The Impacts of Forest Cover Loss and Burning on the Butterfly Community of the Sabangau Peat Swamp Forest, Central Kalimantan, Indonesia

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Photo: Amy Bennett/OuTrop
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The peat swamps of South East Asia account for 56% of global tropical peat swamps and provide a unique habitat for the diversity of flora and fauna found there. They also serve as a vital global carbon store, highlighting their important role in global climate. Peat swamp forest cover is in decline due to deforestation and forest fires, the result being peat degradation and ecosystem imbalance. Research and monitoring is crucial to ensure the successful conservation of this habitat in order to control the negative impacts that this creates. Our current knowledge of peat swamp habitat is limited and OuTrop’s research has, and continues to build on this knowledge in order to conserve and effectively manage peat swamp forest for future generations.

Butterflies make good indicators of the ecological effects of peat forest cover decline due to their ease of sampling, short life span and sensitivity to change. Over a six week period, the butterfly community of the Sabangau peat swamp forest were surveyed from the 7th July to 24th August 2014 to investigate the impacts of burning and subsequent forest cover loss. This involved systematic transect surveying with the use of fruit-baited canopy traps at two forest interior sites, one forest edge site and three areas in the forest exterior. The aim is to establish any differences in the total abundance, diversity and community similarity in the forest interior compared to the forest edge and forest exterior, both at a transect level and a canopy level. The investigation was in collaboration with the Orangutan Tropical Peatland Project (OuTrop) and CIMTROP, and relied on the help of staff and volunteers.

The results indicate that areas with moderate disturbance had the most similar butterfly communities, as well as having the greatest species abundance and diversity. Transects in areas with least forest cover; dominated by long grasses and very few small trees due to historic logging, had similar communities but had the smallest species abundances and diversity. Low traps were found to have greater species abundances and species richness compared with the traps situated in the canopy.
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Introduction

It is well acknowledged that global change, accelerated by human activities, is altering the ecology of our Earth and the diversity of life that is reliant upon it. The growth in the human population and subsequent land use change, increased Nitrogen deposition from agricultural intensification and increased atmospheric carbon dioxide emissions have severe implications for global biodiversity (Sala et al, 2000). Land use change is predicted to have the greatest impact on global terrestrial biodiversity over the next century (Sala et al 2000; Bellard et al, 2014).

Direct human activities such as; agricultural expansion and intensification, commercial logging, infrastructure development and settlement expansion create environmental pressures (Bonebrake et al, 2010; Gardner et al, 2010). Since the 1980s, attempts have been made to address the ecological impact of this change (Roy et al, 2001). There have been shifts in the geographical range of species and increased instances of invasions, as environmental conditions favour different species. Changes in abundance and diversity are also apparent, directly influencing community structure and altering species interactions. Furthermore, species are experiencing changes in phenology and morphology (Roy et al 2001; Walther et al, 2002). Habitat fragmentation induced through its’ loss, is also affecting
the amount of and quality of habitats (Sala et al 2000; Bellard et al, 2014). These effects are not exclusively on a global scale, as evidence also indicates regional level responses (Walther et al, 2002). Ecological effects are centred on the responses of plants or vertebrates, with invertebrate studies under-represented (Thomas, 2005) despite invertebrates accounting for 73.5% of global biodiversity (Hammond, 1995). Current knowledge is focussed on developed countries (Thomas, 2005) due to improved access to resources and funding to enable long term monitoring.

Butterflies make good indicators of ecological effects due to ease of sampling. Their short life span and sensitivity promote a response even to the most subtle changes in habitat (Brown, 1997; Bonebrake et al, 2010). Butterflies are reliant on the success of their host plants and their extent of specialisation determines their extinction risk (Koh, Sodhi & Brook, 2004). Any fluctuations in temperature, humidity, nutrient status and light availability (Brown, 1997) will induce a complex change in community dynamics (Prado, Brown & Freitas, 2007). There are approximately 18,000 to 20,000 species of butterfly (Cleary & Mooers, 2006; Bonebrake et al/ 2010) and early estimates suggest that 82% belong to the Hesperiidae, Lycaenidae, and Nymphalidae taxonomic families (Shields, 1989). As the most studied invertebrate taxon, they take precedence in conservation initiatives and biodiversity management plans (Cleary & Mooers, 2006).

Most butterfly studies are centred on temperate regions (Bonebrake et al, 2010) where populations are under threat from habitat loss as a result of the clearance of areas for agricultural intensification and urbanisation. This leaves habitat patches smaller in size, reduced in quality and less connected as dispersal between them is difficult (Polus et al, 2007). Habitat fragments are also vulnerable to stochastic events such as disease or bad weather (Fox et al, 2011), community structures also shift as the landscape changes. The numbers of habitat specialists, those that have specific biotic requirements, are reduced in favour of habitat generalists that are able to cope with change due to their widespread distribution and less specific requirements (Polus et al, 2007).

Butterfly indicator species have highlighted a declining trend in UK butterfly abundance since 1995 (Figure 2). Poor management and forest clearance are proposed to be the cause of the sharp 51% decrease in woodland butterflies, evident from approximately 2005 (Fox et al, 2011). This decline highlights the need for conservation initiatives.
Butterfly species diversity is highest in tropical regions (Bonebrake et al., 2010). Proportional estimates vary (Shields, 1989; Bonebrake et al., 2010) because of geographically wide ranging species present in both tropical and temperate regions, definitions of a ‘tropical region’ and species taxonomic classification (Bonebrake et al., 2010). An estimate based on species richness per kilometre squared of habitable land area revealed that two-thirds of butterfly species are present within the tropics (Shields, 1989), but an alternative estimation suggests that up to 90% of butterfly species could be in tropical regions, based on extensive species lists by various authors (Bonebrake et al., 2010). Assemblages of tropical butterflies are hugely diverse and contain a high proportion of endemics which are more vulnerable to extinction due to their habitat specialisation and small geographic range (Hill, 1999).

Tropical forest butterfly communities are under threat predominantly from deforestation. Attempts have been made to quantify the scale of this, although different sampling time periods and methods lead to variation and some estimates consider natural forest cover loss alongside human-induced forest cover loss (Houghton, 2012). Satellite data from 1995 to 2005 indicates that net forest cover loss was highest in the tropics, with an estimated 5.6 million hectares per year lost between 1990 and 2000 and 9.1 million hectares per year lost between 2000 and 2005 (FAO & JRC, 2012). Globally, tropical forests are reported to contain between one-half and two-thirds of terrestrial biodiversity (Gardner et al., 2010) therefore this level of deforestation is detrimental to global biodiversity.

South East Asia has some of the most diverse forests globally, with some of the highest known concentrations of endemic species; it is therefore considered to be a biodiversity hotspot (Cleary & Mooers, 2006; Sodhi et al., 2010). Species are under threat as South East Asia has the highest levels of deforestation relative to other tropical regions (Sodhi et al., 2010).
2004) with a 70% loss of original habitat (Sodhi et al, 2010). There is evidence to suggest that the global impact humans have on the environment, through the changes in land use, is highest in Asia (Gibson et al, 2011).

Peat swamp in South East Asia is estimated to account for 56% of global tropical peat swamps (Page, Rieley & Banks, 2011) and not only serves as a unique habitat for the flora and fauna in the region (Miettinen et al, 2012), but also as a vital global carbon store (Miettinen & Liew, 2010). Since the 1980s, peat swamp forest cover has declined and this is predicted to continue, drainage of large areas for timber extraction also leaves drier peat which is vulnerable to forest fires (Miettinen & Liew, 2010) alongside peat degradation and subsequent ecosystem imbalance (Miettinen et al, 2012).

Landscape change has also attributed to a greater impact of forest fires, particularly in countries under the influence of the El Niño Southern Oscillation (ENSO) events such as Indonesia (Harrison, Page & Limin, 2009) and ENSO induced fires are becoming more frequent (Cleary & Genner, 2004). Humans also use fires for disputes or for resource extraction (Harrison, Page & Limin, 2009).

The pressures on this unique environment make this an ideal location for studying. The survey area was located in the 568,000 hectare Sabangau Forest, one of Borneo’s biggest areas of lowland peat swamp forest (Husson et al, 2007), at the Natural Laboratory for the study of Peat Swamp Forest (NLPSF) in the Indonesian province of Central Kalimantan (Figure 3). Illegal logging here ceased in 2004, and the establishment of the NLPSF and Sebangau National Park has given this area some protection status (Husson et al, 2007).

**Figure 3**: Satellite images of the location of the Sabangau Peat Swamp forest in relation to the Island of Borneo. Red circles indicate the specific survey site location. Image taken from Google Earth © with GPS coordinates imposed using BaseCamp © software.
Approximately 1000 species of butterfly have been documented in Borneo, with 98 of them considered to be endemic (Cleary & Mooers, 2006). This survey focussed on the Nymphalidae family of butterflies. In Borneo, an estimated 75% of these are frugivorous so fruit-baited canopy trapping allowed for a good representation of butterflies found here. Six transects were set up in total representing varying degrees of disturbance in order to give an insight into the impact that forest cover loss has on the butterfly communities found here. In particular, to establish differences in abundance, diversity or community similarity in response to forest cover loss, in addition to butterfly morphology and physical condition.

This research was part of the Orangutan Tropical Peatland Project (OuTrop) in collaboration with the Centre for International Cooperation in Sustainable Management of Tropical Peatlands (CIMTROP). Their research has, and continues to build on our knowledge of this unique peat swamp habitat with the wider aim of being able to conserve and effectively manage peat swamp forest for future generations. This study on butterflies is important as current knowledge is predominantly centred on temperate butterflies, and considerably less is known about tropical butterflies (Bonebrake et al, 2010). Developing our understanding of the ecology of the tropical peat swamp forest through biodiversity monitoring is vital to ensure successful conservation which mitigates the negative impacts that human disturbance and subsequent degradation present to this habitat (Houlihan et al, 2013).
Materials and Methods

Transects

Six transects were set up in total representing varying degrees of disturbance. Transect PH was in forest edge habitat and there were three transects leading out of the forest into increasing disturbance representing 60 (transect KH1), 250 (transect KH2) and 350 (transect KH3) metres away from the forest edge. There were two control transects in the forest interior, set up 800 (transect C0.4E) and 2000 (transect C1.6) metres away from the forest edge (Figure 4). These control transects are used by OuTrop for their monthly surveys.

For the purpose of this study, control transect C1.6 was the least disturbed and situated in dense, undisturbed forest with the greatest proportion of forest cover. The other control transect, C0.4E was situated in close proximity to the site of an old railway line, where the trees had been cleared, thus presenting some degree of disturbance to the surrounding area. Transect PH was situated in forest edge habitat where the abundance of trees was less of that in the forest interior. Similarly, it would therefore be reasonable to assume that transects C0.4E and PH were moderately disturbed. Transects KH1, 2 and 3 were habitats dominated by long grasses and small trees and shrubs as a consequence of forest clearing and subsequent partial secondary growth. KH2 and 3 were the most disturbed transects with very little tree cover.

Figure 4: Satellite image showing the GPS locations of survey area, including all six transects in relation to the forest edge. Darker green areas represent the peat swamp forest. Taken from Google Earth © with a BaseCamp © GPS data overlay.
Canopy Traps

A total of 24 bugdome \textsuperscript{©} canopy traps were used. The traps consisted of a cylindrical mesh structure with closed top and an open bottom to which a tray containing bait could be attached (Figure 5). These are successful traps, as the bait at the base serves to attract the butterflies and upon leaving the bait, the butterfly flies upwards ensuring it is trapped within the interior of the mesh cylinder. The mesh cylinder has a zip running down one side to provide access to the caught specimens.

![Canopy Traps](Image)

Figure 5: Left - One of the canopy traps in the forest edge (PH) transect. Right - The bait used. This was made from a mix of banana, sugar and Malaga. Fresh and older bait present in the tray. Photos: Amy Bennett/OuTrop

The canopy traps were placed in pairs; with one trap approximately one to two metres from the ground and another placed approximately ten to fifteen metres above the ground. Each pair of traps was situated 50m apart. The use of high and low traps ensured that both species which forage in upper parts of the canopy and at ground level were attracted. In accordance to OuTrop’s monthly survey, the control transects consisted of six pairs of canopy traps and these were able to be suspended from trees. Transects PH, KH1, KH2 and KH3, had three pairs of canopy traps set up for each survey block, with traps in PH suspended from the trees, but traps in the forest exterior suspended from constructed bamboo structures (Figure 6).
Prior to any survey the bait was mixed. The quantity of which ensured that approximately 1.5 tablespoons of fresh bait could be added to the trays in the traps following the survey. The quantity of bait was made using approximately; 40/50 small overripe bananas; three tablespoons of granulated sugar and 150ml of Malaga which is a local wine with alcohol content of 14%. This recipe is one which has been used in previous surveys and has shown be effective due to the fermentation of the overripe bananas and the Malaga alcohol.

Method

The canopy traps were set up and baited for survey blocks consisting of five consecutive days. The daily surveys were conducted as close to 11am – 3pm as possible as this is the period of the day at which butterflies are at their most active. There were two starting points for the surveys which were alternated during the survey period to ensure that the traps were not surveyed at the same time each day and in the same order.

The traps were re-baited following every survey and the old bait was left on the tray to give a mixture of old and new bait to suit difference butterfly preferences. Following the five days of
survey, the traps were taken down and removed from the forest and the bait plates were washed. In the days following, trap structures were moved, traps were reset and baited ready for the next survey block. In total, five sets of survey blocks were completed between 13th July 2014 and 20th August 2014 giving a total of 25 trap days.

Data Collection

A handheld GPS device was used to locate all transects and create waypoints for individual trap locations. A hand net was taken for every survey which was cupped under the bait tray in an attempt to catch any Lepidoptera on the bait as the trap was approached. Some escaped but where possible the species was identified, either by eye or through the use of binoculars.

The trap was lowered and details such as transect name, trap number and time was recorded. Butterflies were removed one by one via the zip on the canopy trap and securely but carefully held between the thumb and index finger close to the thorax, with the wings pressed together to prevent any damage to the wings, as shown in Figure 7. Using an identification guide (Houlihan, Marchant and Harrison, 2012) alongside local knowledge, each butterfly was identified and sexed. Some species were sexually monomorphic so abdominal characteristics were used for identification.

Using callipers, a measurement was taken of the wing length and of the body from head to vent (Figure 7). The butterfly was then assessed visually to record its condition. A scale of one to three was used for scale colour and wing condition, with one being the best possible condition (Figure 8). A unique identification code was given to each individual and the butterfly was marked on the underside of its wing using permanent marker, prior to being released. This code enabled the identification of recaptures.
Additional information recorded included the amount of moths present in the trap and whether they were large or small (roughly >2cm or <2cm). Any instances of butterfly predation were recorded as well as whether the bait was missing or had other species present. Significant weather events since the last survey were also recorded.
Results

Diversity

The traditional diversity indices such as the Simpson's Diversity Index and Shannon's Entropy do not fulfil the doubling properties of species richness and are non-linear measures (MacArthur, 1965; Whittaker, 1972; Jost et al, 2010). Transforming these traditional indices to give an 'effective number of species' (Hill, 1973), which gives the diversity of an equivalent community with species being equally common (Jost et al, 2010), allows direct comparison with species richness as properties and units are similar (Jost et al, 2010; Hill, 1973).

Table 1: An assessment of the diversity of each transect using Hill's numbers (Hill, 1973) where $S =$ total species richness. $\text{Exp}(H) =$ the exponential of Shannon Index ($H$). $1/D$ is the reciprocal of the Simpson’s Diversity Index ($D$). $\text{Exp}(H)$ and $1/D$ measures give increasing weight to more common species, whereas, species richness is largely biased by less common species and calculating all three includes all aspects of diversity.

<table>
<thead>
<tr>
<th>Hill's Number</th>
<th>C1.6</th>
<th>C0.4E</th>
<th>PH</th>
<th>KH1</th>
<th>KH2</th>
<th>KH3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S$</td>
<td>7.00</td>
<td>11.00</td>
<td>10.00</td>
<td>4.00</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>$\text{Exp}(H)$</td>
<td>5.56</td>
<td>7.54</td>
<td>6.21</td>
<td>2.60</td>
<td>1.00</td>
<td>1.51</td>
</tr>
<tr>
<td>$1/D$</td>
<td>4.88</td>
<td>6.32</td>
<td>4.75</td>
<td>2.08</td>
<td>1.32</td>
<td>0.24</td>
</tr>
</tbody>
</table>

With reference to Table 1, transect C0.4E, with some degree of disturbance shows the highest true diversity using Hill's numbers (Hill, 1973). Transect PH in forest edge habitat shows the second highest true diversity under two of the measures ($S$ and $\text{exp}(H)$) and has a $1/D$ true diversity close to the least disturbed of the transects, C1.6. The forest exterior transects (KH1, 2 and 3) which are the most disturbed, have the lowest true diversity of all transects.
Community Similarity

By creating a presence or absence table in Excel © and loading it into GenStat © (16th edition), dendrograms were constructed to assess community similarity of each transect overall, and at both a high and low trap level.

The analysis of community similarity at a transect level (Figure 9(a)) indicates that C0.4E and PH are more similar to each other than they are to C1.6. KH1, 2 and 3 are very similar to each other. When considering the community similarity of high traps (Figure 9(b)) KH3 is substantially different as it stands alone. C1.6 shares the most similarity to PH than to the other transects. The analysis of low traps (Figure 9(c)) indicates that KH3 and KH1 are more similar to each other than they are to KH2. C0.4E and PH share more similarity with each other than they do with C1.6.
Abundance

Table 2: A summary of species counts for each transect and in total. Counts represent the amount of individuals caught not inclusive of recaptures.

<table>
<thead>
<tr>
<th>Family</th>
<th>Sub-Family</th>
<th>Species</th>
<th>Total Captures</th>
<th>Transect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>C.1.6</td>
<td>C.0.4E</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Charaxinae</td>
<td>Agatasa calydonia</td>
<td>49</td>
<td>13</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Charaxinae</td>
<td>Charaxes bernardus</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Charaxinae</td>
<td>Charaxes borneensis</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Charaxinae</td>
<td>Charaxes solon</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Charaxinae</td>
<td>Prothoe franck</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Limenitidinae</td>
<td>Dophla evelina 34</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Charaxinae</td>
<td>Zeuxidia aurelius</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Nymphalinae</td>
<td>Lexias cyanipardus 5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Nymphalinae</td>
<td>Lexias pardalis</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Nymphalinae</td>
<td>Tanaecia clathrata 1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Nymphalinae</td>
<td>Tanaecia munda</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Nymphalidae</td>
<td>Satyrinae</td>
<td>Melanitis leda</td>
<td>62</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>43</td>
<td>62</td>
</tr>
</tbody>
</table>

With reference to Table 2, the most common species, found across all transects was the *Melanitis leda* with a total of 62 individuals caught, representing 30.2% of the total number caught in this study. The majority were caught in transect PH (16) and transect C0.4E (15). The second most common species was the *Agatasa calydonia* with 49 individuals caught (23.9%), of which almost half (24) were caught in transect PH. This species however, was not found to be present in transects KH1, KH2 or KH3. The third most common species found was the *Dophla evelina* with 34 individuals caught (16.6%) which primarily occurred in transects C1.6 (10), C0.4E (11) and PH (12) and were found only once in KH1, and not in KH2 and KH3.
The results of a Kruskal Wallis Test performed on the number of individuals caught in respect of the distance from the forest edge found a significant result ($H=52.54$, 5d.f., $P<0.001$) indicating that the number of individuals caught at each distance are significantly different from one another. With reference to Figure 10, the greatest mean number of individuals were caught at transect C0.4E (5.2) with a total of 70 individuals caught. This was followed by a mean of 3.6 at transect C1.6 with a total of 43 individuals caught. A total of 70 individuals were caught at transect PH, however the mean number caught fell below that of transect C0.4E and C1.6, at 2.9.

Similarly, a significant result was found when comparing the number of individuals caught with respect to the trap height ($H=5.309$, 1d.f., $P=0.015$) with significantly more individuals caught in low traps than higher traps across all transects. With reference to Figure 11, the
greatest mean number of individuals were found in low traps across all transects. In addition, Figure 12 shows that low level traps had a greater total number of species. With 9 of the 12 species caught in this study more abundant in low traps, one species more abundant in high traps and two having equal abundances in high and low traps across all transects.

**Morphology and Condition**

![Figure 13: Mean Forewing and Body length (mm). Error bars represent standard deviation of the mean.](image)

Larger mean measurements for both body and forewing were taken in the forest interior and in the forest edge, with reference to Figure 13. By log$_{10}$ transforming the datasets for forewing and body measurements, they were suitable for ANOVA of unbalanced design in respect of distance from the forest edge.

The forewing measurements with distance from the forest edge were found to be significantly different ($F_{(5,60)} = <.001$). A standard error of 0.019, indicated that the measurements taken in the control transects (C1.6 and C0.4E) were not significantly different from each other but were significantly higher than those in PH and KH1, 2 and 3. Similarly, the body measurements with distance from the forest edge were also found to be significantly different ($F_{(5,60)} = <.001$). A standard error of 0.026, indicated that measurements taken in transects C1.6, C0.4E and PH were not significantly different from each other but that all measurements in these transects were significantly higher than those in transects KH1, 2 and 3.
Table 3: The mean condition scores with associated standard deviations of the mean for each transect. Scores are on a scale of 1 to 3 with 1 being perfect (see methods).

<table>
<thead>
<tr>
<th>Transect</th>
<th>Colour</th>
<th>Wing</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1.6</td>
<td>1.17 (±0.38)</td>
<td>1.46 (±0.60)</td>
</tr>
<tr>
<td>C0.4E</td>
<td>1.24 (±0.43)</td>
<td>1.45 (± 0.68)</td>
</tr>
<tr>
<td>PH</td>
<td>1.31 (± 0.50)</td>
<td>1.77 (± 0.80)</td>
</tr>
<tr>
<td>KH1</td>
<td>1.24 (±0.44)</td>
<td>1.47 (± 0.72)</td>
</tr>
<tr>
<td>KH2</td>
<td>1.00 (± 0.00)</td>
<td>1.83 (± 0.98)</td>
</tr>
<tr>
<td>KH3</td>
<td>1.50 (± 0.55)</td>
<td>1.50 (± 0.84)</td>
</tr>
</tbody>
</table>

The mean condition scores for colour of scales range between 1.00 and 1.31. The mean scores for wing condition range between 1.50 and 1.83. Butterflies from transect KH2 on average had the best colour condition but the worst wing condition scores (Table 3).

Additional Trap Information

![Figure 14: Mean number of moths found at each distance from the forest edge. Error bars represent the Standard Error of the mean.](image)

The greatest mean numbers of large moths were found in the forest interior at transects C1.6 (3.6) and C0.4E (2.8) (Figure 14) with a total of 151 large moths caught in transect C1.6 and 115 in C0.4. The greatest mean numbers of small moths were found in transects C0.4E (1.4) and KH3 (1.3) with highest total number of 24 small moths caught in C0.4E followed by 5 caught in transect PH.
Discussion

The forest exterior transects (KH1, 2 and 3) were dominated by long grasses and small trees and shrubs from forest loss leading to partial secondary growth. KH2 and 3 had the least forest cover and Figure 15 allows a visual representation.

![Figure 15](image)

**Figure 15**: Condition of the forest exterior sites (KH2 and KH3). Vegetation dominated by long grasses and small trees and shrubs. Photo: Amy Bennett/OuTrop.

**Community similarity**

At a transect level, considering just low traps, the community at transects PH and C0.4E were the most similar. These habitats both have some degree of disturbance greater than that found at transect C1.6 and therefore support similar butterflies that can tolerate some disturbance.

Analysis of the forest exterior communities revealed that the three transects situated there (KH1,2 and 3) had similar community compositions. Fewer species were found here overall potentially as a result of harsh conditions this habitat presents (Figure 15). A greater degree of exposure, strong sunlight penetration and a lack of edible resources make this environment difficult to tolerate.
The community at transect KH3 was found to be substantially different when considering the high traps, which may be as a result of canopy feeders not dispersing such a distance outside of the forest exterior due to the lack of canopy cover.

**Abundance**

Factors such as temperature, humidity, nutrient status and light availability affect butterfly species (Brown, 1997). Studies have shown a decline in abundance of some species, whilst others have increased when comparing disturbed sites with protected areas (Koh, 2007) supporting the notion of species specific responses.

Less dense forest is associated with greater light penetration of the canopy which in turn has an effect on the butterflies present (Hamer *et al*, 2003; Dumbrell & Hill, 2005), with some species being more sensitive to this than others. The ability of light to penetrate the canopy impacts the moisture status and humidity of the forest which in turn has the potential to create pockets of varied conditions. This has direct effects on adult and larval survival because of their tolerances and feeding resources, but also indirectly though habitat quality (Hamer *et al*, 2003). A greater abundance of individuals were found in transects PH and C0.4E, followed by transect C1.6. This suggests that butterflies may have a preference for moderate to low light penetration in the studied forest.

Very few studies consider the forest exterior where the lack of forest has resulted in extreme light penetration, peat degradation and harsh conditions. The adverse effect this has on the butterflies is evident as abundance was at its lowest in the forest exterior. In particular, KH2 and KH3 sites, where high sunlight exposure and poor quality soil restricts the plant species which are able to tolerate these conditions.

Logged forest has been associated with a greater abundance of wide-ranging species (Cleary *et al*, 2009). The most abundant species in this study, found in all transects was the *Melanitis leda* from the sub-family Satyrinae, implying that this species is a widespread, common species. Its higher counts around forest edge habitat indicate a preference for moderately disturbed habitat with some degree of forest cover loss. Generally Satyrinae species have less of a preference for forest gaps, an exception being the *Melanitis leda* (Hamer *et al*, 2003).

The second most abundant species, *Agatasa calydonia* of the Charaxinae sub-family was only found at forest and forest edge sites in this survey. A similar trend was exhibited by *Prothoe franck*, whereas *Charaxes solon* was only found at the forest edge and forest...
exterior. This only partially supports the idea that Charaxinae species are generally present in less dense or open areas because of a preference for forest gaps, and large, broad thoraces with smaller wing lengths enabling strong, rapid flight in less-dense forest (Hamer et al, 2003; Houlihan et al 2013). The study by Houlihan et al (2013) did not include Prothoe franck species which could be why this study found that some Charaxinae species have less of a preference for open areas.

Diversity

The response and adaptation of a species in response to human-induced change influences its survival (Koh, 2007) and it is important to explore beyond patterns in abundance. It has been suggested that moderately disturbed habitats with moderate forest cover present higher diversities of butterflies (Willott et al, 2000; Hamer et al, 2003). This study found most diversity in the forest edge and the more disturbed C0.4E forest site. This may be as a result of the co-existence of wide-ranging pioneer species which tolerate high disturbance levels enabling them to quickly exploit new areas, alongside established climax species which form a stable species community from reduced disturbance (Hamer et al, 2003; Cleary & Mooers, 2006). In contrast, the forest exterior had very little diversity highlighting the lack of species able to tolerate these conditions.

There is discrepancy within the literature regarding the response of species diversity in relation to forest loss, with reports of higher diversity in disturbed sites (Willott et al, 2000; Hamer et al, 2003; Fermon et al, 2005) and reports on the contrary (Hill et al, 1995; Dumbrell & Hill, 2005). A meta-analysis of 20 South-East Asian studies on butterfly community response to habitat loss found seven studies concluded decreasing diversity with disturbance, but nine showed the opposite (Koh, 2007). Diversity may be higher in disturbed sites, but endemic butterflies with restricted ranges and more specialist requirements are more abundant and species diverse in ‘natural’ forest (Fermon et al, 2005) highlighting the importance of forest cover for these unique species. The Hill’s numbers (Hill, 1973) used in this study allow diversity to be represented with both increasing weight to common species (Exp(H) and 1/D) and those that are more rare (S). The choice of diversity indices, spatial scale, time frame and methods used are not consistent within the literature, making direct comparisons difficult as these factors will greatly influence the overall findings. Spatial scale allows for a wider representation, a longer time frame incorporates seasonal fluctuations and trapping in the canopy and at ground level shows vertical stratification.
**Canopy level**

Across all transects, more individuals were caught in low canopy traps suspended approximately one or two metres above the ground than in those traps suspended ten to fifteen metres above the ground. For areas with forest cover, this suggests a preference for the understory as opposed to within the canopy. Fruit-feeding butterflies, shown in this study and others in the area (Houlihan *et al.*, 2013), are attracted to rotting, fermenting fruit. The presence of fruit trees in the forest indicate that fruit from these trees that has fallen to the ground and started to rot, may serve as a food source for the butterflies. Thus, the availability of food is greater closer to the ground and this may indicate why a greater number of individuals were found in lower traps. For external forest transects, the lack of potential resources at canopy level would be a potential explanation for the lack of butterflies caught at this height.

Canopy level appears to have an effect on species, with typically more species being found in lower traps (Tangah *et al.*, 2004). A study found 31 species more common in low traps compared to 23 being more common in high traps (Tangah *et al.*, 2004). Although on a much smaller scale, this study found 9 of 12 species caught more abundant in low traps compared with only one species being more abundant in high traps. It is difficult to gain an overall representation of the effect of trap level on butterflies due to there being a bias towards the amount of ground level surveys (Dumbrell & Hill, 2005).

**Morphology**

Morphology of the butterflies is said to provide a means of explaining their presence within dense forest or open areas. Those with broad wings are more adapted to slow flight within dense forest, and those with larger thoraces which give rise to more powerful flight are better adapted to faster flight in more open areas (Hamer *et al.*, 2003; Houlihan *et al.*, 2013). This study looked at forewing length and thorax length, so is not directly comparable but, larger forewing and thorax lengths were recorded in more dense forest. This suggests that larger wings are more suited to dense forest as the slower flight enables the butterfly to navigate.

The condition of the butterflies in this study showed little variation. Although it was a subjective condition score, it had the potential to assess the condition of the butterfly in respect of forest cover loss. The results are inconclusive and no comparisons can be made with other studies.
Conclusion

Transects situated in areas with moderate disturbance had the most similar butterfly communities, as well as having the greatest species abundance and diversity. Whilst diversity is highest in moderately disturbed sites, this may be due to a co-existence of pioneers and climax species, and a decline in range-restricted species in favour of wide-ranging species.

The transects in exterior sites dominated by long grasses and very few small trees due to historic logging, also had similar communities, but abrupt declines in species abundances and diversity were evident. Beyond the forest edge habitat into the forest exterior is less favoured by butterflies. Conditions here are harsh and extreme sunlight exposure adversely affects the plants able to survive there, in turn reducing resource availability for butterflies. This has adverse effects on larval and adult survival.

This study represents a small area of peat swamp forest within the 568,000 hectare Sabangau Forest (Husson et al, 2007). This unique habitat is under studied and comparatively little is known about the diversity of species found here. A larger scale study is needed to fully understand the impact of forest cover loss on the butterfly communities of the Sabangau. This would allow a wider application to tropical peat swamp habitats and increased knowledge how best to protect and manage this unique habitat.


