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The Changing Fate of Thailand's Elephants, But a Future Worth Fighting For: The Interplay of Culture and Ecology for Conservation

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Abstract:

The elephant is historically and culturally significant in Thailand. However, there has been a sharp decline in their population. In 1900, there were 100,000 known elephants in Thailand, but today the number is at a maximum of 7,000. This paper aims to understand the causes of the decline and predict the future prospects for Thailand's elephants. Throughout history, elephants in Thailand were captured to be used in war, then for use in the logging industry, and now for use in tourism. Culturally, the elephant is significant in Buddhist and Karen traditions, but there has been a disconnect between the symbol of the elephant and the living one. Using observations of the elephant tourism industry, interviews with major stakeholders, and a species distribution model, I find that elephants now are vulnerable to overexploitation and extinction. Too many live in captivity, human-elephant conflict is wide-spread, and the laws that protect the elephants are outdated. However, there is plenty of optimal habitat for elephants, land becomes more habitable for elephants with climate change, and there are people who care about working to create lasting change. With the correct conservation measures and more prioritization of these measures, elephants in Thailand could prosper.

Introduction:

Upon arriving at Bangkok's Suvarnabhumi Airport, one is bombarded by a myriad of signs warning travelers that it is illegal to export elephant products. Yet within an hour drive north, ivory bracelets, earrings, and statues among other elephant products are abound and being sold at an elephant camp[1]. If you fly an hour north of Bangkok to Chiang Mai, the largest city in Northern Thailand, you hardly can go anywhere in the city without seeing flyers for different elephant camps. Elephants decorate all kinds of buildings from Buddhist temples to hotels (Figure 1). It seems that this city is exclusively a hub for elephant tourism. Yet, despite the cultural and historical significance of elephants, there is a serious decline in Thailand's elephant population. At the beginning of the twentieth century, there were over 100,000 elephants

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[1] Elephant camps are areas places where captive elephants live and where tourists go to interact with these elephants. There are many names for places that house elephants for tourism—camp, sanctuary, project, foundation, conservation site, etc. The names generally are just semantics, but sometimes does have meaning. Throughout the paper, I use the term elephant camp or camp for short unless I want to emphasize the mission of the organization.

throughout Thailand. Estimates now suggest that only 7,000 elephants remain (personal

communication with scientist: 2017-08-04).

Figure 1: Left: The Shangri-La Hotel in Chiang Mai, where elephants decorate the exterior (photo by Jess Gibson of https://thetravelista.net) Right: Wat Chedi Luang, an old temple in the center of Chiang Mai where elephants decorate the outside (photo by author).

There is no doubt that elephants inspire a sense of awe. Massive in size, typically gentle

in nature, and incredibly intelligent, it seems impossible not to immediately respect and fall in

love with these magnificent creatures. In fact, many of whom I interviewed—including

conservationists, scientists, and mahouts (elephant keepers)—reminisced about the first time

they saw an elephant. They related feelings of awe and wonder by their intelligence. Many

mentioned some sort of spiritual connection or enthrall that they have with the elephant. They

also felt sorrow to see them mindlessly perform tasks for tourists. As an incredibly special

species, it seems that humankind would be at a loss with its extinction and every effort should be

put to its conservation. However, with factors such as human population growth, land use

changes, and human-elephant conflict, these spiritual connections may not be enough incentive

to protect this majestic creature.

Buddhist traditions run deep throughout the country. All elephants have a special place in

the religion, as the conception of the Buddha occurred after his mother dreamed of a white baby

elephant entering her side (Keown 2001). In current practice, it is believed that there is a spirit on the shoulders of the elephant. When an elephant dies, a monk must bless the elephant and release the spirit. When riding an elephant, it is necessary to wipe the elephant's neck with a clean hand before mounting in respect of the spirit. Additionally, it is thought to be a good omen when an elephant has a right tusk that is higher or longer than the left tusk as it mimics the Buddha's posture (personal communication with elephant owner: 2017-07-25) (Figure 2).
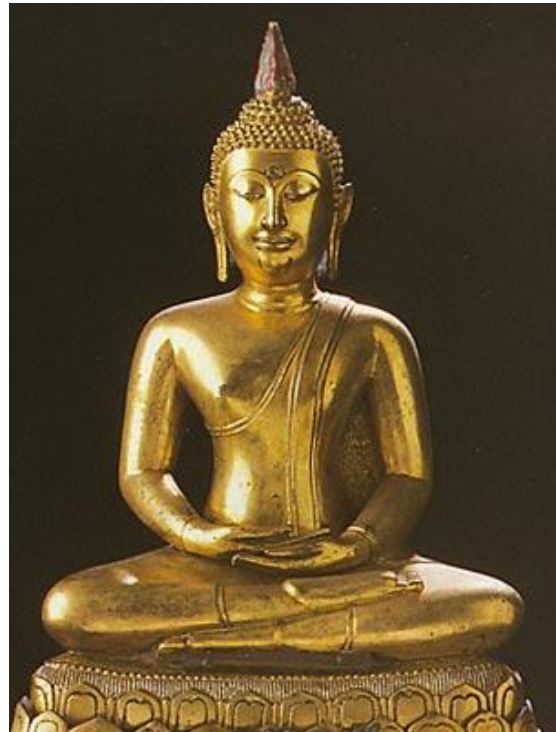

Figure 2: A Buddha figure. Notice how the Buddha's right arm and right leg are located above this left arm and leg, respectively. (photo from http://www.buddha-images.com/meditation.asp)

Furthermore, in Buddhist tradition, special status is given to elephants that are considered white as opposed to the gray elephants. These individuals characteristically have white nails, white skin under the mouth, white tail hair, light gray hair, light gray skin, and blue eyes. Males also have white testicles. All white elephants born must be presented—some of which are given as gifts—to the Thai royal family (personal communication with elephant owner: 2017-07-25). Such individuals are considered sacred and therefore kept with the utmost care in the Royal Elephant Stables. According to Thai tradition, a king's prosperity is reflected by the number of white elephants he possesses or has presented to him (Schliesinger 2012). These elephants are used for royal ceremonies—most recently and notably in the late King Bhumibol Adulyadej's funeral procession in November of 2016. Elaborately dressed, impeccably trained, and attended

by mahouts, the white elephants were a key part of a ceremony to honor the King's passing (Figure 3) (Silva 2016).

Figure 3: The white elephants in King Bhumibol Adulyadei's funeral procession (photo from ABS CBN News)

One cultural group in particular—the Karen people—are an ethnic minority living mainly in Northern Thailand, near the border of Thailand and Myanmar, and are known for capturing and taming elephants throughout history (Ehrlich 2017). Traditionally practicing animism, the elephant plays a role in many of their ceremonies. Each year, the elephants return from elephant camps for a ritual to Karen gods[2] (personal communication with elephant owner: 2017-07-25). There are blessings involving whiskey, orange juice, and rice when elephants leave a home and arrive at a new location (Figure 4). Besides their religious significance, Karen mahouts have historically felt a personal connection with their elephant. Their elephant becomes their closest confidant, as mahouts confess their sins to them throughout the day's work and spend more time

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[2] Often, elephants owned by the Karen people are rented by the elephant camps and live at the camps until the end of the rental period.

with their elephant than their own family (personal communication with elephant owner: 2017-07-25). In fact, this connection is clearly forged deeply because the Karen say that "the elephant chooses the mahout" (personal communication with veterinarian: 2017-07-18).

Figure 4: An elephant after being blessed when arriving in a new home. Remnants of the whiskey, orange juice, and rice can be found on her head. With her, is one of her mahouts. (Photo by Casey Trautwein)

Outside of their relationships with elephants, Karen people have numerous superstitions surrounding elephants. A Karen man, who was formerly a mahout and now is an elephant owner, explained that elephant behavior or appearance signifies good or bad luck in Karen culture. If you find a piece of tusk in the jungle, it is lucky since it keeps bad spirits away, but if you remove the ivory from the elephant yourself it is bad luck. Wearing a ring made of elephant hair brings easy childbirth for women and prosperity in business for men. I have seen mahouts sell these rings, elephant owners hold onto elephant hair, and elephant hair rings given as gifts. Clearly, this animal is spiritually significant in Thailand, so how can there be such a dramatic decline in their population?

In this paper, I explore the interplay of culture and conservation and the potential for further elephant decline through climate change, as reflected in perceptions of elephants by scientists, conservationists, mahouts, and elephant owners in Northern Thailand and through my own species distribution modeling that scientifically assess the potential fate of elephants. To this end, my thesis integrates data from interviews and observations of people, elephants, and ethics engaged in the elephant tourism industry to understand what Thai people and major stakeholders perceive to be the challenges facing elephants, what the future holds, and their ideal management styles. This is coupled with geospatial data to examine elephant distribution in relation to potential habitat for understanding how Thailand's elephants have declined and what their future prospects might be given existing and future habitat and people's values toward elephants.

The paper is organized as followed: first, I will discuss what is known in the literature surrounding the elephant's behavior and ecological role. I examine the effects of land development in Thailand and how that leads to habitat loss. Next, I look at the relationships between humans and elephants through culture and history. Then, I report on my own analysis. I start with explaining my methods of observing the elephant industry in Thailand and interviewing major stakeholders. I, then, explain my methods for my geospatial analysis of elephant occurrences in relation to habitat availability and what climate change may do to habitat and elephant occurrence. The literature review, the interviews and observations, and the geospatial model are brought together in the discussion section, revealing that while Thailand's elephants are in a dire situation, there is hope and the possibility of population growth and conservation success for these iconic beings.

Background:

The International Union for the Conservation of Nature and Natural Resources (IUCN) lists Asian elephants (*Elephas maximus)* as endangered, meaning that the population has declined by 50 percent over 3 generations[3]. Indeed, the IUCN states that elephant populations are declining and being isolated into habitat fragments throughout Asia. Fragmented and isolated populations in conjunction with different management styles throughout Asia makes each population require different conservation strategies (IUCN 2017). In Thailand, separate populations of wild and captive elephants face different challenges, growth rates, and management styles. As a keystone species in Asia's jungles (IUCN 2017) and an important driver of Thailand's tourism, the causes of the decline in Thailand's elephant populations, the eventual rise in its captive population, and the population fluctuations themselves are of great concern. But while there are many studies about Asian elephants, few, in particular, look at Thailand alone. Fewer still are up to date and use a multi-disciplinary approach to understand their decline and forecast their future.

Ecology and Behavior:

Six thousand years ago, elephants spread from Mesopotamia to the Indian subcontinent to South East Asia, and into China. Since then, the distribution of Asian elephants has shrunk considerably. Today, Asian elephants exist in India, Nepal, Bhutan, Bangladesh, Myanmar, Thailand, Malaysia, Cambodia, Laos, Vietnam, Indonesia, and Sri Lanka. But collectively, they inhabit only five percent of their historic range; almost all of the populations exist in noncontiguous habitats (Sukumar 2006). Even within Thailand, elephants are not concentrated in

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[3] For this paper, the term elephants will refer to Asian elephants.

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one area. Rather they are spread in several populations throughout the country, often without connectivity between them (IUCN 2017).

Elephants can be considered to be umbrella species—implying that by protecting them and their needs, it will protect the entire ecosystem—due to their large geographic range. Some elephants in India have been known to inhabit over 600 square kilometers, but others like those in Sri Lanka tend to occupy smaller ranges from 30 to 160 square kilometers (IUCN 2017), and depending on the habitat, it is thought that the carrying capacity of elephants can range from 0.1 to 0.3 elephants per square kilometer (Varma et al. 2008). Data for the distribution of Thai elephants are not available. However, since Indian, Sri Lankan and Thai elephants are the same species, one may assume Thai elephants have similar range requirements as that of Indian and Sri Lankan elephants. They primarily live in forest habitats, including tropical evergreen forests, semi-evergreen forest, moist deciduous forest, dry deciduous forest, and dry thorn forests. But they are also found in grasslands and scrublands (IUCN 2017). As a habitat generalist, the elephant is able to feed on a variety of plants and alter various ecosystems, making their presence critically important. Spending up to nineteen hours a day feeding and consuming about 150 kilograms of food a day (IUCN 2017), elephants eat roots, grasses, fruits, and bark ('Asian Elephant' 2017). Importantly though for the ecosystem, elephants produce approximately 100 kilograms of dung a day due to their inefficient digestive system. Elephant dung contains grasses and newly germinated seeds that, thanks to the elephant's large range, have been spread across a wide area, improving the quality of the ecosystem and increasing biodiversity (IUCN 2017).

Within the ecosystem, males and females utilize their ranges differently. Males tend to be solitary, leaving their maternal groups when reaching adulthood, but some may live in bachelor herds. Periodically bulls will go through musth, a time where testosterone levels peak, and

become aggressive and highly sexually aroused (Duer, Tomasi, and Abramson 2016). Females, on the other hand, stay in their maternal herd, which are typically small groups, about three breeding females per group (de Silva and Wittemyer 2012). These groups tend to be stable across years but lose some association in the wet season. Individual elephants are able to associate with long-term companions, but these groups do not have any clear hierarchy (de Silva, Ranjeewa, and Kryazhimskiy 2011). Outside of their strong social structures, elephants also are quite intelligent. They can self-recognize (Plotnik, de Waal, and Reiss 2006) and have insightful problem-solving skills (Foerder et al. 2011).

Landscape Development and Habitat Loss:

The lack of connectivity between different habitat areas and elephant populations in Thailand is a fundamental conservation concern. Each population must exceed a certain minimum size to prevent inbreeding and subsequent loss of genetic diversity and viability. However, obtaining accurate population numbers, to decide on their population status in relation to estimated minimum viable population sizes, is challenging. This stems from the logistical difficulty of conducting population surveys in densely-covered forests (Olivier 1978, Sukamar 2006). Hence, estimates vary widely between 2,600 to 4,450 wild elephants in Thailand (Olivier 1978). These estimates are a good start. But effective conservation will need to obtain more accurate counts as well as an estimated minimum viable population. There is some urgency to this as Thailand is a rapidly developing country. Between 1961 and 1986, forest cover decreased from fifty-three percent to fifteen percent (Hirsch 1988). Habitat loss caused by land development makes it imperative that adequate conservation measures are taken.

Habitat loss stems from land use changes. As early as the nineteenth century, travelers described seeing elephants throughout the country up until reaching Bangkok. Near Bangkok, the

forests were being cleared, depriving elephants of their habitat (Olivier 1978). This was the start of important land use change that continues today to support Thailand's citizens' burgeoning need to develop urban centers and agriculture, particularly rice and cash crops. By the 1950s, Thailand decided that forty percent of their original forests need to remain intact. However, by 1986, less than a quarter of the country was covered by forests, largely due to agricultural expansion, hardwood extraction, and connecting urban centers to isolated areas (Hirsch 1988).

However, deforestation did not occur uniformly throughout the country. Areas with more monetary wealth experienced greater forest loss, largely in response to high demand for timber and forest products (Hirsch 1988). In fact, by 1995, Thailand experienced the fourth highest forest loss among all tropical nations (Trisurat, Alkemade, and Verburg 2010). Deforestation in Thailand is clearly an economic indicator of development, particularly since economic development in Thailand stems in large part from timber extraction (Hirsch 1988). This, in turn, helps to appreciate the basis for elephant habitat loss. For example, Leimgruber and colleagues (2003) used deforestation rates to understand how habitat loss effects elephant population dynamics and how they can be conserved. They argue that Thailand mainly consists of unfragmented and large populations, with patches of highly fragmented areas with small populations; just over half of elephant's wildlands were unfragmented in the 1990s and less than ten percent of their range was actually protected in Southeast Asia. It is the areas of unfragmented populations that have had less forest loss, but with so little habitat protected, elephants' wildlands are still vulnerable to development and further habitat loss. The degree of development can thus be used as a metric to measure habitat loss and, thus, a decrease in elephant population.

Currently, the Thai government aims to protect forests in Northern Thailand by retaining fifty percent of the current forest cover through reforestation efforts and establishing protected areas (Trisurat, Alkemade, and Verburg 2010). A scenario analysis of human land use suggests that the western and upper northern areas of Northern Thailand will still maintain high levels of forest cover, due to a lack of accessibility to the area, while those in the lower regions of the country should face greater deforestation, particularly for land conversion to agriculture by 2050. Agriculture was, in fact, found to be the biggest cause of biodiversity loss in Thailand (Trisurat, Alkemade, and Verburg 2010). Deforestation is particularly harmful to biodiversity because it causes habitat loss, which is worsened by fragmentation, diminishing patch size and core areas, and the isolation of habitats from one another (Trisurat, Alkemade, and Verburg 2010). The patchy nature of development of Thailand's landscape with some areas becoming more developed than others creates complementary patchiness in habitat across landscapes, thus converting what was once contiguous elephant habitat into smaller fragments. Hence, simply choosing to manage for a total percent of forest coverage throughout the country may not be the best management tool for protecting Thailand's rich biodiversity, which requires contiguous areas of habitat. Instead, conservation efforts should aim to preserve the areas with the richest biodiversity and maintain connectivity between them (Trisurat, Alkemade, and Verburg 2010). Still, there also needs to be local conservation plans as individual areas need to be assessed for how they contribute to the local ecosystem and ecological community.

The Human-Elephant Relationship:

Thailand's elephants are not just animals dwelling in the forest. They have a storied past, where the history of Thailand and the modern history of the elephant are intertwined. Piers Locke eloquently describes their relationship:

> Variously representing weapons of war, emblems of prestige, symbols of divinity, objects of entertainment, icons of conservation, commodities for exchange, vehicles for labor, as well as intimate companions, elephants are caught in the human enterprises of power, wealth, worship, pleasure, and preservation. Feared or worshipped, killed or conserved, captured or maimed, appropriated for stories and symbols, they are animals with whom humanity is profoundly entangled. (Locke 2013: 80).

Humans and elephants are so entwined that in the mid to late nineteenth century, every village in eastern Thailand had from 50 to 100 elephants. They are so sacred that for centuries elephants were protected by the King's Department of Royal Elephants. And they are so important for labor that in the late nineteenth and early twentieth centuries, 1,000 elephants were used for trade between Chiang Mai and Chiang Saen (Olivier 1978). These are animals whose lives didn't just change with recent land development. For centuries, humans have captured, tamed, and depended on these animals (Olivier 1978), so much so that their state of being has become interrelated and interdependent with humans, particularly through captivity.

Thailand has the largest population of captive elephants in Asia, with perhaps more in elephants captivity than in the wild in Thailand (Sukumar 2006). This poses an interesting question for conservation: should captive elephants be considered part of an overall conservation strategy or should wild and captive populations be treated separately? Elephant captivity is also a polarizing issue. People tend to think it as a necessary evil, as inhumane, or as perfectly fine. Few studies have attempted to evaluate how captivity affects individual elephants and their population as a whole. It is no secret that elephant tourism is a large industry in Thailand and that it has provided a home and care for many elephants who were previously used in the logging industry. Some can argue that the new tourism industry created a demand for these captive elephants, which allowed for better care of elephants (Kontogeorgopoulos 2009). But living in camps is not a perfect home for captive elephants. Food can become insufficient, since activity

with tourists takes elephants away from their time foraging, elephants tend to be overworked to create large revenues, space on the outskirts of the cities tends to be insufficient, and the experience and attentiveness of their mahouts has declined since the logging era (Kontogeorgopoulos 2009; "Taken for a Ride: The Conditions for Elephants Used in Tourism" 2017). The estimated population of captive elephants is 3,000 (Sukumar 2006), and this number is growing especially because there is evidence that wild elephants are being poached for tourist camps (Kontogeorgopoulos 2009). Elephant tourism can create an excess demand for elephants and possibly have negative consequences for both wild and captive populations due to issues of poaching and insufficient care. It is also equally important to consider why elephants were captured and how captivity is viewed in Thai society.

Elephants have large cultural and historical significance in Thailand, and therefore, its conservation should be deemed of the utmost importance. Humans' cultural history and elephant histories have been intertwined for centuries. However, changing socioeconomic conditions and social values toward elephants in Thailand mean that this intertwining is becoming unraveled. This is compounded by the current lack of information on the conservation status of many populations throughout the country. Such status would be better understood, and best management practices would be enhanced with better population counts, estimates of forest habitat capacity to support them, and if and how captive elephants impact wild elephants. Because no challenge faced by elephants occurs on its own, each challenge, such as deforestation and human-elephant conflict, needs to be analyzed in tandem to fully understand the complexity of this issue.

History:

Some of the earliest depictions of Thai people are from the twelfth century on a stone bas-relief on Angkor Wat in Cambodia. It depicts a battle between the Khmer and the Siamese, which would eventually lead to Siamese independence in the thirteenth century[4]. On such relief, there was a colossal elephant ready for war (Ringis 1996). From the beginning of Thai history, captive elephants were of major importance to daily life and war. In Ayutthaya, elephant roundups were a spectacle to watch[5]. They were captured by being lassoed in the jungle or by driving them into kraals (Ringis 1996). The royal corrals were intricately designed, starting with fifteen to twenty captive elephants being sent into the wild to associate with wild elephants. Then, they were driven into a square enclosure with high stone walls and were driven further into a smaller enclosure made from thick posts (Figure 5). From there, the captive and wild elephants were separated, and wild elephants were tormented by men standing on a raised platform. Once an elephant showed weariness, a gate was opened, where it ran into a smaller enclosure. There two or three captive elephants were bound to it and led the wild elephant to a place where "planks were put in place under the wild one's belly. With a winch they raised the elephant some centimeters" (Schliesinger 2012: 93). After some time in this half-standing half-hanging position, the previously wild elephant was left with captive elephants to be completely tamed

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[4] Thailand was called Siam until 1949.
[5] Ayutthaya was the capital of Siam prior to 1782 (Schliesinger 2012).

(Schliesinger 2012). Roundups could gather fifty to sixty elephants, and the practice continued until 1905 (Schliesinger 2012).

Figure 5: An elephant kraal once used for rounding up elephants in Ayutthaya (Image by Ligeia from Bounding Over Our Steps)

Captive elephants were used for a variety of reasons. For the elite, having numerous elephants was a symbol of wealth and status. Rulers were defined by riding and owning elephants, while those who did not lost their fiefdom. In fact, inheritance laws stated that when a man dies his estate—his elephants, wives, children, granaries, groves, etc. in that order—was passed entirely to his son (Ringis 1996). Additionally, these elephants were used in wars and combat for territory and power. Using elephants in battle is a complex matter. Certain laws allowed for rewards in cases where elephants were used to help defeat opponents. But elephant

owners were punished if they avoided or fled battles or fell three elephant lengths behind their

expected position in battle (Ringis 1996). In fact, for many centuries, war and status were a large

part of the elephant's legacy in Siam and are what most history scholars discuss today from

around 1292 until the fall of Ayutthaya in 1767, where modernization and the building of

Bangkok began to change the elephant's role in Siamese society (Ringis 1996).

The rise of Bangkok is concurrent with increased modernization. Modernization led to

the advent of Thailand's railroad, meaning that the elephant was no longer necessary for

transportation (Ringis 1996). And this was the beginning of the development and the decline of

elephants and their habitat in Thailand. The lowlands of Thailand were deforested until 1950 to

make way for rail and for more rice paddies. Thailand's rice exports increased twenty-eight

times from 1855 to 1934, so more agricultural land was made available through clearing the

jungles. Meanwhile, in the north—the highlands—were sparsely settled, but densely forested

with teak, which provided economic opportunity. British logging traders had started operating in

Thailand in the 1850s, and by the 1880s the British teak companies were fully operating in

Thailand. Being only interested in teak, that was all they cut, and deforestation was not widely

occurring. Logging was dependent on the use of elephants to carry and push wood. In 1900,

approximately 100,000 elephants were used in the industry (Tipprasert 2002). It was hard work,

and the elephants bore all the heavy loads. The strongest and most powerful elephants were

prized by the logging companies, even if they had histories of aggression (Schliesinger 2012).

However, after World War II, Thailand's economy changed. Influenced by the west and their

industrial economies, Thailand's economy began to shift away from focusing on rice and other

agricultural exports and focus more on manufacturing, agribusiness, and logging (Delang 2005).

Prior to World War II, deforestation mainly occurred to create new rice paddies. After the war and with the start of the shift away from focusing on rice production, deforestation for the creation of new rice paddies was still high. In fact, in the 1950s, there were 4.9 million hectares of paddies, and by the 1990s there were 8.992 million hectares (Delang 2005). While occurring in the lowlands, this trickled into the northern highlands. With land scarcity in the lowlands from all the paddy development, poor farmers were forced north and forced to clear the land—often using fire and often accidentally clearing too large of plots of land. Additionally, without practicing crop rotation, they continued to move and clear about 500,000 hectares of forest annually (Delang 2005).

Outside of the agricultural sector, logging became a major reason for the clearing of forests. Starting in the 1950s, logging companies no longer focused exclusively on teak but starting cutting trees more generally (Delang 2005). With the increase in logging, there was also a decrease in elephants in the logging industry. By 1965, there were only about 11,000 elephants left in the industry (Tipprasert 2002). Thai law stated that logging companies had thirty-year concessions to cut as long as areas were replanted, but with little enforcement, some lands were left bare, others were regrown with commercial trees like rubber trees, and some were transformed into agricultural land. Further, these lands also became transformed into roads and offered to farmers—meaning more clear cutting—to prevent communist insurgents from acquiring space (Delang 2005). The development of the road network made the north more accessible for development and living, which would further exacerbate the loss of forests in Thailand. By 1982, only twenty-five percent of the country was forested compared to the sixty-three percent in 1947 (Delang 2005). And it was reported in 1985 that only 3,381 captive elephants remained in Thailand (Tipprasert 2002).

However, logging had reached its peak. In November of 1988, a mudslide carried away two villages, killing 251 people. The mudslide was determined to be caused by deforestation and planting rubber trees, so in 1989 the Thai government outlawed logging (Delang 2005). This did not stop deforestation; villages started cutting trees themselves without any economic incentive to cut sustainably or any commercial regulations to follow after the ban (personal communication with veterinarian: 2017-07-18). Further, the ban on the logging left elephants "unemployed." Logging elephants' owners now had no need for their elephant, as the elephant was no longer providing income for the owner, and the owners could not afford to feed their elephants. This was a massive problem in Thailand, and the Food and Agriculture Organization of the United Nations (FAO) determined that the best solution was to put elephants in tourist camps, giving rides and putting on shows for tourists (Phangkum, Lair, and Angkawanith 2005). But not all elephants ended up in tourism; some illegally log on the border of Thailand and Myanmar, and others street beg in Bangkok and other large cities (Lohanan 2002).

Evaluating Human Values and Perceptions and its Implications for Elephant Geographic Distribution and Conservation:

Methods and Study Area:

All interviews and observations took place in Northern Thailand, where the captive elephant population is concentrated. With a concentration in the north, most non-governmental organizations (NGOs) dedicated to elephant conservation and welfare, elephant veterinarians, and elephant owners tend to be located in this region. One exception is a visit to two camps in Ayutthaya, approximately eighty-two kilometers north of Bangkok, in central Thailand.

Observations:

The inner workings of the elephant tourism industry in Thailand were observed as an intern at the Thai reforestation and conservation NGO, Conserve Natural Forests (CNF). I had the opportunity to observe the inner workings of elephant tourism and compare and contrast how different tourist camps were run and how elephants were treated. Four elephant camps in Pai, Mae Hong Son Province were driven to and elephants' shelters and behaviors were observed to learn of any differences in elephant lifestyle compared to the that of the elephant at CNF. The elephants and their shelters were located on the side of the road, enabling observation of their everyday conditions without worries that the owners would change how animals were being handled for my visit.

Five other camps were visited—two while searching for the perfect elephant to buy in Chiang Mai Province, one that was an interviewee's camp in Chiang Saen, and two in Ayutthaya through a connection with a previous CNF intern, who had previously visited them (Figure 6). The two visited in Chiang Mai were scheduled in advance with the elephants' owners during normal operational hours of the camp[6]. In fact, there were many tourists interacting with the elephants—feeding and bathing the elephants—while there. Due to the nature of the visit, it was

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[6] Many elephants are rented to elephant camps, so the owner does not actually have direct contact with the elephant every day.

possible to go behind the scenes and see where the elephants that are not interacting with tourists are kept. The visit to the camp in Chiang Saen was scheduled to observe another interviewee's research in the camp. A camp manager and a veterinary technician explained the philosophies and daily life at the camp. The elephant stables and their educational elephant experience were also observed. The two camps in Ayutthaya were primarily tourist attractions, where anyone could

Figure 6: A Geographical Map of Thailand. Note that Pai is located just east of Mae Hong Son and Chiang Saen is located just north of Chiang Rai. (Map from Goway Travel)

walk through, allowing me the freedom to come as convenient for myself. Payment was only necessary for interacting with the elephants—riding, feeding, and taking their picture. I was able to come and observe daily activities at the camp, knowing that there were no changes in the camps' handling of elephants.

These camps were all chosen because they were available to visit as an observer rather than a tourist. They also were chosen due to contrasting conditions for elephants. In Ayutthaya, the elephants worked almost the entire day, ate pineapple tops, and had limited access to water[7]. In Chiang Saen, elephants were able to roam in the forest, were given long breaks between work,

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[7] Pineapple tops are fibrous, and because elephants have inefficient digestive systems, they provide little to no nutrients to the elephant.

and were able to feed in the forest. In one camp in Chiang Mai, elephants were kept in a wooded area with a lot of food around but left on short chains. The other camp in Chiang Mai kept elephants near water, but there was no natural food around for the elephants to forage on. The camps in Chiang Saen and Ayutthaya were also chosen for the purpose of contrast. While they both offered elephant riding, the one in Chiang Saen also offered elephant education programs, facilitated research, worked on positive reinforcement training, and was focused on elephant conservation. The camps in Ayutthaya were commercially based, doing little conservation work, offered rides in the center of the city, and practiced brutal punishment techniques on misbehaving elephants.

When observing their conditions, it was noted whether the elephants were chained with long or short chains, if they had access to food and water while chained, and whether they were standing on dirt or concrete (Figure 7). Long chains are classified as any chain that is at least twenty meters long—typically between twenty and thirty meters long—while short chains are classified as anything less than twenty meters long. When used correctly, long chains are typically used in rural and open areas, while short chains can be used in condensed areas (Phangkum, Lair, and Angkawanith 2005: 13). Chains were not officially measured but noted as long or short based on how much the elephant could move around. Dirt is a better floor for elephant shelters as "elephants are likely to have fewer problems with footpads and nails" on dirt floors rather than concrete (Phangkum, Lair, and Angkawanith 2005: 13). In terms of behavior, elephants that were swaying, feeling sleepy, and gazing downward were noted. Swaying, sleepiness, and gazing downward tend to mean that the elephants are not being intellectually

stimulated, a sign of low welfare. These behaviors were chosen based on information that was

provided to me by elephant owners and NGO owners.

Figure 7: Left: An elephant on a short chain in a camp outside of Chiang Mai. Right: An elephant standing in its shelter on concrete at the Elephant Hospital in Lampang. Both elephants have access to food. (Photos by author)

Interviews:

Interviews were conducted with veterinarians, mahouts, elephant owners, elephant camp

managers, scientists, and farmers. Interviews were secured through connections with other CNF

personnel or sending emails to different foundations and elephant camps throughout Thailand

that were conducting research or had conservation aims. These organizations were found through

Google searches, the World Animal Protection 2017 report on elephant tourism, and through

collaborations between different foundations. In some cases, interviewees referred me to other

interviewees. Anyone who expressed interest in being interviewed was interviewed, provided we

could find a mutually agreeable time to talk. Due to the small sample size—fourteen total

interviews—these interviews and information obtained are not generalizable to the entire

elephant industry.

The informed consent of each interviewee was obtained prior to asking questions, as per

Yale Human Subject approved protocol #2000021246. If allowed, the interview would be

recorded for future playback, and notes were taken for each interview. All but one interview was

conducted in person, with the exception being over the phone due to geographical distance. Most interviews were conducted in English, but some interviews were conducted with people who only spoke Thai or a dialect of Karen. For these interviews, a translator that was fluent in Thai and English and one who could translate from Karen to Thai, when necessary, was used.

Questions were prepared before each interview, but more were added depending on the direction of our discussion. Each interview had the same standard questions:

a) Why are elephants disappearing in Thailand?

b) What is the future for elephants in Thailand?

c) Do the laws protecting elephants do enough, and can you explain why?

d) In your opinion, how should elephants be managed?

e) What is your background and experience with elephants?

However, each interviewee also was given customized questions tailored to their specific expertise through research on each interviewee. If an interviewee was associated with a particular organization, I browsed the organization's website to learn about its objectives and projects so that questions could be geared towards the individual's work. For farmers, news on human-elephant conflict were read and questions were asked to the CNF director about their relationships with farmers. Scientists, farmers and those involved in human-elephant conflict mitigation were asked about mitigation strategies, attitudes towards crop raiding, and why elephants raid crops. Veterinarians were asked about care for captive elephants, microchips for elephants, and the role of elephant hospitals. Questions for mahouts were catered from reading news articles about their profession and discussions about their role in the elephant industry from other interviews. Mahouts and elephant owners were asked about their typical day, stories about the elephants they worked with, the cultural and spiritual connections or rituals they have with

elephants, and challenges they face in their occupation. Elephant camp owners were asked about how they care for elephants, what an elephant's daily schedule is, and why they opened their camp.

All interviews took place in the north of Thailand, in the cities of Lampang, Chiang Saen, Chiang Mai, and Pai (Figure 6). Lampang is the home of Friends of the Asian Elephant, the world's first elephant hospital. There, one of the leading veterinarians was interviewed. Situated in the center of Northern Thailand and near a national park where elephants have been reintroduced into the wild, the veterinarian was able to speak about reintroduction, as well as elephant health throughout the country, particularly in Northern Thailand. Chiang Saen is the location of The Golden Triangle Elephant Foundation. There, they offer tourist activities and conduct research. This allowed me to speak with people who ran the foundation about how they run the camp, and it allowed me to observe research and talk to scientists about their research and its implications for conservation. Chiang Mai is the largest city in the north. Most elephant camps are located within a two-hour drive from Chiang Mai. As a busy hub, it is a convenient meeting place. But also, because it is where elephants are concentrated in Thailand, there are a myriad of people involved in the elephant industry there to provide their insights. Pai is a small town located in the mountains near the Thailand-Myanmar border, attracting backpackers. On the edge of a national park, the land used to have many elephants, and now has four elephant camps and an elephant conservation project. As the location of CNF, relationships with locals were easy to establish, many of whom could offer valuable insights.

After the interviews, data were compiled by interviewee. The data were then coded into the following categories: employment of elephants, culture (Thai or Karen), future of elephants, current issues, and ecology. Categories were chosen to integrate ideas from multiple

interviewees, who have different perspectives. There were also recurring themes that came up throughout interviews. These themes are presented in Table 1.

Table 1: The codes and their subsequent recurring themes in each code.

Employment	Culture	Future	Current Issues	Ecology
Captivity	Symbolism	Reintroduction	Laws	Biodiversity
Space	Spiritualism	Foundations	Care	Wild
Health	Elephants in Popular Society	Changes from Past	Human-Elephant Conflict	Scientific Accuracy
Money	Cultural Shifts	Population	Food	Behavior
Camps	History	Movement	Overworked	Intelligence
Logging	Rituals	Development	Farmers	
Mahouts	Superstition	Extinction	Regulations	
Ethics	Perceptions		Tracking	
	Status		Poaching	
			Registering	

Species Distribution Modeling:

The objectives of the modeling are to understand the elephant's spatial niche in terms of climatic variables and habitat conditions that could determine its geographic distribution across Thailand's landscape. The modeling, however, uses most of Southeast Asia to consider the broadest range of habitat that elephants could occupy. Using only data from Thailand could give biased insights. This is because rapid declines in the elephant population mean that some areas in Thailand may be suitable for elephants but are not currently occupied by them. Hence, using only data from Thailand could give a false negative that certain habitats are unsuitable when in fact they may be entirely suitable for elephant occupancy.

Elephant distribution data were acquired through the IUCN Red List, which encompasses elephants' range throughout all of Southeast Asia in 2008. Individual elephant geospatial spottings were compiled and downloaded from the Global Biodiversity Information Facility (GBIF) (https://www.gbif.org/species/5219461) ("*Elephas Maximus* Linnaeus, 1758" 2017) and compiled in a Geographic Information System (GIS). Climate data were obtained from Chelsa

Climate (http://chelsa-climate.org) (Karger et al. 2017b; Karger et al. 2017a), and land cover data came from EarthEnv (http://www.earthenv.org/landcover) (Tuanmu and Jetz 2014). Elevation data were downloaded from the United States Geological Survey's GMTED2010 median statistic (https://topotools.cr.usgs.gov/GMTED_viewer/) (courtesy of the U.S. Geological Survey). Each data set was downloaded with 30 arc-second resolution, the smallest increment offered by each data source. Distribution modeling was completed in R Studio Version 1.1.383 (Script in Appendix A).

The analysis started with a model using the Northern Hemisphere of Southeast Asia. Only data for geographic locations within the northern hemisphere were used because the majority of data for Southeast Asia were sampled there. All of Thailand is located in the Northern Hemisphere, so this is not an issue when the general model is applied to Thailand.

Using the elephant occurrence from GBIF and under laying them with environmental variables (percent forest cover, temperature, precipitation, and elevation) allowed the examination of bivariate plots to provide insight about the relationships between elephant occurrences and potential variables that determine its niche across Southeast Asia. Because elephants prefer jungle habitats, percent forest cover was chosen as a land cover variable (IUCN 2017). Total annual precipitation was used to account for seasonal rainfall patterns. Annual mean temperature was used because temperature remains relatively constant in Southeast Asia across the year since it is in the equatorial zone. Precipitation and temperature were chosen because they are indicators of climate. Elevation was chosen to consider habitable ranges in terms of topographic constraints on mobility as elephants may not be able to traverse some elevations.

I used maximum entropy modeling via MaxEnt software Version 3.4.1 for the statistical analysis because it is comparable to other statistical approaches and is well-suited for presence-

only data and small data samples—the type of data used in this analysis (Trainor and Schmitz 2014). MaxEnt predicted the possible presence of elephants in Thailand based on information about elephant distributions throughout southeast Asia. Model performance was evaluated based on a score measuring sensitivity and specificity (AUC score); a score closer to one indicates a stronger model. MaxEnt sufficiently details the range of a species while also statistically determining which variables contribute most to predicting the likelihood of elephant occurrence across the landscape (Johnston, Freund, and Schmitz 2012). Areas of high habitat preference were arbitrarily considered to be areas of having a 60% chance of elephant occurrence. The MaxEnt predictions were then compared to the occurrence data from within Thailand. This helped to determine whether elephants occur in all suitable habitat across the landscape, or if there is unoccupied suitable elephant habitat that needs further consideration for conservation.

Chelsa Climate also has data on future climatic conditions based on modeling of future climate under different assumptions about global CO_2 emissions. Using these data, I evaluated future habitat areas that may need to be conserved under climate change. The future conditions were determined by using the RCP (Representative Concentration Pathways) 4.5 emission scenario as it is representative of average anticipated emissions. The HADGEM2-CC climate model was chosen to make the future climate predictions as it is generally accepted as the most reliable by the scientific community. The methods used to model elephant habitat under current climate were used to project what would happen in a climate future. I considered future distribution in terms of future temperature and precipitation. This model is used to determine if the locations of the elephant niche will change by the year 2041-2060 and used to make suggestions about how to conserve the species if there are any changes.

I also calculated differences between current and climate future elephant distributions to see how climate change may affect future habitats, and which places will be more climate resilient. The following formula was used to calculate the difference at all geolocations across Thailand: (future - current) / (future + current). A positive result means the probability that the area is hospitable to elephants increases in the future and a negative result means the probability decreases. The differences were mapped to see which parts of Thailand will experience habitat loss and which areas will gain preferable habitat with climate change.

Results:

Perceptions:

The 1989 ban on logging in Thailand was universally accepted among conservationists, elephant owners, and scientists as a change in the status quo for Thailand's elephants. Elephants that were once carrying wood were forced into tourist camps or to log on the border of Thailand and Myanmar (Lohanan 2002). As many interviewees noted, this leads to poor care, as elephants are very expensive to own. Elephant camps tend not to have enough space for elephants to live, thrive, and flourish. Additionally, because they eat so much, it is difficult for camp owners to pay for all their food. This can be exacerbated when camps are not located adjacent to jungle patches, where elephants can go to naturally forage. The high cost of feeding an elephant means that each elephant must spend a lot of time interacting with tourists. These conditions compound to produce malnourished and overworked elephants. This contrasts from the logging industry as elephants worked in the jungles, where they could forage on natural vegetation, and were worked for short periods of time during the day (personal communication with former elephant owner: 2017-08-14).

While the logging industry provided difficult work for the elephants, the transition to tourists camps completely changed the way they were treated and the value of the elephants. About thirty years ago, the cost of an elephant was 10,000 to 30,000[8] Thai baht, but now they can cost over two million Thai baht[9] because the fixed number of trained elephants in captivity make them an increasing limiting resource in service of the tourism industry (personal communication with former elephant owner: 2017-08-14). But also, the mahouts changed. In the logging industry, mahouts lived in the jungle with their elephant and rarely got time away from the elephant (personal communication with veterinarian: 2017-07-18). However, in elephant tourism, the mahouts do not have to spend all their time with the elephants, especially if they do not live nearby.

Spending less time with the elephants decreases the strength of the relationships between the elephant and mahout. With less time invested and weaker relationships, it decreases the level of care at which an elephant receives. Some interviewees blame the increase in technology, other interviewees blame formal education and the move to cities for this disconnect. In fact, the best mahouts are older and ones that worked in the logging industry. Younger mahouts act like city men and fail to learn from the older generations about the best care techniques (personal communication with veterinarian: 2017-07-18). What was once a desired and an admired profession, is now one that makes little money and is often one of undocumented workers from Myanmar (personal communication with veterinarian: 2017-07-18). This is perhaps because it pays little and requires no formal education in a rapidly developing country. The Thai Elephant Conservation Center has tried to remedy this issue by creating a mahout training program, but it mainly attracts Japanese women. With better job opportunities in the cities, being a mahout no

[8] Approximately 320-960 USD today
[9] Approximately 63,000 USD today

longer creates a feeling of pride amongst the Thai people (personal communication with veterinarian: 2017-07-18).

In Thailand, captive elephants are considered to be employed, but one expert I spoke with challenged this idea, as it is not the elephant, but the mahout that is employed (personal communication with researcher: 2017-08-16). There needs to be a shift in thinking of the mahout as the employee rather than the elephant, as mahouts now tend to lack worker rights and tend to be an afterthought in the elephant tourism industry. Additionally, to appeal to western tourists and their ideals of ethical tourism, mahouts are often told to lie about the tools they use when working with elephants, particularly their hooks. Westerners often think that hooks are used to hurt elephants, but "they are the law of the elephant" and used to extend the mahouts arm and guide the elephant (personal communication with elephant owner: 2017-07-25). Hiding their tools that have been used for hundreds of years is deeply shameful for mahouts as they have to lie and secretly use tools that are more harmful to the elephant, like nails instead of a hook (Figure 8) (personal communication with researcher: 2017-08-16). The ideals for caring for elephants have changed with time, but the techniques have not changed, and this burden falls onto the mahout that may have been working with elephants for decades (personal communication with veterinarian: 2017-07-18)
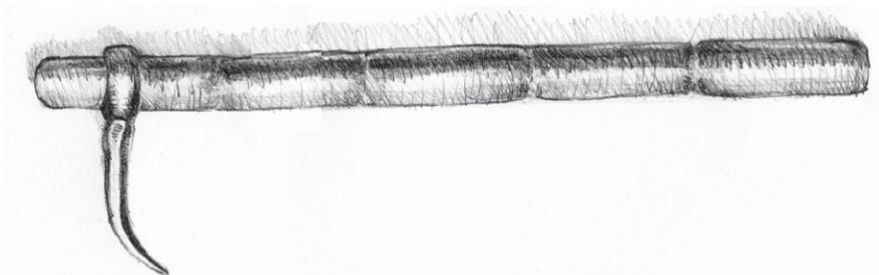

Figure 8: A drawing of a Mahout's hook from *Elephant Care Manual for Mahouts and Camp Owners*. (Drawing by Sirikorn Inkom)

One thing that is not perilous to Thailand's wild elephants is poaching for ivory because African elephants supply enough ivory at the moment to fit the demand. However, calf poaching may be an issue. Females are desired by elephant camps owners are they are much more docile than males since they do not go through musth. Calves are most desired by tourists because they are cute, so there are rumors of people stealing calves from the wild. However, it is hard to quantify if this is really occurring as evidence comes from anecdotal stories and since captive registration systems are not thoroughly monitored. It is almost impossible to know if an elephant is born in captivity or poached from the wild. And, as a job that requires a very specialized skill set that few have since calf poaching requires killing nearby mothers and transporting a baby elephant from the jungle to the cities, there are likely to be few people that can poach (personal communication with camp owner: 2017-07-29). Elephants can even be brought in from neighboring countries due to their high value in Thailand, but this is problematic as it requires elephants to be smuggled out of the wild and into another country to live in captivity. Some suggested ending captive breeding for about five years to see if the captive population is being supplemented by poached and smuggled elephants and if elephants are successfully reproducing in captivity (personal communication with camp owner: 2017-07-29). But there is hope. Captive elephant registration is now being closely monitored by three government agencies—the Department of National Parks, the Department of Livestock Development, and the Provincial Administration—and requires DNA fingerprinting. As long as these efforts continue, calf poaching will be extremely difficult (personal communication with camp owner: 2018-03-31).

But even with conservation efforts on the rise, Thailand still faces space and human-wildlife conflict issues. In the past when the Karen lived with elephants, human-elephant conflict was a small issue because people adjusted their behavior to accommodate elephant behaviors.

However, this is not the case with most people. For every domestic elephant's footprint on a farmer's land, the elephant's owner must pay 10,000 Thai baht[10]. Elephants straying from their owner's lands are also at risk of being shot by farmers (personal communication with foundation director: 2017-08-15). Furthermore, interviewees agreed that there is not enough space left in the jungles for all the elephants in Thailand, requiring elephants to live in captivity (although some mentioned that the captive population is too high since they do not contribute to conservation) (personal communications with camp owner: 2017-07-29; personal communication with scientist: 2017-08-04). Also, since the existing jungle patches are insufficient, elephants tend to leave the jungle and raid crops. This could be an indicator that in some areas, elephants are exceeding their carrying capacity as there is not enough food in the jungle patches to sustain them. Some efforts to curb human-elephant conflict include turning these areas into a tourist attraction, so the farmers can profit even though they are losing crops. Additionally, electric fences, spikey plants, fire, and firecrackers can be used to keep elephants away, but they are not fool-proof methods. They fail to address the reason elephants want or need to raid crops and can cause aggression in the elephants (personal communications with camp owner: 2017-07-29; personal communication with scientist: 2017-08-04). A general sentiment has been that much needs to be done for understanding human-elephant conflict and mitigating it into the future.

Having a tumultuous past and present, it seems from most interviewees that elephants and elephant conservation has a lot of work to do to ensure the species survival. Reintroduction into the national parks is one of the current tactics used for conservation. The Elephant Reintroduction Foundation takes captive elephants from all throughout the country to reintroduce them into a national park that is shut off from tourists. While a theoretically a great idea, some

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[10] Approximately 320 USD

interviewees noted that it was subprime habitat, the area had already reached its carrying capacity, people are not going to donate their elephants for no financial compensation, and the elephants are accustomed to humans, so they will continue to raid crops even if they do not need to. The final objection was refuted by another interviewee that pointed out that as one of the queen's initiatives, no one is going to make a problem with elephants that leave the jungle[11] (personal communication with foundation director: 2017-08-15). But for this project to be fully accepted by the Thai people, they need to buy into the idea that elephant conservation is important. Spiritual connections with elephants could allow this to occur.

There seems to be a loss of significance for the elephant in popular society. It was noted that elephants are merely symbols, toys, and attractions in Thai culture now. The elephant that is depicted on the walls of the temple has been separated in the Thai imagination from the actual living and breathing elephant that inhabits the Thai jungles. Many interviewees noted that this is one of the struggles facing elephant conservation. However, one noted that getting people to care is not impossible. He remarked that "Thai people are proud of the biodiversity in their country, it's just finding ways to balance the love of wildlife and need for biodiversity with the interest of people and what people need" (personal communication with scientist: 2017-08-04). He continues to discuss how elephants are easy to relate to as they possess similar levels of intelligence as humans. By exposing young children to elephants and demonstrating their intelligence, it's easy to get people to care about them. However, with only one (that the interviewee knew of) undergraduate conservation biology curriculum in Thailand, there are little opportunities to study conservation. Additionally, there are fewer types jobs in conservation, and these jobs may not compensate enough for children to take care of their parents. This is

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[11] The Thai Royal Family is revered in Thailand, and it is illegal to speak ill of the family.

especially important due to cultural values where children take care of their parents in their old age. The interviewee points out though that there is interest in conservation and the interest is growing, it still must be encouraged (personal communication with scientist: 2017-08-04). And with more care for elephants, better registration systems and laws can be enacted.

Interviewees commonly reported that the laws need updating. Notably, captive elephants fall under the Draught Animal Act of 1939, which prevents them from being released into the wild or encouraged to go into and forage in the jungles (Lohanan 2002). It is agreed that this law is out of date since it was made for the logging industry, and a new one needs to be established. Wild elephants are protected under the Conservation Act of 1992 (Lohanan 2002). While updated elephant protections are in the works, it is often not prioritized, as it requires several governing bodies to coordinate (personal communication with researcher: 2018-08-16). Interviewees expressed interest in requiring all mahouts to be registered, creating welfare standards for captive elephants—taking space, time working, and food into consideration—creating measures to prevent smuggling elephants, and DNA fingerprinting individual elephants to register them. They also expressed that there is still a lot to be done to ensure the survival of elephants, but they all noted that the future is not grim. There is hope for elephants; they can survive the upcoming trials of surviving in a rapidly developing nation because there are people who care.

Species Distribution Model:

Elephants in the wild have been spotted throughout Southeast Asia—on both island and mainland nations (Figure 9). Many of the sightings occur in Thailand, where they are concentrated in central areas, but also are notably present in the east and 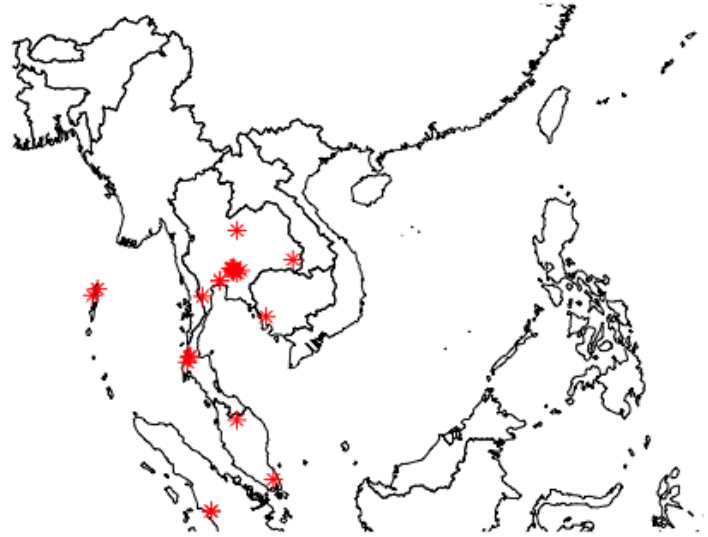the southern peninsula (Figure 10). Elephants tend to inhabit areas that get approximately 150-300 millimeters of precipitation a year, that range from sea level to 1,000 meters above sea level, that have approximately thirty percent cover to complete forest cover, and that have temperatures varying from 10 to 35 degrees Celsius (Figure 11). The bivariate plots show how different environmental factors correlate to each other when discovering the niche. Elevation has little correlation with

Figure 9: Elephant Spottings in Southeast Asia as marked by the red stars
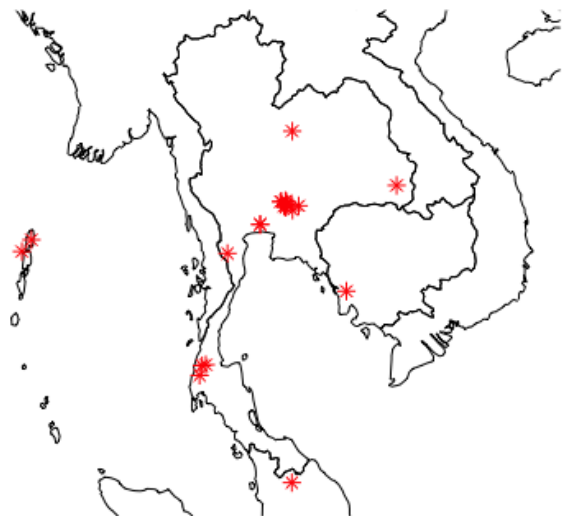
Figure 10: Elephant Spottings in Thailand as marked by the red stars

temperature, and precipitation stays relatively constant with increased temperature. Elevation and precipitation have a strong correlation; precipitation tends to decrease with an increase in elevation within the elephant's niche. Increases in temperature and elevation tend to make more favorable habitat when forest cover increases. However, the level of precipitation tends to decrease with increasing forest cover in the elephant's niche. Therefore, in order to be prime

habitat, areas of high precipitation should have low forest cover and elevation. Areas of high

temperature should have high forest cover; areas high forest cover should have high temperature

and elevation and low levels of precipitation to be hospitable to elephants. Areas of high

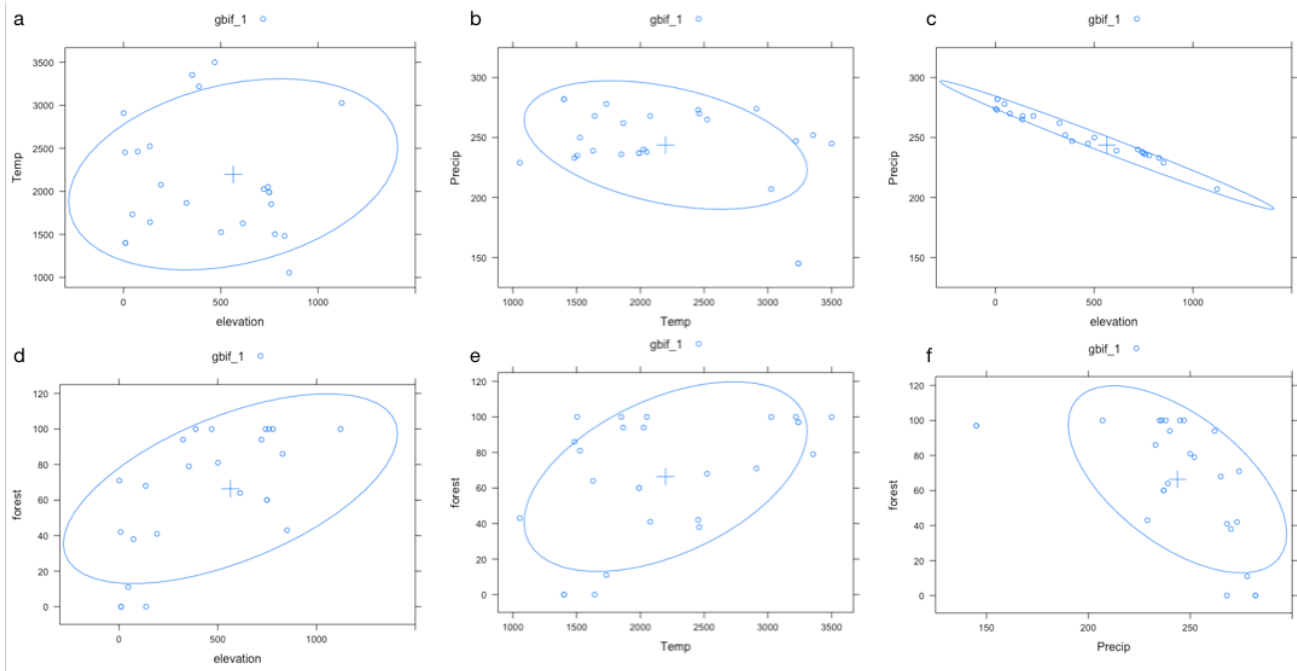elevation where elephants occur tend to have high forest cover and low amounts of precipitation.

Figure 11: The Bivariate Plots with the Confidence Ellipsoid. Areas within the ellipsoid indicate areas where the niche should be. a) Elevation (0-1,000m) vs Temperature (10-35°C). b) Temperature (10-35°C) vs Precipitation (150-300mm annually). c) Elevation (0-1,000m) vs Precipitation (150-300mm annually). d) Elevation (0-1,000m) vs Percent Forest Cover (0-100%). e) Temperature (10-35°C) vs Percent Forest Cover (0-100%). e) Precipitation (150-300mm annually) vs Percent Forest Cover (0-100%).

MaxEnt used temperature, elevation, precipitation, and forest cover to estimate the

habitat preferences of elephants (See Appendix B for MaxEnt statistics). Using the MaxEnt

model and predicting the probability of an elephant living in a certain area, it seems that areas in

Northern Thailand and central Thailand are most hospitable (Figure 12). However, there are

areas in Eastern and Southern Thailand that are not prime areas of habitat but are where

elephants are currently living. These are likely elephants in southern forest complexes (IUCN

2017), but this could be subprime habitat. Northern Thailand, followed by central Thailand, has

the highest probability of elephants existing, but few wild elephants have been observed in either

place. While elephants do not seem to occur in central Thailand's most hospitable areas, they do

occur in adjacent areas, indicating that these may be good and practical areas for elephant

relocation. The majority of the southern peninsula and eastern region have a low probability of

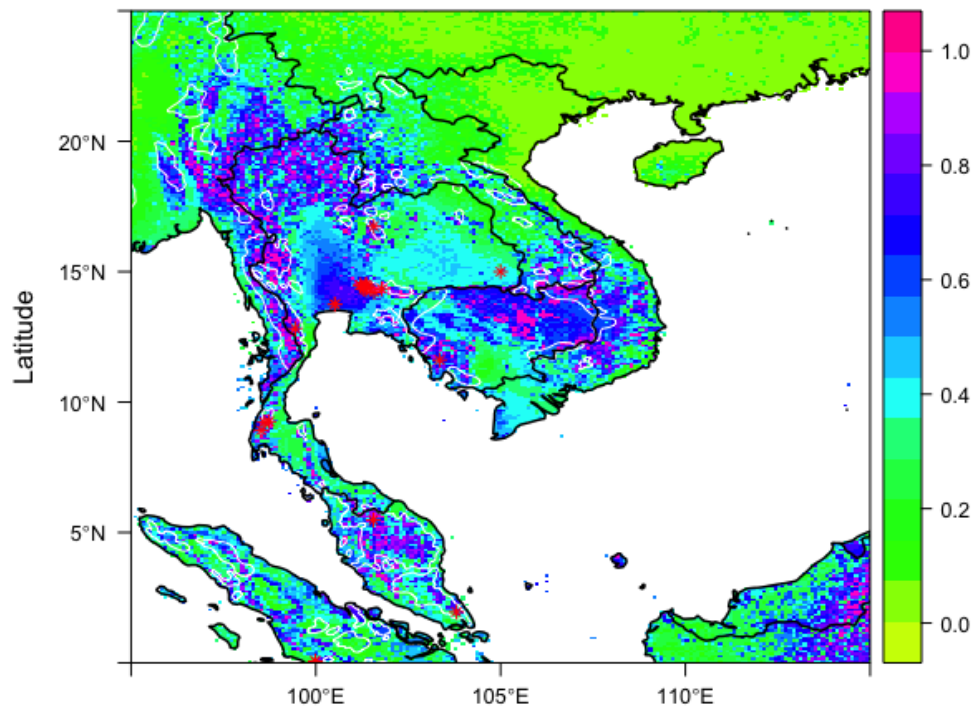being hospitable to elephants and should be of low concern for conservationists.

Figure 12: MaxEnt predictions of hospitable environments for elephants. Pink indicates the highest probability of being hospitable to elephants,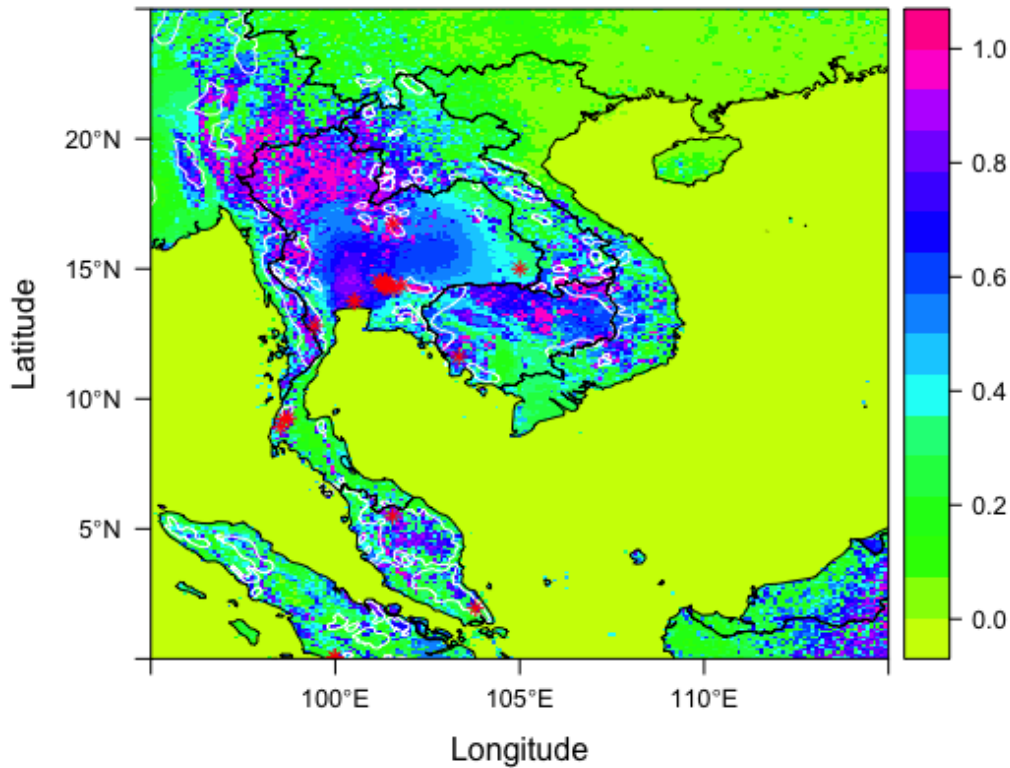 and yellow-green has the lowest. Red stars indicate where elephants have been spotted and documented in GBIF. Black lines are country borders, and white lines indicate the range that the IUCN published.

The future predictions based on changing temperature and precipitation, yield similar patterns. Elevation and temperature have a small correlation, and precipitation stays relatively constant with increasing temperature. Future precipitation has a smaller range than current precipitation, but still decreases with increased elevation. Future temperature still increases with forest cover, while future precipitation still decreases with forest cover. Therefore, the same habitat preference trends occur in the future model as that of the present model (Figure 13).
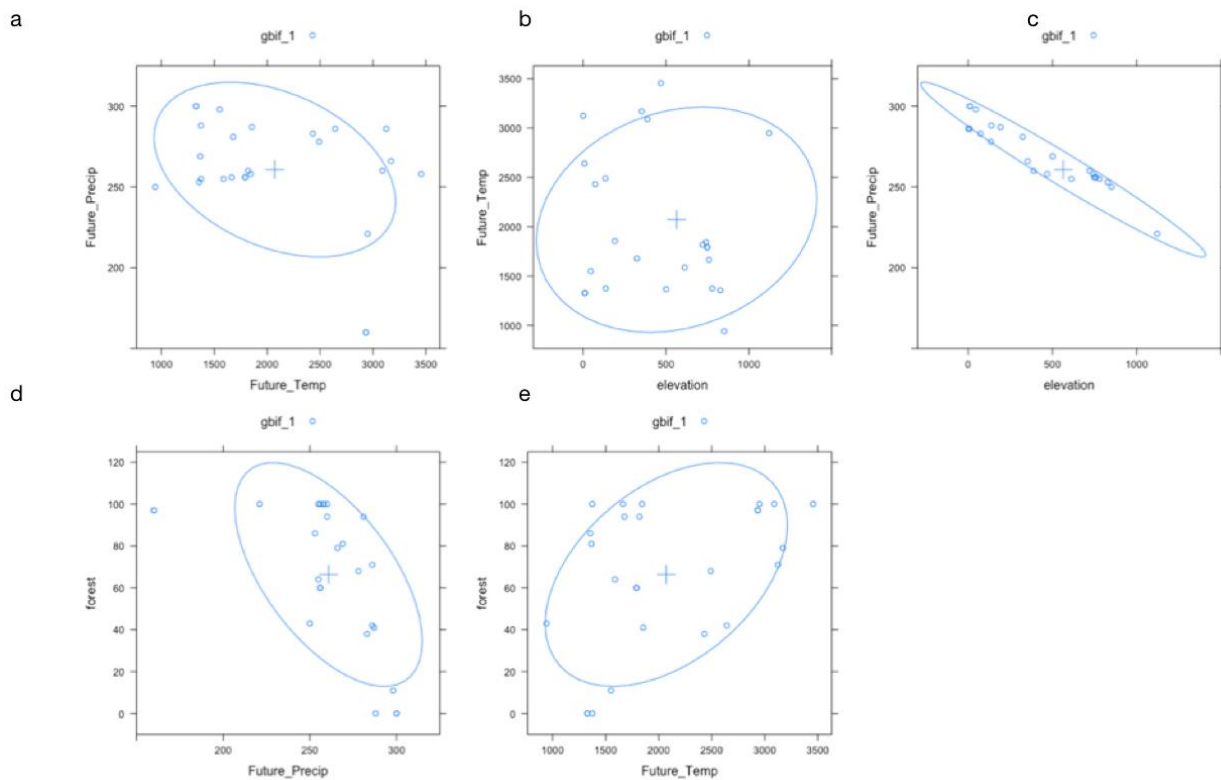
Figure 13: The Bivariate Plots with the Confidence Ellipsoid. Areas within the ellipsoid indicate areas where the niche should be. a) Future Temperature (10-35°C) vs Future Precipitation (200-300mm annually). b) Elevation (0-1,000m) vs Future Temperature (10-35°C). c) Elevation (0-1,000m) vs Future Precipitation (200-300mm annually). d) Future Precipitation (200-300mm annually) vs Percent Forest Cover (0-100%). e) Future Temperature (10-35°C) vs Percent Forest Cover (0-100%).

Future temperature, future precipitation, elevation, and forest cover were used as variables for modeling future elephant habitats. The future model was used to predict the future areas where elephants could live in Thailand (see Appendix B for MaxEnt statistics). On the whole, Thailand's lands become more hospitable to elephants (Figure 14). Northern Thailand remains as a location where there is a high probability that elephants could thrive there, and the

probability actually increases with the climate change model. Central Thailand also becomes a more favorable environment for elephants and this preference extends peripherally from the center of Thailand (Figure 15). In fact, most of central and Northern Thailand increases its land's probability of being habitable up to 0.4. The southern peninsula's land degrades, but it also did not have much favorable habitat in the current day model. Places that are favorable now, seem to increase their likelihood of hosting elephants in the future.

Figure 14: Future MaxEnt predictions of hospitable environments for elephants. Pink indicates the highest probability of being hospitable to elephants, and yellow has the lowest. Red stars indicate where elephants have been spotted and documented in GBIF. Black lines are country borders, and white lines indicate the range that the IUCN published. Water is included with a probability of zero as the climate data does not differentiate between land and water.
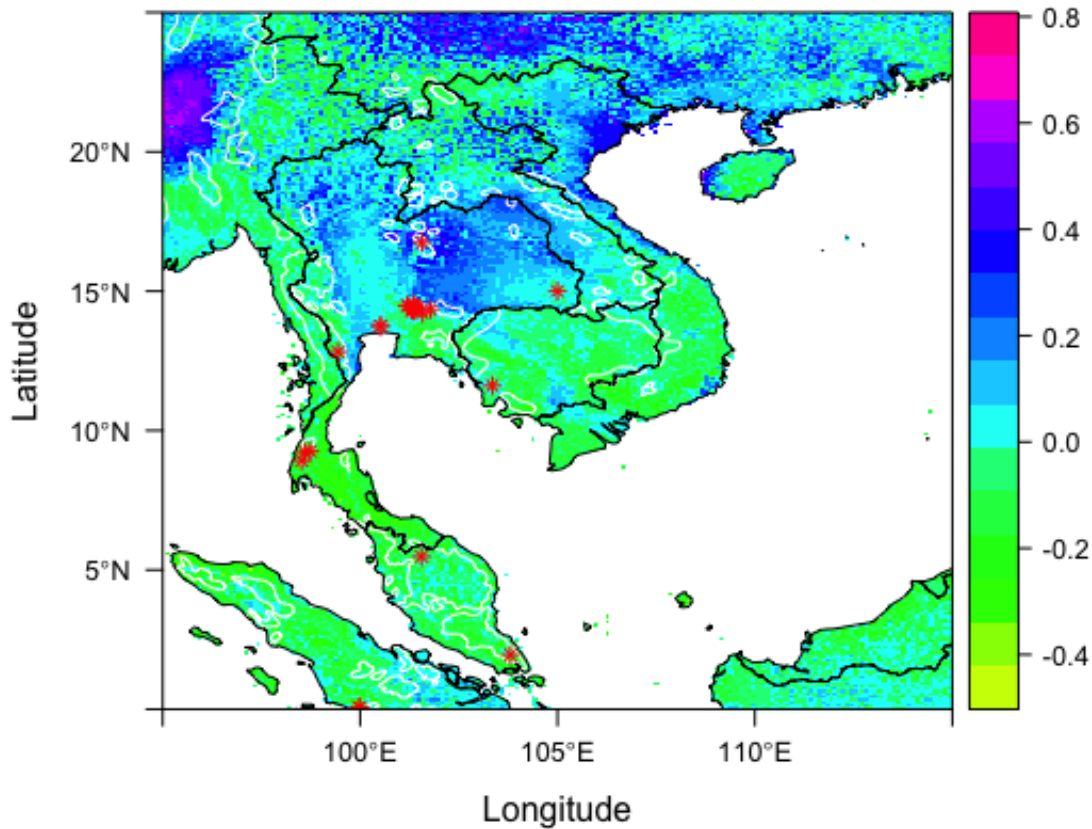
Figure 15: How more or less hospitable Thailand will become with climate change. Positive values reflect land becoming more favorable for elephants with climate change. Negative values represent habitat degradation. Red stars indicate where elephants have been spotted and documented in GBIF. Black lines are country borders, and white lines indicate the range that the IUCN published.

Discussion:

Elephants have had a tumultuous past in Thailand; they were herded in masses for capture, participated in war, lost habitat due to urbanization, and carried wood in the logging industry. Now, they entertain tourists, or the lucky few live in some of Thailand's few remaining jungles. Yet still, the wild elephants face repercussions of human-elephant conflict from crop raiding, the potential loss of more habitat due to urbanization and industrialization, and the threat of being poached for tourism. Captive elephants, which are concentrated in northern Thailand, face threats of overworking, improper care, and low-quality food. But the future of elephants is unclear. The future of Thailand's elephants depends on humans and their ability and desire to take measures to better protect the elephants.

In order for elephants to thrive in the future in Thailand, many reforms must be implemented. Fortunately, Thailand offers many areas now that offers suitable habitat for elephants, often in places where there are no elephants. There is potential to create protected conservation areas in areas of habitat with a high probability where an elephant can exist. What is more promising for conservation efforts is that the areas with high probability of supporting elephants, while small in spatial extent, are located near areas of that may be equally suitable but currently unoccupied. This suggests that connective corridors could be developed to facilitate elephant movements between the two suitable habitats. Since elephants can inhabit over 600 square kilometers, connective corridors are necessary to ensure that elephants have enough space and resources (IUCN 2017). Currently, wild elephants are living in noncontiguous populations (Sukumar 2006; Leimgruber et al. 2003), but creating these wildlife corridors may connect populations, and may prevent any inbreeding issues that surround small isolated populations. Furthermore, the climate change model shows an increase in the quantity of habitable areas for elephants. In fact, most areas that were only somewhat habitable become more favorable. The areas that could now be wildlife corridors would become preferable habitat. By conserving these areas and creating wildlife corridors now, it creates an environment that will enable elephants to populated unoccupied habitats and thrive in the future.

Areas of northern Thailand and central Thailand are places that conservationists should focus on to create new preserved spaces. Northern Thailand ought to be prioritized as the Thai government is already making an effort to conserve the jungles there (Trisurat, Alkemade, and Verburg 2010). Because there are no elephants currently in these areas, reintroduction or translocation could be used to populate the new parks. The Elephant Reintroduction Foundation could continue its operations in more conservation areas throughout the country. This would be a

slow process, as in seven years, twenty-four elephants have been released and have adjusted to a natural home in three national parks ('Activities and Projects' 2018). Also, in areas where the elephants are above carrying capacity, elephants could be relocated to a new area. This would allow for the captive population to decrease and to lessen the pressure of providing food and space to many animals in a human-encroached area. Additionally, for overpopulated areas, it would bring a more stable population count and more resources per capita.

Reintroducing or relocating elephants will do more than just increase the elephant populations. It may also improve the quality of the ecosystem. Elephants are keystone species that create habitat for other organisms, shape the jungle, and germinate seeds (IUCN 2017). If elephants can prime the trees and vegetation, there could be an increase in biodiversity—part of that which makes Thailand's natural areas so unique and special.

Captive elephants are so embedded in the regional political economy that implementing these conservation measures will not be easy. The loss of captive elephants through reintroduction may hurt the tourism industry, but this could be remedied through imitating Africa's tracking style tourism, where tourists trek through the jungle on foot to see wild animals in their natural habitat. Tourists would be able to observe wild elephants in ways that are minimally intrusive to an elephant's life. In fact, the trends among western tourists are moving away from more intrusive interactions like riding and shows and towards a style that only allows tourists to bathe, feed, and observe elephants. One elephant conservation project, the Mahouts Elephant Foundation, only offer a tracking style tourism of their captive elephants[12]. Additionally, by making reintroduction a normal event for captive elephants, it gives them great intrinsic value that is worthy of conservation. Currently, their value is not associated with

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[12] These elephants could be described as semi-wild, since they are living on forested land, but still have mahouts taking care of them.

ecosystem conservation, as an umbrella species. Rather, they are predominantly valued for economic return provided to owners who keep them in captivity. Given the current monetary investment in an elephant, elephant owners likely would not be willing to simply donate their elephants for reintroduction without some monetary return. But perhaps if donors were given status and shares in the revenue from tracking style tourism this could be an effective way to increase tourism revenues and repopulate Thailand's jungles with elephants. This could benefit owners as well since they would not have to worry about day to day expenses of keeping captive elephants like buying enough food. And in turn, elephants will be able to eat a diverse diet and as much as they want. With its jungles finally revitalized, perhaps, the pride that Thai people feel toward their biodiversity (personal communication with scientist: 2017-08-04), particularly elephants, may return.

This pride, though, seems to be overshadowed by a loss of connection with the living elephant. The connection needs to be rediscovered. While its image and symbol are important spiritually, elephants' intelligence can also provide something relatable to humans. If the spirituality is not enough for laypeople to want to protect the wild elephants, then using elephants' social structure and emotions could change that. Their high levels of intelligence make them more relatable to humans (Plotnik, de Waal, and Reiss 2006), and thus makes them more sympathetic figures (personal communication with scientist: 2017-08-04). But also, their communal raising of calves and long-term companionships (de Silva and Wittemyer 2012; de Silva, Ranjeewa, and Kryazhimskiy 2011) offer similar ideals of family in humans and could increase one's ability to relate to and care about an elephant.

The spatial habitat modeling portrays a potential for a positive future for the elephants, but, it requires work from humans to make it possible. Humans need to improve the laws that

protect elephants. Standard minimum levels of care for captive elephants are necessary along with well-trained mahouts to take care of them. Registration systems should include DNA testing to decrease the likelihood of poaching and smuggling elephants, as paternity can be ensured with increasing generations. Scientific research on population counts and carrying capacity, and elephant rehabilitation programs all need more prioritization, because the elephant is a symbol of Thailand. Historically, the elephant played a major role in securing the borders, enhancing industries, and promoting wealth and diplomacy. Culturally, the elephant is imperative to both Buddhist and Karen tradition. It may not be known now how many elephants that Thailand's jungles can support, what techniques successfully prevent human-elephant conflict, and approximately how many elephants are in Thailand, but these are the studies that need to be prioritized. Without this knowledge, conservation measures will be done more by guesswork, and they might not be the best course of action.

This study offers some general understanding of why the elephants are declining in Thailand and what can be done to preserve what is remaining of the population. Possible sources of error in this study are the small sample size for the interviews and lack of randomization of interviewees. Additionally, interviewees may have felt the need to answer questions with answers that they thought were desired, despite being told that there were no right or wrong answers to the questions. For example, farmers may not like elephants coming onto their land, but choose not to say so to an elephant conservation organization. Additionally, the Western-Thai cultural differences may have caused Thai interviewees to answer questions that they believe would appeal to western ideals.

In the species-distribution model, sources of error may come from GBIF, as it is a wiki-like platform for gathering data on species occurrences. There are likely to be other areas where

elephants are spotted but are not reported in the data system, or elephants could be counted twice. Forest cover was held constant for simplicity, but it is likely that with human development and climate change that forest cover will change. Since Thailand is rapidly developing still, areas near cities are more likely to lose forests (Hirsch 1988). Areas near metropolitan areas that may be prone to development are not good candidates for conservation areas, as they may become adjacent to urban sprawl, intensifying the edge effect of the conserved area or human-elephant conflict. This model also only looked at elevation, temperature, precipitation, and elevation for simplicity. Adding more bioclimatic variables may increase the accuracy of the model.

The fact that the areas where elephants would thrive do not have elephants living there now suggests there could be a problem with the model. But the statistics in Appendix B show the model is strong and make it possible that there are other issues at play. Perhaps the areas of Northern Thailand that are hospitable are the national parks in that area that do not currently have any elephants since they are areas that were protected for tree preservation (personal communication with foundation worker: 2017-07-10).

Additionally, one could run the future MaxEnt model with different emission scenarios and based on different climate models for a better sense of how different scenarios of climate futures will affect elephant habitats. More interviews should be conducted with a wider array of the types of people, including government workers, elephant ecologists, and lay-people for a more holistic representation of Thai perceptions of elephants and the steps being taken to conserve them. Finally, studies can investigate the practicality of implementing the necessary reforms to revitalize the elephant population. Before any of this occurs, carrying capacities and accurate population counts need to be obtained for proper conservation efforts.

Despite these possible sources of errors, this study raises more questions as to what can be done to conserve the elephants. Why are the national parks in Northern Thailand free of elephants? How long do the elephants have to recover? How much does the government prioritize elephant protection? With a better understanding of Thailand's plans for elephants now and in the future, we can better make conservation decisions. Because with the right measures, elephants have a future worth fighting for.

Acknowledgments:

References:

'Activities and Projects'. 2018. Elephant Reintroduction Foundation, Accessed 2 April 2018.

'Asian Elephant'. 2017. National Geographic Partners, Accessed 10 December 2017.

de Silva, Shermin, Ashoka DG Ranjeewa, and Sergey Kryazhimskiy. 2011. 'The dynamics of social networks among female Asian elephants', *BMC Ecology*, 11: 17.

de Silva, Shermin, and George Wittemyer. 2012. 'A Comparison of Social Organization in Asian Elephants and African Savannah Elephants', *International Journal of Primatology*, 33: 1125-41.

Delang, Claudio O. 2005. 'The Political Ecology of Deforestation in Thailand', *Geography*, 90: 225-37.

Duer, Connie, Tom Tomasi, and Charles I. Abramson. 2016. 'Reproductive Endocrinology and Musth Indicators in a Captive Asian Elephant (Elephas maximus)', *Psychological Reports*, 119: 839-60.

Ehrlich, Paul. 2017. 'How Life is Changing for Thailand's Karen tribe', *South China Morning Post*.

"*Elephas Maximus* Linnaeus, 1758." In. 2017. *GBIF Secretariat*. GBIF Backbone Taxonomy.

Foerder, Preston, Marie Galloway, Tony Barthel, Donald E. Moore, III, and Diana Reiss. 2011. 'Insightful Problem Solving in an Asian Elephant', *Plos One*, 6: e23251.

Hirsch, Philip. 1988. 'Deforestation and development in Thailand', *Singapore Journal of Tropical Geography*, 8: 129-38.

IUCN. 2017. 'Elephas maximus', International Union for Conservation of Nature and Natural Resources, Accessed 17 October 2017.

Johnston, Kevin M., Kathryn A. Freund, and Oswald J. Schmitz. 2012. 'Projected range shifting by montane mammals under climate change: implications for Cascadia's National Parks', *Ecosphere*, 3: 1-51.

Karger, D. N., O. Conrad, J. Böhner, T. Kawohl, H. Kreft, R. W. Soria-Auza, N. E.

    Zimmermann, H. P. Linder, and M. Kessler. 2017a. "Data from: Climatologies at high

    resolution for the earth's land surface areas." In.: Dryad Data Repository.

Karger, Dirk Nikolaus, Olaf Conrad, Jürgen Böhner, Tobias Kawohl, Holger Kreft, Rodrigo

    Wilber Soria-Auza, Niklaus E Zimmermann, H Peter Linder, and Michael Kessler.

    2017b. 'Climatologies at high resolution for the earth's land surface areas', *Scientific data*,

    4: 170122.

Keown, Damien. 2001. *Buddhism: A Very Short Introduction* (Oxford University Press: Oxford).

Kontogeorgopoulos, Nick. 2009. 'The role of tourism in elephant welfare in Northern Thailand',

    Journal of Tourism.

Leimgruber, P, JB Gagnon, C Wemmer, DS Kelly, MA Songer, and ER Selig. 2003.

    'Fragmentation of Asia's remaining wildlands: implications for Asian elephant

    conservation', *Animal Conservation*, 6: 347-59.

Locke, Piers. 2013. 'Explorations in ethnoelephantology: social, historical, and ecological

    intersections between Asian elephants and humans', *Environment and Society*, 4: 79-97.

Lohanan, Roger. 2002. "The elephant situation in Thailand and a plea for co-operation." In

    GIANTS ON OUR HANDS. Bangkok: Food and Agricultural Organization of the United

    Nations.

Olivier, Robert. 1978. 'Distribution and status of the Asian elephant', *Oryx*, 14: 379-424.

Phangkum, Preecha, Richard C. Lair, and Taweepoke Angkawanith. 2005. *Elephant Care*

    Manual for Mahouts and Camp Managers (FAO & FIO: Lampang).

Plotnik, Joshua M., Frans B. M. de Waal, and Diana Reiss. 2006. 'Self-recognition in an Asian elephant', *Proceedings of the National Academy of Sciences of the United States of America*, 103: 17053-57.

Ringis, Rita. 1996. *Elephants of Thailand in Myth, Art, and Reality* (Oxford University Press: New York).

Schliesinger, Joachim. 2012. *Elephants in Thailand: Through the Ages* (White Lotus Co. Ltd.: Bangkok).

Silva, Jorge. 2016. "Ayuthaya elephants and mahouts pay their respects at the Royal Palace where Thailand's late king Bhumibol Adulyadej is lying in state in Bangkok." In. Phillipines: ABS CBN News.

Sukumar, R. 2006. 'A brief review of the status, distribution and biology of wild Asian elephants Elephas maximus', *International Zoo Yearbook*, 40: 1-8.

"Taken for a Ride: The Conditions for Elephants Used in Tourism." In. 2017. London: World Animal Protection.

Tipprasert, Prasob. 2002. "Elephants and ecotourism in Thailand." In *GIANTS ON OUR HANDS*. Bangkok: Food and Agricultural Organization of the United Nations.

Trainor, Anne M., and Oswald J. Schmitz. 2014. 'Infusing considerations of trophic dependencies into species distribution modelling', *Ecology Letters*, 17: 1507-17.

Trisurat, Yongyut, Rob Alkemade, and Peter H Verburg. 2010. 'Projecting land-use change and its consequences for biodiversity in Northern Thailand', *Environmental Management*, 45: 626-39.

Tuanmu, Mao-Ning, and Walter Jetz. 2014. 'A global 1-km consensus land-cover product for biodiversity and ecosystem modelling', *Global Ecology and Biogeography*, 23: 1031-45.

Varma, Surendra, Nguyen Xuan Dang, Tran Van Thanh, and R. Sukumar. 2008. 'The Asian

elephants Elephas maximus of Cat Tien National Park, Vietnam: status and conservation

of a vanishing population', *Oryx*, 42: 92-99.

Appendices:

Appendix A: R Studio Script for Elephant Distribution Model

```
##ensure the required packages are loaded
library(raster)
library (dismo)
library (XML)
library (rgeos)
library (maptools)
library(sp)
library(rasterVis)
library(rgdal)
library(car)
library(rJava)

##download point occurrences from Global Biodiversity Information Facility
(GBIF)
gbifpoints=gbif('Elephas','maximus',download=T,geo=T)
##eliminate points without latitude and longitude
gbifpoints=gbifpoints[!is.na(gbifpoints$lat),]

##import expert range and make it a data frame
ele_range=readOGR("/Users/Maddy/Documents/School/Thesis/Asian Elephant
Distribution/species_7140.shp","species_7140")
ele_range=spTransform(ele_range,CRS("+proj=longlat +ellps=WGS84
+datum=WGS84 +no_defs"))

##combine the datasets
ele_points=rbind.data.frame(data.frame(src="gbif",obs=1,lat=gbifpoints$lat
,lon=gbifpoints$lon))

##exclude points without lat/long
ele_points1=na.exclude(ele_points)

##turn into a spatial dataframe and define the projection
coordinates(ele_points1)=c('lon','lat')
projection(ele_points1)="+proj=longlat +ellsp=WGS84 +datum=WGS84 +no+defs"

##create a combined src_presence field for easy plotting
ele_points1$type=paste(ele_points1$src,ele_points1$obs,sep="_")

##import country borders
World=readOGR("/Users/Maddy/Dropbox/Solitary_Tinamou/shp/world_country_adm
in_boundary_shapefile_with_fips_codes.shp")
```

```
projection(World)="+proj=longlat +ellsp=WGS84 +datum=WGS84 +no_defs"

##look at data within Southeast Asia
plot( World , xlim=c(92,126), ylim=c(0,29) )
points( ele_points1 , col='red' , pch=8 )

##filter observations that are far from Thailand
##to do so you need to do an equidistant projection
dproj=CRS("+proj=eqc +lat_ts=0 +lat_0=0 +lon_0=0 +y_0=0 +a=6371007
+b=6371007 +units=m +no_defs")
ele_points1$dist=gDistance(spTransform(ele_points1,dproj),spTransform(ele_
range,dproj),byid=T)[1,]


## we now have distance in meters so let's look at the values
hist(ele_points1$dist/1000,xlab="km to expert range")

##drop points that are greater than 10km from expert range
ele_points_distclip=ele_points1[ele_points1$dist<1000000,]

##plot again with points within the range
plot( World , xlim=c(92,126), ylim=c(0,29) )
points( ele_points_distclip , col='red' , pch=8 )
spplot(sp.points(ele_points_distclip, col='red',pch=8))+
  layer(sp.polygons(World))+
  layer(sp.polygons(ele_range, fill = "grey"),under=T)
##plot for only Thailand
plot(World,xlim=c(97,102),ylim=c(5,20))
points(ele_points_distclip,col='red',pch=8)



##import environmental data (land cover, average temp, precipitation) and
stack them
Con1=raster("/Users/Maddy/Documents/School/Thesis/Geospatial_Analysis_Data
/consensus_full_class_1.tif")
Con2=raster("/Users/Maddy/Documents/School/Thesis/Geospatial_Analysis_Data
/consensus_full_class_2.tif")
Con3=raster("/Users/Maddy/Documents/School/Thesis/Geospatial_Analysis_Data
/consensus_full_class_3.tif")
Con4=raster("/Users/Maddy/Documents/School/Thesis/Geospatial_Analysis_Data
/consensus_full_class_4.tif")
Precip=raster("/Users/Maddy/Documents/School/Thesis/Geospatial_Analysis_Da
ta/CHELSA_bio10_1.tif")
Temp=raster("/Users/Maddy/Documents/School/Thesis/Geospatial_Analysis_Data
/CHELSA_bio10_12.tif")

##make same extent
ex=extent(92,126,0,29)
Con1=crop(Con1,ex)
Con2=crop(Con2,ex)
Con3=crop(Con3,ex)
Con4=crop(Con4,ex)
Precip=crop(Precip,ex) ;
```

```
Precip = setExtent(Precip , ex)
Temp=crop(Temp,ex)
Temp = setExtent(Temp , ex)

##create env stack
env=stack(Con1, Con2,Con3,Con4,Temp,Precip)

##get total percent of forest cover
forest=sum(env[[grep("consensus",names(env))]])
names(forest)="forest"
##crop forest
forest=crop(forest,ex)
##add forest to env stack
env=stack(env,forest)
##rename again
names(env)[names(env)=="forest.1"]="forest"

##import elevation data (downlaoded from GMTED 2010)
elevation=raster("/Users/Maddy/Documents/School/Thesis/md30_grd/md30_grd/"
)
##make same extent
elevation=crop(elevation,ex)
elevation = setExtent(elevation , ex)
##add elevation to env stack
env=stack(env,elevation)
##rename again
names(env)[names(env)=="md30_grd"]="elevation"

##rename for convenience
names(env)[names(env)=="CHELSA_bio10_12"]="Temp"
names(env)[names(env)=="CHELSA_bio10_1"]="Precip"

##list all env data
names(env)

##make stack for just variables I care about
env1=stack(elevation,forest,Precip,Temp)

##see how points and compare to each environmental variable
plot(env[["Temp"]],xlim=c(92,126),ylim=c(0,29))+
  points(ele_points_distclip,col='red',pch=8)
plot(env[["Precip"]],xlim=c(92,126),ylim=c(0,29))+
  points(ele_points_distclip,col='red',pch=8)
plot(env[["forest"]],xlim=c(92,126),ylim=c(0,29))+
  points(ele_points_distclip,col='red',pch=8)
plot(env[["elevation"]],xlim=c(92,126),ylim=c(0,29))+
  points(ele_points_distclip,col='red',pch=8)

##add environmental data to the points
ele_points_env=extract(env,ele_points_distclip,sp=T)

##make bivariate plots for each variable versus the other
xyplot(forest~Precip,groups=type,data =
ele_points_env@data,auto.key=T,xlim=c(125,300),ylim=c(-10,125))+
```

```
      layer(panel.ellipse(x,y,groups =
ele_points_env$type,subscripts=T,level=.68))

xyplot(forest~elevation,groups=type,data =
ele_points_env@data,auto.key=T,xlim=c(-300,1500),ylim=c(-10,125))+
  layer(panel.ellipse(x,y,groups =
ele_points_env$type,subscripts=T,level=.68))

xyplot(forest~Temp,groups=type,data =
ele_points_env@data,auto.key=T,ylim=c(-10,125))+
  layer(panel.ellipse(x,y,groups =
ele_points_env$type,subscripts=T,level=.68))

xyplot(Precip~Temp,groups=type,data =
ele_points_env@data,auto.key=T,ylim=c(125,325))+
  layer(panel.ellipse(x,y,groups =
ele_points_env$type,subscripts=T,level=.68))

xyplot(Precip~elevation,groups=type,data =
ele_points_env@data,auto.key=T,xlim=c(-300,1500),ylim=c(125,325))+
  layer(panel.ellipse(x,y,groups =
ele_points_env$type,subscripts=T,level=.68))

xyplot(Temp~elevation,groups=type,data =
ele_points_env@data,auto.key=T,xlim=c(-300,1500))+
  layer(panel.ellipse(x,y,groups =
ele_points_env$type,subscripts=T,level=.68))

##fit maximum entropy model to data
model1=maxent(env,ele_points_distclip)
##get summary
model1
##find out which factors are important
plot(model1)

##Create new stack to only have variables we care about
env1=stack(elevation,forest,Temp,Precip)
##rename for convenience
names(env1)[names(env1)=="CHELSA_bio10_12"]="Temp"
names(env1)[names(env1)=="CHELSA_bio10_1"]="Precip"
names(env1)[names(env1)=="md30_grd"]="elevation"
##run MaxEnt model
model2=maxent(env1,ele_points_distclip)
##getsummary
model2
##find out which factors are important
plot(model2)

##use model to predict the range
max_pred=predict(model2,env1)

##Plot predictions
levelplot(max_pred,col.regions=rainbow(20,start=.2,end=.9),margin=F,xlim=c
(95,115),ylim=c(0,25))+
```

```
    layer(sp.polygons(ele_range,lwd=1.5,col="white"))+
    layer(sp.polygons(World,lwd=1,col="black"))+
    layer(sp.points(ele_points_distclip,col="red",pch = 8))


##Now we do future model!!!!
##Import future data
Future_Precip=raster("/Users/Maddy/Documents/School/Thesis/Geospatial_Anal
ysis_Data/CHELSA_bio_mon_HadGEM2-CC_rcp45_r1i1p1_g025.nc_1_2041-2060.tif")
Future_Temp=raster("/Users/Maddy/Documents/School/Thesis/Geospatial_Analys
is_Data/CHELSA_bio_mon_HadGEM2-CC_rcp45_r1i1p1_g025.nc_12_2041-2060.tif")

##make same extent
Future_Precip=crop(Future_Precip,ex)
Future_Temp=crop(Future_Temp,ex)
Future_Precip=setExtent(Future_Precip,ex)
Future_Temp=setExtent(Future_Temp,ex)
##create future env stack
env_future=stack(forest,Future_Precip,Future_Temp,elevation)

##check future env variable
names(env_future)

##rename for conveinence
names(env_future)[names(env_future)=="CHELSA_bio_mon_HadGEM2.CC_rcp45_r1i1
p1_g025.nc_12_2041.2060"]="Future_Temp"
names(env_future)[names(env_future)=="CHELSA_bio_mon_HadGEM2.CC_rcp45_r1i1
p1_g025.nc_1_2041.2060"]="Future_Precip"
names(env_future)[names(env_future)=="md30_grd"]="elevation"
names(env_future)[names(env_future)=="forest"]="forest"

##see how new environmental data compares to points
plot(env_future[["Future_Temp"]],xlim=c(92,126),ylim=c(0,29))+
  points(ele_points_distclip,col='red',pch=8)
plot(env_future[["Future_Precip"]],xlim=c(92,126),ylim=c(0,29))+
  points(ele_points_distclip,col='red',pch=8)

##add environmental data to future plots
future_ele_points=extract(env_future,ele_points_distclip,sp=T)

##make Bivariate plots for the ones with new variables
xyplot(forest~Future_Temp,groups=type,data =
future_ele_points@data,auto.key=T, ylim=c(-10,125))+
  layer(panel.ellipse(x,y,groups =
future_ele_points$type,subscripts=T,level=.68))

xyplot(forest~Future_Precip,groups=type,data =
future_ele_points@data,auto.key=T, ylim=c(-10,125),xlim=c(150,325))+
  layer(panel.ellipse(x,y,groups =
future_ele_points$type,subscripts=T,level=.68))

xyplot(Future_Precip~elevation,groups=type,data =
future_ele_points@data,auto.key=T,ylim=c(150,325),xlim=c(-300,1500))+
```

```
    layer(panel.ellipse(x,y,groups =
future_ele_points$type,subscripts=T,level=.68))

xyplot(Future_Temp~elevation,groups=type,data =
future_ele_points@data,auto.key=T,xlim=c(-300,1500))+
   layer(panel.ellipse(x,y,groups =
future_ele_points$type,subscripts=T,level=.68))

xyplot(Future_Precip~Future_Temp,groups=type,data =
future_ele_points@data,auto.key=T, ylim=c(150,325))+
   layer(panel.ellipse(x,y,groups =
future_ele_points$type,subscripts=T,level=.68))

##do maxent model, get summary check variable contribution
future_model1=maxent(env_future,ele_points_distclip)
future_model1
plot(future_model1)

##use model to understand future range
future_max_pred=predict(future_model1,env_future)

##Plot predictions
levelplot(future_max_pred,col.regions=rainbow(20,start=.2,end=.9),margin=F
)+
   layer(sp.polygons(ele_range,lwd=1,col="white"))+
   layer(sp.polygons(World,lwd=1,col="black"))+
   layer(sp.points(ele_points_distclip,col="red",pch = 8))

##check to see what the difference between the 2 plots is
max_diff=((future_max_pred - max_pred)/(max_pred + future_max_pred))
levelplot(max_diff,col.regions=rainbow(20,start=.2,end=.9),margin=F,xlim=c
(95,115),ylim=c(0,25))+
   layer(sp.polygons(ele_range,lwd=1,col="white"))+
   layer(sp.polygons(World,lwd=1,col="black"))+
   layer(sp.points(ele_points_distclip,col="red",pch = 8))
```
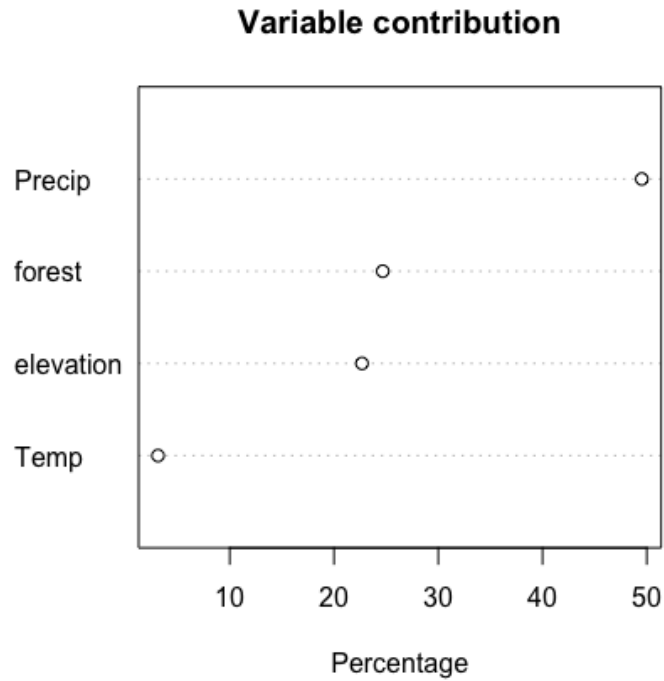
Figure B1: The percent that each variable (precipitation, percent forest cover, elevation, and temperature) contribute to the MaxEnt model. Figure B1 shows the relative importance of a variable, or the variable contribution, in the present day MaxEnt model. Precipitation has the largest effect on the model, and temperature has very little effect on the model. If temperature is removed, there would be little effect on the model and subsequent probabilities, but precipitation would alter the model and the probabilities greatly. Forest cover and elevation have moderate importance to the model.
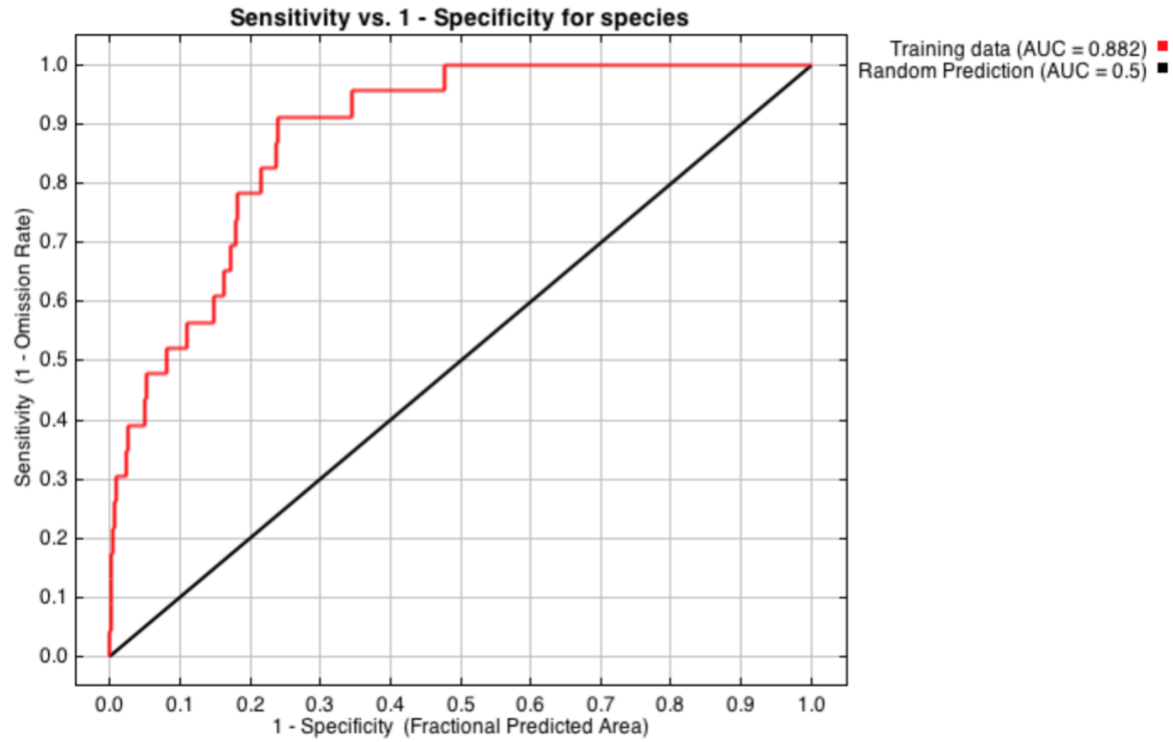
Figure B2: The Fractional Predicted Area vs the Sensitivity for elephants in the present day. The data quickly approaches 1.0, indicating a high strength of the model. This graph shows how much the model deviates from randomness. The best models quickly reach 1.0 and have an AUC near 1.0. With an AUC of 0.882, this model is able to create a habitat map that is much better than random. This is a strong model, with high predictability power.
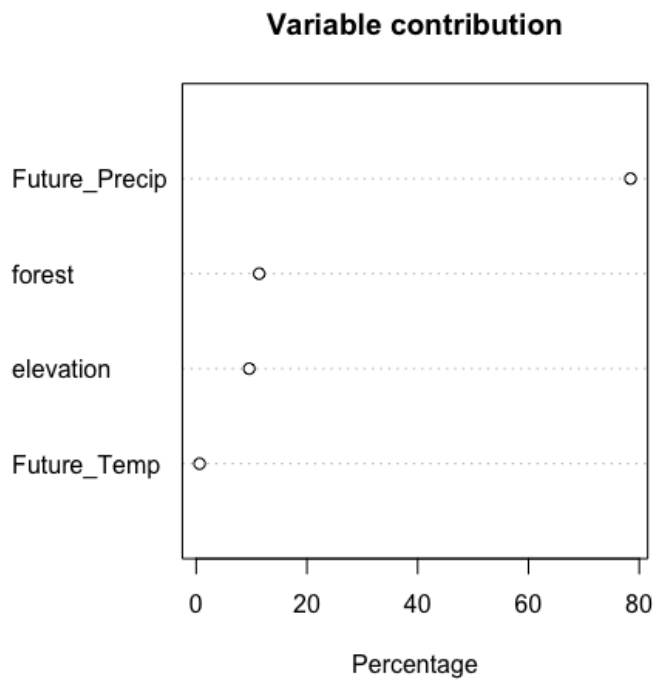
Variable contribution

Figure B3: The percent that each variable (future precipitation, percent forest cover, elevation, future temperature) contribute to the future MaxEnt model. It shows the variable contribution in the future MaxEnt model. Future precipitation has the largest effect on the model, and future temperature almost no effect on the model. Unlike the present model, elevation and percent forest cover have a very small contribution because future precipitation has a dominating impact on the model.
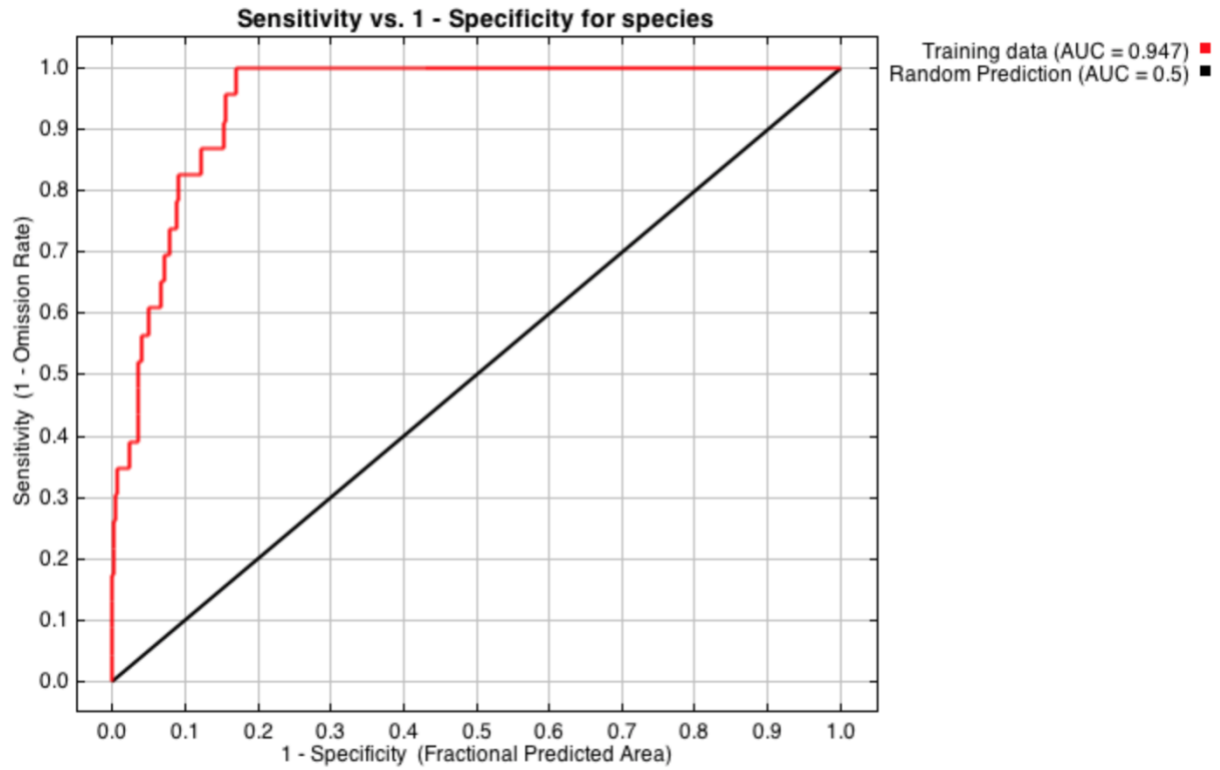
Figure B4: The Fractional Predicted Area vs the Sensitivity for elephants in the future. The data quickly approaches 1.0, indicating a high strength of the model. It shows how the future model deviates from randomness. The data approaches 1.0 faster than that of the present model and has a higher AUC (0.947). The future model clearly deviates from a model created with random data. The future model is strong and has a high degree of predictability.