SH	HG
Angled castor ^{PF}	<i>Ariadne ariadne</i>	25.0	6.3	0.0	0.0	0.0
Blue Mormon ^{PF}	<i>Papilio polymnestor</i>	12.5	6.3	0.0	0.0	0.0
Chocolate soldier ^{PF}	<i>Junonia iphita</i>	12.5	0.0	0.0	0.0	0.0
Common cushbrown ^{HG}	<i>Mycalesis perseus</i>	0.0	0.0	0.0	0.0	18.8
Common crow ^{SF,WM,SH,HG}	<i>Euploea core</i>	0.0	31.3	56.3	43.8	43.8
Common grass yellow ^{HG}	<i>Eurema hecabe</i>	6.3	6.3	18.8	6.3	37.5
Common gull ^{SF}	<i>Cepora nerissa</i>	0.0	37.5	6.3	12.5	12.5
Common jay	<i>Graphium doson</i>	0.0	6.3	0.0	0.0	0.0
Common mime	<i>Papilio clytia</i>	0.0	0.0	0.0	6.3	0.0
Common Pierrot	<i>Castalius rosimon</i>	0.0	6.3	0.0	6.3	0.0
Dark grass blue ^{WM,HG}	<i>Zizeeria karsandra</i>	12.5	0.0	31.3	0.0	25.0
Double-branded crow	<i>Euploea sylvestor</i>	0.0	12.5	18.8	6.3	6.3
Glassy tiger ^{HG}	<i>Parantica aglea</i>	6.3	0.0	18.8	0.0	18.8
Gram blue ^{WM,HG}	<i>Euchrysops cnejus</i>	0.0	12.5	37.5	18.8	31.3
Great eggfly	<i>Hypolimnas bolina</i>	0.0	0.0	0.0	0.0	6.3
Jezabel	<i>Delias eucharis</i>	0.0	0.0	0.0	0.0	6.3
Lemon emigrant ^{PF,SF,WM,SH,HG}	<i>Catopsilia pomona</i>	12.5	43.8	25.0	62.5	43.8
Lemon pansy	<i>Junonia lemonias</i>	0.0	0.0	0.0	0.0	6.3
Painted sawtooth	<i>Prioneris sita</i>	0.0	6.3	0.0	0.0	0.0
Peacock pansy	<i>Junonia almana</i>	0.0	6.3	0.0	0.0	6.3
Pioneer	<i>Belenois aurota</i>	0.0	0.0	0.0	0.0	18.8
Plain tiger	<i>Danaus chrysippus</i>	0.0	12.5	6.3	0.0	18.8
Plains cupid	<i>Chilades pandava</i>	0.0	0.0	0.0	18.8	0.0
Plum Judy	<i>Abisara echerius</i>	0.0	6.3	0.0	0.0	0.0
Small grass yellow ^{SH,HG}	<i>Eurema brigitta</i>	0.0	0.0	6.3	25.0	18.8
Sri Lankan one-spot grass yellow	<i>Eurema andersonii</i>	0.0	0.0	0.0	6.3	0.0
Unidentified 1	—	6.3	0.0	0.0	0.0	0.0
Unidentified 2	—	6.3	0.0	0.0	0.0	0.0
Unidentified 3 ^{PF}	—	18.8	0.0	0.0	0.0	0.0
Unidentified 4	—	6.3	0.0	0.0	0.0	0.0
White fourring ^{SF}	<i>Ypthima ceylonica</i>	0.0	25.0	0.0	0.0	0.0

Species driving within assemblage similarity (i.e., > 5%; SIMPER). Superscripts identify assemblage: PF = primary forest, SF = secondary forest, WM = wetland margins, SH = shrublands; HG = home gardens.

types had overlapping assemblages with the exception of PF (Figure 1). Pairwise comparisons revealed that the assemblage in PF differed from those in secondary forest ($R = 0.125$, $p = 0.011$), wetland margin ($R = 0.236$, $p = 0.001$), shrubland ($R = 0.237$, $p = 0.001$), and home gardens ($R = 0.183$, $p = 0.001$). The only other pairwise comparison that was statistically significant was that between secondary forest and wetlands ($R = 0.101$, $p = 0.039$). SIMPER analysis revealed that the similarity within the PF butterfly assemblage was driven by angled castor, *Ariadne ariadne* (similarity contribution, 46.6%), blue Mormon, *Papilio polymnestor* (10.2%), lemon emigrant *Catopsilia pomona* (6.4%), chocolate soldier, *Junonia iphita* (5.7%), and an unidentified species (all Nymphalidae; 25.5%) (Table 2).

Discussion

PFs presented distinct microhabitats and were cooler and more humid than most modified habitats. PF, the habitat type least influenced by anthropogenic influences, held the lowest abundance and richness of butterflies but held an assemblage that differed from that found in the other habitat types. Some butterflies (e.g., Lycaenidae) readily exploit human-modified habitats yet rely on natural or seminatural habitats within those landscapes (Van Halder 2017; Van der Poorten and Van der Poorten 2016). Modified habitats were important for butterflies in our study also; indeed, those habitats held higher abundances, richness, and larger butterflies, but the assemblage in those modified but varied set of habitats was more or less uniform. Specialist species decrease as plant diversity decreases; Nymphalidae tend to be more generalized and dominant (Suryawanshi and Shaky 2018). Many Sri Lankan butterflies use exotic plants as their larval food plant; this includes plants that are introduced as ornamental plants, food crops, medicinal plants, weeds, and cover crops (Jayasinghe et al 2014). Given

that these modified habitats are expansive and expanding, these butterfly assemblages are likely to prosper, provided emergent threats do not occur. We note that changes to agricultural practices can impact butterfly assemblages (Luppi et al 2018), but the assemblages we describe additionally occur beyond agricultural lands. Rarer butterfly species may be less tolerant of habitat disturbance, yet effects can be masked by common butterfly abundance and richness (Jain et al 2017).

The assemblage structuring we describe results from species-specific responses to habitat change and to associations with resource requirements and are also likely influenced by other aspects such as prevailing predator environments. Insufficient information is available on the preferences of the individual species we located to unambiguously explain how species-specific patterns drive assemblage structure in all cases, although some species patterns are known. *Papilio* spp. (recorded only in PF) prefer thick forest and utilize forest paths; they will venture out of the forest for food but will only search for a mate within a damp forest (Van Der Poorten and Van Der Poorten 2016). *Eurema* spp. (found in home gardens and shrubland) are highly specialized species, having very few larval food plants (Jain et al 2016); such plants are possibly not available in forests in our study area. Genera *Euploea* and *Parantica* (found in all habitats except PF) are generalist species common in urban/disturbed areas; these species tend to be more specialized when found in PF (Jain et al 2016), and we did not locate them there. *Junonia* spp. (PF only) are regarded as generalist across all habitat types (Jain et al 2016), yet we report they were habitat specialists in our system, suggesting that preferences may vary geographically. Mapping of resources between habitats will likely explain species-specific occurrences.

Elsewhere in the world, specific critical habitat elements (e.g., host or food trees, gardens), are being reestablished in the name of butterfly conservation (Pleasants 2017; Thakur et al 2017). In our

study area, resources and butterflies abound outside PF, yet PF harbors a specific butterfly assemblage. In the absence of more specific detail on what sustains that unique assemblage in PFs, conservation of PF is required as a priority to ensure the persistence of the butterfly assemblage we describe (Montejo-Kovacevich et al 2018). Moreover, the risk of catastrophic events such as fire, which may become more likely under climate change scenarios in these systems, could likely threaten this butterfly assemblage (Kim and Kwon 2018).

Conflict of interest

The authors declare that there is no conflict of interest.

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