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„Small-scale topographic differences affect moth communities across three forest types in the Golfo Dulce region, SW Costa Rica“

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Zusammenfassung

Tropische Regenwälder in Regionen mit ausgeprägtem Relief sind kleinräumig stark durch topographische Gegebenheiten charakterisiert, wobei diese Unterschiede großen Einfluss auf den Artenreichtum und die Artenzusammensetzung der Lebensgemeinschaften dieser Wälder haben können. Der Einfluss der Topographie auf die Diversität von Nachtfaltern tropischer Regenwälder wurde durch einige Studien auf regionaler Ebene (z.B. entlang von Höhengradienten) gezeigt, allerdings fehlen Studien über mögliche Differenzierungen auf sehr lokaler Ebene. Am Beispiel von drei naturnahen Waldtypen tiefer Lagen in unterschiedlicher topographischer Position (Schluchtwälder, Hangwälder und Kammwälder) in einem Schutzgebiet in der Golfo-Dulce-Region im Südwesten von Costa Rica habe ich anhand von Lichtfallenfängen analysiert, wie stark die Nachtfalter-Artengemeinschaften dieser Lebensräume voneinander differenziert sind. Es stellte sich heraus, dass selbst sehr kleinräumige topographische Unterschiede auf einer Skala von wenigen hundert Metern die Nachtfaltergemeinschaften prägen. Untersucht wurden drei unterschiedliche phylogenetische Linien – die Unterfamilie Erebiidae-Arctiinae (Bärenspinner), die Überfamilie Bombycoidea (Spinnerartige Nachtfalter) und die Familie Geometridae (Spanner). Insgesamt konnten 6720 Individuen aus 501 Arten von Nachtfaltern in den drei Fokustaxa beobachtet werden. Die drei Waldtypen unterschieden sich sehr stark hinsichtlich Artenzahl, Individuenzahl, Diversität, Biomasse und Artenzusammensetzung von Nachtfaltern, wobei es bemerkenswert ist, dass alle drei taxonomischen Gruppen völlig identische Muster zeigten. Artenzahl, Individuenzahl, Diversität und Biomasse waren hochsignifikant am niedrigsten in den Schluchtwäldern und am höchsten in den Kammwäldern. Die Hangwälder lagen hinsichtlich Artenzahl, Individuenzahl, Diversität und Biomasse zwischen Schlucht- und Kammwäldern. Des Weiteren bildeten alle drei Taxa gut abgrenzbare Artengemeinschaften in dem jeweiligen Waldtyp aus. Eine Indikatorartenanalyse ergab, dass die Mehrzahl der dabei erkannten charakteristischen Arten mit dem Kammwald bzw. mit Kamm- und Hangwald assoziiert waren, 2 Arten nur mit dem Hangwald und keine Art mit dem Schluchtwald. In Bezug auf diverse biometrische Eigenschaften der Nachtfalterarten konnten nur sehr wenige Unterschiede zwischen den Artengemeinschaften der drei Waldtypen festgestellt werden. Ausschließlich die Bombycoidea zeigten ein Ansteigen des Verhältnisses von Flügellänge zu Flügelbreite von den Schluchtwäldern zu den Kammwäldern. Bei den Geometriden ließ sich ein Anstieg der Biomasse, der Thoraxbreite bzw. ein Absinken des Body shape index (definiert als Körperlänge/Thoraxbreite) von den Schluchtwäldern zu den Kammwäldern beobachten. Diese Ergebnisse zeigen, dass sich auch bei relativ mobilen Tieren wie Nachtfaltern in dem topographisch heterogenen Untersuchungsgebiet kleinräumig sehr charakteristische Artengemeinschaften aus dem

regionalen Artenpool herausbilden, was auf gravierende Unterschiede in den für diese Organismen relevanten Umweltfaktoren in diesen Ökosystemen hindeutet.

Abstract

Tropical rainforests on rugged terrain are characterized by strong topographic variation. These topographic differences have repeatedly been shown to greatly affect species richness and species composition of organismal communities. While for nocturnal moths a couple of studies have addressed effects of topographic differences on species diversity and composition on regional scales (e.g. along extensive elevation gradients), there are no such studies about possible topographic effect at very local scales. The present study addressed such effects, at distances of less than a few hundred meters, on moth communities in a lowland rainforest landscape in the Golfo Dulce region (SW Costa Rica). Three phylogenetic lineages of moths – Erebidae-Arctiinae (tiger and lichen moths), Bombycoidea, and Geometridae (inchworm moths) – were examined by means of automatic light traps in three different forest types: creek forest, slope forest, and ridge forest. Altogether, 6720 individuals of 501 moth species were observed. The three forest types differed significantly regarding to species richness, total abundance, and biomass and species composition. Moth richness and abundance were lowest in creek forests and highest in ridge forest, with slope forest taking an intermediate position. Remarkably, all three taxonomic units showed identical biodiversity patterns. Moreover, each forest type was characterized by a distinct moth assemblage. An indicator species analyses revealed that most of the identified indicator species were associated with either the ridge forest alone, or with ridge and slope forest. Just two species were significantly associated with slope forest only, and no species with creek forest. Only a few biometric traits revealed differences between the moth assemblages of the three forest types. Among Bombycoidea, the aspect ratio of the fore wings increased from the creek to the ridge forest. For Geometridae, thorax width and biomass increased, while a body shape index (defined as body length/thorax width) decreased. These results corroborate that even for mobile organisms such as moths the three forest types provide very different environments. Local moth assemblages are highly differentially filtered from the same regional species pool. Hence, environmental factors relevant for moths leave a characteristic signature in the insect assemblages at this small spatial scale.

Key words: Moth communities, topography, tropical lowland rainforest, species richness, species diversity, Arctiinae, Bombycoidea, Geometridae, biomass, morphometric traits

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1. Introduction

Tropical rainforests harbour a large part of the animal and plant species which occur on Earth and therefore are known as hot spots of biodiversity (Gaston 2000, Wilson 1988, Myers *et al.* 2000, Brooks *et al.* 2006). This extraordinary species richness is the result of a historically larger area, a high geological age, a high diversification rate and a higher maintenance of species diversity because of the special climatic and geographic conditions at low latitudes (Mittelbach *et al.* 2007). Tropical rainforests comprise multiple vegetation layers which provide a wide range of microhabitats and ecological niches, facilitating the coexistence of a vast number of plant and animal species. Especially species diversity of herbivorous animals tends to be very closely linked to plant diversity across various spatial scales, although correlations to plant species richness are often not very tight (Fiedler 1998, Novotny *et al.* 2002 & 2006, Forister 2015). Only few herbivores feed on a single plant species when alternative congeneric hosts are available, but a high proportion feeds on one single plant genus or family (Novotny and Basset 2005), because these herbivores are specialised on secondary metabolites of their host plants (Coley & Barone 1996, Dyer *et al.* 2007). Accordingly, communities of plant-feeding insects massively change along with the plant communities they inhabit.

Regional and small scale topographic heterogeneity indirectly affects biodiversity to a great extent (Coblentz & Ritters 2004, Homeier *et al.* 2010, Werner *et al.* 2012, Werner & Homeier 2015). The local topography offers very different microclimatic and edaphic conditions (exposure to wind, precipitation, soil properties and nutrient availability, etc.) and ecosystem functions (e.g. atmospheric deposition, canopy exchange), at close distances (Hofhansl 2008, Hofhansl *et al.* 2011, Pamperl 2001). This heterogeneity creates a mosaic of forest types with a characteristic vegetation structure and species composition, especially across rugged terrain (Chen *et al.* 1997, Costa *et al.* 2005, Fu *et al.* 2004, Valencia *et al.* 2004, Weissenhofer *et al.* 2008). Many tropical rainforests are not flat and the arrangement of hilly terrain from ridges through slopes to creek sites represents important environmental gradients for plant species, further enhancing biodiversity of rainforests in hilly and mountainous regions (Gibbons & Newbery 2003, Valencia *et al.* 2004, Weissenhofer *et al.* 2008). Several studies from different regions have indicated the strong influence of such small scale spatial differences on the assemblages of sessile plants (e.g. Clark *et al.* 1999, Gentry 1988, Costa *et al.* 2005, Vormisto *et al.* 2004, Miyamoto 2003) as well as mobile animals (e.g. Binz 2010, Binz *et al.* 2015, Gering *et al.* 2003).

Ectothermic insects very strongly depend on micro-climatic conditions like temperature, humidity, exposure to wind and solar radiation. Yet, many moth species can actively regulate their body

temperature. They warm up their bodies by muscular contractions (Heinrich 2013) and thereby reduce their dependence on the microclimatic conditions of their environment. Some moth species typically fly at very high thoracic temperature, while others may fly at very low body temperatures too, even close to zero (Heinrich 1974, Heinrich & Mommson 1985, Goller & Esch 1990). There are great differences in thermoregulation between taxonomic groups (e.g. Heath & Adams 1967, Casey & Joos 1983, Kingsolver 1985). The less mobile developmental stages, such as caterpillars, are even more dependent on suitable microclimatic conditions than the adults. Caterpillars are entirely ectothermic. Many studies have shown that their development depends on the quality and quantity of the food resource as well as on the local micro-climatic conditions. Hence, for many species a heterogeneous vegetation structure that provides variable conditions with regard to temperature, sun exposure or shelter is beneficial for completing development (e.g. Weiss *et al.* 1988, Hellmann 2002, Turlure *et al.* 2011). As a consequence, habitat suitability may differ for herbivorous insects at very small spatial scales.

Current large-scale molecular phylogenetic studies support classification of the Macrolepidoptera into three major phylogenetic lineages: The Bombycoidea (e.g. Bombycidae, Lasiocampidae, Mimallonidae, Saturniidae, Sphingidae), Geometroidea (e.g. Geometridae, Uraniidae), and Noctuoidea (e.g. Erebiidae, Noctuidae, Notodontidae: Regier *et al.* 2010, Regier *et al.* 2013). Since these clades differ from another in many ways concerning morphology, physiology, host-plant relationships, feeding habits etc., one might expect that biodiversity patterns are not necessarily concordant. For example, in an elevation gradient in the Ecuadorian Andes strikingly different patterns of local species diversity were observed, whereas species turnover was largely parallel between three studied moth groups (Erebiidae-Arctiinae; Pyraloidea; and Geometridae: Fiedler *et al.* 2008).

During the past two decades, moths have served as focal taxa in a range of biodiversity studies in tropical forest ecosystems throughout the world (e.g. Intachtat & Holloway 2000, Beck *et al.* 2002, Axmacher *et al.* 2004, Hill & Fiedler 2005, Chen *et al.* 2009, Ashton *et al.* 2015). The advantages of moths for biodiversity studies are that they are very abundant and species rich and can be easily recorded at light traps. Furthermore, they occupy a lot of different ecological niches and are responsible for a wide range of ecosystem functions as pollinators, as herbivores, and as prey for a variety of predators and parasitoids. The Arctiinae, a subfamily of the Erebiidae, the Bombycoidea and the Geometridae are well defined monophyletic groups. They are particularly suitable to examine small scale spatial biodiversity patterns in a tropical rainforest, because they are species rich, a substantial proportion can be identified to species level and they cover a lot of different life history traits. Especially tropical geometrid species have been shown to be very strongly dependent

on forest habitats and react very sensitively to land use changes, while Arctiinae may often be more tolerant to land use changes (Fiedler *et al.* 2007, Hilt & Fiedler 2008). Accordingly, moth communities may serve as indicators for the health condition of a forest.

While a couple of studies have addressed how elevation (Brehm *et al.* 2003, Brehm & Fiedler 2003, Axmacher *et al.* 2004, Hilt & Fiedler 2005, Fiedler *et al.* 2008, Brehm *et al.* 2013 & 2016, Beck *et al.* in press) or disturbance gradients (Ricketts *et al.* 2001, Beck *et al.* 2002, Hilt & Fiedler 2005, Alonso Rodríguez 2014) may drive tropical moth diversity, almost nothing appears to be known about very small scale patterns in moth assemblages within areas broadly classified as near-natural tropical lowland forest, but characterized by more subtle topographic gradients. The hilly topography of the Piedras Blancas National Park and its vicinity is responsible for a pronounced heterogeneity with different forest types growing under specific environmental conditions. The aim of the present study was to analyse the moth communities between creek, slope and ridge forests in the Southwest Costa Rican lowlands. Specifically, the following hypotheses were tested.

- (1) Species richness, abundance and diversity of the three focal moth taxa (Arctiinae, Geometridae, Bombycoidea) differ between the three different forest types (creek, slope and ridge forest), but these differences are not necessarily concordant across moth taxa
- (2) Species composition of the three examined moth taxa (Arctiinae, Geometridae, Bombycoidea) differs between creek, slope and ridge forest sites, such that characteristic assemblages are filtered from the regional species pool for each forest type
- (3) Indicator species can be found in all three moth taxa, with some being representative for each forest type
- (4) Within each taxonomic unit, moth assemblages differ in biometric traits between the three forest types
- (5) In near-natural lowland rainforest, moth biomass is equally distributed between the three forest types

2. Material and Methods

2.1. Study area and study sites

The study was conducted in the vicinity of the Tropical Research Station La Gamba (N 8°42.61', W 83°12.97'), in the province Puntarenas in the Pacific lowlands of the Golfo Dulce Region, southwestern Costa Rica (Fig. 1). The station is located at an elevation of 78 m a.s.l., adjacent to the Piedras Blancas National Park, which represents one of the last remaining larger tracts of Pacific

lowland rainforest of Central America. Costa Rica is one of the most biodiverse countries in the world (Kapeller *et al.* 2003), and the Golfo Dulce region is particularly rich in biodiversity, for example about half of Costa Rica's butterfly species (Wiemers & Fiedler 2008), over three hundred bird species (Tebb 2008) and at least 2369 vascular plant species (Weber *et al.* 2001). The average annual temperature in La Gamba is 28.1 C° and the average annual precipitation is about 6000 mm (Weber *et al.* 2001, Hofhansl *et al.* 2011). The driest months are from January to March, with a peak of precipitation from August to November (Weissenhofer & Huber 2008). Because of the climatic conditions, the natural vegetation is characterized as a wet tropical lowland rainforest (Holdridge *et al.* 1967) extending from sea level up to 580 m altitude.

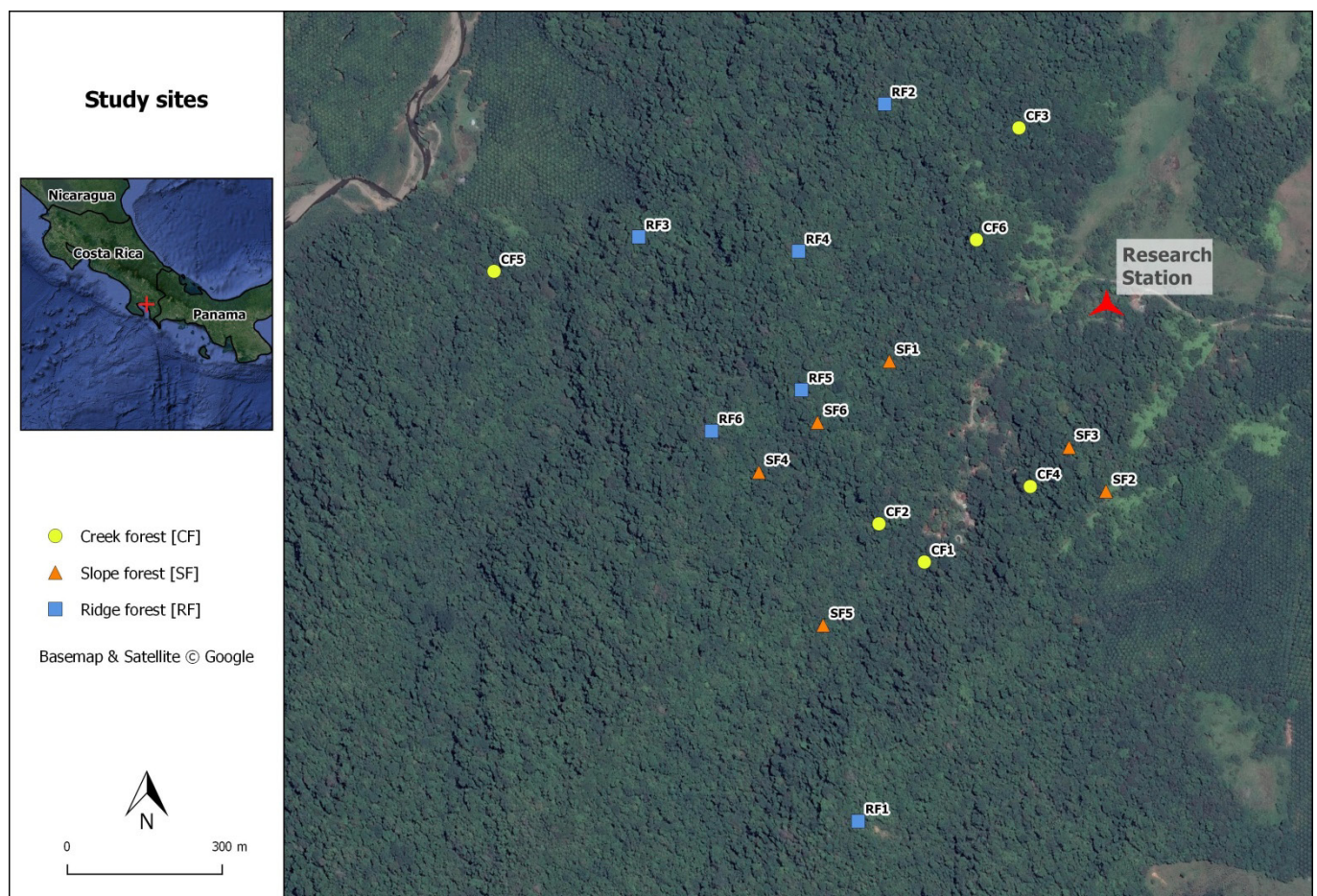


Figure 1: Map of the study sites in the vicinity of the Tropical Research Station La Gamba, Costa Rica (= Research Station)

The station is embedded in a mosaic of primary forest, secondary forest, and different stages of forest regrowth, agricultural lands (including oil palm plantations) and cattle pastures (Weissenhofer *et al.* 2008, Höbinger *et al.* 2012). The study sites were all located in old-growth forest, dispersed around the research station. The orographic heterogeneity of near-natural forest areas suggests a classification into three forest types: ridge forest (RF), slope forest (SF), creek forest (CF). All selected

sites were connected by surrounding forest, so there were no dispersal barriers for forest animals. A total number of 18 sites were surveyed, six of each forest type. Although, the study area was very small-scaled, it was tried to keep largest possible distance between the sites and alternate between the forest types to avoid spatial autocorrelation. The creek forest sites were located at altitudes between 80 and 123 m a.s.l in the low-lying areas alongside small creeks. The ridge forest sites were located at the crests around the research station between an altitude of 150 and 290 a.s.l. The altitude of the slope forest sites was intermediate between the other two forest types (136 to 175 m a.s.l.). Forest types were identified according to the vegetation map by Weissenhofer *et al.* (2008). These differences between the vegetation occur due to the special microclimatic conditions caused by the topographic situation. The ridge forests grow at the top of the hills, where sun exposure is highest and most of the precipitation runs off. Hence the conditions at the crests are much dryer and create a more open vegetation structure. At the quite steep slopes, water supply seems to be better and vegetation is denser and more closed. But, especially the herb layer is very poor, maybe as a consequence of the floods caused by the heavy rainfalls and the unstable ground layer. The creek forest grows at the foot of the hills. Most of the precipitation runs off the slopes down to creeks and causes inundations, resulting in a very high humidity. Therefore, the vegetation is very dense and closed at the creek forest sites (compare Fig. 2).



Figure 2: Pictures of a ridge forest, slope forest and a creek forest (from top to bottom)

2.2. Data collection

2.2.1. Moth sampling and identification

The moth communities of the three different forest types were surveyed over three months from July to October 2014 during the rainy season, using automatic funnel light traps. Each site was sampled seven times during this period and three sites were sampled on each sampling night simultaneously, one site of each forest type per night. The maximum linear distance between two sites was 1.4 km (between RF1 and CF5) and the minimum linear distance between two sites was 100 metres (between CF1 and CF2). The sequence of sampling the sites was set to minimize the footways, because all sites had to be reached on foot. To eliminate the influence of the lunar phase, sampling was restricted to four days prior to and after the full moon nights, which reduced the negative effect of moonlight on moth catches (e.g. McGeachie 1989, Jonason *et al.* 2014).

Moths were sampled with automatic funnel traps (Fig. 3), using two 8W UVA emitting weak fluorescent light tubes. The light traps had a height of one meter, the bucket and funnel had a diameter of 25cm and the funnel opening had a diameter of 6cm. A detailed description of the used light traps is provided in Brehm & Axmacher (2006). The use of weak light sources ensures that the radius of moth attraction is small and excludes cross-attraction of moths from distant habitats to the light trap. Therefore the method achieves a very high spatial and ecological resolution in a heterogeneous landscape (Truxa & Fiedler 2012). Light traps were placed in the understorey at a height of 1–1.5m above ground and were operated during the entire night from dusk to dawn using a 12V lithium ion battery as power supply and a twilight switch. Upon attraction, moths collide with transparent vanes of acrylic glass round the light tube, glide down and drop through a funnel in a black bucket, where chloroform as a killing agent was applied. Traps were emptied before sunrise, to prevent ants and other insects from clearing out the bucket. In general, automatic light traps capture only a subset of moth diversity: The method is biased towards larger species. Individuals which land on the trap vanes may escape without falling into the funnel. Trapping may cause some damage to the collected specimens, which may aggravate taxonomic classification of samples (Axmacher & Fiedler 2004, Brehm & Axmacher 2006). Especially small-sized moths are more likely to escape from the trap or more sensitive to get damaged in the trap by other insects. Nevertheless, automated light-trapping is a very suitable method for long-term and all-night sampling of moths.

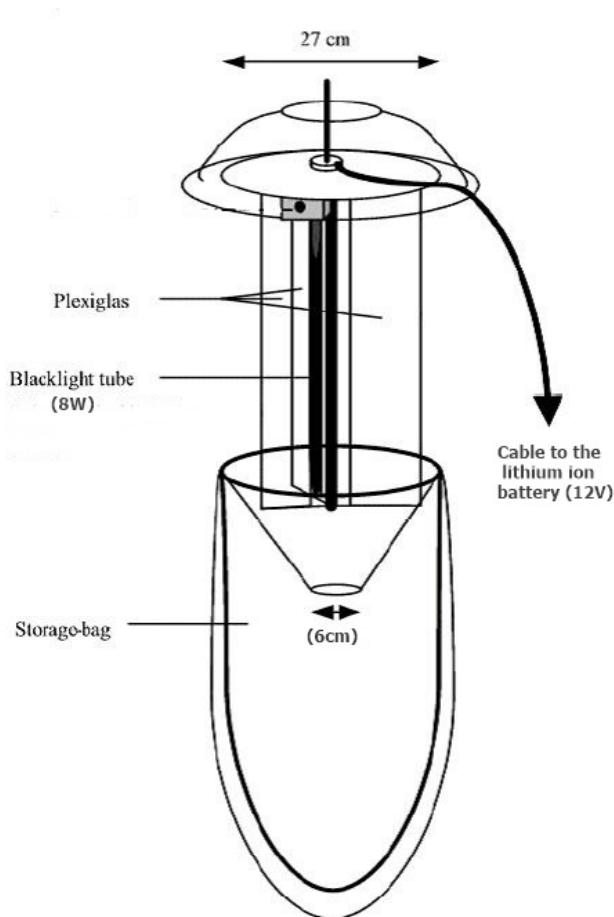


Figure 3: Left: Illustration of an automatic funnel trap (modified from Brehm & Axmacher 2006); Right: Image of the automatic funnel trap as used in this study.

Subsequently, sampled moths were bagged by taxonomic groups and stored in a refrigerator. Only species of the monophyletic group of Macrolepidoptera were collected (Regier *et al.* 2010 & 2013). In this study, only the representatives of the three focal groups Erebiidae (Arctiinae), Bombycoidea (Bombycidae, Lasiocampidae, Mimallonidae, Saturniidae, Sphingidae) and Geometridae were processed (Fig. 2), because in-depth analyses of their faunal diversity are available from a few other places in the Neotropical region (e.g. Piñas Rubio *et al.* 2000, Chacón & Montero 2007). Sampled specimens were later sorted to morphospecies level and taxonomically identified as far as possible. Specimens which were closely related to a described species, but differed to a considerable extent, were classified with the abbreviation cf. (short for the Latin: confer, meaning “compare”). Since no comprehensive guide to the moth fauna of Costa Rica does exist, I allocated genus and species names by comparison with labelled photographs that had been taken in the course of an earlier moth survey around La Gamba (Alonso Rodriguez 2014), whose author had compared her sampled moths with the Lepidoptera collection of the National Biodiversity Institute (INBio) in San José (Costa Rica). Various online plates provided by John Pickering

(http://www.discoverlife.org/mp/20q?guide=Moth_Costa_Rica), Gunnar Brehm (<http://www.personal.uni-jena.de/~b6brgu2/>), Daniel H. Janzen (<http://janzen-2007.bio.upenn.edu/caterpillars/checklists/>) and Boldsystems (<http://www.boldsystems.org/>) facilitated identification. Subsequently, identifications were reviewed by consulting expert taxonomists (Geometridae and Arctiinae: Gunnar Brehm; Arctiinae: Michel S. Laguerre and Benoit Vincent; Saturniidae: Wolfgang A. Nässig). Voucher specimens are currently kept at the Division for Tropical Ecology and Animal Biodiversity, University of Vienna, and the Zoological Institute of the Jena University.



Figure 4: Pictures of selected moths from La Gamba (Costa Rica), a) *Automeris belti* (Bombycoidea, Saturniidae), b) *Manduca occulta* (Bombycoidea, Sphingidae), c) *Apatelodes pandariodes* (Bombycoidea, Bombycidae), d) *Elysia* cf. *conspersus* (Erebidae, Arctiinae), e) *Aclytia albistriga* (Erebidae, Arctiinae), f) *Nemoria scroptaria* (Geometridae, Geometrinae)

2.2.2. Habitat descriptors of the study sites

Three parameters were measured to characterise the vegetation structure of the sampling sites in the three forest types.

Canopy density

To measure the canopy cover, at each site six photographs were shot (camara model: Olympus SP590UZ, image resolution: 2976 x 3968 pixels, focal distance: 5mm, exposure time: 1/1000 sec.) in

vertical direction along a 100m linear transect with the light trap in the centre. The photographs were converted to black and white images with the ImageJ 1.48v software (<http://imagej.nih.gov/ij>) and the percentage of black pixels was computed as a proxy for canopy cover. Data of the six images were averaged to obtain a mean percentage of canopy cover at each study site.

Herb layer cover

Herb layer cover was measured at each site by taking six photographs of a precisely gauged square on the ground along a 100m linear transect with the light trap in the centre. The contrast between the brown soil or litter and the green vegetation was great enough to convert the photographs (similar to the computation of canopy density) to black and white images with the ImageJ 1.48v software to compute herb layer cover. Again, data of the six images were averaged for each study site.

Understorey density

Understorey vegetation density was measured at each site by measuring the distance to the nearest understorey plant with a laser rangefinder. 50 measurements were done in a circle around a fixed point at three spots near the light traps, resulting in 150 measurements per site. Measurements were averaged to get the mean understorey density of each site. A lower mean distance indicates a higher understorey density.

2.2.3. Biometric measurements of the moths

To compile biometric data of the moths, one to three spread representative specimens of each species were selected and photographs of upper- and underside were shot (camera model: Nikon D700, image resolution: 4256 x 2832 pixels, focal distance: 105mm, exposure time: 1/5 sec.).

Biometrical data were measured with the ImageJ 1.48v software. The following biometric data were determined: fore- (hind-) wing length and width; thorax width and length; and body length (distance from tip of the head to the tip of abdomen). From these measurements wing area, thorax area and volume, abdomen volume (assuming a rotational paraboloid), body volume (abdomen volume + thorax volume), a body shape index (body length/thorax width), an aspect ratio ($[4 * (\text{forewing length}^2)] / \text{forewing area}$), a wing ratio (forewing length/forewing width ratio) were calculated. For each focal taxonomic unit (Arctiinae, Geometridae and Bombycoidea) the community weighted means (CVM) of the biometrical measurements at each study site were calculated.

Species with a slender body structure reach a higher body shape index. A low aspect ratio, as well as a low wing ratio, indicates a larger induced drag and correspondingly high power requirements of

flight (Dudley 1990, Dudley 2002, Berwaerts *et al.* 2008, Jones *et al.* 2013). Slender moths with a lower induced drag have a better maneuverability.

2.2.4. Biomass calculation

To estimate the average moth biomass of each species, length – weight and length * width – weight regressions were generated, using the power function $y = a(X)^b$, which is considered being the best model for biomass calculation (Rogers *et al.* 1976, Collins 1992, Sample 1997). The values for a and b were abstracted from Wardhaugh (2013). For each studied taxonomic group (Arctiinae, Geometridae and Bombycoidea) the community weighted means were calculated per site.

2.3. Data analysis

One-way analyses of variance (ANOVAs) was used to test whether abundance, species richness, species diversity (expressed as exponential Shannon diversity and Fisher's alpha) biometric traits, estimated biomass of the observed moths, as well as habitat descriptors (canopy closure, understorey density, herb layer), per site differed between the three forest types. General linear models (GLMs) were used to test for effects of forest type and the habitat descriptors (canopy closure, understorey density, herb layer) on species abundance, richness and diversity of the observed moths. These calculations were performed using the package of Statistica 10.0 (StatSoft, Inc. 2011). All values given in percentages were logit-transformed (Warton & Hui 2010) and habitat descriptors were additionally normalised before analysis. To evaluate simultaneously the significance of the multiple biometric traits between the three forest types, they were corrected by false discovery rates (FDR) to avoid inappropriately increasing number of null hypotheses that are wrongly rejected without a greater loss of power (Benjamini & Hochberg 1995, Pike 2011). The moth species composition was tested for effect of the forest type through a PERMANOVA (999 permutations) using the package PERMANOVA+ for Primer7 (Anderson *et al.* 2008, Clark & Gorley 2015) and also habitat descriptors were took in consideration. Prior the abundance data's were square-root transformed to reduce the weight of a few highly abundant species and a similarity matrix based on Bray-Curtis similarity was generated. Similarities between sites were visualized in a non-metric multidimensional scaling (NMDS) plot (Clarke 1993). The R package 'Indicspecies' (De Cáceres &

Legendre 2009, De Cáceres *et al.* 2010) was used, which statistically determines the association of a species to one or several groups, based on the indicator value (IndVal) (Dufrêne and Legendre 1997).

3. Results

3.1. Abundance, species richness and diversity

A total of 6720 moths belonging to 501 species of the three focal groups Arctiinae, Bombycoidea and Geometridae were recorded during a total of 126 trap nights with automatic light traps. Arctiinae were represented with 3480 individuals of 172 species, Bombycoidea with 719 individuals of 80 species, and Geometridae with 2521 individuals of 249 species. The three different forest types differed prominently regarding the total number of observed moth individuals and species. Approximately eight times more individuals and three times more species were recorded at the RF-sites than at the CF-sites (Table 1). An intermediate number of total moth individuals and species were recorded at the SF-site. In detail, 484 individuals of 133 species were recorded at Creek forest sites, 2438 of 343 species at Slope forest sites and 3798 individuals of 402 species at Ridge forest sites. The five most abundant Arctiinae species (in percentage of all recorded Arctiinae individuals) were *Melese sixola* (18.2%), *Aclytia punctata* (13.1%), *Virbia* sp1. (5.2%), *Eucereon* sp. (4.8%), *Heliura* cf. *thysbodes* (4.4%). The most abundant Geometridae species (in percentage of all recorded Geometridae individuals) were *Physocleora pauper* (10.4%), *Glena subannulata* (4.1%), *Lobocleta* sp. (3.72%), *Pyrinia* sp. (3.7%), *Epimecis* sp. (3.5%). The most abundant Bombycoidea species (in percentage of all recorded Bombycoidea individuals) were *Euglyphis* sp. (11.13%), *Euglyphis rundula* (7.09%), *Euglyphis* cf. *definita* (6.82%), *Anticla antica* (6.68%), and *Colla coelestis* (5.98%). The five overall most abundant species (in percentage of the total number of recorded moths) were *Melese sixola* (9.57%), *Aclytia punctata* (6.79%), *Physocleora pauper* (3.91%), *Virbia* sp1. (2.68%), and *Eucereon* sp. (2.47%). All of these mentioned most abundant species were found in all three different forest types, except *Euglyphis rundula* (Lasiocampidae) which was absent in the CF-sites. For a full species list, see Appendix.

At a lower taxonomic level, the Arctiini tribe dominated at all three different forest sites within the Arctiinae subfamily. More than 76% of the observed Arctiinae individuals belonged to the Arctiini (CF: 76%; SF: 87%; RF: 87%). Lichen moths (tribe Lithosiini) were much less abundant at all sites (Table Appendix 3), but the forest type did not significantly affect the relative proportions of these

two tribes (one-way ANOVA, relative proportion (logit-transformed) of the Arctiinae: $F_{2,15} = 2.97$, $p = 0.081$; Fig. 5).

The most abundant families within the Bombycoidea superfamily were the Bombycidae, Lasiocampidae and Saturniidae, which showed a very even pattern regarding to their total abundance across forest types, while Mimallonidae and Sphingidae were much less numerous (Fig. 6). With 35 species, Saturniidae were represented with the most observed species and most species per site (CF: 50%; SF: 42 %; RF: 43%). There was no significant effect of forest type on the relative proportion (logit-transformed) of one of these Bombycoidea families (one-way ANOVAs, $p > 0.05$).

The Geometridae were represented with six subfamilies (Desmobathrinae, Ennominae, Geometrinae, Larentiinae, Oenochrominae and Sterrhinae). Ennominae was the by far most abundant subfamily, representing between 48-54% (RF-SF) of geometrid species and between 58.5-71% (SF-CF) of geometrid individuals (Fig. 7). The relative proportion (logit-transformed) of Ennominae individuals was significantly affected by the forest type (one-way ANOVA: $F_{3,14} = 2.97$, $p < 0.001$). Ennominae were relatively more prevalent among geometrid moths at CF rather than at SF and RF sites. Much less abundant were the Geometrinae (CF: 9%; SF: 9 %; RF: 11%) and Larentiinae (CF: 7%; SF: 7 %; RF: 11%) subfamilies. Desmobathrinae and Oenochrominae were represented only by a few species and individuals.

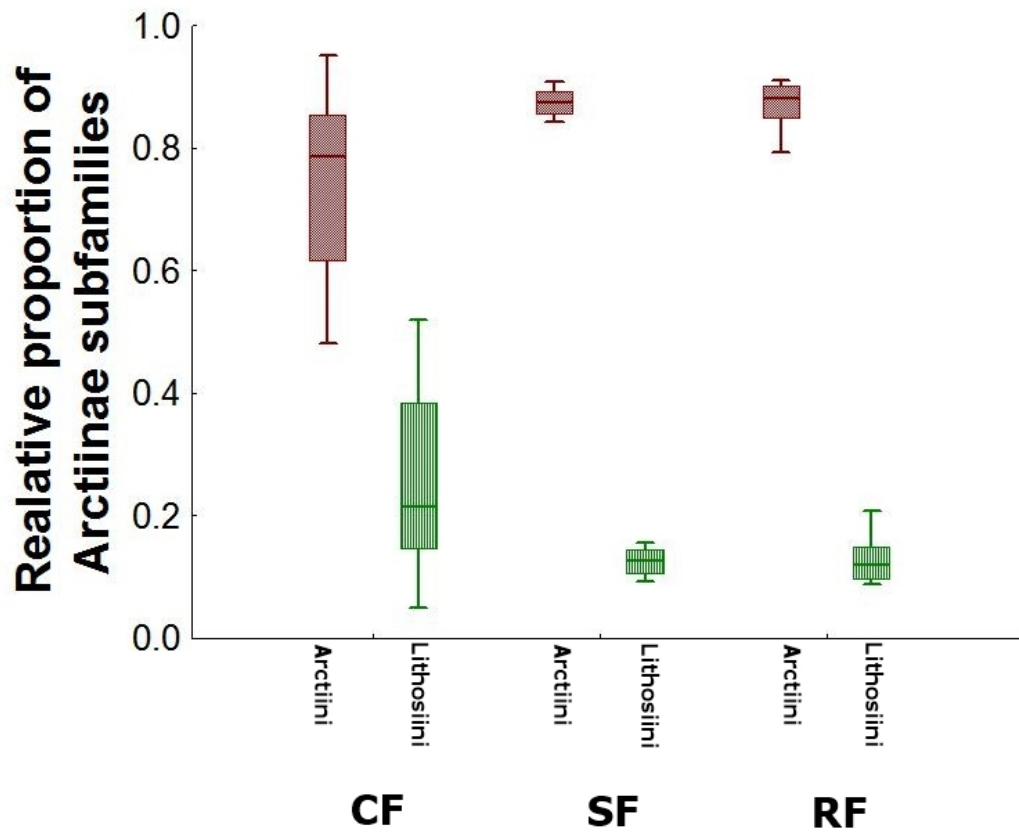


Figure 5: Relative proportions (individuals) of the Arctiinae tribes Arctiini and Lithosiini in each forest type. Given are the inter-quartile range (box), median (horizontal bar) and range of values (whiskers).

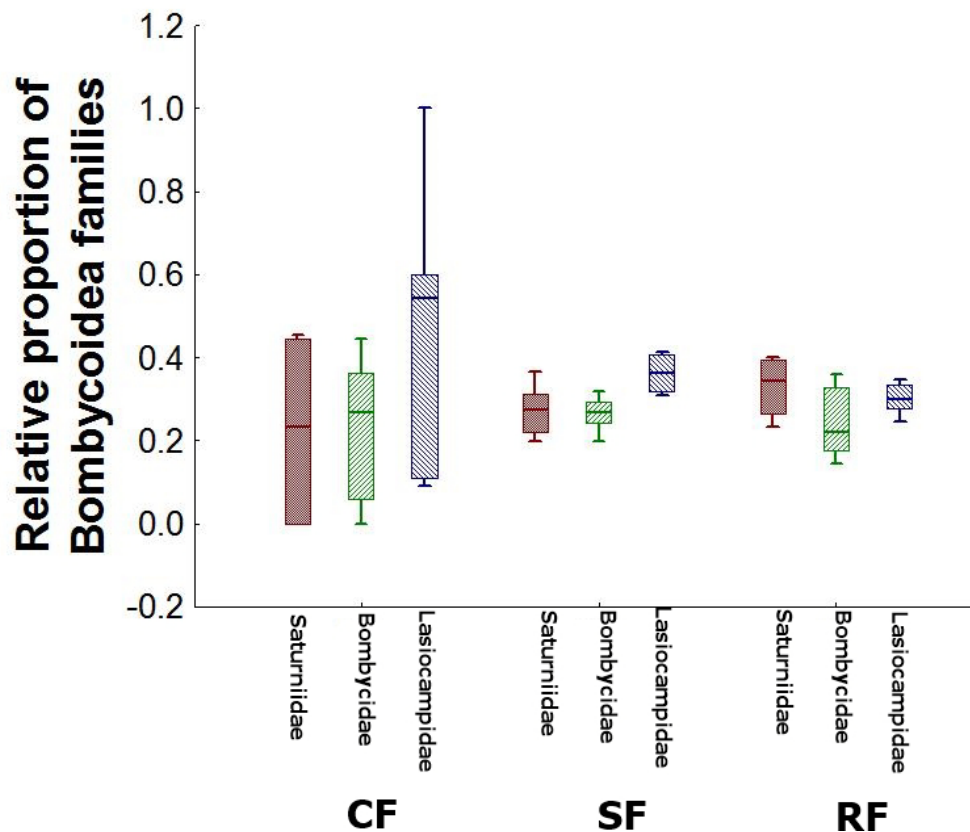


Figure 6: Relative proportions (individuals) of the Bombycoidea families Bombycidae, Lasiocampidae, and Saturniidae for each forest type; Mimallonidae and Sphingidae excluded because of very low sample sizes. See Fig. 3 for further explanation.

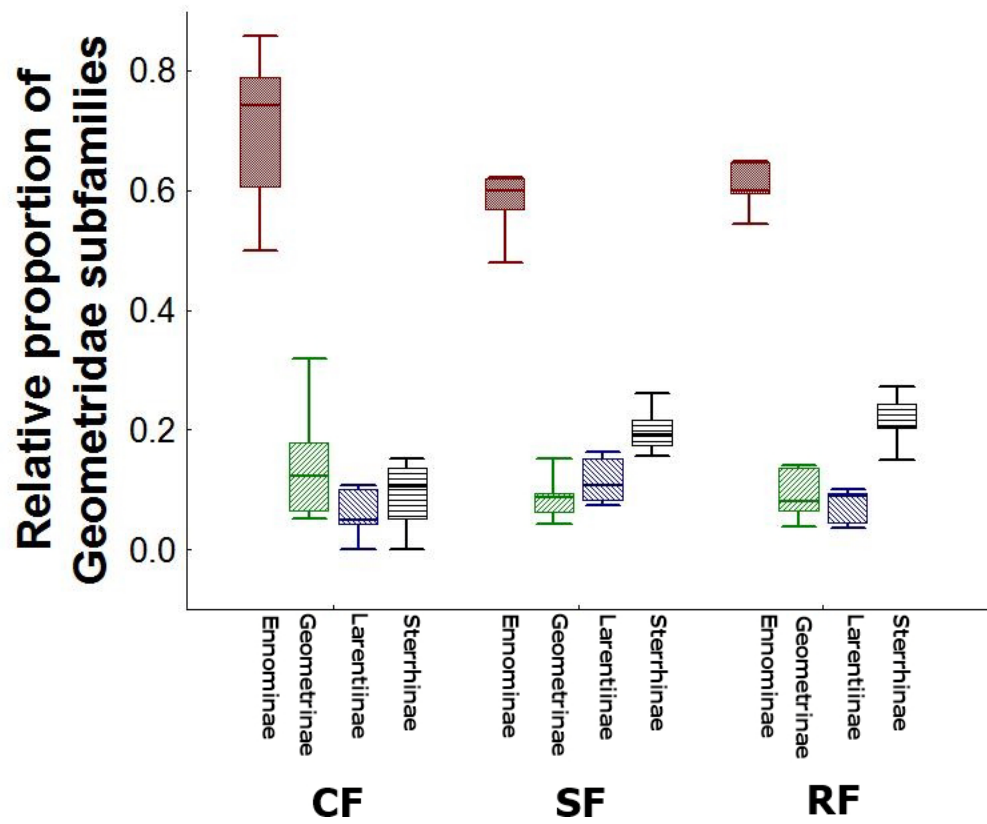


Figure 7: Relative proportions (individuals) of the Geometridae subfamilies Ennominae, Geometrinae, Larentiinae, and Sterrhinae; Desmobathrinae and Oenochrominae excluded because of very low sample sizes. See Fig. 3 for further explanation.

Table 1: Summary statistics of moth assemblages in three types of near-natural forest around the La Gamba station (SW Costa Rica). Given are means \pm standard deviations for 6 replicate sites per forest type. exp(H'): Shannon's bias corrected exponential diversity index; Fisher's alpha: species diversity index based on logseries distribution. CF = Creek Forest, SF = Slope Forest, RF = Ridge Forest.

	All moths			Arctiinae			Bombycoidea			Geometridae		
	CF	SF	RF	CF	SF	RF	CF	SF	RF	CF	SF	RF
Observed species	39 \pm 17.3	137.5 \pm 18.5	190.8 \pm 16.9	15.7 \pm 6	53.3 \pm 10.7	77.2 \pm 10.9	6 \pm 3.5	22.2 \pm 3.8	29.5 \pm 4.2	17.3 \pm 9.2	62 \pm 7.3	84.2 \pm 9.6
Observed individuals	633.0 \pm 93.5	406.3 \pm 90.5	80.7 \pm 46.7	37.1 \pm 23.3	204.4 \pm 47	339 \pm 52.3	9.2 \pm 4.7	51.1 \pm 24.9	60.1 \pm 21.6	235.0 \pm 33.1	151.2 \pm 36.6	35.7 \pm 24.1
exp(H')	26.1 \pm 11.7	75.6 \pm 10.3	93.2 \pm 13	10.3 \pm 4.5	24.8 \pm 6.3	32.1 \pm 7.1	5.3 \pm 3.1	16.8 \pm 1.8	23 \pm 2.2	12.6 \pm 7	43.3 \pm 6.7	52.1 \pm 9.2
Fisher's alpha	31.1 \pm 8.1	74.6 \pm 9.6	93.9 \pm 12.1	12.8 \pm 5.8	23.7 \pm 7.9	31.5 \pm 5.6	14.3 \pm 19.4	18.2 \pm 6.2	27.2 \pm 9.6	15.5 \pm 7.8	42 \pm 10.6	47.6 \pm 7.5

Total moth number (aggregated over Arctiinae, Bombycoidea and Geometridae) per study site was significantly affected by forest type (Fig. 8a, Table 1). Moth abundance was highest at the ridge forest sites, followed by slope forest sites and lowest abundance at the creek forest sites. This pattern in the spatial distribution of moth abundance was fully consistent over all three focal taxonomic groups (Tables 1 & 2; Figs. 8b-8d). The mean number of moths caught in the light traps (with equal sampling effort) was universally highest at the RF-sites, followed by SF-sites, and lowest abundance was observed at the CF-sites.

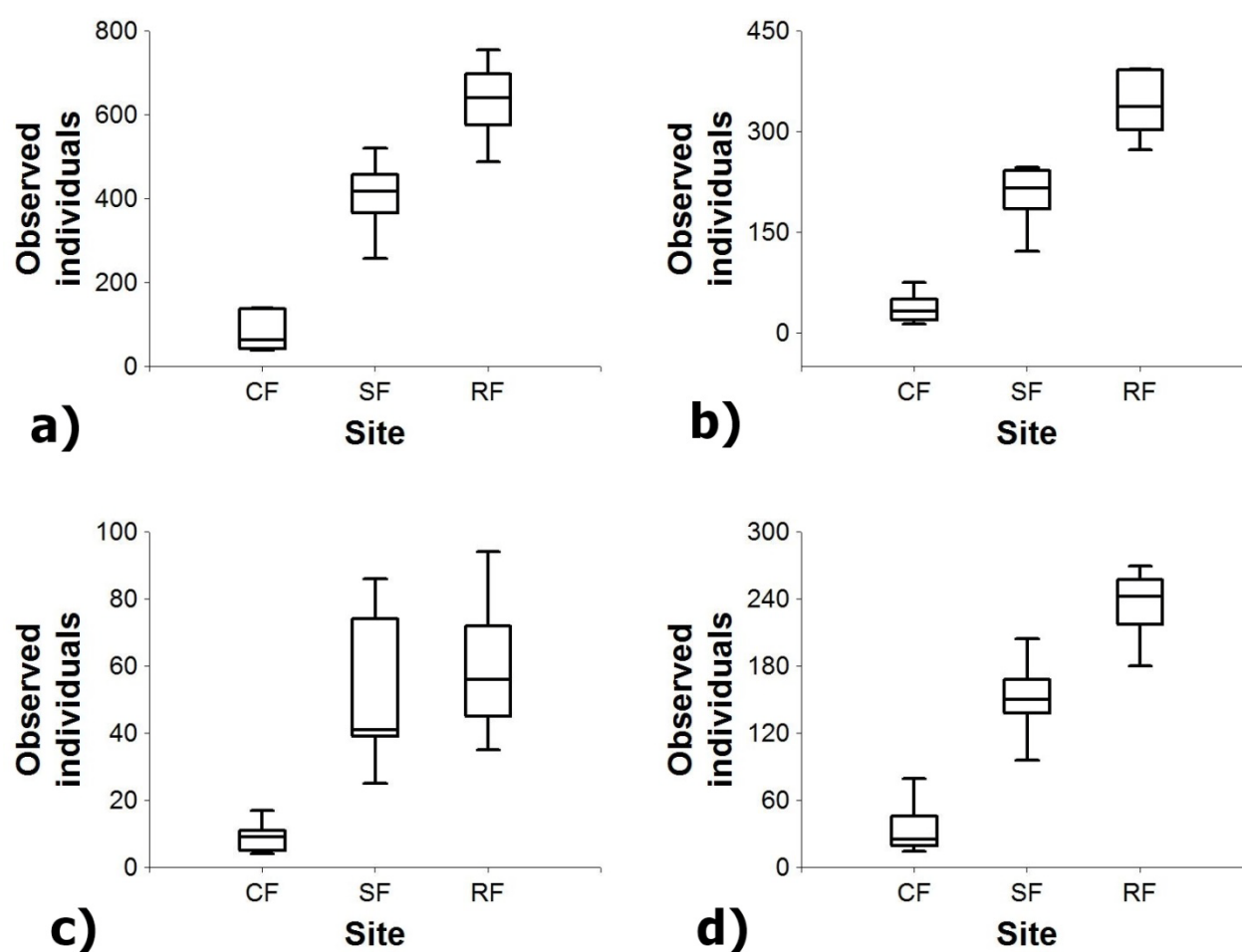


Figure 8: Numbers of observed individuals per site (aggregated from 7 nightly samples each) in relation to forest type of (a) all considered moth species (b) Arctiinae (c) Bombycoidea and (d) Geometridae. CF = Creek Forest, SF = Slope Forest, RF = Ridge Forest. Given are medians (horizontal bars), interquartile ranges (boxes) and total range of values (whiskers).

Observed moth species richness per study site revealed largely the same pattern as moth abundance. Highest species richness was recorded at RF-sites, lowest richness at the CF-sites, and intermediate

values at SF-sites. Again, all three focal taxa showed exactly the same pattern as the whole assemblage (Tables 1 & 2, Fig. 9).

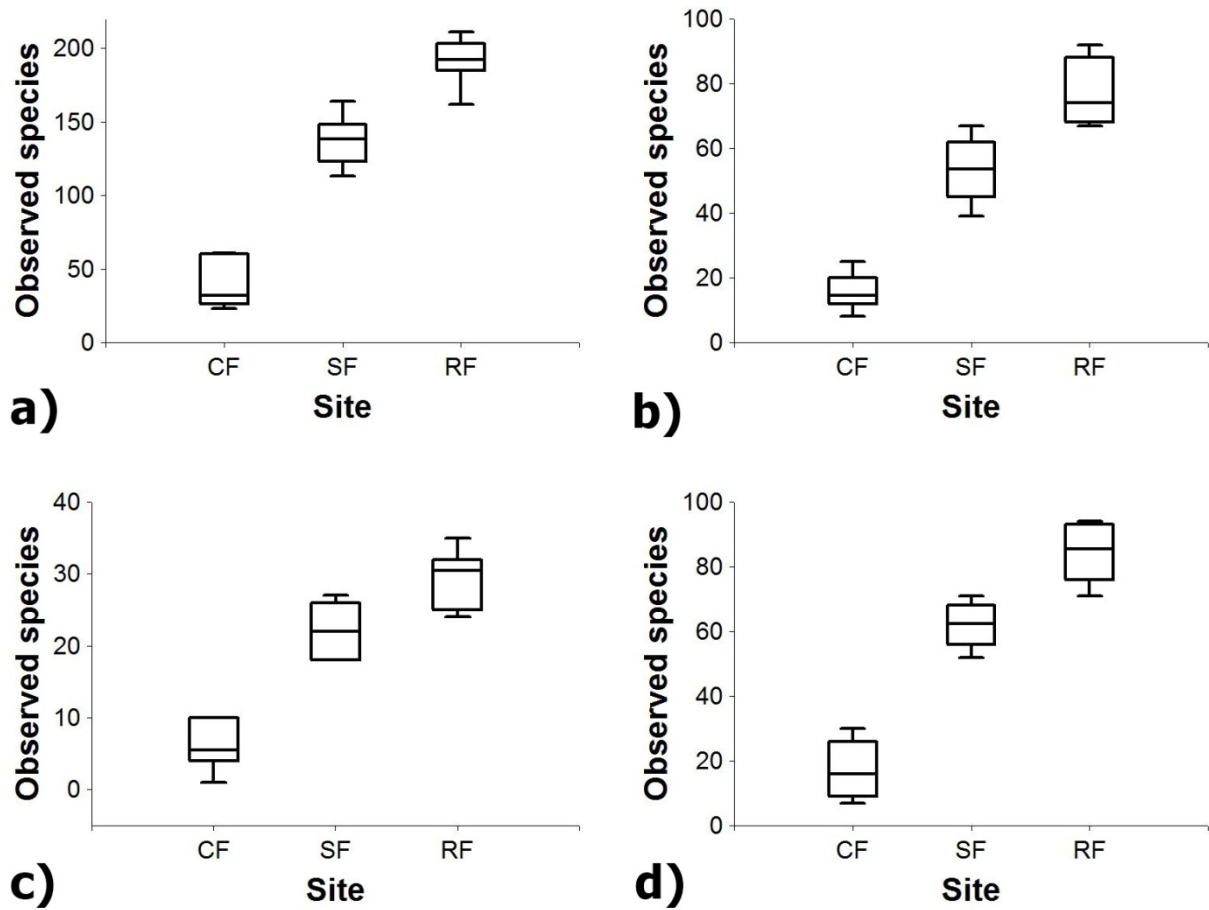


Figure 9: Species richness per site of (a) all considered moth taxa (b) Arctiinae (c) Bombycoidea and (d) Geometridae in relation to forest type (CF = Creek Forest, SF = Slope Forest, RF = Ridge Forest). See Fig. 8 for further explanations.

Since observed species richness may strongly depend on sampling success, I calculated two different species diversity indices (Shannon's bias-corrected exponential diversity ($\exp H'$) and Fisher's alpha) which are largely independent of sample size. With both diversity measures the same differences between the three different forest types were detected as with species richness and moth abundance. Highest moth diversity was recorded at the ridge forest sites, followed by the slope forest sites and lowest moth diversity occurred at the creek forest sites (Tables 1 & 2, Figs. 10 & 11). This pattern in the spatial distribution of species diversity was fully consistent over all three focal taxonomic groups. When the structural habitat descriptors (canopy closure, herb layer cover, understorey density) were included together with forest type as predictors in GLMs, these three descriptors never contributed significantly to explaining variance in moth assemblage metrics (Table 3). Except for Fisher's alpha with Arctiinae, all GLMs explained a very sizeable fraction of variance (>73%). The herb layer (one-way ANOVA: $F_{2,15} = 8.01$, $p = 0.0043$) and the understorey density (one-

way ANOVA: $F_{2,15} = 10.02$ $p = 0.0017$) varied significantly between the three forest types while the canopy closure was nearly significant (one-way ANOVA: $F_{2,15} = 3.64$; $p = 0.0515$). Understorey density and canopy closure was lowest at ridge forest sites and equally higher at the creek forest sites and the slope forest sites. The herb layer was highest at the ridge forests and the creek forest and much lower at the slope forests.

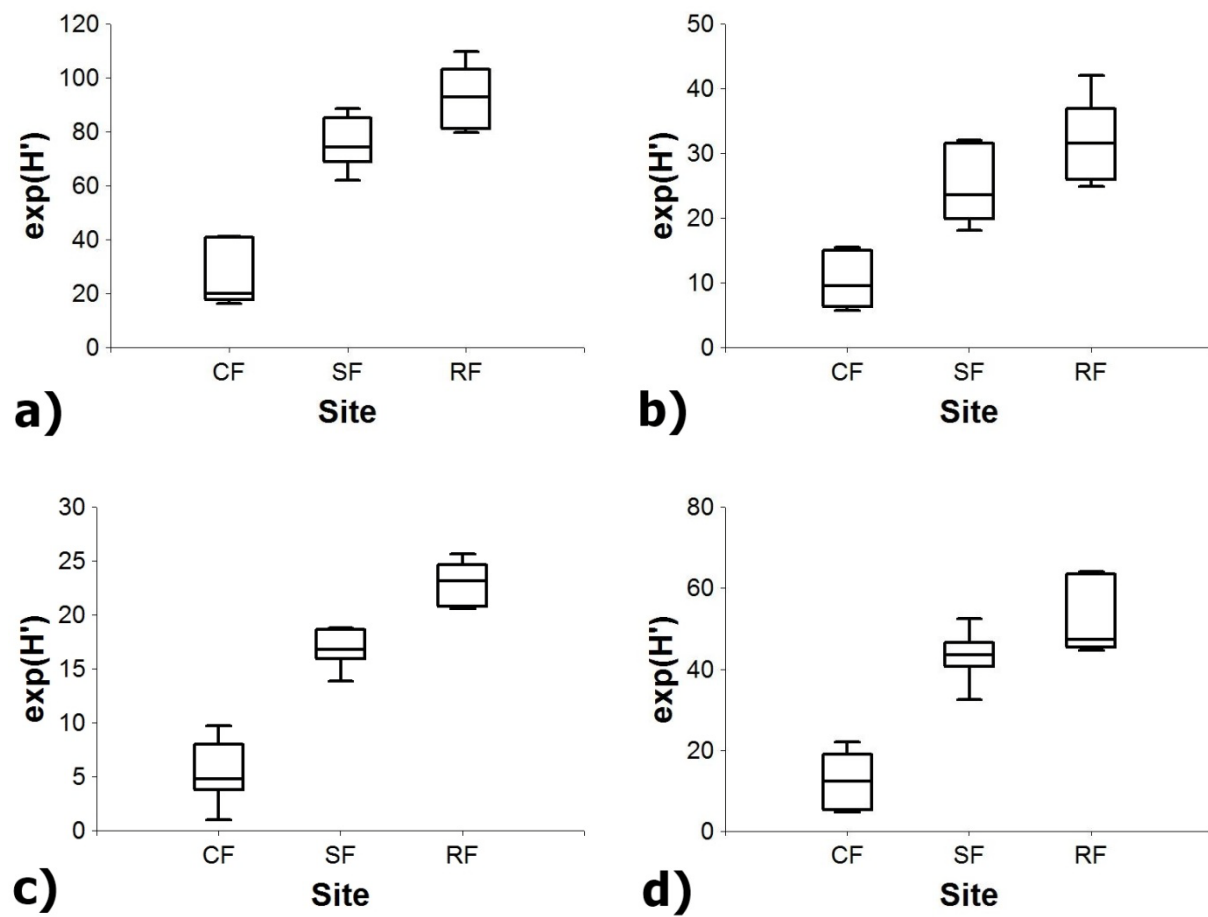


Figure 10: Species diversity of moth assemblages (expressed as Shannon's bias corrected exponential index ($\exp(H')$) of (a) all considered moth species (b) Arctiinae (c) Bombycoidea and (d) Geometridae in relation to each forest type. (CF = Creek Forest, SF = Slope Forest, RF = Ridge Forest).

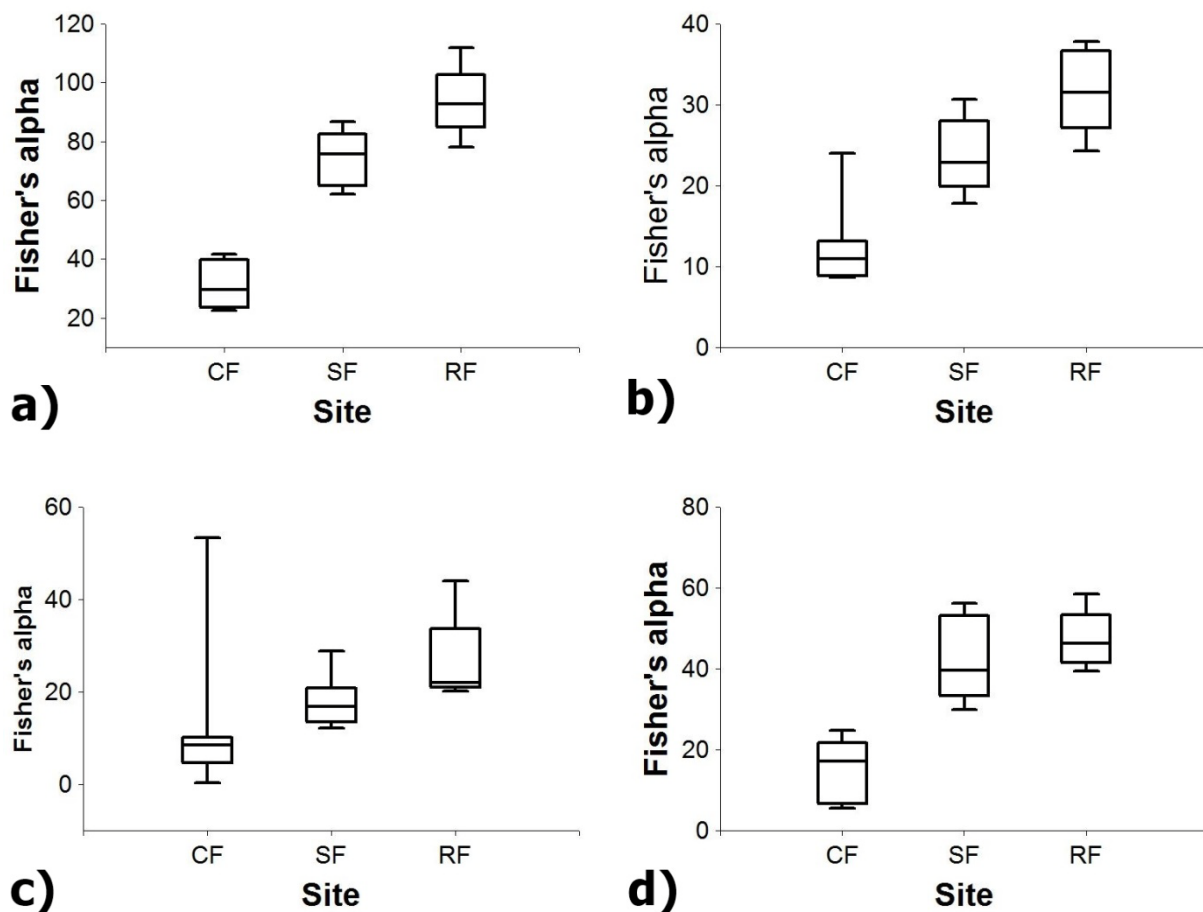


Figure 11: Species diversity of moth assemblages (expressed as Fisher's alpha) of (a) all considered moth species (b) Arctiinae (c) Bombycoidea and (d) Geometridae in relation to forest type. (CF = Creek Forest, SF = Slope Forest, RF = Ridge Forest).

Table 2: Results of one-way ANOVAs testing the effect of the forest type on a) the number of observed moth species, b) number of observed moth individuals, c) the Shannon diversity index $\exp(H')$ and d) Fisher's alpha. Results are reported for all considered moth taxa together, as well as separately for the focal taxa Arctiinae, Bombycoidea and Geometridae.

	df	F	p		df	F	p
(a) observed species				(c) exp (H')			
All moths	1; 12	115.13	<0.001	All moths	1; 12	53.17	<0.001
Arctiinae	1; 12	63.93	<0.001	Arctiinae	1; 12	20.36	<0.001
Bombycoidea	1; 12	90.84	<0.001	Bombycoidea	1; 12	79.51	<0.001
Geometridae	1; 12	90.38	<0.001	Geometridae	1; 12	43.19	<0.001
(b) observed individuals				(d) Fisher's alpha			
All moths	1; 12	72.57	<0.001	All moths	1; 12	61.26	<0.001
Arctiinae	1; 12	76.17	<0.001	Arctiinae	1; 12	17.87	<0.001
Bombycoidea	1; 12	12.64	<0.001	Bombycoidea	1; 12	1.55	0.246
Geometridae	1; 12	60.67	<0.001	Geometridae	1; 12	23.11	<0.001

Significant effects ($p < 0.05$) in bold case

Table 3: Results of GLMs testing the combined influence of forest type and three structural habitat descriptors (canopy closure, herb layer cover, understorey density) on a) the number of observed moth species, b) number of observed moth individuals, c) Shannon's diversity exp (H') and d) Fisher's alpha. Given are results for all observed moths together and separately for the three focal groups Arctiinae, Bombycoidea and Geometridae. Habitat variables were logit-transformed and normalized prior to analysis.

All moths	df	F	p		df	F	p
(a) observed species				(c) exp (H')			
Forest type	2	59.239	<0.001	Habitat	2	37.929	<0.001
Canopy closure	1	0.263	0.617	Canopy closure	1	0.277	0.608
Herb layer cover	1	0.06	0.81	Herb layer cover	1	0.0712	0.793
Understorey density	1	0.84	0.38	Understorey density	1	2.482	0.141
$r^2_{adj} = 0.921$				$r^2_{adj} = 0.868$			
(b) observed individuals				(d) Fisher's alpha			
Forest type	2	31.634	<0.001	Habitat	2	61.332	<0.001
Canopy closure	1	0.012	0.914	Canopy closure	1	0.749	0.404
Herb layer cover	1	0.54	0.477	Herb layer cover	1	0.119	0.736
Understorey density	1	0.288	0.601	Understorey density	1	5.673	0.035
$r^2_{adj} = 0.884$				$r^2_{adj} = 0.911$			
Arctiinae	df	F	p		df	F	p
(a) observed species				(c) exp (H')			
Forest type	2	40.427	<0.001	Habitat	2	18.427	<0.001
Canopy closure	1	0.106	0.751	Canopy closure	1	0.023	0.882
Herb layer cover	1	0.006	0.942	Herb layer cover	1	<0.001	1
Understorey density	1	2.449	0.144	Understorey density	1	4.519	0.055
$r^2_{adj} = 0.879$				$r^2_{adj} = 0.729$			
(b) observed individuals				(d) Fisher's alpha			
Forest type	2	34.982	<0.001	Habitat	2	14.739	<0.001
Canopy closure	1	0.035	0.854	Canopy closure	1	0.522	0.484
Herb layer cover	1	0.335	0.573	Herb layer cover	1	0.245	0.629
Understorey density	1	0.301	0.593	Understorey density	1	2.683	0.127
$r^2_{adj} = 0.883$				$r^2_{adj} = 0.665$			
Bombycoidea	df	F	p		df	F	p
(a) observed species				(c) exp (H')			
Forest type	2	24.565	<0.001	Habitat	2	33.231	<0.001
Canopy closure	1	0.09	0.769	Canopy closure	1	0.006	0.942
Herb layer cover	1	0.015	0.906	Herb layer cover	1	0.058	0.814
Understorey density	1	2.357	0.150	Understorey density	1	0.004	0.951
$r^2_{adj} = 0.87$				$r^2_{adj} = 0.879$			
(b) observed individuals				(d) Fisher's alpha			
Forest type	2	13.413	<0.001	Habitat	2	4.467	0.035

Canopy closure	1	1.071	0.321	Canopy closure	1	0.067	0.801
Herb layer cover	1	0.345	0.569	Herb layer cover	1	1.478	0.247
Understorey density	1	20.358	<0.001	Understorey density	1	2.856	0.117
$r^2_{\text{adj}} = 0.84$				$r^2_{\text{adj}} = 0.229$			
Geometridae	df	F	<i>p</i>		df	F	<i>p</i>
(a) observed species				(c) exp (H')			
Forest type	2	50.139	<0.001	Habitat	2	47.9	<0.001
Canopy closure	1	0.697	0.42	Canopy closure	1	1.197	0.295
Herb layer cover	1	0.138	0.716	Herb layer cover	1	0.643	0.438
Understorey density	1	0.789	0.392	Understorey density	1	3.992	0.069
$r^2_{\text{adj}} = 0.904$				$r^2_{\text{adj}} = 0.889$			
(b) observed individuals				(d) Fisher's alpha			
Forest type	2	26.744	<0.001	Habitat	2	17.147	<0.001
Canopy closure	1	0.112	0.743	Canopy closure	1	0.068	0.799
Herb layer cover	1	0.714	0.415	Herb layer cover	1	0.364	0.558
Understorey density	1	0.292	0.599	Understorey density	1	1.975	0.185
$r^2_{\text{adj}} = 0.86$				$r^2_{\text{adj}} = 0.736$			
Significant effects ($p < 0.05$) in bold case							

3.2. Moth assemblages

Non-metric multidimensional scaling (NMDS) plots based on Bray-Curtis similarities show a clear segregation of the RF, SF and CF forest sites into three point clouds. This indicates the existence of distinct moth assemblages of all three different forest types. Remarkably, this pattern was totally concordant over the three focal taxa (Arctiinae, Bombycoidea, Geometridae; Figure 12a -12d). Especially in the Arctiinae and Geometridae with large sample sizes moth assemblages form very clear and well segregated clusters due to the forest types. But also in the Bombycoidea with a much lower sample size form well-defined moth assemblages emerged. The low stress values of all ordinations (<0.10) indicate a reliable visualisation of the faunal similarity relationships by the NMDS ordination.

PERMANOVAs performed on the Bray-Curtis similarity matrices tested for effects of forest type on species composition and showed significant differences in the assemblages of all moths as well as in the assemblages of the Arctiinae, Bombycoidea and Geometridae (Table 4). Only the forest type affected moth species composition, while none of the three tested habitat descriptors contributed significantly to explain variance in assemblage composition (Table 4). Additionally pairwise comparisons of the Bray-Curtis similarities indicated significant differences in almost all contrasts

between forest types (Table 5). Bray-Curtis similarity values were not correlated with the topographic distances between the sampling sites, although the distance between some sites was less than 150m (Spearman matrix rank correlation coefficients; all moths: $Rho = -0.001$, $p = 0.466$; Arctiinae: $Rho = -0.013$, $p = 0.516$; Bombycoidea: $Rho = 0.017$, $p = 0.529$; Geometridae: $Rho = -0.013$, $p = 0.427$). Correlation coefficients were strikingly close to zero, indicating that results were not affected by strong spatial autocorrelation. For all analyzed moth groups, multivariate dispersion was larger amongst the CF sites than within the two other forest types, indicating a greater site-to-site variance in species composition in creek forests. In contrast, Moths at RF sites formed very strongly clumped assemblages, independently from the taxonomic unit, while moth assemblages at SF-sites were slightly more dispersed (Figure 12a -12d). In line with these observations on the ordination plots, an index of multivariate dispersion (MVDISP) attained lowest values for the RF sites and highest at the CF sites (for all moths together, as well as for each of the three focal taxa: Table Appendix 3). With this index, values below 1 indicate a higher homogeneity of species composition, while values above 1 indicate a higher dispersion of the communities. Therefore, moths in Ridge and Slope Forest formed very homogeneous communities, while those at Creek Forest sites were much more heterogeneous.

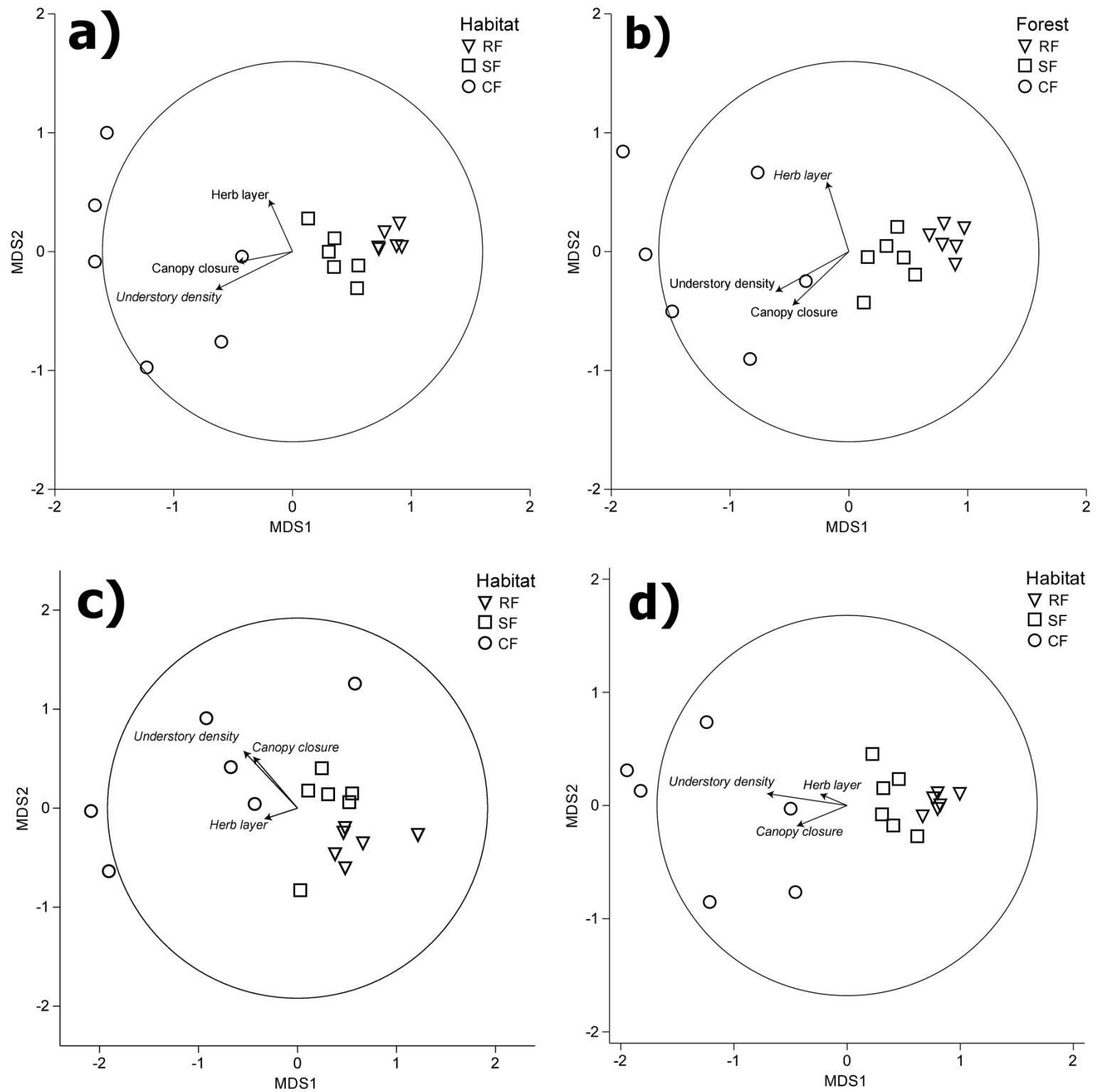


Figure 12: Non-metric multidimensional scaling (NMDS) ordination plots (based on Bray-Curtis similarities) for a) all observed moths b) Arctiinae c) Bombycoidea and d) Geometridae assemblages at Ridge forest (RF), Slope forest (SF) and Creek forest (CF) sites. 2D stress value = 0.06. Habitat descriptors (Canopy closure, Herb layer cover and Understorey density) were logit-transformed and normalized, and then overlaid *post-hoc* on the ordination diagrams. Arrows indicate direction and strength of the correlations between habitat descriptors and species composition.

Table 44: Results of PERMANOVAs testing the effect of the forest type and three habitat descriptors (canopy closure, herb layer cover, understorey density) on the species composition (expressed as Bray-Curtis similarities) of all considered moths, as well as separately for Arctiinae, Bombycoidea and Geometridae.

All moths	df	<i>F</i>	<i>p</i>
Forest type	2	5.077	<0.001
Canopy closure	1	0.689	0.85
Herb layer	1	0.983	0.502
Understorey density	1	0.746	0.789
Arctiinae			
Forest type	2	5.828	<0.001
Canopy closure	1	0.688	0.821
Herb layer	1	1.049	0.399
Understorey density	1	0.694	0.795
Bombycoidea			
Forest type	2	3.292	<0.001
Canopy closure	1	0.619	0.825
Herb layer	1	0.876	0.599
Understorey density	1	1.121	0.35
Geometridae			
Forest type	2	4.93	<0.001
Canopy closure	1	0.724	0.785
Herb layer	1	0.963	0.479
Understorey density	1	0.635	0.885

Given are pseudo-*F* values and *p* values for each habitat describing variable. Factors that significantly ($p < 0.05$) influenced species composition in bold case.

Table 55: Results of pairwise post-hoc comparisons by PERMANOVA based on Bray-Curtis similarities (square-root transformed abundances) testing for the effect of the forest type (CF=Creek forest, SF=Slope forest, RF=Ridge forest) on species composition of all observed moths, as well as separately for Arctiinae, Bombycoidea and Geometridae.

Pairwise comparisons

All moths	<i>t</i>	<i>p</i>
CF vs. RF	2.789	<0.001
CF vs. SF	2.105	<0.001
RF vs. CF	1.721	<0.001
Arctiinae		
CF vs. RF	3.009	<0.001
CF vs. SF	2.243	<0.001
RF vs. CF	1.846	<0.001
Bombycoidea		
CF vs. RF	2.192	<0.001
CF vs. SF	1.663	0.004

RF vs. CF	1.56	<0.012
Geometridae		
CF vs. RF	2.762	<0.001
CF vs. SF	2.09	<0.001
RF vs. CF	1.623	<0.001
Significant effects ($p < 0.05$) in bold case		

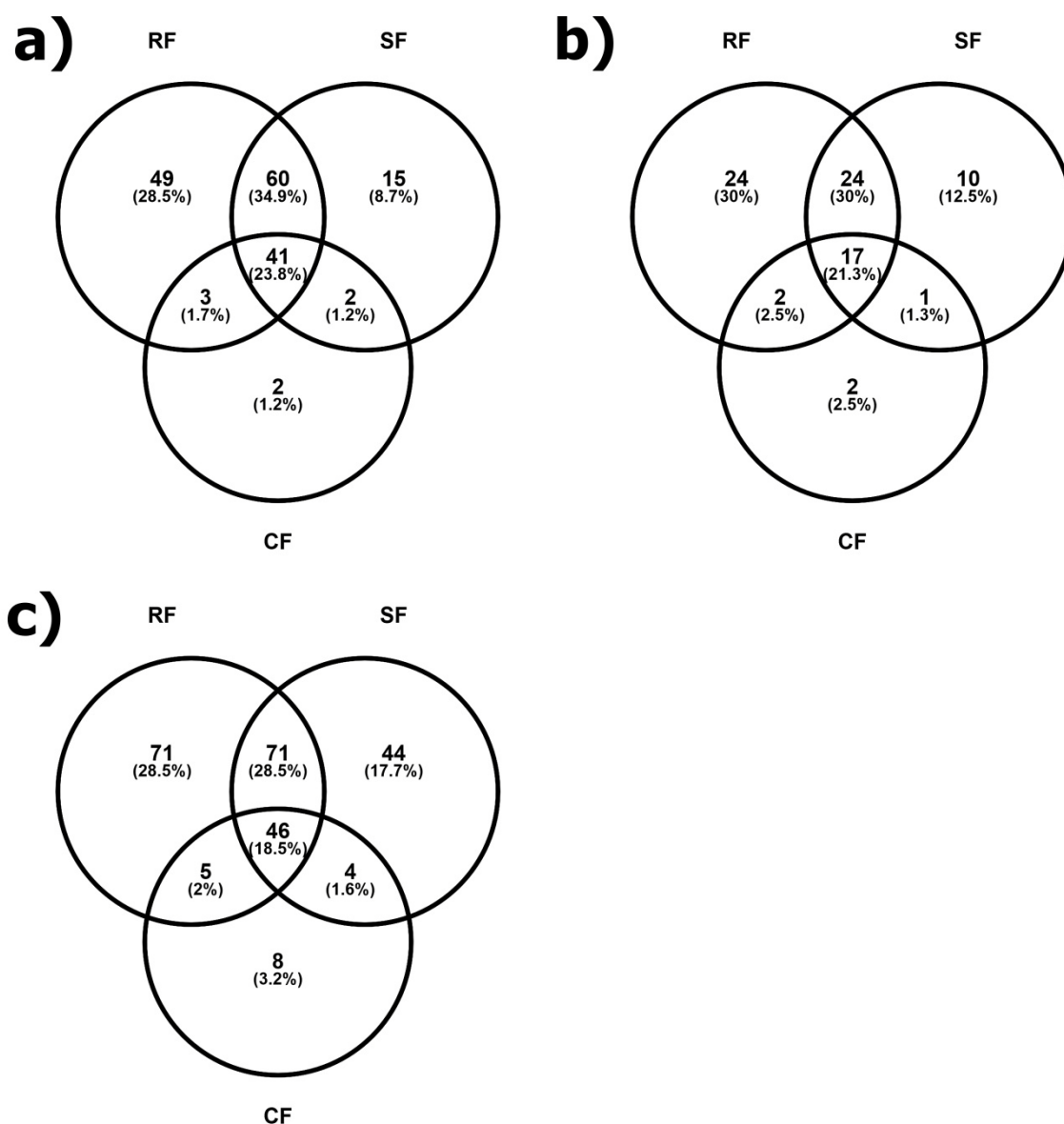


Figure 13: Venn diagram indicating the species overlaps of moth assemblages of (a) Arctiinae (b) Bombycoidea (c) Geometridae in relation to forest type. (CF=Creek forest, SF=Slope forest, RF=Ridge forest)

The analyses of the species overlaps of the moth assemblages indicates that ridge forest sites contained the highest, creek forest sites the lowest and slope forests an intermediate number of unique species and the pattern is very similar between the three focal taxa. The ridge and the slope

forest sites share the highest percentage of moth taxa (>28.5%), even more than all three forest types (18.5-23.8%). It is remarkable that most of the species observed at the creek forest were found in the ridge and the slope forests too. Only a very small fraction of species at the creek forests were unique or were shared with only one of the two other forest types (Fig. 13).

3.3. Indicator species

The indicator value analysis revealed a wide range of moth species to be characteristically associated with one of the three investigated forest types. Of a total number of 501 observed moth species, 245 species were significantly associated with ridge forest, but just two species were significantly associated with the slope forest; 53 moth species were significantly associated with ridge and slope forests combined, corroborating the faunal similarity between these two forest types that was also apparent from the ordination analyses (see above). So nearly half (49%) of the observed moth species were significantly associated with the ridge forest and another 10% with both, the ridge and the slope forest. On the other hand, no single moth species was significantly associated with the creek forest sites. Remarkably, 220 of the 245 (or 90%) moth species associated with ridge forest were geometrids, whereas only 18 species were Arctiinae and 7 species belonged to Bombycoidea. So the vast majority of observed Geometridae species (> 88%) were characteristically associated with the ridge forest sites. Moreover, another 25 geometrid species were associated with the ridge and slope forest combined. Accordingly, 245 of 249 (or 98%) of all geometrid species observed during this study were significantly associated with ridge or slope forests. Additionally, 22 species of Arctiinae and 6 species of Bombycoidea were associated with ridge forests or slope forests. For detailed information see Table Appendix 4.

3.4. Biometric traits

To compare the biometric traits of moths between the different forest types, the community weighted mean (CWM) of each trait was calculated for each site, as a proxy for the “typical” moth individual of the three focal taxa to be encountered at each site. CWMs of all measured wing features (forewing and hindwing length; forewing, hindwing and total wing area) showed no significant differences between the three forest types (one-way ANOVA: p -values all >0.05). Only the wing ratio (forewing width / forewing length) and the aspect ratio of the Bombycoidea superfamily differed significantly between the three forest types (one-way ANOVA; $F_{1,15} = 8.19$, FDR-adjusted $p < 0.05$), but there was no effect on these wing features among Arctiinae and Geometridae between the

forest types (Table 6). The mean CMV of the aspect ratio of Bombycoidea moths continuously increased from the CF-sites (mean \pm SD: 9.9 ± 0.47), over the SF-sites (10.4 ± 0.44) to the RF-sites (10.87 ± 0.32). The lower aspect ratio indicates a higher induced drag and so these moths need more power for flight. Moreover, three CWMs of body features, viz. the thorax width, the body shape index and the biomass of the Geometridae family differed significantly between the three forest types, but none of these body features showed comparable patterns in Arctiinae and Bombycoidea (Table 6). Mean thorax width of the Geometridae increased continuously from the Creek forest ($2.24 \pm 0.23\text{mm}$), over the Slope forest ($2.47 \pm 0.13\text{mm}$) to the ridge forest ($2.56 \pm 0.07\text{mm}$) as well as the mean estimated individual biomass from the CF ($10.57 \pm 4.61\text{mg}$) over the SF ($15.13 \pm 3.27\text{mg}$) to the RF ($16.86 \pm 1.91\text{mg}$). The body shape index decreased significantly from CF (4.68 ± 0.18) over SF (4.36 ± 0.06) to RF (4.31 ± 0.02) sites. Further body features, like body length and the volume of the abdomen did not reveal any significant patterns relative to the forest types. Also the three habitat descriptors had no detectable effects on the biometric traits.

Table 6: Result of one-way ANOVAs testing the effect of forest type on the community weighted means of aspect ratio, biomass, body shape index and thorax width, separately for Arctiinae, Bombycoidea and Geometridae.

One way ANOVA	df	F	FDR <i>adjusted p</i>		df	F	FDR <i>adjusted p</i>
(a) Arctiinae				(c) Geometridae			
Aspect ratio	1; 12	3.87	0.088	Aspect ratio	1; 12	0.869	0.43
Biomass	1; 12	1.18	0.32	Biomass	1; 12	4.709	0.035
Body shape	1; 12	2.12	0.2	Body shape	1; 12	19.42	<0.001
Thorax width	1; 12	4.458	0.088	Thorax width	1; 12	6.37	0.02
(b) Bombycoidea							
Aspect ratio	1; 12	8.19	0.016				
Biomass	1; 12	1.913	0.307				
Body shape	1; 12	0.242	0.788				
Thorax width	1; 12	1.64	0.307				

Significant effects ($p < 0.05$) in bold case

3.5. Aposematism and Mimicry of Arctiinae

Prior to statistical analyses all relative proportions were logit-transformed. The relative proportion of Arctiinae species with any aposematic coloration in resting posture differed significantly between the three forest types (one-way ANOVA: $F_{1,15} = 7.14$; $p < 0.01$), but the forest type had no effect when individuals instead of species were considered. The relative proportion of species with aposematic coloration in resting posture continuously increased from the creek forests (33%), over the slope

forests (39%) to the ridge forests (47 %). On the other hand, the relative proportion of Arctiinae individuals which were aposematic at any part of their body or wings differed significantly between the forest types (one-way ANOVA: $F_{1,15} = 5.909$; $p = 0.013$), but not when considering species as units of analysis. The relative proportion Arctiinae individuals with any aposematic coloration were overall very high, but lower in creek forest (76.6%) than in slope forest (87.7%) and ridge forest (89.3%).

The relative proportion of Arctiinae participating in a mimicry ring (lycid mimicry and Hymenoptera mimicry) differed significantly between the forest types (one-way ANOVA, individuals: $F_{1,15} = 7.85$; $p < 0.01$; species: $F_{1,15} = 6.37$; $p = 0.01$). The percentage of individuals which were members of a mimicry ring was very low in creek forest (2.4%) and much higher in slope (7.9%) and ridge forest (10%). On species level, the respective fractions were 5,3% (CF), 16.9% (SF), and 18.1% (RF). There was no single species of Arctiinae with Hymenoptera mimicry found at the creek forest, so for the further analysis only slope and ridge forests were considered. The relative proportion of Arctiinae with Hymenoptera mimicry differed significantly between slope and ridge forest (one-way ANOVA, individuals: $F_{1,10} = 9.83$; $p = 0.01$; species: $F_{1,10} = 10.55$; $p = 0.08$). The percentage of individuals which are members of the Hymenoptera mimicry ring was lower at the slope (individuals: 2%; species: 4.7%) than the ridge forest sites (individuals: 4.6%; species: 8.7%).

3.5.1. Biomass calculation

The contributions of each forest type to the total estimated moth biomass (taken from length * width – weight regressions) differed severely between the three forest types. Highest percentage of moth biomass was estimated for the RF-sites (58% of total moth biomass), while moth biomass was much lower at SF-sites (36% of total moth biomass) and even far lower at CF sites (6% of total moth biomass). Interestingly, the distribution of moth biomass across the three forest types was very similar between the three focal taxonomic groups (Figure 14). The moth biomass varied at the RF-sites from 56.1% (Bombycoidea) to 59.8% (Arctiinae), at SF-sites between 34.9% (Arctiinae) and 37.2% (Bombycoidea), and at CF-sites between 5.3% (Arctiinae) and 6.6% (Bombycoidea). Moreover, mean percentage of each study site to the total estimated moth biomass (Arctiinae, Bombycoidea and Geometridae) per forest type differed significantly between the three forest types (one-way ANOVA: $F_{1,12} = 35.9$, $p < 0.01$). Arctiinae, Bombycoidea and Geometridae showed the same pattern (Table 7). GLMs testing the influence of the forest type type (CF = Creek Forest, SF = Slope Forest, RF = Ridge Forest) in combination with the habitat descriptors (canopy closure, herb layer

cover, understorey density) on the distribution of moth biomass of the different taxonomic units did not reveal any additional insights.

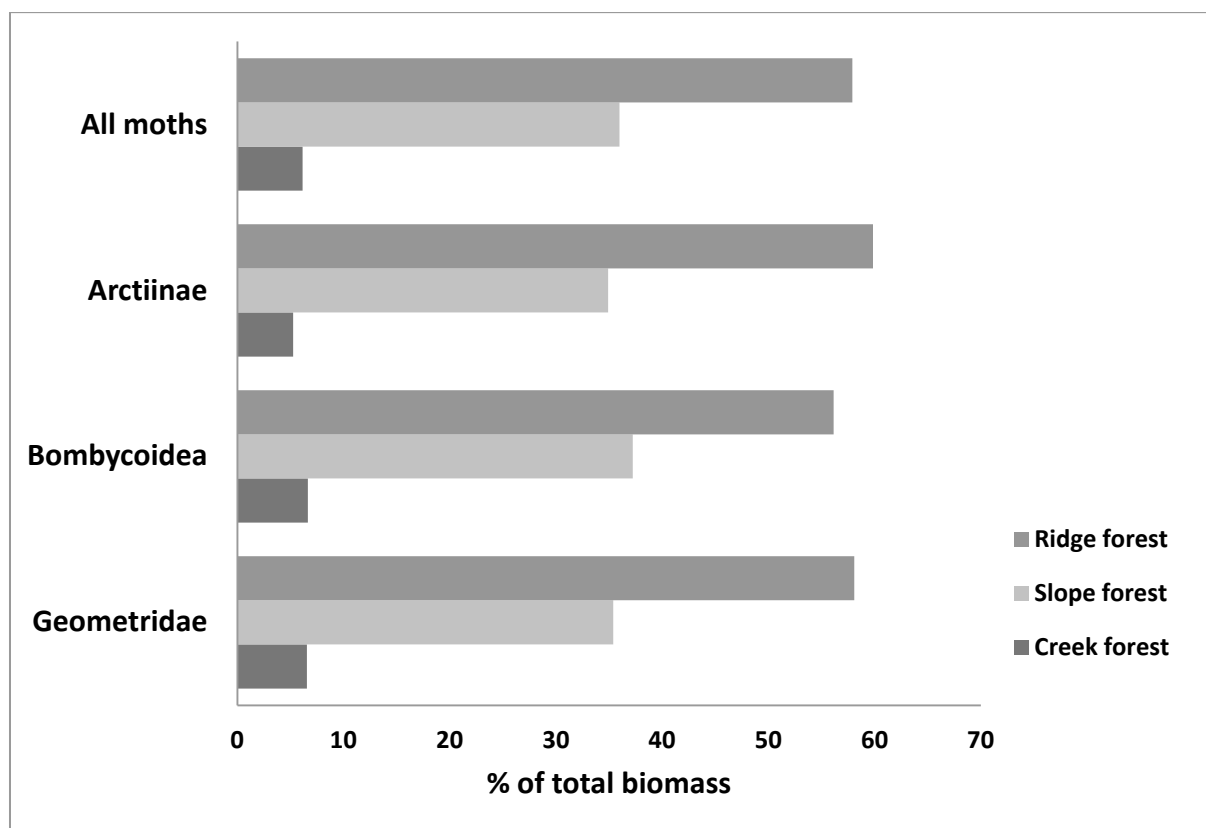


Figure 14: Distribution of the contribution of each forest type to overall estimated moth biomass or all observed moths and separately for the three focal taxonomic groups Arctiinae, Bombycoidea and Geometridae.

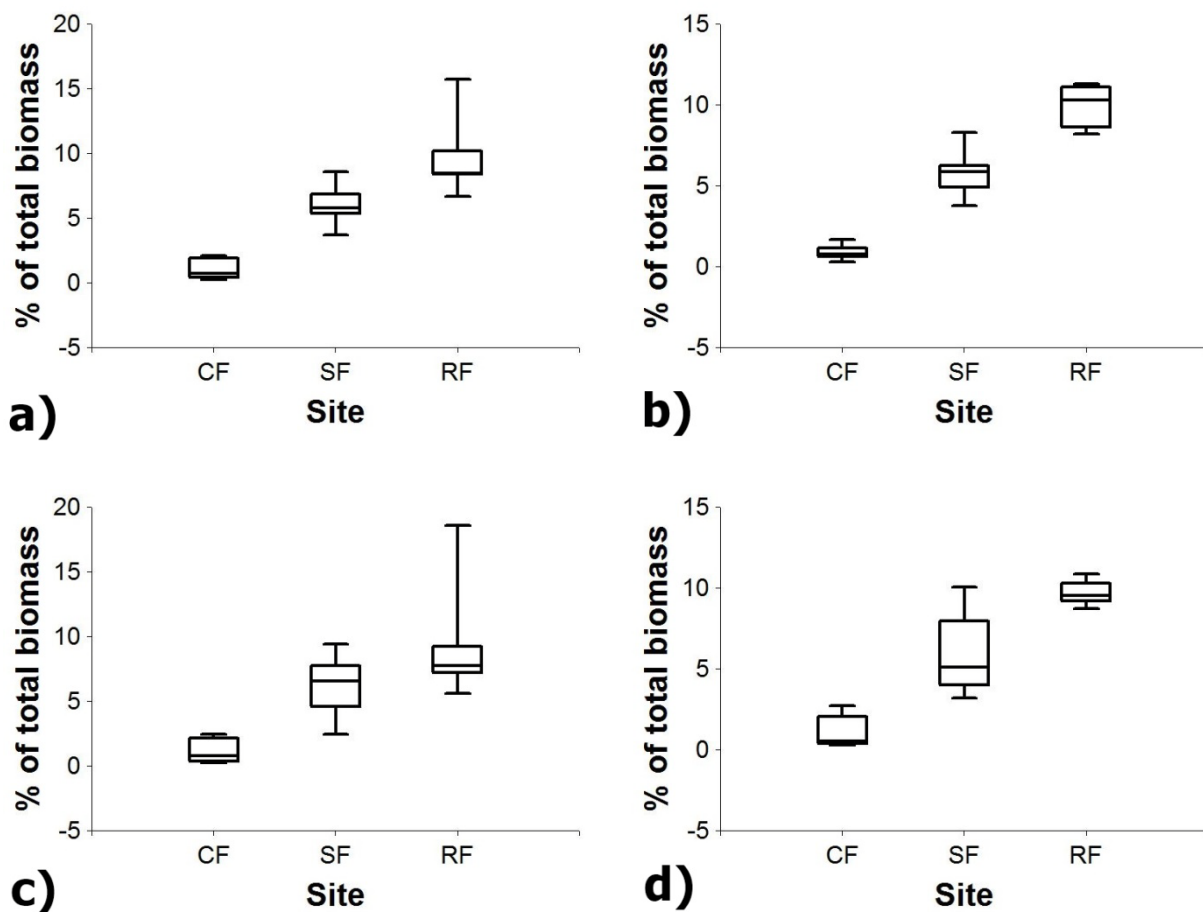


Figure 15: Distribution of mean contribution (percentage %) of forest type to overall estimated moth biomass (a) all observed moth individuals (b) Arctiinae (c) Bombycoidea and (d) Geometridae (CF = Creek Forest, SF = Slope Forest, RF = Ridge Forest).

Table 7: Results of one-way ANOVAs testing the effect of the forest type on the contribution of XXXXX to estimated total moth biomass (logit transformation of the relative proportion) of all observed moths, Arctiinae, Bombycoidea and Geometridae.

One way ANOVA	df	F	p
(a) calculated biomass			
All moths	1; 12	35.9	<0.001
Arctiinae	1; 12	76.03	<0.001
Bombycoidea	1; 12	21.71	<0.001
Geometridae	1; 12	31.05	<0.001

Significant effects ($p < 0.05$) in bold case

Logit transformed data

4. Discussion

4.1. Abundance, species richness and diversity at local site level

This is the first study to quantitatively evaluate the impact of topographic variation, at very small spatial scales of just a few hundred meters, on diversity patterns and community structure of assemblages of mobile moths in an old grown lowland rainforest in southwest Costa Rica. Even though one might expect that individuals of all studied moth species can easily cover far larger distance by active flight than the actual distances between trap sites, the three topographically defined forest types harbour strikingly different local moth assemblages. This indicates that, despite their mobility, moth assemblages in these forest ecosystems are shaped by ecological factors that act at surprisingly small scales. Similarly, studies on other mobile animals in the same forest types (diurnal butterflies, birds, ...: Binz *et al.* 2015) have revealed substantial faunal divergence between creek, slope and ridge forest.

Local species richness of the Arctiinae and Geometridae was very similar or even higher than in other lowland rainforest areas in Costa Rica (Brehm & Axmacher 2006, Brehm *et al.* 2007). In the present study, a total number of 501 species, 172 arctiines, 80 Bombycoidea, 249 Geometridae, in the old-growth forest habitats in the area of the tropical research station of La Gamba were recorded. Compared with Alonso Rodríguez (2014) slightly higher species richness was observed. In that study 142 arctiines and 170 geometrids were collected in oil palm plantations, secondary forests and old-growth forests in the vicinity of the tropical research station. Other studies registered similar species richness in central Costa Rica with 146 arctiines and 140 geometrids (Brehm *et al.* 2007) or 162 arctiines and 196 geometrids (Brehm & Axmacher 2006). Yet, the complete Bombycoidea superfamily has not been addressed in earlier diversity studies in Costa Rica, so it is difficult to compare my results on this moth taxon with other studies. Overall, however, the study area around La Gamba can be considered as a but moderately species rich tropical region, compared with the much higher regional and local moth richness observed in the biodiversity hot spot of the Ecuadorian Andes (e.g. more than 1857 geometrid species) (Brehm *et al.* 2005, Hilt & Fiedler 2005, Brehm *et al.* 2016) as well as some areas in Brazil (e.g. 294 arctiine species) (Hawes *et al.* 2009, Zenker *et al.* 2015). Coverage of species rich insect communities through empirical sampling is usually incomplete, and especially rare species will always be missed. Also the current study does not represent the total moth species richness, because not all moths were attracted to light sources to the same extent and only crepuscular and nocturnal moths were attracted. Moreover, only the understorey stratum was sampled, but it is known that moth species composition may differ between the canopy and the understorey strata. Especially, Arctiinae richness seems to be higher in the canopy than in the

understorey (Schulze *et al.* 2001, Beck *et al.* 2002, Schulze & Fiedler 2003, Brehm 2007). As in other diversity studies of tropical moth assemblages, there was a high proportion of singletons and doubletons and only a few very abundant species (e.g. Novotný & Basset 2000, Hilt & Fiedler 2005, Zenker *et al.* 2015). So many rare taxa are underrepresented, which could contain much ecological information (Hilt & Fiedler 2005). Like in most other studies from tropical habitats, many moths could only provisionally be sorted as morpho-species. Many of these very likely represent undescribed species, but voucher specimens are available for future studies (compare Janzen *et al.* 2012, Brehm *et al.* 2016). It is, however, very unlikely that this taxonomic uncertainty affected the biodiversity patterns analysed here, since the degree of uncertainty did not vary between the three forest types.

The present study indicates a much higher abundance, species richness and species diversity of moth assemblages at ridge forest sites than in the nearby creek and slope forest. Especially, creek forest sites harboured only a small fraction of moth species and individuals compared with the other two forest types, while slope forest sites were taking an intermediate position. This biodiversity pattern was totally concordant over the three studied moth taxa (Arctiinae, Bombycoidea and Geometridae) and a previous study in the same region showed a similar pattern concerning diurnal butterflies (Binz *et al.* 2015). This is quite surprising, because these different phylogenetic lineages vary strongly regarding their morphology, physiology, larval host plant relationships, adult feeding habits, etc.

Several reasons could explain these results. Due to the rugged terrain of the study area, micro-topography in tropical rainforests causes strong variation in abiotic factors like drainage, moisture, nutrients and soil condition, which vary from ridges to the creeks over just a few meters. These spatial gradients of abiotic factors lead to different ecological conditions and accordingly many plants are non-randomly distributed (Clark *et al.* 1998 & 1999, Wright 2002, Hofhansl *et al.* 2012) and ridges of tropical mountains often differ severely from neighbouring ravines in terms of forest structure, productivity and species composition (Werner & Homeier 2015). For the Golfo Dulce region, Weissenhofer *et al.* (2008) postulated plant species diversity of ridge forest sites to be higher than in slope and creek forest. If this comes true, then the higher diversity of plant species should lead to a higher abundance, species richness and diversity of moths, because more potential larval host plant species are available and therefore a greater number of species with different ecological requirements can coexist (Novotný & Weiblen 2005, Novotný *et al.* 2006, Lewinsohn & Roslin 2008). In general, higher species diversity of herbivorous insects is facilitated by greater diversity of potential host plants (Beck *et al.* 2002, Lin *et al.* 2015) and especially more insect species with a very tight trophic relationship to a plant genus or species may then coexist locally. Axmacher *et al.* (2006) and Brehm *et al.* (2003) could not assess a link between alpha diversity of geometrids and species richness of vascular plants, but in contrast, plant species composition explains a lot of variation of the alpha

diversity of geometrids. So, sometimes plant composition and the selection of plant species is more important for the species richness of moths than the simple plant species richness. However, life-history information is not yet available for most moth species encountered during my sampling campaigns in Costa Rica, rendering in depth analyses of the distribution of host specialists versus generalists along topographic gradients impossible.

This study was conducted over a relatively short time period of three months during the wet season. It is possible that species abundances (and species richness) change due to seasonal effects, as has been found in other studies (Pinheiro 2002, Silva *et al.* 2011). Under perhumid conditions, high rainfall and high relative humidity may contribute to reduce moth abundance, possibly because of the spread and activity of pathogens increasing early life-stage mortality (Intachat *et al.* 2001, Hilt *et al.* 2007). Also, Alonso Rodríguez (2014) observed a decrease in species richness of arctiines and geometrids from dry to wet season at the same study area in the vicinity of La Gamba. In contrast, Janzen describes at dry- forest of Guanacaste region, northeast Costa Rica, a massive “appearance” of a large number of species when the rain begins, because species immigrate or become active. Many univoltine species remain as prepupae or pupae from the second month of the rainy season (Janzen 1987 & 2004). Maybe, the massive rainfall during the wet season has a greater influence on the moth community at the creek forest than at the slope and ridge forest, because of waterlogging, floodings, a higher relative humidity and moisture, while the precipitation can run off quickly from the slope and the ridge forest. On the other hand, it is possible that microclimatic differences in moisture, temperature and sunlight between the three forest types permanently affect the local diversity patterns of the moth community, such that creek forest sites provide an unfavourable habitat for most moth species in the region, independently of the phylogenetic lineage. Especially the lower temperature and the lack of sunlight, which characterize the narrow creek forests, could have a negative effect on the abundance and species richness of the moth assemblages. Further examinations are needed to clarify the reasons for the exceptionally low moth density and richness observed at creek forest sites.

Weissenhofer *et al.* (2008) described differences in the understorey vegetation density among the forest types in the study area. Indeed, in the course of the present study significant differences in understorey density and herb layer coverage, but only weak, non-significant differences in canopy cover were found between the three forest types. However, none of these habitat descriptors turned out to be significantly associated with the abundance, richness or diversity of the observed moth assemblages. Similar patterns were observed by Axmacher *et al.* (2006) near Mount Kilimanjaro (Africa), where vegetation structure had only a very weak effect on alpha diversity of geometrids, while the study of Alonso Rodríguez (2014) indicated strong relations between

geometrids and arctiines and structural differences and complexity of vegetation, but the investigated habitats, an old-growth forests, secondary forests and old growth-forests were very different. With increasing structural complexity of a habitat, there will be more ecological niches, and therefor structurally homogenous land use types (e.g. oil palm forests) do not harbour diverse moth assemblages. Maybe the weak differences in vegetation structure of old-growth forest habitats do not differ in an extent that they affect moths. Nevertheless, forest type strongly influenced the moth communities, indicating that either other vegetation traits (such as plant species diversity) or abiotic factors (such as microclimate) could have a greater effect than vegetation structure.

The few measured habitat descriptors indicated a more open forest structure along the ridges. This may also allow moth species that are otherwise restricted to canopy layers to find their ways to the light trap positioned in the forest understorey. Usually, moth communities have a clear vertical stratification in tropical forests (Schulze et al. 2001, Beck *et al.* 2002, Schulze & Fiedler 2003, Brehm 2007), but this may disappear through forest disturbance (Fermon *et al.* 2005). Due to the topographic situation of the ridge forest sites, a larger fraction of canopy species may have strayed into the lower vegetation strata. In addition, some widespread species of more open and disturbed habitats may occur in the rather open ridge forests, but are not expected to show up in dense slope or creek forest. Collectively, these factors might have contributed to the higher species richness and abundance of moth assemblages at the ridge forest sites. Furthermore, it has been hypothesized that higher light availability in forest gaps increases the plant resources and decreases the resource limitation of herbivores relative to the less productive understorey (Bugmann 2001). Thereby, small-scale disturbances can cause higher species richness in rainforest gaps of animals (Spitzer *et al.* 1997, Richards & Coley 2007) and plants (Schnitzer *et al.* 2008, Bongers *et al.* 2009). In summary, the more open structure of the ridge forest sites might be responsible for their higher moth species richness and diversity. It remains to be shown whether this is due to sampling effects (light traps more visible, larger representation of canopy species) or relates to more favourable local conditions (higher plant richness, more resources in gaps). One important way to enter into in-depth analyses of these questions would be to analyze the distribution of moth functional traits across the three forest types. Unfortunately, this is currently impeded by the lack of pertinent information for the vast majority of Neotropical rainforest moth species. Much larger diversity patterns were found in studies about small-scale land use gradients. Highly anthropogenic disturbed habitats were compared with natural forests and the land use change leads to variation in microclimatic conditions, resource availability and a reduction of structural diversity. Therefore, species richness, diversity and abundance are only a fractional part of the natural habitats (e.g. Ricketts *et al.* 2001, Beck *et al.* 2002, Brehm & Fiedler 2005, Alonso Rodríguez 2014)

4.2. Moth assemblages

The present study indicates that the topographic heterogeneity of lowland rainforest in the Golfo Dulce region has a great impact on species composition of all three observed moth taxa. The three forest types harboured clearly differentiated moth assemblages. Especially for the ridge forest, but to a lesser extent also for the slope forest characteristic indicator species could be recognized. It has sometimes been suggested that in tropical lowland forests local alpha diversity exceeds beta diversity (Tuomisto 2010), such that locally co-existing species, if sufficiently covered through sampling, represent a large proportion of the regional species pool (Novotný & Weiblen 2005, Novotný *et al.* 2007). If this concept were to apply to the forests around La Gamba, then only weak differentiation of assemblages would have been expected to occur. On the other hand, various studies addressing compositional changes in moth communities along more extensive altitudinal gradients of natural tropical rainforests (e.g. Brehm *et al.* 2003 & 2013, Axmacher *et al.* 2004, Zenker *et al.* 2015, Ashton *et al.* 2015) or along land-use gradients in tropical landscapes (e.g. Ricketts *et al.* 2001, Beck *et al.* 2002, Fiedler & Schulze 2004, Alonso Rodríguez 2014) frequently revealed very strong differentiation diversity (in the sense of Jurasinski *et al.* 2009).

The reasons for differentiation of insect communities in tropical old-growth forests at scales of only a few hundred meters are poorly understood. Thus far, only few studies have addressed the influence of local topographic heterogeneity on species composition of tropical insects (e.g. Spitzer *et al.* 1997, Vasconcelos *et al.* 2003, Binz *et al.* 2015). As discussed above for local richness and abundance, a multitude of ecological differences is associated with topography (microclimate, species richness or structure of the vegetation), but it is presently impossible to reliably disentangle causal relationships. Canopy cover, understory density and herb layer cover had no significant effect on any of the moth assemblages, even though these habitat descriptors significantly differed between the forest types. Plant species composition may exert species-specific effects on moths through the differential availability of adequate host plant species for the larvae in the three forest types, but this would at most apply to host-specific moth species. Indeed, several earlier studies indicated changes in moth assemblages in relation to vegetation composition (Beck *et al.* 2002, Summerville & Crist 2004, Axmacher *et al.* 2009).

Additionally, abiotic factors like temperature, humidity, exposition, etc. might alter the composition of the moth community, because species-specific ecological constraints often determine the niches of insect species. Only species with similar ecological responses can exist in the particular forest type. One would therefore assume that local habitat conditions filter those species from the regional pool

whose requirements are best met at the respective sites (e.g. Kraft et al., 2007). Unfortunately, for the vast majority of Neotropical moth species there is insufficient information about habitat requirements and niche dimensions (Kraft et al. 2007). Hence, for the time being, it was not possible, for example, to assess whether moth assemblages associated with the three forest types might differ consistently with regard to relevant functional traits.

Although the moth communities of ridge, slope and creek forests showed a clear segregation, there was also a high degree of nestedness: assemblages with low species richness represented only subsets of more species-rich assemblages seen at other sites. Especially the species-poor creek forest sites showed a much less uniform moth community than slope and ridge forests, indicating a high degree of stochastic site-to-site variation. A larger part of local differentiation of moth assemblages occurs due to the differences of moth abundances at the different forest sites. Hence, the weighting of particular species (often abundant species) formed the differences in the moth assemblages. Most of the species found in creek forest were observed at slope and ridge forest sites, too. Accordingly, there was only a very small number of unique species at the creek forest sites, and no single indicator species could be statistically identified for this forest type. Either unique creek forest species are overall rare and therefore need a higher sampling effort to be sufficiently covered, or species abundance and occurrence may fluctuate seasonally and is higher only during the dry season. Nearly all abundant species (>10 individuals) occurring in all three forest types had their greatest abundance at the ridge forest, whereas only a few were more common in the slope forest and hardly any species in the creek forest. Alternatively, the dense understorey of the creek forest sites might indeed represent a rather hostile habitat for moths of the focal taxa, supporting only a small fraction of the regional species pool.

On the other hand, ridge and slope forest harboured a much higher number of unique species compared with the creek forest. It is tempting to hypothesize that for these species their preferred habitats offer superior conditions, even though in most cases available life-history information is too fragmentary to offer some first hints as to what these habitat requirements might be. Independently of the taxonomic unit, most unique species occurred only at the ridge forests. Moreover, a sizeable proportion of moth species recorded in all three forest types had their greatest abundance in the ridge forests, while only a few species were most numerous at slope forest sites. Only a very small number of species showed an idiosyncratic pattern. *Pyrinia* sp1., *Isochromodes* sp1. (both Geometridae), *Agaraea minuta*, *Ochrodota pronapides* (both Arctiinae), *Anticla antica* (Bombycidae) and *Euglyphis* sp2. (Lasiocampidae) had highest abundance at creek and slope forest sites and were very rare at the ridges. The two species of Geometridae and also the species of Lasiocampidae very likely represent undescribed species and therefore no ecological information is available for these

taxa. *Agaraea minuta*, *Ochrodota pronapides* and *Anticla antica* are widespread in Central and South America, but it is very likely that all three “species” in fact comprise several cryptic species (Laguerre, pers. Communication)). Larvae of *Agaraea minuta* feed on Costaceae, a pantropically distributed plant family (Tavares et al. 2012), which is also quite common in the understorey of La Gamba. Also the three species, *Euglyphis* sp2., *Ochrodota pronapides* and *Anticla antica* seem to be quite specific due to their range of used host plants. Species of the genus *Euglyphis* and *Ochrodota pronapides* feed mainly on Lauraceae, while *Anticla antica* is a specialist on Moraceae, especially on the tree genus *Brosimum*. Species of the genus *Pyrinia* tend to be polyphagous on shrubs and woody plants, maybe there exist very host plant specific *Pyrinia* species too. Species of the geometrid genus *Isochromodes* seem to be very polyphagous on herbs, shrubs and woody plants and use a broad range of different host plant families. Interestingly, caterpillars of *Isochromodes* are known to switch between vascular plants and epiphylls during the larval development. Maybe, the more humid microclimate of the creek forests provides a greater amount of epiphylls (Coley et al. 1993, Toomey et al. 2009) and so positively affects the species of the genus *Isochromodes*. All data of to host plants were extracted of the database by Janzen & Hallwachs (2009).

Using the indicator species analysis I tried to work out some species which are “typical” for a certain forest type. It is remarkable that most of the indicator species identified this way were geometrids. It seems that Geometridae respond more sensitively to small-scale environmental gradients, while species in the Arctiinae and Bombycoidea appeared to be less habitat-specific (Kitching et al. 2000, New 2004, Alonso Rodríguez 2014,). In this context it is worthy to recall that the study sites were situated rather close to another. The short distances of only a few hundred meters between some sites would be easy to overcome by most moths during regular dispersal flights. Moths often leave their breeding habitat when they were looking for food resource and start to disperse. Certainly, some of the moths sampled at low abundances at any forest type were just “tourist species”. Yet, to reduce the cross attraction of moths from adjacent forest types, a weak light source was used (Beck & Linsenmaier 2006, Truxa & Fiedler 2012). Hence, the vast majority of captured moths in all likelihood were drawn from the immediate vicinity of the trap sites.

4.3. Biometrical traits and wing patterns

Morphological traits are shaped by natural selection and phylogenetic constraints. For insects capable of flight, wing morphologies determine maneuverability, strength of flight and dispersal capacity, especially in highly cluttered space as in a dense forest understorey (Chai & Srygley 1990, Dudley 2002). Some earlier studies on tropical moths indeed showed differences in biometric traits

between canopy and understorey species (e.g. Schulze et al. 2001). I therefore tested for differences between moth assemblages of the three forest types. However, even though forest understorey density differed between the three forest types, only few biometric traits of the moth assemblages showed some signal of differentiation between habitats.

Bombycoidea showed a low aspect ratio at creek forest sites, which continuously increased to the ridge forest sites. A low aspect ratio indicates a higher induced drag, limited maneuverability and the need of more power to fly. Four bombycoid families (Bombycidae, Lasiocampidae, Mimallonidae and Saturniidae) are characterized by a reduction of the proboscis (Lemaire & Minet 1999) and therefore a very short adult life-span of only a few days (Janzen 1984a & 1984b). To find a mating partner, females are sitting passively in the vegetation and try to attract the males by emitting pheromones (Janzen 1984b). For this, good maneuverability is not required. Maybe the dense understorey of the creek forest is not a suitable habitat for faster flying moths with a good optical orientation, like the hawkmoths (Sphingidae). A total number of 37 individuals of 13 species of Sphingidae were observed during the study, but only one specimen of *Xylophanes zurcheri* was observed in the creek forest. *X. zurcheri* is a host-plant specialist on Rubiceae, especially of the genus *Psychotria*) and was more common in ridge forests and slope forests. Also Binz *et al.* 2015 observed at the same sites a higher proportion of slow flying butterfly species in creek forests. It seems that in this highly cluttered space it is advantageous to fly rather slowly in order to avoid damaging the wings; therefore a less directional flying style does not matter. Geometrids showed a similar pattern, which in ridge forests had a greater thorax width and biomass, as well as a more slender body shape, both indicating a good maneuverability (Chai & Srygley 1990). A possible driver of these morphological patterns is the predation pressure by bats. Bats usually have a greater body size, relatively to most moth species (Kalko *et al.* 2001, Avila-Cabadilla *et al.* 2009). Therefore, it is easier for them to maneuver and hunt in the more open vegetation structure of the ridge forests than in the dense creek forest sites (Kusch *et al.* 2004, Caras & Korine 2009). Consequently, stouter built moths with higher maneuverability may have an advantage in more open forest because they have a better possibility to escape. Overall, differences between the moth assemblages of the forest types in biometric traits were rather small. Probably, the structural differences between the forest types were too subtle, and habitat fidelity of most moth species too limited, to measurably influence moth morphology at this small spatial scale. Rather, the morphological traits of the moths were probably more strongly determined by phylogenetic constraints and only to a lesser extent by ecological factors.

Aposematism is defined as the combination of an anti-predator defence or avoidance with an outward signal that indicates unpalatability. In the Lepidoptera, unpalatability is frequently caused by secondary plant metabolites sequestered from larval or adult resources (Merilaita & Kaitala 2002,

Talianchich *et al.* 2003, Honma *et al.* 2015, Rojas *et al.* 2015). The present study indicates a higher proportion of arctiine species with a visible warning coloration in resting position at the ridge forest sites, but this pattern disappears if individuals rather than species are considered as units of analysis. The proportion of arctiine individuals with any aposematic coloration continuously increases from creek forest to ridge forest sites, but there is no pattern if species are considered. Hence, these patterns are still somewhat inconsistent with the data currently available. Visually hunting predators are the major selective factors for the evolution of aposematic coloration in Lepidoptera. The open vegetation structure of ridge forests provides a higher light availability for visually hunting predators like birds, mammals, amphibians, reptiles (Thery & Gomez 2010). In line with this consideration, the defence of moths through aposematic colorations was relatively more prevalent in the open vegetation along ridges. Conversely, a lower number of arctiines investing in aposematic coloration occurred in the denser and darker creek forest understorey, suggesting that a cryptic appearance is more favoured here. Furthermore, Brehm (2007) found an increase of warningly coloured arctiid species from the understorey to the canopy in a Costa Rican lowland forest. Maybe the open forest structure of the ridges enables moths otherwise preferring the canopy layer to penetrate into the understorey.

A similar pattern showed those Arctiinae moths which belong to a Batesian mimicry ring: highest relative proportions of individuals as well as species occurred at ridge forest sites. Remarkably, no single species with wasp mimicry was found in creek forest, while the highest proportion of this morphotype was observed at the ridge forests. Like arctiines with an aposematic coloration, arctiines embedded in Batesian mimicry rings appeared to preferentially occur in the more open vegetation structure of the ridge forests. As with aposematism in general, this defensive strategy addresses visually hunting predators. Hence, there is at least some evidence that the distribution of these two functional traits in Arctiinae wing pattern are shaped, beyond phylogenetic constraints, through the local ecological situation in the three forest types. In this context, it would be desirable to assess whether activity of visually hunting predators of moths is indeed higher in ridge forest as compared to the other two forest types.

I used the morphometric data of moths to estimate their biomass by means of length-weight regressions (Rogers *et al.* 1976, Wardhaugh 2013). Even though these methods retain some uncertainty, they yield useful first proxies also for considerations of biomass up to the community level (Ganihar 1997, Höfer & Ott 2009). The total amount of moth biomass at ridge forest sites was far higher than at slope forest sites and more than nine times higher than at creek forest sites. This pattern of moth biomass distribution was identical between the three focal moth taxa and mirrors the higher abundance of moths at the ridge and slope forest sites. These huge differences in moth

activity density and biomass, respectively, may indicate that the functional significance of moths in the food web differs between the forest types. Herbivore communities are controlled by a combination of available food sources (bottom up) and by predators (top down) (e.g. Hairston 1960, Power 1992, Walker & Jones 2001, Richards & Coley 2007). Adult moths, as well as their developmental stages, are important food resources for many predators (e.g. birds, bats, spiders, other insects, etc.) and parasitoids (ichneumonids, tachinids). Consequently, a lower number of moth individuals means that a lower amount of food resources are available for their predators and parasitoids. One might therefore hypothesize that abundance and species richness of specialist moth predators and parasitoids is also low at creek forest sites, i.e. that the low biomass of their prey has repercussions on higher trophic levels. Since most parasitoids are quite host-specific (Hawkins 2005), the absence or lower abundance of their hosts is expected to negatively affect their densities. Moreover, the larvae of most lepidopteran species are herbivorous and may be capable of reducing plant biomass to a great extent (Richards & Coley 2007). In tropical rainforests herbivory rates are often higher than in temperate zones (Coley & Barone 1996). As a consequence, low numbers of caterpillars lead to less defoliation, if they are not replaced by other herbivore taxa. Otherwise, the lack of sunlight and low productivity of creek forest sites inhibits fast leaf turnover (compare Richards & Coley 2007). Accordingly, foliage in creek forest is often too old to be acceptable by herbivores and due to the high humidity overgrown by epiphytes. So a huge amount of plant biomass is not available for strictly herbivorous insects because they prefer fresh leaves (Coley & Barone 1996). This could also be one reason for the tendency to a higher proportion of lichen moths (Lithosiini) at the creek forest sites, compared with slope and ridge forest sites: caterpillars of many Lithosiini are known to feed on epiphyll, especially lichens, algae and fungi. Recent studies have shown that, in tropical mountain forests, caterpillars with food sources other than vascular plants play a very substantial role (Bodner *et al.* 2015, Seifert *et al.* 2016).

5. Conclusions

The results of the study clearly indicate the impact of very small-scale topographical habitat differentiations into creek, slope and ridge forests in a perhumid lowland rainforest on the diversity pattern of moth communities. Further studies have to identify the abiotic (e.g. microclimatic conditions) and biotic (e.g. plant species richness) factors which are predominantly responsible for the differences in the biodiversity patterns and have to discover the distribution of functional traits of moths among the three forest types. Furthermore, to achieve a high completeness of species

inventories for arthropod diversity studies, the whole topographic al heterogeneity has to be considered. Also for conservation efforts to maintain a large fraction of regional diversity it is necessary to consider small-scale habitat differentiations into different forest types through topographical heterogeneity.

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Appendix

Table A1: Full species list of the observed moth species and their abundances at the different forest types (CF=Creek forest, SF=Slope forest, RF=Ridge forest).

Family/Subfamily/ Species	Creek forest	Slope Forest	Ridge Forest	Total
Arctiinae				
Arctiini				
<i>Abrochia moza</i>	-	4	22	26
<i>Aclytia albistriga</i>	1	2	1	4
<i>Aclytia gynamorpha</i>	4	18	29	51
<i>Aclytia punctata</i>	58	144	254	456
<i>Agaraea cf. minuta</i>	9	2-	3	32
<i>Agaraea semivitrea</i>	-	1	-	1
<i>Amasia apyga</i>	-	-	3	3
<i>Ammalo cf. helops</i>	-	1	-	1
<i>Amphelarctia priscilla</i>	-	1	-	1
<i>Baritius cf. eleuthera</i>	-	3	-	3
<i>Cercopimorpha sylva</i>	-	-	6	6
<i>Cissura plumbea</i>	-	1	18	19
<i>Correbia cf. affinis</i>	1	15	27	43
<i>Correbia cf. undulata</i>	-	6	9	15
<i>Correbia lycoides</i>	1	1	-	2
<i>Correbia sp1.</i>	-	2	1	3
<i>Correbia sp2.</i>	1	13	18	32
<i>Correbia sp3.</i>	1	3	3	7
<i>Correbia sp4.</i>	-	11	13	24
<i>Correbia sp5.</i>	-	1	3	4
<i>Correbidia cf. germana</i>	-	1	3	4
<i>Correbidia costinotata sp1.</i>	-	5	4	9
<i>Correbidia costinotata sp2.</i>	-	1	-	1
<i>Correbidia sp1.</i>	-	2	1	3
<i>Correbidia sp2.</i>	1	2	3	6
<i>Correbidia sp3.</i>	1	9	22	32
<i>Cosmosoma achemon</i>	-	-	1	1
<i>Cosmosoma angustimargo/stibostictum</i>	-	1	9	1-
<i>Cosmosoma cf. gemmata</i>	-	-	1	1
<i>Cosmosoma hector</i>	-	4	6	10
<i>Cosmosoma saron</i>	3	3	2	8
<i>Cosmosoma semifulva</i>	-	-	1	1
<i>Cosmosoma teuthras</i>	-	2	2	4
<i>Cosmosoma xanthostictum</i>	-	1	5	6
<i>Delphyre testacea</i>	2	34	92	128

<i>Elysium conspersus</i>	1	-	-	1
<i>Epanycles imperialis</i>	-	4	13	17
<i>Epidesma cf. ursula</i>	-	-	2	2
<i>Epidesma sixola</i>	-	-	1	1
<i>Epidesma sp1.</i>	-	-	36	36
<i>Epidesma sp2.</i>	-	-	3	3
<i>Epidesma sp3.</i>	-	2	3	5
<i>Episcepsis aelia</i>	-	-	1	1
<i>Episcepsis capysca</i>	2	4	7	13
<i>Episcepsis demonis</i>	1	33	24	58
<i>Episcepsis hypoleuca sp1.</i>	-	-	4	4
<i>Episcepsis hypoleuca sp2.</i>	1	-	5	6
<i>Episcepsis inornata sp1.</i>	2	6	2	10
<i>Episcepsis inornata sp2.</i>	-	3	-	3
<i>Episcepsis thetis sp1.</i>	-	1	5	6
<i>Episcepsis thetis sp2.</i>	-	2	5	7
<i>Episcepsis xanthura</i>	-	-	1	1
<i>Eucereon aeolum</i>	1	-	1	2
<i>Eucereon aoris</i>	-	1	7	8
<i>Eucereon atrigutta</i>	-	-	6	6
<i>Eucereon aurantiaca</i>	1	13	17	31
<i>Eucereon cf. obscura</i>	-	1	2	3
<i>Eucereon cf. varium sp1.</i>	1	12	5	18
<i>Eucereon cf. varium sp2.</i>	-	1	-	1
<i>Eucereon latisfasciata</i>	-	-	2	2
<i>Eucereon maia</i>	1	4	3	8
<i>Eucereon mitigatum</i>	2	18	11	31
<i>Eucereon pometina</i>	-	3	-	3
<i>Eucereon pseudarchias</i>	-	-	1	1
<i>Eucereon rosinum</i>	-	1	4	5
<i>Eucereon sp.</i>	1-	78	78	166
<i>Eucereon tesselata</i>	-	-	3	3
<i>Eupseudosoma aberrans</i>	-	-	1	1
<i>Evius hippia</i>	-	1	2	3
<i>Halysidota fumosa</i>	-	1	2	3
<i>Heliura rhodophila</i>	-	3	7	1-
<i>Heliura thysbodes</i>	8	53	79	140
<i>Hyalurga sixola</i>	-	10	4	14
<i>Hyalurga sora</i>	-	-	1	1
<i>Hyalurga urioides</i>	-	-	1	1
<i>Hyperandra excavata</i>	-	3	29	32
<i>Hypocrita arcae</i>	-	-	1	1
<i>Idalus critheis</i>	-	2	4	6
<i>Idalus tybris</i>	-	1	2	3
<i>Isanthrene cf. azia</i>	-	-	1	1
<i>Isanthrene cf. fulvipicta</i>	-	-	1	1
<i>Kirrostopla metaxantha</i>	-	-	5	5
<i>Leucanopsis cedon</i>	-	-	1	1
<i>Leucanopsis cf. polydonta</i>	-	6	2	8
<i>Lophocampa cf. maroniensis</i>	-	2	2	4
<i>Lophocampa cf. modesta</i>	-	11	12	23
<i>Lophocampa debilis</i>	-	-	2	2

<i>Lophocampa subannula</i>	-	3	-	3
<i>Loxophlebia flavipicta</i>	-	-	1	1
<i>Loxophlebia</i> sp.	-	1	-	1
<i>Lymire</i> cf. <i>fulvicollis</i>	1	11	16	28
<i>Macrocneme</i> sp.	-	-	1	1
<i>Melese</i> cf. <i>incertus</i>	-	7	22	29
<i>Melese flavimaculata</i>	-	1	-	1
<i>Melese laodamia</i>	-	8	11	19
<i>Melese sixola sixola</i>	20	247	376	643
<i>Ochrodota</i> cf. <i>pronapides</i>	1	13	2	16
<i>Ormetica atania</i>	-	-	1	1
<i>Ormetica guapisa</i>	-	6	5	11
<i>Ormetica sicilia</i>	-	3	6	9
<i>Pareuchaetes insulata</i>	-	2	1	3
<i>Pelochyta</i> cf. <i>cervina</i>	-	-	3	3
<i>Pelochyta</i> cf. <i>ruficollis</i>	-	2	-	2
<i>Phaeomolis vampa</i>	-	-	10	10
<i>Phoenicoprocta sanguineum</i>	-	-	1	1
<i>Poliopastea</i> sp1.	-	2	2	4
<i>Psoloptera basifulva</i>	-	-	1	1
<i>Ripha flammans</i>	-	-	2	2
<i>Robinsonia bartolana</i>	-	-	1	1
<i>Robinsonia</i> sp.	-	2	8	10
<i>Saurita</i> cf. <i>concnica</i>	-	-	5	5
<i>Saurita tipulina</i>	-	12	32	44
<i>Sutonocrea</i> cf. <i>lobifer</i>	-	13	48	61
<i>Symphlebia ipsea</i>	-	6	39	45
<i>Symphlebia ipsea</i>	-	1	2	3
<i>Timalus caeruleus</i>	-	2	5	7
<i>Trichromia cardinalis</i>	-	2	1	3
<i>Trichromia</i> cf. <i>flavimargo</i>	-	-	2	2
<i>Trichromia</i> cf. <i>granatina</i>	-	2	3	5
<i>Trichromia</i> cf. <i>peninsulata</i>	-	7	11	18
<i>Trichromia</i> cf. <i>flexuosa</i>	-	2	4	6
<i>Trichromia lophosticta</i> sp1.	-	3	10	13
<i>Trichromia lophosticta</i> sp2.	-	-	3	3
<i>Trichromia parnelli</i>	-	1	-	1
<i>Trichromia</i> sp.	-	-	1	1
<i>Trichromia tipolis</i>	-	-	11	11
<i>Trichura</i> sp	-	-	1	1
<i>Tricypha imperialis</i>	1	1	1	3
<i>Tricypha</i> sp.	1	-	-	1
<i>Uranophora walkeri</i>	-	-	3	3
<i>Virbia</i> cf. <i>medarda</i>	5	15	4	24
<i>Virbia</i> cf. <i>mentiens</i>	4	6	1	11
<i>Virbia sanguicollis</i>	15	82	83	180
<i>Viviennea salma</i>	-	-	6	6
<i>Viviennea tegyra</i>	-	-	2	2
<i>Watsonidia reimana</i>	1	4	19	24
Lithosiini				
<i>Abrochocis esparanza</i>	4	2	5	11
<i>Agylla</i> sp1.	4	7	4	15

<i>Agylla</i> sp2.	8	14	22	44
<i>Agylla</i> sp3.	1	1	-	2
<i>Agylla</i> sp4.	10	30	60	100
<i>Agylla</i> sp5.	-	-	8	8
<i>Agylla</i> sp6.	7	2	12	21
<i>Agylla</i> sp7.	2	3	1	6
<i>Balbura dorsisigna</i>	8	48	36	92
<i>Cloesia digna</i>	-	2	1	3
<i>Dolichesia falsimonia</i>	-	2	7	9
<i>Epeiromulona</i> cf. <i>lephina</i>	-	1	31	32
<i>Euthyone grisescens</i>	-	1	-	1
<i>Euthyone simplex</i>	-	2	7	9
<i>Euthyone</i> sp.	1	6	1	8
<i>Illice citrina</i>	-	1	-	1
<i>Illice croesus</i>	-	-	2	2
<i>Illice tessellata</i>	-	-	2	2
<i>Lithosiinae</i> undet.	-	1	5	6
<i>Lithosiinae</i> undet.	2	4	3	9
<i>Lithosiinae</i> undet.	-	7	5	12
<i>Lithosiinae</i> undet.	1	-	4	5
<i>Lithosiinae</i> undet.	-	-	1	1
<i>Lithosiinae</i> undet.	-	1	3	4
<i>Lycomorphodes sordida</i>	-	1	2	3
<i>Macroptila</i> sp.	3	1	1	5
<i>Metalobosia</i> sp1.	-	2	10	12
<i>Metalobosia</i> sp2.	-	-	1	1
<i>Nodozana hieroglyphica</i>	2	2	7	11
<i>Nudur fractivittarum</i>	3	7	7	17
<i>Odozana</i> sp.1	-	2	6	8
<i>Odozana</i> sp.2	-	3	6	9
<i>Palaeozana mida</i>	-	-	1	1
<i>Prepiella</i> sp.	2	4	6	12
<i>Talara</i> cf. <i>mona</i>	-	1	5	6
<i>Talara</i> cf. <i>rubida</i>	-	9	21	30
Bombycoidea				
Bombycidae				
<i>Anticla antica</i>	7	12	29	48
<i>Apatelodes albipunctata</i>	-	2	3	5
<i>Apatelodes pandariodes</i>	-	5	-	5
<i>Apatelodes satallitia</i>	-	11	-	11
<i>Colla coelestis</i>	1	26	16	43
<i>Drepatelodes umbrilinea</i>	-	2	1	3
<i>Epia casnonia</i> sp1.	-	2	2	4
<i>Epia casnonia</i> sp2.	-	-	2	2
<i>Epia muscosa</i>	-	4	6	10
<i>Olceclostera</i> cf. <i>magniplaga</i>	1	13	20	34
<i>Olceclostera</i> cf. <i>reperta</i>	1	6	7	14
<i>Olceclostera nigripuncta</i>	-	1	1	2

<i>Phiditia cuprea</i>	-	4	1	5
<i>Quentalia chromana</i>	-	2	9	11
Lasiocampidae				
<i>Artace cribraria</i>	-	-	1	1
<i>Euglyphis amaturia</i>	1	1	5	7
<i>Euglyphis cf. asapha</i>	5	6	21	32
<i>Euglyphis cf. definita</i>	6	18	25	49
<i>Euglyphis cf. larundo</i>	-	5	1	6
<i>Euglyphis maria</i>	-	7	2	9
<i>Euglyphis rundula</i>	-	40	11	51
<i>Euglyphis sp1.</i>	13	25	42	80
<i>Euglyphis sp2.</i>	1	-	-	1
<i>Euglyphis sp3.</i>	-	1	-	1
<i>not determined</i>	-	1	-	1
<i>Prorifrons antonia</i>	-	1	2	3
Mimallonidae				
<i>Alheita cf. counamama</i>	-	2	-	2
<i>Bedosia sp1.</i>	-	2	-	2
<i>Bedosia sp2.</i>	-	2	-	2
<i>Druentia inscita</i>	-	-	1	1
<i>Druentica partha</i>	1	7	1	9
<i>Psychocampa prominens</i>	-	8	1	9
Saturniidae				
<i>Adeloneivaia jason</i>	-	-	2	2
<i>Adeloneivaia sp.</i>	-	-	1	1
<i>Arsenura batesii</i>	-	1	-	1
<i>Automeris belti</i>	2	8	6	16
<i>Automeris postalbida</i>	1	7	5	13
<i>Automeris zugana</i>	-	-	1	1
<i>Automeris zurobara</i>	-	1	-	1
<i>Caio championi</i>	1	-	3	4
<i>Citheronia volcan</i>	-	2	-	2
<i>Copaxa moinieri</i>	-	-	1	1
<i>Copiopteryx semiramis</i>	-	2	-	2
<i>Eacles imperialis</i>	-	1	-	1
<i>Hylesia aenides</i>	-	1	-	1
<i>Hylesia continua</i>	-	3	1	4
<i>Hylesia invidiosa sp1.</i>	-	1	-	1
<i>Hylesia invidiosa sp2.</i>	1	2	-	3
<i>Hyperchiria nausica</i>	-	11	1	12
<i>Lonomia rufescens</i>	-	5	3	8
<i>Molippa tusina</i>	2	5	2	9
<i>Othorene purpurascens</i>	-	2	-	2
<i>Oxytenis beprea</i>	-	1	4	5
<i>Oxytenis modestia</i>	-	1	3	4
<i>Oxytenis naemia/nubila sp1.</i>	1	9	3	13
<i>Oxytenis naemia/nubila sp2.</i>	1	2	-	3
<i>Oxytenis naemia/nubila sp3.</i>	-	9	1	10

<i>Periphoba arcae</i> sp1.	3	5	9	17
<i>Periphoba arcae</i> sp2.	1	-	-	1
<i>Pseudodirphia meander</i>	1	1	2	4
<i>Pseudodirphia regia</i>	3	8	15	26
<i>Rhescyntis hippodamia</i>	-	20	12	32
<i>Rothschildia triloba</i>	-	5	7	12
<i>Schausiella santarosensis</i>	-	1	-	1
<i>Syssphinx quadrilineata</i>	-	1	1	2
<i>Therinia transversaria</i>	-	2	1	3
<i>Titaea tamerlan</i>	-	1	-	1
Sphingidae				
<i>Callionima pace</i>	-	1	-	1
<i>Cocytius lucifer</i>	-	-	1	1
<i>Eumorpha obliquus</i>	-	1	1	2
<i>Eumorpha phorbas</i>	-	2	-	2
<i>Eumorpha triangulum</i>	-	1	-	1
<i>Madoryx plutonius</i>	-	1	-	1
<i>Manduca florestan</i>	-	3	-	3
<i>Manduca occulta</i>	-	-	1	1
<i>Pachylia darceta</i>	-	5	-	5
<i>Xylophanes guinanensis</i>	-	1	-	1
<i>Xylophanes loelia</i>	-	-	1	1
<i>Xylophanes undata</i>	-	3	2	5
<i>Xylophanes zurcheri</i>	1	6	6	13
Geometridae				
Desmobathrinae				
<i>Dolichoneura cf. oxypteraria</i>	-	1	1	2
<i>Dolichoneura</i> sp1.	-	8	2	10
<i>Dolichoneura</i> sp2.	-	1	5	6
<i>Dolichoneura</i> sp3.	-	1	-	1
Ennominae				
<i>Aplogompha costimaculata</i>	-	11	34	45
<i>Argyrotope</i> sp.	-	1	-	1
<i>Ballantiophora gibbiferata</i>	-	-	5	5
<i>Betulodes</i> sp.	-	1	1	2
<i>Bryoptera</i> sp1.	-	1	1	2
<i>Bryoptera</i> sp2.	1	-	-	1
<i>Bryoptera subbrunea</i>	-	-	2	2
<i>Cimicodes albicosta</i>	7	7	1	15
<i>Clena cf. bannulata</i>	8	40	56	104
<i>Cyclomia minuta</i>	-	-	2	2
<i>Cyclomia</i> sp.	-	1	-	1
<i>Cyclomia vinosa</i>	-	1	1	2
<i>Cyclophora nivestrota</i>	1	8	15	24
Ennominae sp1.	6	25	21	52
Ennominae sp2.	3	3	15	21
Ennominae sp3.	1	2	1	4
Ennominae sp4.	1	-	-	1

Ennominae sp5.	1	-	-	1
<i>Epimecis cf. patronaria</i>	-	1	-	1
<i>Epimecis subroraria</i>	10	35	42	87
<i>Euclysia dentifasciata</i>	-	-	1	1
<i>Eusarca cf. nemora</i>	-	1	1	2
<i>Eusarca crameraria</i>	-	4	-	4
<i>Eusarca flexilis sp1.</i>	-	1	-	1
<i>Eusarca flexilis sp2.</i>	-	1	-	1
<i>Eusarca minucia</i>	3	3	3	9
<i>Eusarca sp1.</i>	-	2	1	3
<i>Eusarca sp2.</i>	-	3	-	3
<i>Eutomopepla artena</i>	-	1	-	1
<i>Eutomopepla discuneata</i>	-	-	2	2
<i>Herbita lilacina sp1.</i>	1	2	2	5
<i>Herbita lilacinas sp1.</i>	-	1	38	39
<i>Herbita merdona</i>	-	-	2	2
<i>Hymemomima camerata</i>	1	1	1	3
<i>Hymenomima sereata</i>	5	10	8	23
<i>Hymenomima sp1.</i>	-	19	15	34
<i>Hypometalla sp.</i>	-	6	7	13
<i>Ischnopteris illineata sp1.</i>	-	1	-	1
<i>Ischnopteris illineata sp2.</i>	-	1	-	1
<i>Ischnopteris sp1.</i>	-	3	-	3
<i>Isochromodes sp1.</i>	-	-	2	2
<i>Isochromodes sp2.</i>	2	1	11	14
<i>Isochromodes sp3.</i>	-	2	-	2
<i>Isochromodes sp4.</i>	17	14	-	31
<i>Leucris sp.</i>	-	-	2	2
<i>Leucula festiva</i>	9	4	4	17
<i>Macaria cf. catualda</i>	-	-	1	1
<i>Macaria gambarina</i>	-	1	1	2
<i>Macaria infusata</i>	-	1	-	1
<i>Macaria sp1.</i>	-	1	3	4
<i>Macaria sp2.</i>	-	-	3	3
<i>Macaria sp3.</i>	-	-	1	1
<i>Macaria sp4.</i>	-	-	2	2
<i>Macaria sp5.</i>	1	-	-	1
<i>Microgonia cf. rufaria</i>	-	1	5	6
<i>Microgonia sp.</i>	-	1	11	12
<i>not determined</i>	1	2	5	8
<i>Opisthoxia bella</i>	1	5	2	8
<i>Opisthoxia sp2.</i>	-	1	6	7
<i>Opisthoxia sp3.</i>	-	1	3	4
<i>Opisthoxia sp4.</i>	-	-	3	3
<i>Opisthoxia sp5.</i>	-	1	-	1
<i>Oxydia sp1.</i>	-	1	1	2
<i>Oxydia sp2.</i>	-	1	-	1
<i>Oxydia sp3.</i>	2	-	2	4

<i>Oxydia</i> sp4.	2	1	4	7
<i>Oxydia</i> sp5.	-	1	2	3
<i>Oxydia</i> sp6.	-	-	1	1
<i>Paragonia</i> cruraria	-	1	1	2
<i>Paragonia</i> sp1.	-	5	11	16
<i>Paragonia</i> sp2.	-	-	2	2
<i>Patalene</i> aenethusaria	-	-	3	3
<i>Patalene</i> cf. hamulata	-	1	6	7
<i>Patalene</i> sp1.	-	-	7	7
<i>Patalene</i> sp2.	-	1	7	8
<i>Patalene</i> sp3.	-	-	1	1
<i>Patalene</i> sp4.	-	-	1	1
<i>Patalene</i> sp5.	-	-	4	4
<i>Perigramma</i> albivena	-	8	22	30
<i>Perigramma</i> sp1.	-	1	-	1
<i>Perigramma</i> sp2.	-	21	36	57
<i>Perigramma</i> sp3.	-	-	1	1
<i>Perigramma</i> sp4.	-	4	5	9
<i>Perigramma</i> sp5.	-	-	8	8
<i>Perigramma</i> sp6.	-	-	1	1
<i>Perigramma</i> sp7.	1	-	-	1
<i>Perissopteryx</i> sp1.	-	1	3	4
<i>Perissopteryx</i> sp2.	-	2	1	3
<i>Perissopteryx</i> sp3.	-	1	-	1
<i>Perissopteryx</i> sp4.	-	-	1	1
<i>Perissopteryx</i> sp5.	-	1	-	1
<i>Perissopteryx</i> sp6.	-	1	-	1
<i>Pero</i> chapela	-	2	3	5
<i>Pero</i> sp.	-	6	1	7
<i>Petelia</i> sp1.	-	1	-	1
<i>Phrygionis</i> cf. privignaria	-	8	3	11
<i>Phyllodonta</i> sp.	-	-	5	5
<i>Physeocleora</i> pauper	3	89	171	263
<i>Physocleora</i> dukiinfieldi	3	30	32	65
<i>Physocleora</i> sp1.	-	10	13	23
<i>Physocleora</i> sp2.	1	1	1	3
<i>Physocleora</i> taeniata	-	1	9	10
<i>Procherodes</i> striata	-	2	-	2
<i>Prochoerodes</i> cf. tetragonata	-	2	4	6
<i>Pyrinia</i> helvaria	-	3	3	6
<i>Pyrinia</i> sp1.	51	36	7	94
<i>Pyrinia</i> sp2.	1	1	23	25
<i>Pyrinia</i> sp3.	-	-	1	1
<i>Pyrinia</i> sp4.	-	1	3	4
<i>Pyrinia</i> sp5.	2	12	2	16
<i>Pyrinia</i> transitata	-	11	23	34
<i>Sericoptera</i> reducata	-	2	1	3
<i>Sphacelodes</i> sp.	-	2	3	5

<i>Sphacelodes vulneraria</i>	1	3	2	6
<i>Thyrinteina arrobiata</i>	-	1	1	2
<i>Thysanopaga sp1.</i>	1	3	8	12
<i>Thysanopaga sp2.</i>	-	14	43	57
<i>Thysanopyga sp3.</i>	-	1	-	1
<i>Thysanopyga sp4.</i>	-	1	1	2
<i>Thysanopyga sp5.</i>	1	1	6	8
<i>Thysanopyga sp6.</i>	-	2	5	7
<i>Thysanopyga sp7.</i>	-	-	1	1
<i>Tmetomorpha bitias</i>	-	7	11	18
Geometrinae				
<i>Chloropteryx sp1.</i>	3	8	6	17
<i>Chloropteryx sp2.</i>	3	10	8	21
<i>Chloropteryx sp3.</i>	-	4	10	14
<i>Chloropteryx sp4.</i>	-	-	4	4
<i>Chloropteryx sp5.</i>	-	2	-	2
Geometrinae	2	1	4	7
<i>Hydata povera</i>	-	2	-	2
<i>Hydata sp.</i>	-	-	1	1
<i>Nemoria cf. defectiva</i>	2	1	1	4
<i>Nemoria scriptaria</i>	-	17	14	31
<i>Nemoria adjunctaria</i>	1	4	-	5
<i>Nemoria cf. punctilineata</i>	-	-	4	4
<i>Nemoria sp1.</i>	1	1	2	4
<i>Nemoria sp2.</i>	-	-	1	1
<i>Nemoria cf. pacificaria</i>	-	-	1	1
<i>Oospila albicoma</i>	2	1	2	5
<i>Oospila sp.</i>	-	-	1	1
<i>Oospila albipunctulata</i>	-	2	-	2
<i>Oospila ruptimaculata</i>	-	1	-	1
<i>Oospila atopochlora</i>	-	-	2	2
<i>Phrudocentra albicoronata</i>	-	-	2	2
<i>Pyrochlora ranis</i>	-	-	2	2
<i>Rhodochlora brunneipalpis</i>	2	11	13	26
<i>Synchlora sp1.</i>	1	-	7	8
<i>Synchlora sp2.</i>	-	3	5	8
<i>Synchlora sp3.</i>	-	-	1	1
<i>Synchlora sp4.</i>	-	-	2	2
Larentiinae				
<i>Dyspteris sp.</i>	5	28	44	77
<i>Dyspteris tenuivitta</i>	1	8	20	29
<i>Dyspteris trifilaria</i>	-	1	2	3
<i>Dyspteris vecinaria</i>	-	2	1	3
<i>Eios apyraria sp1.</i>	-	-	1	1
<i>Eios apyraria sp2.</i>	-	1	1	2
<i>Eois cf. cedon</i>	-	-	1	1
<i>Eois cf. plana</i>	1	-	-	1
<i>Eois cf. subtectata</i>	-	1	-	1

<i>Eois cf. undolosata</i> sp1.	-	10	2	12
<i>Eois cf. undolosata</i> sp2.	1	1	-	2
<i>Eois cf. zenobia</i>	1	4	3	8
<i>Eois russearia</i>	1	4	1	6
<i>Eois</i> sp1.	-	4	-	4
<i>Eois</i> sp2.	-	-	1	1
<i>Eois</i> sp3.	-	1	-	1
<i>Eois</i> sp4.	-	1	-	1
<i>Euphyia</i> sp.	-	-	1	1
<i>Eupithecia</i> sp1.	3	11	22	36
<i>Eupithecia</i> sp2.	2	15	14	31
<i>Eupithecia</i> sp3.	4	16	23	43
<i>Eupithecia</i> sp4.	-	-	1	1
<i>Eupithecia</i> sp5.	1	-	-	1
<i>Spargania</i> sp.	-	1	-	1
Oenochrominae				
<i>Ergavia</i> sp1.	-	2	-	2
<i>Ergavia</i> sp2.	-	1	-	1
<i>Zanclopteryx</i> sp1.	-	-	1	1
<i>Zanclopteryx</i> sp2.	-	1	1	2
Sterrhinae				
<i>Cyclophora griseomixta</i>	-	2	2	4
<i>Cyclophora insignata</i>	-	3	2	5
<i>Cyclophora melitia</i>	-	9	31	40
<i>Cyclophora nodigera</i>	1	-	2	3
<i>Cyclophora</i> sp1.	-	1	-	1
<i>Cyclophora</i> sp2.	-	2	1	3
<i>Cyclophora</i> sp3.	-	-	1	1
<i>Cyclophora</i> sp4.	-	-	1	1
<i>Cyclophora</i> sp6.	4	6	9	19
<i>Cyclophora</i> sp7.	-	-	4	4
<i>Cyclophora</i> sp8.	-	5	2	7
<i>Cyclophora</i> sp9.	-	1	-	1
<i>Cyclophora</i> sp10.	-	-	8	8
<i>Dithecodes</i> sp1.	-	-	1	1
<i>Dithecodes</i> sp2.	-	1	-	1
<i>Hemipterodes subnigrata</i>	-	-	2	2
<i>Hemipterodes subrotundata</i>	2	5	3	10
<i>Idaea cf. rubidentata</i>	1	9	5	15
<i>Idaea</i> sp1.	-	1	-	1
<i>Idaea</i> sp2.	-	-	1	1
<i>Idaea</i> sp3.	-	2	2	4
<i>Idaea subfervens</i>	2	-	-	2
<i>Leptostales angulata</i>	-	-	1	1
<i>Leptostales delia</i>	-	-	1	1
<i>Leptostales</i> sp.	-	-	3	3
<i>Lobocleta</i> sp.	-	-	4	4
<i>Lopocleta subcincta</i>	-	-	1	1

<i>not determined</i>	-	1	7	8
<i>not determined</i>	1	-	3	4
<i>Paragonia cf. tasima</i>	-	-	5	5
<i>Petelia sp1.</i>	-	1	-	1
<i>Petelia sp2.</i>	-	-	5	5
<i>Pleuroprucha sp1.</i>	-	-	1	1
<i>Pleuroprucha sp2.</i>	-	2	2	4
<i>Pleuroprucha sp3.</i>	-	3	2	5
<i>Proutoscia mirifica</i>	-	9	31	40
<i>Ptychamalia cf. dimplex</i>	1	-	2	3
<i>Scopula sp.</i>	-	1	-	1
<i>Semaeopus illimitata</i>	-	2	1	3
<i>Semaeopus paplamearia sp1.</i>	-	-	1	1
<i>Semaeopus paplamearia sp2.</i>	-	-	1	1
<i>Semaeopus sp1.</i>	4	6	9	19
<i>Semaeopus sp2.</i>	-	-	4	4
<i>Semaeopus sp3.</i>	-	5	2	7
<i>Semaeopus sp4.</i>	-	1	-	1
<i>Semaeopus sp5.</i>	-	-	8	8
<i>Semaeopus sp6.</i>	-	-	1	1
<i>Semaeopus sp8.</i>	-	1	-	1
<i>Semaeopus sp9.</i>	-	-	2	2
<i>Semaeopus sp10.</i>	2	5	3	10
<i>Semaeopus sp11.</i>	1	9	5	15
<i>Sterhinae undet.</i>	-	1	-	1
<i>Tricentogyna sp1.</i>	-	-	1	1
<i>Tricentogyna sp2.</i>	-	2	2	4
<i>Tricentogyna sp3.</i>	2	-	-	2
<i>Tricentra sp1.</i>	-	-	1	1
<i>Tricentra sp2.</i>	-	-	1	1
<i>Tricentra sp3.</i>	-	-	3	3
<i>Tricentra sp4.</i>	-	-	4	4
<i>Tricentra sp5.</i>	-	-	1	1
<i>Tricentra sp6.</i>	-	1	7	8
<i>Tricentra sp7.</i>	1	-	3	4
<i>Tricentra sp8.</i>	-	-	5	5
Unknown genus				
<i>not determined</i>	-	1	2	3
<i>not determined</i>	-	7	5	12
<i>not determined</i>	-	-	2	2
<i>not determined</i>	-	-	2	2

Table A2: Results of multivariate Dispersion (MVDISP) analyses showing the dispersion of all observed moths, Arctiinae subfamily, Bombycoidea superfamily and Geometridae family at the three different forest types (CF=Creek forest, SF=Slope forest, RF=Ridge forest) based on Bray-Curtis similarities.

	Relative Dispersion		
	Creek Forest	Slope Forest	Ridge Forest
All moths	1,652	0,957	0,391
Arctiinae	1,652	0,875	0,472
Bombycoidea	1,572	0,722	1,571
Geometridae	1,6	1,038	0,362

Table A3: Summary of the lower-taxonomic levels of the Arctiinae (Arctiini, Lithosiini), Bombycoidea (Bombycidae, Lasiocampidae, Mimallonidae, Saturnidae, Sphingidae) and Geometridae (Desmobathrinae, Ennominae, Geometrinae, Larentiinae, Sterrhinae) and abundance, species richness and relative proportion at the three different forest sites.

	CF		SF		RF	
	N (%)	S (%)	N (%)	S (%)	N (%)	S (%)
Arctiinae						
Arctiini	168 (76,02)	33 (68,75)	1070 (87,28)	89 (75,42)	1768 (86,97)	121 (79,08)
Lithosiini	53 (23,98)	15 (31,25)	156 (12,72)	29 (24,58)	265 (13,03)	32 (20,92)
Bombycoidea						
Bombycidae	10 (18,18)	4 (18,18)	97 (31,7)	12 (23,08)	90 (24,59)	13 (19,4)
Lasiocampidae	26 (47,27)	5 (22,73)	110 (35,95)	9 (17,3)	105 (28,69)	10 (14,93)
Mimallonidae	1 (1,81)	1 (4,55)	3 (0,98)	3 (5,77)	21 (5,74)	5 (7,46)
Saturnidae	17 (30,91)	11 (50)	84 (27,45)	22 (42,31)	118 (32,24)	29 (43,28)
Sphingidae	1 (1,81)	1 (4,55)	12 (3,92)	6 (11,54)	24 (6,56)	10 (14,93)
Geometridae						
Desmobathrinae	-		11 (1,21)	4 (2,42)	8 (0,57)	3 (1,55)
Ennominae	148 (71,15)	31 (49,21)	530 (58,5)	90 (54,54)	853 (60,58)	93 (48,19)
Geometrinae	23 (11,06)	11 (17,46)	81 (8,94)	16 (9,7)	129 (9,17)	24 (12,44)
Larentiinae	15 (7,21)	9 (14,29)	98 (10,82)	17 (10,3)	108 (7,67)	16 (8,29)
Oenochrominae	-		4 (0,44)	3 (1,81)	2 (0,14)	2 (1,04)
Sterrhinae	22 (10,58)	12 (19,05)	174 (19,21)	33 (20)	297 (21,09)	51 (26,42)
Not assigned	-		8 (0,88)	2 (1,21)	11 (0,78)	4 (2,07)

Table A4: Results of the indicator value analysis relative to the forest types (). Presented are the test statistic (IndVal) and its associated p-value, but only for species with significant association with one or two forest types. Except for the species of the ridge forest (RF), because there only species with an IndVal of >1 are presented to reduce the great number of species associated with this forest type.

	(Sub)-Family	Species number	Species	IndVal	p
Slope forest					
	Bombycidae	Bmb007	<i>Quentalia chromana</i>	0.826	0.013
	Arctiinae	Arc021	<i>Ochrodota pronapides</i>	0.823	0.005
Ridge forest					
	Arctiinae	Arc123	<i>Ecereon cf. atrigutta</i>	1.000	0.001
	Geometridae	Geo004	<i>Ballantiophora gibbiferata</i>	1.000	0.001
	Geometridae	Geo014	<i>Bryoptera subbrunea</i>	1.000	0.001
	Geometridae	Geo041	<i>Chloropteryx sp4.</i>	1.000	0.001
	Geometridae	Geo047	<i>Cyclomia minuta</i>	1.000	0.001
	Geometridae	Geo050	<i>Cyclophora melitia</i>	1.000	0.001
	Geometridae	Geo058	<i>Cyclophora sp3.</i>	1.000	0.001
	Geometridae	Geo063	<i>Cyclophora sp6.</i>	1.000	0.001
	Geometridae	Geo066	<i>Cyclophora sp7.</i>	1.000	0.001
	Geometridae	Geo073	<i>Eios apyraria sp1.</i>	1.000	0.001
	Geometridae	Geo079	<i>Eois cf. cedon</i>	1.000	0.001
	Geometridae	Geo082	<i>Euphyia sp.</i>	1.000	0.001
	Geometridae	Geo083	<i>Eutomopepla discuneata</i>	1.000	0.001
	Geometridae	Geo091	<i>Herbita merdona</i>	1.000	0.001
	Geometridae	Geo093	<i>Hydata sp.</i>	1.000	0.001
	Geometridae	Geo094	<i>Isochromodes sp1.</i>	1.000	0.001
	Geometridae	Geo107	<i>Leucris sp.</i>	1.000	0.001
	Geometridae	Geo109	<i>Leptostales sp.</i>	1.000	0.001
	Geometridae	Geo114	<i>Nemoria cf. punctilineata</i>	1.000	0.001
	Geometridae	Geo115	<i>Nemoria sp2.</i>	1.000	0.001
	Geometridae	Geo121	<i>Nemoria cf. pacificaria</i>	1.000	0.001
	Geometridae	Geo122	<i>not determined</i>	1.000	0.001
	Geometridae	Geo132	<i>Oospila sp.</i>	1.000	0.001
	Geometridae	Geo133	<i>Opisthoxia sp4.</i>	1.000	0.001
	Geometridae	Geo134	<i>Patalene aenethusaria</i>	1.000	0.001
	Geometridae	Geo136	<i>Patalene sp1.</i>	1.000	0.001
	Geometridae	Geo139	<i>Patalene sp2.</i>	1.000	0.001
	Geometridae	Geo147	<i>Patalene sp3.</i>	1.000	0.001
	Geometridae	Geo151	<i>Patalene sp5.</i>	1.000	0.001
	Geometridae	Geo154	<i>Perigramma sp3.</i>	1.000	0.001
	Geometridae	Geo156	<i>Perigramma sp5.</i>	1.000	0.001
	Geometridae	Geo157	<i>Perigramma sp6.</i>	1.000	0.001
	Geometridae	Geo159	<i>Perigramma sp7.</i>	1.000	0.001
	Geometridae	Geo166	<i>Phrudocentra albicoronata</i>	1.000	0.001
	Geometridae	Geo169	<i>Phyllodonta sp.</i>	1.000	0.001
	Geometridae	Geo172	<i>Paragonia cf. tasima</i>	1.000	0.001
	Geometridae	Geo176	<i>Semaeopus paplamearia sp1.</i>	1.000	0.001
	Geometridae	Geo177	<i>Semaeopus sp2.</i>	1.000	0.001
	Geometridae	Geo178	<i>Semaeopus sp5.</i>	1.000	0.001
	Geometridae	Geo179	<i>Semaeopus sp10.</i>	1.000	0.001

	Geometridae	Geo182	<i>Synchlora sp4.</i>	1.000	0.001
	Geometridae	Geo183	<i>Tricentra sp1.</i>	1.000	0.001
	Geometridae	Geo186	<i>Tricentra sp2.</i>	1.000	0.001
	Geometridae	Geo188	<i>Tricentra sp5.</i>	1.000	0.001
	Geometridae	Geo189	<i>Tricentra sp7.</i>	1.000	0.001
	Geometridae	Geo190	<i>Thysanopyga sp7.</i>	1.000	0.001
	Geometridae	Geo191	<i>Dithecodes sp1.</i>	1.000	0.001
	Geometridae	Geo198	<i>Eois sp2.</i>	1.000	0.001
	Geometridae	Geo200	<i>Euclysia dentifasciata</i>	1.000	0.001
	Geometridae	Geo201	<i>Eupithecia sp4.</i>	1.000	0.001
	Geometridae	Geo202	<i>Dithecodes sp2.</i>	1.000	0.001
	Geometridae	Geo203	<i>Macaria cf. catualda</i>	1.000	0.001
	Geometridae	Geo211	<i>Macaria sp3.</i>	1.000	0.001
	Geometridae	Geo212	<i>Macaria sp4.</i>	1.000	0.001
	Geometridae	Geo213	<i>not determined</i>	1.000	0.001
	Geometridae	Geo215	<i>not determined</i>	1.000	0.001
	Geometridae	Geo218	<i>Oospila atopochlora</i>	1.000	0.001
	Geometridae	Geo219	<i>Oxydia sp6.</i>	1.000	0.001
	Geometridae	Geo220	<i>not determined</i>	1.000	0.001
	Geometridae	Geo221	<i>Paragonia sp2.</i>	1.000	0.001
	Geometridae	Geo222	<i>Patalene sp4.</i>	1.000	0.001
	Geometridae	Geo225	<i>Perissopteryx sp4.</i>	1.000	0.001
	Geometridae	Geo226	<i>Pyrinia sp3.</i>	1.000	0.001
	Geometridae	Geo229	<i>Pyrochlora ranis</i>	1.000	0.001
	Geometridae	Geo236	<i>Ptychamalia cf. dimplex</i>	1.000	0.001
	Geometridae	Geo238	<i>Scopula sp.</i>	1.000	0.001
	Geometridae	Geo240	<i>Semaeopus sp3.</i>	1.000	0.001
	Geometridae	Geo241	<i>Synchlora sp3.</i>	1.000	0.001
	Geometridae	Geo244	<i>Tricentogyna sp1.</i>	1.000	0.001
	Geometridae	Geo245	<i>Tricentogyna sp2.</i>	1.000	0.001
	Geometridae	Geo247	<i>Tricentogyna sp3.</i>	1.000	0.001
	Geometridae	Geo248	<i>Tricentra sp8.</i>	1.000	0.001
				1.000	0.001
Ridge forest and Slope forest					
	Geometridae	Geo010	<i>Perigramma albivena</i>	1.000	0.001
	Geometridae	Geo011	<i>Perigramma sp2.</i>	1.000	0.001
	Geometridae	Geo146	<i>Hymenomima sp1.</i>	1.000	0.001
	Arctiinae	Arc029	<i>Delphyre testacea</i>	0.992	0.001
	Arctiinae	Arc025	<i>Episcepsis demonis</i>	0.991	0.001
	Geometridae	Geo017	<i>Physeocleora pauper</i>	0.989	0.001
	Arctiinae	Arc001	<i>Melese sixola sixola</i>	0.984	0.001
	Geometridae	Geo018	<i>Physocleora dukinfieldi</i>	0.980	0.002
	Geometridae	Geo024	<i>Lopocleta subcincta</i>	0.973	0.001
	Arctiinae	Arc012	<i>Heliura thysbodes</i>	0.971	0.007
	Geometridae	Geo019	<i>Nemoria scriptaria</i>	0.966	0.001
	Geometridae	Geo037	<i>Ennominae sp1.</i>	0.958	0.005
	Arctiinae	Arc004	<i>Virbia sp1.</i>	0.957	0.002
	Arctiinae	Arc127	<i>Saurita tipulina</i>	0.957	0.001
	Geometridae	Geo020	<i>Dyspteris sp.</i>	0.957	0.003
	Geometridae	Geo029	<i>Thysanopaga sp2.</i>	0.957	0.003

Geometridae	Geo032	<i>Cyclophora nodigera</i>	0.957	0.003
Geometridae	Geo036	<i>Eois cf. undolosata sp1.</i>	0.957	0.003
Geometridae	Geo059	<i>Physocleora sp1.</i>	0.957	0.002
Arctiinae	Arc028	<i>Balbura dorsisigna</i>	0.956	0.001
Geometridae	Geo068	<i>Clena cf. bannulata</i>	0.955	0.002
Geometridae	Geo105	<i>Semaeopus sp8.</i>	0.948	0.005
Arctiinae	Arc026	<i>Correbia sp.</i>	0.946	0.003
Bombycidae	Bmb004	<i>Colla coelestis</i>	0.946	0.008
Bombycidae	Bmb001	<i>Olceclostera cf. magniplaga</i>	0.943	0.002
Arctiinae	Arc128	<i>Correbidia sp.</i>	0.942	0.007
Arctiinae	Arc006	<i>Eucereon aurantiaca</i>	0.942	0.004
Geometridae	Geo162	<i>Eupithecia sp2.</i>	0.941	0.010
Geometridae	Geo056	<i>Rhodochlora brunneipalpis</i>	0.940	0.007
Geometridae	Geo161	<i>Eupithecia sp1.</i>	0.931	0.019
Arctiinae	Arc007	<i>Eucereon mitigatum</i>	0.926	0.007
Geometridae	Geo163	<i>Eupithecia sp3.</i>	0.926	0.009
Arctiinae	Arc013	<i>Aclytia cf. gyanomorpha</i>	0.919	0.015
Geometridae	Geo062	<i>Hymenomima sereata</i>	0.914	0.022
Arctiinae	Arc002	<i>Hyalurga sixola</i>	0.913	0.007
Arctiinae	Arc022	<i>Correbia sp.</i>	0.913	0.005
Arctiinae	Arc039	<i>Talara cf. rubida</i>	0.913	0.004
Saturniidae	Bmb015	<i>Rhescyntis hippodamia</i>	0.913	0.002
Lasiocampidae	Bmb066	<i>Euglyphis rundula</i>	0.913	0.009
Geometridae	Geo043	<i>Pyrinia transitata</i>	0.913	0.006
Geometridae	Geo074	<i>Aplogompha costimaculata</i>	0.913	0.005
Geometridae	Geo078	<i>Pleuroprucha sp1.</i>	0.913	0.005
Geometridae	Geo165	<i>Idaea sp2.</i>	0.913	0.006
Saturniidae	Bmb025	<i>Pseudodirphia regia</i>	0.900	0.022
Geometridae	Geo025	<i>Cyclophora insignata</i>	0.900	0.006
Arctiinae	Arc081	<i>Correbia sp.</i>	0.898	0.018
Lasiocampidae	Bmb065	<i>Euglyphis cf. definita</i>	0.897	0.050
Arctiinae	Arc110	<i>Melese cf. incertus</i>	0.866	0.013
Arctiinae	Arc087	<i>Lymire cf. fulvicollis</i>	0.850	0.020
Arctiinae	Arc034	<i>Lophocampa cf. modesta</i>	0.816	0.042
Arctiinae	Arc043	<i>Ormetica guapisa</i>	0.816	0.043
Arctiinae	Arc056	<i>Cosmosoma hector</i>	0.816	0.031
Arctiinae	Arc078	<i>Melese laodamia</i>	0.816	0.029