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Drivers of reptile diversity in Serra da Bocaina National park and surrounded agriculture areas, SE Brazil

Master thesis

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Statement

I declare that I worked out this M.Sc. diploma thesis titled ”Drivers of reptile diversity in Serra da Bocaina National Park and surrounded agriculture areas, SE Brazil” alone and that I used only literature that is cited and mentioned in references.

In Prague, 22.4.2016

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Jaroslav Karhánek

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Abstract

The Atlantic Forest is pristine forest and it is also one of areas with the highest biodiversity, it is included in hotspots of the World with high percentage of endemic fauna and flora. It is also one of the most threatened environments with more than 90 % of total area already destroyed. In the area of states Rio de Janeiro and Sao Paulo it is possible to find largest remnants of forest, which is called Serra do Mar. The main aims of the thesis were to describe the herpetofauna of the Serra da Bocaina NP. The study was conducted in the private parts in buffer zones of Serra da Bocaina National Park, state of Sao Paulo, Brazil. In this study we were using visual encounter survey method via diurnal and nocturnal transects. The study sites were chosen in 3 different altitudes and environments. Study sites included disturbed open areas presented by pasture, wetland, agriculture land near households. The forest areas were mostly represented by secondary forest with connection to primary forests.

During the study I found a total of 87 individuals of 10 reptile species, belonging into 8 families: (1) Viperidae; (2) Dipsadidae; (3) Leiosauridae; (4) Tropiduridae; (5) Teiidae; (6) Gekkonidae; (7) Chelidae. Species diversity was given according to height elevation and preserved forest area. The highest diversity was in mid elevation (700 m a.s.l.) and the lowest in the highest elevations of the study (1,100 m a.s.l.).

Key words: Atlantic Forest, biodiversity, reptiles, ecology, conservation, forest

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1. Introduction and literature review

1.1. Brazilian Atlantic forest – Mata Atlantica

Mata Atlantica is one of the terrestrial biomes in South America (Luhr, 2003). The region extends along the Atlantic coast of Brazil and up to northeastern Argentina where the area is known as Selva Misionera and to eastern Paraguay (Colombo, 2010). In Brazil the Mata Atlantica is present in 13 of 26 states, spreading into the interior from fifty to several hundred kilometers. Originally it stretched in uninterrupted line of approximately 4,000 km from Rio Grande do Norte to Rio Grande do Sul (Hance, 2015; Colombo 2010). In the past it was the second largest forest in South America of the size of more than 1,300,000 km^2. The present size is around 100,000 km^2, it is less than 8 % of the original size. It fits into tropical and subtropical regions. Coastal line is almost entirely followed by highlands, which consist of several mountain ranges. The highlands are extended from Bahia in Brazil to Santa Catharina and northeastern Rio Grande do Sul. Sea elevation varies from 0 m a.s.l. up to 2,900 m a.s.l (Diegues, 2005; Oliveira, 2007).

Climate in Mata Atlantica region is tropical and subtropical with rain and dry season (Luhr, 2003). The main rain season is from November to March with some geographic exceptions in some parts of Mata Atlantica where rain season has more peaks during the year (Joly, 1999; Hance, 2015). Dry season has several periods during April to September. Annual rainfall average in Mata Atlantica region is around 1,100 mm. The most rain fall in coastal forest area is concentrated mostly in the rain season. One of the most rain areas is Serra do Mar coastline forest with annual rainfall ranging between 1,400 – 4,000 mm per year. Temperatures are dependent on the area (latitudinal). In highlands during dry season the temperature can drop down to 0°C (Colombo, 2010).

Mata Atlantica as a region includes several biomes, vegetation types. The Mata

Atlantica forest sensu lato is classified as the area with three types of forest. Ombrophilous dense forest, semi-deciduous and deciduous stationary forests from the south regions, and ombrophilous mist forest, known as Araucaria forest from southern Brazil (Siminski, 2011; Hance, 2015, Colombo, 2010). By another studies in the region we will find another types of environments for example mangroves, savannas, open ever green forest.

The area of Mata Atlantica is heavily populated, around 70 % of Brazilian population lives there, which is around 130 million people. Two of the world´s largest cities and metropolitan areas, Sao Paulo and Rio de Janeiro were built over the Mata Atlantica. Increased urban and rural sprawl has cut into remaining pockets of forest (Herzog, 2013; Hance, 2015; Marino, 2004).

1.1.1. Serra da Bocaina National park

Serra da Bocaina National Park was created by Federal Degree in 1971 and current area is established on 104 000 hectares. It is located at the border between the states of Rio de Janeiro (40 %) and Sao Paulo (60 %) in southeastern part of Brazil. The park headquarters is located in Sao Jose de Barreiro, Sao Paulo state (Ribeiro et al., 2009). The surrounding area is heavily populated with several population centers such as Ubatuba, Bananal, Paraty, Sao Jose de Barreiro, Cunha Areias, Mambacuba, Angra dos Reis (Herzog, 2013). On the west part it has borders with another protected area which is Serra do Mar National Park, it is a 1,500 km long system of mountain ranges (Ribeiro et al., 2009). Both of these national parks are considered as a very unique and important because of very variable on habitats and topography. Region of Serra do Mar (including Serra da Bocaina) is the biggest continuous forested area in Atlantic forest. Topographically is Serra da Bocaina NP very complicated. Most of the area is in higher altitudes, between 600 and 1,300 m a.s.l. with the highest point 2,088 m a.s.l. which belongs to Pico do Tira o Chapéu. By the sea coast the altitudes are dropping down very fast from 1,000 m a.s.l to almost sea level (Hance, 2015). We can find in this park several different environments such as mangroves, cloud forest, auracaria forest,

rainforest, mountain highland, grassland etc. There are also several springs such as Bracui, Barra Grande, Mambucaba.

1.1.2. History of Atlantic Forest

Atlantic Forest is very ancient forest. Atlantic forest always been isolated from its neighbor, Amazon basin. The first approach of European colonizators in 16th century started the era of large scale deforestation. Colonial settlements were established from the beginning by the coastline. Since that time the region came across the variety of landscape transformations which ended in current situation. First logging started immediately after arrival of colonizators (Galindo & Camara, 2003; Dean, 1997). At the beginning the wood was mainly used as firewood. Since that time the logging did not stop for another almost 500 years. Logging progressed mainly along the river systems deeper to the interior. Later created infrastructure enabled to transport wood more easily and it was not dependent on river systems and deforestation could start in large scale. The forest was logged or burned down to make place for ranches, farms and plantation, mostly of sugar cane, cacao and coffee. It happened in several waves, the first region was north-eastern, which was cultivated for sugar cane plantations, around 400 years ago (Dean, 1997). Population growth was also projected to logging, to make place for growing cities and population, especially in the 19th century the areas of Rio de Janeiro, Sao Paulo and Minas Gerais were cleared for high urbanization level which also increased demand for charcoal (Marino, 2004). Large areas are now used for cattle ranches and cattle grazing. Small areas had been reforested by monoculture of pines or eucalyptus in recent times. Even forest remnants in presence are under threats of illegal logging and firewood collection (Galindo & Camara, 2003).

1.1.3. Habitat fragmentation

Habitat fragmentation is generally breaking up large compact vegetation cover into smaller units. At this moment it is considered to be one of the biggest threats for the

biodiversity on the planet (Lord & Norton, 1990). Especially Atlantic Forest is in big problems with habitat fragmentation and large scale deforestation. As it was mentioned before, Atlantic Forest had size around 1,300,000 km^2 but now the size is only around 100 000 km^2, which is less than 8 % of the original size. 80 % of all fragments of the forest are smaller than 50 ha (Ranta et al. 1998).

Distribution and size of the fragments is dependent on several factors. Lowlands and mid elevation are or used to be under the highest threat. They were the most easily accessible areas and were representing the largest amount of the forested area. At this moment these lowlands are mostly totally deforested or are surviving in small fragments. In the lowlands the forest mostly disappeared or is remained in small fragments which are surrounded with pastures. On the another hand in higher elevations, over 1,100 m a.s.l. are located the largest forest remnants. In general, places with unsuitable terrain, steep hills or hard accessible places are mostly preserved with forest cover (Ranta et al. 1998; Ribeiro et al, 2009).

This effect cause problem with migration of the animals as the forest is fragmented and the fraction are sometimes far away from each other. Also in the small fragments cannot live many species, survive only the most successful with high tolerance to change of the environment. The fragmentation also leads to another problem, edge effect. It is a micro-climatic change which can lead to change of light, wind conditions, temperature, soil and water content. Alien species can easier disturb into the original population of animals or plants and can supplant them. It is important to mention that the original species are responding to that differently. Some of them can be just less abundant (Malcolm, 1994).

1.2. Biodiversity hotspot

Loosing of the major natural habitats is the main reason why is so rapid decline of biodiversity in the world. Humans are causing global change of the ecosystems, by

destroying them. Many species of animals went to extinction, it is natural process but human impact caused higher rate of extinction by at least thousand times more than natural rate (Myers et al., 2000).

The concept of first biodiversity hotspots were created by Norman Myers in 1988, consisting of 10 tropical forest hotspots. Every biodiversity hotspot have to complied 2 conditions to be recognize as a hotspot. First is to have more than 1,500 species of vascular plants, it is 0.5 % of world´s total, it has to have high percentage of plants found nowhere else. The second condition is to have more than 70 % of destroyed original area. Most of the current hotspots exceed this conditions. At this moment 35 areas in the world are recognized and valid (fig.1). These hotspots hold about 150,000 species of endemic plants, almost 50 % of all vascular plants on Earth. More than 12,000 endemic vertebrate animal species (mammals, birds, reptiles and amphibians) and over 3,500 endemic fish species lives there. Combined area of all hotspots covers only 2.3 % of total Earth surface (Russel et al., 2005; Possingham & Wilson, 2005; Colombo & Joly, 2010).

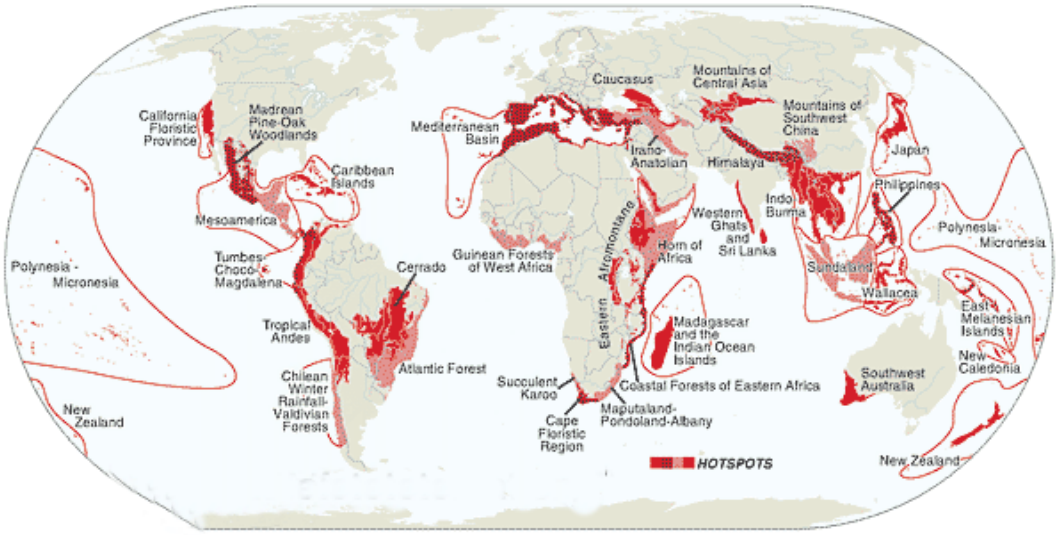

Figure 1: Biodiversity Hotspots of the world, Conservation international, 2005.

1.2.1. Atlantic Forest as hotspot

Atlantic forest meets the conditions to be hotspot already for several decades. Long isolation from Amazon basin by the dry cerrado helped to Atlantic ecoregion to evolve into unique form, also according to wide latitudinal and elevation differences it has helped to evolve high number of animal and plant species with high percentage of endemism. Many of the species are under threat of extinction (Colombo & Joly, 2010). This area is very rich in endemic species, around 40 % of vascular plants from 20,000 species. Endemism in trees is very high, more than half of them. Some of the trees are very rare, for example *Paratecoma peroba*. The bird diversity is also on very high level, we can find there almost 1,000 species. The level of endemism in birds is almost 15 % and 23 genera are endemic to this region. Because of large forest logging some of the species are highly threatened, for example Alagoas antwren (M*yrmotherula snowi* Texeira & Gonzaga, 1983), Brazilian merganser (*Mergus octosetaceus* Vieillot, 1817). Atlantic forest is home to more than 260 mammalian species from which is about 70 of them endemic in 12 genera. Even though the most of the area is destroyed and remaining forests are fragmented it is home to some big mammal species like Jaguar (*Panthera onca* Linnaeus, 1758), Cougar (*Puma concolor* Linnaeus, 1771) and South American tapir (*Tapirus terrestris* Linnaeus, 1758). It is home to some critically endangered species, for example Brazilian arboreal mouse (*Rhagomys rufescens* Thomas, 1917) (Galleti et al., 2009). In the case of amphibians, we will find there more than 450 species with more than half of them endemic, from which 15 genera are endemic to the ecosystem and even one whole family is endemic (Brachycephalidae). There is several critically endangered frog species (*Phyllomedusa eyeaye* Lutz, 1966, *Scinax alcatraz* Lutz, 1973 and *Hyla cymbalum* Bokermann, 1963). Reptiles are mentioned in section 1.3.2. In the waters of Atlantic forest lives more than 350 fish species and 130 species in 10 genera are endemic to this place (Galindo & Camara, 2003; Hance, 2015).

1.3. Reptiles

Reptiles are group which belongs to vertebrate animals, superclass Tehtrapoda.

They are covered by scales and scutes of many types and are “cold-blooded” animals, it can be understood as a mix of poikilothermy, ectothermy and bradymetabolism. Reptiles reproduce sexually (viviparity, ovoviviparity and oviparity), only few of them are able of asexual reproduction, parthenogenesis (6 families of lizards) (Modesto, 2004; O´shea & Halliday, 2002).

Modern reptiles are in several subgroups:

1) Testudines – turtles, tortoises and terrapins (344 species)
2) Sphenodontia – tuataras (1 specie)
3) Squamata – snakes, lizards and worm lizards (9 939 species)
4) Crocodylia – crocodiles, gavials, aligators (25 species)

(reptile.database, 2016)

At this moment there is around 10,309 species recognized worldwide. The number is not accurate because new species are still being discovered, rediscovered from old museum collections and also the status of some species, subspecies can be changed.

Some reptile species are more closely related to birds than to another reptiles so some scientist are making Reptilia a monophyletic group, which includes birds (Modesto, 2004; O´shea & Halliday, 2002).

They have large distribution area. It is given by large number of species. Reptiles went through remarkable adaptive process and became and exhibit large diversity, which helped them to populate most of the habitats on Earth (Modesto, 2004). It is possible to find them on all continents except Antarctica, although they are most abundant in tropics and subtropics. They inhabit large scale of environments, several species are specialized for living in the seas or in fresh waters. On the mainland they are occurring even under the ground but most of them are arboreal or terrestrial. They live in the dry environments such as desert, semi-deserts and arid colder deserts out of tropical or subtropical area. Reptiles are capable to live in humid conditions of rainforest, open grassland areas like savannas, pampas or in forested areas of temperate zone, also in mountain regions. Some of the species are able to survive in the high altitudes more than 3,500 m a.s.l. During intolerant weather conditions the reptiles from

those habitats are able to hibernate or aestivate. Colonization of the islands is also very high, one the first animals which inhabit the island of Krakatoa in Indonesia after volcano eruption (1883) were reptiles (O´shea & Halliday, 2002). Zoogeographical dispersal of reptiles has the highest concentrations in Neotropical and Oriental regions (Cambell & Lamar, 2004).

Their size range varies from 1.7 cm (*Sphaerodactylus ariasae* Hedges & Thomas, 2001) to 9.75 m (*Malayopython reticulatus* Schneider, 1801) and weight over 1 ton (*Crocodylus porosus* Schneider, 1801). Most of the species have size up to 80 cm (Ritchie & Jong, 2002). All reptiles are breathing by lungs, some of the aquatic species have developed more permeable skin which helps them to absorb an oxygen. In each of main reptile group is some specialization for breathing according to their conditions of living aspects and body type. The movements are done by several locomotion movements according to families, few species are able of gliding between the trees (*Chrysopelea paradisi* Boie, 1827*, Draco sp.*). Reptiles are both diurnal and nocturnal animals, in some families the eyesight is reduced (Typhlophidae). The vision has more advanced visual depth perception than for example in amphibians. Diurnal species has colorful vision. In some snakes have developed special visual organ, infrared vision (heat sensitive pits), it is evolved in several snake groups (Crotalinae and some Pythonidae, Boidae). These sensors can distinguish temperatures in 0.025°C and detect it to distance of around 1 m which helps them to visualize their surrounding and detecting the prey (O´shea & Halliday, 2002).

The most of the reptiles are insectivorous and carnivorous, have mostly simple and short digestive tract. Digestion of reptiles is slow comparably to mammals, it is much more dependent on temperature and it represent slow metabolism rate. Their metabolism has low energy requirements, allowing to large species to swallow only one larger prey which allows them to survive even for several months (large snakes, crocodiles). Reptiles are using several types of defensive behavior, most of them are preferring camouflage and warning signals. The skin of many species has cryptic coloration which allows them to blend with the surrounding environment, because most of the predators are birds or reptiles and both of the groups have color vision. Another

species had evolved warning display, it can be colorful display or active movements, inflating of the body or making noise by rattling, scale friction. Threatening or camouflage behavior is not always working, next step is active defense, attack (O´shea & Halliday, 2002; Ritchie & Jong, 2002).

Reptiles always had important role in human race and culture and the humans are important factor for reptile populations. Snakes play important role in the book of Genesis. In some cultures in South and Central America, Papua New Guinea, Indonesia, China, parts of Africa the reptiles are playing important role in religions (O´shea & Halliday, 2002). Very important role in mankind are playing venomous snakes which cause death of around 100,000 people annually worldwide (Chippaux, 1998). From other side, reptiles are used in traditional medicine, especially in East and South-east Asia, mainly China and Vietnam. Humans have high impact to reptile extinction nowadays.

1.3.1. Evolution of reptiles

The origin of earliest known reptile type animals lies about 320 million years ago during Carboniferous period in which time they have evolved from reptiliomorphs. They started to develop stronger skeleton, muscles and scales. Before that time the reptiles were dependent on water, for laying eggs and their early evolve stage could not get far away from water surface (Laurin et al., 1995, Campbell & Lamar, 2004). The oldest evidence comes mostly from fossil tracks, footprints. Those tracks were attributed to *Hylonymus*, at this moment the oldest reptile species. It was a small species of maximum size 30 cm in length. It had sharp teeth and is supposed that it was insectivorous predator. Earliest reptiles were in shadow of larger amphibians such a *Cochleosaurus* (Sahney et al., 2010).

After first amniotes appeared during the Permian period and they were diverged into three groups, synapsids, anapsids and diapsids. It was assumed that the first reptiles were anapsids. At the Permian period happened second main divergence of reptiles into

Archosaurus and Lepidosaurus. These two groups were dominant till the Triassic period (Modesto, 2004).

At the end of Carboniferous and beginning of Permian period the amniotes became the dominant tetrapod fauna. The primitive reptiliomorphs still existed. The amniotes evolved into first truly terrestrial megafauna (*Edaphosaurus, Dimetrodon*). In the mid-Permian period the climate changed to drier, resulting in change of fauna. In this period evolved modern reptiles, split into two main lineages, first Archosauromorpha (ancestors of dinosaurs, turtles and crocodiles) and Lepidosauromorpha (predecessors of lizards and tuataras) (Colbert & Morales, 2001).

During Mezoic period the mass extinction happened, most of the megafauna disappeared, being replaced by true reptiles, archosauromorphs. Became the dominant form of Triassic period. Archosaurus looked like long-legged crocodiles which later evolved into dinosaurs, pterosaurus and pseudosuchians (Colbert & Morales, 2001; Sahney & Benton, 2008).

The Cretaceous period ended with large scale extinction of species, only crocodiles, smaller species of reptiles and sea turtles survived. However, reptiles were still important components of fauna (Sahney & Benton, 2008).

1.3.2. Reptiles of Atlantic forest

Currently the domain of Atlantic forest holds more than 310 species of reptiles and numbers are still increasing. Number of endemic reptile species is 95 in 8 genera. New species are still appearing in this area, although the most of the forest area is destroyed. Even though the forests are still disappearing and total area of forest is only in around 10% of the original distribution, the reptiles are still largely distributed across the environments (Oliveira & Oliveira, 2004; Rodriguez, 2005). The part of Serra do Mar mountain range where the study was conducted is very rich in herpetofauna with about 80 species of snakes (Marques et al., 2004), yet many parts of this area are poorly

documented, this fact is valid for the all parts of Atlantic forest.

The formation of Atlantic forest holds several large species of reptiles, such as Broad-snouted Caiman (*Caiman latirostris* Daudin, 1801), Red-tailed boa (*Boa constrictor* Linnaeus, 1758), Argentine black and white tegu (*Salvator merianae* Dumeril & Bibron, 1839), Jararacussu (*Bothrops jararacussu* Lacerda, 1884), Yellow ratsnake (*Spilotes pullatus* Linnaeus, 1758) (Condez et al., 2009, Citelli et al., 2016). In Atlantic forest lives 17 species of Pitvipers of genus *Bothrops*, several of them are critically endangered such as *Bothrops insularis* Amaral, 1922, which lives only on one small island off the coast of Brazil and also *Bothrops muriciensis* Ferrarezzi & Freire, 2001, which is known only from few individuals from very small locality of Murici forest (Cambell & Lamar, 2004). Very recently (April of 2016) was described new critically endangered species of snake, *Bothrops sazimai,* which lives on small island of the coast, Ilha dos Franceses (Barbo et al., 2016).

Reptiles are threatened by habitat loss and fragmentation of the forests as some of the species are not able to migrate to new areas and are highly specialized for their habitats and can not adapt to it. The fragments at the most parts of the area are distributed far away from each other, mostly with insurmountable obstacles like cities and suburban areas. Big threat to reptiles, especially to snake is by humans, which are killing the animals of first sight in afraid of them (Almeiada-Gomes, 2014; Gouveia et al., 2015; Herzog & Finotti, 2013; Hartmann, et al., 2009)

1.3.3. Comparison of Atlantic forest with Amazonia

Amazon is the largest area covered by rainforest in the world. Covering total size of 7,000,000 km^2 from which around 5,000,000 km^2 is covered by rainforest. In periphery areas are different types of environments such as savannahs, cerrados, gallery forest and mountain forests. The Amazon river is key water flow in this area. Most of the Amazon area is basin with lowlands, the highest peak is Yerupajá which has 6,635 m a.s.l. Climate of the region is stable, only at periphery areas on the west where the Andean region occur is climate not so stable with large scale of temperatures given by

height altitude. Most of the basin is dependent on floods during rain season. Water level fluctuates during year around 15 meters (UNEP, 2004; Luhr, 2003).

Amazon basin is well known for its high diversity rate of animal and plant species, yet not so many endemic species occur there. Much of the size of Amazon is still unexplored, many of plant and animal species are still unknown to science, especially of insect where about 90 % of them is probably still undescribed. In Amazon basin we will find more than 450 species of reptiles. Some of the species is possible to find also in Atlantic forest such as Red-tailed boa (*Boa constrictor*), Yellow ratsnake (*Spilotes pullatus*) and Green iguana (*Iguana iguana* Linnaeus 1758) (Fraga et al., 2013).

In comparison to Atlantic forest, the Amazonia is poorly inhabited by people. Most of the population lives in few big cities (Manaus, Belém, Iquitos), the rest is scattered across the whole area. Including several indigenous tribes which lives out of civilization and some of them have never been contacted by (Toohey, 2012). Amazonia is more preserved in the way of forest area but large scale deforestation is also happening there in the last decades. Large areas are burn down to make place to farms, ranches and plantations. The most extensive deforestation is in Brazil which leads to extinction of many unknown species (Soares-Filho et al., 2006; Luhr, 2003).

1.3.4. Description and ecology of encountered species

In this part are described general informations about the species which were found during research.

***Bothrops jararaca* Wied-Neuwied, 1824**

Family: Viperidae
Synonyms: *Cophias jararaca* Wied, 1824

Bothrops megaera Wagler, 1824
Bothrops leucostigma Wagler, 1824
Bothrops tesselatus Wagler, 1824
Bothrops taeniatus Wagler, 1824
Cophias jararakka Wied, 1825
Bothrops jararaca Wagler, 1830
Bothrops jararaca Duméril & Bibron, 1854
Lachesis lanceolatus Boulenger, 1896
Bothrops jararaca Peters & Orejas-Miranda, 1970
Bothrops jararaca Cei, 1993
Bothrops jararaca McDiarmid, Campbell & Touré, 1999
Bothropoides jararaca Fenwick et al., 2009
Bothropoides jararaca Oliveira et al., 2010
Bothrops jararaca Carrasco et al., 2012
Bothropoides jararaca Wallach et al., 2014

Common names: In Argentina they are known under the names of yararaca, yararaca perezosa. In Brazil it is caissaca, jaraca, jararaca, jararaca-da-mattavirgem, jararaca-do-rabo-branco, jararaca-do-campo, jararaca-do-cerrado, jararaca-dormideira, jararaca-dominhoca, jararaca-preguicosa, malha-de-sapo and in Paraguay yarará (Cambell & Lamar, 2004).

Distribution: This species is found in southeastern Brazil (S Bahia, Espirito Santo, Rio de Janeiro, Minais Gerais, Sao Paulo, Parana, Santa Catarina, Rio Grande do Sul and extended into extreme E Mato Grosso and possibly Goiás), northeastern Paraguay and northern Argentina (Misiones). It is found on several island, up to 30km offshore, for example Franceses islands off Espírito Santo, Ilha dos Porcos off Sao Paulo and Santa Catarina. The type locality is given in Mucurí, Lagoa de Arara, Brazil. The vertical distribution is from near sea level up to 1,000 m a.s.l. (Cambell & Lamar, 2004).

Habitat: It prefers dense evergreeen and deciduous (broad-leaved) tropical forests as well as savanna country. Can be found also in semitropical upland forest, scrubs,

generally in most of the environments including open areas such as farmlands, cultivated lands in close proximity to vegetation cover (Marques et al., 2004).

Description: It is terrestrial species which can grow up to maximum length of 150 cm, in average around 110 cm, dependent to locality. The females are larger than males. On the head we can see thermal receptors which are able to detect heat of the surrounding and helps them to spot prey or predators. The color pattern is extremely variable. Coloration is related to geographical variations in the substrate and the environment. The main ground color is tan, brown or yellow. The dorsal ground color is overlaid with series of pale-edged, dark brown or black sub-triangular or trapezoidal markings on either side of the body. Those markings can be situated partially, opposite each other or completely juxtaposed, most of the individuals have pattern with all three types. The venter is pale greenish to yellowish white with irregular blotching or a powdering of gray pigment. The tip of the tail is white in juvenile stage. On the head is dark brown postorbital stripe extends from behind the eye to the angle of the jaw, usually encroaching on the posterior 3 supralabials. The stripe is bordered dorsally by a distinct pale zone (Campbell & Lamar, 2004; Marques et al., 2004).

Ecology: It is nocturnal species which is hidden during day. Most of the time is coiled in the vegetation where is waiting for the prey (passive predators) or just resting. In the danger they are able to rattle with their tail and due to the substrate it is possible to hear it. Juveniles are eating mostly frogs and small lizards whereas adults prioritize mainly rodents. Juveniles are mostly using "tail luring", it is attracting the prey by movements of its tail which imitate the worm (Campbell & Lamar, 2004; Araújo & Martins, 2006).

***Oxyrhopus quibei* Hoge & Romano, 1977**

Family: Dipsadidae

Synonyms: *Oxyrhopus trigeminus guibei* Hoge & Romano, 1977

Oxyrhopus guibei Zaher & Carmaschi, 1992

Common names: -

Distribution: This species is widely distributed across several states in South America in the central parts. They are listed in Bolivia, Brazil (in the parts of Minas Gerais, Sao Paulo, Paraná, Mato Grosso, Alagoas and Goias), Paraguay and Argentina (Chaco, Corrientes, Formosa and Misiones). Type locality is given to Brazil, Londrina in Paraná state. It can be found mostly in the lowland area with maximum of 1,000 m a.s.l. (Marques et al., 2004; Sousa et al., 2010).

Habitat: Mostly found in forest edges but also in open areas, sometimes seen near to human habitation, for example on farms, ranches, backyards (Marques et al., 2004).

Description: It can reach maximum length of about 120 cm bust mostly around 1m. Females are larger than males. They use the mimicry and are pretending to be venomous coral snake (*Micrurus decoratus*). The background color of the body is red. On top of it we can see several black and white rings (Oliveira & Silvano, 1996).

Ecology: It is predominantly nocturnal species but is possible to see him basking during day. Most of the time is spending on the ground but is capable of climbing to the trees (Pizzatto & Marques, 2002:). It is preying mostly on rodents or lizards but also on frogs. Lizards are mostly eaten alive and rodents are constricted (Andrade & Silvano, 1996). Some of the prey which is dominantly eaten are rats (*Rattus sp.*), hairy-tailed bolo mouse (*Necromys lasiurus*), house mouse (*Mus musculus*), small vesper mouse (*Calomys laucha*), delicate vesper mouse (*Calomys tener*), Hocicudos (*Oxymectyrus sp.*) and lizards (*Tropidurus sp.*). It is active predator (Otavio, 2001; Oliveira & Silvano, 1996).

***Thamnodynastes strigatus* Gunther, 1858**

Family: Dipsadidae

Synonyms: *Tomodon strigatus* Gunther, 1858
Mesotes obstrusus Jan, 1863
Dryophylas nattereri Wagler, 1886
Thamnodynastes strigatus Boulenger, 1886
Tachymenis strigatus Cope, 1887
Thamnodynastes nattereri Boulenger, 1896
Dryophylas natrereri Amaral, 1926
Thamnodynastes strigatus Peters & Orejas-Miranda, 1970

Common names: Coastal house snake

Distribution: This species is known from Uruguay, Paraguay, Argentina (Corrientes, Misones, Formosa, Chaco, Entre Rios, Santa Fé) and south and south-east of Brazil (Rio Grande do Sul, Santa Catarina, Paraná, Sao Paulo, Minais Gerais, Rio de Janeiro and Espiríto Santo). Mostly found in lowlands with maximum altitude of 1,500 m a.s.l (Bailey et al., 2005; Coelho et al., 2013).

Habitat: Mostly found in grasslands with bushes near water streams, ponds and swamps (Coelho et al., 2013).

Description: It is medium sized snake with maximum length around 1 m. The body is slender with longer tail, short head with large eyes and elliptical pupil. The body color is mostly brownish, greyish with darker stripes or points. It is rear-fang snake, which means that they have in the back of its mouth, under eyes the pair of longer fangs with groove which are connected to venomous glands (Marques et al., 2004).

Ecology: It is nocturnal species and mostly active predator. In the danger they are able to widen their first 1/3 of the body and make yourself bigger, also threatening with open mouth. Most of the time spends on the ground or in low vegetation where it looks for

the prey. The main prey items are anurans (66 %), fish (28 %), mammals (4 %) and reptiles (2 %). They are able to constrict the prey and also injecting the venom, dependent on the type of the prey (Bailey et al., 2005; Ruffato et al., 2003).

***Erythrolamprus poecilogyrus* Wied-Neuwied, 1825**

Family: Dipsadidae

Synonyms: *Coluber poecilogyrus* Wied-Newid, 1825
Liophis subfasciatus Cope, 1862
Liophis poecilogyrus Boulenger, 1886
Leimadophis poecilogyrus Parker, 1931
Liophis poecylogyrus Schmidt & Inger, 1951
Leimadophis poecilogyrus Peters & Orejas-Miranda, 1970
Liophis poecilogyrus Vitt & Vangilder, 1984
Erythrolamprus poecilogyrus Forlani et al., 2010
Liophis poecilogyrus Bernarde et al., 2012

Common names: -

Distribution: This species is widely distributed over South America. We can find it in Argentina (Formosa, Corrientes), Uruguay, Paraguay, Brazil (Amazonas, Rio Grande do Sul, Maranhao, Amapá, Roraima, S Ceará, Sao Paulo, Mato Grosso, Piauí, Santa catarina, Goiás), Ecuador, Bolivia, Peru, Venezuela (Bolivar, Amazonas, Anzoategui) and Guyana. Is possible to find the up to 2 500 m a.s.l. (Pinto & Fernandez, 2004; Marques et al., 2004))

Habitat: This snake can be found in different types of habitats. It can live in the tropical forests, grasslands with bushes, urban areas, near water areas (Sousa et al., 2010).

Description: This species has huge variety in coloration according to 4 subspecies and the large area of distribution. The length of the animal is around 80 cm, females are

larger than males. Juveniles are more colorful than adults. On the body we can see stripes, spots or it can be unmarked. It is rear-fang snakes with pair of larger teeth in the back of the mouth with groove which are connected to venomous glands (Marques et al., 2004)).

Ecology: Their activity is diurnal and also nocturnal. They are active predators, the prey are mostly anurans and lizards. Mostly are found on the ground but are capable of climbing up to the trees. In the danger they are able to widen their body. (Pinto & Fernandez, 2004)

***Salvator merianae* Duméril & Bibron, 1839**

Family: Teiidae

Synonyms: *Salvator merianae* Duméril & Bibron, 1839
Teius teguixim Gray, 1845
Tupinambis teguixin Boulenger, 1885
Tupinambis rufescens Presch, 1973
Tupinambis merianae Dirksen & De La Riva, 1999
Salvator merianae Harvey et al., 2012
Tupinambis merianae Avilla et al., 2013

Common names: Argentine black and white tegu, Argentine giant tegu (O´shea & Halliday, 2002).

Distribution: This species can be found in several South American countries. In Brazil we will find it in the states of Rio de Janeiro, Sao Paulo, Amazonas, Para, Goia, Rio Grande do Sul, Mato Grosso, Pernambuco, Minas Gerais, Espirito Santo, Ceará, Bahia. In Argentina (Formosa, Corrientes), Bolivia (Santa Cruz), Paraguay, Uruguay and was introduced also to USA (Florida) (Vieira et al., 2015).

Habitat: Throughout its range of distribution can be found in several different habitats.

Mostly in primary and secondary forest, grasslands, savannas, semi-deserts, agriculture lands, near households and urban areas (O´shea & Halliday, 2002; Condez et al., 2009).

Description: It is the largest species of the genus. Males are larger and more robust than females. Their maximum size might be up to 140 cm but usually they are smaller, around 120 cm in length. They are very heavily builded, especially the head and neck is very strong, but they are very fast and agile. Their jaws are very powerful. As the juveniles their coloration is bright green with dark markings over the body. After several months the coloration will start to change mostly to black (O´shea & Halliday, 2002).

Ecology: It is terrestrial and diurnal species. Only the juveniles are climbing up to the bushes and trees. During the night they are sleeping in hideouts. They are active omnivorous predators. They are able to eat almost everything, as the juveniles they are eating insect, seeds, fruit, spiders. When they grow up, their diet is changing to more protein prey. They are scavenging eggs, eating reptiles, mammals, anurans, birds, dead animal corpses and still able to eat insects, fruits, seeds because it supply them with some essential nutrients. Recently has been discovered that they are first partially warm-blooded lizards, having body temperature higher than ambient temperature (up to 10°C) (Vieira et al., 2015).

***Enyalius perditus* Jackson, 1958**

Family: Leoisauridae

Synonyms: *Enyalius perditus* Jackson, 1958

Enyalius perditus Rodriguez et al., 2014

Common names: -

Distribution: Their area of distribution is only in South-east Brazil (Barreto-Lima, 2012).

Habitat: They can be found only in moist forested areas in mid or higher elevations (Barreto-Lima, 2012).

Description: It can grow up to 30 cm in total. Females are longer and heavier than males. Males has leaf-green on their backs and irregular dark or light spots on the limbs. Females are mostly brown with dark spots over their paravertebral region, limbs and tail. Possible to display parallel white lines along their back from body to tail includes. Male lizards may shift their coloration to darker shades of brown, it can happen during stress, mating, sick and temperatures (Vargas et al., 2015; Barreto-Lima, 2012).

Ecology: It is not much known about their ecology. They are active diurnal predators which are resting in the night on the branches of the trees and in need of quick fly they can jump on the ground and run away. They are hunting mostly some very active prey like Formicidae and Orthoptera, also low mobility prey Larvae but they are eating also other types of insect and arachnids (Sturaro & da Silva, 2010; Barreto-Lima, 2012).

***Enyalius iheringii* Boulenger, 1885**

Family: Leiosauridae
Synonyms: *Enyalius iheringii* Boulenger, 1885
Enyalius iheringii Rodriguez et al., 2014

Common names: Ihering´s Fathead Anole (Barreto-Lima, 2012).

Distribution: it can be found only in SE part of Brazil (Sturaro & da Silva, 2010; Rautenberg & Laps, 2010).

Habitat: They inhabit the forest interiors and forest edges (Rautenberg & Laps, 2010; Barreto-Lima, 2012).

Description: It is medium sized lizard, up to 30 cm, including tail which is more than

half of the total size. Females are larger and heavier than males. There is color dimorphism between males and females. Males are mostly green and the females darkly colored, into brown (Sturaro & da Silva, 2010; Rautenberg & Laps, 2010).

Ecology: It is not much known about their ecology. They are diurnal lizards which are active during day, hunting their prey. At the night they are sleeping on roots and branches. Their prey are different species of insect and arachnids. They are able to change their coloration due to stress, day time and mating behaviors (Rautenberg & Laps, 2010; Barreto-Lima, 2012).

***Hemidactylus mabouia* Moreau de Jonnes, 1818**

Family: Gekkonidae

Synonyms: *Gekko mabouia* Moreau de Jonnes, 1818
Gekko incanescens Wied, 1824
Gecko acuelatus Spix, 1825
Gecko cruciger Spix, 1825
Hemidactylus tuberculosus Fitzinger, 1826
Gecko mabuia Cuvier, 1829
Hemidactylus mabouia Duméril & Bibron, 1836

Common names: House gecko, Moreau´s tropical house gecko, Wood slave (Rocha et al., 2011).

Distribution: This species is native to sub-Saharan region. It can be found in Mali, Senegal, Central African Republic, Democratic Republic of the Congo, Ghana, Benin, Togo, Nigeria, Guinea, Republic of South Africa, Zimbabwe, Tanzania, Kenya, Zambia, Gabon, Ethiopia, Eritrea, Cameroon, Swaziland, Mozambique, Sao Tome, Principe, Chad and Namibia. It is possible to find them also on some of the Seychelles islands.
They were introduced by humans to USA (Florida), Central America (Mexico,

Honduras, Costa Rica, Panama), South America (Colombia, Ecuador, Peru, Bolivia, Brazil, French Guiana, Guyana, Suriname, Venezuela, Paraguay, Argentina, Uruguay) and into Caribbean area (Antilles, Trinidad, Tobago, Puerto Rico, Mona, Vieques, Culebra, Virgin islands, Grand Cayman, Martinique, Cuba, Caicos islands, Jamaica) and also to Portugal (Madeira) (Rocha et al., 2011; Ituriraga & Marrero, 2013).

Habitat: It can be found in anthropic or perianthropic environments in different ecosystem. In South America it can be found in Amazon, Atlantic forest, the Cerrado (savannah vegetation), restingas (coastal sand dunes habitat). It has status of invasive species which has inhabited natural environments. But mostly is possible to find them near households and in urban areas (Rocha et al., 2011).

Description: It is medium sized gecko of the maximum size of 13 cm (snout to vent). It has large eyes which helps them to see in the night. The coloration is mostly brownish or greyish. It has lamels on his fingers which helps them to climb on the walls, glass etc (Rocha et al., 2011).

Ecology: It is strictly nocturnal species which hunts mainly insect or small wall spiders. They are waiting for them near the house light which attracts the insect to fly closer (Rocha et al., 2011; Ituriraga & Marrero, 2013).

***Tropidorus torquatus* Wied-Neuwied, 1820**

Family: Tropiduridae

Synonyms: *Stellio torquatus* Wied-Neuwied, 1820
Agama operculata Lichtenstein, 1822
Agama brasiliensis Raddi, 1823
T*ropidurus torquatus* Wied, 1824
Tropidorus torquatus Wied-Neuwied, 1825
Tropidorus torquatus Kunz & Borges-Martins, 2013

Common names: Amazon lava lizard

Distribution: This species is possible to find in several South American states, in Argentina, Bolivia, Brazil, Colombia, French Guiana, Guyana and Surinam (de Arruda et al., 2008).

Habitat: It can be found mostly in open and light habitats. In Brazil especially in the part of Atlantic Forest which is called Restinga. It is open coastal tropical and sub-tropical moist broadleaf-forest, characterized by medium sized trees and shrubs adapted to dried conditions. Also possible to find them in residential areas (Vieria et al., 2011).

Description: Medium sized lizards with maximum size of 20 cm including the tail. The coloration is mostly greyish with darker markings on the body (Vieria et al., 2011).

Ecology: Males are very territorial and are guarding their territory with harem of females in it. They are performing signaling behaviors such as head shaking and exhibiting aggressive behaviors to another males which they are chasing or fighting to them. They are omnivorous, eating invertebrates and plant materials (fruits and flowers (Vieria et al., 2011).

***Hydromedusa tectifera* Cope, 1869**

Family: Chelidae

Synonyms: *Hydromedusa tectifera* Cope, 1869
Hydromedusa platanensis Gray, 1873
Hydromeduda wagleri Gunther, 1884
Hydromedusa tectifera Boulenger, 1885
Hydromedusa tectifera Alderton, 1988

Common names: South-American snake-headed turtle (Clavijo-Boquete et al., 2010).

Distribution: It can be found in South Brazil, northern Argentina, Uruguay and Paraguay (Clavijo-Boquete et al., 2010)

Habitat: Living mostly in slow moving ponds, rivers, streams, marshes with aquatic vegetation. In coastal area they can enter brackish waters (Clavijo-Boquete et al., 2010)

Description: It can grow up to 28 cm in length. Females are generally larger than males. They have long neck which they can hide along their body under the carapace. Coloration is mostly brownish, the carapace is strongly keeled, on the neck and head we can see black and yellow marking (Clavijo-Boquete et al., 2010)

Ecology: They are carnivorous, eating fishes, snails, insect, arthropods and amphibians (Alcalde et al., 2010). Their attack is a combination of vacuum suction and the stabbing neck motion. In colder areas of the distribution can hibernate. Mostly diurnal animals (Clavijo-Boquete et al., 2010)

2. Aims of the thesis

General aim is to get knowledge about herpetofauna of the Atlantic forest, namely about the species, habitats and their fragmentation in the area and human impact to the environment.

Concrete aims of the thesis were:

1) Describe the species diversity of herpetofauna in the part of Serra da Bocaina NP and surrounded agriculture land, SE Brazil.

2) To identify the mutual relationship in the herpetofauna community in different habitats (agriculture, wetland, primary and secondary forest) and in different altitudes (400 – 1,100 m a.s.l.).

3. Materials and Methods

3.1. Study area

The study sites were based on several private parts in buffer zones of Serra da Bocaina National Park and close surrounding land (geographic coordinates are 22°57′46.8″S and 44°40′12″W). All transects were in state of Sao Paulo. The elevation in study areas varies from 400 – 1,200 m a.s.l. On the chosen location we can find variable topography, deep valleys, steep cliffs, plateau and lowland equal parts. Streams were present in all locations as one of the most important elements. The climate in the area is classified as a megathermic, tropical with dry season during winter (June – October) and rain season (November – February/March). Annual rainfall is about 2,000 m a.s.l. The vegetation in study areas are variable, from pastures through cultivated land, different stages of secondary forest, auracaria forest, semi-deciduous forest to primary rainforest and cloud forest. Study areas were on different places to cover the most habitats and height altitudes.

Our research started in February 2015 at the end of rain season and ended at the end of the same month. For the first two weeks, the rain appeared almost every day, especially in late afternoon or evening. Rain was very fast, only between 2 or 3 hours but in high density due to it the streams flowing down from the high elevation were overflowing. The days were very warm, temperature was dependent on height elevation but mostly around 35°C with night drop down to 17 – 25°C. After two and half weeks the rains stopped and did not appear anymore for the rest of our stay.

3.2. Transects and description of environment

Sampling was done in 4 chosen transects. Transect were located on different places, in different height altitudes and environment to try cover more species. Trail in

the forest were not clear and it was need to re-cut them first in most parts of the study area. Trails were cut to the width of about 1 m. Searching was done in the surrounding area of the trails to the distance of several meters where was possible to see. In each transect were at least 2 different environments and edge of between. Each transect was described by number of various variables. Each environment was categorized by several of these variables: 1) Pasture; 2) Wetland; 3) Household/garden; 4) Secondary forest; 5) Primary forest and 6) Forest edge. Composition of ground cover, such as leaf litter, water stream, swamps, logs/trees. Tree cover and vegetation density was calculated. Also in non-forested area if it is there any connection to forest or in forested land and if it is a fragment or we can see some connection to larger forested area. Important fact if the cattle, horses, donkeys or other domestic animals are present on study sites.

3.3. Research methods – data collection

Methods were for all transects the same. It was examined only by visual survey during day and night. Each survey on each transect started at the same defined point. Transects were observed by 3 persons. Each person searched the transect on his own on both sides continuously one by one. During survey researchers were moving slowly in the environment and searching for reptiles on the ground, trees, bushes, under leaf litter, rocks, vegetation and all other suitable places. Survey was done at the same time every day. Morning survey started around 7:00 AM and ended around 10:00 – 11:00 AM. Night surveys were started around 7:30 – 8:00 PM and usually ended around 11:00 – 0:00 PM.

Animals were caught by hand or in some cases with combination of snake hook and hand. Snake hook was collapsible of possible length 40 – 90 cm. During night researchers used 2 sources of lights (headlight and hand flashlight as a secondary source). Immediately after capturing the animals were documented. Samples were measured differently, depends if it was lizard or snake. In lizards were measured total length and length of the body (Snout-Vent length), the length from tip of the nose to anus. In snakes was measured only the total length. Measurement was accurate in lizards to 1 mm. After measurement, sexing was done to get know the sex of the animal.

After that, samples were photographed in detail. Photographed was the whole body from several angles, and most importantly the head with the scalation; dorsal, ventral and lateral view. Also was taken information about the place of capture, weather condition, height altitudes, activity of the animal. After all procedures the animals were released on the exact same place.

3.3.1. Transect I description – Lucia

The first transect was established in lowland area, around 7 km from Bananal city in private land. The altitude of the area was around 450 m a.s.l. This transect was set up in pasture/garden environment with wetland area which was surrounded by pasture land. The main environment on this transect was swamp area with small stream, the rest of the study area was pasture/garden part in the close distance of the house, all in private fenced area. This specific study site is considered to be the most disturbed area of the research. with very destroyed, deforested area with almost no forest left, only in very small fragments in the surrounding area. The closest forest fragment (very small) was 200 m far away and another larger one 900 m far away. The distance to closest large continuous forest remnants was 10 km. On the research area was present cattle, horses and dogs from domestic animals which were moving freely. The animals were present every day, except the cattle which was possible see there only few times per month. Otherwise was cattle presented behind the fences around the whole study site. Area was poorly forested, only few trees were presented in one part of the area. Transect was predominantly open with few shrubs. Swamp area was very well grown by water plants and the access to water was impossible to try to search directly in it. Average deepness of the swamp was not possible to count but it was assumed that the maximum deepness might be around 1 m. Water is presented during the whole year. Swamps are connected with a small stream which goes through the area. During the days the temperatures are very high because of low altitude and no forest cover. The humidity is during day very low from the same reason. It is possible to state that in this site are the highest temperatures with the lowest humidity from all study sites.

Figure 2: Lucia transect, scheme map.

Figure 3: Examples of environments on transect.

3.3.2. Transect II description – Xandoca

The second transect was designed in mid elevation between 600 and 700 m a.s.l. and was designed to include fragment of primary forest and secondary forest with small part of cultivated land. This area is also under private privacy. It was designed to go through the dense forest edge. Presence of cattle or another domesticated animals was not observed directly on the transect. Forest area was in close distance of water stream or was directly situated along it. Study site was rough with steep hills, only few plateaus were presented. The trail was not very clear, had to been re-cut to allow searching. The vegetation was dense, especially at some parts. Low vegetation with larger amount of shrubs and fallen branches, trees. The most parts of ground were covered by leaf litter. In some forest parts of the transect were larger amount of rocks and small caves but without any chance to enter into those cages because of their relative small size. Relatively small amount day light is presented during whole day in the forest because of high density of canopy. The temperature was very similar during day and night with small drop during night. Humidity was higher, dependent on rain which had big influence on it, especially at night. The stream was after heavy rains often swollen and very fast for several hours.

Figure 4: Xandoca transect, scheme map.


Figure 5: Examples of environment on transect.

3.3.3. Transect III description – Pesegao

The third study site was set up in higher elevation, around 1,150 m a.s.l. in primary and secondary forest. The study site is also set up on private land. Transect was established mainly in forest with only small part of open pasture. It was established on one mountain plateau in close distance to small water stream which flowed through transect area. There was no presence of cattle on this site in the last few decades. In the past was this area occupied by slaves, who had houses in the forest and on the pasture. They were working there on small plantations which were set up in this area. The biggest part of the transect is primary forest with large trees which was not disturbed by people but the boundaries are secondary forest which was used in the past by slaves. The vegetation on the study site has very high density, shrubs and another low vegetation with fallen trees and branches. There was no trail, so it was need to make it first, only small thin trail which allowed to walk was set up along the stream. The temperatures were lower than in previous locations. In the nights the temperature was dropping down very rapidly with big amount of rainfall every day. This transect was close to the second one, about 1 km far away

Figure 6: Pesegao transect, scheme.

Figure 7: Examples of environments on transect.

3.3.4. Transect IV description – Bruno

The last transect was established also in higher elevation, around 1,050 m a.s.l. in private land area. The transect was mixed of several environments; mix of primary and secondary forest, road and pasture/wetland area. Dominant part was wetland compartment. Surrounding environment of the road and pasture/wetland was forest and another farms on the boundaries. On the pasture/wetland and road area were cattle presented in large groups. During day they were freely moving and overnight they were closed in small fenced area. Forested area had a small trail which was used without any

extra re-cutting and was possible to move there because of lower amount of ground vegetation. Ground was covered by leaf litter. On the trees were in larger amount presented bromeliads, orchids and moss. Along road the vegetation was secondary forest and farm with several houses. Pasture/wetland area was large without any tree cover, only few shrubs and larger amount of water plants. Temperatures were during day very warm and high but at night was dropping down very rapidly. The area was visited in the very dry climate with no rain, it was very clearly visible in the forest which was very dry especially in our transect part.

Figure 8: Bruno transect, scheme map.


Figure 9: Examples of environments on transect.

3.4. Species identification

The identification of captured reptile species directly in terrain or later from photos was performed using Almeiada-Gomes et al. (2014), Aruajo et al. (2010), Barreto-Lima (2010) and web pages: reptile.database.reptarium.cz.

3.5. Multivariate analyses

To analyze multiple relationship in the reptile community and the environment, we applied the multivariate ordination analyzes in the Canoco 5 program (ter Braak & Šmilauer, 2012).

Then, to test the effects of environmental variables (habitat, water, household, secondary stuff and leaf litter) on the reptile community, the redundancy analyses (RDA) and followed by Monte Carlo permutation test (999 permutations) was applied. Data were centered and standardized in the course of analyses. The results of both PCA and RDA were visualized in the form of ordination diagrams constructed by the Canoco program (ter Braak & Šmilauer, 2012)

3.6. Biodiversity Indices

Simpson´s index and Shannon-Wiener index were calculated in order to compare reptile diversity between four selected transects in different altitudes. Simpson´s index is a measure of diversity, it is used to quantify the biodiversity of the habitat. It takes into account the number of presented species, as well as the abundance of each species. In general, the higher the value the lower in diversity. To calculate this index is need to use the formula: $D = 1-[\sum n(n-1)/N(N-1)$, where n = the total number of individuals of a particular species. N = the total number of individuals of all species. Shannon-Wiener index is measure of species diversity in community. This index is used to accounts to abundance and evenness of the presented species. The proportion of the species is relative to the total number of species, is calculated, and then multiplied by

the natural logarithm. In general, the higher the value the higher in diversity. The formula for the index is: $H' = -\sum p_i \ln p_i$, where p_i = proportion of individuals found in species i. For sampled community, estimate the proportion as $p_i = n_i/N$, where n_i = the number of individuals in species i. N = total number of individuals in community (Kerhoff, 2010).

4. Results

A total of 87 individuals belonging into 10 species and 7 families (Viperidae, Dipsadidae, Teiidae, Leoisauridae, Gekkonidae, Tropiduridae and Chelidae) were found during the research on the transects. More species were found during night survey (7 species) and during day was found (6 species). Unique encounters of species only in night (4 species – *Enyalius iheringii*, T*hamnodynastes strigatus*, *Oxyrhopus guebei* and *Hemidactylus mabouia*) and only during day (3 species – Erythrolamprus poecilogyrus, *Hydromedusa tectifera* and *Salvator merianae*). The rest of the species were found both, day and night (*Bothrops jararaca, Tropidurus torquatus* and *Enyalius perditus*), those species were observed the most times, therefore were considered as the most abundant.

4.1. Transects

On Transect number I – Lucia, we have found 4 species in 9 individuals. It was the lowest set transect (450 m a.s.l.). The most of species, 3 of the 4 species were found during night survey. Two most abundant species were *Bothrops jararaca* and Tropidurus torquatus, both with 3 individuals. *Tropidurus torquatus* is typical diurnal animal, which is very hard to find at night, spending night very well hidden. At day it was very warm area, so we have tried to find animals in bushes and old buildings. Number of individuals is possible to see in Tab. 1.

The most diverse transect was number II – Xandoca, where 7 species in 59 individuals were found. The area was in the mid elevation with good preserve forest in the valley. The forest was moist and in some parts were very dense vegetation. The terrain was more dynamic than in the rest of the transects. The specimens were found both during day and night survey, almost half to half. More species were situated on pasture area (5 species) than in forest part (3 species). The most abundant species on this transect were *Tropidurus torquatus* (31 individuals) which were only in the first part of the transect, on pasture/garden type near the household and *Bothrops jararaca*

(12 individuals), with most individuals found in the forest (both edge and primary forest) and only one individual on pasture part out of the forest. Number of individuals is possible to see in Tab. 1.

On the transect number III – Pesegao was found 3 species in 10 individuals. The most abundant species on the transect was *Enyalius* perditus (8 individuals). They were found sleeping on branches or roots of the trees in the night or early in the morning. Otherwise on this transect were found only another 2 individuals of 2 species (*Enyalius iheringii* and *Tropidurus torquatus*) both of them observed in the early morning. Only juvenile of *Tropidurus torquatus* was found in open pasture area. Number of individuals is possible to see in Tab. 2.

On the last transect number IV – Bruno, were found 4 species in 9 individuals, the most abundant species were *Thamnodynastes strigatus* with 3 individuals and *Enyalius perditus* with 3 individuals as well. On the road part was observed two DOR snake specimens, one of them was *Thamnodynastes strigatus* (fresh dead body) and the second one was not possible to identify due to only small part of the body which was very destroyed and in higher level of decay. All the animals were found only during night survey. Snakes were found only in wetland part of the transect. Number of individuals is possible to see in Tab. 2.

Table 1: number of species on transects 1 and 2.

		Lucia		Xandoca			
Family	**Species**	Wetland	Suburban	Pasture	Edge	Forest	**TOTAL**
Viperidae	*Bothrops jararaca*	-	3	1	3	5	**12**
Dipsadidae	*Oxyrhopus guibei*	-	1	-	-	-	**1**
	Erythrolamprus poecilogyrus	-	-	1	-	-	**1**
Teiidae	*Salvator merianae*	-	-	4	-	-	**4**
Leoisauridae	*Enyalius perditus*	-	-	-	6	4	**10**
Gekkonidae	*Hemidactylus mabouia*	-	2	3	-	-	**5**
Tropiduridae	*Troppidorus torquatus*	-	3	31	-	-	**34**
Chelidae	*Hydromedusa tectifera*	-	-	-	-	1	**1**
TOTAL		**-**	**9**	**40**	**9**	**10**	**68**

Table 2: Number of species on transects 3 and 4.

Family	Species	Pesegao			Bruno			TOTAL
		Pasture	Edge	Forest	Wetland	Road	Forest	
Dipsadidae	*Thamnodynastes strigatus*	-	-	-	2	1	-	**3**
Leoisauridae	*Enyalius perditus*	-	2	6	-	-	3	**11**
	Enyalius iheringii	-	-	1	-	-	1	**2**
Gekkonidae	*Hemidactylus mabouia*	-	-	-	-	2	-	**2**
Tropiduridae	*Troppidorus torquatus*	1	-	-	-	-	-	**1**
TOTAL		**1**	**2**	**7**	**2**	**3**	**4**	**19**

4.2. Encountered species

In this section is description of observed species and their habitats in the study site.

***Bothrops* (*Bothropoides*) *jararaca* Wied-Neuwied, 1824**

Figure 10: Sub-adult specimen of *Bothrops jararaca*, Photo: Jaroslav Karhánek.

Family: Viperidae

During our research it was the most abundant species of snakes in most of the

locations, was not found in transects number III and IV, because of too high altitudes, which is above distribution area of the species. It was found in total 12 individuals. From which were only 1 adult animal, the rest was juveniles (9 individuals) and sub-adults (2 individuals). In transect number I we have found 3 individuals, 2 juveniles of the size of 43 cm and 35 cm and 1 sub-adult animal of the length of 67 cm. In transect number II we have found 9 individuals. One adult animal (female) of size 108 cm in length and then 1 sub-adult animals around 58 cm (fig.10) and 7 juveniles which varied in size from 25 cm up to 45 cm in length. Most of the animals were found on the ground, coiled in the vegetation, only 4 individuals (juveniles) were found higher in the vegetation, branches, logs and in bromeliad about 2 m above the ground. All animals were found in the night or very shortly after sunrise, only one animal (adult) was found later during day in the open pasture area hidden in the grass. 8 individuals were found in forest area, secondary forest and 4 individuals in urban or pasture area with few solitary trees and bushes.

Coloration of the animals were variable, mostly in the juveniles, the color was from golden yellow to light brownish with classical dark markings over the body.

***Oxyrhopus guibei* Hoge & Romano, 1977**

Figure 11: Adult specimen of *Oxyrhopus guibei*, Photo: Jaroslav Karhánek.

Family: Dipsadidae

This species was found only once in transect number I at 21:30 PM. The area where it been found was between pasture/garden part and wetland area, crawling in grass on the ground from wetland where it was most probably on the hunt of frogs. It was an adult animal, female of total size 74 cm (Fig. 11).

***Thamnodynastes strigatus* Gunther, 1858**

Figure 12: adult specimen of *Thamnodynastes* strigatus, Photo: Jaroslav Karhánek.

Family: Dipsadidae

It were found 3 individuals in total, only on transect number IV. First individual was DOR specimen found on the road, juvenile animal of the total length of 28 cm. Another two specimens were found at night, around 10 PM. One animal was juvenile, around 27 cm long and the second adult animal (Fig.12) around 65 cm in length. Both animals were found in wetland area hanging on bushes in ambush position above water, probably waiting for the prey, frogs. At the beginning of the manipulation they were very active, trying to intimidate us by strikes with open mouth and inflating the body. The coloration was classic for the species, the juvenile was more light in compare of adult animal.

***Erythrolamprus poecilogyrus* Wied-Neuwied, 1825**

Figure 13: Juvenile specimen of *Erythrolamprus poecilogyrus,* Photo: Dalibor Sýkorovský.

Family: Dipsadidae

It was found only one animal, juvenile specimen (Fig.13) of total size of 29 cm. on transect number II. It was found during day, early in the morning around 8 AM crawling around house in the grass between the rocks to find hideout. Identified this species was more difficult because of their huge variety of coloration across their distribution habitat, juvenile pattern is also different from adult animals and can vary even in juvenile individuals from one litter.

***Salvator merianae* Duméril & Bibron, 1839**

Figure.14: Adult specimen of *Salvator merianae,* Photo: Jaroslav Karhánek.

Family: Teiidae

This species was observed 4 times on the transect number II on the pasture part between house and forest. We were unable to capture those animals for detail study, to take their size and better photography. They are very fast and careful during day. At night they are resting hidden in the holes, under rocks or logs. They were observed only in the morning when they were obtaining energy from sun, they were partly hidden or moving in the vegetation on the pasture in the grass or in the bush. The fly distance was around 10 m. All 4 individuals were adults, most probably 2 males (Fig.14) and 2 females according to body physique (male were robust in body and head, also much larger in length), size was estimated from 75 up to 120 cm.

***Enyalius perditus* Jackson, 1958**

Figure 15: Adult specimen of *Enyalius perditus*, Photo: Jaroslav Karhánek.

Family: Leoisauridae

The most abundant lizard species in the forested area in every elevation where research was done. In total it was found 21 individuals, 12 males and 9 females (Fig.15) from which were 6 juveniles or sub-adults. They were found on transects number II, III and IV. Maximum length of SVL was 8.2 cm and tail length 18 cm. All of them were found on the branches, logs, roots. During night they were found sleeping on the branches around 1.5 m above ground even during heavy rainfall. During day was possible to observe them only early in the morning. The coloration of individuals was variable according to the sex and age of the animals and day time.

***Enyalius iheringii* Boulenger, 1885**

Figure 16: Adult specimen of *Enyalius iheringii*, Photo: Jaroslav Karhánek.

Family: Leiosauridae

There were found only 2 individuals (Fig.16) on transects number III – Pesegao and transect IV – Bruno on forest edges. Both of the individuals were adult males which were found at the night sleeping on the branches, one of them on transect number three – Pesegao in heavy rainfall. The total size of both individuals were 25 cm and 27 cm.

***Hemidactylus mabouia* Moreau de Jonnes, 1818**

Figure 17: Adult specimen of *Hemidactylus mabouia*, Photo: Jaroslav Karhánek.

Family: Gekkonidae

These geckos were observed on transect number I, II and IV in 7 individuals total. They are not native to this country but they were introduced there by humans, accidentally due to transports by ships with cargo. They are spreading across the country, feeling most comfortably near houses where they can get food and hideouts very easily. It was observed 2 juveniles and 5 adult/sub-adult specimens (Fig.17) in sex ratio 3 males and 4 females. The length was in juveniles between 3.3 – 3.6cm (SVL) and tail between 2.9 – 3,4cm. In adult (sub-adult) animals the SVL length were between 5.4 – 6.5cm and tail between 5.9 – 6.8 cm. All individuals were found at night on the

walls of the houses, mostly near lights where they were catching the insect.

***Tropidorus torquatus* Wied-Neuwied, 1820**

Figure 18: Adult specimen of *Tropidurus torquatus*, Photo: Jaroslav Karhánek.

Family: Tropiduridae

Very abundant species of lizards in open environment in lower altitudes. They were found on transect number I, II and III. In total was documented 35 individuals (Fig.18) in all stages (juveniles, adults). Only one juvenile animal was captured on transect number three on pasture. It is very unusual capture. It was most probably migrating animal because there was not suitable habitat for this species. The most of the animals (31 individuals) were found on transect number one on pasture where was low grass, lot of rocks which were used by animals as a place for sunbathing, catching insect and by males to control their harem of females. Close to that habitat was house with garden, it is also one of the reasons why they were presented in such high density. Flowers are attracting insect and cultivated garden keeps grass low around the rocks. Another 3 individuals were found on transect number one in similar conditions.

***Hydromedusa tectifera* Cope, 1869**

Figure 19: Adult specimen of *Hydromedusa tectifera,* Photo: Dalibor Sýkorovský.

Family: Chelidae

It was observed only one sample (Fig.19), the turtle was found only in transect number II in forest in small pond under the waterfall and in surrounding were steep hills and difficult terrain. It was an adult male. It is interesting that he was able to live there. Not enough food in the pond (fish, shrimps). He was probably migrating to find new territory and ended in that pond for some time. From the pond was flowing small stream through the forest to large stream where at one point was established big pond from which he was probably migrating.

4.3. Mutual relationships of herpetofauna community and habitats.

The results from the constrained RDA showed that the principal components are explaining of 24 % of variability in species-environment. First axis has the biggest impact to composition of species, explained 13 % of variability in the data and represented the gradient of vegetation cover (from open pastures to closed forest). The second axis explained 5 % of variability in data, representing the most likely the moisture in the area (from ponds to secondary forest). The permutation test has shown that both first and all four axis are significant for the effect of environmental variables (1^{st} axis: F=8.1, P=0.001, all 4 axes: F=2.1, P=0.001).

The forest area is represented by ellipses IV and V. Ellipse IV is representing secondary forest and forest edges with high correlation to medium leaf litter, close water source, high canopy and bushes/shrubs. In the case of *Bothrops jararaca* is possible to see some close correlation to open areas which represent the opportunity to find them there. On the other hand ellipse V has strict compartment of primary forest with presence of high leaf litter. Ellipses I, II and III are showing us the species which correlation to open areas with human settlements and pasture sites, important to mention absent of the water surface. The species were not found in any other environments. The differences between those ellipses lies in compartment of secondary vegetation or house settlements. In ellipse I is only pasture area with rocks. Ellipse II mainly correlate to human settlements (houses) and ellipse III has closer connection to water area. The last ellipses VI represent open environment in close distance or direct contact to wetlands with plenty water vegetation and close distance to human settlements, roads.

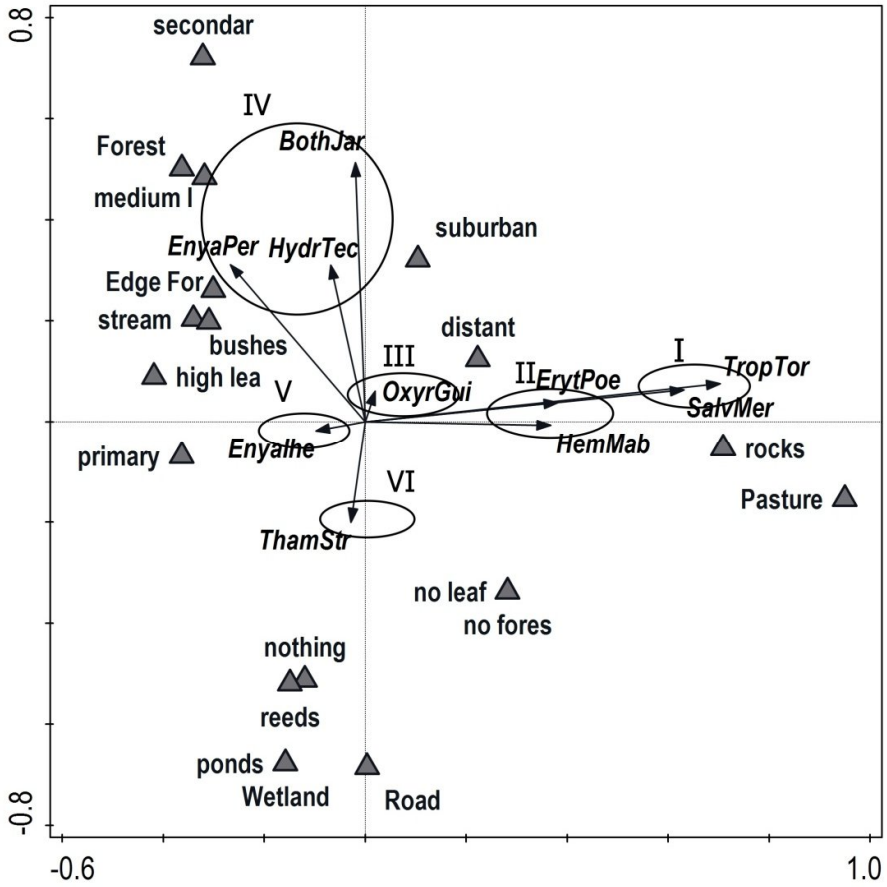

Figure 20: Ordination diagram results.

Area abbreviation: Forest – Forest area, Edge For – Forest edge area, suburban – Suburban area, Pasture – Pasture area, Wetland – Wetland area, Road – Road area

Environmental abbreviations: secondar – Secondary forest, stream – Stream, primary – Primary forest, distant – Water distant, rocks – Rocks, no leaf – No leaf litter, medium l – Medium leaf litter, high lea – High leaf litter, reeds – Reeds, nothing – No secondary vegetation, ponds – Ponds, no fores – No forest cover, bushes – Bush vegetation

Species abbreviations: BothJar – *Bothrops jararaca*, EnyaPer – *Enyalius perditus*, HydrTec – *Hydromedusa tectifera*, EnyaIhe – *Enyalius iheringii*, OxyrGui – *Oxyrhopus guibei*, ThamStr – *Thamnodynastes strigatus*, ErytPoe – *Erythrolamprus poecilogyrus*, HemMab – *Hemidactyus mabouia*, TropTor – T*ropidurus torquatus*, SalvMer – *Salvator merianae*.

4.4. Biodiversity Indices

To test the diversity we have calculated two indexes, Simpson´s and Shannon-Wiener index, tab. 3. In the table we can see, that Shannon-Wiener index shows the transect number II – Xandoca as the one with the highest reptile diversity. The lowest diversity was in transect number III – Pesegao. The diversity is decreasing with higher altitude but also with expectation in agriculture land in the low altitudes. Simpson´s index shows that transect I – Lucia and IV – Bruno has the highest diversity and the lowest is again in transect number III – Pesegao.

Table 3: Shannon-Wiener and Simpson´s indices

Transect	Transect I Lucia	Transect II Xandoca	Transect III Pesegao	Transect IV Bruno
Shannon-Wiener Index	1.09	**1.39**	0.40	1.09
Simpson´s Index	**0.19**	0.32	0.62	**0.19**

5. Discussion

The main purpose of the study was to find out and describe the diversity of reptiles in the Atlantic Forest, Serra da Bocaina NP and surrounding buffer zones and to discover the differences in abundance of species and diversity in different environments and altitudes. Directly in Serra da Bocaina NP was not previously done any official research which would have resulted in science paper published in science magazine or published in web-pages of this National Park. Therefore the complete list of species in this National Park and buffer zones is missing. There are only unofficial records of the herpetofauna by local rangers in Headquarters which are not presented in public. From obtained photos was possible to count 28 species of reptiles.

In total we have found 10 species of reptiles, 1 turtle (*Hydromedusa tectifera*), 4 snakes (*Bothrops jararaca, Oxyrhopus guibei, Thamnodynastes strigatus, Erythrolamprus poecilogyrus*) and 5 lizards (*Salvator merianae, Tropidurus torquatus, Hemidactylus mabouia, Enyalius perditus* and *Enyalius iheringii*) in all transects. We have missed one species of snake at night on transect number III in wetland area which has disappeared in the vegetation before it was possible to catch it. Therefore it was supposed that according to appearance and length of the animal, it was most probably adult specimen of *Spilotes pullatus*. Another unknown species of snake was found dead on the road but due to only small part of the body and advanced stage of decomposition was unable to identify it. We have tried to incorporate the most of the environments which are the most common in buffer zones of Serra da Bocaina NP. The transects were set up in high elevations because of the fact, that NP is situated mostly in similar altitude. Searching for reptiles in higher elevations is more problematic than in lowlands where the diversity of species and number of individuals is higher as was suggested also by McCain, 2010 and by our results with Shannon-Wiener and Simpson´s indices. The low determined diversity was probably caused by several limitation of the study. One of them was limited time of the study which was very short, To determine all diversity in such complex and difficult environment. Although the research was done during February (rain season) when the reptiles should be most active. The relatively short

research time did not allow us to map all environments which are occurring in the area. Another very important factor was to set up transects in proper locations because of the private property of the land or set them up directly in large preserved remnants of primary forests in the Serra da Bocaina NP due to absent of the permission. We have received the observation from local people on seen species in study sites, the information must be taken lightly because of the lack of knowledge in reptile species. The species which were reported and confirmed by photos are only *Erythrolamprus aesculapii* Linnaeus, 1758 and *Bothrops alternatus* Dumeril, Bibron & Dumeril, 1854.

Discovered differences among the researched environments showed that the most diverse environments were surprisingly open areas where was found 7 species of reptiles in comparison to independent forest types where was found only 4 species. It is probably because of the fact, that open environments had connection to forested area due to it, this area is potentially more diverse in prey possibilities. But on the other hand in open environments might be more predators or other danger in general for reptiles (humans, birds, cattle and domestic animals, such as cats or dogs).

We have discovered relatively high abundance of *Bothrops jararaca* in the low and mid elevations in all environments. This species is very abundant in the whole area of its distribution (Cambell & Lamar, 2004; Sazima, 1992). According to our observation we assume that juveniles are distributed mainly in the forest or near wetlands because of the possibility of prey (anurans of proper size) and shelter. On the other hand sub-adult and adult animals tend to be more abundant in open areas or in forest edges where is higher possibility of larger prey and are gathering back into forests more during breeding season. This theory is not supported by any official evidence and it would need to conduct study on it, but this might be probably possible only in partly devastated environments, agriculture land with small fragmented forests across the area.

Important discovered fact is spreading of tropical house gecko (*Hemidactylus mabouia*) which was observed in several locations only with human settlements. On the Xandoca transect number two they were observed for the first time, the previous year were not seen there. They got here most probably with building material which was

used in the house and garden area. The same observation was done by Rocha et al., 2011 where they studied invasion methods and impact to native species of geckos.

Due to deforestation and spreading of open environments some of the observed native species, for example Amazon lava lizard (*Tropidurus torquatus*) is enlarging their distribution area to the location were in the past it would not be suitable to them due to forests.

The major problem with distribution of reptile species is agriculture, which was observed also in Brazil. It cause huge effect to terrestrial ecosystems from soils, plants, invertebrates to vertebrate fauna (Biaginni & Cortis, 2015). Almost one fifth of the land surfaces have been changed to human use, in Brazil is the scale much larger. Reptiles are well known to be highly sensitive to habitat changes due to their ecological constraints which was observed by Ribeiro et al., 2009. In the work of Biaginni & Cortis, 2015 was discovered the fact, that reptile diversity in agriculture land lies in buffer strips around the agriculture land, which is confirmed also in our study. The richness of individuals and species is increased with connection to some semi-agriculture area otherwise in intensive agriculture areas is diversity on very low level, 1 or 2 species according to Biaginni & Cortis, 2015 which was partly confirmed in our study where in intensive agriculture land in lowlands were found 4 species of reptiles in few individuals. For reptile diversity in this land is important to have some buffer zones or strips which are connected to some natural environments that helps to survive reptiles the changes of the habitat.

In comparison to researches which were done by Araujo, et al., 2006; Condez, et al., 2009; Almeida-Gomes, et al., 2014, some of them in "close" distance (dozens of kilometers) but in large scale on several large locations across the states of Rio de Janeiro and Sao Paulo. The time schedule of their searching varied from 15 days up to several months during several years, and in different parts of the season (rain and dry season) in large scale of altitudes, most of their research was done in low or mid elevations of primary forest or in well undisturbed secondary forest in large preserved areas. Neither of those researches were done in strictly agriculture land. Therefore they

found more species of reptiles (31 species by Araujo, et al., 2006; 56 species by Condez, et al., 2009; 37 species by Almeida-Gomes, et al., 2014). In our study was not found any species which they would have miss in their researches. Compare to us their composition of found species was different to our results, the dominant group were snake species in average of 73 %, in our research the dominant group of reptile species were lizards in 50 %, the rest 40 % snakes and 10% turtles. This might be because of different types of environment, where in forested areas lives more species of snakes than in open areas.

This work can be used as the part of future studies which are necessary in this National Park. I would recommend to continue in study also in different parts of the year and also in different places.

6. Conclusions

During the study of reptile diversity in buffer zones of Serra da Bocaina NP and surrounding agriculture land was observed in total 87 individuals which belonged in 10 species from 7 families.

Reptile composition showed high diversity in open (disturbed) areas, mainly with connection to forest fragments in low or mid elevations (400 – 700 m a.s.l.). With growing elevations the diversity of reptile species was decreasing. It was given by natural dispersal of reptile species in different elevation and also it was evaluated by Shannon-wiener and Simpson´s indices.

From evaluated RDA it is possible to see the separation of species in open and closed environments with preferable conditions (vegetation structure). We can state that the found snake species were preferring more open habitats and lizard species were found in both open and closed environments.

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