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The Endangerment and Conservation of Wildlife in Costa Rica

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The Degradation of Forest Ecosystems in Costa Rica and the Implementation of Key Conservation Strategies

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Introduction

Biodiversity is defined as the "variability among living organisms… [including] diversity within species, between species, and of ecosystems" (CBD 1992). Many of the world's most biodiverse ecosystems are found in the tropics (Brown 2014a). The country of Costa Rica, which is nestled within the tropics of Central America, is no exception. Costa Rica is home to approximately 500,000 different species, which include mammals, birds, reptiles, amphibians, fish, invertebrates, and plants. Though Costa Rica's land area accounts for only 0.03 percent of the earth's surface, its species account for almost 6% of the world's biodiversity (Embajada de Costa Rica), demonstrating the high density of biodiversity in this small country. Much of Costa Rica's rich biodiversity can be found within its forests.

There are four major types of forest in Costa Rica. The rainforest has an annual rainfall of at least 2540 millimeters, or approximately 100 inches, and is distinguished by a continuous canopy of broad-leaved evergreen trees (Merriam Webster). The humid forest, while also a relatively wet environment, experiences less rainfall than the rainforest; the minimum annual rainfall is 2000 millimeters, or approximately 78 inches (Sector Bosque Húmedo Tropical). The humid forest may be either semi-deciduous or evergreen. The cloud forest is located on the highest parts of the mountains of Costa Rica and on some of its volcanoes (Áreas Protegidas y Parques Nacionales de Costa Rica 2013). It is generally covered by a thin layer of clouds and experiences light drizzles. Finally, the dry forest is found in the lowlands of Costa Rica (Janzen and Hallwachs 2016). It has a dry season that lasts from four to eight months, during which there is essentially no rain.

All types of forest in Costa Rica have undergone severe degradation due to various anthropological factors. Human society is largely responsible for forest destruction in Costa

Rica. Between 1950 and the late 1980s, Costa Rica lost a massive amount of forest cover. While forests covered 70 - 75% of the land in 1943 (Sader and Joyce 1988, Garita 1989), a survey revealed that only 29% of the land was forested in 1987 (McDade et al. 1994). Forest loss in Costa Rica is of particular concern because it results in an immense loss of biodiversity. Currently, 179 of the species in Costa Rica's forests are listed on the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species (IUCN 2020). 70 of these species are categorized as "Vulnerable" and 76 as "Endangered." The remaining 33 species on the list are classified as "Critically Endangered", meaning that they are in a "particularly and extremely critical state" (Mongabay 2019). The country of Costa Rica is rapidly losing its beautiful and diverse array of wildlife, and this process is irreversible. Once these species permanently disappear, there is no going back.

Though the destruction of forests in Costa Rica has proven to be both dire and extensive, measures are being taken to protect the threatened forest ecosystems. Over one quarter of the land in Costa Rica is protected by national parks, wildlife refuges, marine sanctuaries, national reserves, conservation areas, and biological reserves. At the head of these efforts are the Ministry of the Environment and Energy (MINAE) and the National System of Conservation Areas (SINAC). Costa Rica is recognized internationally as an exemplar of effective conservation. According to the Animal Welfare Institute, "Costa Rica has long been admired as the quintessence of principled and effective nature conservation in general and wildlife protection in particular" (Animal Welfare Institute 2020). Costa Rica's conservation efforts have slowed down the destruction of forests, restored previously damaged forests, and increased the populations of threatened and endangered wildlife species.

The goal of this study is to highlight and explain the major threats, both past and present, to Costa Rica's forest ecosystems. In other words, I discuss the anthropogenic processes that have destroyed forest cover and decreased the populations of local wildlife. I then demonstrate how Costa Rica's conservation system works to combat the threats to forests ecosystems. I highlight the major principles that have guided the conservation efforts of SINAC, Costa Rica's national system of conservation areas. These key principles have allowed Costa Rica to recover a substantial amount of forest cover and forest ecosystems, which demonstrates their ability to successfully counteract the major threats. There are many aspects of conservation that can be learned by a close examination of Costa Rica's strategies of forest recovery.

Threats to Forest Ecosystems

In this analysis, I discuss the major categories of threats to Costa Rica's forest ecosystems. The four main classes of threats are deforestation, forest fragmentation, climate change, and the hunting and capture of animals. Overall, these factors have led to the decline of many wildlife populations in Costa Rica's forests. Some of these threats lead to habitat destruction, which indirectly impacts the survival of wildlife. Other threats have directly killed off individual members of the species. Across the board, the declines of many of the wildlife species in Costa Rica's forests can be attributed to some or all of these categories of disturbances.

Deforestation

Deforestation has been occurring in Costa Rica as far back as the 1500s, with the first arrival of European settlers. Colonial records document that many houses in Lima, Perú were built during this time using wood from the coastal forests of the Guanacaste Province of Costa Rica (Janzen and Hallwachs 2016). The wood from these coastal forests also served as an easy and valuable resource for the colonizers' boats. However, damage to the country's forests did not halt after the sixteenth century. The most recent, major loss of forest area occurred throughout the period between 1950 and 1990, as can be seen in **Figure 1**. Estimated annual deforestation rates for the nation were 0.68% during the period from 1960-1979 and 0.89% from 1979-1986. (Calvo-Alvarado 2019). In the Guanacaste province alone, forest cover decreased from 37.8% to 23.6% during the period from 1960 to 1979, with an annual deforestation rate of 0.74%, a value even higher than the national rate. By the year 1994, Costa Rica had reported one of the highest relative deforestation rates in all of Central America (McDade et al. 1994). Though forest cover began to increase during the 1990s due to Costa Rica's conservation efforts (as can be seen in **Figure 1**), the destruction of forests has not stopped in the twenty-first century. As a result, Costa Rica continues to lose its primary forest, or the forest area with little visible indication of human activities and little ecological disturbance (Greenfacts Scientific Board 2020). Between 2001 and 2018, 1.6% of Costa Rica's primary forest cover was lost (Mongabay 1995-2020). In just the period from 2011 to 2018, 1,834.38 hectares of primary forest were destroyed. Although forest cover is increasing in Costa Rica, deforestation continues to occur to this day.

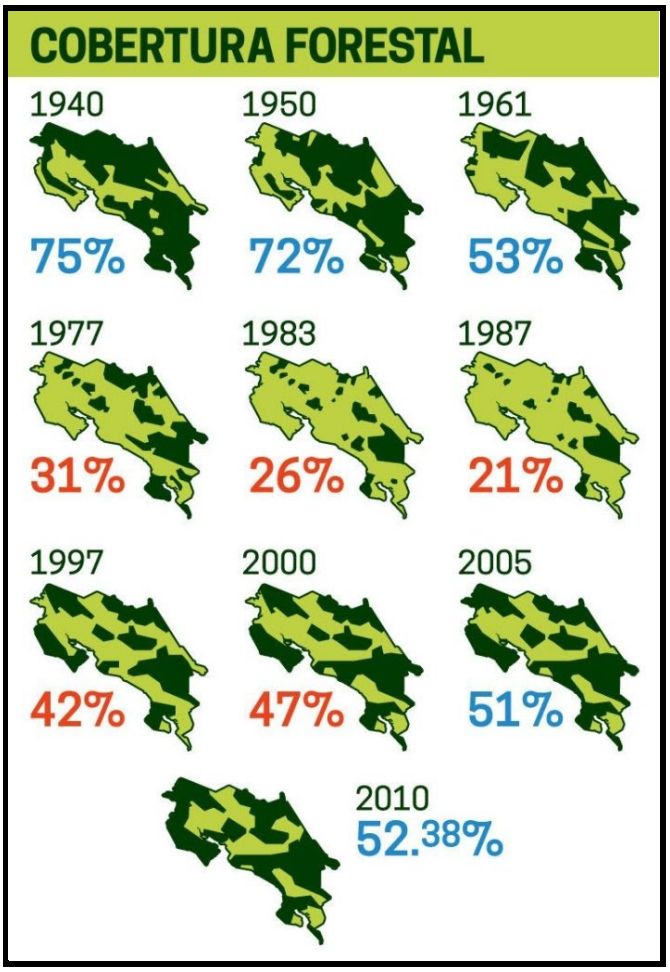

Figure 1. Costa Rica experienced its greatest losses of forest cover between 1950 and 1990. Percentages of forest cover for the whole country are displayed for each year from 1940 to 2010. The percentages in red indicate the smallest amounts of forest cover, which were of the highest concern (Source: Ortiz 2017).

A major driver of deforestation in Costa Rica has been the agricultural industry. Throughout most of the latter half of the twentieth century, there was a significant rise in agriculture in Costa Rica. The 1950s brought an increase in the international market price of meat, which motivated Costa Rica to expand its cattle industry (McDade et al. 1994). As a result, throughout the 1960s, pasture land increased by a total of 62%. Several decades later, in the early

1980s, a severe economic crisis hit in Costa Rica. The crisis led to a massive recession, during which employment shifted "in favor of the poorer jobs" (Fields 1988). Agriculture, which is a low-paying field, gained the largest amount of employment during this time, accounting for a total of 80% of new job creation. During the 1980s, people and farms began to encroach on the national park land in search of resources and land to live on during this time of economic crisis (Allen 2001). This led to the clearing of trees in the forests of the national park to create more areas for farming. Due to the unstable economic conditions of the country and people's need for land, tropical biologist Daniel Janzen referred to these local citizens as "almost undefeatable contenders" (Allen 2001). Land clearing for cattle ranching, subsistence production, and industrial agriculture was a major cause of the decline of forests during the 1980s (de Camino Velozo et al. 2016). Costa Rica reached its minimum forest cover in the late 1980s, as can be seen in **Figure 1**.

Agricultural practices often lead to forest fires, which contribute further to deforestation. Fires are highly prevalent in the forests of Costa Rica, especially in the dry forest. Despite conservation efforts that have led the recovery of forest area since 1990 (as shown in **Figure 1**), wildfires contributed significantly to forest destruction during the period from 1998 to 2004. **Table 1** displays the total amount of area covered by forest fires (in hectares) per year throughout this period. On average, between 1998 and 2004, wildfires burned through an average of 4,694.31 hectares of forest per year.

Area Burned by Forest Fires in Costa Rica from 1998 - 2004 (in Hectares)

1998	1999	2000	2001	2002	2003	2004	Mean Annual	Total (from 1998 to 2004)
7,818.00	2,003.00	3,500.50	5,741.50	7,375.90	976.27	5,445.01	4,694.31	25,042.18

Table 1. The numbers of hectares of forest area burned per year by wildfires in Costa Rica, during the period from 1998 to 2004 (Source: MINAE/SINAC 2005, cited by Robbins 2006).

Although fires can occur naturally in the dry forest ecosystem, most fires in the dry forests of Central America are induced by humans (Middleton et al. 1997) The Guanacaste province is the most susceptible to forest fires, as it is the driest region of the country (de Camino Velozo et al. 2016) and contains a particularly large section of dry forest. According to *The Green Phoenix*, an analysis of forest restoration in Guanacaste by William Allen, although some fires are accidental, many farmers and ranchers intentionally set fires during the dry season to burn the cover off of their fields (Allen 2001). These fires are mainly created to prevent the forest from advancing into their fields and to trigger the growth of grass shoots, which their cattle love. Although these fires are intended to be "controlled," they are often anything but that. The natural conditions of the Guanacaste region allow fires to spread rapidly; the hot temperatures, the winds blowing at 20 to 30 miles per hour, and the strong swirling gusts all kindle the fires (Allen 2001). The fires quickly enter the dried-out forests of Guanacaste, where they spread further and further, leading to large scale forest fires.

The open pastures of Guanacaste consist of an exotic, highly-invasive grass called Jaragua (*Hyparrhenia rufa*), which is native to Africa. Jaragua was introduced to Costa Rica in

the 1920s to provide aid to the cattle industry, because the native grasses of Costa Rica were not well-adapted for the large-scale grazing of cattle in pastures (Sáenz-Maroto 1955). The high flammability of jaragua grass allows the fires created by farmers to spread with immense speed into the nearby forests.

In addition to those induced by farmers, some fires are also set by local hunters. William Allen states that hunters in Guanacaste create fires both inside and outside of the national park, in order to open up meadows and to concentrate game (Allen 2001). This practice makes their prey easier to hunt. In some cases, the fires of Guanacaste are set as a recreational hobby. Some local residents intentionally create fires in order to enjoy watching the fields of jaragua grass burn.

The obvious consequence of these forest fires is that many, many trees are burnt to the ground, resulting in a major loss of forest cover. Furthermore, William Allen explains that the fires incinerate tree seedlings and saplings beneath the grass and destroy young trees that had the potential to create new patches of forest (Allen 2001). Thus, the fires kill off future generations of trees, preventing the forests from recovering from the damage that has been done to them. After a fire has swept through an area, the invasive jaragua grass begins to grow in place of the burned trees, essentially out-competing the native plant species. As fires continue to burn throughout the future, the jaragua can push back the forest until only pasture and grassland remains in its place. Not only do forest fires destroy the original habitats of local wildlife, they destroy the next generations of trees that could have become a secondary forest habitat for displaced organisms.

Fragmentation

Habitat fragmentation is a process through which a large area of habitat is transformed into a number of smaller patches, "isolated from each other by a matrix of habitats unlike the original (Wilcove et al. 1986). This definition implies four major effects: the reduction in the amount of habitat, the increase in the number of habitat patches, the decrease in the size of the habitat patches, and the increase in the isolation of the patches (Fahrig 2003). Therefore, the fragmentation of forest habitats differs from basic deforestation in that it does not only decrease the size of forest habitats, it also decreases connectivity *within* the habitats. It impacts not just the areas of forest that are cut down, but also the areas that remain. Species that are unable to cross through the "non-habitat", or the "matrix" area, will be confined to the habitat fragments (Fahrig 2003). Eventually, these fragments will be too small and too sparse to sustain the populations within them.

The fragmentation of forests is one of the most prominent threats to biodiversity and ecosystems in the tropics (Zahawi et al. 2015). Particularly in the dry forest, animals require large territories in order to ensure an adequate food supply in an adverse region with fluctuating conditions (Costa Rica 21, 1997-2019). Water is scarce during the dry season, so migration routes towards moist areas are critical for survival. In general, large mammals require particularly extensive amounts of territory in order to maintain their populations. The larger the animal, the more territory it will need to ensure enough food, water, shelter, etc. for the entire population. Forest fragmentation has significantly affected the survival of large mammal species such as jaguars (*Panthera onca*) by destroying the connectivity of their habitats. The monitoring of transects in the Barra del Colorado Wildlife Refuge in Northeast Costa Rica revealed a higher presence of jaguars on transects with larger areas of contiguous forest and lower levels of

disturbance (Khazan et al 2016). This indicates the importance of the connectivity of undisturbed forest; it allows large mammals such as jaguars to spread out into different parts of the forest to obtain resources. Forest fragmentation prevents jaguars from accessing all areas of their original habitat, which ultimately leads to decreases in their populations.

The effects of forest fragmentation are also exemplified in the case of the Central American squirrel monkey (*Saimiri oerstedii)*. The Central American squirrel monkey has a small geographic range that is restricted to the Pacific lowlands of southern Costa Rica and northern Panama. In Costa Rica, urban expansion, cattle ranching, and agriculture - mainly the creation of banana plantations and sugar cane and rice farms (Baldwin 1972 and 1976, Freese 1977), have deforested particular areas of this species' habitat. As a result, it was divided into two distinct areas. This forest fragmentation has diminished the Central American squirrel monkey's "extent of occurrence" (Ceballos et al. 2019), or the area contained within the shortest contiguous boundary that encompasses all the sites of present occurrence of the species. It was determined that the extent of occurrence of the Central American squirrel monkey is currently less than half of its historical value (Ceballos et al. 2019). In addition, the connectivity of its habitat has decreased greatly.

The patches of forest that compose the new, fragmented habitats of both the Central American Squirrel Monkey and the jaguar are smaller and more irregularly shaped than their original habitats. As a result, the populations of these two species are confined to areas that are unsuitable for maintaining their populations. Due to a lack of sufficient resources in these fragments, such as food and shelter, the survival and reproduction of the Central American squirrel monkey and the jaguar have been greatly affected. The Central American squirrel monkey is currently listed as "Endangered" on the IUCN Red List, and its populations continue

to decline (IUCN 2020) due to the effects of forest fragmentation. Although the jaguar is listed as "Near Threatened" on a global scale, its populations are currently decreasing. So, it is likely that it will become endangered in the future, if these trends continue.

Forest fragmentation places pressure on the wildlife in Costa Rica's forests. It is true that species such the Central American squirrel monkey and the jaguar do not only exist in Costa Rica, but as their numbers decrease in Costa Rica, their overall global populations decrease. This impacts the ability of these species to rebound from endangerment and to recover their populations' original numbers.

Climate Change

It is widely known that climate change is a highly damaging global process. Climate change refers to a significant variation in weather conditions over several or more decades (Denchak 2017). The most common climatic changes are those related to precipitation and temperature. In Central America, climate change is predicted to be highly prevalent throughout the coming years. The Intergovernmental Panel on Climate Change (IPCC) projected that by the year 2080, temperatures in Central America will have increased by 1- 5 °C during the dry season and by 1.3-6 °C during the wet season (Magrin et al. 2014). Magrin et al. 2014 projected that the overall precipitation of Central America in 2080 will have decreased by 30% or increased by 5%, with a high spatial variability (Magrin et al. 2014).

As a relatively narrow strip of land that is bordered by two oceans, Costa Rica is highly vulnerable to climatic events. The El Niño - Southern Oscillation (ENSO) cycle causes severe droughts on the Pacific Coast, while cold air masses from North America cause floods on the Caribbean side. Costa Rica also suffers from storms and cyclones that are induced by climate change. The country's forest ecosystems are particularly threatened by climatic fluctuations. In

Costa Rica, temperature and precipitation have a profound effect on forest ecosystems, as the different forest types have very specific ranges of temperature and precipitation. The United Nations Development Programme determined that climate change events can lead to a significant reduction of tropical, humid premontane, and highly human montane forests.

According to researcher Diane Srivastava in a lecture at Área de Conservación Guanacaste, climate change in the tropics leads to changes in precipitation within forests, which increase the frequency and intensity of droughts (Srivistava and Amundrud 2019). According to Srivastava, the variability in precipitation in Costa Rica has collectively increased since the turn of the century. Some models have suggested that in pre-montane areas of Costa Rica, up to 40% of rain may be lost as a result of climate change.

One part of the forests that faces the highly detrimental effects of climate change are the aquatic ecosystems (Srivistava and Amundrud 2019). This is demonstrated through the case of bromeliads, a type of epiphyte found in the humid forests of Costa Rica. In the montane humid forests, bromeliad size correlates with elevation, since it is colder at the top of the mountain and warmer near the bottom. Strivastava refers to bromeliads as the most important aquatic ecosystems within forests (Srivistava and Amundrud 2019). These exotic plants fill up with water when it rains, and they can hold quite a significant amount of water (Srivistava and Amundrud 2019). Invertebrates such as insects live within bromeliads; the bromeliads produce approximately half a kilogram of fresh insects per hectare of forest area. In fact, the bromeliads house entire trophic networks within themselves. However, the survival of bromeliads is greatly compromised by droughts. Due to decreases in precipitation in the humid forests of Costa Rica, bromeliads sometimes dry out, especially the smaller ones. This affects the ability of insects to survive and reproduce within them. For example, the larvae of one particular species of

damselfly must spend at least nine months in a bromeliad before they are able to mature. So, in times of drought, this damselfly species must seek shelter in the larger bromeliads, which are less susceptible to droughts. Since larger bromeliads only survive in the lower part of the montane forest, where it is warm and wet, this species of damselfly has become specifically restricted to these areas.

Drought patterns can also lead to changes in trophic roles in Costa Rican forests (Srivistava and Amundrud 2019), which damages the trophic networks. For example, insects of the family *Tipulidae* become predators during periods of drought, posing a threat to other insects such as mosquitoes. Before water became scarce in the forests, *Tipulidae* did not predate on other insects. Climate change has disrupted the natural balance of the trophic network within the bromeliad's aquatic ecosystem.

Climate change has also been linked to more extreme periods of El Niño, a phase of natural temperature fluctuations in which the climate becomes hotter and drier (Steffens 2018). This has led to more frequent and intense droughts in Costa Rica. The El Niño of 2014-2016 produced the strongest drought that has occurred on Costa Rica's pacific coast since the year 1937 (Hidalgo et al. 2016). According to Jenkins 2012, droughts often have spatially extensive impacts that can affect regions for indefinite periods of time (Vignola et al. 2018). The forest is one region that is negatively impacted by the increases in droughts. The example of the white-collared manakin (*Manacus candei*), a tropical bird in Costa Rica, demonstrates the impacts of El Niño on forest wildlife. A study by Wolfe et al. revealed that the dry weather induced by El Niño influenced manakin survival in young forest areas (Wolfe et al. 2015). The survival of manakins is variable in the young forest, and this species is therefore very vulnerable to climatic changes.

The forests of Costa Rica and the wildlife they contain are acclimated to very specific climatic conditions, especially precipitation. Climatic changes such as the increase of droughts affect the survival of these wildlife species, which leads to major declines in their populations.

The Hunting and Capture of Animals

In the tropics, people hunt for both food and income (Benitez-López et al. 2019) Most tropical forest areas are relatively accessible to hunters, as more than 80% of pantropical forest area is located within 20 kilometers of human settlements. Some of the most severe damages of over-hunting are done to big cat populations.

The human - big cat conflict in Costa Rica is a vicious cycle. Hunting by humans drives the big cats out of their natural territories, which forces them into closer proximity with human society (The Tico Times 2014). Big cats are often targeted by farmers after the cats have preyed upon their livestock. In the words of Daniel Corrales, the director of Costa Rica's jungle cat and livestock conflict program, "... the rancher has always seen… the jaguar, as an enemy." (The Tico Times 2014) However, a main reason why jaguars attack livestock is because their prey has been over hunted by humans. The effect on jaguars from the over-hunting of their prey was exemplified in Corcovado National Park. During the early half of the 2000s, the population of peccaries in this national park decreased due to poaching (Williams 2014). As a result, the jaguar population in the park fell too. Even when the peccary population began to restore itself, the jaguar population was not replenished as quickly. When jaguars' prey is diminished due to over-hunting, they are forced to turn elsewhere to find food. For large mammals such as jaguars, the decrease in prey substantially affects their ability to survive and to reproduce in the wilderness.

Another species that has been greatly affected by hunting is the Baird's tapir, the largest land mammal in all of Central America. The Baird's tapir is a coveted source of protein, especially for people living in rural areas (Freese and Saavedra 1991). Tapirs leave distinctive trails as they travel between waterholes and feeding patches, making them easy hunting targets. The hunting of tapirs has restricted the species to the least accessible wilderness areas. The Baird's tapir was once commonly found in most types of vegetation between sea level and the subalpine paramo, but it is now endangered throughout its entire range (IUCN 1994). Along with habitat loss, overhunting has been a principal cause for the decline of tapirs (IUCN 1982, Vaughan 1983, Emmons and Feer 1990).

Animal trading, which has mainly targeted birds and monkeys, has also been highly detrimental to the forest wildlife of Costa Rica. Tropical birds such as parrots and parakeets are often extracted from their natural habitats and sold illegally as pets. It was estimated that almost a quarter of Costa Rica's population has illegal pets such as tropical birds in their houses (BBC 2016). The capture of tropical birds has been extremely detrimental to their populations in the wild. For instance, the trapping of the flamboyant scarlet macaw has expelled the bird from most of its natural range, and it is now extinct throughout most of Central America (Lonely Planet 2018).

Monkey species have also suffered from declines due to the pet trade. During the 1960s, the Central American squirrel monkey was heavily traded, primarily for the biomedical industry (IUCN 1982, 1994). It was also captured for the pet trade (Mena Moya 1978). The geoffroy's spider monkey (*Ateles geoffroyi*) is also subject to pet trafficking in some regions of Costa Rica (IUCN 2020). Both the Central American squirrel monkey and the geoffroy's spider monkey are listed as "Endangered" on the IUCN Red List (IUCN 2020). Hunting and capture for the pet

trade, combined with the effects of habitat loss, have contributed to the endangerment of these species.

Costa Rica's forest ecosystems have been threatened for many years, due to deforestation, forest fragmentation, climate change, hunting, and the pet trade. However, all hope is not lost. In the 1990s, Costa Rica began to ramp up its conservation efforts. Part of this involved the establishment of the National System of Conservation Areas (SINAC). As a result, forest cover in Costa Rica has been increasing since the early 1990s, and the populations of some wildlife species have increased right along with it. The work of SINAC has been largely responsible for these positive trends. Due to the implementation of key effective strategies, Costa Rica can be viewed as an international role model in forest conservation.

Forest Conservation in Costa Rica

Internationally, Costa Rica holds a stellar reputation in conservation. It is considered to be a "pioneer in reforestation, forest management, and forest protection policies" (Baum et al. 2019). Costa Rica's National Protected Areas System (NPAS) is considered to be among the most successful in all of Latin America (González-Maya et al 2015). The National System of Conservation Areas (SINAC) is responsible for this system and the conservation that occurs within it. SINAC manages a number of conservation areas, which are smaller organizations that direct conservation in specific areas of the country. One of these organizations, Área de Conservación Guanacaste (ACG), has had particularly great success in its conservation efforts. ACG restores, conserves, and protects almost 235,000 local species. Birds such as the toucan and mammals such as the peccary, which had previously been restricted to the mountains, can now be observed at lower elevations and nearer to the coast. ACG is considered to be one of the most innovative and influential conservation projects in the entire world (Allen 2001). There are many

conservation lessons we can learn from Costa Rica's National System of Conservation Areas, including the principles that guide the smaller organizations such as Área de Conservación Guanacaste.

Overall, there are three key elements that form the foundation of forest conservation in Costa Rica. These components are the decentralization of power, the engagement of the public, and economic sustainability. The decentralization of power is important because it allows people to make decisions who are specialized in specific fields of conservation. Public engagement allows local citizens to coexist successfully with nature in the long term, without harming it. And finally, SINAC's focus on economic sustainability is vital; without sufficient funding, their quality conservation projects could not be carried out. In this section, I explain the importance of these principles in Costa Rica's national conservation work. I provide examples of how these strategies have worked both in the past and present to conserve forest ecosystems, mainly through the guiding actions of SINAC.

Decentralization of Power

International issues such as logging and uncontrolled deforestation are increasingly blamed on weak government management systems (Colfer 2016). Some governments have limited resources for managing illegal activities such as logging. In some cases, national laws against logging are unclear or too relaxed. These governments have demonstrated a lack of capability of managing the national protection of forests on their own. Thus, many countries are moving away from centralized systems of decision-making in forest conservation. (Colfer 2016).

Costa Rica is an example of a country that has created a decentralized system of conservation. The decentralization of power has given it massive advantages in the ability to protect its forests. The Ministry of Environment and Energy (MINAE) is a national organization

in Costa Rica that is in charge of administering resources to the country for environmental protection (Ministerio de Ambiente y Energía website). Under MINAE is the "National System of Conservation Area (SINAC). SINAC has divided its national territory into eleven different conservation areas, which together span across Costa Rica's seven provinces, essentially covering the entire country. "SINAC is a concept of integral conservation," displays the SINAC website, "which offers the possibility of developing a responsible governance, involving the State, civil society, private enterprise, and every individual of the country concerned and committed to building a healthy environment..." (National System of Conservation Areas website). According to an analysis of Costa Rica's protected areas system by the First Asia Parks Congress, SINAC has moved "from vertical to horizontal decision-making" (Induni et al. 2013). SINAC has both National and Regional Councils, which are responsible for deciding on institutional budgets and policies, as well as approving conservation plans. Regional Councils then create Local Councils for the management of protected areas, watersheds, biological corridors, etc. These National, Regional, and Local councils have brought SINAC closer to local governments, local communities, non-governmental organizations, and private entrepreneurs. It was determined that the empowerment of local stakeholders through this system improves public awareness and participation in conservation. It also allows the SINAC to be more responsive to the needs of local ecosystems.

The participation of local citizens in conservation is important because they are the most familiar with the local ecosystems. They have the greatest potential to develop site-specific solutions that are tailored to the needs of each region. For example, Área de Conservación Guanacaste is run by staff members who live in the Guanacaste province. These people see and experience the local wildlife of Guanacaste every day. They are familiar with the threats that

Guanacaste's human society presents to forest ecosystems. On the other hand, the staff members of Área de Conservación Tortuguero, located on the northeastern Caribbean side of Costa Rica, have expert knowledge of that specific region. They develop conservation solutions that address the specific needs of their area. It is clear that SINAC follows a model of decentralized power, as it relies on smaller institutions and groups of people to carry out conservation efforts throughout the country.

On a smaller scale, Área de Conservación Guanacaste has initiated its own decentralization of power, which it has accomplished by dividing its functions into programs. Each of ACG's programs falls under one of three categories: Support and Service, Management of Protected Areas, and Management of Natural Resources. The programs within these categories range from Restoration and Silviculture, to Protection and Fires, to Wildlife Management, to more. Each program has staff members that are trained in a specific field of conservation. This system allows ACG's conservation efforts to be carried out to the highest possible caliber. "It is in this way, through the specialization of functions, that we are able to operate and to focus our management towards the biodevelopment of ACG," state's ACG's website. This system demonstrates the decentralization of power because the different components of conservation are not carried out by one central entity. Instead, the projects are carried out by groups of staff members who are given the liberty to make their own decisions. Because it gives power to its individual departments, Área de Conservación Guanacaste is able to efficiently accomplish its goals in all aspects of conservation. This system also ensures support for staff members who may need help with certain projects. For example, Administrative Management, which falls under the Support and Service category, provides logistical support, such as the managing of finances.

Overall, the decentralization of power allows Costa Rica's conservation system to function on a regional basis. This is achieved in large part by the freedom given to smaller departments, which allows for the development of regional human capacity. Conservation is a long, exhausting, and difficult process that requires the collaboration of many minds that are specialized in different fields. It is clear that decentralization leads to specialization, which allows people to develop conservation solutions for many different species and ecosystems across Costa Rica.

Public Engagement

Área de Conservación Guanacaste is a perfect example of how SINAC's value of public engagement is put into action. ACG was originally created as a pioneer project with the goal of finding a model of conservation that transcended the traditional management of national parks (Blanco Segura 2002), by sustainably integrating human society with the ecosystems. This has meant using dynamic processes to integrate the biological, social, economic, political, and legal aspects of conservation. Instead of simply focusing on the basic conservation of wildlife, ACG went above and beyond by developing ways for human beings to cohabitate successfully with nature in the long term. ACG strives to not only protect local wildlife species, but to ensure their perpetual survival. Guided by its mission "to preserve, to utilize, and to get to know", ACG has achieved its goals through conservation work on local, national, international scales. This has largely involved the education and participation of local citizens.

The Biological Education Program is an integral component of Área de Conservación Guanacaste's effort to integrate human society with the environment. According to an analysis of biological education in Costa Rica, "To incorporate and integrate these species and their ecosystems into Costa Rica's socioeconomic fabric, and therefore sustain them into perpetuity,

we need to come to intensively know who they are, where they live, what they do, how to find them, and freely distribute this information to all society" (Área de Conservación Guanacaste 2018). In order to become *bioliterate*, people must be familiar with the natural capital of the area and be able to use it without causing damage to the ecosystems. Through the Biological Education Program, ACG instilled bioliteracy in 2,500 children from 48 local schools, for more than 14 years (Blanco Segura 2002). By educating local school children about local ecosystems and how human society can be destructive to them, ACG allows these young minds to develop into Costa Rica's future leaders in conservation. According to Daniel Janzen, an effective conservation area must have "very knowledgeable caretakers focused on the end goals of maximum quality biodiversity…" (Janzen 2000). Biological education transforms local children into these "knowledgeable caretakers." As children go through the Biological Education program, they begin to understand the diversity of interactions among different wildlife species and that they, as human beings, are a part of nature themselves (Área de Conservación Guanacaste 2012). This motivates the children to help protect the wildlife species they see on their walks on the forest's trails. One of the goals of the biological education program is for children to implement practices into their daily lives that will aid in conservation. These practices may be as simple as picking up trash on forest trails or educating their friends and family about the impacts of wildfires.

ACG has also used eco-tourism to aid its conservation efforts. It engages the public by educating tourists about local wildlife and conservation, as well as stimulating love for wildlife and a desire to protect it. For example, Área de Conservación Guanacaste's Ecotourism Program receives visitors from all over the world, who come to the national park having heard about, read about, or seen pictures of the beautiful landscapes and wildlife of Guanacaste. This program is a

"win-win" system. On one hand, tourists get to experience the stunning beauty of the wilderness of Guanacaste. From a lookout point, they can see the magnificent volcanoes Rincón de la Vieja, Orosí, y Cacao. They can walk the trails in the forest and observe white-faced monkeys, deer, exotic birds, guinea-pig-like "guatusas," and many unique tree species. As tourists gain a love and passion for the wildlife they see in the national park, they typically gain motivation to help protect it. It is much more likely that someone will make a donation to ACG after they watch a baby squirrel monkey swinging in the trees, whose survival, they then learn, is in jeopardy due to habitat loss. And upon a closer look at the beautiful fig trees with winding branches, a farmer may hesitate before setting fire to his fields that season.

The importance of exposing the public to threatened wildlife species extends beyond the bounds of Costa Rica. In June of 2019, a giant squid was spotted in U.S. waters for the very first time, in video footage from a research mission on the Gulf of Mexico (CNN 2019). Dr. Sonke Johnson, the leader of the expedition, reflected on the potential of the footage to help ocean conservation. "At a time when the environment is in crisis, people protect what they love," said Johnson, "and they love what they see." He asserted that seeing animals in their natural habitat can stimulate a love for animals that people do not normally see. "Love of nature is a stronger force for conservation than fear of doing the wrong thing," Johnson concluded. The Ecotourism Program of ACG seeks to prolong small moments of the public's exposure to Costa Rica's wildlife, and it has quite literally paid off. By exposing the public of Costa Rica to the wildlife of the national park, ACG stimulates passion in local citizens. In return, these citizens make donations of money and equipment to the organization, and sometimes they even apply to work at ACG or become volunteers. Área de Conservación Guanacaste's unique relationship with local citizens is truly a model of "what goes around, comes around."

Economic Sustainability

Área de Conservación Guanacaste functions on the basis that the conservation of ecosystems and biodiversity is everybody's collective responsibility (Área de Conservación Guanacaste, website). Therefore, ACG has collected donations and resources from non-governmental organizations and individual citizens as much as it has from the national government. Área de Conservación Guanacaste has a "Patrimonial Fund", the profits of which are applied in the administration and operation of the organization (Blanco Segura 2002). Since the beginning of its development, over $45 million have been invested in ACG, from both national and international donors. All staff members of ACG share the responsibility of seeking resources from private donors, a large part of which is done through the Foundation of National Parks of Costa Rica and the Guanacaste Dry Forest Conservation Fund (Área de Conservación Guanacaste, website). ACG stimulates imagination in its staff; they brainstorm new sources of income that will continue to strengthen the Patrimonial Fund (Blanco Segura 2002). As a result, ACG has been able to carry out its conservation efforts with as little cost to the national government as possible. ACG reaches out national and private organizations in Costa Rica, as well as local citizens, for donations. They also form connections with people and organizations in other areas of the world. For example, ACG hires interns from other countries. These interns are typically college students. After the interns spend several months learning about and participating in ACG's conservation programs, they are politely asked to request a donation from their university (or another local organization) to ACG. Sometimes these donations come in the form of money, and other times they are donations of equipment and resources. Overall, ACG has had over 10,000 private donors, which has been fundamental in the development and administration of this organization (Área de Conservación Guanacaste, website).

Another source of income for ACG are the ecosystems themselves. In accordance with one of its fundamental principles, that "the wilderness should be visualized as a productive sector of the region and of the country," ACG strives to obtain socio-economic benefits from local ecosystems. Área de Conservación demonstrates the value of obtaining benefits from the environment in a sustainable way. ACG does this through the "recognition and comprehensive assessment of the biodiversity and the ecosystems that are found within the conserved area, as a productive sector generating multiple benefits and services for society" (Blanco Segura 2002). One example of this is the Ecotourism Program. As tourists enjoy the beauty and wildlife of the natural park, they also contribute financially to ACG, because there is an admission fee to the national park. This money is then used to further ACG's conservation efforts. SINAC's other conservation areas also benefit financially from ecotourism. In just 2009, tourism in Costa Rica's national parks generated $1.357 billion (CINPE 2010), which represented 4.5% of Costa Rica's gross domestic product (Área de Conservación Guanacaste, website). Not only do SINAC's national parks protect forest ecosystems; they are also a source of funding for SINAC. Finding small ways to profit from local ecosystems allows Costa Rica's conservation system to sustain itself throughout time. In this way, conservation can be continued for many years to come.

CONCLUSIONS

It is clear that the forest ecosystems of Costa Rica are in great danger due to anthropological disturbances. This is due in large part to the close proximity of human society to forests in Costa Rica. The biodiversity contained in these forests is rich, unique, diverse, and ultimately irreplaceable. It is important to be aware of the detrimental effects of human society on these forests, so that informed, effective conservation actions can be taken to counteract them.

The major phenomena that have led to the decline of forest species and ecosystems in Costa Rica are deforestation, forest fragmentation, climate change, and the hunting and capture of animals. A main driver of deforestation and fragmentation has been the agricultural industry, which grew substantially throughout the second half of the twentieth century. Agriculture often leads to wildfires, which increase both the amount and the extent of deforestation. Climate change causes changes in temperature and precipitation, which alter the natural conditions that forest ecosystems depend on for survival. Through the hunting and capture of wildlife, large numbers of individuals are removed from wildlife populations. This directly causes their numbers to decline and affects the population's ability to reproduce.

Although the forests of Costa Rica have suffered from these harsh damages, the country is taking counteractive measures. Costa Rica's national conservation efforts, directed by the National System of Conservation Areas, have had great success in protecting the wildlife and ecosystems of the forests. There are three main categories of effective conservation that can be learned from Costa Rica's work. The first, the decentralization of power, allows for the development of regional human capacity and the incorporation of the needs of local ecosystems. The engagement of the public has the power to educate local citizens about the processes that damage forest ecosystems. At the same time, it drives local citizens to protect the forests. Finally, economic sustainability ensures financial support that allows conservation projects to be carried out effectively in the long term.

It is clear that people's ignorance of how their actions affect the wilderness has been a huge contributor to forest degradation in Costa Rica. Many Costa Ricans have relied on the environment to provide them with resources such as food, nutrients, land, and economic gain; however, they have failed to weigh the costs to local wildlife and ecosystems. As a result, the

habitats of many animals have been altered or destroyed, ecosystem services have been disrupted, and wildlife has been over hunted and captured. As a result of all of this, the populations of many species of Costa Rica's forests have massively declined, placing them in the categories of Threatened and Endangered. The almost 200 species listed on the IUCN Red List (IUCN 2020) emphasizes the danger to forest wildlife in Costa Rica. These animals and plants have existed on the planet Earth long before human beings, but the expansion of our society into their habitats has compromised their ability to survive and persevere in the wilderness.

SINAC's strategies should be viewed as a model for how conservation should occur in other countries throughout the world. By applying the principles of decentralization, public engagement, and economic sustainability, it may be possible to effectively recover damaged forest ecosystems, as well as other ecosystems, in other places on Earth. Costa Rica is a living reminder to the world that all hope is not lost with the environment. A strong commitment to conservation and the incorporation of these key principles have the ability to continue to reverse population losses on Earth throughout the future.

REFERENCES

Áreas Protegidas y Parques Nacionales de Costa Rica. 2013.

Bosque Nuboso. https://areasyparques.com/arboles/bosque-nuboso/

Allen, W. 2001. Green Phoenix: restoring the tropical forests of Guanacaste, Costa

Rica. Oxford University Press, New York. pp 310.

Animal Welfare Institute. 2020. Costa Rica Adopts Enlightened Wildlife Rules.

Annual report of the department of forestry. 1917. Annual Report of the Department of Forestry.

Área de Conservación Guanacaste (ACG). 2012. [Internet]. Youtube.com.

https://www.youtube.com/watch?v=4cDayq3MM_E

Área de Conservación Guanacaste. 2018. Project: "Bioliteracy for all: BIOALFA". Derived from “BioAlfabetización para todos”. Costa Rica - to become a bioliterate tropical country.

Área de Conservación Guanacaste: Fuente de Vida y Desarrollo [Internet]. c2012. Área de Conservación Guanacaste. https://www.acguanacaste.ac.cr/index.php.

Baldwin, J.D. and Baldwin, 3. (1972). The ecology and behaviour of Squirrel Monkeys (Saimiri oerstedi) in a natural forest in western Panama. Folia primat. 18: 161-18^. 2.

Baum A, Harms W, Foley T, Falz H. 2019. Costa Rica. Hamburg: Jahreszeiten Verlag GmbH.

Benitez-Lopez A, Santini L, Schipper AM, Busana M, Huijbregts MAJ. 2019. Intact but empty forests? patterns of hunting-induced mammal defaunation in the tropics. PLoS Biology. 17(5):e3000247.

Beth A. Middleton, Eduardo Sanchez-Rojas, Beth Suedmeyer, Astrid Michels. 1997. Fire in a tropical dry forest of Central America: A natural part of the disturbance regime? Biotropica. 29(4):515-7.

Blanco Segura, Roger. 2002. La conservación de la biodiversidad por medio de su biodesarrollo, un caso concreto: El Area de Conservación Guanacaste.

Brown JH. 2014a. Why are there so many species in the tropics? J Biogeogr. 41(1):8-22.

Calvo-Alvarado J, Jiménez V, Calvo-Obando A, Castillo M. 2019. Current perspectives on forest recovery trends in Guanacaste, Costa Rica. Int for Rev. 21(4):425-31.

De Camino Velozo, Ronnie; Villalobos, Roger and Morales Aymerich, Jean Pierre. 2016. Costa Rica Case Study. Food and Agriculture Organization of the United Nations.

CBD. 1992. *Convention on Biological Diversity. Article 2*. CBD.

Ceballos et al. 2019

Centro Internacional de Política Económica para el Desarrollo Sostenible [Internet]. CINPE; [updated 2019].

CNN [Internet]. 2019. Cable News Network; [updated 2019 June 22]. https://www.cnn.com/2019/06/21/us/giant-squid-on-camera-in-us-trnd/index.html

Colfer, Carol J. Pierce, and Doris Capistrano. *The Politics of Decentralization: Forests, Power, and People*. Routledge, 2016.

Costa Rica 21. 1997-2019. Tropical Dry Forest of Costa Rica.

Denchak, Melissa. 2017. "Global Climate Change: What you Need to Know." NRDC.

Embajada de Costa Rica [Internet]. Washington, D.C: Embassy of Costa Rica; [cited May 2020].

Emmons, L., and Feer, E. 1990. Neotropical rainforest mammals, a field guide. University of Chicago, Illinois.

Fahrig L. 2003. Effects of habitat fragmentation on biodiversity. Annu Rev Ecol Evol Syst. 34(1):487-515.

Fields GS. 1988. Employment and economic growth in Costa Rica. World Development. 16(12):1493-509.

Frankie GW, Mata A, Vinson SB. 2004. Biodiversity conservation in Costa Rica: learning the lessons in a seasonal dry forest. Berkeley: University of California Press.

Freese, Curtis H. 1977. Food habits of white-faced capuchins Cebus capucinus L. (Primates: Cebidae) in Santa Rosa National Park, Costa Rica. Brenesia. p. 43-56.

Freese, Curtis H. and Saavedra, Carlos J. 1991. Prospects for wildlife management in Latin America and the Caribbean. Neotropical wildlife use and conservation. P. 430-444.

Garita C, D. 1989. Nuestras reservas forestales y zonas protectoras. DGF [Internet].

Global Facility for Disaster Reduction and Recovery. 2011. Vulnerability, Risk Reduction, and

Adaptation to Climate Change.

González-Maya JF, Víquez-R LR, Belant JL, Ceballos G. 2015. Effectiveness of protected areas for representing species and populations of terrestrial mammals in Costa Rica. PLoS ONE. 10(5).

Greenfacts Scientific Board. 2020. Green Facts: Facts on Health and the Environment.

Hidalgo, Hugo G; Alfaro, Eric J; Mora, Natalie P; Durán-Quesada, Ana M; Amador, Jorge A; Muñoz, Ángel G. 2016. "La Sequía en Guanacaste: Qué tan Grande es?" Ojo al Clima.

Holling, and C.S. "Adaptive Environmental Assessment and Management." *Welcome to IIASA PURE*, John Wiley & Sons, 1 Jan. 1978, pure.iiasa.ac.at/id/eprint/823/.

BBC. c2016. BBC: Earth. BBC. Saving the 'wild pets' of Costa Rica; 2016. [updated 2020]. http://www.bbc.com/earth/story/20160207-saving-the-wild-pets-of-costa-rica.

Induni, Gustavo; Castillo, Jeffry; Osawa, Masaki. 2013. An overview to the Costa Rican protected areas´ governance model, some of the main gathered lessons to date. National system of conservation areas

IUCN. 2020. "IUCN List of Threatened Species."

IUCN. 1982. The IUCN mammal red data book, part 1. World Union for Nature, Gland, Switzerland. –

1994. The IUCN mammal red data book, part 1. IUCN red list of threatened animals. World Union for Nature, Gland, Switzerland

Janzen, DH. 2000. Costa Rica's Área de Conservación Guanacaste: A long march to survival through non-damaging biodevelopment. Biodiversity. 1(2):7-20.

Janzen, DH and Hallwachs, Winnie. 2016. Conservación de la Biodiversidad -Su Historia y Su Futuro en Costa Rica: El Caso del Área de Conservación Guanacaste (ACG). Costa Rican

Ecosystems. Chicago; London: The University of Chicago Press.

Khazan ES, Arias M, Fernández LM. 2016. Large mammal community composition and density under a disturbance gradient in northeast Costa Rica. Rev Biol Trop. 64(4):1553-64.

La Nacion. 2015. Sequía de 2014–2015 es la más intensa desde 1930 en Costa Rica.

Lonely Planet. 2018. Endangered Species.

Magrin, G.O. and Marengo, J.A. et al. 2014. Central and South America. In: Barros, V.R., et al., Eds., Climate Change 2014: Impacts, Adaptation, and Vulnerability, Part B: Regional Aspects, Cambridge, University Press, Cambridge, 1499-1566.

McDade, Lucinda A; Bawa, Kamaljit S.; Hespenheide, Henry A.; Hartshorn, Gary S. 1994. La Selva: Ecology and Natural History of a Neotropical Rainforest. Chicago (USA) and London (UK): The University of Chicago Press.

Mena Moya, R.A. 1978. Fauna y Caza en Costa Rica. R.M. Costa Rica.

Merriam-Webster. Rain Forest. https://www.merriam-webster.com/dictionary/rain forest.

Ministerio De Ambiente y Energía - República De Costa Rica, www.minae.go.cr/.

Middleton, Beth A.; Sanchez-Rojas, Eduardo; Suedmeyer, Beth; Michels, Astrid. 1997. Fire in a Tropical Dry Forest of Central America: a Natural Part of the Disturbance Regime? Biotropica. 29(4): 515-517.

Mongabay. 1995-2020. Deforestation Statistics for Costa Rica.

Mongabay. 2019. 1995-2018. List of Critically Endangered Species in Costa Rica [Internet].

National System of Conservation Areas (SINAC - Sistema Nacional De Áreas De Conservación), www.sinac.go.cr/EN-US/conozca/Pages/default.aspx.

Ortiz, Diego Arguedas. 2017. Mientras América latina deforestaba, Costa Rica ganó bosque. Por Que? https://www.ecoportal.net/temas-especiales/biodiversidad/arboles/mientras-

america-latina-deforestaba-costa-rica-gano-bosque-por-que/.

Robbins, A.M.J. 2006. Global Forest Resources Assessment 2005 - Report on Fires in the Caribbean and Mesoamerican Regions.

Sader, Steven A. and Joyce, Armond T. 1988. Deforestation rates and trends in Costa Rica, 1940 to 1983 source: Biotropica, vol. 20, no. 1, pp. 11-19: Association for tropical biology and conservation stable URL: Https://Www.jstor.org/stable/2388421

Sáenz-Maroto, A. 1955. Los forrajes de Costa Rica.

Sector Bosque Húmedo Tropical. https://www.acguanacaste.ac.cr/1999/educacion/sectorbhg.html

Srivistava, Diane and Amundrud, Sarah. 2019. Cambio Climático y Redes Tróficas en CR. Youtube.

Steffens, Gena. 2018. Changing Climate Forces Desperate Guatemalans to Migrate. National Geographic.

Sterling, E.J; Bynum, N; and Blair, M.E. 2013. Primate Ecology and Conservation: A Handbook of Techniques (1st ed.), Oxford University Press, Oxford.

The Tico Times. 2014. To Save a Predator: A History of Human-Jaguar Conflict in Costa Rica.

Vaughan, C. 1983. A report on dense forest habitat for endangered species in Costa Rica. Editorial de la Universidad Nacional, Heredia, Costa

Vignola R, Kuzdas C, Bolaños I, Poveda K. 2018. Hybrid governance for drought risk management: The case of the 2014/2015 El Niño in Costa Rica. International Journal of Disaster Risk Reduction. 28:363-74.

Wilcove DS, McLellan CH, Dobson AP. 1986. Habitat fragmentation in the temperate zone. Conservation Biology. ed. ME Soulé, pp. 237–56. Sunderland, MA: Sinauer

Williams, Adam. 2014. In Costa Rica, the Fight to Save the Hunted Jaguars. The Tico Times Costa Rica. www.ticotimes.net/2011/05/27/in-costa-rica-the-fight-to-save-the-hunted-jaguars.

Wolfe, Jared D.; Ralph, C. John; Elizondo, Pablo. 2015. Changes in the apparent survival of a tropical bird in response to the El Niño southern oscillation in mature and young forest in Costa Rica. Oecologia. 178(3):715-21.

Zahawi RA, Duran G, Kormann U. 2015. Sixty-seven years of land-use change in southern Costa Rica. PloS One. 10(11):e0143554.