Spring 2019

Mammals of the Northern Andes: An analysis of camera trap data and observation in Angochagua, Ecuador

Risa Berman

Mammals of the Northern Andes

An analysis of camera trap data and observation in Angochagua, Ecuador

Berman, Risa
Academic Director: Silva, Xavier
Project Advisor: Laguna, Andres
Saint Michael's College
Environmental Science

Parroquia de Angochagua, Provincia de Imbabura, Ecuador

Submitted in partial fulfillment of the requirements for Ecuador: Comparative Ecology and Conservation, SIT Study Abroad, Spring 2019

Acknowledgements

I would like to thank Andres Laguna and Big Mammals Conservation (BMC) for making this project possible and providing broad and technical guidance and support. The Parroquia of Angochagua welcomed my partner and me into the community and provided logistical help. The Sandoval family generously opened their home to us for the duration of our stay in Angochagua. My classmate Megan Frederick shared in wildlife observation and camera trap work, and some of these data have been shared between our two projects. Finally, I would like to thank SIT, Xavier Silva, Javier Robayo, Diana Serrano, and Ana Ana María Ortega Alvarez for their support in the formation and execution of the project.

Abstract

The high Andes of Ecuador are home to a diverse community of mammals, many of which are threatened. These include the Andean bear, Andean fox, puma, and mountain tapir. This study used camera traps, direct observation, and indirect observation over three weeks to monitor the wildlife in the mountains of the Parroquia of Angochagua. The five species observed during this period were Andean bear, Andean fox, dog, mountain paca, and mouse. While this short study did not completely survey the mammalian community of the area, it confirmed the presence, diet, sociality, temporal habits, elevational range, and habitat preferences of the species detected, as well as documenting interactions between livestock, Andean bear, and free-roaming dogs. These data will contribute to ongoing conservation efforts by Big Mammals Conservation and the Parroquia of Angochagua to protect their high forest and páramo areas.

Resumen

La zona altoandina de Ecuador es el hogar de una comunidad diversa de mamíferos, incluso muchos que son amenazados. Estas especies incluyen el oso andino, el lobo andino, el puma, y el tapir andino. Esta investigación usó las cámeras trampas, la observación directa, y la observación indirecta durante tres semanas para monitorizar la vida silvestre en las montañas de la Parroquia de Angochagua. Las cinco especies observadas durante este período fueron el oso andino, el lobo andino, el perro, el paca de montaña, y el ratón. Aunque este estudio no reconoció completamente la comunidad de mamíferos de la región, confirmó la presencia, la dieta, la socialidad, las costumbres temporales, la distribución de altura, y las preferencias del hábitat de las especies detectadas, además de documentar las interacciones entre el ganado, el oso andino, y los perros. Estes datos contribuirán a los esfuerzos en marcha de Big Mammals Conservation y la Parroquia de Angochagua para proteger sus zonas de bosque alto y páramo.

Ethics

Research was completed through Big Mammals Conservation, with permission granted through the project advisor Andres Laguna to access private land. Camera traps were placed far from human activity to avoid unintentional detection of human subjects. Camera traps and indirect observation are non-invasive methods of wildlife monitoring which do not involve any human interaction with wildlife. Direct observations were conducted from afar, without interaction, with the exception of the bear capture which was conducted with expert guidance from BMC and experienced veterinarian Diego Medina.

Introduction

Mammal species, both predators and herbivores, are critical to the functioning of healthy ecosystems of all types. The páramo and Andean forest ecosystems of the high Andes of Ecuador support a community of large mammals which includes the puma, pampas cat, Andean fox, Andean bear, Colombian weasel, long-tailed weasel, striped hog-nosed skunk, and mountain coati (Zapata-Ríos, 2014). A survey of large mammals in the páramo and Andean forests of Llanganates National Park, Ecuador also detected Andean white-eared opossum, mountain paca, tapeti, oncilla, mountain tapir, little red brocket deer, Andean white-tailed deer, and northern pudu (Palacios, Naveda-Rodríguez, & Zapata-Ríos, 2018). Healthy ecosystems rely on their complete community of native species. In our study area, pumas and Andean bears reside at the top trophic level. Pumas are carnivorous while Andean bears and Andean foxes are omnivorous. Mountain paca, mountain tapir, little red brocket deer, Andean white-tailed deer, and northern pudu are herbivorous. Smaller rodents such as mice form the bottom tier of the mammalian trophic levels.

Top predators such as pumas (*Puma concolor*) control herbivore populations, limiting overgrazing. In addition to the direct trophic cascade effect of predators controlling herbivore population sizes, predators also can indirectly protect plants by influencing the behavior of their herbivorous prey species. Pumas indirectly discourage herbivory by increasing the “antipredator behavior” of vicuñas, discouraging them from the relaxed consumption of plants in physically complex areas (Donadio & Buskirk, 2016). Top predators also often make food sources available to scavenger species. For example, Perrig, Donadio, Middleton, and Pauli investigated Andean condors’ dependency on pumas for food provisioning. The majority of vicuña carcasses fed upon by condors were killed by pumas, revealing an obligate relationship between the species (Perrig, et al., 2017). These solitary, nocturnal and diurnal animals prey on large mammals including deer and pacas, as well as smaller animals such as mice and other vertebrates. Pumas occasionally attack livestock such as cattle, sheep, and goats (Zarco-González, Monroy-Vilchis, Rodríguez-Soto, & Urios, 2012). While they have a large distribution, occupying nearly the entire country of Ecuador, pumas are considered vulnerable, and are threatened by habitat loss and hunting (Tirira, 2017). Lack of sufficiently large protected areas can encourage pumas to resort to livestock predation. While much of this predation can be prevented through proper livestock management practices, many farmers go after the pumas, killing 40 in the 15-year period between 1993 and 2008 in Central Mexico. In many cases, farmers poison carcasses which may unintentionally kill other species as well, such as ocelots, margays, Andean bears, Andean foxes, and dogs (Zarco-González, et al., 2012). While rare, pumas are an apex predator in the study community.

Herbivores also perform important ecosystem functions such as seed dispersal, which is critical to the maintenance of plant communities. The Andean tapir (*Tapirus pinchaque)*, or mountain tapir, plays a critical role in dispersing large seeds over long distances. Andean tapirs are selective herbivores with refined diet preferences, consuming leaves, twigs, shoots, and fruit. This endangered species has one of the most restricted ranges of all the large neotropical mammals (Tirira, 2017). Residing in the páramo, upper Andean forests and cloud forests, habitat loss is one of the species’ primary threats. Despite its large size, the Andean tapir is rare and elusive, making camera traps one of the most effective monitoring strategies. It is estimated that the population size has decreased by 50 percent in the last three decades and will continue to decline (Verdugo, 2013). Further reduction of tapir populations could result in cascading impacts on ecosystem function (O’Farrill, Galetti, & Campos-Arceiz, 2013). Tapirs’ and other large mammals’ role in maintaining plant communities contributes to ecosystem services such as land stabilization and water filtration.

Mountain pacas (*Cuniculus taczanowskii*) also play an important herbivory role in the mammalian community of this region. Nocturnal and solitary, their diet consists primarily of fruits and nuts, and the species acts as a short-distance seed disperser. Found in the forests and páramos of the high Andes, mountain pacas favor habitats far from human impacts (Tirira, 2017). Like many other wildlife species, both herbivores and carnivores, mountain pacas are threatened by feral dogs. In Cayambe-Coca National Park, mountain pacas as well as three other native mammalian species (mountain coati, long-tailed weasel, and northern pudu) were absent in areas with feral dog occupancy (Zapata-Ríos & Branch, 2016).

The Andean fox (*Lycalopex culpaeus*), or culpeo, is a solitary species with an omnivorous opportunistic diet of small mammals and other vertebrates, carrion, and fruit. It prefers high forest and páramo habitats, especially open spaces, usually from 2600 to 4810 meters in elevation. This species acts as an effective seed disperser for plant families such as Fabaceae and Anacardiaceae (Maldonado, Pacheco, & Saavedra, 2014). Like the puma, the Andean fox is considered vulnerable despite its large distribution, and is often hunted (Tirira, 2017). While many biologists believe these foxes' nocturnal tendencies are a response to pressure from human persecution, nocturnal activity may also be a natural response to prey availability and activity (Monteverde, & Piudo, 2011).

Andean bears (*Tremarctos ornatus*) play a critical yet controversial and vulnerable role in this region. They are important seed dispersers, and can even accelerate germination due to stomach acids dissolving seed coverings (Rogers & Applegate, 1983). Many local people believe the Andean bear is a threat to their livestock, primarily cattle. Although a few cases of bear attacks on livestock have been verified, Andean bears are often blamed for any livestock disappearance or death, many of which are in fact caused by free-roaming dogs (Goldstein et al., 2006; A. Laguna, personal communication, April 16, 2019). Andean bears eat mostly plants, and generally prefer high forest and páramo habitats to lower farming areas. In many cases bears have been found scavenging the carcasses of dead livestock, but were not the cause of death. Although cattle remains have been found in bear excrement in Peru and Ecuador, many cases lack proof that this consumption arose from predation rather than scavenging carrion. While there have been strong indicators of livestock predation by Andean bears, no direct evidence was found in Venezuelan surveys completed between 1985 and 1987 (Goldstein, 2002).

The Galo Plaza Lasso Foundation at Hacienda Zuleta has documented 39 Andean bear individuals since they began monitoring bears with camera traps in 2009. In January of 2018, one bear was captured, radio collared, and released in nearby Cayambe-Coca National Park (Y. Potaufeu, personal communication, April 16, 2019). On April 19, 2019 we captured an Andean bear and radio collared it with a collar with a camera as well. This is the first time any Andean bear has worn a camera collar and will provide new insights into the species' diet, movement and range, interactions, and other behaviors.

The blame placed on bears often causes people to fear and/or hunt them, which is detrimental to their conservation. From 2000 to 2005, 50 Andean bears were killed (Tirira, 2017). Augmenting the knowledge base about Andean bears and their interactions with other species will contribute to conservation efforts. The International Union for Conservation of Nature (IUCN) lists the Andean bear's conservation status as "vulnerable" with a total number of 2,500 to 10,000 individuals (Velez-Liendo & García-Rangel, 2017). The Red Book of Ecuador lists them as endangered. Protecting the Andean bear also benefits other species, as it is an umbrella species for conservation. As a charismatic species with a large range, protecting this species and its habitat also protects many other species and ecosystems (Crespo-Gascón & Guerrero-Casado, 2019).

While the high Andean mammal community has high species richness, there is a lack of population data for many of these species (Shipper, 2008). Carnivores of the Ecuadorian Andes are one of the most poorly understood groups of neotropical mammals. Many páramo species are endemic, with small restricted ranges (Llambí & Cuesta, 2014). In fact, the high Andes have the highest endemism of any Ecuadorian ecosystem, with a total of 15 endemic mammal species (Tirira, 2007). Many of the species, such as the mountain tapir, Andean bear, Colombian weasel, northern pudu are endangered, threatened, or vulnerable (Tirira, 2011).

Cayambe Coca Ecological Reserve and National Park, a massive reserve spanning 40,4103 hectares in four provinces, protects a large area of land near Angochagua, helping to conserve many species and their habitats ("Cayambe Coca National Park," n.d.). Conservation groups such as the Andean Bear Foundation are working to protect the most charismatic mammal species. Over the past decade, the Andean Bear Foundation has been conducting their Large Mammals Project in Cayambe Coca National Park, using GPS collars to survey the Andean bear, mountain tapir, and puma ("Large Mammals of the Cayambe Coca National Park, Ecuador," n.d.). Hacienda Zuleta and the Galo Plaza Lasso Foundation have been monitoring wildlife on their protected land for the past decade as well. All of these endeavors are critical to conservation, but there remains a need to survey the entire mammalian community of the Angochagua highlands region, which contains many unprotected areas. An updated and extended community composition survey of this location will contribute to Angochagua's conservation efforts.

This project used camera traps, direct observations, and indirect indicators to survey the community of mammals in the highlands of the Angochagua area in Ecuador. Few studies have been done to survey populations of animals such as the mountain tapir, little red brocket deer, northern pudu, and puma (Fox, 2018). This study will supplement the body of knowledge of the community composition of the area, updating Sage Fox's survey from the fall of 2018.

The communities of the Angochagua Parroquia are in the midst of an ongoing process to conserve their páramos, with the primary objectives being the protection of water resources, carbon storage, and the preservation of wildlife habitats. The community of Zuleta has already taken important steps to prohibit agricultural and other human activities from certain areas. On April 27, 2019 the community of Cochas mobilized in a town meeting and voted to conserve their wild lands above a certain elevation as well. The Parroquia of Angochagua has a highly engaged local government with numerous community development and environmental initiatives, which include the monitoring of wildlife within the Parroquia's lands. Working with the support of Big Mammals Conservation, a non-profit organization that collaborates with the Parroquia of Angochagua, this mammalian community survey will contribute to ongoing wildlife monitoring efforts and give the group an updated, more accurate knowledge base about the presence, habitat preferences, and behavior of some of the species present in the area. Many of these species are threatened, and this new knowledge will inform management decisions and conservation efforts by Big Mammals Conservation and reserves in the region. Many of the areas in this region where threatened species live are unprotected, so this community composition survey will contribute to efforts to expand protected areas for these species.

Methods

Camera Traps

The study period lasted from April 15 through May 10. I analyzed camera trap data collected between November 2018 and April 2019. The traps were left running for a range of times, from a week to several months. Cameras used in this study were placed far from human development to prevent nonconsensual photography of people.

The camera traps used in this study were deployed in the Angochagua area of Ecuador, just southeast of Ibarra. *Bushnell Trophy Cam HD* camera traps were utilized, some of which had been previously placed by BCM a few months ago in páramo and Andean forest habitats at approximately 2800 to 3200 meters in elevation. Some camera traps were also newly deployed during this project, taking advantage of time-sensitive situations such as the presence of a horse carcass. The cameras captured footage of wildlife inhabiting the mountains around the communities of la Rinconada, Angochagua, and Zuleta in the Parroquia of Angochagua. Cameras were set to a combination of still photograph, video, and hybrid modes. Activated by an animal's motion, three still photographs were taken every two seconds. Videos were ten seconds long, and on hybrid mode the traps took a video preceded by three photographs.

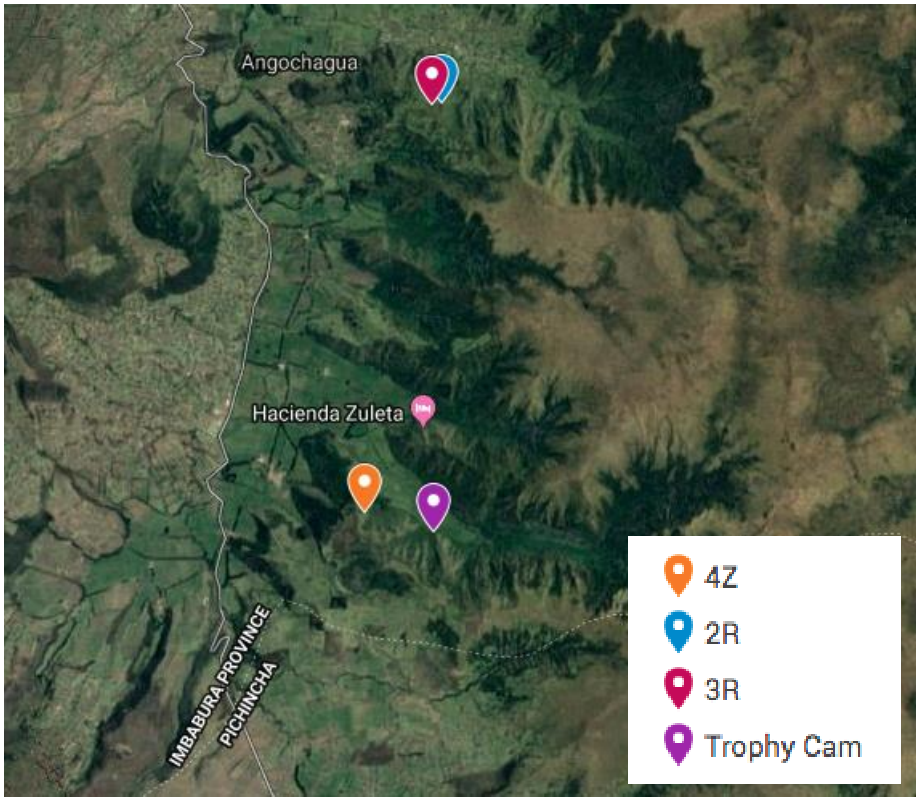

Figure 1. Map of camera trap locations in the Parroquia of Angochagua, Ecuador. From Google Maps.

Table
1. Camera trap site descriptions.

Camera Trap	**Habitat Type**	**Latitude**	**Longitude**	**Elevation (meters)**	**Site Description**	**First Registry**	**Last Registry**
4Z	Páramo	0.197717	-78.07725	3038	Placed on convergence of two bear trails near man-made trail high in Hacienda Zuleta. Border páramo with high humid montane forest.	11/13/18	1/3/19
2R	Forest	0.241217	-78.068967	3094	Small clearing in middle of patch of Andean forest bordering with páramo. Bear eating signs and game trails nearby.	11/12/18	11/28/18
3R	Páramo	0.241033	-78.070017	3167	Along an animal path that runs along a rock wall. Bear eating signs nearby. Páramo south of La Rinconada.	11/14/18	3/25/19
Trophy Cam	Forest/ pasture	0.195698	-78.069838	2846	Edge of forest in horse pasture in front of horse carcass.	4/24/19	4/30/19

Camera traps are triggered by the motion of a passing animal, and can capture a combination of photographs and video recordings. The use of camera traps is a noninvasive technique for monitoring wildlife, which allows animals to carry out their natural behavior without human disturbance. Rare and elusive species such as pumas, which can rarely be directly observed, can be detected on camera traps. In addition to observing natural behavior, camera traps provide observations of wildlife in areas which are difficult for humans to frequently reach. The cameras can be left for lengthy periods of time and then the data chips collected with abundant data. Camera traps are effective tools for wildlife monitoring which provide continuous sampling (Trolliet et al., 2014). Camera traps placed on significant geographic scales, as in this study, can be used to develop occupancy models for different species and estimate their occurrence in different habitats within a region (O'Connell et al., 2006). As a relatively recently developed tool, camera trap technology is constantly improving. While most data sorting is currently conducted manually, new software programs are being developed to perform data sorting and analysis, reducing human error, improving consistency and standardization, and decreasing necessary time allotted (Young, Rode-Margono, & Amin, 2018). These enhanced technologies will make camera traps an even more useful wildlife science and conservation tool in the future.

Camera traps have been used repeatedly and extensively in this region to monitor Andean bears and other species, supporting the methodology used in this investigation. Camera traps, with video and photograph features, have been used to successfully identify individual Andean bears, with video having greater success than still photographs (Reyes et al., 2017). Zapata-Ríos has used camera traps in several studies to observe the impact of dogs on Andean mammalian carnivores (Zapata-Ríos, 2014; Zapata-Ríos & Branch, 2018). Palacios, Naveda-Rodríguez, and Zapata-Ríos used camera traps in their 2018 study of large mammal richness in Llanganates National Park. These studies show the proven success of camera traps for precise wildlife monitoring.

Observation

When hiking to and from camera traps and around the area, direct and indirect observations were conducted. Indirect indicators of animal presence include feeding sites, resting sites, game trails, tracks, feces, and scratch marks. Most common signs observed were feeding sites and game trails left by Andean bears. Puya, a genus of terrestrial spiky succulent plants in the family Bromeliaceae, form one of the most important parts of the diet of Andean bears. They grow abundantly in the bears' habitat and are consumed in large amounts. Bears eat the leaf bases of these bromeliads, leaving torn and crushed yellowish white remains, a clear sign of past bear presence. Bear trails in forested areas appear as tunnels formed through vegetation, and in open páramo areas can look like human trails (Figueroa & Stucchi, 2009). Resting sites are also clear indicators of Andean bear presence, appearing as gathered collections of plant material forming nests up to six meters across (Tirira, 2017). Knowledge from accompanying forest guards and local experts confirmed the identification of species from these indicators. Photographs of indirect observations were taken for reference.

Especially in Zuleta, many bears were also directly observed, and in some cases it was possible to use previous records to identify the individual. On April 19, 2019 one was trapped and collared with a camera collar for BMC's monitoring efforts and in collaboration with a Japanese documentary company (Figures 2, 3). An Iznachi trap was used, constructed out of ten square meter metal panels. It was baited with a cow bone wrapped in trout and smeared with honey, and small amounts of honey and trout innards were also placed outside around the trap.

Figure 2. Iznachi bear trap.

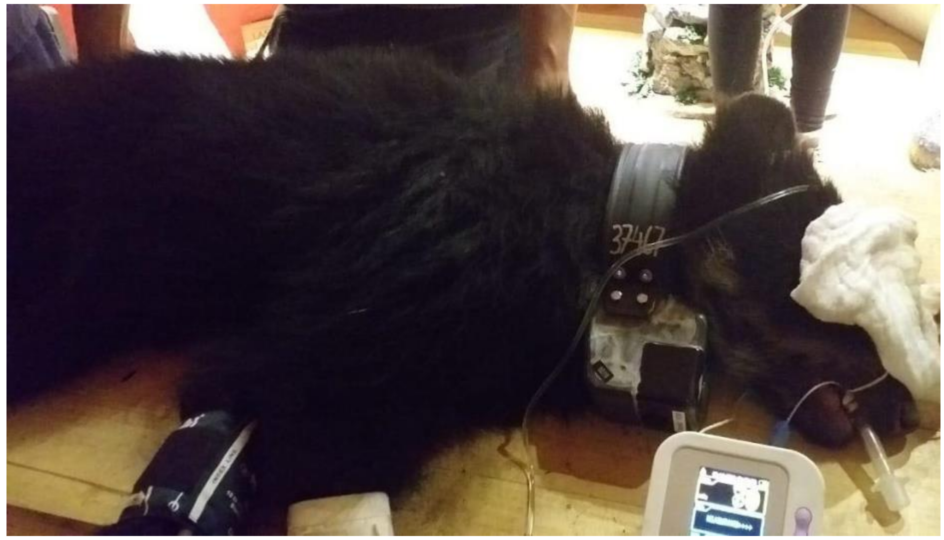

Figure 3. “Kinku”, 2 year-old female Andean bear fitted with GPS radio collar with camera. Photo credit: Hernán Sandoval.

Data Analysis

The camera trap data, direct observations, and indirect observations were combined for data analysis. For each observation, elevation and GPS coordinates were measured using a Garmin GPSMAP 64, and habitat type and time were recorded. Temporal activity was graphed for each species, and species accumulation and sample coverage curves were created to determine how completely we sampled the mammalian community of the area. This data analysis was completed for observations registered during this study period, and combined with Sage Fox’s data from December of 2018 to increase the sample size and evaluate how completely the BMC has sampled the community over the past seven months.

Results

A total of 10 species were detected by camera traps, direct observation, and indirect observation during December of 2018 and May of 2019, with 174 registries total (Figure 6). This sampling effort was thorough with an estimated sample coverage of 98.85 percent (Figure 7). The four camera traps used in this month-long study detected all of the species observed, and direct and indirect observations supplemented the Andean bear registries (Tables 3, 4, 5). A timeline graph laid out the temporal habits and coexistence of the species detected on the camera traps (Figure 9).

A total of 10 species were detected by camera traps, direct observation, and indirect observation during December of 2018 and May of 2019, with 174 registries total. In December of 2018, 140 registries yielded nine species: Andean bear, Andean rabbit, Andean fox, dog, mountain tapir, puma, mountain paca, Andean white-tailed deer, and pampas cat. In May of 2019, 34 registries yielded five species: Andean bear, Andean fox, dog, mountain paca, and mouse (Table 2).

Table 2. Total registries by species, compiled in December 2018 (from Sage Fox), May 2019, and totaled. Sorted high to low by Total Registries.

Species	**December 2018**	**May 2019**	**Total Registries**
Andean bear	89	16	105
Andean rabbit	16	0	16
Andean fox	8	3	11
Dog	6	4	10
Mountain tapir	9	0	9
Puma	8	0	8
Mountain paca	2	6	8
Mouse (species undetermined)	0	5	5
Andean white-tailed deer	1	0	1
Pampas cat	1	0	1

In May of 2019, 34 registries (n) yielded 5 species (S.obs), with an estimated sample coverage (C.hat) of 1 (Figures 4, 5).

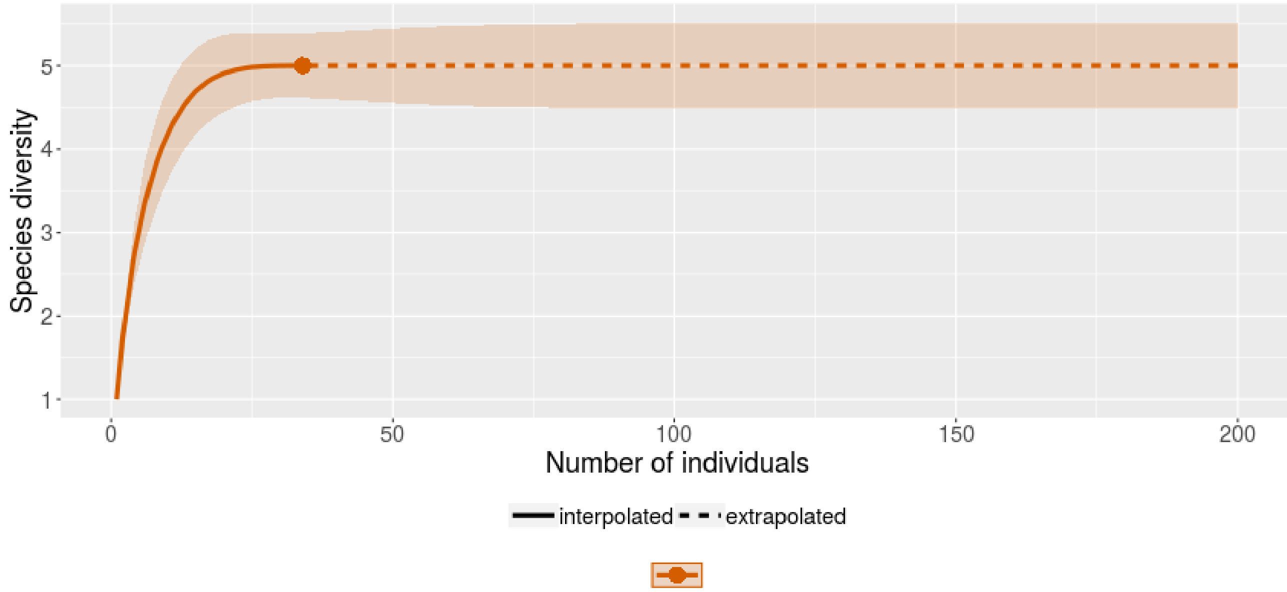

Figure 4. Species accumulation curve for all registries (n=34, S.obs=5, C.hat=1). Figure from iNext Online.

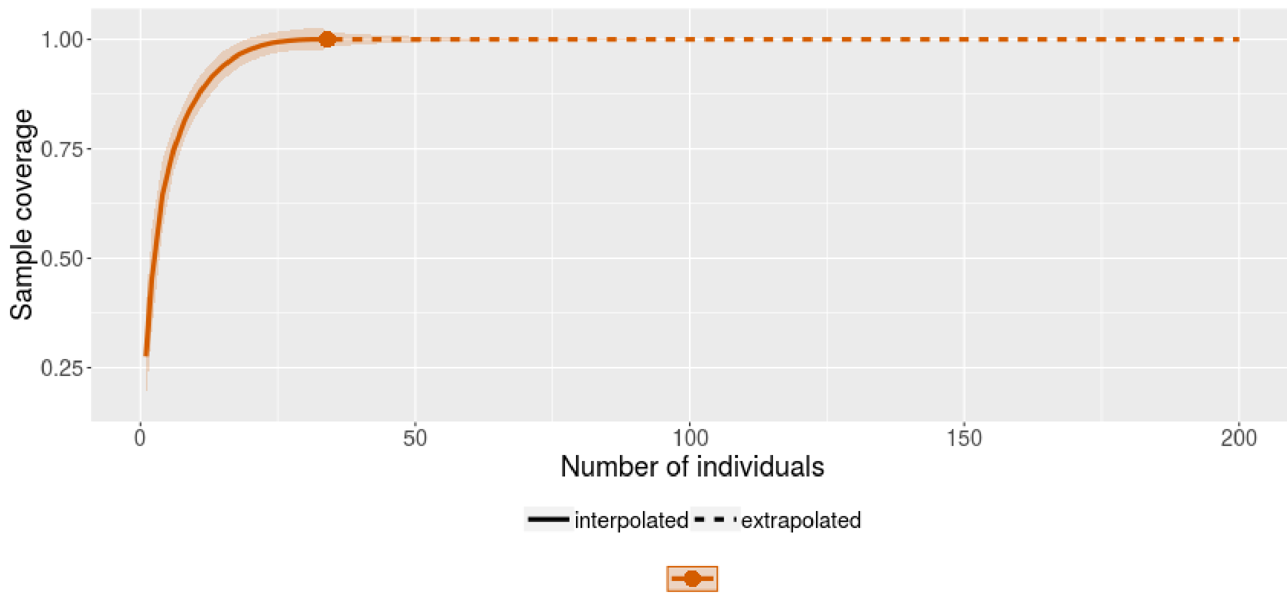

Figure 5. Sample coverage curve for all registries (n=34, S.obs=5, C.hat=1). Figure from iNext Online.

Compiling data from December of 2018 and May of 2019, 174 registries (n) yielded 10 species (S.obs), with an estimated sample coverage (C.hat) of 0.9885 (Figures 6, 7).

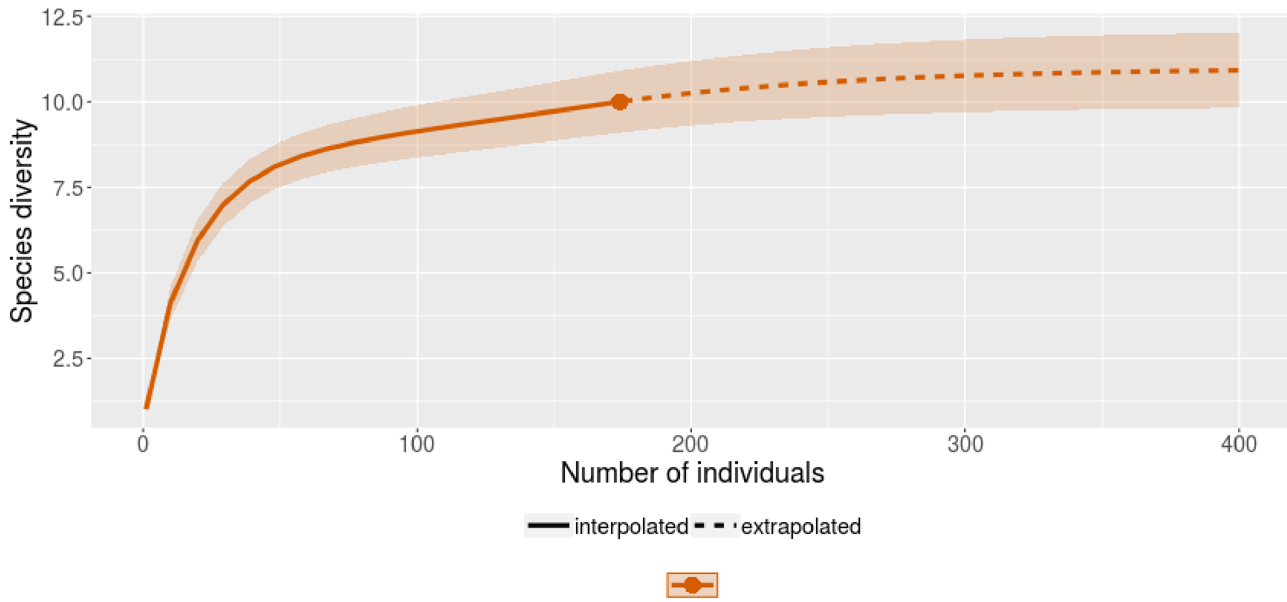

Figure 6. Species accumulation curve for all registries, combined with Sage Fox's data from December (n=174, S.obs=10, C.hat=0.9885). Figure from iNext Online.

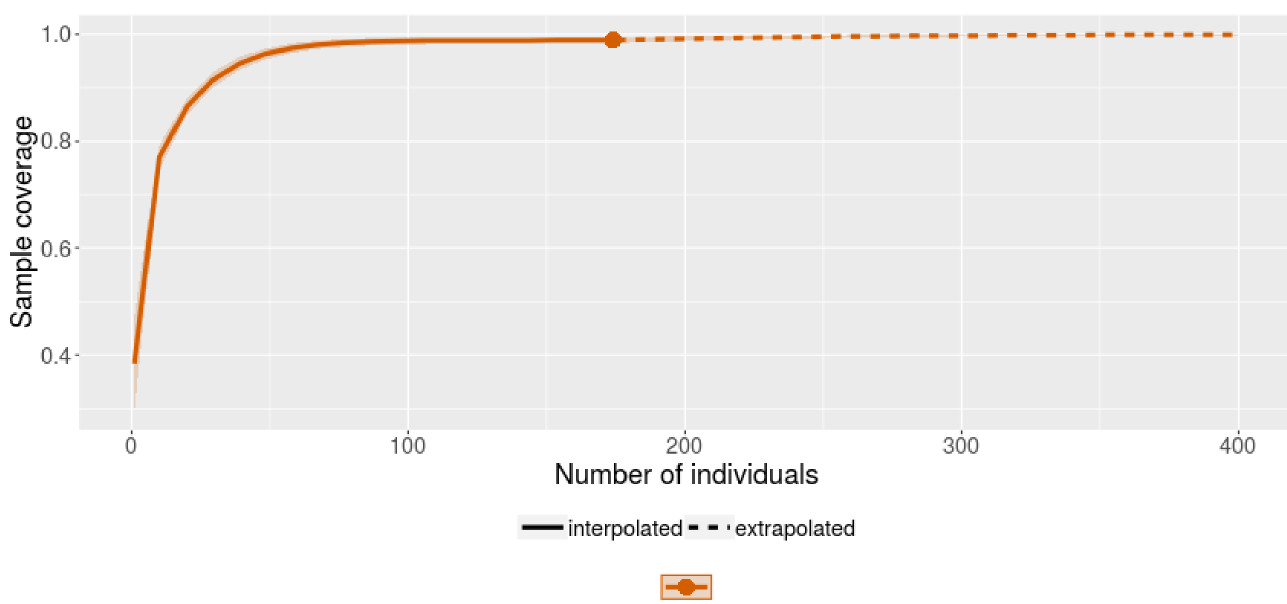

Figure 7. Sample coverage curve for all registries, combined with Sage Fox's data from December (n=174, S.obs=10, C.hat=0.9885). Figure from iNext Online.

Of the four camera traps used in this study, camera trap 4Z captured many false detections (moving plants) but no animal observations. Camera trap 2R captured six observations, four of mice and two of mountain paca. Camera trap 3R captured seven observations, four of mountain paca, one of Andean bear, one of mouse, and one of a person. Camera trap “Trophy Cam” captured 11 observations, three of Andean fox, four of dogs (two individuals identified), three of Andean bears (two individuals identified), and one person (Table 3, Figure 8).

Table 3. Camera trap registries.

Camera	**Species**	**Time**	**Date**
4Z	no animal observations		
2R	mouse	21:57	11/12/18
	mouse	1:51	11/15/18
	paca	20:22	11/21/18
	mouse	21:02	11/26/18
	paca	19:18	11/27/18
	mouse	20:14	11/27/18
3R	paca	4:40	1/11/19
	bear	7:57	1/12/19
	paca	5:08	11/26/18
	mouse	19:24	11/26/18
	person	9:13	11/28/19
	paca	2:36	11/30/18
	paca	3:09	12/19/18
Trophy Cam	fox	20:05-3:33	4/24/19
	dog	7:35	4/25/19
	dog	7:36	4/25/19
	fox	22:00	4/26/19
	bear	9:20	4/27/19
	fox	21:09	4/27/19
	person	13:06	4/28/19
	dog	20:24	4/29/19
	dog	21:43	4/29/19
	bear	7:47	4/30/19
	bear	18:12	4/30/19

Figure 8. Juvenile Andean bear captured on camera trap at horse carcass.

Six direct observations were made, all of Andean bears, and all on the south side of the valley in Hacienda Zuleta. Bears were seen at elevations ranging from 2846 meters to 3022 meters in the morning, midday, and afternoon. In some cases, individual identification was possible with the help of local guides from the Galo Plaza Lasso Foundation at Hacienda Zuleta (Table 4).

Table 4. Direct observations.

Species	**Individual, if known**	**Location**	**Habitat**	**Latitude**	**Longitude**	**Elevation (meters)**	**Date**	**Time**
Andean bear	Victorio	Hacienda Zuleta	Páramo/forest border on steep south canyon side	N/A	N/A	~3000	4/15/19	9:00
Andean bear	juvenile	Hacienda Zuleta	Páramo/forest border on steep south canyon side	0.113475	-78.035835	3022	4/15/19	1:20
Andean bear	Victorio? Big male	Hacienda Zuleta	Páramo/forest border on steep south canyon side	N/A	N/A	~3000	4/15/19	16:15

Andean bear		Hacienda Zuleta	Páramo/forest border on steep south canyon side	N/A	N/A	~3000	4/16/19	8:10
Andean bear	Kinku	Hacienda Zuleta	Páramo/forest border on steep south canyon side	0.113475	-78.035835	3022	4/19/19	13:45
Andean bear	Yautu	Hacienda Zuleta	Forest/horse pasture	0.195698	-78.069838	2846	4/23/19	10:00

When hiking to and from camera traps and around the area, six indirect observations were made, all of Andean bears. The two sign types observed were eaten puya and game trails. Eaten puya appeared as the torn and crushed yellowish white remains of bromeliads left by bears, while game trails looked like human trails or tunnels formed through the vegetation in the forest and páramo. The GPS coordinates, elevation, habitat, and date observed were recorded for each of these indirect observations (Table 5).

Table 5. Indirect observations.

Species	**Sign Type**	**Latitude**	**Longitude**	**Elevation (meters)**	**Date**	**Habitat**
Andean bear	Eaten puya	~0.241033	~ -78.070017	3180	4/22/19	Páramo
Andean bear	Eaten puya	~0.241034	~ -78.070018	3164	4/22/19	Páramo
Andean bear	Eaten puya	~0.241035	~ -78.070019	3160	4/22/19	Páramo
Andean bear	Eaten puya	~0.241036	~ -78.070020	3151	4/22/19	Páramo
Andean bear	Game trail	~0.241217	~ -78.068967	3138	4/22/19	Páramo & forest
Andean bear	Game trail	~0.241218	~ -78.068968	3138	4/22/19	Páramo & forest

Most species were only detected on the camera traps for short amounts of time (one minute), but these temporal data showed that most species were most frequently observed in the early hours of the morning (about 3:00 to 8:00) and in the evening (about 19:00 to 22:00). Mice were observed only at night under cover of darkness between the hours of 19:24 and 1:51. Mountain paca was also observed only at night under cover of darkness, between the hours of 19:18 and 5:08. Andean bear was detected mostly in the morning from 7:47 to 9:20, and once in the evening at 18:12. Free-roaming dogs showed similar patterns, arriving in the morning at 7:35 and in the evening between 20:24 and 21:43. Andean fox was observed only at night between

20:05 and 3:33. People were detected in the morning at 9:13 and in the afternoon at 13:06 (Figure 9).

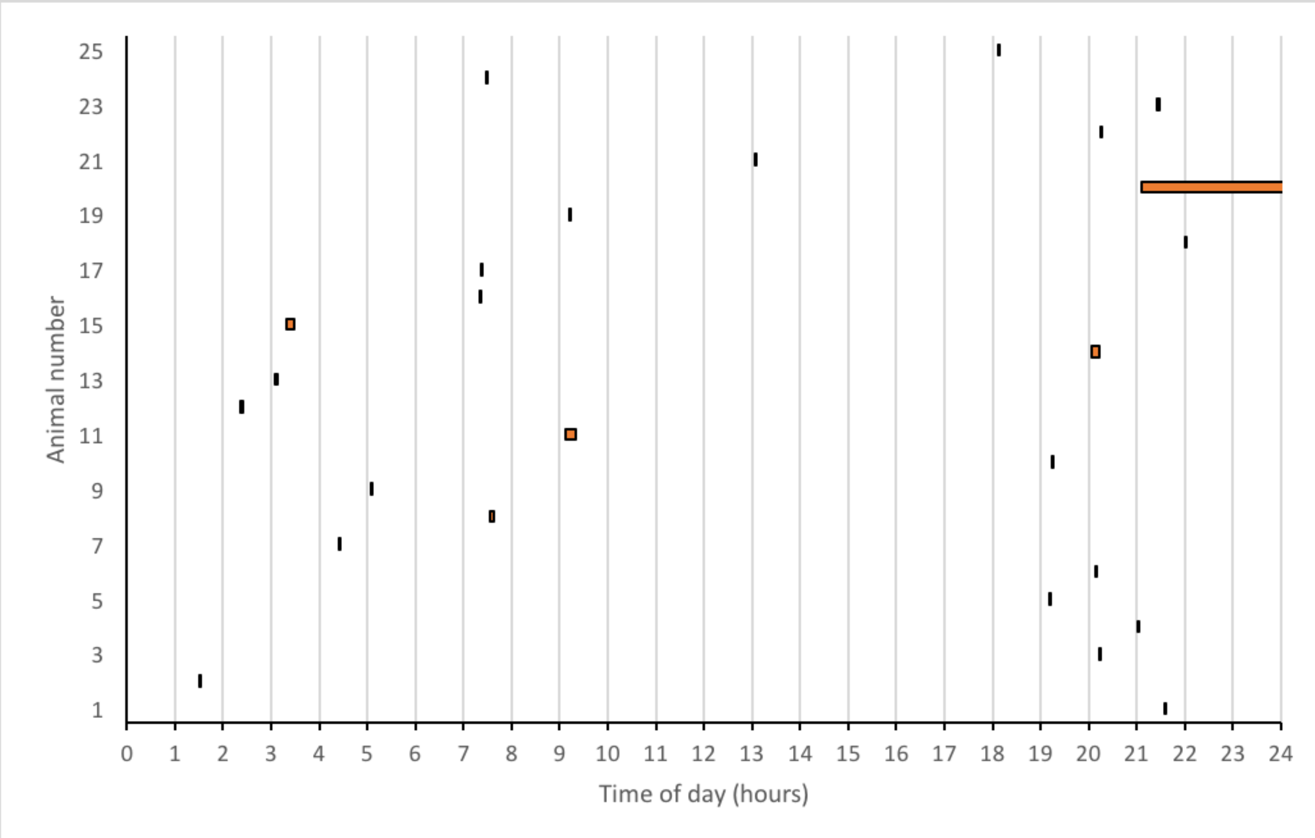

Figure 9. Time of species detection on camera traps (mouse 1-5, mountain paca 6-11, Andean bear 12-15, dog 16-19, Andean fox 20-23, person 24-25).

Discussion

Despite the theoretical sample coverage estimate of 1 (Figure 5), it is doubtful that this study thoroughly sampled the mammalian community of the area. During this month-long study period, the four camera traps, direct observation, and indirect observation yielded five species: Andean bear, Andean fox, dog, mountain paca, and mouse (Table 2). Likely due to larger sample size, Sage Fox's similar study from December of 2018 registered nine species in the area: Andean bear, Andean rabbit, Andean fox, dog, mountain tapir, puma, mountain paca, Andean white-tailed deer, and pampas cat (Table 2). During the past decade, however, monitoring efforts by the Galo Plaza Lasso Foundation at Hacienda Zuleta have confirmed the presence of 12 large mammal species: Andean bear, northern pudu, puma, striped hog-nosed skunk, mountain coati, porcupine, long-tailed weasel, Andean fox, oncilla, little red brocket deer, Andean white-tailed deer, and mountain paca (Y. Potaufeu, personal communication, April 16, 2019). This study failed to register occupancy of any ungulate species (northern pudu, little red brocket deer, Andean white-tailed deer, mountain tapir), cat species (puma, oncilla, pampas cat), rodents such as Andean rabbit, long-tailed weasel, and porcupine, or other carnivores such as striped hog-nosed skunk and mountain coati.

The small sample size (34 total registries) and small range of sampling locations (four camera trap locations) likely caused the incomplete survey of mammals in the area. The extremely irregular schedule of the BMC and collaboration on other projects greatly reduced the quantity of camera trap data and direct and indirect observations possible. The small number of sampling locations inhibits broad conclusions about the elevational and habitat preferences of different species, but can confirm current occupancy.

Similarly, the lack of standardization of time and locations for direct and indirect observations prevented methodical observations. I rather recorded direct and indirect registries as I happened to see them in the field hiking to and from camera traps and on other expeditions. This methodology prevented any conclusions regarding species abundance and was more useful in confirming the presence of species and providing spatial and temporal information about their occupancy. A more standardized methodology for observation would involve regular, perhaps daily, periods of time dedicated to observation, with the same amount of time allotted to each observation location.

A limitation of the camera trap sampling was that the camera traps were running for different lengths of time (the longest being over four months and the shortest being a week) which means that some locations were more thoroughly sampled than others. The time differences arose due to the cameras being deployed and collected at different times. Also in some cases the batteries had already died or the SD card was full due to many false detections of motion by vegetation, preventing further potential detections of wildlife species during the time the camera traps were in place. Researchers deploying new camera traps would be well advised to prune back vegetation around the sites of the camera traps to discourage these false motion detections. Another factor that influenced the results of the camera traps was the placement of "Trophy Cam" at the horse carcass, which favored detections of carnivores and omnivores coming to feed on the carcass over herbivore species. While this camera trap was the most successful placement in terms of capturing the highest number of registries, it is important to note that its location targeted certain species and was unlikely to capture others.

Using a combination of the three sampling techniques (camera traps, direct observation, and indirect observation) was critical to the success of the study because each technique had different advantages and disadvantages. Camera traps were valuable in providing records of species active at night (mouse, mountain paca, Andean fox), when they would have been impossible to directly observe, and detecting rare and elusive species as well. Direct species observations were entirely of Andean bears, due to the BMC's focus on the species and current collaboration with the Japanese documentary company NHK. Indirect observations were also completely of Andean bears, possibly because the local guides were most familiar with their signs. A more thorough knowledge base of indirect signs of all the species would be necessary to more accurately sample them through this technique. While indirect observations did provide habitat and elevational information, they lacked temporal data due to the difficulty of determining exactly when the animal had passed through the area.

While the methodology was limited by the erratic schedule of the BMC, this study included some landmark accomplishments such as camera collaring an Andean bear for the first time and capturing interactions between livestock, Andean bear, and free-roaming dogs.

Although capturing and collaring the Andean bear "Kinku" counted in this paper only as one direct observation registry, the event was historic as the first time an Andean bear has been fitted with a camera collar. The bear will be recaptured three months from the date of capture and the camera footage from the collar collected, so these data clearly could not be used in this paper, but it is important to emphasize the importance of this event. This never-seen-before footage will be used in a documentary about Andean bears produced by the Japanese film company NHK and will also provide BMC with new information about the bears' diet, movement and range, interactions, and other behaviors. Andean bears have traditionally been studied through camera traps, direct observation, and indirect observation, but this camera collar promises a new frontier for monitoring methodology which will produce new data on this understudied species.

The camera trap observations of Andean bears consuming a horse carcass in Hacienda Zuleta highlight the issue of bear interactions with livestock. In this case, the two individuals were observed feeding on a horse that had been left in the pasture for two weeks after dying of natural causes. The carcass should have been immediately buried to discourage bear presence, and this instance highlights the important management role humans play in maintaining healthy and distant relationships between Andean bears and livestock. While in this case the bears did not kill the horse, but were rather scavenging a carcass, this behavior can encourage bears to develop a taste for livestock and to frequent agricultural areas in the future. This behavior is detrimental to the conservation and public perception of Andean bears. Based on interviews in local communities, many people who inhabit the area consider these bears a danger to their communities (M. Frederick, personal communication, May 7, 2019). In order to continue improving public opinion of the species and gathering support for its protection, it is critical to discourage Andean bears from interacting with livestock. In January of 2018, BMC had to remove a bear that had been frequenting haciendas in the area. The individual was released in the nearby protected area of Cayambe-Coca National Park (Y. Potaufeu, personal communication, April 16, 2019). While this is a last resort mitigation strategy for dealing with "problem bears", farming practices play an important preventative role in discouraging Andean bear interactions with livestock. Bear conflicts with cattle usually occur where small herds are left unprotected in high elevation areas far from human habitation. The cattle in these conditions are generally visited at most every few weeks, with carcasses left to decompose in the pasture instead of being removed or buried, similar to the horse at Hacienda Zuleta (Goldstein, 2006). The Parroquia of Angochagua is already developing a program to expand sustainable cattle farming practices, which include proper fencing and guarding, and keeping cattle out of the higher páramo areas that serve as some of the primary habitat of Andean bears (A. Laguna, personal communication, April 16, 2019). The camera trap footage from this study contributes to ongoing documentation of Andean bear interactions with livestock and efforts to mitigate them.

Dogs were also detected on the camera trap at the horse carcass, highlighting the impact of free-roaming dogs on wildlife populations. Two individuals were identified, both of which came on two different days, both together and separately, in a week-long period. These dogs were clearly free-roaming and did not belong to Hacienda Zuleta, underscoring the hacienda's ongoing problem with groups of feral dogs which threaten their livestock and protected wildlife

(M. Narvaez, personal communication, May 1, 2019). This instance was a clear example of dogs in direct competition with species such as the Andean bear and Andean fox which were also feeding on the carcass. The dogs and Andean bears came to feed on the carcass at similar times of day, increasing competition. Andean bears were detected mostly in the morning from 7:47 to 9:20, and once in the evening at 18:12. Likewise, free-roaming dogs arrived in the morning at 7:35 and in the evening between 20:24 and 21:43 (Figure 9). The dogs and bears were detected on different days, but whether this separation was intentional (bears avoiding dogs) or coincidental is uncertain. This documentation of competition between dogs and Andean bears supports Zapata-Ríos and Branch's findings that occupancy of Andean bear, Andean fox, puma, and striped hog-nosed skunk were predicted even more accurately by the presence of free-roaming dogs than by threats such as habitat loss (2018).

While the Andean fox may be diurnal as well as nocturnal, it was only detected in camera traps in this study at night, between the hours of 20:05-3:33. In some of these nocturnal camera trap registries, Andean foxes were observed feeding on a horse carcass in the protected area of Hacienda Zuleta. This behavior supports Monteverde and Piudo's findings that Andean foxes can exhibit nocturnal tendencies even in areas protected from hunting, driven by availability of food sources rather than avoidance of pressure from humans (2011). While Andean foxes do not face harassment from humans in Hacienda Zuleta, they may face pressure from free-roaming dogs. It is possible that by coming to feed on the carcass only at night, the foxes were avoiding competition from dogs, which came in the morning and evening (Figure 9). As Zapata-Ríos and Branch found, the Andean fox was one of four species most strongly negatively affected by the presence of dogs (2018).

For each of the wildlife species detected, their diets, sociality, temporal habits, elevational range, and habitat preferences were mostly confirmed by my registries. While Andean fox was only documented here as nocturnal rather than also diurnal, its elevational range, habitat preferences, and diet were confirmed, as it was observed solitary in upper Andean forest at 2846 meters eating carrion. The diet, sociality, temporal habits, elevational range, and habitat preferences of Andean bears were also confirmed by my registries, which indicated solitary individuals eating bromeliads and carrion mostly during the day in Andean forest and páramo areas ranging from 2846 to 3167 meters in elevation. Mountain paca was confirmed to be solitary and nocturnal, eating plant matter in high Andean forest and páramo areas far from the impacts of humans and dogs.

While many of the communities in the Parroquia of Angochagua have already taken steps to conserve their páramos, this study shows that some threatened species such as the mountain paca favor forest habitats (Tables 1, 3). This information is important for the communities to know when going forward with their conservation efforts, which they will hopefully expand to lower elevations as well as the high páramos. Wildlife monitoring in the area with the use of camera traps, direct observation, and indirect observation must continue, ideally with more standardized techniques. BMC hopes to capture two more Andean bears in the near future to be fitted with GPS/camera collars. Although much work has already been done, Angochagua holds great promise for discovering new information about its diverse mammal community.

Conclusion

This project served as a continuation of the BMC and Parroquia of Angochagua's wildlife monitoring efforts in their high forests and páramos. While standing alone it did not document the complete mammalian community of the area, it did confirm the presence, diet, sociality, temporal habits, elevational range, and habitat preferences of species previously registered. Together with Sage Fox's survey from December of 2018, these data provide a fairly complete picture of the community, with ten species documented and an estimated sample coverage of 98.85 percent (Figure 7). The ten species documented in the mountains around the communities of la Rinconada, Angochagua, and Zuleta in the past seven months were: Andean bear, Andean rabbit, Andean fox, dog, mountain tapir, puma, mountain paca, mouse, Andean white-tailed deer, and pampas cat (Table 2).

In addition to surveying the mammalian community, this study documented significant interactions between livestock, Andean bear, and free-roaming dogs, conflicts which directly impact these species' conservation. In the future, camera traps should be placed at carcass sites whenever possible to gather more data about these relationships. Finally, this project played a critical role in camera collaring an Andean bear for the first time, using new methodology to discover previously unseen aspects of these bears' lives. BMC's work in Angochagua promises to greatly expand the knowledge base about Andean bears and the many other threatened species of the area, as the Parroquia moves forward with its conservation goals.

Bibliography

Cayambe Coca National Park | Sistema Nacional de Áreas Protegidas del Ecuador. (n.d.). *Ministerio del Ambiente.* Retrieved March 30, 2019, from http://areasprotegidas.ambiente.gob.ec/en/areas-protegidas/cayambe-coca-national-park

Crespo-Gascón, S., & Guerrero-Casado, J. (2019). The role of the spectacled bear (Tremarctos ornatus) as an umbrella species for Andean ecoregions. *Wildlife Research*, *46*(2), 176–183. https://doi.org/10.1071/WR18056

Donadio, E., & Buskirk, S. W. (2016). Linking predation risk, ungulate antipredator responses, and patterns of vegetation in the high Andes. *Journal of Mammalogy*, 97(3), 966‑977. https://doi.org/10.1093/jmammal/gyw020

Figueroa, J. & Stucchi, M. (2009). *El Oso Andino: Alcances sobre su historia natural.* Asociación para la Investigación y Conservación de la Biodiversidad-AICB. 1st ed. Lima, Peru.

Fox, S. (2018). Large mammals of the high Andes: A survey of community composition and habitat usage in the highlands of Angochagua.

Goldstein, I. (2002). Andean bear–cattle interactions and tree nest use in Bolivia and Venezuela. Ursus. *Ursus* 13:369-372. Retrieved March 28, 2019, from ResearchGate website: https://www.researchgate.net/publication/277720667_Goldstein_I_Andean_bear-cattle_interactions_and_tree_nest_use_in_Bolivia_and_Venezuela_Ursus

Goldstein, I., Paisley, S., Wallace, R., Jorgenson, J., Cuesta, F., & Castellanos, A. (2006). Andean Bear-Livestock Conflicts: A Review. *Ursus, 17*(1), 8-15. Retrieved from http://www.jstor.org/stable/3873043

Large Mammals of the Cayambe Coca National Park, Ecuador. (n.d.). Lincz: Linking Nature Conservation and Zoos. Retrieved March 30, 2019, from https://www.lincz.org/project/large-mammals-of-the-cayambe-coca-national-park-ecuador/

Llambí, L.D. & Cuesta, F. (2014). La diversidad de los páramos andinos en el espacio y en el tiempo. In: *Avances en investigación para la conservación de los páramos andinos*, CONDESAN.

Maldonado, D. E., Pacheco, L. F., & Saavedra, L. V. (2014). Legitimidad en la dispersión de semillas de algarrobo (Prosopis flexuosa, Fabaceae) por zorro andino (Lycalopex culpaeus, Canidae) en el Valle de La Paz (Bolivia). *Ecología en Bolivia*, *49*(2), 93-97.

Monteverde, M. J., & Piudo, L. (2011). Activity patterns of the culpeo fox (Lycalopex culpaeus magellanica) in a non-hunting area of northwestern Patagonia, Argentina. *Mammal study*, *36*(3), 119-126.

O'Connell, A. F., N. W. Talancy, L. L. Bailey, J. R. Sauer, R. Cook, & A. T. Gilbert. (2006). Estimating site occupancy and detection probability parameters for mammals in a coastal ecosystem. *Journal of Wildlife Management* 70:1625–1633.

O'Farrill, G., Galetti, M., & Campos‐Arceiz, A. (2013). Frugivory and seed dispersal by tapirs: an insight on their ecological role. *Integrative Zoology*, 8(1), 4‑17. https://doi.org/10.1111/j.1749-4877.2012.00316.x

Palacios, J., Naveda-Rodríguez, A., & Zapata-Ríos, G. (2018). Large mammal richness in Llanganates National Park, Ecuador. *Mammalia*, 82(4), 309‑314. https://doi.org/10.1515/mammalia-2017-0071

Perrig, P. L., Donadio, E., Middleton, A. D., & Pauli, J. N. (2017). Puma predation subsidizes an obligate scavenger in the high Andes. *Journal of Applied Ecology*, 54(3), 846‑853. https://doi.org/10.1111/1365-2664.12802

Reyes, A., Rodríguez, D., Reyes-Amaya, N., Rodríguez-Castro, D., Restrepo, H., & Urquijo, M. (2017). Comparative efficiency of photographs and videos for individual identification of the Andean bear (Tremarctos ornatus) in camera trapping. Therya, (1), 83. https://doi.org/10.12933/therya-17-453

Rogers, L. & Applegate, R. Dispersal of fruit seeds by black bears. *Journal of Mammalogy*, 64(2), 310 – 311. https://doi.org/10.2307/1380564

Schipper, J., Chanson, J. S., Chiozza, F., Cox, N. A., & Hoffmann, M. (2008). The Status of the World's Land and Marine Mammals: Diversity, Threat, and Knowledge. *Science*, 322(5899), 225-230.

Tirira, D.G. (2007). Mamíferos del Ecuador: Guía de Campo (Ediciones Murciélago Blanco). Quito, Ecuador.

Tirira, D.G. (2011). Libro rojo de los mamíferos del Ecuador. Quito, Ecuador: Fundación Mamíferos y Conservación.

Tirira, D.G. (2017). *A field guide to the mammals of Ecuador.* First English ed. Quito, Ecuador: Editorial Murciélago Blanco.

Trolliet, F., Huynen, M., Vermeulen, C., & Hambuckers, A. Use of camera traps for wildlife studies. A review. (2014). Biotechnol. Agron. Soc. Environ. 18(3),446-454. Retrieved March 28, 2019, from ResearchGate website: https://www.researchgate.net/publication/266381944_Use_of_camera_traps_for_wildlife_studies_A_review

Urgilés-Verdugo, C., Viracocha, F.G., Trávez, H., Torres, R., Collaguazo, F., & Collaguazo, R. (2018). Pichincha - Mammals from the Yunguilla Conservation and Sustainable Use Area, Tropi-Andino Connectivity Corridor. Retrieved March 28, 2019, from Field Guides: https://fieldguides.fieldmuseum.org/guides/guide/1028

Velez-Liendo, X. & García-Rangel, S. (2017). *Tremarctos ornatus*. The IUCN Red List of Threatened Species. Retrieved March 28, 2019, from IUCN Red List of Threatened Species website: https://www.iucnredlist.org/en

Verdugo, C.U. (2013). Densidad poblacional y patrones de actividad del tapir de montaña, en cuatro localidades del Parque Nacional Cayambe Coca y Reserva Ecológica Antyisana, ander tropicales del norte de Ecuador: Informe técnico. *Instituto para la Conservación y Capacitación Ambiental ICCA*.

Young, S., Rode-Margono, J., & Amin, R. (2018). Software to facilitate and streamline camera trap data management: A review. *Ecology and Evolution*, *8*(19), 9947-9957.

Zapata-Ríos, G. (2014). Impacts of domestic dogs on the native mammalian fauna of the Ecuadorian Andes. University of Florida.

Zapata-Ríos, G., & Branch, L. C. (2016). Altered activity patterns and reduced abundance of native mammals in sites with feral dogs in the high Andes. *Biological Conservation*, *193*, 9-16.

Zapata-Ríos, G. & Branch, L. (2018). Mammalian carnivore occupancy is inversely related to presence of domestic dogs in the high Andes of Ecuador. *PLoS ONE* 13(2): e0192346. https://doi.org/10.1371/journal.pone.0192346

Zarco-González, M., Monroy-Vilchis, O., Rodríguez-Soto, C., & Urios, V. (2012). Spatial factors and management associated with livestock predations by Puma concolor in Central Mexico. *Human Ecology, 40*(4), 631-638. Retrieved from http://www.jstor.org/stable/23280270

Appendix

Camera trap registries of each of the five mammal species detected.

Figure 1. Andean fox feeding on horse carcass at Hacienda Zuleta.

Figure 2. Free-roaming dog feeding on horse carcass at Hacienda Zuleta.

Figure 3. Mountain paca in the páramo south of La Rinconada.

Figure 4. Andean bear at site of buried horse at Hacienda Zuleta.

Figure 5. Mouse (species undetermined) in high Andean forest south of La Rinconada.