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# DIPLOMARBEIT

Titel der Diplomarbeit

## „Arthropod fauna in the leaf litter material of two humus collecting understorey plants in a tropical lowland rainforest, Costa Rica“

verfasst von

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**Abstract**. Arthropod assemblage in the leaf litter material of a lowland rainforest in Costa Rica. As low nutrient offer in tropical forests is an important limiting factor for plant growth, humus collecting, also called litter-trapping evolved as alternative alimentary strategy. Plant material from overstorey layers is collected in funnels, caused by the inclination of leaves, and turned by decomposers into humus, which can be tapped by using adventitious roots in the crown section, absorbation of nutrients by the leaf bases or other strategies of nutrient uptake. The funnel material is inhabited by a series of invertebrates, sometimes even lizards or birds use the humus material for egg deposition. Between July and October of 2008 the leaf litter material of two humus collecting understorey plant species, as well as leaf litter material from adjacent soil was collected at the two sampling sites hill-ridge and steep slope. Arthropod extraction was performed by using Berlese-Tullgren-Apparatus and showed that from more than 28,000 collected animals of 25 orders the most frequent are Acari, Collembola and Hymenoptera, the latter mostly Formicidae, forming groups of up to 300 individuals and coexisting with other species in the same leaf litter material. In general arthropods prefer colonising leaf litter material of collecting plants to the one of adjacent soil whereby the leaf litter material from palms along the slope is obviously favoured. Inhabited by a remarkable higher number of animals than the ones along the hill-ridge it seems to provide with various niches and stages of decomposition the most favourable and attractive biotopes of the investigated sampling areas.

**Keywords**. tropical arthropods, leaf litter fauna, humus collection, litter-trapping

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## 1. Introduction

The Golfo Dulce region in the southwest of Costa Rica shelters the last primary tropical lowland rainforest along the pacific coastline of Central America. It is one of the most species-rich areas in the Neotropics and holds the highest species-diversity within Costa Rica (WEISSENHOFER 2005). Since 1999, 148 km² of the eastern zone is declarated as Piedras Blancas national park and contain among secondary forest and grasslands dense primary vegetation. As low nutrient offer in tropical forests is an important limiting factor for plant growth, humus collecting, also called litter-trapping evolved as alternative alimentary strategy. The inclined position of the leaves, especially of the younger ones causes a funnel where dead leaves, twigs, fruits and other detritus from overstorey plant layers are collected and turned by decomposers into humus. Some litter trappers extract nutrients directly with adventitious roots in the crown section that grow into the humus, others are able to absorb the nutrients by their leaf bases (WEISSENHOFER & WEBER 1999). RAICH (1983) assumed that some understorey palms benefit from the nutrients washed out of the funnel litter and diverted down the stem directly to the rooting zone. Further absorbing mechanisms concerning nutrient uptake are under way.

Litter-trapping is a well-known stragety of epiphytes but NG described this phenomenon 1980 in Malaysia for the first time on the understorey tree *Agrostistachys longifolia var. longifolia* (WIGHT 1888-1889). Biodiversity studies in the Piedras Blancas national park (WEISSENHOFER 1996, HUBER 1996) show that beside trees some of the understorey palms, herbs and grass use the litter collecting strategy as well.

In the funnel material colonise a series of animals as earthworms, mites, ants, spiders, chilopods, diplopods and more. Sometimes even birds and lizards use the humus material for egg deposition. VASCONCELOS (1990) counted in his study in Central Amazonia a high abundance of Formicidae which concures with the results of a study on the litter trapping epiphytic Bird’s Nest Fern (*Asplenium* nidus) by ELLWOOD, JONES and FOSTER (2002).

The aim of the study is the investigation of the arthropod fauna in the leaf litter material of two humus collecting plant species at the two sampling sites hill-ridge and steep slope. Questions, whether there is a difference between the two sites on the one hand, and between leaf litter collecting plants and adjacent soil leaf litter on the other hand are likely to be answered.

## 2. Material and Methods

### 2.1. Sampling Area

The investigation took place in a primary lowland forest at the eastern border of the Piedras Blancas National Park near the Tropical Field Station La Gamba, Golfo Dulce region, Costa Rica.

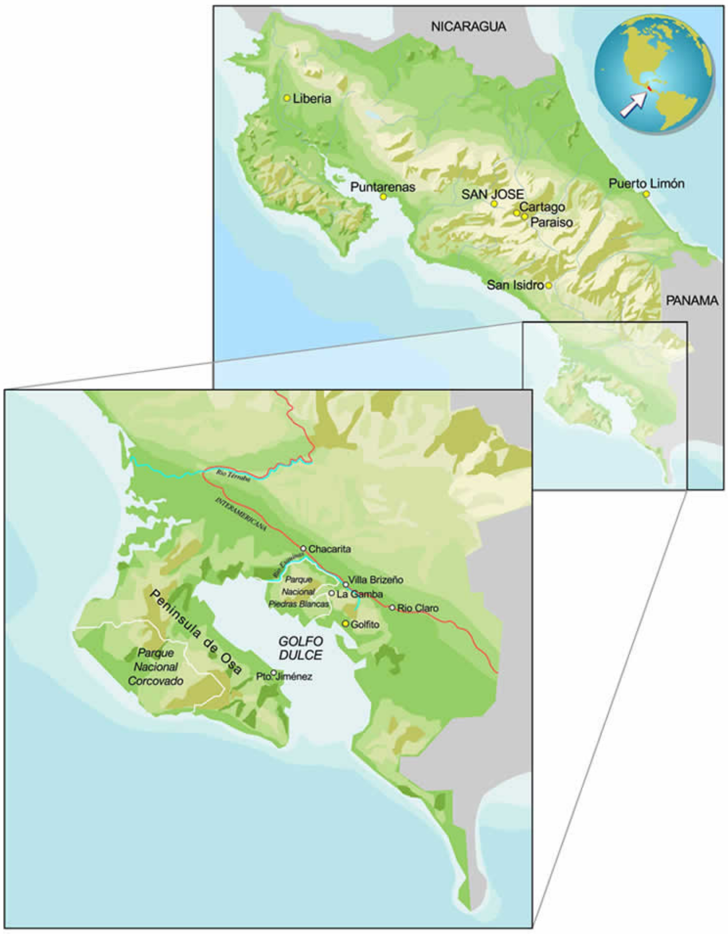


**Figure 1: Costa Rica and the Golfo Dulce Region with the Piedras Blancas National Park (Parque Nacional Piedras Blancas).**
**Source: http://www.lagamba.at/researchdb/pagede/index.php**

**Soils.** The most common soils are Ultisols, strongly weathered, clayey, acidic, yellowish-red subsoils with low nutrient supply and due to leaf litter decomposition a slightly nutrient richer surface horizon. Mainly they are found on ridges and upper slopes (WEBER et al.2001).
Where erosive processes and high precipitation washed away the older Ultisol layers Inceptisols developed. Slightly weathered and still partly containing parent rock material and primary minerals, these yellowish-brown soils mostly show a higher nutrient supply as Ultisols. At slopes they are found more from lower parts down to riverine areas (WEBER et al.2001).

**Climate.** The majority of Costa Rica's pacific side is part of the zone of tropical-subtropical rainy season forests and savanna (GRABHERR 1997). Seasonality is shown by a distinct rainy season (May – November) with heaviest rainfalls occurring around October and November and a dry season (December – April). The driest months are February and March, sometimes it does not rain for days, however precipitation rarely falls below 200 mm per month (WEBER et al.2001). During the drier period some trees drop their leaves completely which plays an important role for the quantity and the composition of the leaf litter on the forest floor. Temperature measurements, done by employee of the Field Station La Gamba ("Tropenstation La Gamba") since 1993, show monthly averages ranging from 22.3°C to 28°C and a mean annual temperature of 25.2°C inside the forest. The Golfo Dulce region is classified as one of the most rain-laden of the world. On average, rain falls occur 302 days per year with around 6000mm annual precipitation (WEISSENHOFER et al. 2009). Relative humidity is 97.7% on average (WEBER et al.2001).

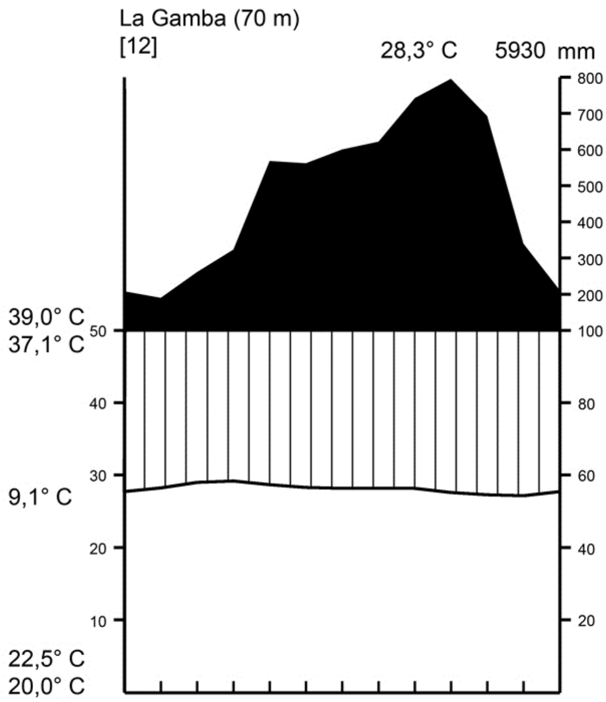


**Figure 2: Climograph La Gamba, Costa Rica.**
**Source: A.Weissenhofer & W.Huber 2008, The climate of the Esquinas rainforest in Natural and Cultural History of the Golfo Dulce Region, Costa Rica, edited by A.Weissenhofer, W. Huber, V. Mayer, S. Pamperl, A.Weber and G.Aubrecht – STAPFIA Series 88 Linz**

**Sampling sites.** The landscape is characterised by a varied relief mainly composed of hill-tops and ridges, steep slopes (slope gradients around 60% and more) and ravines. Following two sampling sites were selected: (1) a narrow hill-ridge and (2) an adjacent steep slope, bordered at the bottom by a brook.

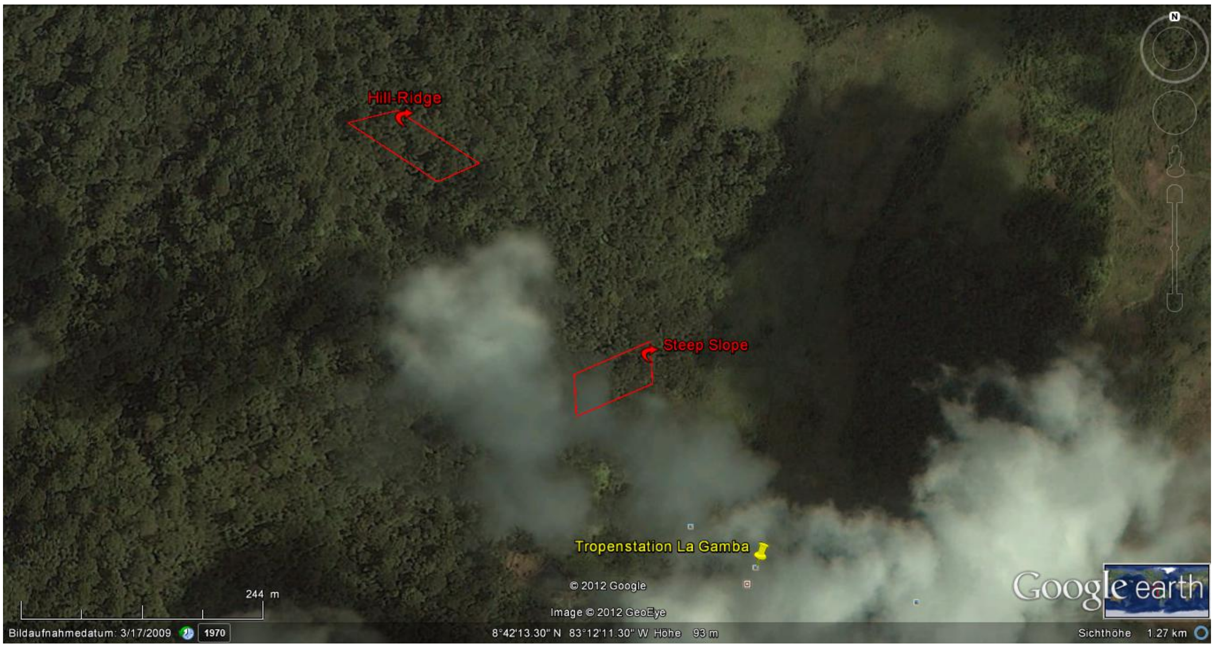


**Figure 3: The two sampling sites hill-ridge (8°42’19’’N, 83°12’17’’W; 155m) and steep slope (8°42’11’’N, 83°12’11’’W; 86m)**
**Source: Google Earth**

(1) Hill-top and ridge forests are with around 179 different tree species and 847 individuals per hectare (diameter at breast height = d.b.h. > 10 cm) the most species-rich and individual-rich forests of the region (HUBER 2005, WEISSENHOFER 2005). As a result of exposed position, light irradiation, wind and rain influence the development of the plant cover (WEBER et al.2001; WEISSENHOFER et al. 2008). Up to 50 m tall canopy trees overtop a dense layer of mid- and subcanopy trees and palms. Below, clustered palms and treelets are common, building a heterogeneous understorey. Depending on density of upper forest layers, ground vegetation can be diverse. At more open sites, mostly older tree-fall gaps, plants as the Cyperaceae ***Becquerelia cymosa*** (BRONGIART 1833) are very common whereas at young gaps vines and ferns can develop impenetrable thickets (WEISSENHOFER et al. 2008). Larger tree-fall gaps are vegetated by pionier trees, treelets and shrubs (WEBER et al.2001).

(2) Slope forests are more humid than the ones on hill-tops and ridges (WEBER et al. 2001). As in ridge forests, the canopy trees grow up to 50 m tall but the middlecanopy is usually less dense than the subcanopy. Worth mentioning is the

high amount of palms in the substorey with up to 25% of the individuals with diameter at breast height over 10 cm (WEISSENHOFER et al. 2008). The understorey is mainly formed by treelets and dwarf palms as ***Asterogyne martiana*** (H. WENDL. ex HEMSL 1885), *Geonoma cuneata* (H. WENDL ex. SPRUCE 1869) and *Calyptrogyne ghiesbreghtiana* ((LINDEN & H. WENDL) H. WENDL 1859). Ground vegetation usually is relatively bare (WEBER et al. 2001).

**2.2. Period of Investigation and Sampling**

**Period.** The period of investigation and data collection was from 12th of July until 13th of October 2008.

**Litter trapping plants for sampling.** The leaf litter material was removed from the collecting leaf funnel of the two understorey plant species ***Becquerelia cymosa*** (Cyperaceae) and ***Asterogyne martiana*** (Arecaceae).

*Becquerelia cymosa* is a perennial herb with a short, solitary culm. The up to 1.5 m long leaves build at their base a rosette-shaped funnel where the litter material accumulates. In the Esquinas Rainforest it mainly grows at more open sites along hill ridges. It is found in Central America and tropical areas of South America.

*Asterogyne martiana* is an up to four meters tall dwarf palm, forming solitary reptant or erect stems up to 5 cm thick. The simple, bifid leaves form at the leaf base a funnel where fallen off small branches, leaves, fruits etc. from upper plant layers are collected. It grows preferentially along moist slopes and valley bottoms. Distribution ranges from Guatemala and Belize to northwestern Colombia (WEBER et al. 2001).

 

**Figure 4:** ***Becquerelia cymosa*** **(Cyperaceaea)**
**Source: [http://bioexplorador.inbio.ac.cr](http://bioexplorador.inbio.ac.cr)**

**Figure 5:** ***Asterogyne martiana*** **(Arecaceaea)**
**Source: [http://www.vinv.ucr.ac.cr/herbario/](http://www.vinv.ucr.ac.cr/herbario/)**

**Sampling.** Altogether 65 samples were taken at the two sites hill-ridge and slope forest. In the hill-ridge area material was removed from 15 specimen of *Becquerelia cymosa* (Cyperaceae). In the slope forest litter sampling happened on 30 specimen of the understorey litter trapping palm *Asterogyne martiana* (Arecaceae), 15 taken from plants with the collecting funnel at ground level and 15 at in about 1.5 - 2 meters of height. Additionally at each sampling site, hill-ridge and slope forest, 10 leaf litter samples of the adjacent soil were taken by collecting the material of 20*20 centimeter sized plots.

The funnel material was collected by hand, falling down parts caught by a plastic layer on the ground. The ground leaf litter samples were removed by a hand shovel. As the rainfalls during the rain season occur typically in the afternoon, sampling happened before noon to avoid falsification regarding humidity measurement and ratio fresh weight/dry weight.

**Table 1: Number of samples and collecting locations**

| Site code | Label | Description | Site | Samples |
|---|---|---|---|---|
| 1 | SH | Soil litter at hill-ridge | hill-ridge | 10 |
| 2 | PH | Plant litter at hill-ridge from *Becquerelia cymosa*; funnel position low near ground level | hill-ridge | 15 |
| 3 | SS | Soil litter at steep slope | steep slope | 10 |
| 4 | PSl | Plant litter at steep slope from *Asterogyne martiana*; funnel position low near ground level | steep slope | 15 |
| 5 | PSh | Plant litter from *Asterogyne martiana* ; funnel position in 1.5 – 2m height | steep slope | 15 |

### 2.3. Additional habitat investigations.

With a measurement device for humidity (Testo Hygrotest 6250; Testosterm, Vienna) and temperature (Measurement device for Temperature 4210; Testosterm, Vienna) air humidity and temperature outside and inside the litter material were taken at the 5 sampling areas.

### 2.4. Sorting.

Macroinvertebrates over approximately 5 millimeters were handsorted. The seperation of the remaining invertebrates from the funnel material was performed by using Berlese-Tullgren-Apparatus (25 W light bulb, 25-cm-diameter funnel, 2 mm mesh size). The run time for each apparatus was 24-48 hours, depending on the sample moisture content and mass, but in all cases until the material was completely dry. The invertebrates were collected in bins with glycerine diluted with water 1:1 (back in Austria the animals were transfered to ethanol 75%). After invertebrate extraction, the residual litter material was oven-dried for ≥ 48 hours and weighed to the nearest 0.1g on an electronic balance (Acculab Sartorious group Vicon, 6kg).

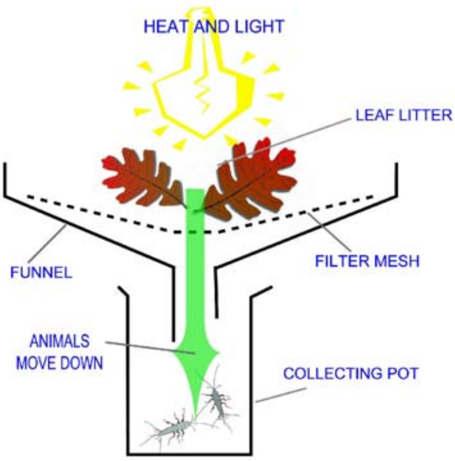


**Figure 6: Design of a Berlese-Tullgren-Apparatus.**

### 2.5. Data Analysis.

**Presence-Absence.**

Presence of the collected arthropods presentated in tables.

**Fauna distribution.**

Presentation of the collected arthropod fauna in bar graph.

**SPSS.**

The statistical analyses were carried out using the programme SPSS version 14.0. All results are based on mean individual densities per dry weight, tested were only groups which were found in at least 33,3% of the samples of each sampling zone. Boxplots were made for visual comparison. Kruskal-Wallis test was used for significant differences within the five sampling zones, Mann-Whitney for analysing specific sample pairs.

A hierarchical cluster analysis was applied to demonstrate similarieties between the five observed sampling zones. Pearson correlation and average linkage grouping stragety were chosen.

## 3. Results

All in all 28,120 individuals of 25 orders were collected. The identification of terrestrial tropical invertebrates is difficult as the topic partly is not investigated yet or specialists are necessary.

### 3.1. Additional habitat investigations.

Air humidity measurements show a steady trend throughout the investigation time. At all five collecting locations data ranges from 99,9-100%.

Temperature measurements were conducted in each of the 65 sampling points investigated. Comparing between the five sampling areas does not show noteworthy trends. Data ranges from 25 to 28 degrees but none of the sampling sites is in a noticable contrast to the others. Figure 7 shows exemplarily the comparison of temperature outside and inside the leaf litter material by means of samples of *Asterogyne martiana* since at all five collecting locations the values of the two temperatures are mostly the same or differ less than 0.3 degrees.

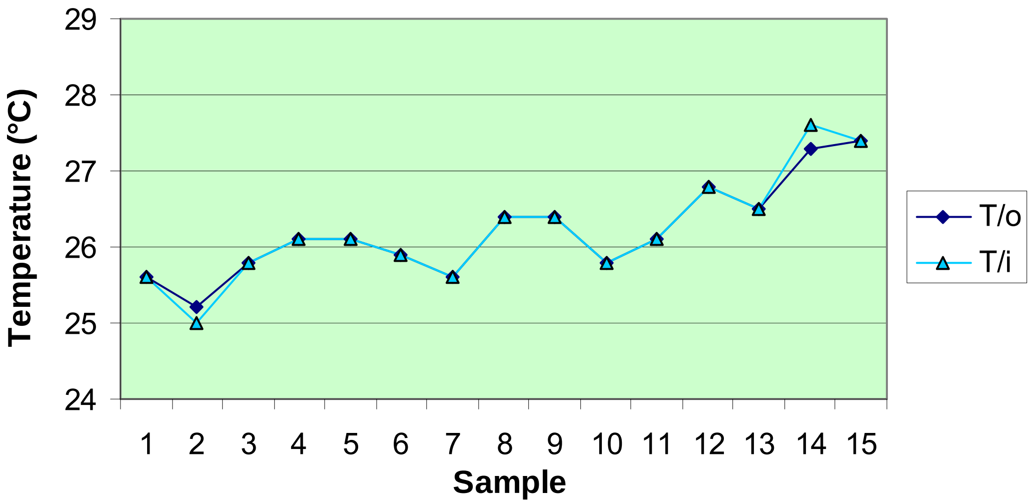


**Figure 7: Temperature measurements at 15 plants of *Asterogyne martiana*. Temperature gauged outside (T/o) and inside the litter (T/i).**

### 3.2. Presence-Absence.

Table 2 shows presence respectively absence of the 25 collected orders at every of the five sampling zones. More than 50% of the orders appear at every collecting zone. Five orders only occur along the steep slope (Scorpiones, Blattodea, Julida, Polyxenida, Siphonophorida) while no order is exclusively restricted to the hill-ridge. It is noticeable that termites (Isoptera) are limited to funnel leaf litter of plants (PH, PSl, PSh) while Chordeumatida only appear in the leaf litter taken from the forest floor.

**Table 2: Presence-Absence of orders at the five sampling zones.**

| | SH | PH | SS | PSl | PSh |
|---|---|---|---|---|---|
| Acari | X | X | X | X | X |
| Araneae | X | X | X | X | X |
| Opiliones | X | X | X | X | X |
| Pseudoscorpiones | X | X | X | X | X |
| Ricinulei | X | X | X | X | |
| Scorpiones | | | X | | |
| Blattodea | | | X | X | X |
| Coleoptera | X | X | X | X | X |
| Collembola | X | X | X | X | X |
| Diptera | X | X | X | X | X |
| Hemiptera | X | X | X | X | X |
| Hymenoptera | X | X | X | X | X |
| Isoptera | | X | | X | X |
| Lepidoptera | | X | X | X | X |
| Orthoptera | X | X | X | X | X |
| Isopoda | X | X | X | X | X |
| Chordeumatida | X | | X | | |
| Glomeridesmida | X | X | | X | X |
| Julida | | | | | X |
| Polydesmida | X | X | X | X | X |
| Polyxenida | | | X | | |
| Siphonophorida | | | X | X | |
| Stemmiulida | | X | | X | |
| Geophilomorpha | X | X | X | X | X |
| Scolopendromorpha | | X | X | X | X |

Regarding Table 3, only three of the 13 collected beetle families inhabit every sampling zone (Curculionidae, Ptiliidae, Staphylinidae), seven were just collected along the steep slope and only one is restricted to the area on the hill-ridge (Chrysomelidae).

**Table 3: Presence-Absence of families of Coleoptera at the five sampling zones.**

| | SH | PH | SS | PSl | PSh |
|---|---|---|---|---|---|
| Carabidae | X | | X | X | |
| Cerylonidae | | | | | X |
| Chrysomelidae | | X | | | |
| Curculionidae | X | X | X | X | X |
| Elmidae | | | | | X |
| Endomychidae | | | X | | |
| Erotylidae | | | | | X |

| | | | | | |
|---|---|---|---|---|---|
| Hydrophilidae | X | X | X | | X |
| Mycetophagidae | | | X | | |
| Nitidulidae | | | | | X |
| Ptiliidae | X | X | X | X | X |
| Ptilodactylidae | | | | X | |
| Staphylinidae | X | X | X | X | X |

One third of the listed subfamilies in table 4 is found at any of the five collecting areas while the four taxa, Aleocharinae, Piestinae, Staphylininae and Tachyporinae are restricted to the area along the steep slope.

**Table 4: Presence-Absence of subfamilies of Coleoptera at the five sampling zones.**

| | SH | PH | SS | PSl | PSh |
|---|---|---|---|---|---|
| Aleocharinae | | | | X | X |
| Osoriinae | | X | X | X | X |
| Oxytelinae | X | X | X | X | X |
| Paederinae | | X | X | | X |
| Piestinae | | | X | | X |
| Pselaphinae | X | X | X | X | X |
| Scydmaeninae | X | X | X | X | X |
| Staphylininae | | | | X | X |
| Tachyporinae | | | X | | |

### 3.3. Fauna distribution.

Figure 8 shows the rate of the ten most abundant orders at the five sampling areas. The results are based on mean individual density per dry weight and show that leaf litter collected from plants along the steep slope is inhabited by a remarkable higher amount of animals than soil leaf litter or the one taken from plants along the hill-ridge. In general, Acari, Hymenoptera and Collembola are the most abundant orders. In soil leaf litter and leaf litter from plants along the hill-ridge mites even make up more than 50% of the collected animals. The abundance of Hymenoptera, those mostly Formicidae, is noticeably higher in leaf litter collected from plants along the slope, the same holding for Isopoda and Coleoptera.

Araneae are found in any of the five areas but seem to prefer habitats along the slope. The three families Linyphiidae, Oonopidae and Pholcidae make up half of the collected spiders. The other 13 identified families mostly occur as single individuals. As specimen of the remaining 15 orders partly only occur as single individuals they will be discussed seperately in chapter 4.3..

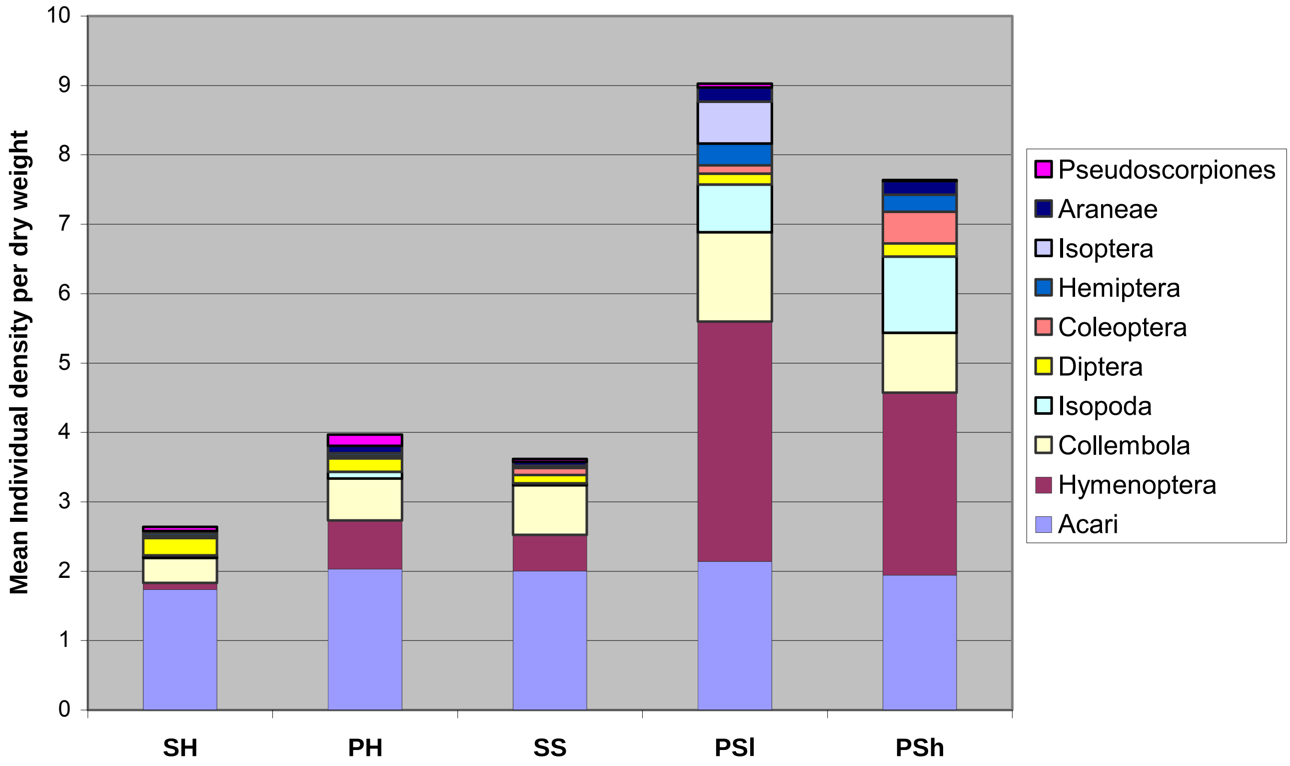


**Figure 8: Rate of the ten most abundant orders at the five sampling areas (SH=soil litter hill-ridge, PH=plant leaf litter hill-ridge, SS=soil litter steep slope, PSl=plant leaf litter from low funnel, PSh=plant leaf litter from high funnel).**

### 3.4. SPSS data analysis.

Figure 9 shows boxplots of the most abundant orders at the five sampling zones and serves as visual comparison for results shown in figure 8. Site 1 and 2 are the sampling zones at the hill-ridge (1=soil litter, 2=plant litter), site 3, 4 and 5 the ones along the steep slope (3=soil litter, 4=plant litter near ground level, 5=plant litter in 1,5-2m height).

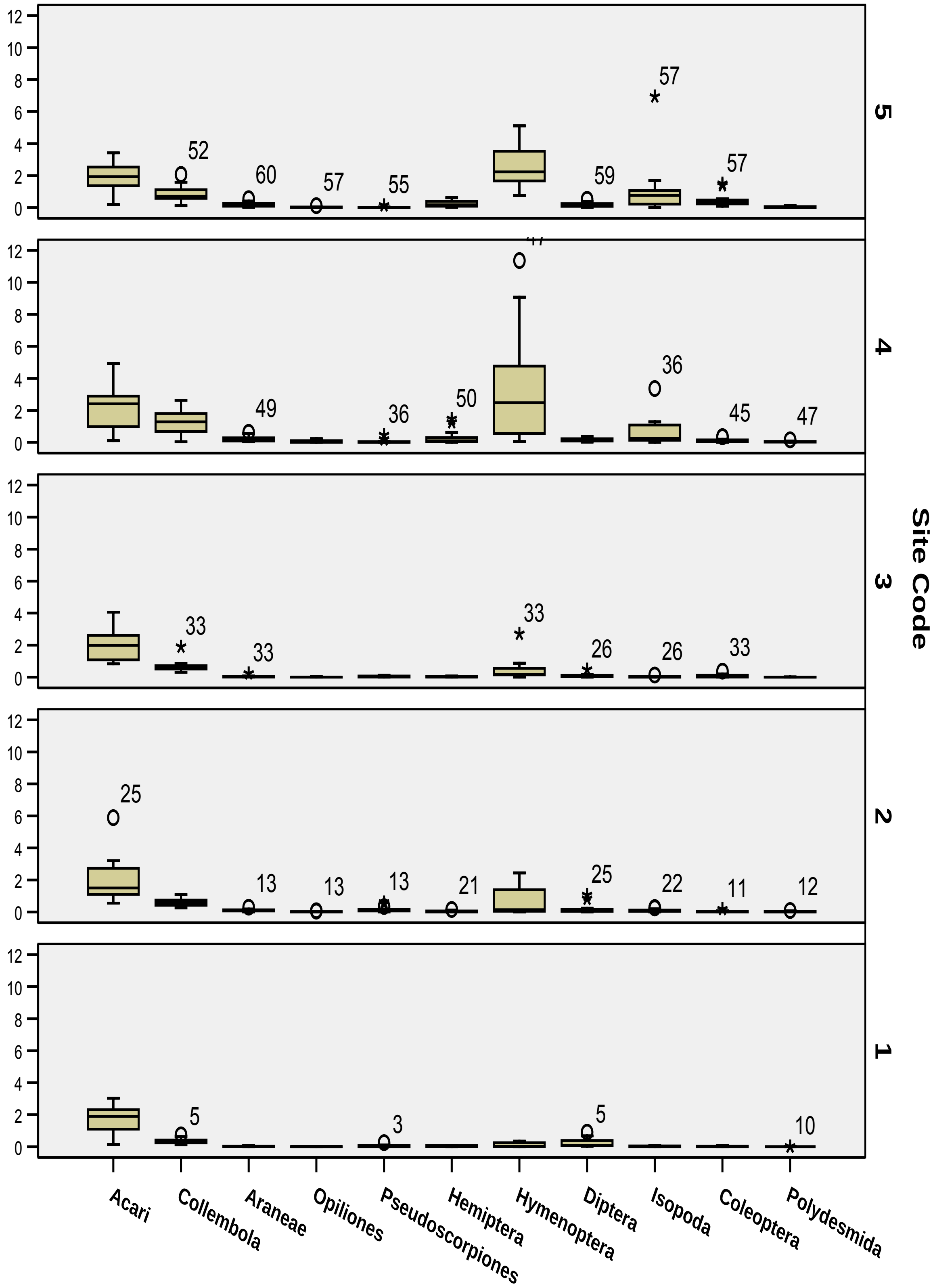


**Figure 9: Boxplots of most abundant orders at the five sampling sites (site 1=SH; site 2=PH; site 3=SS; site 4=PSl; site 5=PSh).**

Performing Kruskal-Wallis and Mann-Whitney tests brought results regarding differences in abundance of arthropods between the five sampling zones. Tested were differences between the two sites hill-rige and steep slope on the one hand and between plant leaf litter and leaf litter of adjacent soils on the other hand. Table 5 reveals the significant outcomes of Mann-Whitney U-tests, abundance of the quoted order is significantly higher at the collecting areas listed in the right sampling zone-row compared to the ones on the left side. Noticeable is that differences are mostly between plant and adjacent soil rather than between the two sampling sites hill-ridge and steep slope.

**Table 5: Significances determined by using Mann-Whitney U-test. MID is mean individual density per dry weight of the respective sampling zone. Sites in right row are significantly higher in abundance than sites in left row.**

| Order | Sampling zone | MID | Sampling zone | MID | z | p | |
|---|---|---|---|---|---|---|---|
| Collembola | SH | 0,364 | PH | 0,605 | 2,39 | 0,017 | * |
| | SH | 0,364 | SS | 0,716 | 2,419 | 0,016 | * |
| | PH | 0,605 | PSl | 1,287 | 2,427 | 0,015 | * |
| Aranae | SH | 0,030 | PH | 0,105 | 3,191 | 0,001 | *** |
| | SS | 0,055 | PSl | 0,206 | 3,162 | 0,002 | * |
| | SS | 0,055 | PSh | 0,196 | 3,051 | 0,002 | * |
| Hemiptera | PH | 0,042 | PSl | 0,314 | 2,567 | 0,01 | * |
| | SS | 0,032 | PSl | 0,314 | 2,61 | 0,009 | ** |
| | SS | 0,032 | PSh | 0,247 | 3,551 | 0,001 | *** |
| Hymenoptera | SH | 0,095 | PH | 0,701 | 2,221 | 0,026 | * |
| | PH | 0,701 | PSl | 3,457 | 2,966 | 0,003 | ** |
| | SS | 0,519 | PSl | 3,457 | 2,552 | 0,011 | * |
| | SS | 0,519 | PSh | 2,631 | 3,661 | 0,001 | *** |
| Isopoda | SH | 0,035 | PH | 0,098 | 2,011 | 0,044 | * |
| | PH | 0,098 | PSl | 0,688 | 2,374 | 0,018 | * |
| Coleoptera | SS | 0,102 | PSh | 0,454 | 3,273 | 0,001 | *** |
| | PSl | 0,122 | PSh | 0,454 | 3,548 | 0,001 | *** |

* p<0,05; ** p<0,01; *** p<0,001

The dendrogram in figure 10 demonstrates similarities of the five sampling zones to one another. Results are based on mean individual densities per dry weight on taxonomical level of order. The arthropod composition in leaf litter taken from plants along the steep slope differs remarkably from the remaining sampling zones. It is noticeable that the soil litter fauna collected at the steep slope is more similar to the soil fauna along the hill-ridge than to the one of adacent plants.

```
  PH        2    ⇩×⇩⇩⇩⬂
  SS        3    ⇩⬃
▫⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⬂
  SH        1    ⇩⇩⇩⇩⇩⬃                                    ⬄
  PSl       4
⇩⇩⇩⇩⇩×⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⬃
  PSh       5    ⇩⇩⇩⇩⇩⬃
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**Figure 10: Dendrogram of a Hierarchical Cluster Analysis on taxonomical level of order of the five sampling zones.**

### 3.5. Collected litter.

Differences in litter composition between the material collected from adjacent soil and the one from the plant funnels are notable. Whereas soil litter consists mainly of intact and little decomposed leaves, samples taken from the litter collecting plants show a vertical stratification, from intact leaves to more advanced stages of decomposition, as small leaf parts or even fine grained mould as shown in figure 11.

**Figure 11: Decomposition stages of a soil litter sample (left picture) and a plant litter sample (right picture).**

The stages of decomposition of material taken from litter collecting plants varies between sampling sites. Plants along the steep slope contain a more structured and remarkable higher amount of material than the ones at the hill-ridge.

Both, litter from soil and from plants contain fruits and small branches (mostly < 3cm diameter) which are inhabited by various arthropods. Involute leaves are often used by ants as nests or temporary residence.

### 3.6. Fauna List and biological data.

The identification of tropical invertebrates is difficult as some habitats are little or not at all investigated yet. For many groups of small arthropods identification keys don't exist or specialists are needed. The following list is an excerpt of the total amount of animals collected, identified to the respectively possible taxonomical level.

**Table 6: Fauna List.**

| Order | Family | Subfamily | Genus | Species |
|---|---|---|---|---|
| **Araneae** | Anapidae | | | |
| | Ctenidae | | | *Cupiennius granadensis* (KEYSERLING 1877) |
| | Corinnidae | | *Trachelas sp* (KOCH 1872) | |
| | Gnaphosidae | | | |
| | Hahniidae | | | |
| | Linyphiidae | | | |
| | Lycosidae | | | *Pirata turrialbicus* (WALLACE & EXILINE 1978) |
| | Mimetidae | | | |
| | Oonopidae | | | |
| | Pholcidae | | | *Anopsicus turrialba* (GERTSCH 1982) *Modisimus dominical* (HUBER 1998) |
| | Salticidae | | *Cobanus sp.* (CAMBRIDGE 19oo) | *Itata completa* (BANKS 1929) *Sidusa femoralis* (BANKS 1909) |
| | Scytodidae | | | |
| | Theridiidae | | | |
| | Theridiosomatidae | | | |
| **Opiliones** | Cosmetidae | | | |
| | Cranaidae | | | |
| | Gonyleptidae | | | |
| | Phalangodidae | | | |
| | Zalmoxidae | | | |
| **Ricinulei** | Ricinoididae | | *Cryptocellus sp.* (WESTWOOD 1874) | |

| | | | | |
|---|---|---|---|---|
| **Scorpiones** | Buthidae | | *Ananteris sp.* (THORELL 1891) | |
| **Coleoptera** | Carabidae | | | |
| | Cerylonidae | | | |
| | Chrysomelidae | | | |
| | Curculionidae | | | |
| | Elmidae | | | |
| | Endomychidae | | | |
| | Erotylidae | | | |
| | Hydrophilidae | | | |
| | Mycetophagidae | | | |
| | Nitidulidae | | | |
| | Ptiliidae | | | |
| | Ptilodactylidae | | | |
| | Staphylinidae | Aleocharinae | | |
| | | Osoriinae | | |
| | | Oxytelinae | | |
| | | Paederinae | | |
| | | Piestinae | | |
| | | Pselaphinae | | |
| | | Scydmaeninae | | |
| | | Staphylininae | | |
| | | Tachyporinae | | |
| **Diptera** | Ceratopogonidae | | | |
| | Chironomidae | | | |
| | Chloropidae | | | |
| | Dolichopodidae | | | |
| | Drosophilidae | | | |
| | Empididae | | | |
| | Limoniidae | | | |
| | Mycetophilidae | | | |
| | Phoridae | | | |
| | Psychodidae | | | |
| | Sciaridae | | | |
| | Sphaeroceridae | | | |

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|---|---|---|---|---|
| | Tachinidae | | | |
| **Hemiptera** | Anthocoridae | | | |
| | Aradidae | | | |
| | Ceratocombidae | | | |
| | Hydrometridae | | | |
| | Lygaeidae | | | |
| | Schizoptenidae | | | |
| **Hymenoptera** | Formicidae | | *Apterostigma sp.* (MAYR 1865) | |
| | | | *Anochetus sp*. (MAYR 1861) | |
| | | | *Crematogaster sp*. (LUND 1831) | |
| | | | *Cyphomyrmex sp*. (MAYR 1862) | |
| | | | | *Dolichoderus bispinosus* (OLIVIER 1792) |
| | | | *Hypoponera sp*. (SANTSCHI 1938) | |
| | | | *Octostruma sp*. (SCHULZ 1906) | |
| | | | | *Odontomachus bauri* (EMERY 1892) |
| | | | *Pachycondyla sp*. (SMITH 1858) | |
| | | | *Paratrechina sp*. (MOTSCHOULSKY 1863) | |
| | | | *Pheidole sp*. (WESTWOOD 1839) | |
| | | | | *Pheidole harrisonfordi* (WILSON 2003) |
| | | | *Procryptocerus sp*. (EMERY 1887) | |
| | | | *Pyramica sp*. (SMITH 1860) | |
| | | | *Rogeria sp*. (SLANTSCHI 1922) | |
| | | | *Solenopsis sp*. (SMITH 1858) | |
| | | | *Strumigenys sp*. (SMITH 1860) | |
| | | | *Tetramorium sp*. (MAYR 1855) | |
| | | | *Typhlomyrmex sp*. (MAYR 1862) | |
| | | | *Wasmannia sp*. (FOREL 1893) | |
| **Chordeumatida** | Cleidogonidae | | | *Cleidogona huebnerae* (SHEAR 2013) |
| **Glomeridesmida** | Glomeridesmidae | | | |

| | | | | |
|---|---|---|---|---|
| **Polydesmida** | Cryptodesmidae | | | |
| | Cyrtodesmidae | | | |
| | Platyrhacidae | | | |
| | Pyrgodesmidae | | | |
| **Polyxenida** | Lophoproctidae | | | |
| **Siphonophorida** | Siphonophoridae | | | |
| **Stemmiulida** | Stemmiulidae | | | |

**O. Ricinulei** (Hooded tickspiders)

Ricinulids are are species-poor group of archaic Arachnoidea.There are 58 described living species in 3 genera, all belonging to the family Ricinoididae. The genus *Ricinoides* occurs in West and Central Africa, *Cryptocellus* and *Pseudocellus* live in Central and South Amerika. Furthermore there are known two fossil families, Curculioididae with 11 fossil species in two genera, and Poliocheridae with four species in two genera. The first discovered 'Hooded Tickspider' was a fossil, described 1837 by the English geologist WILLIAM BUCKLAND who misinterpreted it as a beetle. Investigation on living repesentatives of the family set in lately, from the 58 known species, 37 were described by SELDEN (1993) only since 1960. Ricinulei are about 5-10mm long and because of the morphology they have often been mentioned as 'living fossils' (SELDEN 1996) – a fitting appellation regarding the bizarre appearance and gait - but in many respects they are highly modified arachnids with a number of autapomorphies, including a peculiar pre-carapaceal structure, the cucullus, which can be raised and lowered over the head to cover mouth and chelicerae, a characteristic mode of sperm transfer and modified pedipalps (HARVEY 2002). Additionally the second, elongated pair of legs operates as pray-catching and tactile organ (WEYGOLDT 1997). As they are ombrophile, ricinuleids occur in moist habitats as leaf litter, the upper humus layers of primary rainforests (eg *Cryptocellus becki* from Amazon Basin (ADIS et al. 1999) ) and as well in caves where they feed on small arthropods as springtails.

**G. *Cryptocellus*.** Following species are known from Costa Rica: *Cr. fagei* (COOKE & SHADAB 1973), *Cr. centralis* (FAGE 1921), *Cr. goodnighti* (COOKE & SHADAB

1981 a), *Cr. striatipes* (COOKE & SHADAB 1973) and *Cr. verde* (PLATNICK & SHADAB 1981b).

ADIS, J. U., MESSNER, B. & PLATNICK, N.I. (1999): Morphological structures and vertical distribution in the soil indicate facultative plastron respiration in Cryptocellus adisi (Arachnida, Ricinulei) from Central Amazonia.Stud. Neotrop. Fauna Environ. 34.1-9.

ADIS, J. U., PLATNICK,N. I., DE MORAIS, J. W. & RODRIGUES, J. M. G. (1989): On the abundance and ecology of Ricinulei (Arachnida) from Central Amazonia, Brazil. J. New York Entomol. Soc. 97. 133-140.

COOKE, J. A. L. (1967): Observations on the biology of Ricinulei (Arachnida) with descriptions of two new species of Cryptocellus. Journal of Zoology 151. 31-42.

HANSEN, H. J. (2010): On Two Orders of Arachnida; Opiliones, Especially the Suborder Cyphophthalmi, and Ricinulei, Namely the Family Cryptostemmatoidae. Cambridge Scholars Publishing. Cambridge. 204 pp.

HARVEY, M. S. (2002): The neglected cousins: what do we know about the smaller arachnid orders? J. Arachnol. 30.357-372.

WEYGOLDT, P. (1997): Ricinulei, Kapuzenspinnen. In Westheide, Rieger (Hrsg.): Spezielle Zoologie Teil 1: Einzeller und Wirbellose Tiere. Gustav Fischer Verlag. Stuttgart. Jena. 488-489.

WEYGOLDT, P. & PAULUS, H. (1979): Untersuchungen zur Morphologie, Taxonomie und Phylogenie der Chelicerata. I. Morphologische Untersuchungen (in German). Z. Zool. Syst. Evolutionsforsch. 17. 85-116.

**O. Scorpiones** (Scorpions)

Scorpions include about 1750 species and subspecies in 13 families that are distributed over all continents but Antarctic. They inhabit various terrestrial habitats, living predatorily on small arthropods although larger species are known to prey mice or lizards. As scorpions are fossorial and nocturnal they are often found under rocks or in underground holes during day time. The size ranges from 9mm (*Typhlochactas mitchelli* (SISSOM 1988)) to 20cm (*Hadogenes troglodytes* (PETERS 1861)).

**F. Buthidae: G. *Ananteris sp.*** The genus includes 18 species that are mainly resided from Panama to Brazil, two of them located in Costa Rica (*A. Platnicki* (LOURENÇO 1993) with a size up to 3cm and found on the ground or in low vegetation, and *A. Ashmolei* (LOURENÇO 1981), with 4cm body lenght and distribution in Colombia and Panama as well).

FRANCKE, O. F., STOCKWELL, S. A. (1987): Scorp. From costa Rica. Spec. Pub. Mus.Texas Tech.Univ. 25. 1-65.

POLIS, G. A. (1990): The Biology of Scorpion. Stanford University Press.Stanford.CA. 587pp.

WILSON, R., LOUREN, W. R., (1993): A review of the geographical distribution of the genus *Ananteris* Thoreli (Scorpiones: Buthidae), with description of a new species. Rev. Biol. Trop. 41 (3): 697-701.

## O. Coleoptera

### **F. Cerylonidae** (Minute Bark Beetles)

The family includes 450 species in 5 subfamilies and occurs in all major zoogeographic regions of the world but are most diverse and abundant in the tropics and forested areas of the subtropics (SEN, GUPTA & CROWSON 1973). Information regarding the habitats of cerylonids is relatively rare. They are found under the bark of rotten logs and in decaying leaf litter, where they probably feed on fungal hyphae and spores or slime molds. A few species of Ceryloninae and Euxestinae are associated with ants [e.g., *Mychocerus hintoni* (SLIPINSKI 1991) (with *Atta mexicana* (SMITH 1858)), *Hypodacne punctata* (LECONTE 1875) (with *Camponotus* spp.), and *Euxestoxenus* spp. (with *Myrmicaria* spp.) (ŚLIPIŃSKI, 1990; ŚLIPIŃSKI & LAWRENCE, 2010)]. Termite associations are restricted to fungus growing termites (e.g., *Odontotermes*) and occur only among members of Euxestinae (e.g., *Cycloxenus*, *Euxestoxenus*) (ŚLIPIŃSKI & LAWRENCE 2010).

SCHEDL, K. E. (1962): Forstentomologische Beiträge aus dem Kongo. Räuber und Kommensalen. Entomol. Abh. Ber. Staatl. Mus. Tierkde Dresden 28:37-84.

SEN GUPTA, T. &. CROWSON, R. A (1973): A review of the classification of Cerylonidae (Coleoptera: Clavicornia). Trans. R. Ent. Soc. Lond. 124:365-446.

ŚLIPIŃSKI, S. A. (1990): A monograph of the world Cerylonidae (Coleoptera: Cucujoidea) Part I - Introduction and higher classification. Ann. Mus.Civico Storia Nat. "Giacomo Doria" 88:1-273.

ŚLIPIŃSKI, S. A. & LAWRENCE, J. F. (2010): Cerylonidae Billberg, 1820. pp. 422- 432 in Handbuch der Zoologie (BEUTEL, R. G. & LESCHEN, R. A. B., eds.). De Gruyter. Berlin.

### **F. Curculionidae** (‘True Weevils’, ‘Snout Beetles’)

Snout beetles are with over 40,000 a very species-rich and divers family. Classification is still controversial and bibliographical references are contradictory. Weevils are almost entirely plant feeders on both living and dead material. Larvae mostly develop in plant parts as branches, flowers, fruits, buds, roots or wood. Only a few species develop on the plant as butterfly larvae do.

Many snout beetles are mono- or polyphag and associated with one or a few host plants.

**Sf. Scolytinae** (Bark Beetles): Before, bark beetles were considered a distinct family, Scolytidae, but nowadays rank as high specialized members among Curculionidae. Scolytinae include over 6000 species in approximately 200 genera. In Central and South America the genus *Scolytodes* is remarkably present. It includes 189 species, of these 45 in Costa Rica (JORDAL 1998). The number of species decreases northway due to climatic reasons. Only 1998 Jordal described further 7 species. Most species live in deadwood, weakened or dying trees. Larvae develop in inner bark, deadwood, decayed branches (e.g. *Ficus, Cecropia*) or in stalk of older leaves.

JORDAL, B-.M (1998): New species of Scolytodes (Coleoptera: Scolytidae) from Costa Rica and Panama., Rev. biol. trop.46. 407-420.

KIRKENDALL, L. R. & WOOD, S. L., (1997): Cloud forest bark and ambrosia beetles (Scolytidae, Platypodidae) of Costa Rica, (in press). In N. Nadkarni (ed.). The natural history, ecology, and conservation of Monteverde. Costa Rica. Oxford University. Oxford

RICH, P. V. & RICH T. H. (1983): The Central American dispersal route: biotic history and paleogeography. p. 12-34. In D. Janzen (ed.). Costa Rican natural history. University of Chicago. Chicago

WOOD, S. L. (1982): The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae). Great Basin Nat. Mem. 6: 1-1359.

**F. Elmidae** (Riffle Beetles)

The family includes 1400 species worldwide, many of them living in the tropics, 30 in Costa Rica (BROWN 1991). Mostly adults and larvae show aquatic living mainly in running or at times in lentic water. Some species live amphibious along the shore of rivers or lakes. Typical is the plastron respiration where small hair, coated with a layer of wax, keep an air cover around the body surface (Larainae) or along the ventral side and legs (Elminae). It is connected with a bubble kept under the wings (if present). As oxygen is drawn directly from the water by diffusion Elmidae do not need to get up to the water surface for respiration (BROWN 1991). The beetles cannot actively swim, their typical long legs with strong claws eases moving on rocks, solid debris or moss and many species show reduction of wings.
They oviposit into water and whereas most of the larvae spend the lifetime under

water, some live in wet organic substrate. They scrape off the periphyton, micro-organisms on semi-aquatic cover on plants or detritus. Occasionally larvae of some species are phytophagous (BROWN 1991; WHITE & BRIGHAM 1996) or xylosaprofagous on decaying wet wood and leaves (SPANGLER & SANTIAGO-FRAGOSA 1984). Pupation happens outside the water in moist soil at the bank. Adult beetles get a size from 1 to 8mm and can live up to some years long. In Central Amerika the two Subfamilies Elminae and Larainae occur frequently, former represented with 400 and latter with 8 species. SPANGLER and SANTIAGO-FRAGOSA (1984) partially describe them as new species and refer to their occurence in Costa Rica.

BROWN, H. (1991): Elmidae (Dryopoidea). Pp. in F Stehr, ed. Immature Insects, Vol. 2. 404-407Kendall/Hunt Publishing Comp.Dubuque. Iowa. USA

HAMMOND, G. (2009): "Elmidae" Animal Diversity Web. Accessed 2012 at. http://animaldiversity.ummz.umich.edu/site/accounts/information/Elmidae.html

WHITE, D., BRIGHAM W. (1996): in MERRITT, R., CUMMINS, K., eds.: Aquatic Coleoptera. An Introduction to the Aquatic Insects of North America, 399-473. Kendall/Hunt Publishing Company. Dubuque. Iowa. USA

SPANGLER, P., SANTIAGO-FRAGOSO, S. (1984): The aquatic Beetle subfamily Larainae (Coleoptera: Elmidae) in Mexico, Central America and the West Indies. Smithon. Centr. Zool. 528, 75 pp.

### **F. Endomychidae** (Handsome fungus beetles)

The family contains around 1300 species in 120 genera worldwide with the highest diversity in tropics and subtropics. The beetles get 1-7.5mm long. Mostly they are found under the bark of dead trees, feeding mycetophagously on spores and hyphae of fungi as well as on fruiting bodies of mould fungi, in leaf litter or rotting wood. A few even live in nests of ants and temites.

ARNETT, R.H. Jr., THOMAS, M. C., SKELLEY, P. E. & FRANK, J. H.. (eds.) (2002): American Beetles, Volume II: Polyphaga: Scarabaeoidea through Curculionoidea. Crc-Press. Boca Raton. 861 pp.

ARRIAGA-VARELA, E., TOMASZEWSKA, K. W. & NAVARRETE-HEREDIA, J.L. (2007): A synopsis of the Endomychidae (Coleoptera: Cucujoidea) of Mexico. Zootaxa. 1594: 1-38.

ARRIAGA-VARELA, E., TOMASZEWSKA, K. W. (2010): New records of the Neotropical handsome fungus beetle genus *Ephebus* GERSTAECKER (Endomychidae; Epipocinae) from Mexico and Costa Rica. Dugesiana 17. 209-211.

SHOCKLEY, F. W., TOMASZEWSKA, K. W. & MCHUGH, J. V. (2009): A review of the natural history of the Handsome Fungus Beetles (Coleoptera: Cucujoidea: Endomychidae). *Insecta Mundi* 0072: 1-24.

**F. Erotylidae** (Pleasing Fungus Beetle)

Comprehending 5 subfamilies with over 100 genera and around 2500 species Erotylidae mainly inhabit tropic zones. They get a size between 2 and 8mm, some exceptions reach 20mm. Mostly they are eye-catching coloured with combination of red or yellow with black. Nourishment is vegetarian, including feeding on tree saps. Often both adults and larvae are found in superior tree fungi.

BORROR, D. J. & DELONG, D. M. (1970): An Introduction to the Study of Insects (3rd. Ed.). Rinehart & Winston. New York.812 pp.

LESCHEN, R. A. B. (2003): Erotylidae (Insecta: Coleoptera: Cucujoidea): Phylogeny and review (Part 1). *Fauna of New Zealand 47*. Manaaki Whenua Press. New Zealand. pp. 108 pp.

ROBERTSON, J. A., MCHUGH, J. V. & WHITING, M. F. (2004): A molecular phylogenetic analysis of the pleasing fungus beetles (Coleoptera: Erotylidae): evolution of colour patterns, gregariousness and mycophagy. Syst. Entomol. 29. pp. 173–187.

WĘGRZYNOWICZ, P. (2002): Morphology, phylogeny and classification of the family Erotylidae based on adult characters (Coleoptera: Cucujoidea). Genus 13. 435–504.

HURKA, K. (2005): Käfer der Tschechischen und Slowakischen Republik. Kabourek. Zlim. 390 pp.

**F. Mycetophagidae** (Hairy Fungus Beetles)

Worldwide exist 200 species in 18 genera whereas the main distribution is known from the tropics (IVIE 2000). Body length reaches from 1mm to 6.5mm. Hairy fungus beetles are brown and black, the elytra often show a red and orange-coloured patterns. They inhabit agarics, various fungi, moist leaf litter, wood duff and also the area under moulding bark (BORROR & DELONG 1970).

PARSONS, C.T., 1975: Revision of Nearctic Mycetophagidae (Coleoptera). *Coleopterists Bull.* 29, pp. 93-108.

BORROR, D. J. & DELONG, D. M. (1970): An Introduction to the Study of Insects (3rd. Ed.). Rinehart & Winston. New York.

IVIE, M. A. (2000). IN: ARNETT, R. H., Jr., & THOMAS M. C. (eds.): American Beetles. CRC Press. Gainesville. Florida.(in press).

**F. Nititulidae**. (Sap Beetles)

The family is supposed to consist of 9 subfamilies ranged into 271 genera and at least 3000 species, although the expected number of species should be estimated at over 7000 – 8000 (BORROR & DELONG 1970). The size is 2-3mm on average but some species can reach 7mm. (BORROR & DELONG 1970, HURKA 2005). The beetles are very variable in body shape and colour, often metallic green and blue or brownish. Adults and larvae feed on flowers, sap, fruits, fungi and decaying and fermenting plant tissues, seldom also predatory on scale insects or bark beetles. Some species live under bark, in decaying wood and moist tree duff.

BORROR, D. J., DELONG, D. M. (1970): An Introduction to the Study of Insects (3rd. Ed.). Rinehart & Winston. New York.

HURKA, K. (2005): Käfer der Tschechischen und Slowakischen Republik. Kabourek. Zlim.

LESCHEN, R. A. B., BEUTEL, R. G., LAWRENCE J. F. (2010): Handbuch der Zoologie - Coleoptera, Beetles, Volume 2: Morphology and Systematics (Elateroidea, Bostrichiformia, Cucujiformia partim). 1. Auflage. de Gruyter. 390pp.

**F. Ptiliidae** (Featherwing Beetles)

Ptiliidae is a highly diverse yet poorly known group of beetles (HALL et al. 2001). Around 400 (HURKA 2005) – 630 (HALL et al. 2001) species are known worldwide with notably diversity in tropical ecosystems. Representatives of this family are the tiniest beetles ever found, *Nanosella fungi* (LECONTE 1863) in North America with 0.25 mm the smallest, and also most of the other species are less than 1mm. The Nearctic genus *Acrotrichis,* the largest genus, presently contains more than 150 species, among those *A. godmani* (MATTHEWS 1884) with 2mm body size the largest of the family. Characterising is the structure of the hindwings, composed of a central blade with dense, fine setae along the sides, giving them a feather-like appearance, and reduced membrane (HURKA 2005). Certain genera (*Pteryx* Matthews, 1858*; Ptinella* Motschulsky, 1844; *Ptinellodes* Matthews, 1872) are characterised by a striking polymorphism, in which each sex is represented by two different forms, a ‘normal morph’ with well-developed eyes, wings and body pigmentation and a ‘vestigial morph’ where eyes, wings, and body pigmentation are reduced or lacking. Both forms are capable of reproduction but as under favorable conditions vestigial morphs account for around 90% of the population in some species, TAYLOR (1980, 1981) assumed that the form depends on ecological circumstances. It was noticed that more unfavorable conditions result in an increased production of normal morphs which allows the species to relocate to more attractive habitats. Usually ptiliids appear to reproduce continuously, larvae mostly appear together with adults at different times of the year. Female ptiliids produce one egg at the time as egg size usually is half of the body length (DYBAS 1966). The developmental period seems to take around one month. Larvae are pale, slender, and active (DYBAS 1976). Some genera breed parthenogenetic (*Acrotrichis, Bambara,* ao). Featherwing beetles are found in a variety of habitats as moist leaf litter, rotting cacti, mammal dung and nests, ant or termite colonies, along gravel and sand banks of rivers and streams, under bark of dead trees and other habitats including moist or rotting organic material. It is believed that they play an important role in the decomposition cycle in many environments (MAJKA & SÖRENSSON 2010). Both adults and larvae are mycetophagous, feeding in the same niche on the spores of fungi, preferably mould fungi (HALL 2001).

DYBAS, H. S. (1966): Evidence for parthenogenesis in the featherwing beetles, with a taxonomic review of a new genus and eight new species (Coleoptera: Ptiliidae). Fieldiana. Zoology 51: 1152.

DYBAS, H. S. (1976): The larval characters of featherwing and limulodid beetles and their family relationships in the Staphylinoidea (Coleoptera: Ptiliidae and Limulodidae). Fieldiana. Zoology 70: 2973.

HALL, W. E. (2001): Ptiliidae. pp. 231-246 *in* ARNETT, R.H., Jr., & THOMAS, M. C. (eds.). American Beetles. Volume 1. Archostemata, Myxophaga, Adephaga, Polyphaga: Staphyliniformia. CRC Press Boca Raton. 443 pp.

MAJKA, C. G. & SÖRENSSON, M. (2010): Featherwing Beetles (Coleoptera: Ptiliidae) of the Atlantic Maritime Ecozone. In Assessment of Species Diversity in the Atlantic Maritime Ecozone. *Edited by* MCALPINE, D. F. & SMITH, I. M. NRC Research Press. Ottawa. Canada. pp. 433-438.

**F. Ptilodactylidae** (Toed-winged Beetles)

The family includes around 500 species of which ¾ belong to genus *Ptilodactyla.* The beetles inhabit most areas of the world (Nearctic, Palearctic, Neotropical, Afrotropical, Oriental, Australian), but are absent from Europe. Body size is 2-6mm, they are brownish coloured and the head is usually hidden from above. Toed-winged Beetles are found in riparian, semiaquatic and aquatic habitats. Adults often appear on vegetation along the shore or near water at moist and shady places, larvae prefer decaying wood and leaf mould, some aquatic areas (ARNETT et al. 2002) for which they developed various adaptions for survival under water, such as anal gills or a spiracular siphon (LAWRENCE 1991). Some groups (e.g. genera *Daemon*, *Aploglossa*) have maxillary brushes for feeding on surface microfungi (IVIE 2000).

ARNETT, R.H. Jr., THOMAS, M. C., SKELLEY, P. E. & FRANK, J. H.. (eds.) (2002): American Beetles, Volume II: Polyphaga: Scarabaeoidea through Curculionidea. Crc-Press. Boca Raton.

IVIE, M. A. (2000): 54. Ptilodactylidae. IN: ARNETT, R. H. Jr. & THOMAS, M. C. (eds.). American Beetles. CRC Press. Gainesville. Florida (in press).

LAWRENCE, J. F. (1991): Ptilodactylidae (Dryopoidea). IN STEHR, F. W. (ed.). Immature Insects. Vol. 2. Kendall/Hunt Publishing Co.. Dubuque. Iowa. pp. 391–394.

**F. Staphylinidae** (Rove Beetles)

**Sf. Aleocharinae**. With over 1000 genera and more than 12,000 described species *Aleocharinae* is the most species-rich subfamily of staphylinids and there are a lot more expected, specially in tropical regions. Their distribution is not limited to specific biogeographic areas but can be found in any terrestrial habitat worldwide. With 0,9-6mm the Rove Beetles count to the microcoleopteran fauna, the average size is 3-5mm. While many aleocharine species are predators in moist leaf litter or soil, others developed highly spezialised habits as for example a commensally life style as inquilines in nests of ants and termites (SEEVERS 1957, 1965, ao), assosiations with fungi or even as major pollinators of some palm trees in South America (BERNAL & ERVIK 1996).

**Sf. Osoriinae.** This subfamily of staphylinids is distributed over all biogeographical regions but the main inhabited areas are the Tropics and Subtropics of Nearctic region. Mostly they are found in plant litter of forest floors where both beetles and larvae feed on small, rotten wood or bark pieces, interveined by fungal hypha, as well as on other vegetal detritus. The asymmetric mandibula operates as a press for mouldy food particles. Because of the detritivorous nutrition osoriines play an important role in the cycle of decomposers of litter on forest floors.

**Sf. Piestinae.** Imagos reach a size up to 5mm. The beetles are mostly found under the bark of decaying trees and wood duff.

**Sf. Pselaphinae.** There are 9000-10,000 described species within this subfamily (NEWTON et al. 1989) with a high species-richment in the tropical regions. Their size is 1-2,5mm. Little is known about the biology but they are supposed to be predators on mites and springtails. Prefered habitats are moss, the area under decaying vegetal litter and bark and moist wood duff.

**Sf. Oxytelinae.** There are little facts known concerning the biology but they use to be found in moist habitats like leaf litter or riparian moss along streams.

**Sf. Scydmaeninae.** The so called 'ant loving beetles' contain 4700 species. The body measures 0,7-2,3mm and is from yellowish red to redish brown. Scydmenines live predatory on mites which for they developed specialized mandibles. Prefered habitats of Scydmaeninae are moss, leaf litter of forest floors, under bark and mould vegetal detritus. Some species are found in ant nests and therefore adapted by developing an ant-like morphology.

**Sf. Tachyporinae.** Just as many other representatives of the family Staphylinidae Tachyporinae inhabit moist biotopes as leaf litter and rotting wood as well.

BERNAL, R. & ERVIK, F. (1996): Floral biology and pollination of the dioecious palm *Phytelephas seemannii* in Colombia: An adaptation to staphylinid beetles. Biotropica 28(4b): 682-686.

BERNHAUER, M. (1912): Zur Staphylinidenfauna von Südamerika. Entomologische Blätter 8: 167-179.

BERNHAUER, M. (1939): Zur Staphylinidenfauna Argentiniens und Brasiliens (Col.). Revista de Entomología. 10: 231-249.

BLACKWELDER, R. E. (1944): Checklist of the Coleopterous Insects of Mexico, Central America, The West Indies, and South America. Part 1. United States National Mus. Bull. 185: 1-188.

MCCOLL, H.P. (1975): The invertebrate fauna of the litter surface of a *Notophagus truncatus* forest floor and the effect of microclimate on activity. New Zealand Soil Bureau. 20 pp.

NADKARNI, N. M. & WHEELWRIGHT, N. T. (2000): Monteverde. Ecology and Conservation of a tropical cloud forest. Oxford university Press. 398 pp.

NEWTON, A. F., Jr., THAYER, M. K., ASHE, J. S. & CHANDLER, D. S. (2001): 22. Staphylinidae Latreille, 1802. p. 272–418. In: ARNETT, R. H. Jr. & THOMAS, M. C. (eds.).

American Beetles. CRC Press; Boca Raton.

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## C. Diplopoda

### O. Chordeumatida

This very large order of millipeds is represented by around 30 families and most abundant and diverse in the Holarctic although new taxa were discovered in Chile and southern Argentina (Eudigonidae) as well as southwards from Mexico (Cleidogonidae) in recent years.

**F. Cleidogonidae.** Members of this extremely species-rich family are recognisable by the nearly cylindrical segments in combination with a size of 15-30mm. Mostly they inhabit leaf litter but many are known living troglobitic in caves and at least one in Chiapas (Mexico) only appears with bromeliads (ADIS 2002). The newest discovered cleidogonid species is *Cleidogona huebnerae* (SHEAR 2013), collected in the course of this study and described by William A. SHEAR, Department of Biology, Hampden-Sydney, Virginia. It is distinct from all other known Central American cleidogonid millipeds in the small size of mature specimen, being with 7mm about 50% smaller than the next smallest congeneric species (SHEAR 2013).

### O. Glomeridesmida

Glomeridesmids are a very ancient group of diplopods and mainly ocurring in Tropics of southeastern Asia, otherwise circum-Tropic. These small representatives of the class are less than 15mm long, dark coloured and get mainly recorded in course of Berlese-Tullgren extraction of leaf litter. Currently are 27 species described in the one single family Glomeridesmidae but there is very little known about biology and ecology of this group. First pictures were published only 2011 (SHELLEY).

**O. Julida**

Julids are found from North America south to Guatemala and most of Eurasia to Japan and Indochina (ADIS 2002). There is a huge variety in body structure and size among the taxa as the length differs between less than 10mm up to more than 175mm.

**O. Polydesmida**

This order is in terms of family, genera and species by far the largest in the class (ADIS 2002). Adults get a size between 2mm and 130mm and have a great variety of colours and patterns. Most species inhabit upper soil and litter horizons.

**F. Cryptodesmidae.** The family includes around 83 species and is widely distributed in the New World from Veracruz, Mexico to Argentina (ADIS 2002). Cryptodesminae inhabit the region from Panama to Argentina, while Peridontodesminae are more concentrated to Middle America, from Mexico to Costa Rica.

**F. Cyrtodesmidae.** With about 30 species in only 3 genera the family is not a large one. Distribution is from Costa Rica to Peru and Trinidad, in the Cordilleran mountain system, in the Surinam Plateau and in Amazonia (ADIS 2002). A remarkable characteristic for example is the formation of a flattened disk when the body enrolls.

**F. Platyrhacidae.** 214 species in numerous subfamilies represents this, mainly in North America located family. Furtheron it is found in South East Asia, East Indies as far as the Solomon Islands and tropical America from Nicaragua to Peru and Guyana (ADIS 2002). Platyrhacids are among others characterised by a distally broadened tail and measure over 60mm lenght and 7mm width and some species rank among the largest Neotropical polydesmidans. Often they are colourful and strongly sclerosed. One representative of Costa Rican rainforests is *Nyssodesmus python* (PETERS 1864), several centimeters long and noticeable white, yellow and black coloured.

**F. Pyrgodesmidae.** Pyrgodesmids are common in most tropical regions and scaled in 246 species, of these 30 in Costa Rica. They represent a major taxonomical problem as many genera have been named based on trivial structural differences, many type species are only known from female specimen, some species were spread throughout the tropics by commerce and furtheron being renamed from different places, and more (ADIS 2002).

**O. Polyxenida.**

Polyxenidans chiefly inhabit the Tropics, but are as well abundant in temperate regions (ADIS 2002). The less than 5mm long diplopods are characterised by a short, setose body, quick movements and large, terminal tuft of pale setae (ADIS 2002). Usually they live at rather dry places as under bark, stones, etc and also have been documented as colonial at times.

**F. Lophoproctidae.** Five genera compose the family of those two inhabit the Neotropical region, *Lophoturus*, occuring in the Southern Hemisphere, and *Ancistroxenus,* pan-Neotropical. Eyes are lacking throughout the family.

**O. Siphonophorida.**

The order consists of three families with 18 species represented in the tropics of both Hemispheres, but only Siphonophoridae ocurring in the Neotropical Region. Eyes are missing throughout the taxa and mouthparts and body form are highly derived (ADIS 2002). The diplopods are light brown to nearly white and often found coiled like a watch-spring (ADIS 2002). Siphonophorids include the millipede with the highest known number of segments: *Illacme plenipes* (COOK & LOOMIS 1928), 192 segments).

**F. Siphonophoridae.** The adults measure less than 30mm, have a slender body and move very slow. They are found in rotting wood, moist plant detritus and caves but nothing is known about their feeding habits. Due to the modification of head and mouthparts a kind of suctorial mode of feeding is assumed (ADIS 2002).

**O. Stemmiulida**

The order is represented by a single family, Stemmiulidae, with four genera ocurring in tropical Africa, southern India, Sri Lanka, East Indies to New Guinea, on the Greater Antilles and from southern Mexico to Brazil. Remarkable are one or two large convex ocelli on each side of the head and defense glands capable to secrete a harmful fluid.

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## 4. Discussion

Originally, the idea of this thesis was a research of the arthropod assemblage in leaf litter material collected by litter trapping plants. On the one hand the aim was finding out whether there are differences in diversity or individual density between the two sites hill-ridge and steep slope. On the other hand investigation should clear if the arthropod fauna differs when the collected litter is at ground level or in a certain height. Additionally was the intention to create a food chain of the funnel material to clear if the established system differs from the litter fauna on the ground. Whereas the study of tropical stream systems already has a long history beginning with VON HUMBOLDT and BONPLAND in 1799, the leaf litter fauna of tropical ecosystems is partly still little explored. Therefore identification on genus- or species level is only possible in some cases and there hardly result specific ecological statements concerning habitat preference, feeding habit etc. This is why this report will more concentrate on giving a general overview of results on the taxonomical level of order and personal observations in the field.

## 4.1. Additional habitat investigations.

Because of tree-fall gaps the canopy along the hill-ridge is part-way open. More sunlight reaches the understorey why temperatures were expected being above the ones measured along the steep slope, where the canopy is noticeably denser. Furthermore it was estimated that humidity along the slope is higher as affected by the close brook. But neither humidity nor temperature measurements approve the supposition. Air humidity data show a steady trend throughout the complete investigation time, ranging at all five collecting zones between 99,9-100%. Temperatures range between 25 and 28 degrees and vary more within each sampling area than between the sites and therefore don't show an expected trend of being remarkably higher along the ridge than in the slope. It seems as if temperature depends more on the density of the forest canopy and the therefore temporary shining through light which can be a reason for the greater variability of temperatures within than between the areas. This and the fact that temperatures inside and outside leaf litter material hardly differ make humidity and temperature not seem to be determining factors for the arthropod fauna at the sites.

## 4.2. Presence-Absence.

Presence and absence serve a general overview of occuring animals in the compiled leaf litter but don't give information about the quantity of the collected arthropod fauna. As some groups are represented by only a few specimen while others occur numerously, occurence and distribution will be discussed more detailed in chapter 4.3. However it is mentionable that 13 of the 25 orders occur at every of the five sampling areas. So, regarded from the taxonomical level of order habitats seem to be chosen occasionally by some groups, independent if in plant litter, soil litter, at hill-ridge or steep slope.

It is noticeable that termites are limited to funnel leaf litter material of litter collecting plants. It is possible that they use the material as nest as more fine grained mould is available compared to adjacent soil.

Focusing on the occurance of beetle families, Table 3 shows that Curculionidae, Ptiliidae and Staphylinidae inhabit every sampling zone while others occur along the slope and one is restricted to the hill-ridge.

Nearly all identified beetles have in common to be found at smilar habitats as under bark of rotten logs, in decaying leaf litter or mould, feeding on fruits, roots, wood, tree saps, mycetophagously on fungal hyphae or spores, or predatory on smaller arthropods. As all five sampling areas meet these requirements, habitat selection could happen in most cases more randomly than directed. The three named beetle families are the most abundant ones in the material which is more likely a reason for occuring at every sampling area and supports the previous presumption.

Only Elmidae (Riffle Beetles) and Ptilodactylidae (Toed-winged Beetles) have specified habitat preferences and therefore are restricted to the steep slope near the brook. Most adults and larvae of Riffle Beetles show aquatic living mainly in running or at times in lentic water. Some species live amphibious along the shore of rivers or lakes where they scrape off the periphyton, micro-organisms on semi-aquatic cover on plants or detritus. Occasionally larvae of some species are phytophagous (BROWN 1991; WHITE & BRIGHAM 1996) or xylosaprofagous on decaying wet wood and leaves (SPANGLER & SANTIAGO-FRAGOSA 1984). Toed-winged Beetles are found in riparian, semiaquatic and aquatic habitats. Adults often appear on vegetation along the shore or near water at moist and shady places (ARNETT et al. 2002). As the brook is less than 20 meters away from the sampling locations it can be assumed that specimen of the two families are temporary guests, maybe feeding on parts of the collected leaf litter material.

Regarding Table 4 one third of the listed subfamilies of Staphylinidae is found at any of the five areas while the four taxa, Aleocharinae, Piestinae, Staphylininae and Tachyporinae only occur along the steep slope. But similar to other beetle families there doesn’t seem to be a defined reason for this distribution. All collected members of the family Staphylinidae inhabit among others moist biotopes as leaf litter, rotting wood, areas under bark of decaying trees or wood duff (BERNAUER 1912, BERNAUER 1939, BLACKWELDER 1944, MCCOLL 1975, NEWTON et. al 2001) feeding predatory on mites or springtails (Pselaphinae, Scydmeninae), on rotten wood or bark pieces interveined by fungal hypha as well as on vegetal detritus (Osoriinae) (NEWTON et. al 2001). Osoriines therefore even developed asymmetric mandibels which operate as a press for mouldy food particles. Because of the detritivorous nutrition they play an important role in the cycle of decomposers of litter on forest floors (SCHAEFER 1993).

### 4.3. Fauna distribution.

Figure 8 shows that leaf litter collected from plants along the steep slope is inhabited by a remarkable higher amount of animals than soil leaf litter or the one taken from plants along the hill-ridge. A main reason seems to be the structure of the collected leaf litter material which includes more stages of decomposition and shows a notable vertical stratification with a variety of niches compared to the less structured material from adjacent soil. Why there is such a big difference in quantity of arthropods between plants along the hill-ridge and the ones along the steep slope is only to speculate. As already mentioned before temperature and humidity don't seem to be determining factors. Maybe the form of the collecting funnel, defined on the position and width of the leaves plays a role. According to observance the funnel of *Becquerelia cymosa* broadens faster than the one from *Asterogyne martiana* and the leaf bases are usually more narrow than the ones of palms. This could have the effect that finer material is washed out easier, causing less material and niches and therefore less attraction to arthropods.

Comparing all five sampling zones <u>Acari</u>, <u>Hymenoptera</u> and <u>Collembola</u> are the most abundant orders. In soil leaf litter and leaf litter from plants along the hill-ridge Acari even make up more than 50% of the collected animals. It is expected that the high amount of Acari and Collembola attract various predators as they represent an important food source (eg. Pselaphinae, Scydmaeninae (NEWTON et. al 2001)). Remarkable is the high quantity of Hymenoptera, most of them <u>Formicidae</u>. They occur in almost every of the 65 samples and can make up to 40% of the arthropod fauna at a sampling area. The abundance is noticeably higher in leaf litter collected from plants along the slope with often some hundred individuals per sample. Material removed from a specimen of *Asterogyne martiana* with the collecting funnel in 1.5-2m height even contained an amount of 935 ants. Often different ant species coexist together in the very same leaf litter material. In one sample were identified 13 different ant species, some of them up to 200 specimen or even more, in an other one 10 different species with more than 400 specimen altogether. Some species occur in low numbers from single individuals to around ten or fifteen, others in high numbers up to 300 specimen. It can't be said for sure if the habitats are used as nests as there was not found a queen ant. But many different developmental stages as eggs, larvae and immatures, as well as males and gynes indicate at least a temporary residence for ant colonies. Mainly they inhabit involute leaves but also insides of rotten wood are used as housing.

Diptera inhabit every of the five sampling zones but occur in higher numbers in soil litter along the hill-ridge. However the biggest assemblage was found in a sample taken along the brook with 60 specimen. The majority belongs to chironomids which explains the high occurance along the brook as larvae develop in water.

The majority of coleopteran fauna inhabits areas along the slope. From more than 800 specimen of beetles almost 700 live in leaf litter from litter collecting plants along the brook with the funnel in 1.5-2m height, hereof more than 600 staphylinids and around 90 ptiliids. As already discussed in chapter 4.2. almost all collected beetle families inhabit similar habitats. A reason that more than 90% chose collected plant leaf litter as residence can be again the various stages of decomposition, from intact leaves and small leaf parts to even fine grained mould. The longer the leaf litter is collected, the more material accumulates and decomposes, involving more niches, usually more animals and therefore better living conditions for both zoophagous and phytophagous species.

Araneae are found in any of the five areas but seem to prefer habitats along the slope. The three families Linyphiidae, Oonopidae and Pholcidae make up half of the collected spiders. The other 13 identified families mostly occur as single individuals. *Anopsicus turrialba* (Pholcidae) is the most abundant spider and makes up a quarter of all collected specimen. Noteworthy is that 67% were found in one single sample of a palm with funnel in 1.5-2 meters height. As there is little known about the ecology it can’t be said why they occur in this one case so numerously but as it is the sample with the most collected material (1260g fresh weight) probable favourable food conditions can be a reason. Oonopidae and Linyphiidae represent in each case more than 10% of the present spiders and are restricted to leaf litter material of collecting plants along the slope. Linyphiidae are very small (usually 3mm or less (PARKER 2001), web building spiders but it is little known about their life style and feeding habits. So it can’t be said what attracs them to the micro habitat plant funnel. Oonopidae are 1-3mm small, free-living spiders which are guessed to live as vagabonds, actively pursuing their prey (PARKER 2001). They are thought to feed on mites and small insects (PARKER 2001).

Isoptera are limited to leaf litter material of litter collecting plants. Two single specimen in the funnel material of a plant on the hill ridge and one with funnel in 1.5-

2m height at the steep slope are negligible. Worth mentioning and with almost ten percent of collected arthropods from PSI (Figure 8) is the occurence of 1679 specimen in the leaf litter from a plant at the slope with the collecting funnel at ground level. It is possible that they use the material as nest. The same sample is inhabited by more than 100 ants which proves the coexistance of these two colonial insect orders.

Some orders are represented by only a few individuals or occur increased in single samples why they are not included in diagrams nor SPSS analysis. Nevertheless their occurence is worth to be mentioned. Along the slope was found a single specimen of *Ananteris* sp. (Scorpiones) in soil leaf litter material. It can't be said if the group is limited to ground areas as a stem could be a possible climbing barrier or if it would haunt in leaf litter material of litter trapping plants as well. For Polyxenida and Siphonophorida counts the same, they occur just once each in soil leaf litter material why it is not clear if they are exclusively restricted to the ground along slopes or found there by random. Only Blattodea and Polydesmida occur with more individuals, those mainly along the slope. Almost half of the diplopod fauna are polydesmids, 90% of them found in the leaf litter of palms at the slope where they seem to be attracted by the rotting and mould material. Blattodea occur with around 15 specimen whereby 99% were collected with the litter material of the plant funnel in 1.5-2m height. As they reach sizes up to 4cm a possible explanation can be the lack of natural enemies in this height above the ground and favourable food availability in the stable system within the plant funnel which attracts cockroaches.

Chordeumatida only appear in the leaf litter taken from the forest floor and here mostly in samples from the hill-ridge. As there is little known about feeding habits or special habitat preferences it can't be assumed that they are restricted to the forest floor or occur only there by random.

### 4.4. SPSS data analysis.

Table 5 demonstrates results of Kruskal-Wallis and Mann-Whitney tests. Tested were differences between the two sites hill-ridge and steep slope on the one hand and between plant leaf litter and leaf litter of adjacent soils on the other hand. Noticeable is that significant differences happen mostly between plant and adjacent soil rather than between the two sampling sites. The outcomes approve the statement of chapter 4.3. that arthropod abundance is remarkably higher in samples taken from plants along the slope compared to the remaining sampling zones. Specially Aranae, Hemiptera, Hymenoptera and Coleoptera show a clear preference for leaf litter habitats in collecting plants along the slope. As already mentioned before ants appear in groups of up to 300 individuals per species and up to 13 species together in several collected plant leaf litter samples. This explains the significances with p=0,003, p=0,011 and p=0,001 comparing plant leaf litter at steep slope to adacent soil leaf litter, respectively to plant leaf litter at the hill-ridge. Distribution of Coleoptera is even more conspicuous. Around 700 of the 800 collected beetles inhabit the leaf litter material of plants along the slope with the collecting funnel in 1.5-2m height which explains the high significant results of p= 0,001 comparing PSh (plant slope with high funnel) with PSl (plant slope with low funnel) or SS (soil litter slope).

**4.5. Collected litter.**

As already mentioned in chapter 3.5., the material taken from leaf litter collecting plants contains more stages of decomposition and This provides various niches contrary to the less structured soil litter and seems to be a main reason for a higher amount of animals inhabiting funnel leaf litter.

Stages of decomposition also vary between sampling sites. Plants along the steep slope contain a more structured and remarkable higher amount of material than the ones at the hill-ridge. A reason can be the age of the collecting plants and therefore more collected litter mass and decomposing time, as well as the form of the collecting funnel defined on the position of the leaves. Also density and structure of the upper forest layers influence composition and quantity of the material.

Both, litter from soil and from plants contain fruits and small branches (mostly < 3cm diameter). It is remarkable that rotten pieces of wood are specially used by chilopods and diplopods. Involute leaves are often used by ants as nests or temporary residence which explains why they often appear as groups of up to 300 individuals.

In summary it can be stated that arthropods prefer inhabiting leaf litter material of collecting plants to adjacent soil litter which concures with the research of

VASCONCELOS in 1990. Furtheron it is obvious that the habitat ‘plant funnel’ along the brook at the steep slope attracts a remarkable higher number of animals than the one on the hill-ridge does. Most frequent are Acari, Collembola and Formicidae, the latter forming groups of up to 300 individuals and coexisting with other species in the same leaf litter material. Several groups are restricted to certain sites whereas others seem to occur at the five areas by random. All in all the collected leaf litter material of palms along the slope seems to provide with various niches and stages of decomposition the most favourable and attractive biotopes of the compared sampling zones.

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## 7. German Abstract.

Arthropodenfauna im Trichtermaterial humussammelnder Pflanzen in einem Tieflandregenwald in Costa Rica. Nährstoffmangel in Böden tropischer Wälder stellt einen wichtigen limitierenden Faktor für das Pflanzenwachstum dar. Als alternative Ernährungsstrategie entwickelten einige Pflanzen das so genannte Humussammeln bei dem herabfallendes, organisches Material wie Äste, Blätter, Früchte usw. in der trichterförmigen Krone gesammelt wird. Durch die rasche Zersetzung werden Nährstoffe freigesetzt, welche von der Pflanze durch oberirdische Organe wie Adventivwurzeln oder Blattbasen aufgenommen werden können. Das angesammelte Material wird von einer Reihe wirbelloser Tiere bewohnt und teilweise sogar von Eidechsen und Vögeln zur Eiablage genutzt. Zwischen Juli und Oktober 2008 wurde an den zwei Standorten Hügelrücken und steiler Schluchtwald das Material zweier humussammelnder Pflanzen sowie Laubstreuproben des anliegenden Bodens gesammelt. Die Extrahierung der insgesamt 28.000 Arthropoden aus 25 Ordnungen erfolgte durch Berlese-Tullgren-Apparaturen und zeigte dass Acari, Collembola und Hymenoptera die mit Abstand am häufigsten vertretenen Tiergruppen sind. Letztere sind meist Formicidae, welche Ansammlungen von bis zu 300 Individuen pro Spezies bilden und oftmals mit anderen Vertretern der Familie im Material eines Trichters zusammenleben.

Im Allgemeinen favorisieren Arthropoden das Trichtermaterial humussammelnder Pflanzen gegenüber der Laubstreu des anliegenden Bodens wobei das Material in Pflanzen entlang des Schluchtwaldes klar bevorzugt wird. Die Vielzahl an Nischen und Zersetzungsstadien machen dieses Habitat offenbar zum Attraktivsten und Vorteilhaftesten der untersuchten Bereiche.

## 8. Curriculum vitae.

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### Personal Data

| | |
|---|---|
| Date of birth | 06.09.1983 |
| Place of birth | Linz |
| Citizenship | Austria |
| Religion | Roman Catholic |
| Marital status | Unmarried |
| Parents | Dr. Hans Heinz Hübner, chemist<br>Mag. Evelyn Hübner, pharmacist |

### Education

| | |
|---|---|
| 1989 – 1993 | Elementary School in Altenberg bei Linz |
| 1993 - 2001 | High School „Europagymnasium Auhof, Lycée Danube“ in Linz |
| 2001 - 2004 | First Section of Academic Studies: Biology |
| since 2004 | Second Section of Academic Studies: Branch of Study: Ecology |

### Practical Courses/Field Excursions

| | |
|---|---|
| 2004 | Practical course in nature conservation: ocean turtles in Turkey |
| 2005 | Practical course in nature conservation: Mediterranean ecosystems on the Croatian island Cres |
| | Practical course: observation of ring-tailed lemures and suricates in the vienna zoological garden “Schönbrunn” |
| 2006 | Ecological field excursion to Andean habitats in Ecuador incl. Galapagos-Islands |
| 2007 | Field excursion „Natura 2000“ – european nature conservation |
| | Field excursion: national parks in Austria |

| | |
|---|---|
| | Practical course: rural conservation |
| 2008 | Practical course: functional ecology of rainforests in Costa Rica |
| | Practical course: ecological fieldcourse to the Croatian island Krk |
| | Practical course in Vegetation and Landscape Ecology: Monitoring in nature reserves |

## Professional Experience

| | |
|---|---|
| 2002 | Internship in the quality control department of the pharmaceutical company Nycomed Austria in Linz; area of operations: analytical chemistry, thin layer chromatography |
| 2003 | Internship in the quality control department of the pharmaceutical company Nycomed Austria in Linz; area of operations: analytical chemistry, high performance liquid chromatography, microbiology, bacterial endotoxin testing |
| since 2004 | Dog walking and dog training |
| 2005 - 2006 | Training-assistance in the vienna pet obedience school “pro-cane” |
| 2008 | Assistance at a reforestation project in Costa Rica |

## Miscellaneous Acquirements

| | |
|---|---|
| Foreign languages | English, Spanish, French, Italian |
| EDP | MS Word, Excel, Powerpoint |
| | Application of Geographic Information Systems, Geostatistics and Terrestrial Analysis in life science |

## Additional Interests

traveling, natural observation, reading, horseback riding, mountaineering, ski mountaineering, skiing, riding motorbikes