Chapter 34
Primates in Fragments 10 Years Later: Once and Future Goals

Laura K. Marsh, Colin A. Chapman, Víctor Arroyo-Rodríguez,
A.K. Cobden, Jacob C. Dunn, D. Gabriel, Ria Ghai, Vincent Nijman,
Rafael Reyna-Hurtado, Juan Carlos Serio-Silva,
and Michael D. Wasserman

Introduction

In 2010, the Food and Agriculture Organization of the United Nations (FAO) estimated that 16 million hectares of forest per year were lost globally in the 1990s (FAO 2010), and approximately 12.5 million hectares/year were lost in countries with primate populations, an area just smaller than Greece or the US State of Mississippi (Chapman and Peres 2001; Chapman and Gogarten 2012). In contrast, in the last decade (2000–2010), the rate of deforestation has decreased globally by approximately 5.2 million hectares/year, and reforestation and natural expansion of forests in some countries significantly reduced the net loss of forest (FAO 2010). This may be in part due to the lack of resonance in satellite imagery between secondary and primary forest regions, particularly in the tropics. Unfortunately, the increase in forested lands has principally affected temperate regions of Europe and eastern Asia (e.g., China, Japan), but deforestation of most tropical forests has continued steadily (e.g., annual loss: 0.5 % in Africa, 1.2 % in Mesoamerica, 0.5 % in South America, 0.4 % in southeastern Asia; FAO 2011).

L.K. Marsh (✉)
Global Conservation Institute, 156 County Road 113, Santa Fe, NM 87506, USA
e-mail: lkmarsh@global-conservation.org

C.A. Chapman (✉)
Department of Anthropology, McGill School of Environment, McGill University,
855 Sherbrooke St West, Montreal, QC, Canada H3A 2T7
e-mail: colin.chapman@mcgill.ca

Of course, whenever sweeping calculations of loss or gain are reported, it is worth a note of caution in responding to the results. Puyravaud (2003) cited: "Deforestation is a non-homogeneous process and it is of interest to focus on the worst affected area in order to understand and predict its dynamics and correlate it to socio-economic trends at different scales (Lambing 1994). At the local level, the annual rate of change can be much higher than the global average because of the unprotected status of the forest, or due to economic or legal reasons (Ramesh et al. 1997)." An increasing number of primate populations are located in isolated forest fragments, and for some species these fragment-dwelling populations are the only

V. Arroyo-Rodríguez (✉)
Centro de Investigaciones en Ecosistemas, Universidad Nacional Autónoma de México (UNAM), Morelia, Michoacán, Mexico
e-mail: victorarroyo_rodriguez@hotmail.com

A.K. Cobden
Department of Anthropology, Emory University, 207 Anthropology Building, 1557 Dickey Drive, Atlanta, Georgia 30322, USA
e-mail: acobden@emory.edu

J.C. Dunn
Primate Immunogenetics and Molecular Ecology Research Group, Division of Biological Anthropology, University of Cambridge, Cambridge, UK
e-mail: jcd54@cam.ac.uk

D. Gabriel
University of Victoria, Department of Anthropology, PO Box 1700 STN CSC, Victoria BC V8W 2Y2
e-mail: denisegabrie@gmail.com

R. Ghai
Department of Biology, McGill University, 1205 Dr. Penfield, Montreal, QC, Canada H3A 1B1
e-mail: Ria.Ghai@mail.McGill.ca

V. Nijman (✉)
Department of Anthropology and Geography, Oxford Brookes University, OX3 0BP Oxford, UK
e-mail: vnijman@brookes.ac.uk

R. Reyna-Hurtado
Investigador Titular A, ECOSUR-Campeche, Avenida Rancho s/n, Poligono 2, Lerma, Campeche, Campeche 24500El, Mexico
e-mail: rreyna@ecosur.mx

J.C. Serio-Silva
Red de Biología y Conservación de Vertebrados, Instituto de Ecología AC, Xalapa, Veracruz, Mexico
e-mail: juan.serio@inecol.edu.mx

M.D. Wasserman
Department of Anthropology, McGill University, 855 Sherbrooke St West, Montreal, QC, Canada H3A 2T7
e-mail: Michael.Wasserman@mail.McGill.ca

ones that remain. Thus, the need to understand the effects of forest fragmentation on primates is still paramount.

Since the publication of the original *Primates in Fragments* book, we have the unique opportunity to reflect on what has been accomplished in the last decade. In 2003, Marsh and her colleagues ended the final chapter by discussing what they perceived as future research needs in the field to facilitate conservation decisions regarding the value of forest fragments to primates. They arrived at five topics: (1) disease, (2) regional comparisons (scale), (3) fragment size, (4) genetic studies, and (5) climate change (Marsh et al. 2003). In response, this volume includes chapters on all of these issues, bringing a considerable amount of clarity to the fate of primates in fragments.

Progress on Previous Research Priorities

Disease

Work in Africa (Chap. 7), Central America (Chap. 30), Southeast Asia (Lane et al. 2011), and Madagascar (Wright et al. 2009) have all demonstrated that anthropological changes in fragmented landscapes can be associated with increased disease levels in primates, which are thought to result in greater mortality. Fragmentation can also increase disease transmission between nonhuman primates and humans, posing a serious threat to wildlife conservation and human health. For example, Goldberg et al. (2008) found that humans living near forest fragments harbored *Escherichia coli* bacteria that were on average 75 % more similar to bacteria from primates in those fragments than to bacteria from primates in nearby undisturbed forests. Likewise, habitat degradation in forest fragments has been related to increases in stress in primates (usually assessed by fecal glucocorticoids), which can have a negative effect on immune function (Chaps. 7 and 30, Sapolsky 2002). A dramatic example of this is cortisol levels in red colobus (*Procolobus rufomitratus*) in forest fragments. They are so elevated that the lowest level recorded in the fragments is higher than the highest level documented in continuous forest (Chapman et al. 2006a, b, 2007). Dunn et al. (in press) suggest that an increase in daily travel time, which is related to increased folivory in primates in fragments, is the most important factor predicting cortisol levels in howler monkeys (*Alouatta palliata*). This highlights the potential conservation significance of studies showing that habitat loss and fragmentation can increase travel time in primates (e.g., Donati et al. 2011; Dunn et al. 2009, 2010; Gonzalez-Zamora et al. 2011; Hardus et al. 2012). However, for most primate species, the proximate causes of increases in stress remain to be identified. We know of several studies currently in progress or that have been published recently that directly examine disease issues in fragments and are trying to identify the causal factors of elevated levels of stress and disease (D. Gabriel unpublished data, Irwin et al. unpublished data, R. Ghai unpublished data, Hodder and Chapman 2012).

Hunting and habitat loss are major drivers of extinction in primates, and ecotourism and academic research projects have been widely promoted as a means of providing alternative value for primates and their habitats (e.g., Butinski and Kalina 1998). However, several diseases, including viruses, bacteria, and whole parasites have been shown to move from humans to wild primates during such projects (e.g., Köndgen et al. 2008) raising concerns that disease transmission risks might outweigh benefits.

Regional Comparisons

Landscape Ecology has emerged as an important intellectual field that can play a central role in conservation, and we have seen clear advances in the last decade considering scale. Chapter 2 by Arroyo-Rodríguez and colleagues clearly illustrates the importance of considering fragmentation as a landscape level process. However, this chapter also quantifies that there is still a great deal of work to be done in this area, as all reviewed fragmentation studies ($n = 100$ studies) were at the fragment scale, which means that extrapolations to the landscape scale were not possible. In fact, 25 % of the 100 studies did not describe the amount or configuration of the surrounding habitat nor the matrix, and hence, these studies cannot test the impact of processes operating at the landscape scale (e.g., neighboring effects, source-sink dynamics, landscape supplementation, landscape complementation; Dunning et al. 1992; Arroyo-Rodríguez and Mandujano 2009). Considering scale issues with respect to how conservation plans are made (i.e., at species distribution, regional, national levels), we do not see great progress, as management or action plans are typically operationalized at the national level (Chaps. 4 and 22). Generally, this is not a problem as whenever a primate species is endangered at a national level, small-scale action is advocated by the nation in question. However, this does point to the need for international NGOs and agencies such as the United Nations (as illustrated in the work by GRASP—http://www.un-grasp.org/) (Nelleman et al. 2010; Wich et al. 2011) to play a larger role, so that conservation dollars can be used in the most effective way.

Fragment Size

A great deal of research has been done on how fragment size influences the probability of primate survival both in the short- and long-term (Chaps. 3, 5 and 7). Although Arroyo-Rodríguez and his colleagues (Chap. 2) found that most fragmentation studies with primates are focused on assessing the effect of fragment size on primates, the effects of fragment size on populations and species can strongly vary among landscapes with different configuration (Pardini et al. 2010); and hence, the effects of fragment size on primates needs to be assessed in landscapes with

different spatial configuration before we will likely be able to produce clear generalizations (Chap. 2). In this sense, despite over a decade of research at many sites (e.g., Chap. 6), large gaps in our knowledge exist (Chap. 4). We are still largely unable to state beforehand which species are more threatened in forest fragments, which was a conclusion drawn 10 years ago as well (Marsh et al. 2003). For example, blue monkeys (*Cercopithecus mitis*) are found in forest fragments throughout East and South Africa (Lawes et al. 2000) and near Budongo Forest Reserve, Uganda. Yet while they are found near Kibale National Park, Uganda, they never occur in any forest fragment, irrespective of fragment size (Onderdonk and Chapman 2000). Understanding the root causes of such issues is a challenge where the key point is time since isolation relative to the generation time of the study species in question. If we want to understand this (which species will disappear first?), we need multiple fragments that have been isolated for considerable periods of time. For primates these datasets are simply few and far between (but see Chap. 5). The way forward is for primatologists to start learning from other zoological fields where we have more species with shorter generation times.

Genetic Studies

Genetic methods have advanced significantly in the last 10 years, and research using these methods has contributed a great deal to our understanding of the consequences of breaking apart populations in forest fragments (Chap. 25). Since many primate species living in fragmented landscapes are endangered, one of the most important methodological advances has been discovering and perfecting tools to noninvasively extract DNA from feces, urine, hair, and saliva (Goossens et al. 2003). In general, habitat fragmentation reduces connectivity between forest-dwelling primate populations, decreasing gene flow among small populations, which can result in decreased genetic variability (Bergl et al. 2008). And while we surmise that this decrease reduces the ability of the population to respond to change, be that climate change or further anthropogenic change, it can be confounded by the additive, amplified effects of fragmentation per se (Ewers and Didham 2005). Populations' isolation can also lead to increased inbreeding and reduce reproductive success, which increases the chances that the population in the fragment will die out. Goosens et al. (2006) were the first to show that genetic data can be used to detect and quantify the effect of human-induced deforestation and habitat fragmentation on an endangered species after the demographic collapse of the orangutan population in North Eastern Borneo.

The increasing interest in genetic approaches to study fragmentation is illustrated by the number of authors using these methods in the current volume (six) as compared to the 2003 book (only one). There are studies in this volume that use genetic approaches to examine issues of reduced genetic variability and population health (de la Torre et al., deVleeschower and Raboy), hybridization and species status (Dias et al., Wallace et al.), dispersal and relatedness of individuals in fragments (Oklander

and Corach), and to discover the origin of populations (Glenn and Benson). However, in general these studies assess the impact of population isolation on primate genetic profiles at local scales, without evaluating (nor controlling) the impact of the landscape spatial context (e.g., landscape forest cover, number of forest fragments, edge density, matrix permeability). This limits our ability to predict future scenarios for alternative management practices: an important challenge in conservation biology and land management (c.f., Feinsinger 2001).

Climate Change

There is mounting data available at both the academic and policy level for the effect that climate change has on biodiversity (Hannah et al. 2002; Lovett et al. 2005a, b; McClean et al. 2005). Some estimates suggest that in this century the climate could warm by up to 5.8 °C (IPPC 2001). Already, there have been numerous documented cases of shifts in the distribution, population abundance, life history, and even survival of species in response to climate change (Pounds et al. 1999; Hannah et al. 2002; Parmesan and Yohe 2003; Malcolm et al. 2006). With primate populations increasingly isolated in protected areas, or in forest fragments surrounded by agricultural land that often supports high human densities, the loss of habitat as the climate changes is of obvious concern as they have nowhere to disperse to (Dunbar 1998; Cowlishaw and Dunbar 2000; Chapman et al. 2006a; Gonzalez-Zamora et al. 2011). As well as direct effects of climate change on primate populations, individuals or groups may be affected by either the loss of particular plant species or changes in the phenological cycles of plant communities. Through a series of modelling exercises, McClean et al. (2005) studied the impact of projected climate change on the distribution of 5,197 African plant species. For 97 % of these species, areas of suitable climate were projected to decrease in size and/or the species would shift location, many to high altitudes, and 25–41 % of species would lose all their area by 2085.

Ramos-Fernandez and colleagues (Chap. 32) modeled the distribution of spider (*Ateles geoffroyi*) and howler (*Alouatta pigra*) monkeys under a current and projected climate change scenario for the year 2020 for the Yucatan peninsula in Mexico. The model suggests that climate change will lead to a slight increase in the extent of similar habitat for both species, but less than 20 % of the extent of potential distribution under current and climate change scenarios lies within protected areas. These models can provide important guidelines to predict what will happen and what must be planned for; however, they are based on sets of assumptions that are largely untested. For example, the models use either biophysical variables or the potential distribution of the most important food plants currently in use by the primates in question. As we have seen both for spider and howler monkeys (Silver and Marsh 2003; Bicca-Marques 2003; Ramos-Fernandez and Ayala-Oozco 2003; González-Zamora et al. 2009; 2011), and several other taxa (Chaps. 14, 17 and 20) primates can adjust to novel habitats, thus potentially confounding even our best

modelling assumptions. What we can glean for conservation purposes is a fact mentioned repeatedly throughout this volume: that primates outside of protected areas are at risk for numerous reasons, climate change being only one of them. But even protected areas that house primates might be impacted by climate change, and that is a much broader challenge.

There are suggestions from Kibale National Park that climate change may have affected some fruiting tree pollinators, a variable that is difficult to consider (Chapman et al. 2005). The Kibale region receives approximately 300 mm more rainfall/annum than it did at the start of the century, droughts are less frequent, the onset of the rainy season is earlier, and the average maximum monthly temperature is 3.5 °C hotter than it was 25 years ago. Using a phenology data set that extends almost continuously from the 1970s to the present, Chapman and colleagues (2005) documented changes in fruiting patterns that they speculated were caused by declines in the pollinator populations. For example, *Pouteria altissima* and *Parinari excelsa* exhibited a relatively regular pattern of fruiting during the 1970s; however, they rarely have fruited since the 1990s (Chapman et al. 2005). It is possible that changes in fruiting patterns are responsible for progressive declines in some primate species (e.g., *Cercopithecus mitis*: Chapman et al. 2010; Lwanga et al. 2011), but this speculation requires further study.

Finally, changes in land use, forest loss and fragmentation, and elevated atmospheric CO_2, all of which are implicated in climate change, have been shown to be associated with large-scale structural changes in tropical forests. The most apparent of these may be the increase in the abundance and biomass of lianas (Schnitzer and Bongers 2011). Lianas are thought to be important fallback foods for many primate species (Dunn et al. 2012; Onderdonk and Chapman 2000; Marshall et al. 2009) and play an important role in primate ecology, including niche partitioning, home range use, reproductive behavior, ranging behavior and grouping patterns (Arroyo-Rodriguez et al. 2013). However, as the structure of tropical forests continues to be modified by climate change, it will be crucial to understand the responses of primates to their changing habitats.

Fragmentation Science and the Future

By examining primates in fragments on a global scale it has become evident that fundamental information is needed to construct informed plans for the adequate management and conservation of primate populations in fragmented landscapes. In other words, we still cannot predict how a primate community would respond to an upcoming anthropogenic change or what the most important variables are for determining long-term survival in a fragmented landscape (Arroyo-Rodríguez and Mandujano 2006, 2009; Chap. 2). To start to rectify this knowledge gap, we would like to end this volume by discussing two important issues: (1) how scientific thought has shifted in the last decade; and (2) what we see as research priorities for the next decade and beyond.

Changing Trends

Ways of thinking about primate research has shifted in the last decade, moving in a direction favoring research on primates in fragments (see Fig. 2.1). In the early studies of primate behavioral ecology, there was an emphasis placed on studying primates in their native environment often with the goal of understanding the selective pressures that shaped their social organization. For example, in John Terborgh's (1983) classic book, *Five New World Primates*, he spent a considerable amount of text explaining how remote the study site was. In 2012, tourists can fly to Puerto Maldonado from Lima or Cusco, drive 10 minutes, to a launch site at Tambopata River Port, and take a speedboat for 2.5 hours until they reach the comfortable lodge at Tambopata Reserve (Go2Peru.com). In part precisely because there is greater ease for reaching remote sites, and that continuous sites are becoming ever more encroached upon, we can clearly see a shift more inclusive of research in disturbed habitats.

This is reflected when comparing the two volumes of *Primates in Fragments*. In the current volume, there are chapters dealing with primates in villages (Carretero-Pinzon), large cities (Gordo), around Buddhist temples (Aggimarangsee), and other sacred sites (Cameron and Gould). There are now a number of studies in Central America that are focusing on highly modified landscapes, such as those that demonstrate that howler monkeys walk along barbed wire, forage In isolated trees, sleep in living fencerows, or use or use introduced *Eucalyptus* plantations (Asensio et al. 2009; Serio-Silva et al. 2006; Bonilla-Sanchez et al. 2012; Chap. 8). And while we certainly touched on some of those topics in the first volume, it is clear that they are now dominating the discussion.

There is a growing tendency for empiricists and theoreticians to work together often leading to modelling the real world, which has facilitated greater understanding and thus drives primatology to be more predictive. Chapman et al. (Chap. 7) demonstrated that metapopulation models may not be of value in dynamic landscapes, where extinction of fragmented populations corresponds to fragment disappearances. But predictive models can contribute to the way we approach conservation on the front end before further damage is levied on already disturbed primate populations. Models rarely used in primate conservation work, such as Agent-Based Simulations would allow for capturing all of the "moving parts" in a fragmented ecosystem, including the human elements, in a way that would describe layered details often not reported in our field. Our continued dialog about modelling may be one of the best avenues we have on the path to making real impacts in maintaining fragmented primate populations.

Lastly, there is a growing appreciation of the value of long-term research at field sites (Chap. 6, Kappeler and Watts 2012). It is now very clear that addressing many of the most important questions in behavior, ecology, and evolution requires data that extends over decades (Clutton-Brock and Sheldon 2010). Primates were some of the first animal species where individuals were followed over a significant period of their lifetimes, and this contributed a great deal to understanding the selective advantages of different behavioral and life-history strategies. In the study of

fragmentation, we need projects that will clearly illustrate the long-term fate of the primate population, the habitat itself, and the shifts in human-created matrices.

In the last decade there has been an increasing realization that the taxonomic diversity within the Order Primates is significantly larger than ever thought. The number of recognized species has increased from some 230 in 1993 (Groves 1993), to close to 400 in 2005 (Groves 2005), and 480 in 2012 (Mittermeier and Wilson 2012). While some may see this as "taxonomic inflation" (Isaac et al. 2004), the reality is that, certainly from a management perspective, we have more primate species to deal with than ever before. Unfortunately for us as diurnal primates, many of the newly described species are nocturnal, including galagos in eastern Africa, slow and slender lorises in Asia, lemurs in Madagascar, and tarsiers in Southeast Asia (Mittermeier and Wilson 2012). While often even the most basic data are lacking it appears that many of these primates have exceedingly small geographic ranges (Nekaris 2012a, b). To the untrained eye many of the nocturnal species look similar being the primate equivalent of what is known amongst birders as "little brown jobs"; there is, however, no reason to assume these myriad of cryptic species respond in the same manner to anthropogenic pressures. Some may thrive while others may wither. Matching forest distribution maps with the known or inferred distribution ranges of these newly described nocturnal primates suggests that there is plenty of work to be done when it comes to understanding the impact of fragmentation on nocturnal primates.

Where Do We Go from Here?

We would like to end this chapter by outlining what we see as research priorities for the next decade with respect to primates in fragments.

Definition of Fragments

We have discussed the issues surrounding scale, fragment definitions for primate studies, and the need for a commonality in the terms we use in fragmentation science, but in a world of ever continuing deforestation, climate change, habitat modification, human population growth, and pollution it is worth stressing the need for our professional consensus. There is still a qualitative shift necessary in how primates perceive fragmentation (Arroyo-Rodríguez and Mandujano 2009): is everything fragmented? Is it truly a mix of fragmented habitat and continuous? Are there large tracts of continuous forest anywhere in primate habitat countries, and if so, by what definition? It is not only a matter of scale, it is a matter of definition of what it means to be *continuous* more than what it means to be *fragmented*. Definitions of this kind exist, but they have been modified to meet the shifting needs of habitat conversion into a human-dominated landscape (c.f., Chap. 1). What is important to
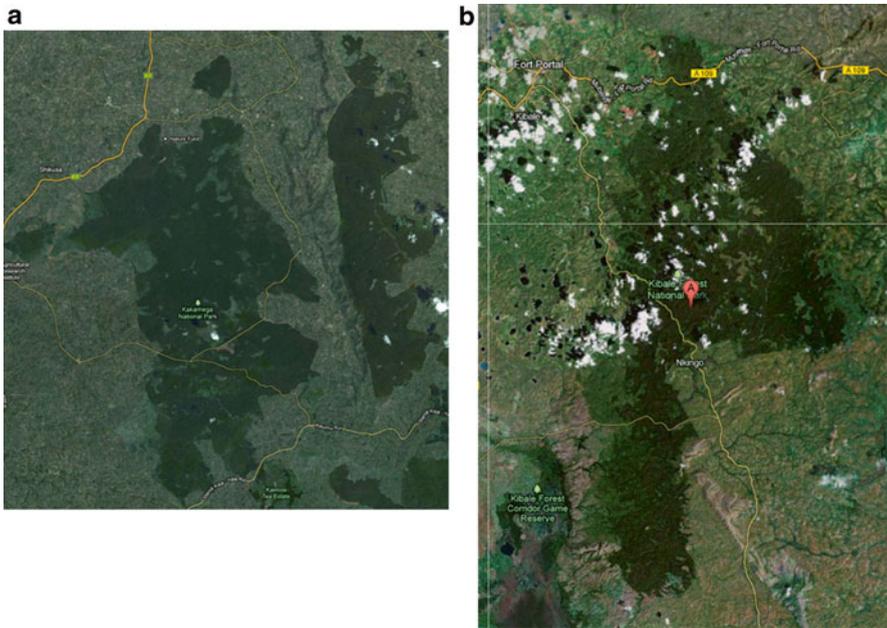
Fig. 34.1 Two national parks in East Africa: (**a**) Kakamega in Kenya and (**b**) Kibale in Uganda

us is a definition within primate science that is consistent no matter the kind of study, that is, whether it is a targeted "fragment" question or not.

We often find studies that compare fragmented habitat to "continuous" forest that lies within a reserve, national park, or other protected area. Similarly, we often find that primate studies on behavior, resource use, or a myriad of other questions are conducted within reserves that are considered "continuous," but are not. We should think of fragmentation as "an unnatural detachment or separation of expansive tracts of suitable habitat into smaller patches, which are spatially segregated by a matrix of non-habitat areas" (Forman 1995; Farina 2007). Ultimately, questions regarding how large is a small patch will depend on the largest known habitat tract in which the species in question is found, and on the ecological, reproductive, and/ or behavioral requirements of the species.

There are numerous examples of "continuous forests in a national park" (see Fig. 2.4b, Chap. 2), but two are illustrated here (Fig. 34.1). Now that satellite imagery is so readily available, it is more and more obvious that our perceptions of what we traditionally describe as continuous may need revision.

Landscape Scale

Studies of primates in fragments usually conclude that fragmentation negatively affects some aspect of their biology or ecology (Chap. 2). Nevertheless, the

definition and quantification of fragmentation vary considerably among studies, resulting in contradictions and results that are difficult to interpret (Arroyo-Rodríguez and Mandujano 2009). It is important to consider that what happens at the fragment scale could be the consequence of processes that interact at various spatial and temporal scales. Fragmentation per se is a landscape scale process (Fahrig 2003), and hence, future fragmentation studies with primates should consider adopting a landscape approach, that is, using landscapes as the independent units of observation (McGarigal and Cushman 2002; Fahrig 2003). Because complete landscapes are very difficult to sample, the fragment-landscape approach (sensu McGarigal and Cushman 2002) can be used to assess the relative impact of both fragment (e.g., fragment size, isolation, shape) and landscape spatial attributes (e.g., number of fragments, forest cover, edge density, connectivity, matrix type) on primates. This approach implicates that fragments are the experimental units, but the independent variables include not only fragment metrics, but also spatial characteristics of the landscape within a specified "neighborhood" distance surrounding the fragment (i.e., within a buffer zone or landscape). With this experimental design and appropriate statistical models (c.f., Smith et al. 2009) we will be able to identify the spatial attributes (including fragmentation per se) with stronger influence on primates.

Taxonomy

Simply put, if you do not know what it is you cannot study it, compare it, or save it. Bortolus (2008) found that biology, ecology, biodiversity, genetics, and like disciplines, tend to disregard reporting the taxonomic pedigree of the species in question resulting in "a cascade of errors with negative consequences for the development of scientific knowledge, as well as for biodiversity and human welfare." He concluded that, "a single incorrect taxonomic identification has a great potential to be assimilated into many different biological and ecological studies and then in several environmental management studies and programs, multiplying its impact synergistically." He maintained that these kinds of errors are likely to have a variety of negative consequences, such as identifying population as homogeneous and monospecific when it is actually recognized as a complex assemblage with completely different geographic distribution patterns. At a minimum, cascading errors in taxonomy in our field are annoying and inaccurate, at worse they are impacting our ability to do good science, conserve species, or get funding (Marsh in press). When it comes to primates in fragments, the need is even greater for taxonomic clarity because we are frequently encroaching where scientists have never been, are working in difficult habitats like swamps or flooded forest, or are studying nocturnal species. Thus, the likelihood for finding new taxa or forms becomes greater the harder it is to study them.

We all need to do a better job in the reporting on nomenclature and taxonomy of primates. We follow Wagele et al. (2011) in proposing that "whenever a species name is used, the author(s) of the species hypothesis be included and the original literature source cited, including taxonomic revisions and identification literature,

which is nothing more than what is done for every other hypothesis or assumption included in a scientific publication." Because it cannot be said enough, a reliable taxonomy is among the major factors guaranteeing the accurate identification of biodiversity hot spots, wilderness areas, endangered species, and areas of greatest concern, including fragments, that impact the entire Order (Marsh in press).

Evolution of Behavioral Flexibility

The study of primate responses to fragmentation is unfortunately still at the stage where we cannot make predictive statements about how different primate communities will respond to different scenarios of fragmentation. The example given earlier where blue monkeys are commonly in fragments across East and South Africa, but not near Kibale National Park is just one of many. A primary reason for the failure to predict responses is that the information is not currently available on which species or populations are sufficiently behaviourally flexible to shift diet, behavior, or social system to changing environmental conditions (Chapman and Rothman 2009). That said, considerable levels of behavioral flexibility have been documented. For example, redtail groups (*Cercopithecus ascanius*) within Kibale varied in the amount of time they spent foraging for leaves (13–35 %), fruit (36–60 %), and insects (15–31 %), and when comparing redtails in different regions, this variation increased (leaves 7–74 %, fruit 13–61 %, and insects 1–16 %) (Chapman et al. 2002; Chap. 15). Likewise, a summary of *Alouatta* species across the Neotropics by Bicca Marques (2003) showed this genus to be extremely flexible overall, with various species relying in some cases almost entirely on invasive or human introduced food species. So while examples exist for taxa that can almost have predictive qualities for survival in fragmented landscapes, there are always exceptions both ways (c.f., Arroyo-Rodríguez and Dias 2009; Cristobal-Azkarate and Dunn for fragment habitability by howlers in Los Tuxtlas, Chap. 6).

Primates in fragmented habitats are almost always surrounded, if not entirely, by human created matrices whether of small villages, timber, firewood, non-timber forest product extraction, cattle, mono-cultural cash crops and other mixed-crop farming or more intensive landscapes with cities, roads, hydroelectric dams, mining, or some combination of all of the above. Primates have been found to live within all of these systems and show some degree of habitat flexibility (c.f., virtually all chapters in this volume, but in particular: Chaps. 8, 11, 12, 15, 19, 20, 21, 22, 23, 31). Primate flexibility for resource use in fragments then, is in part due to their proximity and tolerance of humans, and ultimately, vice versa.

Estrada et al. (2012) reviewed the literature on primates in agroecosystems and found that 57 primate taxa used agroecosystems as temporary or permanent habitats, including 16 species from the Neotropics, 16 from South East Asia, 15 from Sub-Saharan Africa, and 10 from Madagascar. The degree of terrestriality in primates is likely a principal reason we see so much more overt crop-raiding behavior throughout Asia-Africa, but it may also be related to the kinds of crops available.

In Estrada et al. (2012) Table 1, they identified 38 different kinds of agroecosystems (although they missed chimpanzees, baboons, and others species in sugar cane, c.f., Reynolds et al. 2003). But of those identified, there were only 7 of 38 (18 %) overlapping between Old and New World tropics: shade coffee, shade cacao, cacao and *gliricidia*, eucalyptus, banana, oil palm, and mango. And of those, only three: eucalyptus, shade coffee, and cacao/*gliricidia*, were the closest in use between regions, the others did not even nearly compare. Of the overlapping crops, dominant use by Neotropical primates was cacao, and for Asia/Africa banana and oil palm. The authors point out that while use can include primates acting as crop-raiding pests, there are occasions when primates might benefit the farmers by acting as fertilizers, pollinators, seed dispersers, insect control, or tourist attractions (Estrada et al. 2012). In the Neotropics, primates may be successfully incorporated into the agroecosystem culture in ways that may benefit the primate's survival in fragmented habitats because on average, they cause less damage to crops. But it is a fine line where primates are perceived as pests to be hunted (either for food or control) or animals to be tolerated, if not actively conserved. There is a great need to study the primate's flexibility to use these systems for resources and the human ability to allow it.

While our understanding of issues has increased over the last 10 years, our ability to actually develop actions has not. We are not at the stage where it is possible to rigorously quantitatively determine which primate lineages are flexible in ways that facilitate them to respond to fragmentation and those lineages that are not. The main reason for this is that for most species or taxonomic groups we lack a robust number of comparable studies conducted across different spatial or temporal scales to get an understanding of which primates are flexible and positively respond to change, and which are not. Obtaining such an understanding will take us a long way toward predicting response to different scenarios of fragmentation and thus to the development of appropriate conservation plans.

Studying Disease Transmission Using Genetic Tools

There is a critical need for using genetic tools to determine if diseases are being transmitted between humans and nonhuman primates. In Marsh et al. (2003), we pointed out clear zoonotic transmissions, such as ebola, AIDS, and other pandemics between primates and humans, but greater detail is needed in terms of genetic inclusion. The value of genetic analysis to determine if interspecific disease transmission has occurred has been demonstrated by Gasser et al. (2009). They demonstrated that studies employing coproscopic analysis suggested that there was transmission of nodular worm (*Oesophagostomum* sp.) among nonhuman primates and humans, and thus that primates posed a health risk to people. In contrast, genetic analysis suggested that *O. bifurcum* in humans was genetically distinct from populations in nonhuman primates and that these primates did not pose a health risk to people (de Gruijter et al. 2004; Gasser et al. 2006). Similarly cross-species transmission of

avian blood parasites has been confirmed by using both PCR (polymerase chain reaction), direct sequencing, and RAPD (random amplified polymorphic DNA) methods (Waldenström et al. 2002). Genetic methods have also been used to highlight the dangers of primate bushmeat infected with SIV and other diseases (e.g., Peeters et al. 2002).

Climate Change

Climate change was highlighted as a research priority in Marsh (2003) as well. We consider climate change is such a complex issue of which so little is understood that it should remain a research priority in the coming decades for primate science and, in particular, fragmentation science. There is no doubt that climatic change is affecting plant and animal populations around the globe in very apparent ways, such as the loss of geographic range (Dunbar 1998). Yet most changes are likely to be subtle and difficult to detect. For example, in the instance discussed above, primates were likely to be affected by the cessation of fruiting of some species of tropical trees, which the researchers speculated was due to the effect of climate change on pollinators (Chapman et al. 2005). For folivorous primates, one potential consequence of climate change is a decline in nutritional composition of leaves (Coley 1998). Greenhouse experiments have found that elevated CO_2 levels result in a 15–50 % reduction in leaf nitrogen, a 25–30 % increase in fiber (Staudt et al. 2001), and an increase in plant defense chemicals like phenolic compounds (Coley et al. 2002), including a 19 % increase in condensed tannins (Peltonen et al. 2005). All of these changes would be expected to negatively affect folivorous primates, but much more research must be done on the entire range of issues that climate change bears on primate populations (Rothman et al. Submitted).

Restoration of Plant and Animal Communities

For the smallest fragments and most isolated primate populations, managing the species in situ has been proposed (Marsh 2003). However, in general, for primate populations that only occur in fragments, conservation strategies often involve restoring the connectivity among fragments or enlarging the habitat to facilitate the growth of the population. These represent two contrasting management options, and to identify which is the most appropriate for designing successful primate conservation plans we first need to assess the relative impact that habitat loss and fragmentation per se may have on each primate species (Fahrig 1999). As effects and species characteristics can be additive in terms of their ability to remain in a fragmented landscape (Ewers and Didham 2005), often a "both-and" strategy is suitable. If species are more vulnerable to habitat loss, the increment in habitat amount should be the best management option, but if the species are negatively impacted by increasing

fragmentation levels, the best management solution for this species/population should be the creation of vegetation corridors (Fahrig 1999).

While these and other suggestions were made 10 years ago in the first *Primates in Fragments* book, very little has been done to move toward a more direct "hands on" approach at this level of conservation effort. To accomplish any significant impact on the long-term survival of fragmented populations, the scientific community will need an in-depth understanding of methods for restoring plant and animal communities. Restoration of primate communities requires knowledge of the determinants of primate abundance (Feinsinger 2001); however, understanding and predicting factors that affect the abundance of particular species have proven extremely difficult (Chapman et al. 2010; Lwanga et al. 2011). Even so, Silver and Marsh (2003) demonstrated that reintroduction of howlers into a natural habitat that once carried them was successful.

Issues of connectivity were addressed by deVleeschower and Raboy (Chap. 19) where they inform that newer studies take into account the species perspective, since our concept of connectivity is not necessarily the same as the animals'. Lessons from throughout the tropics on living fences, hedgerows, crop borders, agroecosystems, and arboreal forest corridors suggest there are numerous, inexpensive low-tech means of increasing the arboreal surface area for primates (e.g., Asensio et al. 2009). But restoration is not simply creating connectivity or increasing food resources. Long-term viability calls for understanding the mechanisms for ecosystem health beyond primates and fragments that include basic systems, such as seed dispersal, seedling and sapling recruitment, pollination, and abiotic conditions (Marsh and Loiselle 2001). This kind of approach must be handled with the expertise of a larger conservation community involving landscape level ecologists, biologists (species specific experts depending on the region), botanists, soil scientists, local experts from the immediate area, and funding agencies. Restoration will be a useful path in the future of primate conservation, but is one that must take care to involve as many disciplines as possible to incur success.

Incorporating Primates into Humanized Landscapes

In Marsh et al. (2003), we had a separate section entitled, "Politics," to recognize the importance of dealing with the human dimensions associated with fragmentation, and the conservation of primates in humanized landscapes. In the last decade there has been an increased recognition that to address any conservation issue it is necessary to use tools and skills from a number of different disciplines. Ten years ago we stressed that working across disciplines was key, and particularly when it came to habitat areas without protection, it was mandatory. We continue to stress that alliance here: that biologists specializing on other taxonomic groups, social anthropologists, economists, and local and national leaders need to work with primate researchers to aid us in understanding the human element if progress in conserving primates in fragments is to be achieved. An example of the complexity of

issues is the trend in declining human fertility rates and abandonment of rural land as a result of urbanization. If these continue, they will signal a globally significant transformation offering possible conservation opportunities in some regions. This kind of transformation is evident in a number of countries (FAO 2011; Aide et al. 2012), and projections suggest it may occur in the future in many developing nations (Wright and Muller-Landau 2006; Jacob et al. 2008). Such dramatic changes in the human dimension have powerful impacts on primate habitat conservation.

There is a relatively easy means by which academics can incorporate people into change that benefits conservation of primates in fragments. The first is through formal education in urban schools. Ten years ago, we supported education in source countries of rural community members, students, and teachers and numerous examples flood the literature of successes. And while, and while we still believe in both formal and informal education in rural regions, focusing on urban education is key. Of the world's most populated cities, 18 of the top 25 (72 %) are primate source countries, with New York (#19) and London (#21) further down the list (http://en.wikipedia.org/wiki/List_of_cities_proper_by_population). Over 50 % of the world's population lives in cities, and likely a huge majority have little understanding of forest dwelling animals. Educators in cities can often reach hundreds of students a year, and through lectures and lessons, can provide not only appreciation, but a solid basis for understanding the natural world. The impact of this is staggering, especially if we can convince our schools that courses in ecology, biodiversity, and conservation are mandatory. It is true that the majority of students will not become committed to conservation in countries harboring primates, but they do vote, they buy products, and they go on vacation—often to primate rich regions if they are not already from a source country. Educated students would have a better ability for understanding political issues of the day, in terms of how they might impact the environment in their nation, as well as the global environment which ultimately impacts primates. Nations in North America, Europe, and Asia are some of the most rabid consumers on the planet, but with mandatory environmental education, their choices for consumption can become less deleterious.

Further, we can support a growing field of Tropical Urban Ecology. An excellent example is Programa Macacos Urbanos in Porto Alegre, Brazil, where scientists and students work with local landowners in and around a major city to provide knowledge for incorporating wildlife, but especially primates, into urban parks. They also provide education to farmers and ranchers in the extended area on how best to manage their land in a way that aids primates. Where primates are subsumed within cities (Chap. 23), we are seeing action groups popping up to find creative solutions for their safety and long-term management. There are small projects like this all over the world, but the ideas are clear: primates and humans must find a way to co-exist.

Conclusions

It is apparent that there are great challenges ahead of the scientific community if we are to formulate effective conservation plans for primates living in fragments. We still have a great deal to do: we must integrate approaches across disciplines, develop effective predictive models of how species will respond to change, and we must understand how to effectively influence policy. In another decade's time, we hope to report that all of these needs have been met, and the challenges have been embraced to drive our knowledge of primates in fragments toward the broadening goal of never losing a single primate species to extinction.

References

Aide TM, Clark ML, Grau HR, López-Carr D, Levy MA, Redo D, Bonilla-Moheno M, Riner J, Andrade-Nuñez MJ, Muñiz M (2012) Deforestation and reforestation of Latin America and the Caribbean (2001–2010). Biotropica, DOI: 10.1111/j.1744-7429.2012.00908.x

Arroyo-Rodríguez V, Asensio N, Dunn JC, Cristóbal-Azkarate J, Gonzalez-Zamora A (2013) The importance of lianas for primates: more than just a food source. In: Schnitzer S, Bongers F, Burnham R, Putz F (eds) Ecology of lianas. Springer, New York

Arroyo-Rodríguez V, Dias PAD (2009) Effects of habitat fragmentation and disturbance on howler monkeys: a review. Am J Primatol 71:1–16

Arroyo-Rodríguez V, Mandujano S (2006) Forest fragmentation modifies habitat quality for *Alouatta palliata*. Int J Primatol 27:1079–1096

Arroyo-Rodríguez V, Mandujano S (2009) Conceptualization and measurement of habitat from a primates' perspective. Int J Primatol 30:497–514

Asensio N, Arroyo-Rodríguez V, Dunn JC, Cristóbal-Azkarate J (2009) Conservation value of landscape supplementation for howler monkeys living in forest patches. Biotropica 41:768–773

Bergl RA, Bradley BJ, Nsubuga A, Vigilant L (2008) Effects of habitat fragmentation, population size and demographic history on genetic diversity: the cross river gorilla in a comparative context. Am J Primatol 70:848–859

Bicca-Marques JC (2003) How do howler monkeys cope with habitat fragmentation? In: Marsh LK (ed) Primates in fragments: ecology and conservation. Kluwer Academic Publishers, New York, NY, pp 283–304

Bonilla-Sanchez YM, Serio-Silva JC, Pozo-Montuy G, Chapman CA (2012) Does the expansion of Eucalyptus plantations signal hope or despair for black howler monkeys. Int J Primatol 33:233–245

Bortolus A (2008) Error cascades in the biological sciences: the unwanted consequences of using bad taxonomy in ecology. Ambio 37(2):114–118

Butinski TM, Kalina J (1998) Gorilla tourism: a critical review. In: Milner-Gulland EJ, Mace R (eds) Conservation of biological resources. Blackwell, Oxford, pp 280–300

Chapman CA, Chapman LJ, Cords M, Gauthua M, Gautier-Hion A, Lambert JE, Rode KD, Tutin CEG, White LJT (2002) Variation in the diets of Cercopithecus species: differences within forests, among forests, and across species. In: Glenn M, Cords M (eds) The guenons: diversity and adaptation in African monkeys. Plenum, New York, NY, pp 319–344

Chapman CA, Chapman LJ, Struhsaker TT, Zanne AE, Clark CJ, Poulsen JR (2005) A long-term evaluation of fruiting phenology: importance of climate change. Journal Of Tropical Ecology 21:31–45

Chapman CA, Gogarten JF (2012) Primate conservation: is the cup half empty or half full? In.NatureEducation(http://www.nature.com/scitable/knowledge/library/primate-conservation-is-the-cup-half-empty-53872551)

Chapman CA, Lawes MJ, Eeley HAC (2006a) What hope for African primate diversity? Afr J Ecol 44:1–18

Chapman CA, Peres CA (2001) Primate conservation in the new millennium: the role of scientists. Evolutionary Anthropology 10:16–33

Chapman CA, Rothman JM (2009) Within-species differences in primate social structure: evolution of plasticity and phylogenetic constraints. Primates 50:12–22

Chapman CA, Saj TL, Snaith TV (2007) Temporal dynamics of nutrition, parasitism, and stress in colobus monkeys: implications for population regulation and conservation. American Journal Of Physical Anthropology 134:240–250

Chapman CA, Struhsaker TT, Skorupa JP, Snaith TV, Rothman JM (2010) Understanding long-term primate community dynamics: implications of forest change. Ecol Appl 20:179–191

Chapman CA, Wasserman MD, Gillespie TR, Speirs ML, Lawes MJ, Saj TL, Ziegler TE (2006b) Do nutrition, parasitism, and stress have synergistic effects on red colobus populations living in forest fragments? Am J Phys Anthropol 131:525–534

Clutton-Brock TH, Sheldon BC (2010) Individual and populations: the role of long-term, individual-based studies of animals in ecology and evolutionary biology. Trends Ecol Evol 25:562–573

Coley P, Massa M, Lovelock CE, Winter K (2002) Effects of elevated CO_2 on foliar chemistry of saplings of nine species of tropical tree. Oecologia 133:62–69

Coley PD (1998) Possible effects of climate change on plant/herbivore interactions in moist tropical forests. Clim Chang 39:455–472

Cowlishaw G, Dunbar R (2000) Primate conservation biology. University of Chicago Press, Chicago, IL

de Gruijter JM, Ziem J, Verweij JJ, Polderman AM, Gasser RB (2004) Genetic substructuring within Oesophagostomum bifurcum (Nematoda) from human and non-human primates from Ghana based on random amplified polymorphic DNA analysis. Am J Trop Med Hyg 71:227–233

Donati G, Kesch K, Ndremifidy K, Schmidt SL, Ramanamanjato J-B, Borgognini-Tarli SM, Ganzhorn JU (2011) Better few than hungry: flexible feeding ecology of collared lemurs *Eulemur collaris* in littoral forest fragments. PLoS One 6(5):e19807. doi:10.1371/journal.pone.0019807

Dunbar RIM (1998) Impact of global warming on the distribution and survival of the gelada baboon: a modeling approach. Glob Chang Biol 4:293–304

Dunn JC, Asensio N, Arroyo-Rodriguez V, Schnitzer S, Cristobal-Azkarate J (2012) The ranging costs of a fallback food: liana consumption supplements diet but increases foraging effort in howler monkeys. Biotropica 44:705–714

Dunn JC, Cristóbal-Azkarate J, Veà J (2009) Differences in diet and activity pattern between two groups of Alouatta palliata associated with the availability of big trees and fruit of top food taxa. Am J Primatol 71:654–662

Dunn JC, Cristóbal-Azkarate J, Veà J (2010) Seasonal variations in the diet and feeding effort of two groups of howler monkeys in different sized forest fragments. Int J Primatol 31:887–903

Dunn JC, Cristóbal-Azkarate J, Chavira R, Veà J (2013) Travel time predicts fecal glucocorticoid levels in free-ranging howler monkeys. Int J Primatol 34(2):246–259

Dunning JB, Danielson BJ, Pulliam R (1992) Ecological processes that affect populations in complex landscapes. Oikos 65:169–175

Estrada A, Raboy B, Olivera LC (2012) Agroecosystems and primate conservation in the tropics: a review. Amer J Primatol 00:1–16

Ewers RM, Didham RK (2006) Confounding factors in the detection of species responses to habitat fragmentation. Biol Rev 81:117–142

FAO (2010) Global forest resources assessment 2010 – key findings, Rome. foris.fao.org/static/data/fra2010/keyfindings-en.pdf

FAO (2011) State of the world's forests 2011. Food and Agriculture Organization of the United Nations, Rome

Fahrig L (1999) Forest loss and fragmentation: which has the greater effect on persistence of forest-dwelling animals? In: Rochelle JA, Lehmann LA, Wisniewski J (eds) Forest fragmentation; wildlife and management implications. Leiden, The Netherlands, pp 87–95

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

Farina A (2007) Principles and methods in landscape ecology: towards a science of the landscape. Springer, Netherlands

Feinsinger P (2001) Designing field studies for biodiversity conservation. The nature conservancy. Island Press, Washington, DC

Forman RTT (1995) Some general principals of landscape and regional ecology. Landsc Ecol 10(3):133–142

Gasser RB, de Gruijter JM, Polderman AM (2006) Insights into the epidemiology and genetic make-up of *Oesophagostomum bifurcum* from human and non-human primates using molecular tools. Parasitology 132:453–460

Gasser RB, de Gruijter JM, Polderman AM (2009) The utility of molecular methods for elucidating primate-pathogen relationships the *Oesophagostomum bifurcum* example. In: Huffman MA, Chapman CA (eds) Primate parasite ecology: the dynamics and study of host-parasite relationships. Cambridge University Press, Cambridge, pp 47–62

Goldberg TL, Gillespie TR, Rwego IB, Estoff EE, Chapman CA (2008) Forest fragmentation as cause of bacterial transmission among primates, humans, and livestock, Uganda. Emerg Infect Dis 14:1375–1382

González-Zamora A, Arroyo-Rodríguez V, Chavez O, Sanchez-Lopez S, Stoner KE, Riba-Hernández P (2009) Diet of spider monkeys (*Ateles geoffroyi*) in Mesoamerica: current knowledge and future directions. Am J Primatol 71:8–20

Gonzalez-Zamora A, Arroyo-Rodriguez V, Chaves O, Sanchez-Lopez S, Aureli F, Stoner K (2011) Influence of climatic variables, forest type, and condition on activity patterns of Geoffroyi's spider monkeys throughout Mesoamerica. Am J Primatol 73:1189–1198

Goossens B, Anthony N, Jeffery K, Johnson-Bawe M, Bruford MW (2003) Collection, storage and analysis of non-invasive genetic material in primate biology. In: Setchell JM, Curtis DJ (eds) Field and laboratory methods in primatology. Cambridge University Press, Cambridge, UK, pp 295–308

Goossens B, Chikhi L, Ancrenaz M, Lackman-Ancrenaz I, Andau P et al (2006) Genetic signature of anthropogenic population collapse in orang-utans. PLoS Biol 4(2):e25

Groves CP (1993) Order Primates. In: Wilson DE, Reeder DM (eds) Mammal species of the world, 2nd edn. Smithsonian Institution Press, Washington, pp 243–277

Groves CP (2005) Primates. In: Wilson DE, Reeder DM (eds) Mammal species of the world, 3rd edn. Johns Hopkins University Press, Baltimore, MD, pp 111–184

Hannah L, Midgley GF, Lovejoy T, Bond WJ, Bush M, Lovett JC, Scott D, Woodwards FL (2002) Conservation of biodiversity in a changing climate. Conserv Biol 16:264–268

Hardus ME, Lameira AR, Menken SBJ, Wich SA (2012) Effects of logging on orangutan behavior. Biol Conserv 146:177–187

Hodder SAM, Chapman CA (2012) Do Colobus monkeys on humanized forest edges exhibit more severe parasite infections than those on non-humanized forest edges? International Journal of Primatology 33:845–859

Isaac N, Mallet J, Mace G (2004) Taxonomic inflation: its influence on macroecology and conservation. Trends Ecol Evol 19(9):464–469

IPPC (2001) Climate change 2001: the scientific basis. Cambridge University Press, Cambridge

Jacob AL, Vaccaro I, Sengupta R, Hartter J, Chapman CA (2008) How can conservation biology best prepare for declining rural population and ecological homogenization? Tropical Conservation Science 4:307–320

Kappeler PM, Watts DP (2012) Long-term field studies of primates. Springer, New York, NY

Köndgen S, Kühl H, N'Goran PK, Walsh PD, Schenk S, Ernst N, Biek R et al (2008) Pandemic human viruses cause decline of endangered great apes. Curr Biol 18(4):260–264. doi:10.1016/j. cub.2008.01.012

Lane K, Holley C, Hollocher H, Fuentes A (2011) The anthropogenic environment lessens the intensity and prevalence of gastrointestinal parasites in Balinese long-tailed macaques (*Macaca fascicularis*). Primates 52:117–128

Lawes MJ, Mealin PE, Piper SE (2000) Patch occupancy and potential metapopulation dynamics of three forest mammals in fragmented afromontane forest in South Africa. Conserv Biol 14:1088–1098

Lovett JC, Barnard P, Midgley GF (2005a) National climate change conference in South Africa. Afr J Ecol 43:1–3

Lovett JC, Midgley GF, Barnard P (2005b) Climate change and ecology in Africa. Afr J Ecol 43:163–169

Lwanga JS, Struhsaker TT, Struhsaker PJ, Butynski TM, Mitani JC (2011) Primate population dynamics over 32.9 years at Ngogo, Kibale National Park, Uganda. Am J Primatol 73:997–1011

Malcolm JR, Liu C, Neilson RP, Hansen L, Hannah L (2006) Global warming and extinctions of endemic species from biodiversity hotspots. Conserv Biol 20:538–548

Marsh LK. A taxonomic revision of the saki monkeys, genus Pithecia (Desmarest 1804). Neotropical Primates (in press)

Marsh LK (2003) Primates in fragments: ecology and conservation. Kluwer Academic Publishers, New York, NY

Marsh LK, Chapman CA, Norconk MA, Ferrari SF, Gilbert KA, Bicca-Marques JC, Wallis J (2003) Fragmentation: specter of the future or spirt of conservation. In: Marsh LK (ed) Primates in fragments: ecology and conservation. Kluwer Academic Publishers, New York, NY, pp 381–398

Marsh LK, Loiselle BA (2001) Recruitment of black howler fruit trees in fragmented forests of northern Belize. Int J Primatol 24(1):65–84

Marshall AJ, Boyko CJ, Feilen KL, Boyko RH, Leighton M (2009) Defining fallback foods and assessing their importance in primate ecology and evolution. Am J Phys Anthropol 140:603–614

McClean CJ, Lovett JC, Kuper W, Hannah L, Sommer JH, Barthlott W, Termansen M, Smith GF, Tokumine S, Taplin JRD (2005) African plant diversity and climate change. Annals of the Missouri Botanical Gardens 92:139–152

McGarigal K, Cushman SA (2002) Comparative evaluation of experimental approaches to the study of habitat fragmentation effects. Ecol Appl 12:335–345

Mittermeier R, Wilson DE (2012) Mammals of the world, vol 3, Primates. Lynx Edicions, Barcelona

Nekaris KAI (2012a) Family Galagidae (Galagos). In: Mittermeier R, Wilson DE (eds) Mammals of the world, vol 3, Primates. Lynx Edicions, Barcelona

Nekaris KAI (2012b) Family Lorisidae (Pottos, Angwantibos and Lorises). In: Mittermeier R, Wilson DE (eds) Mammals of the world, vol 3, Primates. Lynx Edicions, Barcelona

Nelleman C, Redmond I, Refisch J (2010) The last stand of the Gorilla: environmental crime and conflict in the Congo Basin. Birkeland Trykkeri, Norway

Onderdonk DA, Chapman CA (2000) Coping with forest fragmentation: the primates of Kibale National Park, Uganda. Int J Primatol 21:587–611

Pardini R, Bueno AA, Gardner TA, Prado PI, Metzger JP (2010) Beyond the fragmentation threshold hypothesis: regime shifts in biodiversity across fragmented landscapes. PLoS One 5:e13666

Parmesan C, Yohe GA (2003) A globally coherent fingerprint of climate change impacts across natural systems. Nature 421:37–42

Peeters M, Courgnaud V, Abela B, Auzel P, Pourrut X, Bibollet-Ruche F et al (2002) Risk to human health from a plethora of simian immunodeficiency viruses in primate bushmeat. Emerg Infect Dis 8:451–457

Peltonen PA, Vapaavuori E, Julkenen-Tiitto R (2005) Accumulation of phenolic compounds in birch leaves is changed by elevated carbon dioxide and ozone. Glob Chang Biol 11:1305–1324

Pounds JA, Fogden MPL, Campbell JH (1999) Biological response to climate change on a tropical mountain. Nature 398:611–615

Puyravaud JP (2003) Standardizing the calculation of the annual rate of deforestation. For Ecol Manage 177:593–596

Ramos-Fernandez G, Ayala-Oozco B (2003) Population size and habitiat use of spider monkkeys at Punta Laguna, Mexico. In: Marsh LK (ed) Primates in fragments: ecology and conservation. Kluwer Academic Publishers, New York, NY, pp 191–209

Reynolds V, Wallis J, Kyamanywa R (2003) Fragments, sugar, and chimpanzees in Masindi District, Western Uganda. In: Marsh LK (ed) Primates in fragments: ecology and conservation. Kluwer Academic Publishers, New York, NY, pp 309–320

Rothman JM, Chapman CA, Struhsaker TT, Raubenheimer D, Twinomugisha D, Waterman PG Cascading effects of global change: decline in nutritional quality of tropical leaves. Ecol Lett (Submitted)

Sapolsky RM (2002) Endocrinology of the stress response. In: Becker JB, Breedlove SM, Crews D (eds) Behavioural endocrinology. MIT Press, Cambridge, MA, pp 409–450

Schnitzer SA, Bongers F (2011) Increasing liana abundance and biomass in tropical forests: emerging patterns and putative mechanisms. Ecol Lett 14:397–406

Serio-Silva JC, Pozo-Montuy G, Bonilla-Sánchez YM (2006) Black howler monkeys (*Alouatta pigra*) inhabiting eucalyptus (*Eucalyptus grandis*) plantations in Tabasco, Mexico: habitat use and questions to answer. Am J Primatol 68:35

Silver S, Marsh LK (2003) Dietary flexibility, behavioral plasticity, and survival in fragments: lessons from translocated howlers. In: Marsh LK (ed) Primates in fragments: ecology and conservation. Kluwer Academics, New York, NY, pp 251–265

Smith AC, Koper N, Francis CM, Fahrig L (2009) Confronting collinearity: comparing methods for disentangling the effects of habitat loss and fragmentation. Landscape Ecol 24:1271–1285

Staudt M, Joffre R, Rambal S, Kesselmeier J (2001) Effect of elevated CO_2 on monoterpene emission of young *Quercus ilex* trees and its relation to structural and ecophysiological parameters. Tree Physiol 21:437–445

Terborgh J (1983) Five new world primates. Princeton University Press, Princeton, NJ

Wägele H, Klussmann-Kolb A, Kuhlmann M, Haszprunar G, Lindberg D, Koch A, Wägele JW (2011) The taxonomist - an endangered race. A practical proposal for its survival. Front Zool 8:25

Waldenström J, Bensch S, Kiboi S, Hasselquist D, Ottosson U (2002) Cross-species infection of blood parasites between resident and migratory songbirds in Africa. Mol Ecol 11:1545–1554

Wich SA, Riswan JJ, Refisch J, Nellemann C (2011) Orangutans and the economic sustainable forest management in Sumatra. Birkeland Trykkeri, Norway

Wright PC, Arrigo-Nelson SJ, Hogg KL, Bannon B, Morelli TL, Wyatt J, Harivelo AL, Ratelolahy F (2009) Habitat disturbance and seasonal fluctuations of lemur parasites in the rain forest of Ranomafana National Park, Madagascar. In: Chapman CA, Huffman MA (eds) Primate parasite ecology: the dynamics and study of host-parasite relationships. Cambridge University Press, Cambridge, pp 311–330

Wright SJ, Muller-Landau HC (2006) The future of tropical forest species. Biotropica 38:287–301