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SHORT COMMUNICATION

# Butterfly community recovery in degraded rainforest habitats in the Upper Guinean Forest Zone (Kakum forest, Ghana)

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**Abstract** Successful regeneration of secondary tropical forest might be crucial in the conservation of rainforests, since large areas of primary forest have been destroyed or degraded. Animal communities might play an important role in restoration of biological diversity in these secondary habitats, since some groups have high mobility and capacity for dispersal. Fruit-feeding butterflies were trapped to measure differences between butterfly communities in primary rainforest and disturbed forest habitats of different stage of regeneration including clear-cut, abandoned farmland, newly planted forest and middle-aged secondary growth. 3465 specimens representing 114 species were identified from 56 traps operated for 36 days. Extremely high values of rarefied species richness were estimated in the clear-cut habitat, due to the high number of singletons and doubletons. This was caused by a gap-effect that allowed penetration of canopy and open area species after disturbance. The differences between butterfly communities were best demonstrated through ecological composition, richness and abundance of indicator groups and habitat similarity based on Jaccard's similarity index. The results show a clear ability of butterfly communities in degraded forest habitats to regenerate in 50–60 years after clearance.

**Keywords** Butterfly community recovery · Fruit-feeding butterflies · Rainforest regeneration · Kakum forest · Ghana

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## Introduction

Forest regeneration in tropical areas has received high publicity in the recent years (Wunderle 1997; Parrotta et al. 1997; Aide et al. 2000), since tropical rainforests are known as one of the most important mitigators of the effects of global climate change through fixing and storing a considerable amount of carbon stock (Foody et al. 1996; Chiti et al. 2010). Protection of the remaining rainforest areas in West Africa is also becoming increasingly important to conservation bodies as the Upper Guinean Forest Zone is known as one of the twenty-five biodiversity hotspots in the world (Myers et al. 2000) and the loss of the original forest cover reaches over 90% in several West African countries (UNEP/GRID-Arendal 2002). The recognition of the excessive need for wood products in these countries has led to the initiation of restoration programs, although the new forest plantations mostly consist of fast-growing non-indigenous tree species such as teak and eucalyptus (Tiarks et al. 1998). Although studies on the plant composition have been carried out in regenerating rainforests (Otsamo 1999; Kassi N'Dja 2008), little information has been published on the regeneration of animal communities in rainforests, especially in the Upper Guinean forest zone (Dunk 2004). Butterfly species or communities are well known indicators of different ecological factors since they usually react quickly to negative changes, but their flying ability also allows them to return if conditions become favourable (Lawton et al. 1998). Fruit-feeding butterfly communities are frequently used to measure these factors including their reaction to edge-effect, stratification, fragmentation or habitat loss (Fermon et al. 2000, 2003; Vanclay 2004; Bobo et al. 2006; Bossart et al. 2006; Bossart and Opuni-Frimpong 2009; Elbers and Bossart 2009). In this paper analysis of quantified samples collected in forests at different stages of degradation-regeneration (from clear-cut to primary forest through abandoned farmland, young planted indigenous forest and middle-aged secondary growth) reveals evidence that rainforest associated fruit-feeding butterfly communities are able to recover.

## Study area

Kakum Forest has become a famous tourist attraction in Ghana's Central Region since the completion of the 'canopy walkway', a series of rope-bridges in the canopy level of the rainforest. Besides playing an important role in eco-tourism in the country, Kakum is also a biodiversity hot-spot. Covering more than 360 km$^2$ Kakum is one of the largest protected blocks of intact moist evergreen and semi-deciduous forest (with the adjacent Assin Attandanso Reserve) in Ghana, which hosts a viable population of forest elephant, a good number of primates, hundreds of birds and more than 600 butterfly species (BirdLife International 2009, Larsen 2006a, Riley and Riley 2005). Our sampling sites were selected in a 40 hectare area, which lies on the boundary of Kakum National Park (5°21′35.77″N; 1°22′8.49″W) (Fig. 1). It proved ideal for a comparative study of butterfly communities since the area was originally covered by primary rainforest.

However, during the last four decades parts were used by local farmers who created a sort of mosaic type vegetation structure including patches of untouched primary forest, formerly logged middle-aged secondary growth, oil-palm, cocoa and cassava plantations. The area has now been abandoned for over ten years, and some formerly utilized plantations were replanted with indigenous tree species such as *Ceiba pentandra*, *Chlorophora excelsa*, *Terminalia ivoriensis* and *Khaya ivoriensis* nine years ago by the present owner. An illegal clear-felling of a primary rainforest area within the study site created an extreme disturbance of forest habitat, leaving it practically without forest cover. A full set of disturbed forest habitats in different stages of regeneration were available for a comparative study of the butterfly communities.

The habitats studied were in close proximity and were interconnected by natural corridors that allowed dispersal of butterflies, and therefore extinction and re-colonisation depended mostly on ecological factors but not geographical isolation. The mean distance between sampling sites was approximately 250 m. Two control transects in the primary upland evergreen rainforest of the Atewa Range (6°14′54.83″N; 0°33′53.03″W) were selected (Fig. 1) to be compared with the samples collected in Kakum. With an estimated 700 species, Atewa Range is recognized for hosting the highest diversity of butterflies in West Africa west of the Dahomey Gap (Larsen 2007).

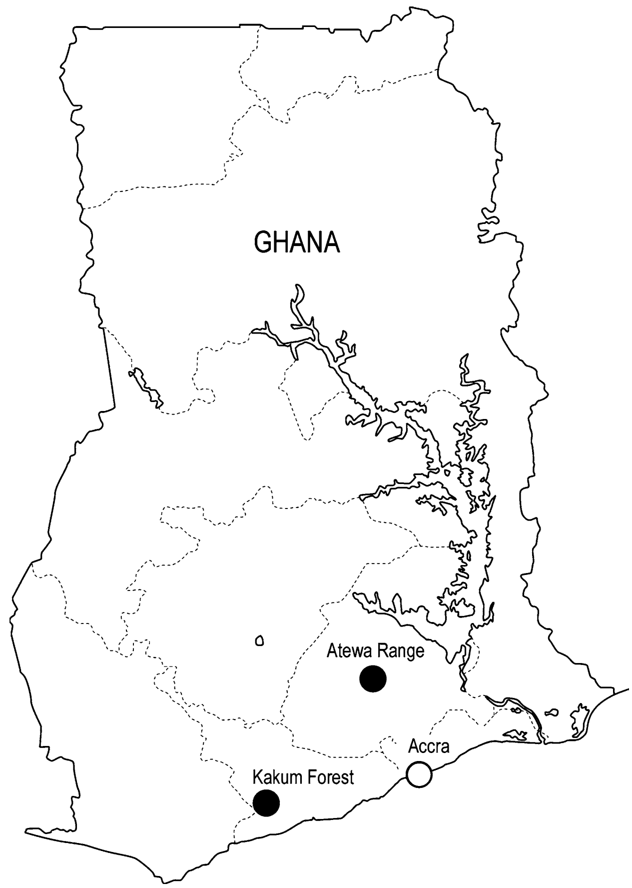

**Fig. 1** Map of sampling areas

Sampled habitats:

Primary Forest (PF): Old primary rainforest with many mature trees, natural forest structure and stratification, including a very dense shrub-layer. Canopy cover is 100%.

Secondary Forest (SF): Middle-aged secondary growth with a few mature trees and dense understorey vegetation. The canopy cover is almost 100%.

Young Planted Forest (NF): Even-aged young forest, planted 9 years ago with indigenous trees. It has 100% closed canopy cover during wet season, but the canopy is more open in the dry period. Large trees and the shrub-layer are completely missing.

Farmland (FL): Semi-open area with middle-aged oil palms and 6–12 year-old trees and thickets. The canopy cover is less than 60%.

Clear-cut (CC): Open area of a few hectares, illegally clear-felled in December 2006 in the forest. There was virtually no arboraceous vegetation only thick coppices, tall grassy vegetation and invasive shrubs in 2007 when the sampling began.

Control 1 (K1): Wet primary evergreen forest with slight disturbance in a valley in the Atewa Range.

Control 2 (K2): Wet primary evergreen forest with slight disturbance on a hilltop in the Atewa Range.

## Methods

### Trap data

Fruit-feeding butterflies (Nymphalidae: Satyrinae, Charaxinae, Nymphalinae and Limenitinae) were attracted by mashed banana bait and captured by net traps, modified from IKEA's children's toy storage net "MINIFÅNGST" by the senior author (http://www.independent.co.uk/life-style/house-and-home/interiors/the-50-best-storage-ideas-964981.html?action=Popup&ino=17) (dimensions: $h = 75$ cm, $d = 23$ cm). The original structure was altered by cutting out the separations between compartments and covering all holes on the side of the net. A new, horizontal entrance gap was opened on the side almost at the bottom to ensure that butterflies are able to enter the trap when seeking the bait, which is placed in a plastic plate at the bottom of the trap. They nearly always fly upwards when alarmed and therefore they get trapped in the top section of the net. The banana bait was changed on every fourth day although the bait was refreshed by stirring every day after emptying the traps. Butterflies were collected from the traps once a day on a regular basis.

Eight traps were set along linear transects in each sampled habitats (56 traps in total). The bait was placed just above ground level (not more than 10 cm from the ground), which allowed sampling of fruit-feeding butterflies that are normally restricted to the forest floor and the dense undergrowth. The traps were operated for twelve consecutive days allowing one sample in each habitat. The data included comprise the results of three sampling periods (36 cumulative days/transects). The distance between traps was in each case 30 m—the same as the distance of the first and last traps from the habitat boundaries, to reduce the bias of sampling and edge effect as much as possible. The uniqueness of this kind of habitat complex and the overall size of each habitat patches did not allow replication of sampling under similar conditions. Sampling of the two control transects was carried out immediately after the Kakum transects to ensure that no seasonal differences would occur in the samples. All the butterflies were indentified by the senior author, with the help of his reference collection of Ghanaian butterflies and the comprehensive work of Larsen (2005) in case of particularly difficult specimens.

### Analysis

The attributes of butterfly communities in the sampled habitats are presented via comparison of species richness, ecological composition, richness and abundance of indicator groups and diversity indices. In addition to the observed species richness nonparametric richness estimators (abundance-based estimators ACE and Chao1 and incidence-based estimators ICE and Chao2) were evaluated using the Species Richness Estimators v2.1 module of www.eco-tools.net. Singletons and doubletons (number of species represented by one or two individuals) were also verified. Three measures of species $\alpha$ diversity were calculated for each habitat: the Shannon index ($H' = -\sum p_i \ln p_i$), equitability ($J = H'/\ln S$—where $S$ is species richness) and Fisher's alpha ($S = \alpha \ln (1 + N/\alpha)$). Community structure comparison between the different forest habitats was estimated using single linkage cluster analysis based on *Jaccard's* similarity index.

## Results

### Species richness and diversity

3,465 specimens belonging to 114 species were collected during three sampling periods (2,016 cumulative trapping days with an average 1, 7 specimens/trap/day) in 2007 and 2009 using 56 traps (Appendix 1). *Bicyclus larseni*, *B. uniformis*, *B. safitza*, *B. silvicolus*, *B. istaris*, *Charaxes candiope*, *C. pollux*, *C. zelica* were recorded as new to Kakum National Park since the latest checklist (Larsen 2006a). The highest observed species richness was identified from the 'primary forest' transect (62) and the control transects (59, 59), while the secondary growth, farmland, clear-cut and new forest had almost evenly low number of species; 51, 52, 53 and 54, respectively (Table 1; Fig. 2). The estimated species richness was the highest in the clear-cut habitat spanning from 77 (incidence-based ICE) to 128 (abundance based Chao1) compared with the 53 actually collected. Chao1 estimator gave the highest estimate of species richness in the two most 'disturbed' habitats (CC and FL). The Shannon diversity index varied from 2.989 (NF) to 3.768 (PF) and Fisher $\alpha$ ranged from 14.54 (FL) to 21.98 (PF). Species evenness was the highest in the

**Table 1** Estimated species richness and diversity indices of the sampled habitats

| Habitat | *S* | *N* | Singletons/doubletons | Richness estimates | | Number of presumed species | *H'* | *J* | α |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ACE/ICE | Chao1/Chao2 | | | | |
| PF | 62 | 347 | 13/12 | 72/72 | 68/69 | 6–10 | 3.768 | 0.9130 | 21.98 |
| SF | 51 | 449 | 17/10 | 72/73 | 63/62 | 11–22 | 3.011 | 0.7658 | 14.81 |
| NF | 54 | 461 | 18/12 | 72/75 | 66/68 | 12–18 | 2.989 | 0.7494 | 15.87 |
| FL | 52 | 505 | 17/3 | 67/67 | 86/79 | 15–34 | 3.016 | 0.7632 | 14.54 |
| CC | 53 | 361 | 22/2 | 78/77 | 128/109 | 25–75 | 3.157 | 0.7952 | 17.13 |
| K1 | 59 | 632 | 12/9 | 69/68 | 66/64 | 5–10 | 3.482 | 0.8539 | 15.92 |
| K2 | 59 | 710 | 14/9 | 69/72 | 68/69 | 9–13 | 3.236 | 0.7936 | 15.29 |

*S* total number of species trapped, *N* number of individuals; *ACE*, *ICE*, *Chao1* and *Chao2* nonparametric richness estimators, *H'* Shannon's diversity index, *J* Pielou's evenness index, α Fisher's alpha diversity index

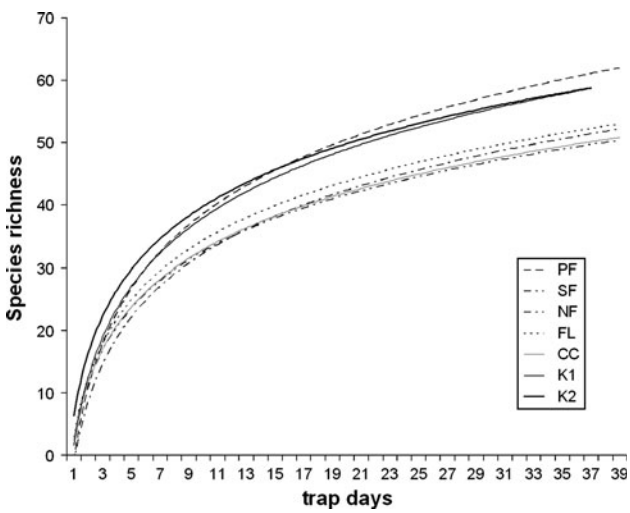


**Fig. 2** Species accumulation curves show the actual number of recorded species against trapping days in each sampled habitat

'primary forest' ($J = 0.913$) followed by the 'clear cut' area ($J = 0.8539$).

## Ecological composition

The analysis of ecological composition of butterflies based on Larsen (2006a) resulted in relatively small but clear differences between butterfly communities (Table 2). Generally all samples were dominated by forest butterflies; ubiquitous species and those centred on savannah land remained generally low in all samples: 0–5.6 and 3.2–5.8%, respectively. Practically no savannah butterflies were recorded from the PF, SF and NF samples. Mesophilous forest species represent almost one-third, while generalist forest species comprise about half of all recorded species. In the former group the PF reached the highest proportion with approximately 10% higher value of all other samples, in the latter, values in PF, K1 and K2 samples reached averagely 10% higher in all disturbed habitats. The differences are well pronounced in the wet forest samples where all forest samples shown relevantly higher proportion than disturbed habitats, reaching one-fifth of all species in the PF and K2.

**Table 2** Number and proportion of butterfly species per ecological categories in the sampled habitats

| | PF | SF | NF | FL | CC | K1 | K2 |
|---|---|---|---|---|---|---|---|
| DRF | 0/0.0 | 1/2.0 | 2/3.7 | 3/5.8 | 1/1.9 | 1/1.7 | 3/5.1 |
| MEF | 23/37.1 | 13/25.5 | 15/27.8 | 13/25.0 | 15/27.8 | 17/28.8 | 15/25.4 |
| WEF | 12/19.4 | 6/11.8 | 7/13.0 | 5/9.6 | 3/5.6 | 10/16.9 | 12/20.3 |
| ALF | 25/40.3 | 29/56.9 | 27/50.0 | 27/51.9 | 30/55.6 | 27/45.8 | 25/42.4 |
| GUI | 0/0.0 | 0/0.0 | 0/0.0 | 1/1.9 | 3/5.6 | 2/3.4 | 2/3.4 |
| UBQ | 2/3.2 | 2/3.9 | 3/5.6 | 3/5.8 | 2/3.7 | 2/3.4 | 2/3.4 |

*DRF* dry forest species, *MEF* mesophilous forest species, *WEF* wet forest species, *ALF* forest species with wide ecological tolerance, *GUI* Guinea savannah species, *UBQ* ubiquitous species (based on Larsen 2006a)

## Habitat quality indication

A comparison of species richness and abundance of three genera was used to demonstrate differences between butterfly communities and as an indicator of habitat quality in the sampled habitats (Fig. 3). Species belonging to *Euphaedra* and *Euriphene* were found restricted to intact forest habitats, showing high richness in PF, SF and the control transects. Samples from strongly disturbed habitats contain many fewer species of these groups. The proportion of *Euriphene* is 0% in both CC and FL samples, while the values of *Euphaedra* reach 7.6% (CC) and 38% (FL) of the highest recorded in the PF. The contrast is even more pronounced when abundance is examined. The highest number of individuals of both *Euriphene* and *Euphaedra* were captured in PF, as was the case in the control transects. Abundance drops significantly in disturbed habitats, showing zero values in CC and FL.

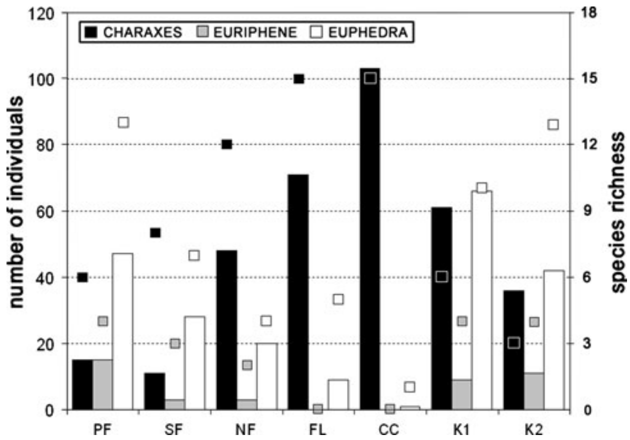


**Fig. 3** Species richness (squares) and abundance (columns) of the genera *Euphaedra* (white), *Euriphene* (grey) and *Charaxes* (black) in the sampled habitats. The highest values of *Euphaedra* and *Euriphene* indicate intact forest, while the highest species richness and abundance of the genus *Charaxes* appeared to be in the most disturbed (open) habitats

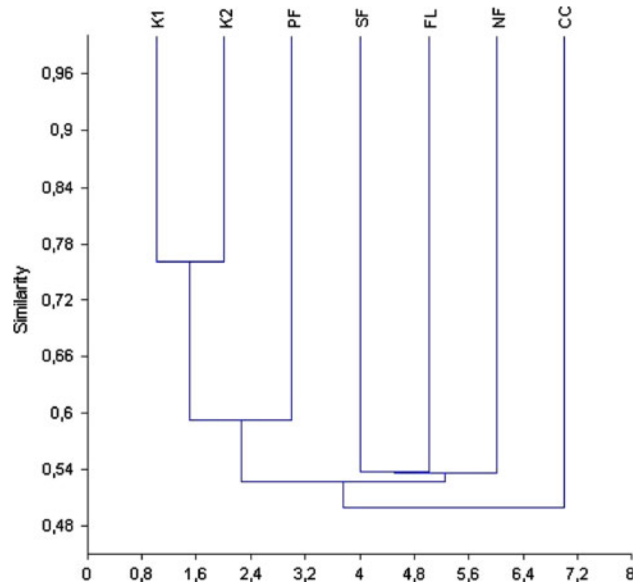


**Fig. 4** Dendrogram based on cluster analysis using *Jaccard's* coefficient of similarity on the butterfly communities of the sampled habitats

The differences between the highest and lowest abundance values are 46 specimens for *Euphaedra* and 15 for *Euriphene* (if the controls are left out of the comparison). *Charaxes* reached significantly higher species richness in more disturbed habitats. The number of *Charaxes* species was 60% higher in FL and CC than in PF and 50% higher than in SF (the lowest species richness of *Charaxes* actually occurred in K1 and K2). The abundance values also show significant differences between disturbed habitats and forests. The lowest abundance values were found in the PF and SF, while outstandingly high values were recorded in the FL and CC where no real canopy cover exists. The difference between CC and PF was 88 specimens (85%), while it is even higher comparing to the SF: 92 specimens (90%). Abundance of *Charaxes* in the control transects appears to be higher than in PF and SF, they remain still 35 and 59% lower than the highest value, quite similarly to NF.

### Habitat similarity

The agglomerative cluster analysis based on Jaccard's single linear similarity index clearly demonstrate the differences and similarities between butterfly communities in different habitat types. Cluster analysis separated the sampled habitats into two main groups: there is a complete separation between the totally open clear-cut habitat (CC) and the forest habitats. This second group was further subdivided into two subgroups, where transects K1 and K2 (which represent the highest similarity) cluster only with PF, while all disturbed forest communities are in a distinct subgroup with relevant differences (Fig. 4).

## Discussion

### Species richness and diversity

Tropical forest butterfly communities are usually characterized by their high species richness and diversity. Although several studies from the Afrotropical region (Rogo and Odulaja 2001; Stork et al. 2003; Bobo et al. 2006; Bossart et al. 2006; Akite 2008) showed evidence that creation of gaps in forest habitats by logging, clearing for farming or complete clear-felling have a significant negative effect on butterfly species richness and diversity, this trend was the opposite in some Neotropical case studies (Wood and Gillman 1998; Horner-Devine et al. 2003). The increase in species richness and diversity can particularly be observed at a relatively small spatial scale (Hill and Hamer 2004; Bonebrake et al. 2010). It was therefore no surprise that estimated species richness was relatively high in the 'clear-cut' transect, compared to the difference between the estimated and observed richness in the 'farmland' (estimates of total richness represents a 22–40% increase).

In both habitats, maximum species richness was predicted by Chao1 which uses the relative proportions of singletons and doubletons for calculating estimates. Percentage of singletons was especially high in these two habitats (33% in FL and 42% in CC). The results can be explained by the nature of temporary gap habitats in rainforests, where more mobile species can occupy the open area, while a number of forest species are still able to utilize or disperse through open gaps in the forest in low numbers (Hill et al. 2001). Elbers and Bossart (2009) captured several real forest butterflies in more open farmland habitat close to the forest boundary. This gap effect is only partially reflected in the butterfly diversity values, since both Shannon and Fisher $\alpha$ indicate the highest diversity in primary forest habitat with evenly lower values in all other samples.

### Ecological composition

The recorded differences between ecological composition of butterflies in the samples are not necessarily emphasised by the penetration of species characteristic of more open country into the degraded habitats but is best viewed through the richness of the 'wet forest species' (WEF). The high values in the PF and the control samples and the opposite in the disturbed forest samples show evidence that butterflies centred in wetter types of forests are sensitive enough to disappear from forest habitats upon disturbance. This is also well supported well by Sáfián et al. (2009) who found WEF almost completely missing from samples collected in heavily degraded forest habitats in the Togo Mountains (Togo), while Larsen (2006b) records several wet forest specialists from the better conserved forest in the same type of area in Ghana (Wli Falls). The generally low number of ubiquitous species (UBQ) and those centred in savannah habitats (GUI) indicates that temporal gaps in forest areas created by smaller scale disturbance might not necessarily establish favourable conditions for colonisation of butterflies inhabiting open areas. Habitat disturbance on a larger scale however caused drastic changes in the butterfly composition in Sierra Leone, increasing the proportion of UBQ and GUI species significantly (Sundufu and Dumbuya 2008; Sáfián et al. 2009). Minor but interesting differences are shown by the value of mesophilous forest species (MEF) in the PF. This 10% higher proportion could be explained by the disappearance of more sensitive species upon disturbance, just like the opposite in the generalist forest species (ALF), where butterflies with higher tolerance for habitat disturbance were able to appear in the SF, NF, FL and CC samples.

### Habitat quality indication

The genera *Euriphene* and *Euphaedra* are known as forest interior species in the rainforest belt of tropical Africa that have strong fidelity to their habitats (Larsen 2005). Fermon et al. (2000) found *Euriphene* and *Euphaedra* almost exclusively in forest samples in Ivory Coast, while they were almost absent from plantation forest. Elbers and Bossart (2009) recorded only a few *Euphaedra* specimens and none of the *Euriphene* from their 'matrix' non-forest samples. This corresponds well with our results, strengthening the hypothesis that higher species richness and abundance of *Euphaedra* and *Euriphene* indicate more intact rainforest ecosystem in the Afrotropics. Although Molleman et al. (2006) recorded several *Charaxes* species both from understorey and canopy traps, other surveys and observations showed that the majority of forest-dwelling *Charaxes* are usually canopy (or middle canopy) butterflies that avoid entering dense undergrowth of forest but are able to appear quickly in open areas in forested habitats (Larsen 2005; Fermon et al. 2003). Our results clearly indicate that disturbance in forest habitats increases the species richness and abundance of *Charaxes* appearing in fruit-baited understorey traps. The abundance values in the control transects were actually caused almost exclusively by a single species *Charaxes fulvescens*, which is among the few *Charaxes* that regularly penetrate forest interior (pers. obs., Molleman et al. 2006).

## Conclusions

The sampled clear-cut habitat has a low degree of similarity with those of forest habitats, based on the ecological analyses of butterfly community composition. However, the recovery of the primary forest butterfly community was observed from newly planted young forest and farm land towards middle-aged secondary growth. Diversity and rarefied species richness indices alone are not necessarily adaptable to evaluate butterfly community collapse and recovery in rainforest habitats, especially when the disturbed area is surrounded by habitats of more natural type, since disturbance allow a wide range of species to penetrate degraded habitats biasing diversity data. The genera, *Euriphene* and *Euphaedra* have proven to be indicators of forest interior in good condition, because they appeared to demonstrate very strong fidelity to the middle-aged and mature forest habitats; their high species richness and abundance in the secondary forest shown clear evidence of regeneration of the forest butterfly community. The presence of canopy dwelling *Charaxes* in large quantities indicated considerable habitat disturbance—extreme abundance was recorded only from the clear-cut with complete absence of forest cover. These results might prove important in further evaluations of the success of forest conservation and regeneration projects especially in afro-tropical areas.

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## Appendix I

See Table 3.

**Table 3** Recorded butterfly species and abundance values from the sampled habitats

| | PF | SF | NF | FL | CC | K1 | K2 |
|---|---|---|---|---|---|---|---|
| *Family Lycaenidae* | | | | | | | |
| Subfamily Polyommatinae | | | | | | | |
| *Anthene larydas* (Cramer, 1780) | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| *Family Nymphalidae* | | | | | | | |
| Subfamily Libytheinae | | | | | | | |
| *Libythea labdaca* Westwood, 1851 | 0 | 0 | 0 | 0 | 11 | 0 | 0 |
| Subfamily Satyrinae | | | | | | | |
| *Gnophodes betsimena* (Boisduval, 1833) | 5 | 14 | 16 | 11 | 4 | 27 | 36 |
| *Gnophodes chelys* (Fabricius, 1793) | 10 | 0 | 0 | 0 | 4 | 18 | 28 |
| *Melanitis leda* (Linnaeus, 1758) | 2 | 2 | 1 | 5 | 1 | 17 | 8 |
| *Melanitis libya* Distant, 1882 | 3 | 17 | 6 | 8 | 8 | 1 | 1 |
| *Elymniopsis bammakoo* (Westwood, [1851]) | 0 | 35 | 44 | 23 | 10 | 0 | 0 |
| *Bicyclus xeneas* (Hewitson, 1866) | 13 | 9 | 2 | 4 | 3 | 2 | 2 |
| *Bicyclus evadne* (Cramer, 1779) | 14 | 7 | 2 | 5 | 6 | 2 | 4 |
| *Bicyclus ephorus* Weymer, 1892 | 3 | 0 | 1 | 0 | 0 | 2 | 3 |
| *Bicyclus zinebi* (Butler, 1869) | 7 | 3 | 2 | 0 | 1 | 27 | 23 |
| *Bicyclus uniformis* (Bethune-Baker, 1908) | 1 | 0 | 0 | 0 | 0 | 27 | 29 |
| *Bicyclus procora* (Karsch, 1893) | 12 | 13 | 0 | 3 | 0 | 16 | 27 |
| *Bicyclus larseni* vande Weghe, 2009 | 3 | 1 | 1 | 1 | 0 | 1 | 2 |
| *Bicyclus taenias* (Hewitson, 1877) | 4 | 49 | 34 | 49 | 19 | 5 | 16 |
| *Bicyclus vulgaris* (Butler, 1868) | 0 | 5 | 8 | 15 | 11 | 5 | 1 |
| *Bicyclus dorothea* (Cramer, 1779) | 1 | 3 | 23 | 55 | 8 | 8 | 4 |
| *Bicyclus sandace* (Hewitson, 1877) | 6 | 14 | 63 | 83 | 30 | 9 | 5 |
| *Bicyclus sambulos* (Hewitson, 1877) | 12 | 12 | 6 | 1 | 0 | 42 | 43 |
| *Bicyclus sangmelinae* Condamin, 1963 | 12 | 14 | 12 | 13 | 5 | 11 | 19 |
| *Bicyclus auricruda* (Butler, 1868) | 0 | 0 | 0 | 0 | 0 | 13 | 14 |
| *Bicyclus sylvicolus* Condamin, 1965 | 6 | 0 | 0 | 0 | 0 | 16 | 17 |
| *Bicyclus abnormis* (Dudgeon, 1909) | 1 | 0 | 0 | 0 | 0 | 2 | 1 |
| *Bicyclus safitza* (Westwood, 1850) | 0 | 0 | 0 | 0 | 3 | 0 | 1 |

**Table 3** continued

| | PF | SF | NF | FL | CC | K1 | K2 |
|---|---|---|---|---|---|---|---|
| *Bicyclus funebris* (Guérin-Méneville, 1844) | 0 | 0 | 0 | 0 | 0 | 21 | 3 |
| *Bicyclus istaris* (Plötz, 1880) | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Bicyclus madetes* (Hewitson, 1874) | 15 | 41 | 20 | 14 | 10 | 36 | 59 |
| *Bicyclus martius* (Fabricius, 1793) | 21 | 98 | 97 | 80 | 87 | 32 | 39 |
| *Hallelesis halyma* (Fabricius, 1793) | 2 | 13 | 0 | 1 | 1 | 3 | 6 |
| *Henotesia decira* (Plötz, 1880) | 0 | 0 | 0 | 0 | 0 | 26 | 29 |
| Subfamily Charaxinae | | | | | | | |
| *Charaxes varanes* (Cramer, 1777) | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| *Charaxes fulvescens* (Aurivillius, 1891) | 4 | 1 | 2 | 0 | 1 | 29 | 19 |
| *Charaxes candiope* (Godart, 1824) | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| *Charaxes protoclea* Feisthamel, 1850 | 3 | 2 | 0 | 1 | 4 | 20 | 14 |
| *Charaxes boueti* Feisthamel, 1850 | 0 | 0 | 3 | 1 | 5 | 0 | 0 |
| *Charaxes cynthia* Butler, 1866 | 1 | 1 | 6 | 5 | 8 | 0 | 0 |
| *Charaxes lucretius* Cramer, [1775] | 0 | 0 | 1 | 4 | 5 | 0 | 0 |
| *Charaxes castor* (Cramer, 1775) | 0 | 0 | 2 | 1 | 0 | 0 | 0 |
| *Charaxes brutus* (Cramer, 1779) | 0 | 1 | 11 | 20 | 14 | 0 | 0 |
| *Charaxes pollux* (Cramer, 1775) | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| *Charaxes tiridates* (Cramer, 1777) | 0 | 2 | 5 | 12 | 22 | 1 | 0 |
| *Charaxes bipunctatus* Rothschild, 1894 | 0 | 0 | 2 | 1 | 2 | 0 | 0 |
| *Charaxes numenes* (Hewitson, 1859) | 1 | 0 | 6 | 3 | 19 | 4 | 0 |
| *Charaxes zingha* (Stoll, 1780) | 6 | 1 | 5 | 3 | 9 | 6 | 3 |
| *Charaxes eupale* (Drury, 1782) | 0 | 1 | 0 | 6 | 1 | 0 | 0 |
| *Charaxes anticlea* (Drury, 1782) | 0 | 0 | 4 | 7 | 4 | 0 | 0 |
| *Charaxes etheocles* agg. (Cramer, 1777) | 0 | 0 | 0 | 4 | 7 | 0 | 0 |
| *Charaxes pleione* (Godart, 1824) | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| *Charaxes paphianus* Ward, 1871 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| *Charaxes zelica* Butler, 1869 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| *Charaxes eurinome* (Cramer, 1775) | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| *Palla violinitens* (Crowley, 1890) | 2 | 0 | 2 | 0 | 5 | 1 | 0 |
| *Palla decius* (Cramer, 1777) | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| *Palla ussheri* (Butler, 1870) | 4 | 1 | 0 | 4 | 6 | 6 | 2 |
| *Palla publius* Staudinger, 1892 | 0 | 0 | 0 | 2 | 1 | 0 | 1 |
| Subfamily Nymphalinae | | | | | | | |
| *Kallimoides rumia* (Doubleday, 1849) | 9 | 3 | 1 | 2 | 1 | 75 | 142 |
| *Antanartia delius* (Drury, 1782) | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Hypolimnas anthedon* (Doubleday, 1845) | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| *Hypolimnas salmacis* (Drury, 1773) | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| *Protogoniomorpha parhassus* (Drury, 1782) | 0 | 0 | 1 | 0 | 1 | 0 | 1 |

**Table 3** continued

| | PF | SF | NF | FL | CC | K1 | K2 |
|---|---|---|---|---|---|---|---|
| *Junonia stygia* (Aurivillius, 1894) | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Subfamily Biblidinae | | | | | | | |
| *Byblia anvatara* (Boisduval, 1833) | 0 | 0 | 1 | 4 | 0 | 0 | 0 |
| *Ariadne enotrea* (Cramer, 1779) | 0 | 0 | 0 | 0 | 5 | 0 | 0 |
| Subfamily Limenitinae | | | | | | | |
| *Cymothoe fumana* (Westwood, 1850) | 8 | 2 | 0 | 0 | 2 | 2 | 6 |
| *Cymothoe egesta* (Cramer, 1775) | 6 | 0 | 2 | 1 | 0 | 2 | 2 |
| *Cymothoe aubergeri* Plantrou, 1977 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| *Cymothoe druryi* van Velzen & Larsen, 2009 | 0 | 1 | 3 | 3 | 0 | 0 | 0 |
| *Cymothoe althea* (Cramer, 1776) | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| *Cymothoe jodutta* (Westwood, 1850) | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| *Cymothoe mabillei* Overlaet, 1944 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| *Cymothoe sangaris* (Godart, 1824) | 0 | 0 | 0 | 0 | 0 | 1 | 5 |
| *Catuna oberthueri* Karsch, 1894 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| *Catuna angustatum* (Felder & Felder, 1867) | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Euryphura chalcis* (Felder & Felder, 1860) | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| *Hamanumida daedalus* (Fabricius, 1775) | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| *Aterica galene* (Brown, 1776) | 11 | 7 | 1 | 8 | 1 | 6 | 12 |
| *Euriphene barombina* (Aurivillius, 1894) | 2 | 1 | 0 | 0 | 0 | 1 | 3 |
| *Euriphene simplex* (Staudinger, 1891) | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Euriphene aridatha* (Hewitson, 1866) | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| *Euriphene gambiae* Feisthamel, 1850 | 10 | 1 | 2 | 0 | 0 | 5 | 5 |
| *Euriphene ampedusa* (Hewitson, 1866) | 0 | 0 | 1 | 0 | 0 | 2 | 2 |
| *Euriphene atossa* (Hewitson, 1865) | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Euriphene doriclea* (Drury, 1782) | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Bebearia tentyris* (Hewitson, 1866) | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Bebearia absolon* (Fabricius, 1793) | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| *Bebearia zonara* (Butler, 1871) | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Bebearia mandinga* (Felder & Felder, 1860) | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| *Bebearia abesa* (Hewitson, 1869) | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Bebearia mardania* (Fabricius, 1793) | 15 | 22 | 23 | 17 | 3 | 3 | 5 |
| *Bebearia cocalia* (Fabricius, 1793) | 6 | 6 | 4 | 3 | 1 | 2 | 1 |
| *Bebearia paludicola* Holmes, 2001 | 5 | 3 | 1 | 5 | 0 | 0 | 0 |
| *Bebearia sophus* (Fabricius, 1793) | 14 | 4 | 3 | 0 | 0 | 3 | 2 |

**Table 3** continued

| | PF | SF | NF | FL | CC | K1 | K2 |
|---|---|---|---|---|---|---|---|
| *Bebearia phantasina* (Staudinger, 1891) | 16 | 2 | 2 | 1 | 0 | 23 | 21 |
| *Bebearia cutteri* (Hewitson, 1865) | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Euphaedra medon* (Linnaeus, 1763) | 14 | 17 | 14 | 3 | 0 | 10 | 6 |
| *Euphaedra gausape* (Butler, 1866) | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Euphaedra xypete* (Hewitson, 1865) | 1 | 2 | 0 | 0 | 0 | 3 | 2 |
| *Euphaedra hebes* Hecq, 1980 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Euphaedra diffusa* Gaede, 1916 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Euphaedra crockeri* (Butler, 1869) | 2 | 0 | 0 | 0 | 0 | 8 | 6 |
| *Euphaedra cyparissa* (Cramer, 1775) | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Euphaedra themis* (Hübner, 1807) | 0 | 1 | 0 | 1 | 0 | 1 | 1 |
| *Euphaedra minuta* Hecq, 1982 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Euphaedra janetta* (Butler, 1871) | 3 | 0 | 0 | 1 | 0 | 3 | 2 |
| *Euphaedra ceres* (Fabricius, 1775) | 8 | 3 | 3 | 3 | 0 | 12 | 5 |
| *Euphaedra phaethusa* (Butler, 1866) | 6 | 2 | 1 | 0 | 1 | 9 | 8 |
| *Euphaedra inanum* (Butler, 1873) | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Euphaedra francina* (Godart, 1824) | 0 | 0 | 0 | 0 | 0 | 2 | 1 |
| *Euphaedra zampa* (Westwood, 1850) | 2 | 0 | 0 | 0 | 0 | 15 | 6 |
| *Euphaedra perseis* (Drury, 1773) | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| *Euphaedra harpalyce* (Cramer, 1777) | 3 | 2 | 0 | 1 | 0 | 3 | 2 |
| *Euphaedra eupalus* (Fabricius, 1781) | 2 | 0 | 2 | 0 | 0 | 0 | 0 |
| Subfamily Heliconiinae | | | | | | | |
| *Lachnoptera anticlia* (Hübner, 1819) | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| *Family Hesperiidae* | | | | | | | |
| Subfamily Pyrginae | | | | | | | |
| *Celaenorrhinus galenus* (Fabricius, 1793) | 0 | 0 | 1 | 0 | 1 | 0 | 0 |

*PF* Primary Forest, *SF* Secondary Forest, *NF* Young Planted Forest, *FL* Farmland, *CC* Clear-cut, *K1* Control 1, *K2* Control 2. Systematics and nomenclature follow Larsen (2005) complemented by the latest taxonomical updates (Libert 2006, Aduse-Poku et al. 2009, van Velzen and Larsen 2009, vande Weghe 2009)

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