A comparative study of the herpetofauna in two different forest types at Caño Palma Biological Station, Costa Rica.

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Company: COTERC, Caño Palma Biological station
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COTERC

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Preface

With the study I hope to contribute to herpetofauna conservation efforts in the area. The study is conducted by Mark Groen and is part of the bachelor program Applied Biology of the HAS hogeschool.

This study aims to demonstrate the dependence of local herpetofauna species in the Tortuguero region on their habitat. Due to the lack of knowledge available specifically for the area, the purposes of herpetofauna study at Caño Palma are for two reasons: first, to provide an idea of what species are found in the two forest types; and second, to gain knowledge about variations in species composition, abundance and diversity in relation to their habitat. So I want to know which dominant habitat factors causes differences in biodiversity and abundance of herpetofauna species in two different forest types.

The success of this study is made possible thanks to the cooperation, guidance and knowledge of Charlotte Foale, Aidan Hulatt, Tom Mason, Lotte Bakermans and the volunteers of Caño Palma Biological Station.

Index

Summary

In all over the world the herpetofauna population is declining, making their conservation a priority (Cousineau, 2007). The largest cause for this decline is through anthropogenic influences, with the number one factor: habitat loss. The lowland wet Atlantic rainforest of Costa Rica support many species of herpetofauna and increasing human populations are putting pressure on these animals through the conversion of land for development and agriculture. Several studies show that herpetofauna species are highly dependent on their habitat (Gibbons, 2000: Lewis, 2009). However, current information about the location of the different species in the Tortuguero region is largely unknown. Therefore it is essential to study abundance and distribution of the herpetofauna population in Caño Palma area.

In the Tortuguero region lies the Caño Palma Biological Station, the area consist of 40 ha Neotropical secondary rainforest. The forest can be divided in two types, a *Manicaria saccifera* palm forest and a mixed hardwood forest (Lewis, 2010). The Manicaria forest and the Mixed forest have their borders against each other. A-biotic factors such as temperature, relative humidity and rain between the two different forest types are equal. The main difference between the forest types lies in the vegetation. Compared with the mixed forest, the results from this study about the vegetation of the Manicaria forest has shown that it had a low amount of herbaceous plants, “true” trees and buttress trees, but a high number of *Manicaria saccifera* trees. The Mixed forest has significant more herbaceous plants ($p = 0.00$) and small trees ($p = 0.027$). Beside the difference in vegetation also the influence of the vegetation on the herpetofauna population was studied. The results of the ANCOVA test showed that the diameter of buttress trees ($p = 0.042$), number of palms ($p = 0.029$) and the number of *Manicaria saccifera* trees ($p = 0.043$) has a significance influence on the number of species in both forest types.

Over 80 species of herpetofauna are living in these different forest types (Lewis, 2009). Herpetofauna are ectothermic animals which means that their body temperature is mostly regulated by their environment. Reptiles have a dry and impermeable skin and therefore they can bask during the day. Amphibians on the other hand have a semi-permeable skin which means that they can absorb water through their skin, but if they are exposed to direct sunlight water will evaporate from their body, this can lead to death. For this reason, generally more amphibians are active during the night (Leenders, 2004; Savage, 2002).

In order to create a good image of the herpetofauna population 12 plots of 5 by 5 meter were evenly distributed in the two forest types. Sampling in these plots was conducted twice a week, at day and nighttime. A total of 368 individuals were monitored in the plots, 176 in the Mixed forest and 92 in the Manicaria forest. Also more species were recorded in the Mixed forest compared with the Manicaria forest. So in these cases the Mixed forest had an overall higher diversity. However, two highly abundant species (*Oophaga pumilio* & *Euleutherodactylus brandsfordii)* were recorded in the Mixed forest causes the relative high number of individuals and this results in a low species evenness (Shannon- Wiener index). This is in contrary with the Manicaria forest that has a high species evenness because the amount of abundant species is lower. The recorded number of individuals, number of species and the species evenness were for both forest higher during the night surveys.

The reason of the differences in the number of species, number of individuals and in the Shannon-Wiener index is caused by the significant difference in vegetation between the two forest types. Since the vegetation is the source of the composition of the species and therefore individuals (Heyer, 1994; Leenders, 2004; Lieberman, 1986; 1998; Savage, 2002; Whitfield, 2005). This will answer the main question: “What are the differences in vegetation, biodiversity and abundance of herpetofauna species between the two different forest types?”

1. Introduction

1.1. Defining the problem

Costa Rica has a land mass that covers approximately 51100 km^2. Despite its relatively small size it supports a large variety of herpetofauna species, from caecilians to the big American crocodile, with around 350 species of reptiles and amphibians known to exist here (Cousineau, 2007). The biodiversity of these animals is declining making their conservation a priority (Gibbons, 2000). The largest cause for this decline is through anthropogenic influences, with the number one factor: habitat loss. In Latin America 40 species have already become extinct and more than 80 species are critically endangered (Lips *et al*, 2005). The lowland wet Atlantic rainforests of Costa Rica support many species of herpetofauna and increasing human populations are putting pressure on these animals through the conversion of land for development and agriculture. Base line data on their abundance and distribution in different habitats is therefore important to help guide future conservation efforts (Gibbons, 2000; Lewis, 2009).

In the Tortuguero region lies the Caño Palma biological station that is managed by “Canadian Organization for Tropical Education and Rainforest Conservation”(COTERC), the area consist of 40 ha Neotropical secondary rainforest. Secondary rainforest can be characterized by a less developed canopy structure, smaller trees, and less diversity. The canopy is less dense this results in more light on the forest floor, supporting ground vegetation (Manuel, 2000). The forest can be divided in two types, a *Manicaria saccifera* palm forest and a mixed hardwood forest (Lewis, 2010). The Manicaria forest and the Mixed forest have their borders against each other. A-biotic factors such as temperature, relative humidity and rain between the two different forest types are equal. The main difference between the forest types lies in the vegetation. Over 80 species of herpetofauna are living in these different forest types (Lewis, 2009). In order for conducting an efficient monitoring program for these species, information about their abundance and distribution is essential. Several studies show that herpetofauna species are highly dependent on their habitat (Gibbons, 2000: Lewis, 2009). However, the dependence of the local species in the Tortuguero region is not clear. Current information about the location of the different species in this area was largely unknown. Let alone the preferred habitat with its difference in a-biotic and biotic factors. This follows in the main question: “What are the differences in vegetation, biodiversity and abundance of the herpetofauna population between the two different forest types?”

Secondary rainforest can be an important habitat for the conservation of the herpetofauna, but little was known about the species composition over long term (Herrera-Montes, 2010). Information about the aspects or location of the different species between the two forest types was mostly unknown, for this reason this study began with a baseline measurement. A four year study by Todd Lewis in Caño Palma has showed that herpetofauna are affected by different biotic factors: number of logs, soil moisture and vegetation. Vegetation provides food, shelter and protection against predators, therefore vegetation is the most important factor to study. This is also shown in a previous study by Norman (1976), in this study was shown that there is a correlation between the amount of vegetation and the number of herpetofauna in the area. Amphibians have a semi-permeable skin that needs moisture or else they dry out. Therefore the soil moisture is an important aspect and can affect distribution of the herpetofauna population (Friend & Cellier, 1990; Vonesh, 1998; Lieberman, 1986). In the two different forest types there are different habitats with their own specific vegetation. The herpetofauna are scattered around in these specific habitats. So in order to give a relationship between the monitored herpetofauna and the vegetation, a record about the vegetation in the plots is necessary (Pearman, 1997; Zampella & Bunnell, 2000; Gardner *et* al, 2007b).

Because of the relatively large area of the Caño Palma Biological Station, this study used 12 survey plots to create a sample of both forest type. Each plot was representative for each forest type. Plot sampling has been successfully conducted in previous studies to determine the biodiversity and the species abundance (Lieberman, 1986).

1.2. Information about herpetofauna

Amphibians (Class Amphibia) and reptiles (Class Reptilia) also called herpetofauna, are ectothermic animals which means that their body temperature is mostly regulated by their environment (e.g., basking, heated rocks or ground). Mainly reptiles are the ones that are basking during the day. Amphibians, on the other hand, generally avoid direct contact with sunlight. Their skin is semi-permeable which means that they can replenish their internal water supply by absorbing water through their skin. This also means that water will evaporate from their bodies and they will dry out rapidly if they are exposed in warm and dry habitats. For this reason the peak of amphibian activity is during night time when the air is cooler and more humid. Those amphibians that are active during the day can be found in water, moist of heavily shaded areas. So the important difference between reptiles and amphibians is that reptiles are less dependent on water for their survival then amphibians. Reptiles have an impermeable scaly skin, this allows them to retain water to prevent evaporation. For this reason reptiles can survive in warm sunny habitats (Leenders, 2004; Savage, 2002).

The ecology of the herpetofauna consists of a large, complicated and dynamic community. The natural environmental changes that can have a short or long affect on the herpetofauna population are not fully understood (Woolbright, 1991; Henderson & Berg, 2005; Hawley, 2006). Other important influences are the less predictable environmental changes e.g. major flooding , fires and storms, which can affect the whole community (Pickett & White, 1985; Townsend, 1989; Yount & Niemi, 1990; Wootton *et* al., 1996). Different studies prove that herpetofauna populations are scattered in different forest types and in different microhabitats. Some herpetofauna lives in specialized niches that are created by the seasons, climate and life zones (Savage, 2002; Wells, 2007). These niches influence herpetofauna abundance and distribution over the different forest types. A previous study conducted by Lieberman, 1986 has shown that the number of palms, number of buttress tree and log cover have a significant effect on species richness and distribution of herpetofauna. Other aspects such as (1) number of lianas, (2) number of (Manicaria) trees and (3) percentage of herbaceous plants in the plot were recorded.

2. Method

2.1. Description of the study site

Costa Rica lies 12° latitude and 80° longitude in Central America. The country covers 51100 km² and lies in between the counties Nicaragua (North) and Panama (South). The nature in Costa Rica has a high variety of ecological zones, from desert land to tropical rainforest to mangrove forest (Baker, 2010). Caño Palma biological station is located in the Tortuguero area in the north east of Costa Rica near the Caribbean coast (Figure 2.1.). It has been owned and managed by the “Canadian Organization of Tropical Education Rainforest Conservation (COTERC)”. The land consists of 40 ha of Neotropical Atlantic lowland tropical wet rainforest and it is considered as one of the most biological rich area of Costa Rica (Lewis, 2009). The area is surrounded with a network of rivers and canals, therefore almost every type of transportation is done by boat. The nearest road can been found 102 km away from the station. The climate of the area is relatively wet and receives 6000 mm rain every year. The average temperature is 26 C° (minimum 23 C°, maximum 32 C°) and the relative humidity is 70% (minimum 60%, maximum 95%). With temperatures constant, seasons in the tropics are not defined but temperatures differences, but by variation in rainfall (Leenders, 2004). The amount of rainfall is unpredictable. Obviously in the rainy season (October– February) the amount of rain will be larger than in the “dry” season (March – September). Not only is the amount of rain greater but also there are a lot more storms. The result of heavy rainfall and storms is an occasional flooded area.

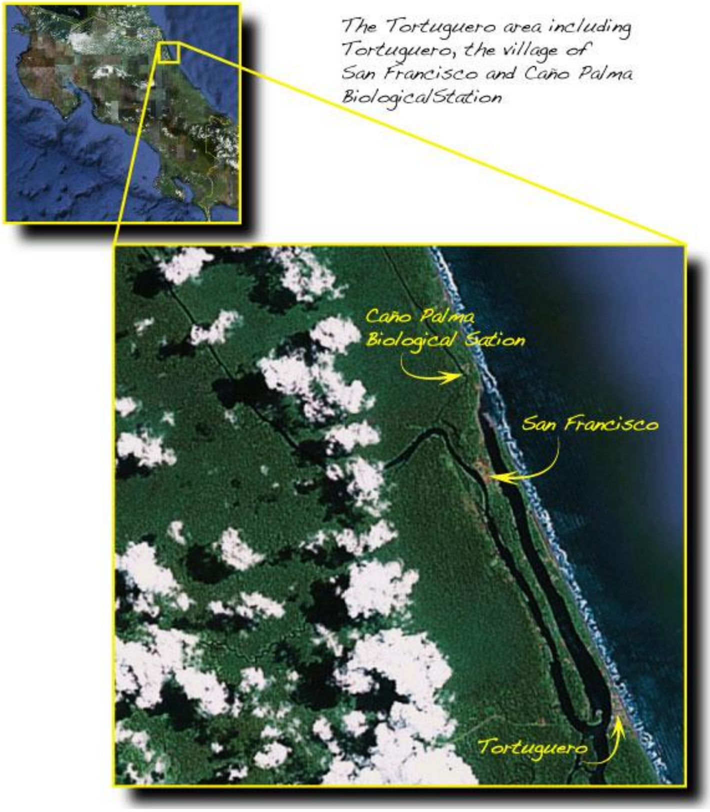

Figure 2.1. Map of Costa Rica, zoomed in at the Caño Palma region. Source: COTERC

The Caño Palma region can be divided into two areas which are next to each other. (1)Mixed forest (Figure 2.3.), this is a mixture of evenly distributed plant species. The vegetation can be classified by understory, middle sized trees or sub-canopy and canopy tree species (Figure 2.2.). The understory is dominated by herbaceous plants like *Psychotria glomerulata, Psychotria saktatrix* and the vine *Strychnos panamensis.* In the sub-canopy middle sized tree species such as *Dendropanax arboreus, Apeiba membranacea and Visia macrophylla* are the most common. The canopy is dominated by hardwood trees including *Pentaclethra macroloba*, *Carapa guianensis* and *Symphonia globulifera*. The palm tree *Manicaria saccifera* is infrequently found in the mixed forest. Compared to the *Manicaria saccifera* forest the altitude of the mixed forest is higher and therefore drier. This results in a dry soil during the

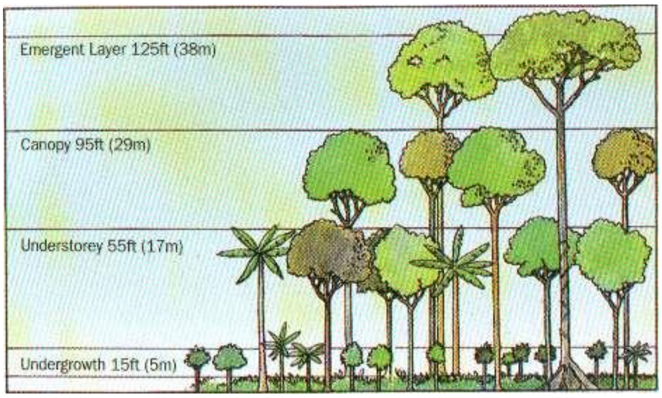

Figure 2.2. Layers of the rainforest Source: Wisdom :: Earth

dry season, but during the rainy season the area occasionally floods and temporally pools will be formed (Lewis, 2009).

Figure 2.3. The Mixed forest with a high percentage of herbaceous plants.

(2)*Manicaria saccifera* palm forest (Figure 2.4.), mostly dominated in the canopy by the palm tree *Manicaria saccifera* and predominated with *Pentaclethra macroloba*. The *Manicaria saccifera* can be found in Trinidad, Central America and South America, it is the only species in the genus *Manicaria*. This plant belongs to the monocotyledons and thus shares some characteristics with grasses, arum, lilies and orchids (Kricher, 1997). Unlike other monocotyledons the *Manicaria saccifera* have woody stems and appears similar to the stems of trees but are not true trees, since the leaves grow out of the center and do not form branches (Chase, 2004). Other characteristics are the large stiff leaves that are shaped like serrated feathers (Snarr, 2010). The long trunk (up to 9 meters in length) en large leaves (up to 8 meters in length) results in reduced sunlight from the canopy and causes shade for the understory. Compared to the mixed forest the amount of understory is little. *Psychotria saltatrix* and palm species are the most common species among the reduced, spatially open understory. The result of shade and highly saturated or flooded soil causes problems for a lot of plant species to grow. Only vegetation that prefers wet soil are capable to grow in the *Manicaria saccifera* palm forest (Lewis, 2009) This forest type is characterized by an abundance of natural high (semi)permanent groundwater pools and is frequently flooded by rain or ocean tides (Lewis, 2009 & Snarr, 2010). In the dry season the soil of the *Manicaria saccifera* palm forest is only saturated, however in the rainy season the area becomes almost permanent flooded.

Figure 2.4. The Manicaria forest with a low percentage of herbaceous plants and a large amount of water.

2.2. Sampling

In order to get a good image of the herpetofauna biodiversity and species evenness 12 of 5 x 5 meter plots are randomly selected in the Caño Palma area following Cousineau, (2007). Because of the limited time and human resources these dimensions are not larger. The plots are divided evenly in the different forest types, the UTM coordinates of the plots can be found in appendix V. The 5 x 5 meter plots were given an ID number and were marked with colored flagging tape. Each plot is monitored 2 times per week for 9 weeks long. The sampling rate was not higher because each plot needs a "resting" time in order to let the herpetofauna return. The herpetofauna consist of nocturnal and diurnal species, for this reason every plot was surveyed at day and night. During the day time the survey was conducted between 1 and 5 pm. The night survey was conducted as soon as possible after sunset because the chance is higher to see crepuscular and nocturnal species. For the monitoring of herpetofauna a minimum of two persons were used during surveys. The persons moved at the same rate together from each side of the plot to the center of the plot. The herpetofauna tended to flee to the center of the plot. At some point the highest concentration of animals was at the center of the plot, because of this the animals were more easily to be caught. On the way to the center the litter were disturbed and removed with a snake hook, this causes the hidden herpetofauna to move out of their shelter. The disturbing and removal of the litter is not attempted with bare hands because of the potential hidden (venomous) creatures such as scorpions and tarantula's. The herpetofauna were caught with a cup or with a snake hook. With this method the chances of fleeing animals were minimized. After the herpetofauna were caught, they were identified with the help of the book "The Amphibians and Reptiles of Costa Rica". After identification the herpetofauna were released at the same spot where they were found.

2.3. Statistics

In order to give a good image of the biodiversity and species evenness in the 2 forest types a Shannon-Wiener index was used. The standard minimum of the index is 1.5(low species diversity) and the maximum is 3.5(high species diversity). The index isn't an absolute number but can give a good image of the biodiversity and species evenness in the 2 different forest types. The Shannon-Wiener Index was used because it takes both species richness and the relative abundance of each of these species in a community into account to determine the coincidence of the monitored herpetofauna.

The data of covariates (Chapter 3.3.) was tested if they have a significant influence on the number of species, number of individuals and the Shannon- Wiener index. This test is conducted with the ANCOVA (Analysis of covariance). To see if there is a difference between the areas and the number of species, number of individuals, Shannon- Wiener index and vegetation an ANOVA (Analysis of variance) was conducted, this method is also used to determine the difference in day and night. To clarify the tests an enumeration is made:

1. Areas → Number of species
2. Areas → Number of individuals
3. Areas → Shannon- Wiener index
3. Areas → Vegetation
4. Covariate → Number of species
5. Covariate → Number of individuals
5. Covariate → Shannon- Wiener index

2.4. Vegetation influence on the herpetofauna population

The vegetation plays a big role in the herpetofauna population (Chapter 1.1. & 1.2.). Therefore the vegetation is monitored in each plot. The amount of changes that the vegetation in a plot makes is not considered to be dynamic, for that reason the vegetation is monitored three times. Previous studies have shown that following vegetation features can affects the species abundance and the biodiversity (Lieberman, 1986; Norman, 1976).

1. The number of buttress trees in the plot.
2. The diameter of the buttress tree in the plot (cm).
3. The number of palms in the plot.
4. The percentage of herbaceous plants in the plot.
5. The number of logs in the plot.
6. The number of large trees in the plot (Can be classified as trees without buttress roots).
7. The diameter of the large trees (cm).
8. The number of lianas in the plot.
9. The number of *Manicaria saccifera* palm trees in the plot.

In order to understand what affect these aspects have on the species evenness and biodiversity between the two forest types a comparison is made. The vegetation features are tested if they have a significant influence on the herpetofauna population (Chapter 2.3.).

2.5. Nocturnal and diurnal herpetofauna

Herpetofauna species can be nocturnal, diurnal or crepuscular. For this reason the surveys were conducted in daytime and nighttime. The amount of surveys at day and night was exact the same for each plot. The night survey was conducted after a few hours of darkness this will give the herpetofauna enough time to expose themselves. The animals in the day survey were not collected in the morning because of the limited time. Therefore the day survey was conducted between 1 and 5 pm. The method of collecting the animals was the same as in chapter 2.2. The only difference is that night survey was conducted with head and flashlights.

3. Results

3.1. The Manicaria & the Mixed forest.

Twenty-one species of amphibians and reptiles were found in the 12 plots (Table 3.1.). Of the 21 species, 15 species were found in the Manicaria forest and 17 species were found in the mixed forest. The number of species of the two different forest types is almost equal. However, there is a large difference in the total amount of recorded individuals. There were more individuals in the Mixed forest than in de Manicaria forest, with a total of 276 in the Mixed forest and a total of 92 in the Manicaria forest. However, no significant difference (F = 2.533, p = 0.143) were found in the total individuals between two forest types. Most of the species has been found in both forest types. This is quantified in that there were no significant difference between the total of amphibian (F = 0.114, p = 0.743) and reptile (F = 0.179, p = 0.682) species of the two forest types.

Table 3.1. The total number of recorded species and the total amount of individuals of each group between day and night.

	Manicaria forest		**Mixed forest**		
Species	Day	Night	Day	Night	**Total**
Bufo coniferus (Cope, 1862b)	0	2	0	1	3
Bothrops asper (Garman, 1883; 1884)	0	1	0	0	1
Eleutherodactylus bransfordii (Cope, 1885; 1886)	9	7	14	59	89
Eleutherodactylus diastema (Cope, 1875)	0	1	0	2	3
Eleutherodactylus fitzingeri (Schmidt, 1857)	7	9	3	8	27
Eleutherodactylus ranoides (Cope, 1885; 1886)	3	2	3	16	24
Gymnopis multiplicata (Peters, 1874)	0	0	0	2	2
Hyla rufitela (Fouquette, 1961)	0	0	0	1	1
Leptodactylus melanonotus (Hallowel, 1860; 1861)	2	2	0	1	5
Lepidoblepharis xanthostigma (Noble, 1916)	0	2	0	2	4
Micrurus alleni (Schmidt, 1936)	0	1	0	0	1
Norops biporcatus (Wiegmann, 1834a)	0	0	0	1	1
Norops humilis (Peters, 1863b)	3	0	0	0	3
Norops lemurinus (Cope, 1861b)	0	0	0	2	2
Norops limifrons (Cope, 1862c)	0	5	1	5	11
Norops oxylophus (Cope, 1875)	10	14	0	0	24
Ninae Sebae (Duméril & Bibron, 1854)	0	1	0	1	2
Oophaga pumilio (Schmidt, 1857)	9	1	72	62	144
Sphenomorphus cherriei (Cope, 1893)	0	0	8	9	17
Scinax elaeochroa (Cope, 1875)	0	1	0	2	3
Sphaerodactylus homolepis (Cope, 1885; 1886)	0	0	0	1	1
Total	43	49	101	175	**368**

Not only was the amount of total individuals different, but there was also a difference in the abundance of the species between the Mixed and Manicaria forest (Figure 3.1. & 3.2.).Figure 3.1. shows the most abundant species of the Manicaria forest: *Norops oxylophus*, *Eleutherodactylus brandsfordii*, *Eleutherodactylus fitzingeri* and *Oophaga pumilio*. The last three are frogs and the first one is an anolis. The abundance of the species in this forest was evenly divided. This is in contrast to the Mixed forest. The four most abundance species in the Mixed forest were not evenly divided. Figure 3.2. shows that the *Oophaga pumilio* is the most abundant species with a total of 122 individuals. The next most abundant species *Eleutherodactylus brandsfordii*, had a total of 73 is individuals recorded. This is reflected in the Shannon-Wiener index of the two forest types (Table 3.2.). The Shannon- Wiener index of the Manicaria forest is higher compared to the Mixed forest.

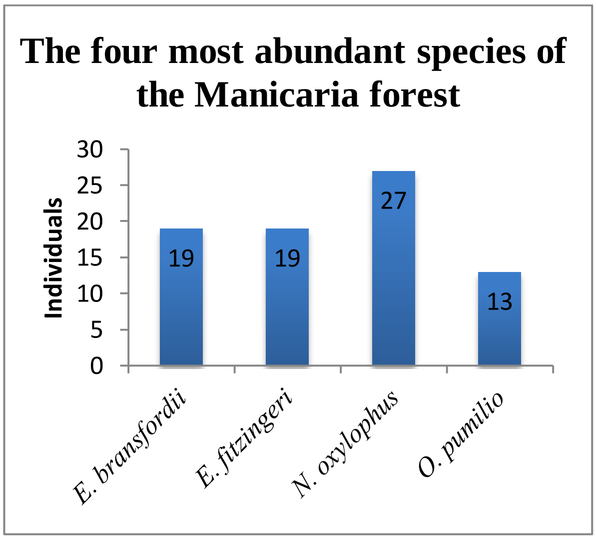

Figure 3.1. The top four abundant species that were recorded in the Manicaria forest.

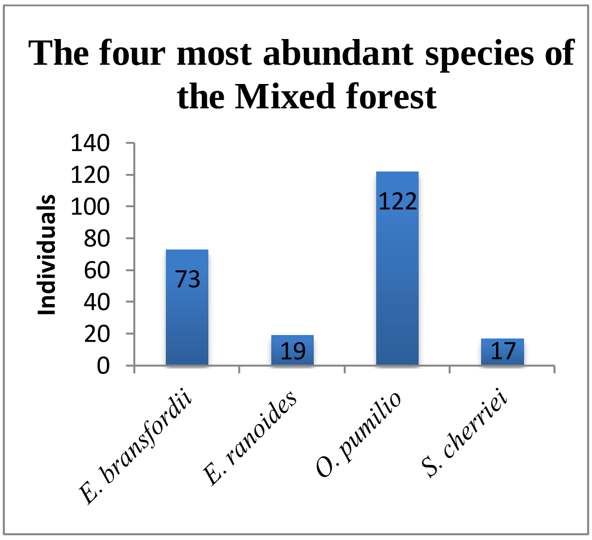

Figure 3.2. The top four abundant species that were recorded in the Mixed forest.

Table 3.2. The Shannon-Wiener index of the total species in both forest types.

Area	Shannon- Wiener index
Total species Manicaria	2.125847
Total species Mixed	1.608290

Figure 3.3. shows a relationship between the total number of species and the total number of individuals per plot. The species richness and total number of individuals per plot were used to make this graph. Compared with the Mixed forest, the Manicaria had a low amount of individuals and has four to 10 species, the clustering is shown in the graph. However, the Mixed forest is showing two clusters in the graph. Three plots are equal with the interrelation of the Manicaria plots and the other three plots had more species and more individuals. The three plots with the low species richness and low amount of individuals are nearer the Caño Palm canal. The species richness of the two forest types appears to be similar.

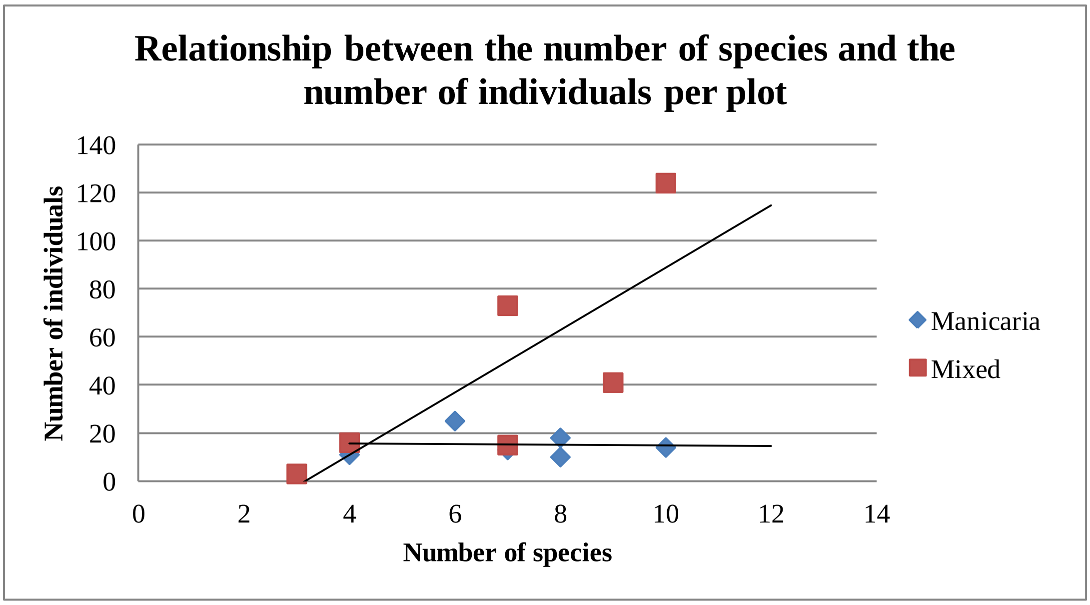

Figure 3.3. Relationship between the number of species and the number of individuals per plot.

3.2. The difference between day and night

In the Mixed forest 17 species were found during night surveys compared to 6 species in the day surveys (Figure 3.4.) Eleven more species were found during night surveys compared to day surveys (p = 0.011). The difference between the Manicaria surveys is 7 more species at night (p = 0.319). In both forest types more species were found during the night surveys (Appendix II). Compared to the Mixed forest more nocturnal species were recorded in the Manicaria forest during the day and night surveys. The Mixed forest had more diurnal species with day surveys and one more nocturnal species with night surveys. (Appendix VI).

Figure 3.5. is showing that there is a large difference of total individuals between the Manicaria forest and the Mixed forest. Six more individuals were recorded during the night surveys compared to day surveys in the Manicaria forest (p = 0.882). The difference in total individuals in the Mixed forest is 74 (p = 0.232). This includes 72 individuals of *O. pumilio* during day surveys and 62 of *O. pumilio* during night surveys.

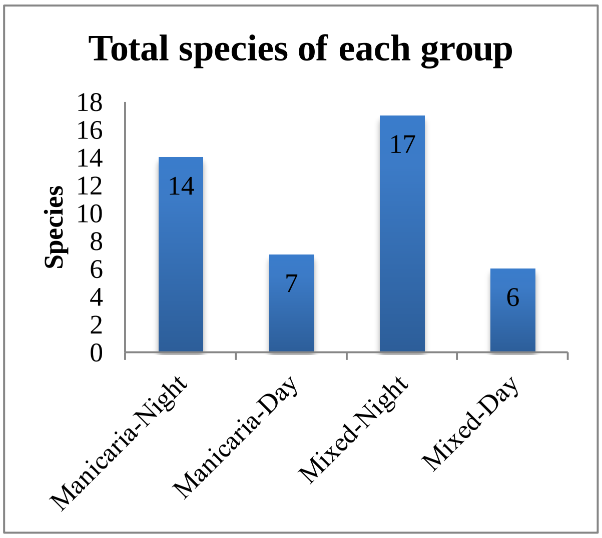

Figure 3.4. The total recorded species of the Manicaria and Mixed forest witin day and night surveys.

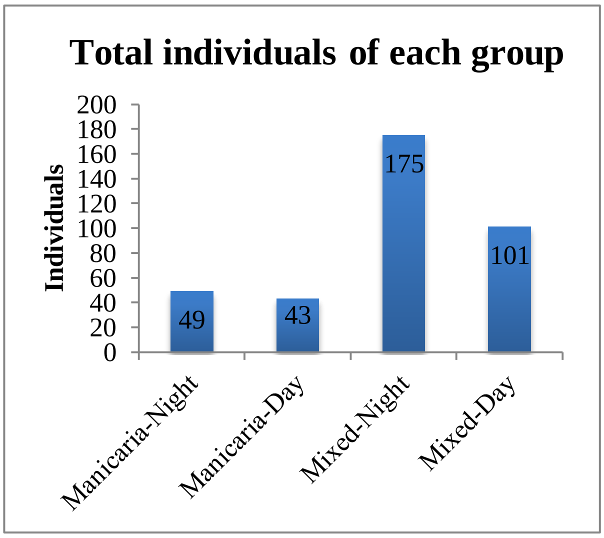

Figure 3.5. The total recorded individuals of the Manicaria and Mixed forest witin day and night surveys.

Not only is there a difference in the species and individuals but there is also a difference in the Shannon- Wiener index between the groups (Table 3.4.). The Manicaria night and the Mixed night both have a higher Shannon- Wiener index compared to the day surveys of the forests. However no significance is found between the Manicaria night and day surveys (p = 0.233). Compared with Manicaria forest, there is a larger difference in Shannon- Wiener index between the Mixed forest night and day surveys (p = 0.009) (Appendix IV).

Tabel 3.4. The Shannon-Wiener index of the day and night surveys for both forest types.

Groups	Shannon- Wiener index
Manicaria - Day	1.803637
Manicaria - Night	2.178850
Mixed - Day	0.097063
Mixed - Night	1.780742

3.3. The vegetation of the two forest types

Average measurements for the vegetation co-variables were measured three times throughout the study and are shown in figure 3.5. The difference in vegetation varies between the two forest types. Overall, the mixed forest has more vegetation compared with the Manicaria forest. All the vegetation aspects (covariates) were tested to determine whether they had a significant influence on the number of species ($F = 274.957$, $p = 0.047$), number of individuals ($F = 4.128$, $p = 0.367$) and Shannon-Wiener index ($F = 2.900$, $p = 0.430$) (Appendix III). The following covariates had a significant influence on the number of species that were recorded: the diameter of the buttress trees ($F = 229.839$, $p = 0.042$), number of palms ($F = 497.873$, $p = 0.029$) and the number of *Manicaria saccifera* trees ($F = 214.172$, $p = 0.043$). Not only is there a large difference in the buttress trees between the two forest types but there is also a significant difference in the number of "regular" trees ($F = 6.657$, $p = 0.027$. Another large difference in vegetation between the two forest types is the number of *Manicaria saccifera* trees and the percentage of herbaceous plants. The Manicaria forest has more *Manicaria saccifera* trees compared with the Mixed forest ($F = 14.578$, $p = 0.027$). The percentage of herbaceous plants is significantly higher in the Mixed forest than in the Manicaria forest ($p < 0.001$). The rest of the covariates did not have a significant influence on the number of species, individuals and or on the Shannon-Wiener index. The Mixed forest has a few more buttress trees compared to the Manicaria forest. The largest difference lies in the average diameter of buttress trees within the two forest types, i.e. 82.66 cm.

Table 3.5. The average measurements from the vegetation of each plot.

	Buttress trees	Ø Buttress trees(cm)	Palms	% Herbaceous plants	Logs	Trees	Ø Trees (cm)	#Lianas	Manicaria trees
Mixed forest									
Mixed 1	0	0	10,00	48.33	0.00	2	3.0	0	0
Mixed 2	0	0	5.67	81.67	4.33	6	11.5	0	0
Mixed 3	1	280	10.67	28.33	2.33	1	210.0	0	0
Mixed 4	1	220	2,00	81.67	0.00	5	33.6	1	0
Mixed 5	2	420	5.33	51.67	0.00	0	0.0	1	1
Mixed 6	0	0	1.00	70.00	2.67	2	46.0	0	0
Average	0.67	153.33	5.78	60.28	1.56	2.67	50.68	0.33	0.17
***Manicaria* forest**									
Manicaria 1	1	137	1.33	6.67	2.00	0	0	0	4
Manicaria 2	1	287	4.00	8.33	0.00	0	0	0	4
Manicaria 3	0	0	8.00	18.33	0.00	0	0	0	7
Manicaria 4	0	0	4.67	13.33	4.67	0	0	0	3
Manicaria 5	0	0	4.67	5.00	0.00	1	21	0	5
Manicaria 6	0	0	7.33	10.00	1.67	0	0	0	0
Average	0.33	70.67	5	10.28	2.78	0.17	3.5	0	3.83

4. Discussion & Conclusion

The area around Caño Palma is known as a secondary rainforest (Lewis, 2009). According to the study of Herrera-Montes, 2010 & Maunel, 2000 the vegetation of a secondary rainforest consist of a large amount of herbaceous plants, small trees and a few buttress trees. Compared with a primary rainforest the understory of the secondary rainforest receives a lot of daylight from the open canopy. This results in an excessive growth of the understory in a secondary rainforest.

The results of the vegetation (Chapter 3.3) from the mixed forest can be classified as a typical secondary rainforest which has a large amount of herbaceous plants (p = 0.00) and small trees (p = 0.027). Compared with the Mixed forest, the results from this study about the vegetation of the Manicaria forest has shown that it has a low amount of herbaceous plants, “true” trees and buttress trees. For this reason the Manicaria forest cannot be classified as a true secondary rainforest. The Manicaria forest can be part of a secondary rainforest but is mostly seen as a palm (swamp) forest (Snarr, 2010). The large leaves of the *Manicaria saccifera* palm are blocking the sunlight and cause the lack of sunlight on the understory. During this study the plots in the Manicaria forest were almost always flooded by heavy rain and groundwater pools, this is typical for the Manicaria forest (Lewis, 2010). The *Manicaria saccifera* palm tree and other palm species thrives well in poorly drained and highly saturated soil. However, the lack of sunlight and poorly drained flooded soil inhibits the growth of herbaceous plants and (buttress) trees (Myers, 1990; Snarr, 2010). The soil of the Mixed forest is much drier and more sunlight from the canopy is reaching the understory. These two factors make it possible that overall more vegetation can grow in the Mixed forest. This results in a higher rate and state of succession in the Mixed forest.

The study of Lieberman, 1986 and Whitfield, 2005 is showing that several vegetation aspects had a significant influence on the herpetofauna population. This study demonstrates as well that vegetation is importance and has an influence on the herpetofauna population. The reason that vegetation aspects such as the diameter of buttress trees (p = 0.042), number of palms (p = 0.029) and the number of *Manicaria saccifera* trees (p = 0.043) has a significance influence on the number of species is that a large part of the plots were covered with this vegetation.

According to the study of Herrera-Montes, 2010 more abundance of herpetofauna species will occur in a more developed secondary rainforest. This is the reason why more individuals and abundance are found in the Mixed forest and not in the Manicaria forest (Chapter 3.1.). This explains why the species evenness (Shannon- Wiener index) is higher in the Manicaria forest than in the Mixed forest. This is also reflected in the relationship between species en their number of individuals (Figure 3.3.). In this figure is shown that there are two clusters from the Mixed forest. One with a relative low amount of species and individuals and the other one with a relative high amount of species and individuals. Because of the lack in space the plots from the cluster with the low amount of species and individuals were close to the edge of the forest and the Caño Palma canal. In this canal there is a lot of activity with boats driving by which causes disturbance. Disturbance and transition of habitat from rainforest to aquatic might cause the so called edge-effect” (Lehtinen, 2002) and can influence the distribution of the herpetofauna. This might explain why there are two clusters in figure 3.3.

The low index of the Shannon- Wiener method in the Mixed forest is caused by two species: *Oophaga pumilio* and *Eleutherodactylus brandsfordii*. These two anuran species are the main cause of the higher number of total individuals in the Mixed forest. Not only the species *O. pumilio* and *E. brandsfordii* were abundant in the Manicaria forest but also two other species were as well abundant *Eleutherodactylus fitzingeri* and *Norops oxylophus* (anolis) were abundant. So the Manicaria forest has four equally spread out abundant species and the Mixed forest has two very abundant species. *O. pumilio*, *E. brandsfordii* and *N. oxylophus* are diurnal species and *E. fitzingeri* is a nocturnal species (Leenders, 2004; Savage, 2002). Both diurnal and nocturnal species were found in their opposite period of activity. According to the literature (Heyer, 1994; Leenders, 2004; Savage, 2002) there is more activity of the herpetofauna at night time, especially with amphibians. Although the difference in day and night should be approached with caution, since diurnal herpetofauna are still presence(sleeping) during night time and can be found with nocturnal herpetofauna. This hypotheses is confirmed since more nocturnal herpetofauna were found in the Manicaria forest during day and night surveys. In the day survey of the Mixed forest more diurnal species were found but during the night survey the number of diurnal and nocturnal herpetofauna is almost equal. Therefore no difference is found between the number of amphibian and reptile species during day and night. Nevertheless, there is a difference in the total species (nocturnal and diurnal) between day and night (Figure 3.4.). This difference is significant in the Mixed forest ($p = 0.011$) and not in the Manicaria forest.

The reason of the differences in the number of species, number of individuals and in the Shannon-Wiener index is caused by the significant difference in vegetation between the two forest types. Since the vegetation is the source of the composition of the species and therefore individuals (Heyer, 1994; Leenders, 2004; Lieberman, 1986 ; Norman, 1976; Vonesh 1998; Savage, 2002; Whitfield, 2005). This will answer the main question: "What are the differences in vegetation, biodiversity and abundance of the herpetofauna population between the two different forest types?"

In addition for the follow-up study and to complete the difference between the two forest types. A study of the seasonal changes and there influences on the herpetofauna population should be included. According to the study of Lieberman, 1986 the difference in seasons has a large influence on the herpetofauna population and fluctuation. In order to get a complete image of the influence of the seasons a long term study should be done. Another addition for the follow-up study is to place the plots away from any edge to prevent the "edge-effect" (Lehtinen, 2002).

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