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Ecological factors affecting nutrient composition of Bromeliads used by the Andean bear (*Tremarctos ornatus*)

MASTER´S THESIS

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Declaration

I hereby declare that this thesis entitled "Ecological factors affecting nutrient composition of Bromeliads used by the Andean bear (*Tremarctos ornatus*)" is my own work and all the sources have been quoted and acknowledged by means of complete references.

In Prague 27.04.2018

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Adéla Paříková

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Abstract

Andean bears (*Tremarctos ornatus*) are considered as Vulnerable according to IUCN Red List of Threatened Species. This situation was caused mainly by habitat losses, fragmentation and poaching. One of the most important parts in conservation of the species is to study diet. Nutritional supply may vary during different seasons. However Bromeliads play important role in the diet of the Andean bear. It is essential to find out key nutrients in the diet of the Andean bear and to understand feeding ecology of this species. Aim of this study was to determine which ecological factors are affecting nutritional composition of Bromeliads. This research was conducted in Southern Ecuador in Loja province. Nutritional composition was evaluated, so it was important to collect the most abundant Bromeliad species in four diverse places (6 study sites) to obtain their nutritional levels of protein, fat, fibre, ash, starch. These Bromeliads were collected in differrent places, ecosystems (forest, páramo), distinct phases of phenological cycle (flowering, not flowering) and under different conditions of place (burnt, unburnt areas). Meristematic tissues (eaten part of Bromeliads by the Andean bear) were separated from the whole plant and were cleaned, dried and grinded. Nutritional analyses of eaten parts were made by using of NIRS method in FOSS DS2500 analyser. Obtained data were statistically analysed firstly by ANOVA, to present difference in nutritional values among all tested ecological factors, and secondly by multivariate analysis (GLMM), to specify which factors are affecting nutritional composition of the Bromeliads. Generally it was found out that ecological factors actually affect the nutritional composition of the Bromeliads. In forest ecosystem nutritional values were rather higher (expect of fat). These affected by fire were higher as well (except of starch). Flowering had also positive effect on the nutritional content of Bromeliads. Further research on nutritional quality of Bromeliads and factors driving the quality is crucial for understanding activity patterns of the Andean bears, and to ensure their conservation.

Key words: *Tremarctos ornatus*, Bromeliads, nutrients, diet selection

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1. Introduction and Literature Review

1.1. Introduction

Andean bear (*Tremarctos ornatus*), also known as Spectacled bear, is the only existing species of bear in South America (Molina et al. 2017; Kattan et al. 2004) and it is one of the most important predators in the Andean mountains (Ruiz-García et al. 2005). Andean bear is one of the eight extant representatives of family Ursidae (Molina et al. 2017) and together with giant panda it is certainly the oldest species (Servheen et al. 1999). Geographical range of the Andean bear is between 250 and 4,750 m a.s.l. (Goldstein et al. 2008) and is native to countries as Bolivia, Colombia, Ecuador, Peru, Venezuela (Paisley 2001; Cuesta et al. 2003). From the year 1982 it is considered as Vulnerable species according The IUCN Red List of Threatened Species (Goldstein et al. 2008). It has become vulnerable mainly because of habitat destruction, fragmentation, poaching and conflicts with farmers, mainly because of attacks to livestock (Peyton 1999; Goldstein et al. 2008). Andean bears attack livestock when there is not enough of the plant food in their habitat as they mainly feed on it (García-Rangel 2012). Most commonly plants from family Bromeliaceae (Ríos-Uzeda et al. 2009). Lack of information about this really important food resource, could be a barrier for long term conservation of Andean bears (García-Rangel 2012).

1.2. General description of the Andean bear

Andean bears are mid-sized bears. Adult males reach 1.5 to 2.0 meters head-body length. Weight of males is usually in the range between 140 to 175 kilograms (Peyton 1980). Sexual dimorphism is significant and typical. Size of females is usually about 1/3 smaller than males. Female´s skull is shorter and the lamboid crest is absent (Peyton 1999; Garshelis 2009).

Hair of the Andean bear is commonly black and can be also dark red brown; with typical white to yellow signs around eye or both eyes, on the bridge of the nose, under the chin and frequently extending down to the chest as shown in Figure 1 (Peyton 1999; Nowak 1999). That is the reason why the common name of this bear is "spectacled". These markings can vary among the individuals (Peyton 1999).

Figure 1. Typical markings and color of the Andean bear (male). Source: Arkive 2010.

As all bears, Andean bears are plantigrade. It means that they have longer front limbs than their hind limbs and this adaptation allows them to climb trees (typical behavior of Andean bears) (Peyton 1980). Andean bears have stout bodies, short tails that are usually covered by fur, short necks, small round ears, modified carnassials and reduced premolars, large lips without gums and five ahead pointing toes with curved claws (Peyton 1999; Nowak 1999; Garshelis 2009).

Mandible of the Andean bear has a premasseteric fossa typical for *Tremarctinae*. Related to their body size, Andean bears have really large *zygomaticomandibularis* muscle. This muscle is adaptation for mainly herbivorous diet together with blunt lophs of premolars and molars (Kattan et al. 2004; Servheen et al. 1999). Dental formula of Andean bear is the typical for ursids. Bears have 42 teeth: incisors 3/3, canines 1/1, premolars 4/4, and molars 2/3 (Sacco & Van Valkenburgh 2004; Christiansen &Wroe 2007).

Information about behavior of the Andean bear has been collected in captivity and from the local people. Adult animals live generally solitary. Pairs are form during mating season. Cubs stay with mothers for about one year of the age. Andean bears are active during day and also night in the cloud forests. They sleep during midday in the cover and it was not found out any evidence about hibernation (Peyton 1999).

1.3. Habitat use

Andean bear are able to live in enormous variety of natural habitats. They live from arid scrublands to forests to grasslands in high altitude (páramo). According to previous reports bears are moving forward the altitudinal gradient and different natural habitats dependently on available feed resources during different seasons (Peyton 1980; Paisley 2001; Cuesta et al. 2003). García-Rangel (2012) proposed two hypotheses which are explaining Andean bear habitat and resource use: (i) a pattern based on periodic seasonal fruiting cycles; (ii) perpetual use of habitat in areas where food resources are available year round, those resources are supplemented with occasional feeding on fruit. Andean bear habitat is also influenced by human presence, approach to the forest and its cover, availability of water, altitude and terrain of the place (Peyton 1980; Cuesta et al. 2003; Sánchez-Mercado 2008). During the months June, July and January bears are mostly present in the montane forest (Cuesta et al. 2003). During other months (May – June and September – December) bears are more frequently in the grass páramo and the mixed páramo forest (Troya et al. 2004).

In Ecuador, Andean bear inhabit an area of approximately 58,000 km^2 between páramo, mountain and cloudy forest. About 8,000 km^2 are in the National System of Protected Areas (SNAP) (Peralvo et al. 2005). These protected areas are fragmented into 24 units, which could possibly form a metapopulation structure. The viability of the bear population, in long term, depends on the degree of isolation and viability of the subpopulations (Kattan et al. 2004). In the southern part of Ecuador is one of the biggest patches of natural Andean bear habitat – Podocarpus National Park, which is the only protected area in Ecuador that conserves adequate habitat for the species (Sánchez et al. 2004). The forest cover is considered as an important part of the landscape where the Andean bear live (Rodríguez & Cadena 1991; Yerena & Torres 1994). However, these plants formations have been reduced in recent years because of the human activity; for example, in Ecuador between years 1999 and 2003 it was lose approximately 5,205 km^2 of forest, which corresponds to a decrease of 8.6 % (Baquero et al. 2004).

1.3.1. Montane forest

The Andes of South Ecuador are one of the places with the highest biodiversity all around the world and also the bird diversity. The dominant proportion of this biological diversity is occurred in native tropical montane forests (Mosandl et al. 2008). However montane forests in the South of Ecuador also suffer the highest deforestation rate amongst the whole South America (Dislich et al. 2009). Forests are also considered as endangered. This is caused mainly by utilization of timber, climatic change and gaining the pasture land from forests (FAO 2005; Mosandl et al. 2008).

1.3.2. Páramo

Páramo is found in the vegetation belt between tropical montane cloud forest and the snow line. It is described as tropical alpine vegetation ecosystem (Cleef 1978). Some authors believe that existence of the páramo could be result of the man activities, primarily in burning (Ellenberg 1979; Laegaard 1992). Above the tree line there were proposed three main types of vegetation in páramo. The grass páramo occurs in treeless areas in altitude between 3,400 m a.s.l. and 4,000 m a.s.l. and is characterized by tussock grasses (usually *Festuca*, *Stipa*, *Calamagrostis* etc.), thickets of shrubs (*Diplostephium*, *Hypericum*, *Pentacalia*) and forest patches (typically *Polylepis*). This type of páramo is grazed quite extensively and burned more – less regulary (Ellenberg 1979; Laegaard 1992; Sklenář & Jørgensen 1999). Other type is called shrubby and cushions páramo which occurs in a belt between 4,000 and 4,500 m a.s.l. Cushion plants

(*Azorella*, *Plantago*, *Werneria*), sclerophyllous shrubs (*Loricaria*, *Chuquiraga*) and disperse grasses grow there. Third type is above altitude 4,500 m a.s.l. and is called desert páramo. The vegetation is rare (*Nototriche*, *Draba*, *Culcitium*); plants grow just in stabilized ground in isolated patches. With growing altitude, plant coverage is decreasing (Sklenář & Jørgensen 1999). Páramo is characteristic ecosystem of Andean region and nowadays habitat loss is extensive (Hofsede et al. 2002; Mena-Vásconez & Hofstede 2006). The main problem affecting páramo are anthropic fires. Fires are set to promote grasses for livestock and it has negative impact to native vegetation (structure and composition). Anthropic páramo usually occurs in places with easier access for cattle (Suarez & Medina 2001). Reduction of natural páramo is evident even in higher elevations (Astudillo et al. 2017).

1.3.2.1. Effect of fire in the páramo ecosystem

In high altitude grasslands in the Northern Andes (páramo) frequent fires are really common. Nowadays fires are generally set by the human to support traditional cattle grazing system (Suárez & Medina 2001), but in the past natural fires were ignite mainly by lightning strikes and volcanic activity. Whether fires in the páramo are man-made or "natural" have fascinated scientists for long. Fires have structured today´s páramo. Profiles of the lakes charcoal sediments prove that fires were present thousand years in the past. This evidence also shows human presence and role for natural burning in the páramo (Horn & Kappelle 2009).

Presently, Ecuadorian páramos are used for extensive grazing of cattle, horses etc. If the forage quality is poor, farmers burn vegetation to boost new growth. New vegetation is more palatable and nutritious to livestock (Ramsay & Oxley 1996). This method has brought about dramatic changes of native vegetation mainly in the structure and composition (Suárez & Medina 2001). Use of páramo for agriculture and recreation is more intensive. About the effect on composition and functioning of fire in páramo, little is known (Ramsay & Oxley 1996).

Frequency of fires is dependent on growth recovery of the plants after fire, usually every 2 – 4 years (Ramsay & Oxley 1996). Fires in páramo typically destroy all biomass above ground and leave the ground charred. The ground is recolonized by growing sprouts from root system that survive and also by fire-resistant seeds or by seeds that enter afterwards (Horn & Kappelle 2009). Also some Bromeliads species are fire-resistant and are able to overcome these unfavorable conditions (Rocha et al. 2014).

1.4. Diet

Andean bears are omnivorous animals. Their diet is mainly frugivorous or folivorous and sometimes they feed on animals (Goldstein 1999; Christiansen &Wroe 2007). Feeding strategy strongly depends on habitat which bears occupy and it makes the diet more diverse (Peyton 1980; Paisley 2001; Ríos-Uzeda et al. 2006). Base of the diet of the Andean bear are fibrous plants. Andean bears consume wide range of the plants from bromeliads with spines to hearts of the palm trees (García-Rangel 2012). Bromeliaceae and Arecaceae are the most important food resources in almost entire range of the Andean bear and are available year round (Peyton 1980; Ríos-Uzeda ae al. 2009). The diet is dependent on seasonal supply (Peyton 1980), the most important components of their diet are the species of the bromeliad family, especially the genus *Puya*, which are common in the páramo environment (Goldstein & Salas 1993). The consumption of this family was found in the majority of studies as the highest percentage in terms of frequency (Peyton 1980; Mondolfi 1989; Suárez 1988; Azurduy 2000; Troya et al. 2004). However, studies conducted by Castellanos (2004) in Ecuador suggest that bamboo (*Chusquea* sp.) may be the most important food resource in the region based on the high frequency of this species in feces and because it is an available resource in the forest all year. Andean bears usually feed on meristems of the plants, but they can also eat lymph (sap), bark, succulent stem and eve the flowers (Peyton 1980; Ríos-Uzeda et al. 2009). Meristems have low nutritional value and in the bromeliads it is the lowest. They contain soluble carbohydrates and small amount of proteins and lipids. That is one of the reasons why Andean bear eats large amount of these feed or even they have to enrich their feed input with fruit or some animal proteins (Paisley 2001; Rivadeneria-Canedo 2008). Bromeliads have high content of water, so this food items might be also a water source (Peyton 1980; Cuesta et al. 2001).

During different seasons fruit is really important. Andean bears eat fruits rich in carbohydrates and fruit rich in lipids with high water content (Kattan et al. 2004). Seeds from the fruits are not damaged by the digestion, so bears could help to spread plant species in their habitat (Rivadeneria-Canedo 2008). Higher frequency in the diet could be related to availability, taste, texture and size of the fruit. In Oyacachi River Valley, Ecuador, it was observed that fruit is the second most frequent part in the diet of the Andean bear. Fruit of motilón (*Hyeronima macrocarpa*) was eaten commonly (Troya et al. 2004).

Andean bears occasionally consume animal protein, but it is just a small part of their food intake (Rivadeneria-Canedo 2008; Ríos-Uzeda et al. 2009). According Suarez (1988) it was reported that animal remains were found in 32 % of the bear´s feces as is reported in the Table 1. These scats include rabbits, mice, domestic calves and birds. This study proved that bear consume animal material, but did not find out whether the bears kill the animals or scavenge carrion.

Table 1. Percentage of food items identified from 49 Andean bear´s scats from Antisana páramo (Ecuador). Extracted from Suarez 1988.

	Food items	Frequency
Bromeliaceae	*Puya* sp	49*
Poaceae	unidentified	22
Asteraceae	*Diplostephium* sp.	6
	Gynoxys sp. 1	5
	Gynoxys sp. 2	2
	Baccharis cf. *arbutifolia*	4
Ericaceae	*Disterigma* sp.	4
	Pernettya prostrata	2
Berberidaceae	*Berberis* sp.	1
Geraniaceae	*Geranium* sp.	1
Polygalacae	*Monnina* sp.	1
Fabaceae	unidentified	1
Xyridaceae	unidentified	1
Dicranaceae	unidentified	10
Rabbit	*Sylvilagus brasiliensis*	8
Mice	*Thomasomys* sp.	5
Domestic calves		1
Birds		2
Unidentified animals		1

* Volume/scat > 80%

1.4.1. Food – related human bear interactions

Andean bears are probably the least aggressive towards human from all bear species. The prevailing interactions between human and bears are that bears eat corn, which is grown intensively in bear´s natural habitat. Corn has replaced bear´s natural food resources as more than 20 % of the corn fields are at the edge of the forest and are surrounded by the bears (Peyton 1999). Attacks of Andean bears to livestock were also registered. These situations lead to conflicts with humans and Andean bears are poached (Peyton 1980; Paisley 2001; Goldstein et al. 2006).

Andean bears are livestock predators and are usually accused of any death or disappearance of the livestock (Goldstein et al. 2006). Until the 1990, only available data about conflicts between Andean bear and livestock were unofficial, secondhand data gained by the researchers (Mondolfi 1971 1989; Peyton 1980). First observation of the Andean bear attack on cattle was made in 1997 in Chingaza National Park in Colombia (Goldstein et al. 2006). Other observations were made in Ecuador (Castellanos et al. 2002; Galasso 2002). Cattle wounds from these attacks were clearly visible. Bites and claw marks were present on the neck, head and also rump of the attacked cattle (Castellanos et al. 2002). Dragging of carcass and feeding behavior were also observed. Density of the beds and nets is also associated with feeding on carcass. In the area 100 meters around carcass were found more than 10 ground beds or tree nests (Goldstein 1991a, b; Poveda 1999; Castellanos et al. 2002). Carcasses on which bears had fed on can be easily identified. Visible signs are common to other bear species. Witnesses of the attack usually arrive shortly after depredation occurs. It is really problematic to determine between scavenging and depredation (Goldstein 1991b; Poveda 1999; Paisley 2001). Bear – sheep attacks were also reported (Goldstein et al. 2006).

Andean bears are perceived by the *ex situ* residents as non-aggressive vegetarian animals. Residents living in the areas, where livestock are in the montane pastures unattended often, consider Andean bears as cattle predators (Goldstein 1991a; Paisley 2001). For the *in situ* residents, almost all loses of cattle are assigned to bear depredation. Bears can be often designated as pests and should be killed to prevent other conflicts. Bears are related with the cattle disappearance even in localities with no recent conflicts. Bears often become subject of persecution and poaching (Castellanos et al. 2002).

1.4.2. Bromeliads

Bromeliads are a family of typically monocotyledons flowering plants with 3 subfamilies and many large genera. According to their phytogeography, Bromeliaceae are native to tropical America and they have been probably recently dispersed to West Africa. They are adapted to various climatic conditions such as many bromeliads are able to store water in special structures in leaf bases. This family includes terrestrial and epiphytic plants. Leaves of the bromeliads take different shapes and color. The produced inflorescences are also really diverse. Some flowers can have more than 10 meters (height) while other can reach 2 – 3 millimeters across. Some species (e.g. *Cottendorfia florida*, *Puya parviflora*) have special stem which is fire-resistant (Benzing, 2000) as is shown in Figure 2. Bromeliads are mainly ornithophily, but there are still just few studies related to the types of floral visitor and also production of the nectar in bromeliads (Rocha et al. 2014). Some previous studies already demonstrated importance of fires for flowering of the various plant species. Fires stimulate flowering and reproductive cycle of this kind of plants. Burning also support dormancy of the buds, dehiscence and seed dispersion in case of some herbs and shrubs (Munhoz & Felfil 2007).

Figure 2. Fire resistant stem of *Puya parviflora*, Source: Author´s photography

Bromeliads subfamilies have distinct growth forms, morphological features, physiological features and also different flower morphology. This may explain their different habitat preferences (Benzig & Burt 1980; Givnish et al. 2011). Leaves of bromeliads are organized in rosettes. Many organisms (microorganism, detritivores, predators) can live in these rosettes and can drive bromeliads functioning (Benzing 2000; Gonçalves et al. 2016). Aquatic and terrestrial predators can directly enhance bromeliad nutrition trough feces, prey carcasses and their activities. However, this contribution can vary among different subfamilies and life form of plant (Benzing 2000; Leroy et al. 2016). Many species of predatory anurans may be dependent on these plants for their survival and reproduction (Silva et al. 1989; Romero et al. 2010). Feces of anurans and others are quite riche in nitrogen and may be one of the important nutrient sources for bromeliads in nutrient poor environments. Morphological and physiological features between different bromeliads may also affect the asset of animal derived nutrient to nutrition of bromeliads (Gonçalves et al. 2016).

Bromeliads have been consumed by native population of Latin America. They are eaten as whole fruit or just a part of the plant, and are eaten as a vegetable or prepared in fermented/unfermented beverages (Hornung-Leoni 2011). In the coastal parts of Ecuador is most commonly consumed wild pineapple (*Ananas comosus*). It is eaten raw, as a juice or in form of typical fermented beverage - “chicha” (Van den Eynden et al. 1999). In the northern part of South America, Andean bears eat terrestrial bromeliads known as “achupaya” or piñuela. They also occasionally consume epiphytes (Pérez-Torres 2001).

Most frequently bears feed on terrestrial bromeliads such as *Puya* sp. and *Greigia* sp. Other genera such as *Tillandsia* sp. and *Pitcairnia* sp. are also eaten, but less frequently (Troya et al. 2004). Cisneros (2012) reported that Andean bears forage on bromeliads: *Puya maculata*, *Puya eryngioides*, *Pitcairnia* sp. and *Guzmania gloriosa* as shown in Table 2. Other studies in Podocarpus National Park (Azuay, Loja and Zamora – Chinchipe provinces) showed that Andean bears forage selectively on the hearts of *Puya eringioides* (DeMay et al. 2014).

Table 2. **Plant and animal species contributed to the diet of Andean bear in Podocarpus National Park.** Extracted from Cisneros 2012.

New families and species in the diet of Andean bear

FAMILY	**SPECIES**
PLANTAE	
Bromeliaceae	*Puya maculata*
	Puya eryngioides
	Pitcairnia sp. 1
	Guzmania gloriosa
Ericaceae	*Macleania sp.*
Clussiaceae	*Clusia ducoides*
Melastomataceae**	*Brachyotum campanulare*
	Miconia sp.
Rosaceae	*Hesperomeles obtusifolia*
Rubiaceae**	Rubiaceae *sp.*
ANIMALIA	
Formicidae	*Camponotus sp*

**Families that have not been previously reported

1.5. Conservation of the Andean bear

Among the main threats for the population of the Andean bear rank fragmentation, habitat loss, poaching and mainly the lack of knowledge about the situation and distribution of this specie throughout the region. Several areas where Andean bears have been living are fragmented by human activities as result of the expansion of the agricultural areas as well as extension of the towns and cities (Peyton 1999; Cuesta & Suárez 2001).

In Ecuador, some populations of the Andean bear are isolated in the intact parts of the forest (Yerena et al. 2003; Kattan et al. 2004). This situation tends to improve in the Andean regions. The northern and central parts of the country still have large areas that still remain intact generally due to its difficult accessibility. Nevertheless, the growth of the population and national development plans in the Andes continue to be an important cause of natural habitat fragmentation, threatening connectivity between the remnants of vegetation for the specie (Castellanos et al. 2010).

Poaching is a serious problem throughout the area of distribution of the Andean bear. Bears are frequently killed after they are found in the corn crops or after attacking livestock of the locals (Goldstein et al. 2006). Furthermore, some parts of the Andean bears are used for medicines or for traditional ritual purposes. In some locations, bear meat is consumed and is much appreciated (Servheen et al. 1999). Some orphaned cubs are sometimes captured and sold (Jorgenson & Sandoval 2005).

The lack of appreciation and knowledge about the distribution and population status is a problem in the whole region. In Ecuador, the information generated about the state of bear populations is scarce, which still does not favor the creation of a plan for future monitoring. Information about its ecology needs to be increased in all areas of distribution of the bear, but mainly in the south and tropical wetlands of the country (Cuesta 2005; Achig 2009).

In Ecuador, the Andean bears are legally protected by the forest and natural law of natural areas and wildlife. In this law is written that all wild animals are the domain of the State and correspond to the Ministry of Environment, and that hunting for any reason is prohibited and they provide sanctions for offenders (Castellanos et al. 2010).

At global level Andean bear is considered as Vulnerable species (IUCN category A2bc), but in Ecuador is listed as Endangered. It is estimated that their populations have been reduced about at least 25 % in the last generation. In addition, there is a small population size (less than 2500 individuals) and any subpopulation exceeds 250 adult individuals (Cuesta & Suárez 2001).

In Ecuador, many different initiatives have been developed to expand knowledge about biology and ecology of the Andean bear. For the conservation efforts, there are 5 most important aspects:

I) Habitat and diet studies: potential and priority areas for the conservation, habitat use, habitat selection, diet (Cuesta et al. 2003; Pelvaro et al. 2005).

II) Monitoring of wild individuals with radio collars: to get valuable information about the habitat use, area where they live, activity and movements of the Andean bear. Few monitoring were already made by the use of different methods – radio collars, molecular techniques (hairs, feces), capture-recapture method, camera traps (Castellanos 2010).

III) Rehabilitation of animals in captivity and breeding of confiscated specimens: imply action of reintroduction of animals to their natural environment (Castellanos 1997; Castellanos et al. 2005).

IV) Genetic studies of wild populations and in captivity at the regional level. It is necessary to accomplish genetic studies of the species in all parts of the country (Ruíz-Garcia 2003). Additionally, there is information about phylogeny of the species and its relationship with the other bear species (Krause et al. 2008).

V) Studies of the livestock-bear conflicts: it is necessary to formulate a management plan to minimize the conflicts (Flores et al. 2005).

These suggestions about the knowledge of the species have been carried out by the researchers as a basis to elaborate the strategy for the conservation of the Andean bear. Currently Ecuador configures its own strategy in a proposal led by the Ministry of Environment as a governmental entity that directs the conservation and management of natural resources in the country (Castellanos et al. 2010).

The information that contributes to the *in situ* conservation of Andean bear in Ecuador has focused on some aspect of the biology and ecology of the species. Many of these efforts have been made in a short period of time. The scare information about the current status of bear population in Ecuador and the urgent need is to include the civil society to the conservation of the species. It is necessary to know the interactions that occur between bears and human close to the bear´s habitat. We also need to understand knowledge, perception and values of people towards the Andean bears. This should be taken into account together with political, socioeconomic aspects and from their considerations should be elaborate and implement the policy of successful wildlife management (Kellert 1994).

There were also several attempts of *ex situ* conservation. In Ecuador have been conducted several successful experiences that include reintroduction of individuals to their natural habitat (Castellanos 2005). Additionally, in some cases, places for *ex situ* conservation have been developed for educational activities through the exhibition of the animals. However, the high investments for the bear care in captivity, as well as the process of quarantine and adaptation makes the initiatives smaller. The facilities for the accommodation of bears, which require ample spaces and special conditions to ensure the welfare of animals, is usually not appropriate (Del Moral & Bracho 2009). Likewise, the animals that are confiscated are not in proper conditions to be transferred to safe sites, where are rescued and then protected. Efforts to understand the characteristic, which are connected with ecology, behavior, genetic and management of the Andean bears in captivity, are fundamental for the conservation of the species in Ecuador. Optimization of management of animals in captivity, will allow stronger programs with individuals that contain genetic diversity in its natural state, for example reinforcement of natural and captive populations (Castellanos et al. 2005).

1.6. Factors affecting variation of nutrients of plants

Plant nutrients are chemical elements essential for the growth and reproduction of the plants. Each element has to fulfil specific criteria to be a nutrient. The first criterion is that the element must be necessary for plant to accomplish its whole lifecycle. The second criterion is that other element cannot substitute the element which is considered as nutrient. The third criterion is that the element is required by all plants. There are 17 elements that meet these criteria and are referred as nutrients. Carbon, hydrogen and oxygen which are derived from the air or water and other 14 are obtained from the soil or solution of nutrient (N, P, K, Ca, Mg, S, Fe, Mn, Cu, B, Zn, Mo, Cl and Ni). Elements that could enhance growth (not in all plants) are referred as beneficial elements (Allen et al. 2007).

The overall plant quality is dependent on chemical and physical characteristic. By the physical properties is determined mainly appearance. By the chemical composition of the plant nutritional and sensory quality is determined. Quality of the plant can be also improved by higher concentrations of some essential nutrients, lipids, carbohydrates, essential amino acids, organic acids, vitamins and bioactive compounds. However, plants can also contain compounds reducing the quality which are called anti-nutrients, for example: heavy metals oxalate (Wiesler 2012).

Quality of the plants is usually controlled by the genetic and physiological factors and it may vary among different species, cultivars, organs of the plant and tissues (White & Broadley 2009). Quality of plant or plant product may be significantly modified by exogenous factors: either natural (climate, soil fertility etc.) or anthropogenic (soil cultivation, fertilization, etc.) factors (Martínez et al. 2010). Nutrient supply can influence the quality traits (Wiesler 2012).

Only a proportional part of nutrients present in the soil may be taken and also utilized by the plant. The amount of this available part is dependent on a range of soil, plant and environmental factors. Availability of the nutrients is also dependent on soil water content, which affects nutrient movement in the soil (Marschner & Rengel 2012).

Epiphytic bromeliads generally obtain nutrients from the canopy leaves deposits, atmosphere and interactions with animals. These nutrient sources are discontinuous. Epiphytic bromeliads can store them and use them during nutritional stress instead of utilizing them to growth of plant body. Roots of terrestrial bromeliads are constantly in the contact with soil so nutrients may be utilized to growth (Laube & Zotz 2003). Benzing (1983) reported that plants from family Tilandsioideae did not grow even with added fertilizer. These plants have slow growing strategy which is a response to oligotrophic environments (Aerts & Chapin 2000).

2. Aims of the Thesis

This thesis is one part of a larger project about the ecology Andean bears in Southern Ecuador and is highlighted by the red colour in Figure 3. The aim was to find out whether ecological factors affect the nutritional composition of the Bromeliads used by Andean bear in the area.

The objective of this master thesis is focused on understanding the factors affecting the variability in the nutrients content in Bromeliads, as one of the most important parts of the diet of the Andean bear (*Tremarctos ornatus*). Thus, following aims were stated:

1) Whether Bromeliads growing in different places have different nutritional composition
2) Detect differences in nutritional content between Bromeliads from two different ecosystems
3) Detect differences in nutritional content between Bromeliads from burnt and unburnt areas
4) Detect differences in nutritional content among four Bromeliad species
5) Detect nutritional content between flowering and not flowering Bromeliads

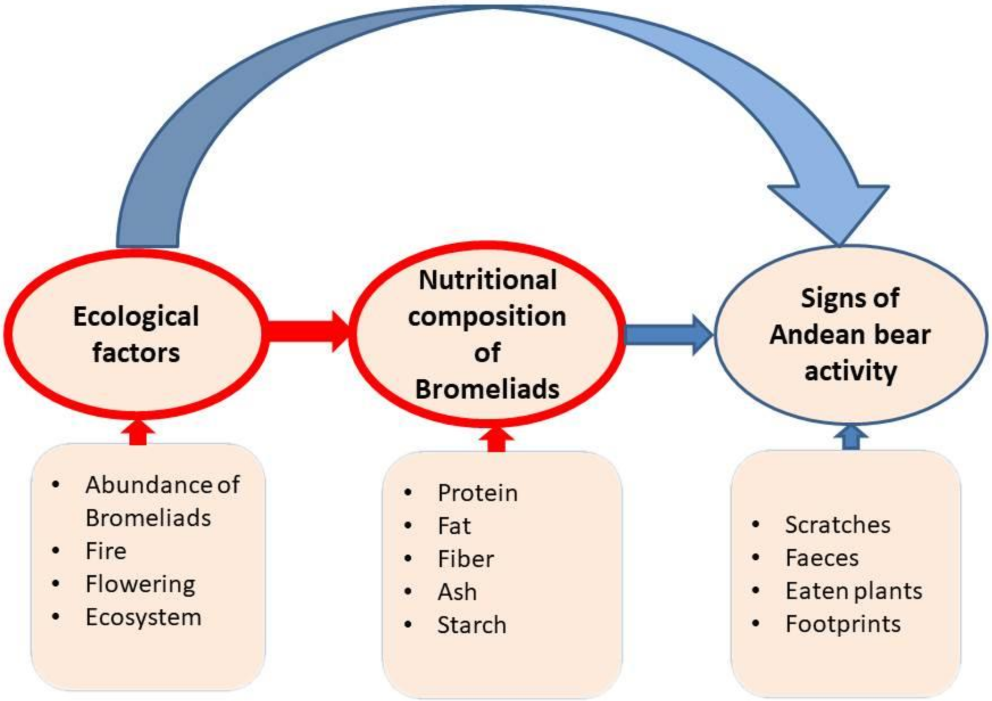

Figure 3. Design of the project

3. Methods

The structure of this master thesis was written according to the Methodological Manual for the Writing of Master´s Theses (FTA 2018). References were cited according to the Citation Rules of the Faculty of Tropical AgriSciences, CULS Prague (FTA 2017).

3.1. Habitat description

Ecuador is situated in north – western South America, it is the fourth smallest country in the continent. Total area is 269, 178 km^2. Ecuador is on the west bounded by the Pacific Ocean. The Andes are located approximately from the north to the south, halving the country. The country is divided into three natural zones – western coastal region (Costa), the Andean Uplands (Sierra) and the eastern lowlands (Oriente or Amazonas) (Harling 1979; Ramsay 1992).

3.1.1. Study areas

The study was carried out during June and July of 2017. Data were collected in three different páramo ecosystems and three different montane forests. Study sites were spread in Loja Province and Zamora – Chinchipe province in southern Ecuador. Climate in the region is classified as temperate oceanic, and annual rainfalls are around 1058 mm (Peel et al. 2007; climate-data.org 2018). June and July is the dry season in this region, and precipitation is just 77 mm monthly (climate-data.org 2018).

Burnt páramo in Madrigal

Reserva Madrigal del Podocarpus (4º02´27"S; 79º10´32"W) is 306 ha large, private – own land, seven kilometers southwestern from Loja city in the province of Loja. Owner is family Tapia. It is situated on the west of Podocarpus National Park and shares more than half of its land with the park. Reserve spans from 2,200 to 3,300 m a.s.l. In the higher elevation there is an anthropic páramo (from 2,600 m a.s.l.) as is shown in Figure 4. On 19, November of 2016, more than 60 hectares were burnt in man-made fire. This fire lasted about five days. Southern ridge is at around 2,640 m a.s.l. and is dominated by anthropic shrub páramo where predominantly occurs *Puya* *parviflora* as it is fire-resistant plant and has great regeneration abilities (Tapia H, personal communication 2017).

Unburnt páramo in Madrigal

Unburnt páramo is situated on the west ridge of Reserva Madrigal del Podocarpus and is not owned by Tapia family. Unburnt páramo is located close to village El Carmen, Loja. It is also anthropogenic páramo in lower elevations than in Madrigal Reserve. This páramo belt is situated on the ridge and on the sides bounded by the forest (as shown in Figure 5.) and on the southern side by meadows. In this area there was no fire recorded for dozen of years and it may have influence to vegetation structure. The lowest part of this ecosystem is covered by shrubs, middle part *Puya parviflora*, upper part *Puya eryngioides* and some species of ground *Tillandsia*.

Natural páramo in El Tiro

Study area in El Tiro is situated northwestern from the city of Loja, beyond the border of Zamora – Chinchipe province (70º57´61"E; 95º57´84"N). There is a composition of herbaceous and shrubby vegetation, characteristic for this ecosystem as shown in Figure 6. In El Tiro typically grow *Puya nitida* and ground *Tillandsia*. In 2009 road from Loja to Zamora was rebuilt and imbalanced this natural ecosystem. However, even after reconstruction of the road the Andean bears have been seen in this area (Cisneros 2012).

Figure 4. Páramo in Reserva Madrigal del Podocarpus, Source: Author´s photography

Figure 5. Upper part of unburt páramo, Source: Author´s photography

Figure 6. Natural páramo in El Tiro, Source: Author´s photography

Montane forest in Madrigal

Reserva Madrigal was described in previous paragraph. In lower elevations (from 2,200 m a.s.l. to around 2,700 m a.s.l.) there is montane cloud forest. Some land used to be a cattle pasture before it was purchased by current owners in 2003 and there have been intensive reforestation efforts to restore the native vegetation. Through the forest leads the trail. Forest is really dense. First part of the trail is in reforested secondary forest and second in the primary cloud forest (Tapia H, personal communication 2017).

Montane forest in Podocarpus National Park

Podocarpus National Park (at 03°58´S, 79°04´W) has a surface area of 146,280 ha and spans from 1,000 to 3,600 m a.s.l. Park is located in southern Ecuador in the provinces of Loja and Zamora – Chinchipe, and was established in 1982 (Apolo 1984). Park is categorized as diverse zone and also an area with really high level of endemic species. In elevations around 1,000 m a.s.l. there is lower montane forest and nearly around 3,000 m a.s.l. "elfin" forests are located (Lozano et al. 2010). Density of vegetation is high.

Montane forest in Volcano

The montane forest in El Volcano is situated north – western from the city of Loja in elevations starting around 2,000 m a.s.l. Forest is next to the valley where the river flows. Forest is quite dense and abundance of bromeliads (*Tillandsia* spp.) is high. Human presence in this area is not common as the forest is in distant area.

3.2. Data collection

Data collection was carried out during June and July of 2017. Most important part of this study was the bromeliads collection. As indicated in chapter 1.3. Habitat use, Andean bears occur in a variety of natural habitat. In area of Loja and Zamora – Chinchipe Andean bears occurs mainly in páramo and montane tropical forest and all study was focused on these two ecosystems. It was established 5 plots in size 50 x 50 m in each study site which were described in previous chapter. These plots were made for counting of signs and activity of the Andean bears and this is reported in diploma thesis of my colleague Anna Bernátková entitled "Analysis of Andean bear activity patterns and habitat use in páramo ecosystems in Southern Ecuador". Both of these studies have been running simultaneously. In each of these plots (50 x 50 m) there were randomly establish two plots in size 10 x 10 m in which bromeliad samples were collected. In each of this small (10 x 10 m) plots, 3 individuals of the most abundant bromeliad species were collected. It was collected samples from two bromeliad subfamilies – Tillandsioideae and Pitcairnioideae. From subfamily Pitcairnioideae it was collected 3 species from genus *Puya* – *Puya eryngioides*, *Puya nitida* and *Puya parviflora*; and from subfamily Tillandsioideae it was collected *Tillandsia sp*. Every sample was marked with appropriate code to know where it was collected and what is the number of the particular individual as shown in Figure 7.

Figure 7. Marked sample in paper bag before drying, Source: Author´s photography

3.2.1. Processing of the plants

All the plants had to be processed – cleaned, dried and grinded for the analysis of the nutrients. Because Andean bears eat only the meristematic tissues (heart) of the bromeliads) collected samples were peeled and eaten (white part) was separated from the rest. This eaten part was then cleaned from the dirt. All collected samples were dried in drier (82 ºC for 12 hours). After drying, all samples were grinded. These procedures were done at UTPL in Loja. Samples were stored in freezer in temperature -18ºC and transported to CULS where analysis of the samples was realized.

3.2.2. Nutritional analyses - NIRS

For the analysis of the nutritional composition of the plants collected, Near Infrared Spectroscopy method was used (NIRS). Analysis was done in a NIRS^{TM} DS2500 from FOSS. This method uses the infrared region of the electromagnetic spectrum (from 850 to 2.500 nm). The sample is exposed to an electro-magnetic scan over this wavelength range. Energy which is in this spectral range is directed on the sample. Reflected energy is then measured by the device. The dispersed reflection is carrying specific information which enables to identify chemical bonds within the tested sample. The reflected energy is stored (as reciprocal logarithm) and all spectra are converted to provide data about chemical composition of the examined sample (Baker & Barnes 1990; Shenk & Westerhaus 1993). Absorbance connected with the chemical bonds in the examined sample is able to form the bases of organic material. It enables to identify structural fibre, saccharides, proteins, lipids and some of their fractions. NIRS instrument require calibration for identification of these components by relating the spectra to specific chemical analysis: wet chemistry, in vivo data (Corson et al. 1999).

All samples were scanned with spectrometer by FOOS in ISI Scan software and spectra were obtained. The Vegetal By-Products calibration was installed in the same software additionally, and it served for interpolation of chemical constituents of the remaining sample, and finally obtaining the results for protein, fat, fibre, ash and starch.

The mean of the three plants analysed in each plot (ten plots per study site) was used in further analyses.

3.3. Data analysis

Data analysis was done in IBM® SPSS® Statistics 20 software. Normal distribution of the studied variables (protein, fat, fibre, ash and starch) was assessed by Kolmogorov-Smirnov tests. ANOVA was used to determine differences in nutritional composition of Bromeliads across study sites, between two different ecosystems, between burnt and unburnt areas, among four different Bromeliad species and between flowering and not flowering Bromeliads. F-test was used to compare these factors of the deviations of individual nutritional components, and Tukey test was applied when more than two groups were compared (i.e. for study sites and Bromeliad species).

A set of generalized linear mixed models (GLMM) were designed to test through multivariate approach the influence of the previously commented ecological variables (site, ecosystem, fire occurrence, Bromeliad species and flowering) on the nutritional composition of Bromeliads used by the Andean bear. Site was always included in the models a random factor, and plot as repeated measures. The other ecological variables also entered the model as factors. Linear response was always used. A traditional stepwise backward selection procedure was used to find the significant variables affecting each nutritional component. The threshold for significance was considered $P < 0.05$.

4. Results

Kolmogorov-Smirnov test was used to check the normality of the variables used in this study. All they were normally distributed: ash (KS=10.08, p=0.396), protein (D=14.13, p=0.867), fat (D=4.51, p=0.831), fibre (D=11.71, p=0.920), starch (D=15.26, p=0.497).

4.1. Preliminary descriptive analyses

4.1.1. Nutritional composition of Bromeliads across study sites

Differences in the nutritional composition of Bromeliads according to study sites are shown in Table 3. Significant differences were found for protein, fat, fibre, and starch, but not for ash.

Table 3. Influence of study site to nutritional values of Bromeliads

	Means and SD				ANOVA test	
	Madrigal (n=30)	Podocarpus (n=10)	Tiro (n=10)	Volcano (n=10)	$F_{(3,59)}$	P-value
Protein	13.32 ± 1.91 ^{b}	16.86 ± 1.64 ^{a}	12.56 ± 1.67 ^{b}	15.38 ± 1.77 ^{a}	14.742	<0.001
Fat	5.22 ± 1.26 ^{a}	3.35 ± 0.64 ^{b}	5.71 ± 1.38 ^{a}	2.34 ± 0.68 ^{b}	23.610	<0.001
Fibre	10.39 ± 3.57 ^{b}	13.75 ± 1.95 ^{a}	11.13 ± 1.31 ^{ab}	14.19 ± 2.82 ^{a}	6.030	0.001
Ash	9.81 ± 2.00 ^{a}	10.40 ± 1.75 ^{a}	10.72 ± 0.86 ^{a}	9.91 ± 2.57 ^{a}	0.668	0.575
Starch	14.59 ± 3.75 ^{b}	18.68 ± 3.46 ^{ab}	10.25 ± 2.08 ^{c}	18.87 ± 5.29 ^{a}	11.835	<0.001

Superscripts indicate grouping according to Tukey tests

4.1.2. Nutritional composition of Bromeliads in the ecosystems

Differences in the nutritional composition of Bromeliads collected in the two studied ecosystems (forest and páramo) are shown in Table 4. Significant differences were found for protein, fat, fibre, ash, starch.

Table 4. Influence of ecosystem to nutritional values of Bromeliads

	Means and SD		ANOVA tests	
	Forest (n=30)	**Páramo (n=30)**	**$F_{(1,58)}$**	**P-value**
Protein	15.87 ± 1.64	12.39 ± 1.24	86.215	<0.001
Fat	3.20 ± 0.97	5.82 ± 1.03	103.342	<0.001
Fibre	13.86 ± 2.94	9.55 ± 2.05	43.310	<0.001
Ash	10.68 ± 1.96	9.48 ± 1.70	6.425	0.014
Starch	17.79 ± 4.20	12.73 ± 3.82	23.798	<0.001

4.1.3. Nutritional composition of Bromeliads in burnt and unburnt areas

Differences in the nutritional composition of Bromeliads collected in burnt and unburnt areas are shown in Table 5. Significant differences were found for protein, fat, fibre, ash and not for starch.

Table 5. Influence of fire to nutritional values of Bromeliads

	Means and SD		ANOVA test	
	Yes (n=10)	**No (n=50)**	**$F_{(1,58)}$**	**P-value**
Protein	12.42 ± 1.16	14.47 ± 2.29	7.582	0.008
Fat	6.42 ± 0.67	4.13 ± 1.52	21.675	<0.001
Fibre	8.65 ± 1.94	12.32 ± 3.21	12.104	0.001
Ash	8.71 ± 1.49	10.35 ± 1.89	6.730	0.012
Starch	13.05 ± 3.97	15.70 ± 7.78	2.694	0.106

4.1.4. Nutritional composition of different Bromeliads species

Differences in the nutritional composition of four Bromeliad species are shown in Table 6. Significant differences were found for protein, fat, fibre, ash and starch.

Table 6. Influence of Bromeliaceae species to nutritional values of Bromeliads

	Means and SD				ANOVA tests	
	Puya eryngioides (n=3)	*Puya nitida* (n=5)	*Puya parviflora* (n=14)	*Tillandsia* (n=38)	$F_{(3,56)}$	P-value
Protein	12.38 ± 0.59 [b]	11.63 ± 0.48 [b]	12.08 ± 1.37 [b]	15.35 ± 1.82 [a]	19.592	0.000
Fat	5.60 ± 0.19 [a]	6.95 ± 0.49 [a]	6.03 ± 0.98 [a]	3.54 ± 1.13 [b]	31.389	0.000
Fibre	7.76 ± 0.28 [c]	12.07 ± 1.04 [ab]	8.39 ± 1.77 [bc]	13.19 ± 2.94 [a]	14.558	0.000
Ash	8.72 ± 0.46 [ab]	10.29 ± 0.51 [ab]	8.31 ± 1.44 [b]	10.81 ± 1.79 [a]	8.933	0.000
Starch	16.96 ± 1.82 [a]	11.14 ± 2.13 [a]	14.11 ± 4.08 [a]	16.10 ± 5.04 [a]	2.198	0.098

Superscripts indicate grouping according to Tukey tests

4.1.5. Nutritional composition of flowering and not flowering Bromeliads

Differences in the nutritional composition of flowering and not flowering Bromeliads are shown in Table 7. Significant differences were found for protein, fat, fibre and not significant for ash and starch.

Table 7. Influence of flowering to nutritional values of Bromeliads

	Means and SD		ANOVA tests	
	Yes (N=13)	**No (N=47)**	$F_{(1,58)}$	**P-value**
Protein	12.61 ± 1.37	14.55 ± 2.30	8.395	0.005
Fat	5.85 ± 0.71	4.14 ± 1.65	13.159	0.001
Fibre	9.17 ± 1.77	12.41 ± 3.31	11.415	0.001
Ash	9.47 ± 1.56	10.25 ± 1.99	1.681	0.200
Starch	13.15 ± 3.46	15.85 ± 4.89	3.451	0.068

4.2. Multivariate analysis of factors affecting nutritional values of Bromeliads

Since the most of the preliminary analyses showed significant results, multivariate analyses were conducted to see which ecological factors are actually important. Effect of the studied ecological factors on each individual nutrient was tested through GLMM as shown in Table 8.

Table 8. Multivariate analysis of factors affecting nutritional values of Bromeliads

	β	t	P-value
PROTEIN			
Intercept	12.986	21.751	<0.001***
Ecosystem – Forest [1]	3.129	5.466	<0.001***
Burnt [2]	1.412	2.385	0.021*
Species [3] **– *P. eringyoides***	-1.065	-1.614	0.113^{ns}
Species – *P. nitida*	-1.922	-5.032	<0.001***
Species – *P. parviflora*	-1.911	-2.538	0.014*
Flowering [4]	0.956	2.658	0.010*
FAT			
Intercept	4.388	13.594	<0.001***
Ecosystem – Forest [1]	-1.096	0.118	<0.001***
Burnt [2]	1.627	4.544	<0.001***
Species [3] **– *P. eringyoides***	0.149	1.261	0.213^{ns}
Species – *P. nitida*	2.459	652.567	<0.001***
Species – *P. parviflora*	-0.620	-1.643	0.106^{ns}
Flowering [4]	0.327	162.219	<0.001***
FIBRE			
Intercept	10.287	59.332	<0.001***
Ecosystem – Forest [1]	3.389	19.548	<0.001***
Burnt [2]	1.784	3.365	<0.001***
Species [3] **– *P. eringyoides***	-3.668	-10.504	<0.001***
Species – *P. nitida*	1.620	5.116	<0.001***
Species – *P. parviflora*	-3.790	-7.178	<0.001***
Flowering [4]	1.176	6.030	<0.001***
ASH			
Intercept	10.280	20.761	<0.001***
Ecosystem – Forest [1]	1.130	5.504	<0.001***
Burnt [2]	1.108	32.919	<0.001***
Species [3] **– *P. eringyoides***	-3.147	-288.269	<0.001***
Species – *P. nitida*	-0.879	-3.401	0.001*

Species – *P. parviflora*	-3.981	-421.056	<0.001***
Flowering [4]	0.816	3.980	<0.001***
STARCH			
Intercept	11.371	12.110	<0.001***
Ecosystem – Forest [1]	5.612	7.714	<0.001***
Burnt [2]	-4.999	-4.816	<0.001***
Species [3] – *P. eringyoides*	6.428	5.211	<0.001***
Species – *P. nitida*	-0.194	-0.475	0.637^{ns}
Species – *P. parviflora*	6.958	5.489	<0.001***

*, *** indicate significance at 0.01 and 0.001 levels respectively

^{ns} not significant values

[1] Páramo was used of category of reference. Therefore, positive β means positive effect on the nutritional content of the bromeliads.

[2] Unburnt conditions were used as category of reference.

[3] *Tillandsia* sp. was used as category of reference.

[4] Not flowering plants were used as category of reference.

In general, the multivariate analyses confirmed the preliminary results. The main difference is that, once controlling for main ecological sources of variability like ecosystem, fire, flowering and species, the study site was never significant, which reflects first the ecological homogeneity across the study area, and second that the most important ecological factors were indeed identified and studied.

5. Discussion

In forest ecosystem nutritional values of Bromeliads were generally higher except of fat content, which was higher in páramo ecosystem. This may be explained by the fact that higher fat content assist in endurance of Bromeliads during fires, as many fire-resistant plants contain high levels of fats and waxes (Rocha et al. 2014). Effect of fire in páramo in Madrigal Natural Reserve (November 2016) had affected nutritional quality of Bromelids. In burnt areas Bromeliads had higher levels of tested nutrient, except of level of starch, which was higher in unburnt areas. This was expected, since burnt areas commonly are highly productive. Flowering of some Bromeliads species had also effect on nutritional composition. Levels of starch were similar in flowering and not flowering Bromeliads, but other tested nutrients were in favour of flowering Bromeliads.

Bromeliads had greater nutritional value in the forest compared to the páramo. Epley (2012) stated that in drought areas protein content of *Vriesea gigantean* (Bromeliaceae) is higher. However our results showed that in forest ecosystem (higher humidity) there was higher protein content than in páramo. In tropical montane forest grow solely epiphytic Bromeliads. Epiphytic Bromeliads grow on plant surface and derive water and nutrients mainly from air and rain, which is different strategy than in terrestrial Bromeliads growing in the páramo ecosystem (Benzing 2000). Thus differences in the nutritional composition detected in our study could be caused by distinct nutrition of the Bromeliad species. Soils in páramo have high content of organic matter (slow decomposition) and higher water content (Buytaert et al. 2005). In the forest ecosystem there are poor-nutrient, acidic soils. In montane forest the most of available nutrients is present in organic layer. Availability of nutrients decreases with altitude (Wilcke et al. 2008). To compare fat content in Bromeliads from páramo and forest, almost same level of fat was detected. This occurrence may also differ during different phenological (*e.g.* flowering) and natural (*e.g.* season) conditions. However for Bromeliads from páramo fat may serve as a protection against ultraviolet light, as there is harsher sunlight in the páramo ecosystem than in forest (forest Bromeliads are protected by vegetation). Long et al. (2003) indicated that waxes and fats help the plants resist ultraviolet light and provide the plants by effective protection from drought and other environmental stresses. The greater nutritional content in forest during our study may explain the greater use of this ecosystem by Andean bears detected during another part of this project (Bernátková 2018).

Fire was reported in one of the study sites in páramo ecosystem and affected quality of the Bromeliads in there. It was reported that fire caused loss of biomass in Bromeliads - *V. friburgensis*, *D. encholirioides* and *A. nudicaulis* (Rocha et al. 2004). Consequences of fire may be, besides the destruction of Bromeliads, evaluated as loss of resources and free water. The highest level of water is accumulated inside the central stem. In the stem meristematic tissue is found. Moisture might protect this tissue from fire and allow subsequent recovery of the plant (Ariani et al. 2004). Debano and Conrad (2018) reported loss of nitrogen during burning of North American grasslands. This fact may suggest that this condition is connected with loss of protein, but our study showed different tendency. Protein content of Bromeliads in burnt areas was significantly higher than protein content of Bromeliads from unburnt areas. Our outcome may be explained by possible recovery of burnt area as the Bromeliad samples were collected seven months after the reported fire. However our finding was supported by Schindler et al. (2004) who reported that spiny hackberry in North American grassland had significantly higher level of crude protein and digestible protein in burnt areas than in areas not affected by fire. Ash content in vascular plants of herb layer vegetation in coastal plain forest in South Carolina showed a positive response to fire (Gilliam 1988), which corresponded with the result of our study (level of ash was significantly higher in burnt areas). It was also reported that new (recovered) vegetation is more nutritious for livestock (Ramsay & Oxley 1996), and this finding agree with our results. In areas affected by fire there was greater nutritional content of Bromeliads, however higher activity and feeding behaviour were not observed.

Bromeliad species have different living strategies (terrestrial, epiphytic, saxicolous) (Benzing 2000) so variety of nutritional values was expected among rated Bromeliad species. Gentry and Dodson (1987) reported that epiphytic Bromeliads are abundant in Andean forest. These epiphytes are important foodstuffs for Andean bears as they are high in soluble carbohydrates, fat and protein (Goldstein 1990). Study of Goldstein (1990) also evaluated composition of diet of the Andean bear in Venezuela and found out nutritional composition of *Puya* sp. (15.32 % of ash, 11.21 % of crude protein, 20.40 % of cellulose, 6.10 % of lignin), *Tillandsia fendleri* (5.97 % of ash, 6.06 % of crude protein, 19.12 % of cellulose, 6.96 % of lignin), *Tillandsia complanata* (9.99 % of ash, 8.88 % of crude protein, 21.80 % of cellulose, 6.83 % of lignin). Cisneros (2012) evaluated nutritional composition of *Puya eryngioides* (1 % of ash, 7.5 % of fiber, 0.5 % of fat, 2 % of protein, 4.5 % of carbohydrates). In each study different methodology was used and this explains different results. Our results are more in the line with the study of Goldstein (1990) as so the ash and was highest in *Tillandsia* sp. among tested species, probably because of stronger absorption of water from environment. Nutritional composition among tested Bromeliads species varied. The most differences were found for ash and fibre content among all examined nutrients. Different ecological factors could affect nutritional composition of tested Bromeliads species. Bernátková (2018) reported that Andean bears consumed (during June, July 2017) *Tillandsia* sp. and *Puya* sp. and it is obvious that they are important food source even in period of time, when was this research conducted.

Flowering occurred mainly in *Puya parviflora* in páramo ecosystem during this research. Flowering occurs spontaneously in Bromeliads once the plants have reached maturity and appropriate size (Mekers et al.1983). Generally, Bromeliads are flowering with low temperatures and during low rainfall season. Phenological cycle is determined by various biotic (pollinators, *zoochory* etc.) and abiotic (temperature, rainfalls, etc.) factors (Rocha et al. 2004). We found that flowering occurred mainly in burnt areas and could be caused, besides other factors, by the effect of reported fire. In our study it was ascertained that starch content did not vary between flowering and not flowering Bromeliads. This result is supported by study of Zotz and Richter (2006), who reported that total carbohydrates did not change in the vegetative parts of reproducing Bromeliad (*Werauhia sanguinolenta*). Our results also highlight higher level of evaluated nutrients in flowering Bromeliads, which could be caused by the environment and conditions of the soil. Flowering of Bromeliad species may cause that the Andean bears are not feeding on them even if they were greatly nutritious.

6. Conclusions

There are no previous studies focused on this topic. We presumed that different ecological factors may strongly affect nutritional composition of Bromeliads, and help to understand habitat use of Andean bears. That was confirmed in this study: the nutritional levels of Bromeliads change when they are affected by fire, flowering, and species and ecosystem also affects them. However, this study was conducted only during one season, and thus more studies are necessary to find out whether the nutritional values of Bromeliads change year round, which may help to explain the preference for *Puya* sp. observed in the same area in previous studies in other periods of the year. A thorough knowledge about these factors will be essential to understand the nutritional needs and feeding ecology of the species, and to anticipate human-bears conflicts.

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