

Protecting Nonhuman Primates in Peri-Urban Environments: A Case Study of Neotropical Monkeys, Corridor Ecology, and Coastal Economy in the Caribe Sur of Costa Rica

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Introduction

Peri-urban environments present an unusual set of challenges for non-human primates (NHP) due to habitat loss, habitat fragmentation, and competition with humans for resources (Jaman and Huffman 2013; Printes et al. 2010, but see Cunha et al. 2006). Although the drivers of habitat loss and fragmentation in these landscapes are numerous, some contributing factors include industrialized agriculture (see chapter “The Threat of Industrial Oil Palm Expansion to Primates and Their Habitats” this volume), urbanization, roads, and electricity and telephone grids (Lokschin et al. 2007; Maibeche et al. 2015; Meijaard et al. 2012; Printes et al. 2010; Vickers et al. 2015). These developments can negatively impact the survival rates of NHP populations (Lokschin et al. 2007; Meijaard et al. 2012, but see Jaman and Huffman 2013). Although protected areas remain a vital part of species conservation strategies, a stark reality is that all primate habitats cannot be strictly protected (Meijaard et al. 2012). In these unprotected areas, community-based conservation (Horwich and Lyon 2007) and ethnoprimateology (Fuentes and Hockings 2010) are essential for effectively managing and preserving NHP populations.

The anthropogenic matrix that is characteristic of peri-urban landscapes may introduce a range of problems for NHPs. This matrix includes areas unsuitable for most primates to occupy aside from brief forays usually associated with traveling or foraging. Examples of the anthropogenic matrix include urban zones, cropland, and roads (Meijaard et al. 2012; Pozo-Montuy et al. 2011; Printes et al. 2010). Furthermore, dog depredation on NHPs is a substantial risk in such areas, especially near human settlements (Anderson 1986; Printes et al. 2010). Wildlife managers,

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road developers, and local communities are increasingly incorporating wildlife corridors into species and population conservation strategies in areas, where habitat loss and fragmentation have created serious barriers to animal movement (Paige 2015). In general terms, wildlife corridors are strips of habitat that link larger habitat fragments. In addition to promoting wildlife movement, such corridors aim to decrease mortality rates associated with ranging in the anthropogenic matrix and to offset the high economic costs of animal-vehicle collisions (AVCs) (Hilty et al. 2006; Paige 2015). While wildlife corridor ecology has undergone tremendous growth in recent years (Bissonette and Cramer 2008; Gilbert-Norton et al. 2009; Haddad et al. 2003; Hilty et al. 2006; Proctor et al. 2015; Silveira et al. 2014; van der Ree et al. 2009; van der Ree et al. 2015; Vickers et al. 2015), few studies have examined primate corridors (Donaldson and Cunneyworth 2015; Lokschin et al. 2007; Teixeira et al. 2013; Valladares-Padua et al. 1995).

Ethnoprimatological approaches are well positioned to contribute to the study of primate corridor ecology. Provided that human land use is often a core issue of corridor ecology (Hilty et al. 2006) and that ethnoprimatology in general seeks to understand the multidimensional relationships between human and nonhuman primates (Fuentes and Wolfe 2002), practitioners will certainly benefit from exploring how such interactions, including the localized socioeconomic and cultural factors, impact the primate populations targeted for conservation. This chapter addresses the gap on primate corridor ecology using a case study of three New World monkey species living in a spatially and culturally complex, peri-urban landscape in and near the Refugio de Gandoca-Manzanillo, Jairo Mora Sandoval (REGAMA) on the coast of southeastern Costa Rica. Specifically, this study deconstructs the multi-causal drivers of primate habitat loss and fragmentation, examines the sources of primate mortality, measures the effectiveness of corridors, and evaluates wildlife barriers aimed at reducing fatalities associated with power lines. Lastly, this chapter outlines management recommendations and identifies the challenges facing NHPs living in peri-urban environments.

Location and Study Period

REGAMA (9° 37'04" N, 82° 38'13" W) is a 9449 ha marine and terrestrial (terrestrial: 5013 ha; marine area: 4436 ha) refuge located along the southeastern coast of Costa Rica. REGAMA is located within the Districts of Sixaola and Cahuita, Canton of Talamanca, and Province of Limon. In 2013, REGAMA was renamed in honor of Jairo Mora Sandoval, a local conservationist from Gandoca that was murdered while patrolling a beach in Moín to protect sea turtle eggs from poachers (Fendt 2015). The vegetation includes a narrow strip of coastal forest as well as premontane moist and swamp forest (Holdridge et al. 1971). The coastal forest is dominated by woody plant species such as *Terminalia catappa*, *Coccoloba uvifera*,

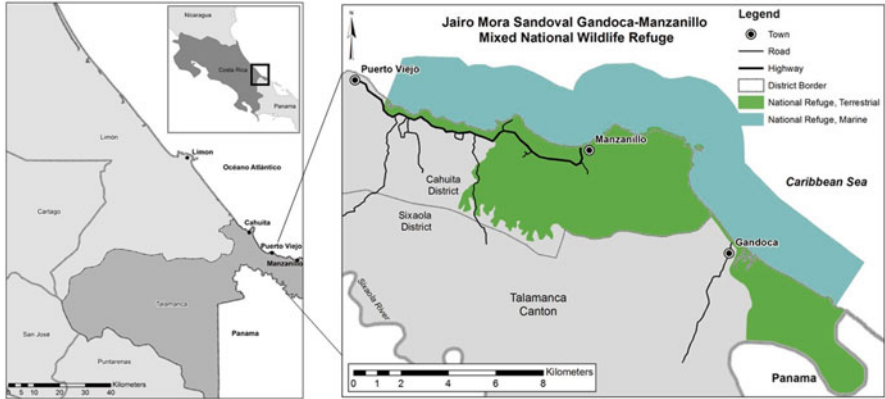


Fig. 1 Location of the study site in southeastern Costa Rica

Cocos nucifera, *Laguncularia racemosa*, and *Rhizophora mangle*. The premontane moist forest is characterized by pioneer species such as *Cecropia obtusifolia*, *Ochroma pyramidale*, *Castilla elastica*, *Genipa americana*, and large trees such as *Ficus werckleana*, *Luehea seemannii*, *Dipteryx panamensis*, *Hura crepitans*, and *Spondias mombin*. The data for this study were collected at REGAMA as well as at public roads near the refuge (Fig. 1) in December 2005, June 2006, May–July 2007, June–July 2008, June–July 2009, January 2010, August 2010, May 2012, and January–August 2015.

Nonhuman Primates of the Caribe Sur

Three NHPs occupy REGAMA: the endangered black-handed spider monkey (*Ateles geoffroyi*) (IUCN Red List A2c ver 3.1, Cuarón et al. 2008), the mantled howler monkey (*Alouatta palliata*), and the white-faced capuchin (*Cebus imitator*). Spider monkeys are the largest of these three species (body weight male average = 8.2 kg; female average = 7.7 kg) and are generally distinguished by their large home ranges, highly frugivorous diet, and fission–fusion social system (reviewed in Di Fiore et al. 2011). The much smaller capuchin monkey (body weight male average = 3.7 kg, female average = 2.7 kg) also ranges widely but tends to socialize in larger, more cohesive groups and displays a greater breadth of dietary items, notably animal prey (reviewed in Jack 2011). The howler monkey is another relatively large New World monkey (body weight male average = 7.2 kg, female average = 5.4 kg). Howler monkey groups have relatively smaller home range areas and usually incorporate a larger proportion of leafy material in the diet relative to *Ateles* and *Cebus* (Di Fiore et al. 2011).

The Peri-Urban Landscape Near REGAMA

REGAMA is located near the towns of Puerto Viejo, Manzanillo, and Gandoca. Most of the peri-urban landscape is located between Manzanillo and Puerto Viejo in the northwestern section of REGAMA, and deforestation is widespread from Puerto Viejo to Playa Chiquita outside of the borders of the refuge. Puerto Viejo, the larger of the two communities, draws thousands of tourists each year due to its beachfront blend of surfing, Afro-Caribbean culture, and ecotourism. Manzanillo also draws many tourists but it is smaller, less urbanized, and has more primate habitat near the town's borders. The Gandoca community situated in the southeastern section of the refuge is considerably smaller than Puerto Viejo and Manzanillo and has the least number of tourists. A highway, the main economic vein along this coast, connects Puerto Viejo to Manzanillo, and also bisects the refuge into coastal and inland sections. This highway does not directly connect to Gandoca. Thus, travelers must take a significant detour around the refuge on highways and unpaved roads to reach this community. The additional effort needed to travel to Gandoca may be related to their smaller ecotourism economy. Further inland, where there are fewer tourists, agriculture (e.g., cattle, banana plantation) is the primary contributor to deforestation outside of REGAMA.

REGAMA is a mixed refuge, meaning that a portion of the land is owned by the State (20%), and the remaining 80% consists of privately owned properties (Universidad de Costa Rica 1996). Many property owners have kept their land within their respective families for generations but increasing foreign interest in coastal development and tourism has led several owners to sell their lands at a premium to foreign investors or immigrants from developed countries such as the United States, Canada, Italy, Argentina, and Spain. Private property owners are allowed to use the natural resources and live on their lands, but they must also follow strict environmental laws regulated by the Ministerio de Ambiente y Energía (MINAE) that are aimed at environmental protection and conservation, primarily through minimizing urban development. These laws prohibit draining wetlands, destroying coral reefs, or building structures higher than 9 m, to name a few (Law 34946-MINAE). However, violations of these laws are numerous. Community vigilance is sometimes used to aid in law enforcement (Quesada 2014, P. Vangoidsenhoven, personal communication). In one prominent case, the owners of two large hotels situated within the refuge were charged with breaking numerous environmental laws. The proceeding legal case unfolded over 18 years and, ultimately, led to the closing and demolition of these hotels, but not without significant local opposition, including political protests (Williams 2011).

Immediately outside of the borders of REGAMA, where environmental restrictions aimed at sustainability and conservation are significantly relaxed, the municipality of Talamanca oversees and enforces legal matters of land use. The impact of these management differences in land zoning and natural resource use are easily visible to the naked eye, with more abundant primate habitat located within REGAMA.

The anthropogenic matrix also includes utility grids. Electric power and telephone lines present life-and-death challenges to NHPs and other arboreal wildlife.

The most serious and obvious problem is the risk of electrocution when individuals directly contact the electric current through non-insulated cables or transformers. A further complication concerning this grid is that telephone lines, which are positioned below the electric cables in REGAMA, offer no risk of electrocution as long as individuals completely avoid the electrified components that are situated overhead. However, it may be the case that primates using telephone lines as corridors are also more likely to perceive electrified cables as safe and, thus, be at risk of electrocution at a later time.

Roads are also dangerous for NHPs and other animals, and these structures are often situated parallel to power and telephone lines at REGAMA. A two-lane highway with asphalt and numerous secondary, unpaved roads are located within and around REGAMA (see Fig. 1). As a consequence, NHPs must either remain on one side of the road, cross the road using a forest canopy corridor, or cross the road by traveling on the ground. The number of AVCs is greatest along the highway because of the higher number of vehicles traveling at higher speeds. Conversely, it is easier for drivers on the gravel and dirt secondary roads to decelerate and avoid animals. High-speed driving is also a public safety issue for pedestrians and bicyclists in the region, and the area is rarely policed for speeding violations. It is within this complex peri-urban context, inside and outside of the refuge, that NHPs must navigate.

The Coastal Economy

The Caribbean coast of Costa Rica plays an important role in the production and shipment of agricultural products. The fertile soils of these lowlands principally support the production of bananas and pineapples (Food and Agricultural Organization of the United Nations 2014). Within this industrialized agricultural context is a network of roads linked to the key shipping port city of Límón. This port is ranked second in trade within the Caribbean, behind only Colon, Panama (World Bank 2015). While agricultural exports are vital to the Costa Rican economy, tourism is the primary source of income for many residents in the coastal areas of the Caribe Sur (Quesada 2014). Historically, the tourism economy here is centered on small-scale ecotourism, domestic tourism, and surfing (Asociación Talamancaña de Ecoturismo y Conservación 2009), in contrast to the large-scale marinas and resorts that populate parts of the Pacific coast. For example, Tortuguero National Park, Cahuita National Part, and the Puerto Viejo area attract a large number of ecotourists drawn to the Caribe Sur for a variety of reasons (Asociación Talamancaña de Ecoturismo y Conservación 2009). As visitor numbers increase, however, so too does the need for infrastructure expansion. Innovative solutions to this conflict are needed to ensure a bright future for both NHPs and the people dependent upon the ecotourism economy. In order to develop a well-informed primate conservation and management plan in this area, basic research on primate ranging and habitat use, corridor use, and mortality risks within the Caribe Sur peri-urban landscape is necessary.

Primate Ranging and Road Surveys

In this study, public roads were surveyed in order to gauge primate ranging within the peri-urban environment. Roadside areas were the focus of this study as habitat loss and fragmentation is strongly associated with road access (Nelson and Hellerstein 1997), and these environments play an important role in primate corridor ecology. Although surveying off-road habitat is essential for accurately estimating ranging behavior, it was not achievable during the study period due to the cultural landscape at REGAMA. Most NHPs ranged among several small properties, which resulted in the need to acquire landowner permission to use each property prior to conducting each survey. Moreover, many owners could not be located and dogs guarded several properties. For these reasons, private properties were avoided but should be included in future studies.

Roads were surveyed on 67 days between May and July 2007, January 2010, May 2012, and January–April 2015. Surveyors walked slowly (1–2 km/h) and searched for all three primate species (see Peres 1999). For each primate encounter, the species, location in geographic coordinates, minimum number of individuals, and the predominant activity (travel, feed, rest, socialize, other, out-of-view) of the group were noted. In addition, all observations of corridor use, road use, and dead animals were recorded.

All three NHP species occupied areas of the peri-urban landscape, inside and outside of the refuge (Fig. 2). Howler monkeys were occasionally encountered along the periphery of Puerto Viejo. Spider and capuchin monkeys were not observed near this densely populated area. All three species inhabited the peri-urban landscape between Puerto Viejo and Manzanillo. Howler monkeys were encountered most often and commonly occupied habitat on either side of the highway bisecting REGAMA into coastal and inland sections. Capuchin and spider monkeys were less often encountered. They usually occupied the inland roadside, although both species ranged within the coastal side in less disturbed areas of the refuge near Manzanillo.

Mortality Risks in the REGAMA Landscape

Monkey-vehicle collisions and electrocutions were assessed using road surveys in addition to anecdotal reports from local residents that were verified with photos whenever possible. During 45 surveys between January and April 2015, two mammal (1%), 24 reptile (17%), 34 crustacean (23%), and 85 amphibian (59%) roadkills were located. The mammal-vehicle collisions involved one kinkajou (*Potos flavus*) and one opossum (*Didelphis marsupialis*). No NHP roadkills were identified during pedestrian surveys but a local resident observed a collision involving one howler monkey near Cahuita in 2015 (C. Orr, personal communication).

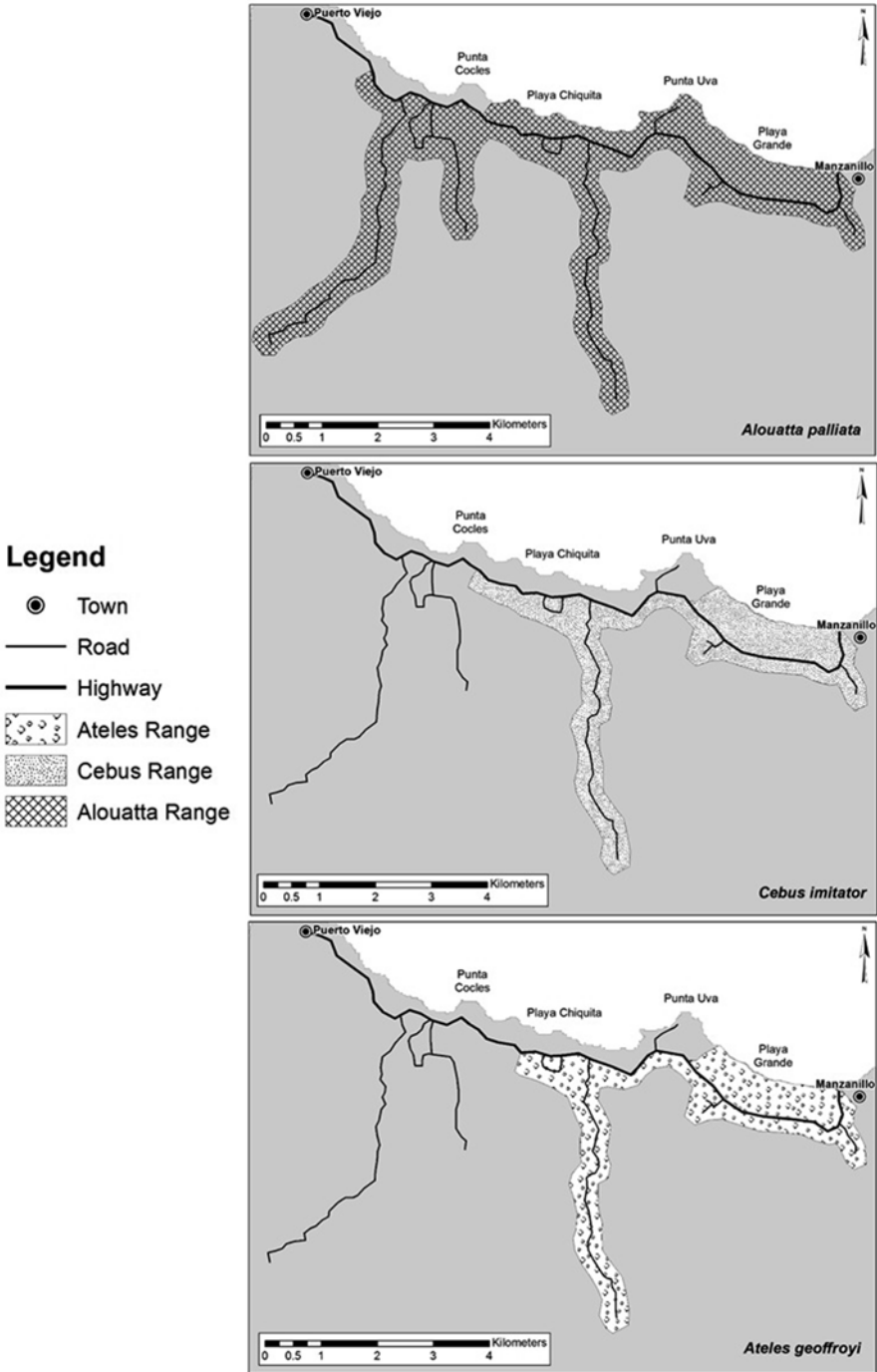


Fig. 2 Estimated ranges for nonhuman primate in the peri-urban landscape between Puerto Viejo and Manzanillo

Two factors complicating this assessment of primate-vehicle collisions include the underreporting of roadkill events and the potentially short interval between an AVC event and the removal of the carcass from the road. Although it is possible for mammal carcasses to mummify along the road, they may also rapidly disappear due to the high abundance of scavengers in REGAMA (e.g., domesticated dogs). For example, one resident witnessed dogs immediately removing a fresh howler monkey carcass. In this case, an adult female with an infant fell from a height of approximately 15 m onto the road while using a natural canopy bridge in 2014 (J. Jones, personal communication). According to the witness, a broken, leafy branch fell with her and she died on impact. Her infant survived the fall and was taken to a local wildlife rescue center. Shortly after her death, several dogs arrived at the site and carried her away. This canopy bridge was used by a group of howler monkeys for at least 2 years prior to her death, and following this incident a rope bridge was installed to reinforce the canopy bridge.

Four mammals were found dead from electrocution during the road surveys in May 2012, and January to April 2015, including three kinkajous and one opossum. In all of these cases, the carcasses were suspended from the electric cables. Although electrocuted primates were not observed during these surveys, two residents reported viewing mummified primates on the roadside in August 2014 that were likely electrocuted (P. Vangoidsenhoven and P. Venegas Vargas, personal communications). A total of three primates ($n=1$ *Ateles*, $n=2$ *Alouatta*) were found on the road in close proximity to several electric lines spanning across a dirt road in a heavily disturbed, forest-pasture matrix (Fig. 3). These events happened on different days, with all three individuals discovered at the same location. The remains were not recovered for analysis and thus the cause of death is not known for certain, but electrocution is inferred due to the proximity of the electric cables.

Forest fragmentation from roads, grids, and settlements in the peri-urban landscape create forest gaps that primates must either avoid or travel across. Although all three species exhibit some terrestrial behavior, this activity is generally rare and in REGAMA it appears to be risky due to the high abundance of dogs. Several residents have reported negative interactions between dogs and howler monkeys, where howler monkeys have dropped branches and feces above dogs, and dogs have barked and directed aggression towards howler monkeys (B. Walker, personal communication). These interactions can result in mortality events, as a resident reported that a dog attacked and killed a howler monkey that was on the ground in 2012 (C. Meeds, personal communication).

In summary, verified anthropogenic mortality risks include electrocutions, falls from the forest canopy, dog attacks, and AVCs. It is possible that monkeys are hunted, as one resident reported that spider monkeys have been targeted by hunters (J. Diaz Villalobos, personal communication) but no direct evidence of hunting has been found to date. In addition, crop raiding behavior could lead people to regard monkeys as pests and exterminate those that reside near plantations and gardens, but there was no evidence of this problem in REGAMA.



Fig. 3 Inferred electrocution events involving *Alouatta palliata* (top right) and *Ateles geoffroyi* (bottom right). Subsequently, wildlife barriers (orange spheres, left photo) were installed at this site. Photos by P. Vangoidsenhoven (right) and the author (left)

Natural Canopy Bridges and Artificial Crossing Structures

One approach to manage and conserve primates in fragmented, anthropogenic landscapes is to improve habitat connectivity with artificial crossings (Silva and Bicca-Marques 2013). These structures are strategically located between habitat patches to provide a relatively safe passageway amidst the surrounding anthropogenic matrix (Bissonette and Cramer 2008; Donaldson and Cunneyworth 2015; Haddad et al. 2003; Lockett et al. 2004; Teixeira et al. 2013; Valladares-Padua et al. 1995). Two corridor types are the focus of this study: (1) natural canopy bridges, where the tree crowns on each side of a road grow together to create a living corridor (Fig. 4), and (2) artificial crossing structures, such as a rope or ladder bridge (Figs. 5 and 6), that connect forest patches on either side of a road or gap. These corridors tend to be relatively small in length (e.g., 10–30 m) and vary in width from a few centimeters to a few meters.

While artificial crossings appear to be a creative solution to the conservation-development conflict, very little is understood about their effectiveness in promoting primate movement and reducing human-related mortality events. Furthermore, it appears that there is high interspecific variation in crossing structure use that may be related to body size, locomotor behavior, and degree of terrestrial versus arboreal



Fig. 4 Natural canopy bridge in use by a spider monkey (photo courtesy of Kelley Littlefield)



Fig. 5 Ladder bridge (photo by the author)

habit (Donaldson and Cunneyworth 2015). Therefore, this management strategy may be ineffective for some primate species. For instance, the relatively small and arboreal Samango (aka Sykes') monkey (*Cercopithecus albogularis*) frequently used monkey bridges ("Colobridges") at Diani Beach, Kenya, whereas the larger and more terrestrial yellow baboons (*Papio cynocephalus*) did not (Donaldson and Cunneyworth 2015). Similarly, the smaller red-backed squirrel monkey (*Saimiri*



Fig. 6 Rope bridge in use by a three-toed sloth (photo courtesy of Pablo Venegas Vargas)

oerstedii) and white-faced capuchin used monkey bridges in Manuel Antonio National Park, Costa Rica more often than the relatively large, mantled howler monkey (Martín 2012). In light of this interspecific variability and the growing interest in corridors within the wildlife conservation and management communities (Paige 2015), more research is urgently needed to improve our understanding of corridor ecology and behavior for primates.

In an attempt to better understand primate mobility near roads or other gaps, artificial crossings were constructed and natural canopy bridges were monitored at REGAMA. Two types of artificial crossing designs were implemented, a ladder model composed of PVC and rubber tubing threaded on wire cable and chain (see Fig. 4) and a rope model that involved one or two strands of thick rope tautly stretched between two or more anchoring trees (see Fig. 5). The ladder bridge model was developed by Colobus Conservation (www.colobusconservation.org) in Diani Beach, Kenya and is used by Samango monkeys, Angolan black-and-white colobus monkeys (*Colobus angolensis*), and vervets (*Chlorocebus pygerythrus*). Kids Saving the Rainforest (kidssavingtherainforest.org) in Quepos, Costa Rica developed a rope bridge model that is used by squirrel, capuchin, and howler monkeys (Martín 2012). In this study, ladder bridges were tested between 2006 and 2012, followed by rope bridges from 2008 to 2015. There was a shift in design from the ladder to the rope model because the Instituto Costarricense de Electricidad (ICE), a collaborating institution that installed and maintained these crossing structures, preferred the rope model as rope was less expensive, easier to purchase from local vendors, and easier to install. Moreover, this rope was nonconductive, which is a vital characteristic for wildlife bridges installed near electric cables. The shift to rope may also benefit wildlife as there were fewer instances of animals using the

ladder bridges, reinforcing the notion that bridge design and bridge materials are important factors to consider (Lindshield 2013).

The location of artificial crossing sites was also important and involved an assessment of habitat structure (e.g., plant species composition, forest canopy height, forest gap width), NHP activity in the immediate vicinity, and the views of property owners towards wildlife. Several hectares of mature secondary or primary forest that included known feeding trees had to occupy both sides of the road. Sites that were located within or near gallery forest were preferred because this vegetation is nationally protected (Article 33 of Forestry Law 7575). In addition, these sites had to have large, hardwood trees (≥ 40 cm diameter at breast height) on each side of the road to anchor the artificial crossings. These anchoring trees had to be positioned no more than 25 m apart from one another or a support post would have been necessary to prevent bridge sagging. Although rare, sites where a landowner or occupant protested an installation were not pursued. Each location was field inspected by ICE for preliminary approval and determination of bridge height. Final approval from ICE required internal reporting and scheduling, as these installations required a work crew, basket crane, and coordinated power outages. Once installed, these bridges ($N=7$; Fig. 7) were monitored using pedestrian surveys, camera traps, and opportunistic sightings from project personnel and local residents. Nine species from six orders were found to use artificial crossings structures (Table 1). Howler monkeys rarely used these structures, while spider and capuchin monkeys were never observed on these bridges during the study period. Camera traps were particularly useful for capturing nocturnal mammal activity on these bridges.

Natural canopy bridges, where trees from opposite sides of the road connected above the road, were also evaluated. There were two natural canopy bridges between Cocles and Manzanillo during the first year of study in 2005, but by 2012, eight more of these bridges had developed within the same area due to natural canopy growth (Lindshield 2013). Altogether, 34 crossings ($n=27$ natural canopy bridges, $n=7$ artificial crossings) now exist around REGAMA. In contrast to the artificial crossings, camera traps were not used regularly at natural canopy bridges because of technical problems (e.g., high rate of device failure, high abundance of vegetation in the motion sensor detection field). Therefore, it is not yet possible to evaluate species' differences in artificial and natural canopy bridge use for nocturnal mammals. There were five independent cases of NHPs using natural canopies ($n=4$ *Alouatta palliata*, $n=1$ *Ateles geoffroyi*), however, suggesting that they are important for NHPs. In two of these cases, a group of howler monkeys used the natural bridges, while the remaining events involved lone individuals.

Preventing Primate Electrocutions

Given that electrocution is a mortality risk for NHPs and other arboreal mammals in REGAMA, several residents and institutions have taken steps to prevent these events from occurring. ICE, a local wildlife sanctuary known as the Centro de

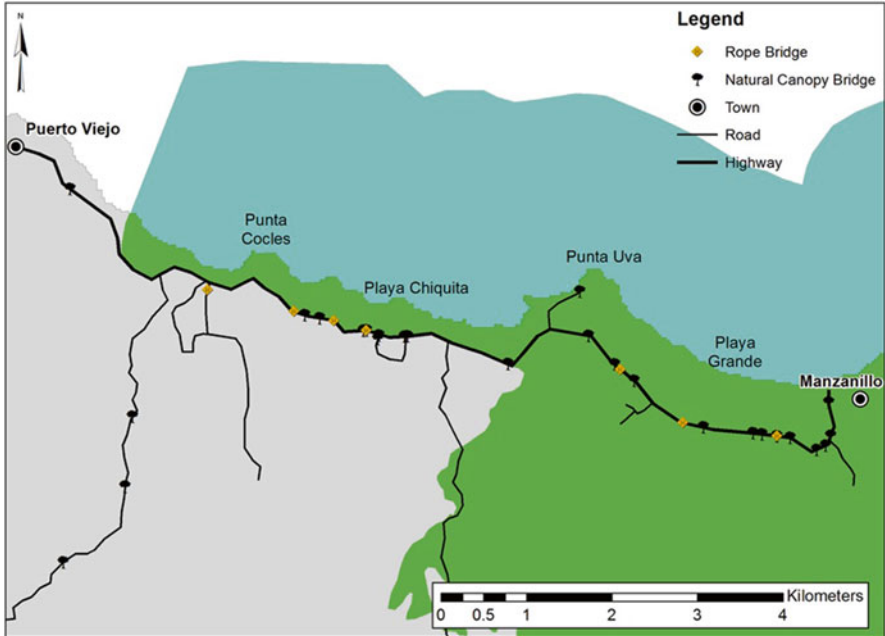


Fig. 7 Locations of the 34 crossing structures ($n=27$ natural canopy and $n=7$ rope bridges) in the peri-urban landscape between Puerto Viejo and Manzanillo

Rescate Jaguar, and this project, which is formally known as the nonprofit Monkey Bridge Project Inc., have implemented management techniques to prevent wildlife from contacting electrified cables. These include the trimming of tree branches to create buffer zones between forest canopies and power lines, insulating power lines, and placing physical barriers on cables to prevent animals from contacting power lines (see Fig. 3). Although there have been no studies to date on the impact of these management techniques on wildlife electrocution prevention in REGAMA, they will likely reduce the number of electrocution events.

One alternative management approach is to bury electric cables. Belowground power lines may effectively eliminate wildlife electrocutions in areas, where residents or organizations can afford the installation and management costs. However, buried cable grids must be several meters wider than many existing power line and road grids within the study area (B. Perez Chaves, personal communication), likely resulting in further deforestation in the refuge, wider forest canopy gaps, and fewer natural canopy bridges. For these reasons, it is not known at this time if burying cables will be a net gain for primate conservation at REGAMA.

Table 1 List of species known to use the artificial crossing structures

Class	Order	Species name	Common name	Mode of detection ^a	Relative use ^b
Mammalia	Primates	<i>Alouatta palliata</i>	Mantled howler monkey	OS	Rare
	Rodentia	<i>Sciurus variegatoides</i>	Variegated squirrel	CT, OS	Common
	Carnivora	<i>Potos flavus</i>	Kinkajou	CT, OS	Common
		<i>Bassaricyon gabbii</i>	Bushy-tailed olingo	CT	Common
	Didelphimorphia	<i>Didelphis marsupialis</i>	Common opossum	CT, OS	Intermediate
		<i>Caluromys derbianus</i>	Derby's woolly opossum	CT	Common
	Pilosa	<i>Bradypus variegatus</i>	Three-toed sloth	OS, PS	Intermediate
		<i>Choloepus hoffmanni</i>	Two-toed sloth	OS	Intermediate
Reptilia	Squamata	<i>Boa constrictor</i>	Boa	OS	Rare

^aCT camera trap, OS opportunistic sighting, PS pedestrian survey

^bRare: <1 sighting per month, intermediate: 1–5 sightings per month, common: >5 sightings per month

Management Recommendations and Challenges

Due to significant population declines for all Costa Rican NHP species (Sherwood 2007), the management and preservation of these charismatic animals in unprotected areas is important. Because of the localized social and economic context of REGAMA, which is principally focused on ecotourism and its associated activities, such as wildlife viewing, supporting primate conservation efforts in the Caribe Sur is an important long-term economic investment for this community. Furthermore, REGAMA was designed to facilitate human–wildlife coexistence, rather than displace human communities with the creation of a national park. Such sympatric living ought to be sustainable provided that national law mandates low impact habitat disturbance and that this law is enforced through governmental and nongovernmental organizations as well as members of the local community acting autonomously. Equally important is the need for residents to maintain a pleasant standard of living within this ecotourism context. Upon considering all of these issues, it is apparent that the protection of NHPs in and near REGAMA requires community-based conservation (Horwich and Lyon 2007), protected areas, corridors, sustainable economies, and a deep understanding of the cultural dimensions shaping primate habitat. Notably, some property owners have strictly designated their land for rainforest conservation, thus there are numerous, small-scale (e.g., 4–100 ha) protected areas

within REGAMA. However, these areas, if isolated from each other through deforestation, will result in NHP population declines and range retractions. Spider monkeys and capuchin monkeys will be particularly vulnerable under this scenario, as these populations need larger areas of forested habitat to thrive. One NGO working within the region, called the Asociación de Organizaciones del Corredor Biológico Talamanca Caribe (ACBTC), addresses the problem of forest fragmentation through collaborating with property owners to map, manage, and reforest private conservation areas (www.corredortalamanca.org). While continued support for projects like the ACBTC are essential to promoting and preserving biodiversity, this approach alone is insufficient for reducing the types of primate mortality events occurring in the REGAMA area, namely dog attacks, electrocutions, and AVCs.

Reconnecting primate habitat that has been fragmented by the peri-urban, anthropogenic matrix is also important and requires natural canopy bridges, artificial crossing structures, or both. This study found that primates used the natural canopy bridges more often than the rope bridges, but this result may be related to differences in sample size, as natural canopy bridges outnumber the other nearly four to one. For the moment, preserving the existing forest canopy over roads and promoting new natural canopy connections are important components of the conservation and management plan for the monkeys of the Caribe Sur. To do this, informing local residents as well as the institutions responsible for managing roads and power lines (e.g., MOPT, ICE) about the importance of natural canopy bridges must be a central component of any conservation tactic as natural canopy bridges are vulnerable, fragile, and dynamic. By Costa Rican law (Civil Code Article 403), large trees may be rooted no less than 5 m from the right-of-way boundary of the roads and branches must be at least three meters from electric cables. Many potential natural canopy bridges may be cut down due to this law, which was designed to protect people from accidental electrocution while working near the electric grid. Care should be used to limit damage to natural canopy crossings while at the same time removing vegetation near power lines in order to reduce the risk of electrocution for animals and people.

The formation of new natural canopy connections is a multi-year process and may require decades of investment. In some cases, artificial crossing structures may be the only option for the rapid connection of forest canopies. Although this study shows that REGAMA monkeys do not frequently use these structures (but see Donaldson and Cunneyworth 2015; Martín 2012), several other mammal species did travel using artificial crossings. Thus, rope bridges are important for the conservation and management of biodiversity in the area. Furthermore, it may be the case that the primate bridge designs, or the height of these bridges, are not well suited for *Alouatta palliata*, *Ateles geoffroyi*, and *Cebus imitator*. Perhaps these species would be more likely to use structures designed in a different way. Alternative crossing designs should be investigated.

While improving habitat connectivity for primates is an important step to preventing roadkill and dog attack events, natural canopy bridges, and artificial crossings are unlikely to prevent all AVCs (Paige 2015). Taking measures to reduce the probability of an AVC via driver behavior, rather than rely exclusively on reforest-

ing roadside habitat and installing road crossing structures, is another important strategy. In REGAMA, the highway and smaller roads serve as important transportation routes for pedestrians and bicyclists. Furthermore, schools, homes, and businesses are located along these roads. For these reasons, many members of the local community are concerned by speeding motorists and have taken steps to reduce high-speed traffic, such as installing speed bumps and posting signs notifying motorists of the importance of driving slowly. Conservationists should support and promote these community efforts because drivers are more likely to avoid hitting animals while traveling at slower velocities.

Reducing the frequency of dog attacks also requires strong community support. There are no leash laws or animal control agencies in this peri-urban environment. In recent years, a veterinary clinic opened and financial support was provided to encourage owners to spade or neuter their companion animals. These are important steps towards managing the large population of domesticated dogs but, ultimately, strong community support for leash laws and mechanisms to manage stray dogs are needed to reduce the dog-related mortality events.

Preserving the population of NHPs in the Caribe Sur requires a multilayered approach that effectively addresses the problems of deforestation, habitat fragmentation, and mortality events caused by human activity. Central to this strategy is the premise that adequate habitat is preserved for the NHP populations. Moreover, innovative strategies are necessary to protect primates living within the anthropogenic matrix. This chapter has shown how small-scale projects that aim to prevent accidental deaths and encourage migrations via natural and artificial corridors are instrumental for protecting wildlife in a changing landscape. It also shows that a deep understanding of the economics and cultural landscape is equally important, and that an ethnoprimateological approach improves our understanding of the primate conservation challenges that lie ahead in southeastern Costa Rica.

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References

- Anderson, J. R. (1986). Encounters between domestic dogs and free-ranging non-human primates. *Applied Animal Behaviour Science*, 15, 71–86.
- Asociación Talamanca de Ecoturismo y Conservación. (2009). *Cool cool: The complete green resource guide to the southern Caribbean of Costa Rica*. Puerto Viejo, Costa Rica: ATEC.
- Bissonette, J. A., & Cramer, P. C. (2008). *Evaluation of the use and effectiveness of wildlife crossings*. National Cooperative Highway Research Program. Report 615. Washington, DC: Transportation Research Board.
- Cuarón, A. D., Morales, A., Shedden, A., Rodríguez-Luna, E., de Grammont, P. C. & Cortés-Ortiz, L. (2008). '*Ateles geoffroyi*', *The IUCN Red List of Threatened Species*, Version 2015.2. Retrieved August 29, 2015, from <http://www.iucnredlist.org>.
- Cunha, A. A., Vieira, M. V., & Grelle, C. E. V. (2006). Preliminary observations on habitat support use and diet in two non-native primates in an urban Atlantic forest fragment: The capuchin monkey (*Cebus* sp.) and the common marmoset (*Callithrix jacchus*) in the Tihuca forest, Rio de Janeiro. *Urban Ecosystems*, 9, 351–359.
- Di Fiore, A., Link, A., & Campbell, C. J. (2011). The Atelines: Behavioral and socioecological diversity in a New World monkey radiation. In C. J. Campbell, A. Fuentes, K. C. MacKinnon, S. K. Bearder, & R. M. Stumpf (Eds.), *Primates in perspective* (2nd ed., pp. 155–188). Oxford, England: Oxford University Press.
- Donaldson, A., & Cunneynworth, P. (2015). Case study: Canopy bridges for primate conservation. In R. van der Ree, D. J. Smith, & C. Grilo (Eds.), *Handbook of road ecology* (pp. 341–343). West Sussex, England: Wiley.
- Fendt, L. (2015, January 26). NOT GUILTY: 7 men acquitted of murder of Costa Rica sea turtle conservationist Jairo Mora. *Tico Times*.
- Food and Agricultural Organization of the United Nations. (2014). *Country profile: Costa Rica*. Retrieved September 1, 2015, from faostat.fao.org/site/666/default.aspx.
- Fuentes, A., & Hockings, K. (2010). The ethnoprimateological approach in primatology. *American Journal of Primatology*, 72, 841–874.
- Fuentes, A., & Wolfe, L. D. (Eds.). (2002). *Primates face to face*. Cambridge, England: Cambridge University Press.
- Gilbert-Norton, L., Wilson, R., Stevens, J. R., & Beard, K. H. (2009). A meta-analytic review of corridor effectiveness. *Conservation Biology*, 24, 660–668.
- Haddad, N. M., Bowne, D. R., Cunningham, A., Danielson, B. J., Levey, D. J., Sargent, S., et al. (2003). Corridor use by diverse taxa. *Ecology*, 84, 609–615.
- Hilty, J. A., Lidicker, W. Z., & Merenlender, A. M. (2006). *Corridor ecology*. Washington, DC: Island Press.
- Holdridge, L. R., Grenke, W. C., Hatheway, W. H., Liang, T., & Tosi, J. A. (1971). *Forest environments in tropical life zones: A pilot study*. Oxford, England: Pergamon Press.
- Horwich, R. H., & Lyon, J. (2007). Community conservation: Practitioners' answer to critics. *Oryx*, 41, 376–385.
- Jack, K. M. (2011). The Cebines: Toward an explanation of variable social structure. In C. J. Campbell, A. Fuentes, K. C. MacKinnon, S. K. Bearder, & R. M. Stumpf (Eds.), *Primates in perspective* (2nd ed., pp. 108–122). Oxford, England: Oxford University Press.
- Jaman, M. F., & Huffman, M. A. (2013). The effect of urban and rural habits and resource type on activity budgets of commensal rhesus macaques (*Macaca mulatta*) in Bangladesh. *Primates*, 54, 49–59.
- Lindshield, S. M. (2013). Reporte sobre el uso del hábitat en primates en un entorno semi-urbano en Puerto Viejo y Manzanillo de Talamanca. El Ministerio de Ambiente, Energía y Telecomunicaciones, Área de Conservación La Amistad Caribe, Puerto Limón, Costa Rica, Julio.
- Lokschin, L. X., Printes, R. C., & Cabral, J. N. H. (2007). Power lines and howler monkey conservation in Porto Alegre, Rio Grande do Sul, Brazil. *Neotropical Primates*, 14, 76–80.

- Luckett, J., Danforth, E., Linsenhardt, K., & Pruetz, J. (2004). Planted trees as corridors for primates at El Zota Biological Field Station, Costa Rica. *Neotropical Primates*, *12*, 143–146.
- Maibeche, Y., Moali, A., Yahi, N., & Menard, N. (2015). Is diet flexibility an adaptive life trait for relictual and peri-urban populations of the endangered primate *Macaca sylvanus*? *PLoS One*, *10*, e0118596. doi:10.1371/journal.pone.0118596.
- Martín, M. P. (2012). Evaluación del uso de puentes para monos según la percepción de la comunidad de Manuel Antonio, Quepos, Costa Rica en Julio y Agosto del 2012. Unpublished report, Kids Saving the Rainforest.
- Meijaard, E., Wich, S., Ancrenaz, M., & Marshall, A. J. (2012). Not by science alone: Why orangutan conservationists must think outside the box. *Annals of the New York Academy of Sciences*, *1249*, 29–44.
- Nelson, G. C., & Hellerstein, D. (1997). Do roads cause deforestation? Using satellite images in econometric analysis of land use. *American Journal of Agricultural Economics*, *79*, 80–88.
- Paige, C. (2015). Putting the crosshairs on deadly crossings. *Bugle*, *32*, 70–81.
- Peres, C. A. (1999). General guidelines for standardizing line-transect surveys of tropical forest primates. *Neotropical Primates*, *7*, 11–16.
- Pozo-Montuy, G., Serio-Silva, J. C., & Bonilla-Sanchez, Y. M. (2011). Influence of the landscape matrix on the abundance of arboreal primates in fragmented landscapes. *Primates*, *52*, 139–147.
- Printes, R., Buss, G., Jardim, M. M. A., Fialho, M. S., Dornelles, S. S., Perotto, M., et al. (2010). The urban monkeys program: A survey of *Alouatta clamitans* in the south of Porto Alegre and its influence on land use policy between 1997 and 2007. *Primate Conservation*, *25*, 11–19.
- Proctor, M. F., Nielsen, S., Kasworm, W. F., Servheen, C., Radandt, T. G., Machutchon, A. G., et al. (2015). Grizzly bear connectivity mapping in the Canada–United States trans-border region. *Journal of Wildlife Management*, *9*, 544–558.
- Quesada, F. (2014). Sustainable tourism planning, and the demolition conflict in the south Caribbean coastal area of Costa Rica. In H. B. Clausen, V. Andersson, & S. Gyimothy (Eds.), *Global mobilities and tourism development: A community perspective* (p. 19). Aalborg, Denmark: Aalborg University Press.
- Sherwood, D. (2007, April 27). Monkey populations shrinking fast. *Tico Times*.
- Silva, F. E., & Bicca-Marques, J. C. (2013). Do patch size and interpatch distance influence the distribution of brown howler monkeys (*Alouatta uariba clamitans*) in a fragmented landscape in south Brazil? In L. K. Marsh & C. A. Chapman (Eds.), *Primates in fragments: Complexity and resilience* (pp. 137–145). New York: Springer.
- Silveira, L., Sollmann, R., Jácomo, A. T. A., Diniz-Filho, J. A. F., & Tôrres, N. M. (2014). The potential for large-scale wildlife corridors between protected areas in Brazil using the jaguar as a model species. *Landscape Ecology*, *29*, 1213–1223.
- Teixeira, F. Z., Printes, R. C., Fagundes, J. C. G., Alonso, A. C., & Kindel, A. (2013). Canopy bridges as road overpasses for wildlife in urban fragmented landscapes. *Biota Neotropica*, *13*, 117–123.
- Universidad de Costa Rica. (1996). *Plan de manejo para el Refugio Nacional de Vida Silvestre Gandoca-Manzanillo (RNVS-GM)*. San Jose, Costa Rica: Universidad de Costa Rica, Programa de Estudios Ambientales, and Ministerio de Ambiente y Energía.
- Valladares-Padua, C., Cullen, L., & Padua, S. (1995). A pole bridge to avoid primate road kills. *Neotropical Primates*, *3*, 13–15.
- van der Ree, R., Heinze, D., McCarthy, M., & Mansergh, I. (2009). Wildlife tunnel enhances population viability. *Ecology and Society* *14*(2), 7. Retrieved from <http://www.ecologyandsociety.org/vol14/iss2/art7/>.
- van der Ree, R., Smith, D. J., & Grilo, C. (Eds.). (2015). *Handbook of road ecology*. West Sussex, England: Wiley.
- Vickers, T. W., Sanchez, J. N., Johnson, C. K., Morrison, S. A., Botta, R., Smith, T., et al. (2015). Survival and mortality of pumas (*Puma concolor*) in a fragmented, urbanizing landscape. *PLoS One* *10*, e0131790. doi: 10.1371/journal.pone.0131490

- Williams, A. (2011, July 28). Hotel closings on Costa Rica's Caribbean coast spark violence. *Tico Times*.
- World Bank (2015, June 24). Costa Rica—port-city of Limon integrated infrastructure project. *Implementation Completion Report Review* (Report Number ICRR14721). Vol. 1, Washington, DC: World Bank Group. Retrieved from <http://documents.worldbank.org/curated/en/2015/08/24916063/costa-rica-port-city-limon-integrated-infrastructure-project>.