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Abstract	This book compiles a remarkable array of studies dealing with Neotropical mammal movement patterns and therefore presents a unique opportunity to analyze the state of the art of movement ecology of some of the rarest and secretive species that are top predators, important prey to those predators, and/or critical to maintaining the ecosystem services of the forest ecosystems they inhabit. In this last chapter, we attempt to summarize lessons learned from all chapters and advance the field with respect to our understanding of the causes and consequences of animal movements in tropical forests.	

Chapter 15
Next Moves: The Future of Neotropical Mammal Movement Ecology

Rafael Reyna-Hurtado and Colin A. Chapman

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This book compiles a remarkable array of studies dealing with Neotropical mammal movement patterns and therefore presents a unique opportunity to analyze the state of the art of movement ecology of some of the rarest and secretive species that are top predators, important prey to those predators, and/or critical to maintaining the ecosystem services of the forest ecosystems they inhabit. In this last chapter, we attempt to summarize lessons learned from all chapters and advance the field with respect to our understanding of the causes and consequences of animal movements in tropical forests.

Tropical ecosystems and its wildlife are in peril globally due to conversion for agriculture and cattle ranching. These forests are being degraded and destroyed at a very high rate. Between 2000 and 2012, tropical forest loss increased by 2101 km^2 per year (Hansen et al. 2013). For example, 20% of Amazon forest has been destroyed in the last 40 years, and in the last 20 years, Indonesia has lost a third of its forest primarily due to the expansion of palm plantations (Hansen et al. 2013; Global Forest Watch; https://www.globalforestwatch.org). In many areas, forests have been left standing, but hunting has eradicated the wildlife. This phenomenon AUT was first described in Neotropical forest almost 25 years ago by Redford (1992), and he called these areas the "empty forests." There is not doubt that tropical forest and its wildlife are fragile and will disappear if we do not protect them, yet these forests harbor remarkable levels of biodiversity, are resilient ecosystems that can recover if we improve protective measures and management, and are simply amazing.

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In this book many of the authors were motivated by the curiosity of understanding how and why an animal moves in highly biodiverse Neotropical forests that at the same time are disappearing at a high rate or are facing tremendous hunting pressure. Understanding how animals adapt their movement to survive in such environments and what kind of relationships or synchronies they have built with other species is fascinating and has driven the authors of the chapters in our book to spend years researching movement in the field, many times under challenging or frustrating conditions.

This is illustrated in Chap. 2 as Jordan and his collaborators were luckily, or unluckily, presented with the opportunity to compare movement of the largest of all Neotropical mammals, the Baird's tapir, before and after a hurricane hit this tropical forest in Nicaragua near the border with Costa Rica. Amazingly, tapirs seem to do well after the disturbance and were able to feed on the super rich variety of herbaceous vegetation that quickly grew after many trees were toppled over during the storm. However, the species' movements were more restricted after the hurricane, probably due to areas becoming impossible to reach because of the obstacles created by the fallen trees and branches on the forest floor. Comparing normal patterns (before hurricane) versus altered movement patterns (after hurricane) provides insights into how animals cope with a disturbance event.

Another excellent example of animal resilience is the chapter by Serio-Silva and collaborators (Chap. 9, this volume) who describe the terrestrial locomotion for black howlers in southern Mexico in an area where forest fragments are increasingly being destroyed and the distances among feeding locations are increasing. However, this flexibility and apparently adaptive behavior comes at the cost of increased risk of predation by domestic dogs that are common in the area. In the absence of conservation interventions, howler monkey in the area will soon be isolated within large forest fragments or groups of smaller, adjacent fragments that are near each other, corralled by feral dogs. These small genetically isolated groups will not be viable and the species will become locally extinct.

Four chapters deal with a species that present some of the most intriguing movement behaviors of the Neotropics, the white-lipped peccary. This species perform some of the longest and most diverse movement patterns ever described for a mammal. Researchers in all Neotropical forest are well aware that white-lipped peccaries movement patterns are not replicated annually and remain as unpredictable up to date (Reyna-Hurtado et al. 2012). Another characteristic that makes this species fascinating is that it is highly social and moves in very large groups that sometime include hundreds of individuals (Reyna-Hurtado et al. 2016). The opportunity to include four chapters about white-lipped peccary movement ecology was unique and very valuable. White-lipped peccaries movements are affected by hunting pressure as demonstrated by Moreira et al. (Chap. 3, this volume) where a group living in a hunted area always keep moving, even in the dry season when other groups living in protected areas just congregate around the few remaining water sources. The fear of hunters likely drives this unique movement pattern. In Darien National Park, Panama, white-lipped peccaries can afford to remain in relatively small areas of old growth tropical forest that provide sufficient resources (Meyer et al., Chap. 6,

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this volume), while in French Guiana white-lipped peccaries congregate around old growth forest with occasional trips to the edge of savanna areas (Richard-Hansen et al., Chap. 5, this volume). In the Pantanal of Brazil, white-lipped peccary groups presented similar behaviors and increased their home range in areas that have less forest than in forested areas (Jorge et al., Chap. 4, this volume). While these chapters offer great examples of this species' ability to modify its behavior in response to man-made disturbances and in a matrix of different habitat types, they also highlight that additional research is needed to determine under what conditions this species cannot be resilient in terms of its movement patterns and what conditions may lead to this species becoming locally extirpated given that it is one of the most sensitive Neotropical mammals to threats.

Grotta-Neto and collaborators (Chap. 7, this volume) present an interesting review about what is known on the movement of a poorly known group of mammals, the tropical forest deer. This group is composed of approximately ten species, mostly of the genus *Mazama*. They are shy species which are difficult to capture to fit them with GPS devices. However, studies of *Mazama gouazoubira* in the Pantanal of Brazil have shown that they can modify their ranging patterns to transverse non-preferred habitats and perform straighter movements when needed. Along the same lines, the white-tailed deer (*Odocoileus virginianus*) inhabiting the swampy areas of Campeche, Mexico (Contreras-Moreno et al., Chap. 8, this volume), were studied using radiotelemetry techniques that revealed deer move more in the dry season than in the flooded season.

Conditions in tropical forests make it extremely for researchers to conduct behavioral studies on the species that inhabit them. This is partly the reason why movement and social behavior of woolly monkeys have been a mystery for so long. Nevertheless, Ellis and DiFiore (Chap. 10, this volume) managed to maintain simultaneously visual contact with four identifiable groups, obtaining detailed behavioral information. Their research indicated that groups could tolerate and share large areas, while keeping spatial cohesion within the group. They also found that increases in movements occurred mostly in the mating season and changes in food availability did not affect movement to a great extent. This study was unique as this took place in a protected Ecuadorian forest with very limited disturbance. Woolly monkeys are unfortunately highly prized for their meat by subsistence hunters (Alvard et al. 1997).

With the same species (woolly monkeys) but in a rugged terrain of Colombia, Garcia et al. (Chap. 11, this volume) tested the performance of GPS collars and found that the deployment of GPS collars, although expensive, was worth the expense due to the large geographic scale that could be sampled and to the quality of the data that could be obtained. Using movement ecology as a theoretical framework, Posadas et al. (Chap. 12, this volume) followed groups of capuchin monkeys and found that ranging patterns are shaped by food availability, but in many instances food availability was difficult to estimate, especially with respect to invertebrates.

To close this book, we were fortunate to include two studies dealing with the largest predator of the Neotropics: the jaguar. The development of new movement models and analytical tools have allowed researchers to make precise inferences

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regarding the space use and movements of this secretive species. De la Torre and Rivero (Chap. 13, this volume) used autocorrelated kernel methods to determine the home range of five jaguars in the Lacandon Forest of southern Mexico and the important areas for each individual and used this information to make conservation recommendations. Movement of jaguars and mountain lions was studied with great detail in Chamela-Cuixmala a protected dry tropical forest in Western Mexico by Nuñez and Miller (Chap. 14, this volume) who found both large cats like to travel along streams and are moving in relatively large areas that make them vulnerable to hunters if they leave the protection of the reserve.

Humans have always been fascinated about animal movement. Since Aristotle (Nathan et al. 2008) we have tried to understand how and why animals move. Species that live in tropical environments are fascinating, and new technology allows us to have a glimpse in movement behavior of secretive species that one rarely sees in the wild (Chapman and Reyna-Hurtado, Chap. 1, this volume). GPS-equipped collars are extremely useful allowing researcher to follow animal paths when observers cannot. With the development of new technology, there became the need to develop better ways to analyze movement patterns, and the chapters of this book are great examples of some of the most innovative statistical techniques and latest models available. Many chapters have advanced beyond home range estimation to elucidate fine temporal movement patterns such as daily distances traveled or core areas or to estimate areas that an animal visits repeatedly. Speed and distance traveled daily are also estimated when consecutive fixes could be collected.

This book has presented a selection of studies from researchers that have overcome logistical challenges and have displayed an amazing level of patience to achieve their goal of acquiring movement data of tropical mammals. The different chapters are also nice examples of thoughtful research design and smart use of statistical methods needed to evaluate animal movement patterns.

The planet now has fewer and fewer places where animals can move without being influenced by significant human perturbations. Large Neotropical protected areas that are not significantly affected by human actions are very rare. This presents us with two opportunities/necessities in the context of research on Neotropical mammal movement ecology. First, we need to get more information about wildlife movement in well-conserved areas that resemble original conditions where species evolved. Alongside this, we need to monitor animal movement patterns in perturbed areas. This is essential to understand the impact of human activities such as logging, hunting, tourism, and other forest-related activities. Changes in behavior can have a large effect on population dynamics and ecosystem function (e.g., elks in Yellowstone changed behavior when wolves were introduced; Laundre et al. 2001). So, studying changes in behavior in contexts with and without significant human influence will allow us to identify when an animal is under stress due to human activities and what the implications of this might be.

Advances in technology, in statistical science, and in spatial modeling, along with the patience, courage, and passion of Neotropical mammal researchers, are changing what we know about Neotropical mammals and their movement patterns. We hope that this book will inspire young researchers to advance what we

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have learned to date about the movement of Neotropical mammals and to use this information for the conservation of nature, so that future generations have the chance to be amazed when, for example, a group of more than a hundred white-lipped peccaries cross paths with them, moving in the way that they have done throughout their evolutionary history. The movement could be motivated by the need of water and food, or maybe they are migrating to a new area or escaping from a jaguar – it will be the next generation's task to determine why and where are those animals moving.

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Queries	Details Required	Author's Response
AU1	The citation "Kent Redford (1993)" has been changed to "Redford (1992)" to match the author name/date in the reference list. Please check if the change is fine in this occurrence and modify if necessary.	
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