Agroecosystems

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Recent assessments indicate the existence of approximately 612 primate taxa recognized by the International Union for Conservation of Nature's Red List (IUCN 2014). Unfortunately, the world's primate taxa are at risk of extinction because of human activities. The IUCN Red List database classifies 37 percent of primate taxa as Least Concern, but the rest (63 percent) as Endangered (24 percent), Vulnerable (22 percent), Critically Endangered (11 percent), and Near Threatened (6 percent). High human population growth translates into local- and landscape-level agricultural intensification that places enormous pressure on natural habitats in many primate range countries, including protected areas (Estrada 2013). In addition, most protected areas are surrounded by, or are part of, a matrix of human-altered habitats. This situation will increase not only the extent of anthropogenic pressures, but also the difficulty in successfully enforcing protected areas. There is a clear and urgent need for the development of additional solutions for compensating primate habitat loss. One avenue in this direction is to explore the value of agroecosystems for primate conservation in human-modified landscapes (Estrada, Raboy, and Oliveira 2012).

Agroecosystems cover more than one-quarter of the global land area (approximately 50 million km^2), as highly simplified systems (e.g., pasturelands) or more complex systems (e.g., polycultures and agroforestry systems) with the capacity to support higher biodiversity. Farmers benefit from agroecosystems and natural vegetation by harvesting plants for food, medicine, and fuel, hunting wild animals, retention of soil and soil fertility, and water conservation (Schroth et al. 2004). Ecological services may be further enhanced in heterogeneous landscapes by patches of native habitat and diverse assemblages of agroecosystems, providing cash income to rural households, and comprise the basis of regional and national economies.

A recent review on the topic showed that 57 primate taxa from four regions—Mesoamerica, South America, Sub-Saharan Africa (including Madagascar), and Southeast Asia and India—used 38 types of agroecosystems as temporary or permanent habitats (Estrada et al. 2012; Figure 1). While 40 percent of the primate taxa recorded in agroecosystems are classified as Least Concern in the IUCN Red List, the remaining 60 percent were under some type of risk category: Vulnerable (23 percent), Endangered (21 percent), Near Threatened (9 percent), and Critically Endangered (4 percent) (Figure 2). The large proportion of threatened primates in agroecosystems suggests that these manmade habitats may play an important role in landscape approaches to primate conservation. The number of primate taxa using agroecosystems and the types of agroecosystems involved in our review is probably an underestimate, as there are very few studies focusing on this issue.

Agroecosystems used by primates in human-modified landscapes represent additional availability of vegetation, potential food resources, shelter, and the possibility to disperse and find conspecifics. In a fragmented landscape where the matrix is agroforest or other types of arboreal agroecosystems, the presence of networks of linear strips of vegetation represented by live fences, hedgerows, and/or riparian corridors supports dispersal of primates. Importantly, agroecosystems bordering forest fragments or natural protected areas may be an important buffer protecting against edge effects, such as desiccation caused by high temperatures and low humidity, soil compactness, wind penetration, and resulting tree mortality (Schroth et al. 2004).

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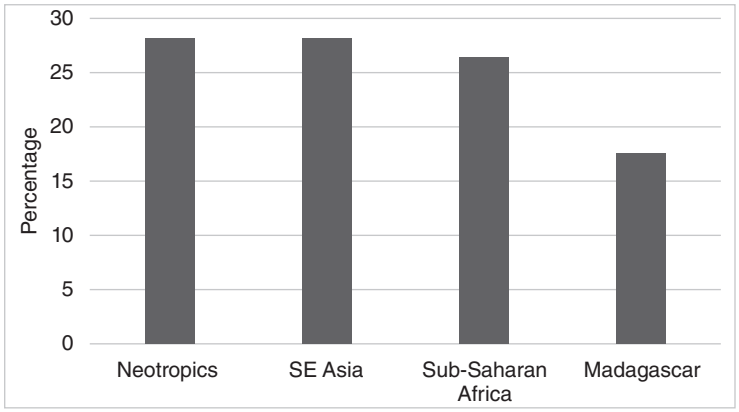

Figure 1 Percentage use of 38 types of agroecosystems by 57 primate taxa in Mesoamerica, South America, Sub-Saharan Africa (including Madagascar), and Southeast Asia.
Raw data from the authors' personal databases.

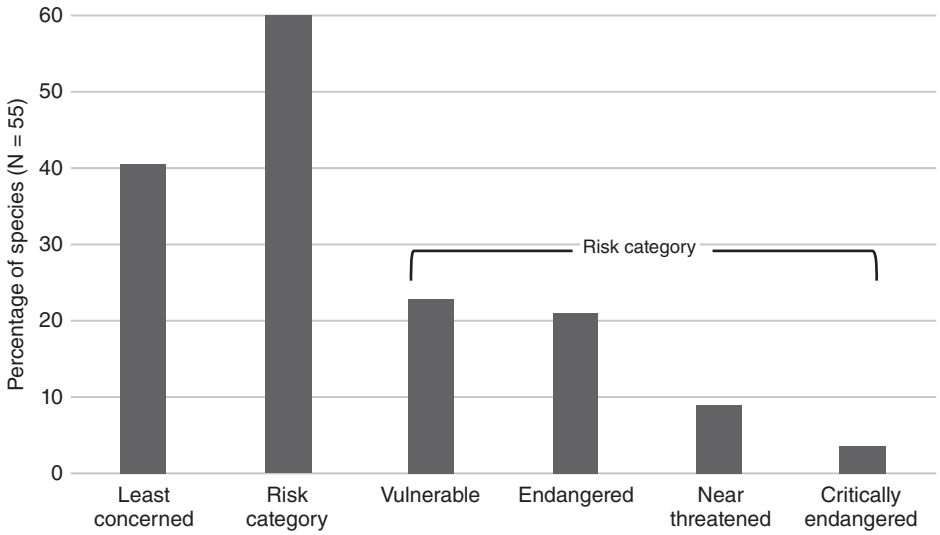

Figure 2 Percentage of primate species using agroecosystems as temporary or permanent habitat and their conservation status according to the IUCN Red List (IUCN 2014). Two species, Griffith's silver langur (*Trachypithecus villosus*) and Geoffroy's dwarf lemur (*Cheirogaleus major*), are not included in the graph because the IUCN Red List indicated Data Deficient for the first and Not Available for the second.
Use of data for building the graph was made following the terms and conditions established by the IUCN for derivative works (http://www.iucnredlist.org/info/terms-of-use#2_Copyrights_and_ownership).

Conservation approaches using agroecosystems may incorporate wildlife-friendly farming or high-intensity farming with land sparing for nature.

The survey of the use of agroecosystems by primates showed that 74 percent of the 57 species detected as using agroecosystems as permanent or temporary habitats were arboreal, 14 percent terrestrial, and 12 percent both. It also showed that 88 percent were diurnal and 12 percent nocturnal (Estrada et al. 2012). These patterns suggest that the use of agroecosystems is not

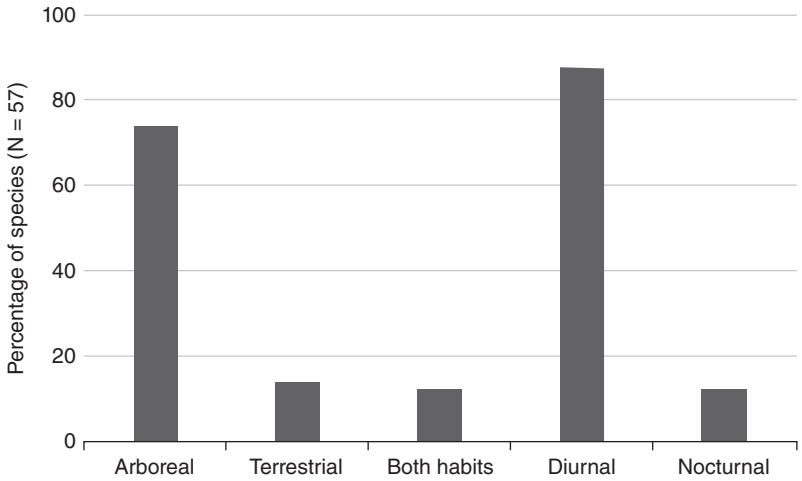

Figure 3 Percentage of primate species classified as arboreal, terrestrial, or both habits, and as diurnal and nocturnal in habits that use agroecosystems.
Graph built with data from the authors' personal databases.

restricted to species with a particular type of habit or activity period. It also shows the predominance of arboreal and of diurnal primate taxa in the use of agroecosystems (Figure 3).

Physical Substrata in Agroecosystems and their Use by Primates

Forest-shaded agroecosystems, such as cacao, coffee, mixed cacao/coffee, and cardamom, and the complexity of the mid and upper canopy, including numerous epiphytes, vines, lianas, and other climbing plants, offer many potential food resources, shelter, resting sites, and cover to primates using these habitats. In Sub-Saharan Africa, Madagascar, and Southeast Asia, many small- (e.g., galago, Geoffroy's dwarf lemur, Dian's tarsier), medium- (e.g., colobus, macaques, gibbons), and even large- (e.g., chimpanzees, orangutans) size primates benefit from the presence of arboreal plantations. Shaded cacao, coffee, and cardamom, mango, and rubber plantations, among others, provide enough substratum for locomotion and other activities, as well as shelter and additional food.

In the Neotropics, primates such as squirrel and capuchin monkeys can reside in large (more than 100-ha) African oil-palm plantations, because the monkeys can find shelter and potential food items represented by the sugary pulp encasing the seed of palm fruits, and insects and small vertebrates found in palm fronds and on tree trunks. Golden-headed lion tamarins use shaded cacao plantations, rich with jack-fruits (*Artocarpus heterophyllus*), as permanent habitat, with reproductive rates similar or even higher than in forested areas (Oliveira et al. 2011).

Risks for Primates in Agroecosystems

Although agroecosystems may be important for primate conservation, there are potential risks for primates using these habitats, such as hunting by humans and disease transmission from humans and domestic animals, as well as conflicts with humans because of widespread or intense crop raiding. Below we briefly sketch some of these risks.

Hunting

Primates living in human-modified landscapes, agroecosystems, and matrix habitats are at greater risk of being hunted by humans and domestic dogs and by open-habitat raptors and other predators. In addition, farmers hunt in

and around their fields for home consumption, local or urban sale, or to eradicate what they believe are pests. Primates in agroecosystems may become victims of hunters seeking young individuals for the pet trade. In general, primates venturing into agricultural fields and using these as stepping stones when moving across the human-modified landscape or as a source of food are much more exposed to hunters, due to lack of dense vegetation cover.

Disease Transmission

The close proximity of human to nonhuman primates in agroecosystems may increase the risk of disease and parasite transmission among humans, nonhuman primates, and domesticated animals. Primates using agroecosystems may have to come to the ground to move from one patch to another and/or may drink ground water, with the possibility of acquiring parasites. The proximity to human settlements and to domestic animals may also expose primates to parasitic vectors or intermediate hosts. In some cases, this may result in high mortality and morbidity. In Tanzania, a population of the Olive baboon living in close proximity with people was infected with yaws, typically transmitted through flies. In another region of Africa, gorillas and chimpanzees living in fragmented habitats and exploiting agroecosystems are contracting diseases and parasites from humans and their livestock. At a cacao plantation in southeast Mexico, mantled howler monkeys had a high prevalence of coccidia, commonly found in poultry and cattle. In general, Old World monkeys and apes seem to be more susceptible to human-borne diseases such as tuberculosis, shigellosis, salmonellosis, colibacillosis, *Klebsiella pneumoniae*, *Hemophilus influenzae*, malaria, and amoebiosis, among others, than New World primates and strepsirhines.

Primate Crop Raiding and Conflict with Humans

Cropland agroecosystems in the tropics often border primate habitat. Consequently, crop raiding is a major cause of conflict with humans. As a result, some primates are viewed as a serious menace to agriculture in many tropical countries, leading in some cases to the implementation of primate control or eradication plans (McLennan and Hockings 2014). Furthermore, crop damage may lead to the clearance of natural vegetation to eliminate or discourage crop raiding (Bitty et al. 2015). Crop raiding by primates seems to be more common in the Paleotropics than in the Neotropics. This may be because Neotropical primate species assemblages are generally arboreal, in contrast to the many semiterrestrial forms of the Paleotropics. In Africa and Asia, primates are responsible for 50– 70 percent of the crop damage in agricultural areas surrounding protected areas. Species in the widespread groups of baboons, macaques, vervet monkeys, and guenons are the most frequent primates responsible for such damage (Priston, Wyper, and Lee 2012).

Potential Benefits to Humans from Primates in Agroecosystems

Studies on the ecological value of forest-dwelling primates indicate that the role primates play in seed dispersal is essential for the regeneration of plant species. Such a role cannot be compensated for by other taxa, stressing the importance of primate persistence for continuing forest dynamics and natural regeneration and for local economies. It is likely that primates disperse the seeds of human-grown plants in a similar manner to the well-documented process in native forest. In southern Mexico, for example, seedlings from seeds dispersed by howler monkeys in shaded cacao plantations are harvested by humans for reforestation within and outside the plantation.

The foraging activities of primates in agroecosystems may result in the removal of foliage and dislodging of branches and other organic matter in canopy trees that provide shade to underlying cultivars such as cacao, coffee, and cardamom. This may stimulate growth of foliage and accelerate the addition of organic matter to the soil. Primate feces may add important nutrients to the soil, such as nitrogen and phosphorus. High dispersal of nutrients via feces in agroecosystems may result from the primates'

daily movements, benefiting, to some extent, the cultivated plants.

Population outbreaks of some insect species can have an overwhelming effect on agroecosystems, because the insects severely defoliate the trees or attack the fruit, the seed, or the bark. The foraging activities of insect-eating primates may be important in ameliorating the impact of insect pests. In Guaviare, Colombia, shaded cacao plantations are visited by squirrel monkeys to feed on ants, and in Amazonian Peru, this primate feeds on insects in mixed agroecosystems (corn, bananas, and fruit trees) to supplement its dietary needs. Insect foraging is common in golden-headed lion tamarins living in cacao plantations in Brazil. Insect eating has also been reported for Dian's tarsier in mixed-species plantations of cacao and gliricidia in Sulawesi, Indonesia.

Occasionally, plantation managers/owners benefit from the presence of primate groups, especially when tourism generates extra income. In Bali, Indonesia, farmers tolerate damage to crops by the Bali macaque because of the economic yield from tourism (Riley and Priston 2010). In southeast Mexico, some shaded cacao plantations successfully integrate the presence of howler monkeys into a marketing and conservation strategy attracting tourists.

General Considerations

Global human population growth will continue to increase in the next decades, with most growth taking place in primate range regions. Global economic trends indicate important pressures to expand cash crops to satisfy local needs and exports. Highly simplified agroecosystems (e.g., pasturelands) or more complex systems (e.g., polycultures and agroforestry systems) will continue to expand and dominate primate range landscapes.

Changes in local and global market demands may result in changes in the distribution of agroforests and other agroecosystems where primate populations are able to exist. For example, the current trend to switch from shade coffee to sun coffee and shaded cacao to sun cacao could result in a loss of important primate habitat. Similarly, the trend to expand cultivation of sun coffee at the expense of areas dedicated to shade cacao has similar consequences. In areas where cacao agroforestry systems have been abandoned due to disease problems, plantations are converted to other land uses (e.g., pasture, banana and oil-palm production, *Eucalyptus*), which may have a lower value for primate conservation.

Cautionary Comment

While some primate populations are able to persist in agroecosystems, it is important to stress that this is no substitute for preserving primates in their natural habitats. However, the pressure of rapidly increasing human populations and the resultant demand for tropical resources is rapidly transforming primate habitats into mosaics dedicated to the production of food and other goods (e.g., oil palm for biodiesel). Globally, agroecosystems have a major presence in fragmented landscapes. At local and regional scales, well-managed agroecosystems have the potential to positively impact the long-term conservation of biodiversity, including that of some primate taxa and populations, and must be considered in landscape-level approaches to conservation.

Conservation Approach

Evidence suggests that agroecosystems could be used as permanent or temporary habitat by primates, and that they may be useful as buffer zones for forest fragments in a fragmented landscape. A series of studies showed the effectivity of agroecosystems as buffer zones to protected areas, decreasing the pressure of hunting in the forests, avoiding fires within forest fragments, and protecting against biotic and abiotic edge effects (Schroth et al. 2004). As primates may use agroecosystems as habitat, it may also increase the amount of habitat available for primates, and consequently allow the persistence of their populations.

Research Needs

Not many studies exist today that provide specific information on patterns of use and the success

of primate populations persisting over the long term in agroecosystems or in their vicinity. Further research is necessary to monitor primate populations in agroecosystems throughout their range. It is likely that more species will be recorded as additional surveys are completed. For example, we recently recorded the presence of the southern Bahian masked titi (*Callicebus melanochir*) and the yellow-breasted capuchin (*Sapajus xanthosternos*) in shaded cacao in the state of Bahia, Brazil (Oliveira, unpublished). Studies of foraging ecology and population sustainability will be useful to determine the relative success of primates in persisting in agricultural landscapes. The development of models to augment landscape connectivity to favor the medium- and long-term persistence of primate populations using agroecosystems as temporary or permanent habitats or corridors is also of relevance. Investigations on the ecological and economic impact of primate presence and activities in agroecosystems, and the incidence and consequence of human–primate interactions are of great importance.

SEE ALSO: Anthropogenic Landscapes; Deforestation; Habitat Fragmentation; Primate Conservation and Human Livelihoods; Protected Areas

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