Comparison of the Herpetofauna between Terra Firme Rainforest and Aguajal Swamp in the Madre de Dios Region, Peru

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Abstract

Approximately 41% of amphibians and 21% of non-avian reptiles are threatened with extinction worldwide. Herpetofaunal inventories are important parts of environmental assessment programs, which help to better understand the causes behind population declines. My field survey took place in Madre de Dios region, southeastern part of the Peruvian Amazon. I compared the herpetofauna of two habitats, the Terra Firme rainforest and a palm swamp locally called aguajal. My methodology included the usage of pitfall traps with drift fences, and visual encounter surveys as well. All in all, 2 specimens were found in the aguajal swamp, and 10 in the Terra Firme rainforest. Due to the small sample size, the results are inconclusive.

Introduction

The Amazon basin is home to the world's largest rainforest biome, the Amazon rainforest. Roughly 13% of the forest belongs to Peru, and more than 60% of the country's territory is part of Amazonia (Villacorta, 2007). The Madre de Dios department is one of the most biodiverse locations on Earth, making it the biodiversity capital of Peru (WWF). Despite the fact that it represents only 1% of the Amazon basin's land area, it is home to around 30% of all known Amazonian herpetofauna (Duellman, 2005; von May et al., 2008; Warren-Thomas et al., 2013). Although about 45% of its area is designated as natural protected area, the region is threatened by gold mining and deforestation due to human settlements, illegal logging and slash-and-burn agriculture (Oliveira et al., 2007; WWF).

Comprehensive global assessments of species' extinction risks have documented that approximately 41% of amphibians and 21% of non-avian reptiles (hereinafter: "reptiles") are threatened with extinction (Böhm et al., 2013; Cox et al., 2022; IUCN Red List). The most significant threats to their populations are the same as with other Tetrapod groups, namely habitat degradation and loss, invasive species, environmental pollution, diseases, unsustainable human use and the global climate change (Gibbons et al., 2000; Cox et al., 2022). Environmental assessment programs should include inventories of herpetofauna, and field surveys should be encouraged. With long-term and widespread monitoring of herpetofauna, population declines will be better understood. It will be easier to differentiate them from natural fluctuations, and the causes will be easier to understand (Gibbons et al., 2000).

In the case of herpetofauna, field surveys are especially challenging, as most species are cryptic, with activity largely depending on climatic factors and time of the day (Todd et al., 2007). Long-term

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monitoring must be aided by establishing standard methods and techniques. According to numerous studies, using pitfall and terrestrial funnel traps can maximize the number of individuals and number of herpetofauna species found. Therefore, it is particularly useful for determining species richness and relative abundance of a researched area (Nelson & Gibbons, 1972; Semlitsch et al., 1981; Hanlin et al., 2000; Enge, 2001; Russell et al., 2002; Ryan et al., 2002; Todd et al., 2007). However, this method also has disadvantages. Capture biases are possible, as some species may display trap attraction or aversion. Large snakes and tree frogs can escape from the pitfall trap, and the capture of strictly arboreal species is less likely. These drawbacks can somewhat be mitigated by using active sampling methods as well, for example visual encounter surveys (Eekhout, 2010).

The aim of my research project is to get a broader picture of the amphibian and reptile species occurring in the study site. I compared two natural habitats: the Terra Firme rainforest, and a palm swamp (local name aguajal). For the investigation, I was taking into consideration the species composition, species richness and abundance of the aforementioned habitats. In order to compensate for the limitations of my short-term survey, I used data from the previous on-site herpetological studies as well, for further comparisons. My research took place during the austral winter, which corresponds with the dry season in the southeastern part of the Peruvian Amazon.

Methods

Study Site, Habitats

The survey took place at Finca Las Piedras Research Station, the field site of the nongovernmental organization Alliace for a Sustainable Amazon, in the Madre de Dios department of Peru. The 54 ha-sized site consists of multiple different habitats. Most of the property is Terra Firme forest, which is a type of elevated forest lacking seasonal floodings. This forest habitat is mostly undisturbed, although in the last couple decades, it was selectively logged for its hardwood (such as big-leafed mahogany, Spanish cedar and ironwood). The other typical forested habitat of the region is the aguajal, a palm swamp wetland dominated by the palm *Mauritia flexuosa*, one of the keystone species of the region (van der Hoek et al., 2020).

Visual Encounter Survey (VES)

For the survey, I used the technic called visual encounter survey. VES is a time-constrained method for sampling species richness and abundance along a survey path. During the sampling period, I did regular visits to the two researched habitats. Before I started to conduct the surveys, I chose one route each out of the trail system of the study site. For picking the survey paths, I took in consideration the length and geographic orientation of the tracks. The chosen routes were around 600 meters long, with Northern – Southern approximate direction. Because of the daytime heat, many reptile and amphibian species are nocturnal, therefore I conducted the surveys after sunset, starting after 21:00. If it was possible, I was accompanied by another naturist during the fieldwork, as to increase the efficiency of finding specimens. I used the GPS application Geo Tracker on my mobile phone in order to track my movement during the surveys, and also for taking the coordinates of the encountered herpetofauna. During the VES, each time I alternated the route and direction I took: one night the Terra Firme habitat, next time the aguajal; one time from North to South, next time from South to North. At each survey, I visually searched

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the vegetation within 2 meters of either side of the route, and up to 3 meters in height.

Traps

To choose the location of the traps, I picked five random points five meters away from the survey paths, using the software QGIS (version 3.36.2). I visited each point to see if there were circumstances which made the location not adequate for the construction of the traps (for example too thick vegetation, or too close to the edge of the habitat). After this, I used the code "runif" from the software RStudio (version 4.3.1.) to generate a random number in order to choose the final location. The trap's coordinates are -12.226904°; -69.110403° for the Terra Firme forest, and -12.225138°; -69.118217° in the case of aguajal. For constructing the traps, I followed the methodology by Süess (2017). Originally, I intended to use terrestrial funnel traps as well, but due to the lack of time and the relative complexity of the construction, I ended up not including them. The drift fences are built using Raschel mesh in an Y-shape, each arm exceeding five meters between two wooden stakes. Each trap had four 20-liter buckets dug in as pitfall traps, one in the middle, and one at the end of each arm. The wooden stakes were cut to 1,60 meters length and buried 50 centimetres deep. Fences were dug in 10 centimetres deep, to prevent animals from digging under them. To prevent the drowning of the captured animals during rainy weather, I drilled five holes in each bucket. The traps were opened for 12 hours in the night. For this, I departed at 6:00 from the camp and started opening the trap in aguajal first, and closed the traps departing at 18:00. Outside the sampling time, I put branches in the buckets as escape routes.

Previous Surveys

On the site Finca Las Piedras, there were four previous herpetological surveys using pitfall traps and VES (Süess, 2017; Cruz, 2018; Matthews, 2022; de Wit, 2022), comparing the diversity of the Terra Firme forest edge, the forest interior, and the grassland. I compared my data with their publicly available data from their intern reports.

Species Inventory

With the herpetofauna I encountered outside of the scope of the habitat comparison, I made a species inventory. Only specimens from when I was present at their finding were included, and only if they were documented by photos.

Data Analysis

The captured or detected amphibians and reptiles were photographed from multiple angles, then identified to a species level if it was possible, otherwise to a genus or family level. To describe the diversity of each habitat, the Shannon-Wiener diversity index and the effective number of species were calculated using RStudio (version 4.3.1.).

Results

VES

In total, there were 9-9 visual encounter surveys. With a cumulative duration of 23 hours and 24 minutes, each survey took 1 hour 18 minutes on average.
Thirteen specimens were seen during the sampling period, nine in the aguajal and four in the Terra Firme forest, totalling an encounter rate of 0.6 animals per survey hour. In the case of three of them – all frogs – I was not able to capture them or take photos, so these were excluded from the further analysis. The ten identified individual belonged to eight species. At the aguajal, I encountered six of them, The most common species were with 2-2

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specimens the Schubart's Rondonia tree frog *Dendropsophus schubarti* and the South American common toad *Rhinella margaritifera*. Two further frog species were found there, the lesser tree frog *Dendropsophus minutus*, and the Fringe-lipped tree frog *Scinax garbei.* During the survey, I found two reptile species at the aguajal swamp, the Blue-lipped tree-runner *Plica umbra* and the Black-skinned parrot snake *Leptophis nigromarginatus.* In the Terra Firme forest, I found 1-1 specimens of two species, the Bolivian spiny-backed frog *Osteocephalus castaneicola*, and the slender anole *Anolis fuscoauratus.*

Traps

The traps were open for ten (non-consecutive) nights. This part of the survey resulted in two specimens of tropical bullfrogs (*Adenomera sp.*) at the aguajal swamp, which is 0.2 specimens per array day.

Figure 1: The abundance of amphibian and reptile families in the aguajal.
Blue and its shades: amphibian families; red and its shades: reptiles. *Hylidae* (tree frogs and their allies): 4 specimens; *Bufonidae* (true toads): 2 specimens; *Leptodactylidae* (southern frogs): 2 specimens; *Tropiduridae* (neotropical ground lizards): 1 specimen; *Colubridae* (colubrid snakes): 1 specimen.

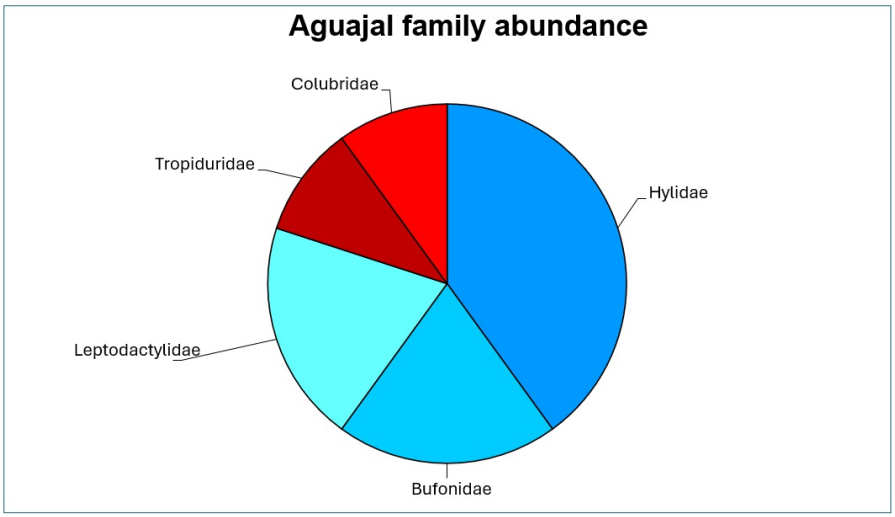
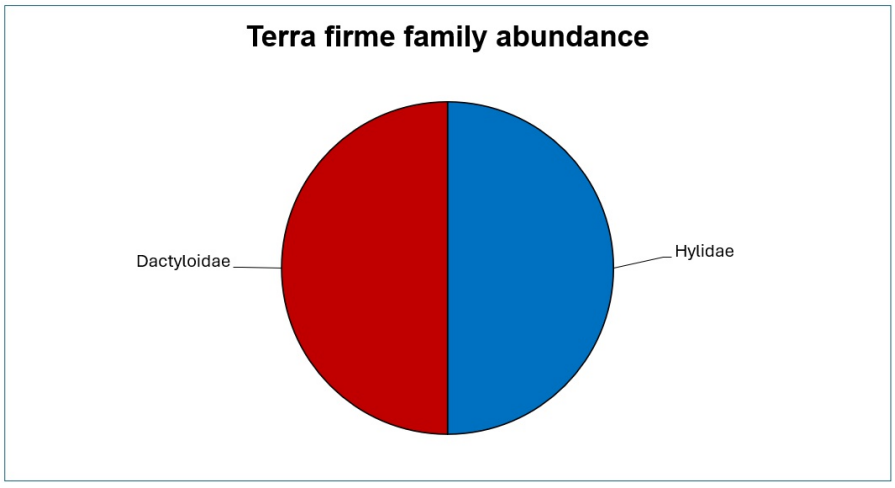


Figure 2: The abundance of amphibian and reptile families in the Terra Firme rainforest.
Blue and its shades: amphibian families; red and its shades: reptiles. *Hylidae* (tree frogs and their allies): 1 specimen; *Dactyloidae* (anole lizards): 1 specimen.



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Previous Surveys

Süess (2017) compared the herpetofauna of a recently burned grassland, a Terra Firme forest edge, and a Terra Firme forest interior. He used both pitfall traps with drift fences and VES, with more focus on the former. In total, he found 20 specimens in the traps during the 15 days and 14 nights of his survey. This translates to 0.28 species/array day in the forest interior. During the nine visual surveys he took, he encountered two specimens, which is an encounter rate of 0.5 individuals per survey hour. In the forest, the most common species was the lowland neotropical bullfrog *Adenomera andreae* (n=5).

The survey of Cruz (2019) researched the herpetofauna of the Terra Firme forest edge, and Terra Firme forest interior. His survey took 39 days and 38 nights with a total of 42 species, and 162 individuals. With the pitfall traps, he caught 58 examples of this. He made roughly one VES per day, which resulted 104 specimens. The most commonly found species was the chestnut's slender-legged treefrog *Osteocephalus castaneicola* for the VES, and the tropical bullfrog *Adenomera sp*. for the pitfall traps.

Matthews (2022) studied the grassland and the Terra Firme forest, using pitfall traps with drift fences, and VES. His survey took 24 days and 23 nights in total. He found 20 individuals in the forest, belonging to eight species. The most common were the Bolivian bleating frog *Hamptophryne boliviana* with eight specimens, and the brown egg frog *Ctenophryne geayi* with four specimens. The Shannon-Wiener diversity index was 2.49 for the forest.

De Wit (2022) compared the herpetofauna of the grassland and the Terra Firme forest, for a total of 31 days and 30 nights. He found seven species in the Terra Firme forest, using pitfall traps with drift fences.

Species Inventory

The species inventory resulted in 29 individuals (7 frogs, 10 lizards, 12 snakes) belonging to 22 species. Out of these specimens, ten were found around camp, nine in the Terra Firme forest, eight in the aguajal and one each at the nearby dirt road and the village called Monterrey. The most common species were the cane toad *Rhinella marina* and the blue-lipped tree lizard *Plica umbra* with three examples documented during my stay. Relatively common were the slender anole *Anolis fuscoauratus* and the garden tree boa *Corallus hortulana* with 2-2 specimens.

The most commonly found family was *Colubridae*, the family of colubrid snakes. All in all, I found nine examples of this family, each belonging to different species. Other common families with 4-4 specimens were *Bufonidae* (true toads), *Dactyloidae* (anoles) and *Tropiduridae* (neotropical ground lizards). Out of some families, I encountered one individual each: the Amazon racerunner *Ameiva ameiva* of the family *Teiidae*, the gecko *Thecadactylus solimoensis* from *Phyllodactylidae*, the black-necked Amazonian coral snake *Micrurus obscurus* from the family *Elapidae* and the South American bushmaster *Lachesis muta muta* belonging to the family *Viperidae*.

Data Analysis

The pitfall traps did not catch any specimens at the Terra Firme forest. Therefore, I did not separate them from the individuals found during the visual surveys for the sake of the statistical analysis. The Shannon-Wiener index was 0.69 for the Terra Firme forest, and 1.89 for the aguajal.

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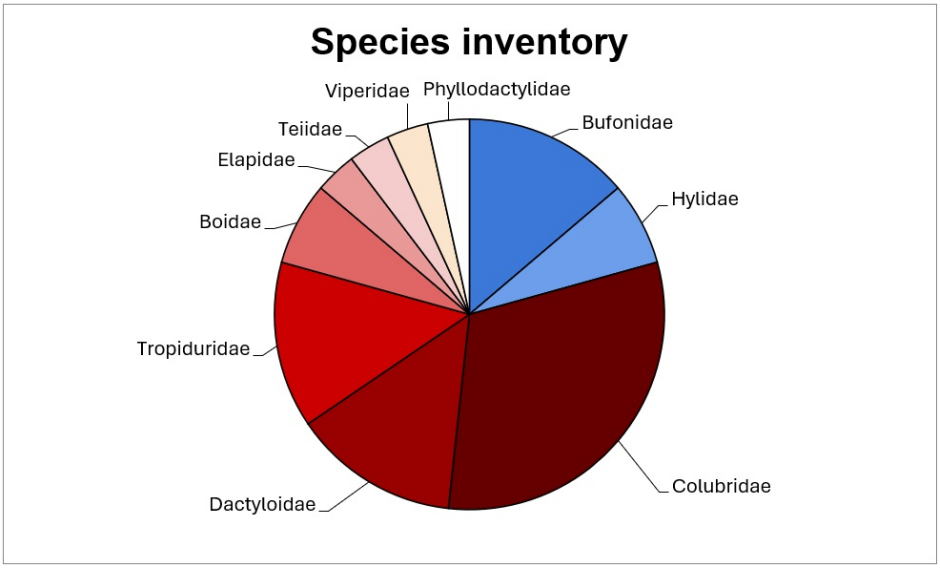
Figure 3: The abundance of amphibian and reptile families.
Blue and its shades: amphibian families; red and its shades: reptiles. *Bufonidae* (true toads): 4 specimens; *Hylidae* (tree frogs and their allies): 2 specimens; *Colubridae* (colubrids): 9 specimens; *Dactyloidae* (anoles): 4 specimens; *Tropiduridae* (neotropical ground lizards): 4 specimens; *Boidae* (boa snakes): 2 specimens; *Elapidae* (elapid snakes): 1 specimen; *Viperidae* (vipers): 1 specimen; *Phyllodactylidae* (leaf-toed geckoes): 1 specimen.



The effective number of species was 2.00 and 6.60, respectively. Because of the small sample sizes, I omitted the use of further statistical tests.

Discussion

As predicted, the aguajal has different species composition than the Terra Firme rainforest, with substantially higher species richness and abundance. In particular, the effective number of species differed strongly, taking on a value more than three times higher for the palm swamp. The differences are undoubtedly mathematically significant. However, the result came out of a very limited dataset: ten specimens were found in the aguajal during the survey, and only two at the rainforest. Therefore, the observed differences cannot be considered scientifically significant. Likewise, the effectiveness of the pitfall traps and visual encounter surveys cannot be accurately compared, also due the low sample size.

As to why my survey resulted in such a low sample size, my internship took place during the austral winter, which corresponds with the dry season in the southeastern part of the Peruvian Amazon. Much of the survey's sampling period occurred in July and August, the driest time period, with the former being the month with the smallest rainfall with an average of less than 60 mm (Aucahuasi-Almidon & Segura-Ttitom, 2022). It is known that the lifecycle of amphibians is largely dependent on the availability of water. Generally speaking, there is a direct connection between precipitation and the abundance of amphibians (Allmon, 1991; Arzabe, 1999). However, the activity of frogs mostly correlates with peak rainfall – the highest intensity during a specific time period – and not with the total rainfall (Duellman, 1995). Thus, the relative sparsity of major rainstorms during the dry season means that amphibians are less likely to be seen during visual encounter surveys, as well as caught by traps. Therefore, their predators – many arboreal and semiarboreal snakes for

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example – are less likely to be encountered as well. The abundance of some insects is also lower during the dry season, which in turn negatively affects the occurrence of insectivorous species (Jahn et al. 2010). Lastly, it is important to note my little previous experience with trapping herpetofauna.

To put my results in context, I searched the available literature for herpetofauna inventories in Peru, which included the two habitats. Catenazzi et al. (2013) compiled a list of the amphibians and reptiles of the Manu National Park; their methods included reviewing species descriptions, museum records, and their own fieldwork in the area. It is important to note that the Manu National Park is relatively close to my survey's study site. Therefore, it can be assumed with a high certainty that the species composition is largely similar between the two habitats of the aforementioned areas. The thesis of Panaifo & Ramirez (2016) included a herpetofauna inventory in Loreto, by visual encounter survey. Tapia et al. (2020) used VES paired with bibliographic review to determine the diversity of herpetofauna in the interfluve of the rivers Putumayo, Napo and Amazonas.

Catenazzi et al. (2013) confirmed the presence of 95 amphibian and 97 reptile species for the Terra Firme forest. In the case of the aguajal, it was 35 and 28, respectively. As the number of encountered specimens is not available, I was unable to calculate the Shannon-Wiener diversity index, nor the effective number of species. Panaifo & Ramirez (2016) found 21 amphibian species in the Terra Firme forest, and 16 in the aguajal. Regarding reptiles, it was 18 and 8 species for the two aforementioned habitats. The number of individuals were available, as well as the Shannon-Wiener diversity index of all herpetofauna for each habitat (Terra Firme: 2.462, aguajal: 2.157). Therefore, I calculated the effective number of species, which were 11.7 and 8.65, respectively. Fifteen amphibian and eleven reptile species were noted in the Terra Firme rainforest by Tapia et al. (2020). The survey at the aguajal swamp resulted in 19 amphibian and 10 reptile species. As the number of encountered specimens is not available, I was unable to calculate the Shannon-Wiener diversity index, nor the effective number of species.

Contrary to my initial hypothesis, these herpetofauna inventories – with the exception of Tapia et al. (2020) – confirmed the occurrence of more amphibian and reptile species at the Terra Firme rainforest. The structure and characteristics of the vegetation determines the diversity of microclimates, and the number of available ecological niches, as well as the type, quantity, and quality of the accessible resources (shelters, food, and breeding sites for example) (Panaifo & Ramirez, 2016). As the Terra Firme rainforest has higher number of plant species (Gema, 2011), more species can find their optimal living conditions there. My data differed substantially from the aforementioned herpetofauna inventories' results. The probable reason behind this is that my research project was rather short-term. Most of the data was collected in July and August of 2024, during the peak of the dry season. In contrast, the fieldwork part of the inventories took place during a longer time periods – including both the dry and rainy season – therefore having a higher likelihood of encountering herpetofauna specimens. During my survey, significantly more specimens were found in the aguajal palm swamp, which is contradictory with the inventories' results. A possible

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explanation for this contradiction could be that the aguajal contains microhabitats which stay moist during the dry season. The amphibians and reptiles living in these niches could remain more active than their counterparts living in the dryer Terra Firme rainforest, thus increasing the probability of encountering them.

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