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With a Special Section on the Crowned Sifaka (*Propithecus coronatus*)

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Front cover: Adult female eastern patas monkey *Erythrocebus patas pyrrhonotus*, Laikipia County, central Kenya. The patas monkey is a highly threatened species in Kenya. See pages 117–128 in this issue for more information on the primates of Laikipia and their conservation. Photograph by Yvonne de Jong and Tom Butynski.

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Back cover: The crowned sifaka, *Pithecia coronatus*, is one of 106 lemur taxa endemic to Madagascar, over 90% of which are threatened with extinction. This issue of *Primate Conservation* highlights the current knowledge and conservation needs of the crowned sifaka across its highly fragmented distribution. Katsepy, Madagascar, July 2010. Photo by Tony King / The Aspinall Foundation.

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Primate Conservation in the Rangeland Agroecosystem of Laikipia County, Central Kenya

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Abstract: Maintenance of the diversity of primates depends not only on the conservation of protected areas, but also on the conservation of areas that lack formal protection and are occupied by people, crops, and/or livestock. Livestock rangelands, when well-managed, can support viable populations of primates. This article describes (1) the primate community in the rangeland agroecosystem of Laikipia County, central Kenya, (2) how primates use this agroecosystem, (3) the importance of this agroecosystem to the primates of Laikipia, and (4) the threats to these primates. Patas monkeys *Erythrocebus patas*, olive baboons *Papio anubis*, vervet monkeys *Chlorocebus pygerythrus*, and northern lesser galagos *Galago senegalensis* in the Laikipia rangeland agroecosystem benefit from man-made perennial water sources, habitat protection, reduced large predator densities, and an array of research and conservation activities. The level of conflict between humans and non-human primates in this rangeland agroecosystem is low relative to that in neighboring cropland agroecosystems. The main threats are habitat fragmentation, degradation and loss, and the decline of perennial water sources. Hunting is not a serious threat to primates in Laikipia. *Erythrocebus patas* is the most threatened primate in Laikipia and the one least tolerant of humans and habitat degradation and loss. Habitat conservation in Laikipia should focus on water-associated vegetation types and the adjacent whistling thorn *Acacia drepanolobium* woodlands, particularly along the Ewaso N'yiro River and its major tributaries.

Key Words: agroecosystem, conservation, cropland, Kenya, Laikipia County, primate, rangeland

Introduction

Africa supports a high diversity of primates (Groves 2001; Grubb *et al.* 2003), with 25 genera and 94 species (Butynski *et al*. 2013). The survival of many of Africa's primate species and subspecies is, however, under threat; the human population of Africa continues to double about every 20 years. There is no indication that the growth rate of Africa's human population (now about 3% per year), or the associated increasing demand for natural resources, will decline any time soon. The continent's current population of about 1 billion people is projected to rise to between 3.1 and 5.7 billion people (median projection of 4.2 billion) by the end of this century (Gerland *et al.* 2014).

The rising demand for natural resources in Africa has spear-headed increases in the hunting of primates for meat, and in the rates of degradation, loss and fragmentation of primate habitats, primarily through logging and conversion to agriculture (including the raising of livestock). These activities have greatly impacted most of Africa's primate taxa, leading to reduced numbers and geographic distributions and, thereby, to an increase in the number of threatened primate taxa (Butynski 2001; Chapman *et al.* 2006; Oates 2011; De Jong and Butynski 2012; Butynski and De Jong in press). Importantly, however, some of the land used for agriculture, including livestock production, can be of value to primate conservation (Estrada *et al.* 2012).

The persistence of biodiversity, including primates, depends not only on the conservation of official protected areas, but also on the conservation of vast tracts of land that lack formal protection, are privately or communally owned, and are occupied by people and their crops and/or livestock (Hutton *et al.* 2005; Didier *et al.* 2011; Georgiadis 2011b; Kinnaird and O'Brien 2012). Agroecosystems are ecosystems in which indigenous plants and animals are partially or completely replaced with crops and/or livestock (Altieri 2003; Estrada *et al.* 2012). The literature is replete with examples of primates of many taxa living, if not thriving, in agricultural

matrices and in crop plantations (for example, Salafsky 1993; Michon and de Foresta 1995; McCann *et al.* 2003; Medhi *et al.* 2004; Raboy *et al.* 2004; Somarriba *et al.* 2004; De Jong *et al.* 2008; Schwitzer *et al.* 2011; Estrada *et al.* 2012).

The importance of agroecosystems to primate conservation has been rarely assessed for Africa. This article describes (1) the primate community in the rangeland agroecosystem of Laikipia County, central Kenya, (2) how primates use this agroecosystem, (3) the importance of this agroecosystem to the primates of Laikipia, and (4) the threats to these primates. In addition, recommendations are made for four activities that are expected to enhance the long-term conservation of Laikipia's primate community.

Description of Laikipia County, Kenya

Laikipia County (*c.* 9,700 km²; Figs. 1 and 2) is demarcated by Mount Kenya (5,200 m asl) to the east and south-east, Aberdares Range (4,000 m asl) to the south and south-west, Eastern (Gregory) Rift Valley (*c.* 970 m asl) to the west, Karisia Hills (2,580 m asl) to the north-west, Mathews Range (2,688 m asl) to the north, and Samburu National Reserve (*c*. 900 m asl) to the north-east.

Through Laikipia County (hereafter referred to as 'Laikipia') there is considerable variation in geography, altitude, rainfall, soil, flora, fauna, human population density, and land use (Georgiadis 2011a; LWF 2011, 2013). These environmental variables generally change spatially through gradual transition, but sometimes the change is abrupt. Laikipia ranges in altitude from 1,260 m (Mukutan Gorge) to 2,400 m (Enghelesha Hill). Much of Laikipia is covered by the Laikipia Plateau (*c.* 1,600–2,400 m asl), an area composed of a mix of flat ground (mostly), undulating plains, rolling hills, steep hills (some with extensive erosion gullies), and scattered, often steep, granitic inselbergs (or "kopjes"). There are several small perennial rivers—the largest being the Ewaso N'yiro—and many seasonally dry stream channels and gullies, some of considerable size.

Mean annual rainfall ranges from *c*. 40 cm in the north to *c*. 120 cm in the south-west (LWF 2013). Mean annual temperature ranges from 16ºC to 26ºC (CAS 2013). The primary vegetation types are grassland, bushland, woodland, and, on the higher ground, dry forest. Dry forest is typically dominated by pencil cedar *Juniperus procera* (Cupressaceae), wild olive *Olea europaea* (Oleaceae), podo *Afrocarpus gracilior* (Podocarpaceae), euclea *Euclea divinorum* (Ebenaceae), acokanthera *Acokanthera schimperi* (Apocynaceae), and croton *Croton megalocarpus* (Euphorbiaceae). Riparian forest is a scarce, but biologically important, vegetation type in Laikipia. It is often dominated by fever trees *Acacia xanthophloea* (Fabaceae). Other large trees in the riparian forest include Gerrard's acacia *Acacia gerrardii* (Fabaceae), *A. gracilior*, water pear *Syzygium guineense* (Myrtaceae), water berry *Syzygium cordatum* (Myrtaceae), cape chestnut *Calodendrum capense* (Rutaceae), East African greenheart *Warburgia ugandensis* (Canellaceae), and figs *Ficus* spp. (Moraceae) (especially sycamore fig *F. sycomorus*).

The most widespread soil type on the plains of Laikipia is 'black cotton', which is *c.* 50% clay and *c.* 24% sand (Young *et al.* 1998). Bushland and woodland on black cotton is typically dominated by whistling thorn *Acacia drepanolobium* (Fabaceae) and/or euclea *E. divinorum.* Shrub and tree cover on black cotton in central Laikipia is *c.* 31% (Young *et al*. 1997; Riginos *et al*. 2009). Grass cover is more or less continuous. The more common grasses (Poaceae) include *Pennisetum stramineum*, *Pennisetum mezianum*, *Brachiaria lachnantha*, *Themeda triandra*, and *Setaria sphacelata*.

Figure 1. Location of Laikipia County (in red), Kenya.

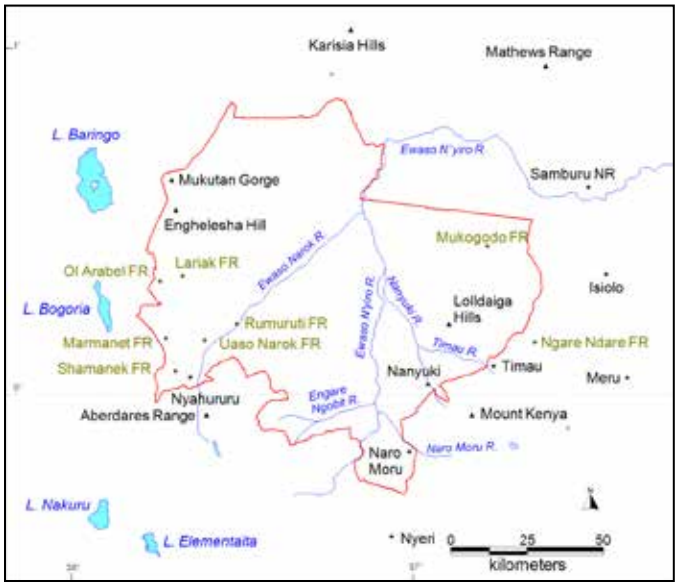

Figure 2. Laikipia County, central Kenya (outlined in red) with place names that are mentioned in the text. FR = Forest Reserve. NR = National Reserve.

The other widespread soil type in Laikipia is 'red sand', which is *c.* 74% sand and *c.* 15% clay (Augustine 2003a). Red sand typically supports bushland and woodland dominated by hook-thorn *Acacia mellifera*, savanna thorn *Acacia etbaica*, and wait-a-bit thorn *Acacia brevispica.* Other, often common, trees there are umbrella thorn *Acacia tortilis*, desert date *Balanites aegyptiaca* (Zygophyllaceae), small bead-bean *Maerua triphylla* (Capparaceae), and boscia *Boscia angustifolia* (Capparaceae). Shrub and tree cover on red sand in central Laikipia is *c*. 28% (Augustine 2003b). Grass cover there is usually discontinuous and, sometimes, sparse (Augustine *et al*. 2011). The more common grasses (Poaceae) include *Digitaria milanjiana*, *Cynodon dactylon*, *P. stramineum*, and *Chloris roxburghiana*. See LWF (2011) for more detailed information concerning the habitats and vegetation of Laikipia, and LWF (2011, 2013) for vegetation maps.

Land Use in Laikipia

There are *c.* 400,000 people in Laikipia Country, approximately 76% of which live in rural areas (LWF 2013). Mean human population density is *c*. 42 people/km² (CAS 2013). Although some locations in south and south-west Laikipia have 100–300 people/km², most of Laikipia has <20 people/km². This population is expected to increase to 600,000 people by 2030 (LWF 2013).

Nearly 90% of Laikipia is too dry for cultivation (LWF 2013). About 65% (5,820 km²) is defined as wildlife habitat (Frank *et al*. 2005) and sizeable populations of most species of large wild mammals still occur there (Litoroh *et al*. 2010; Kinnaird *et al.* 2012; LWF 2012). At this time, *c.* 38% (3,650 km²) of Laikipia comprises relatively intact, contiguous, natural habitat managed in ways compatible with the maintenance of the original biodiversity, including the larger mammals. There is an area of similar size (*c*. 33%; 3,196 km²) of high potential wildlife habitat that is currently used in ways not compatible with the maintenance of the original biodiversity and over which large mammals are absent or nearly so (LWF 2012). In 2012, Kinnaird *et al.* (2012) found that 61% of the "observation cells" surveyed contained no large wild ungulates.

Black cotton soil and red sand soil are both suitable for livestock ranching (cattle, goats, sheep, camels), but poor for crop production. Laikipia's soils, semi-arid climate, and low availability of water, dictate that the only viable, sustainable, economic uses for most of the land are livestock production and tourism. Only 1.7% of Laikipia is classified as having high potential for agriculture, although, as of 1995, 8.4% was already under cultivation (Huber and Opondo 1995). As of 2013, 21% was occupied by small-holder farmers (LWF 2013). Attempts to grow crops in Laikipia on land that is not on the lower slopes of Mount Kenya or the Aberdares Range (where soil fertility and rainfall are highest) typically result in poor or no yields. A recent review of land use concluded that most of Laikipia's cultivation "is marginal, with detrimental effects on people and environmental health" (LWF 2013, p.5). Climate change is predicted to exacerbate this situation (LWF 2013).

Livestock ranching on privately-owned, government-owned, company-owned, or community-owned ("group ranches") rangeland is currently the primary economic activity in Laikipia. Over 80% of the people depend on livestock farming (CAS 2013). In 2011, large ranches and group ranches comprised 40% and 7%, respectively, of Laikipia. The ten largest ranches are each greater than 200 km², with the largest being 375 km². In 2011, 48% of Laikipia was tenured as rangeland and at least 29% was tenured as cropland (Table 1). Forest reserves and government land, together, comprise 14% of Laikipia. Both support livestock raising and crop production, but the size of the areas used for these activities is not known. Overall, in 2013, 37% of Laikipia was used for large-scale ranching, 32% was used by pastoralists, 21% was occupied by small-holder farmers (most of whom grow crops as well as graze livestock), and 5% was used exclusively for wildlife-based tourism (LWF 2013). Land-use maps for Laikipia are presented in Georgiadis (2011b), Kinnaird and O'Brien (2012), Kinnaird *et al.* (2012), and LWF (2012, 2013).

In Laikipia, rangeland management involves the removal of shrubs, trees, and invasive plants, burning of vegetation, manipulation of livestock numbers, movement of livestock, development and maintenance of sources of drinking water through dams and boreholes, and the control of large predators. The limiting resource for people, livestock and wildlife is most often water. The vast majority of the larger ranches encourage wildlife, tourism, and ecological/conservation research, and several have ecological/conservation training programs/centers. A number of ranches are managed primarily for the purpose of conserving Laikipia's biodiversity and some of these hold "Conservancy" status.

Large Mammals and Primates of Laikipia

Unlike other semi-arid areas of this size in Kenya, including officially protected areas, Laikipia has not lost any

Table 1. Summary of land tenure types in Laikipia County, central Kenya, in 2011. Based on Letai (2011).

Type of land tenure	Total area (km²)	Number of properties	Mean area (km²)	Percent of total land
Large scales ranches (rangeland)	3,794	48	79	40.3
Small holder farms (cropland)	2,562	122	21	27.2
Group ranches (rangeland)	702	13	54	7.4
Forest reserves	701	12	58	7.5
Government land (mostly rangeland)	620	36	17	6.6
Large scale farms (cropland)	140	23	6	1.5
Others	880	?	?	9.4

species of indigenous large mammal. The large mammal fauna includes African buffalo *Syncerus caffer*, savanna elephant *Loxodonta africana*, giraffe *Giraffa camelopardalis*, black rhinoceros *Diceros bicornis*, wild dog *Lycaon pictus*, cheetah *Acinonyx jubatus*, leopard *Panthera pardus*, and lion *Panthera leo*. Laikipia is believed to hold the highest diversity of large mammal species of any site of its size in the world (T. M. Butynski and Y. A. de Jong pers. obs.).

With the exception of the Maasai Mara National Reserve, Laikipia supports higher densities of large wild mammals than any landscape in Kenya. In sharp contrast to major declines in large mammal numbers throughout Kenya, both inside and outside official protected areas, including the Maasai Mara (Western *et al.* 2009), Laikipia's populations of large mammals were, until recently, considered to be stable and, for some species, increasing (Georgiadis 2011b; Kinnaird and O'Brien 2012; LWF 2012). The most recent county-wide aerial census, however, indicates a decline between 2001 and 2012 in the abundance of 11 of 14 large ungulate species (Kinnaird *et al.* 2012).

Seven (37%) of Kenya's 19 species of non-human primate (De Jong and Butynski 2012) occur in Laikipia, of which two are galagos and five are monkeys. Of these seven species, three are forest-dependent and four are rangeland-dependent, two are nocturnal and five are diurnal, and four are arboreal and three are semi-terrestrial. The primate taxonomy applied in this article follows Butynski *et al.* (2013).

Forest Primates of Laikipia

Over Laikipia, closed evergreen forest is limited to the vicinity of the larger rivers (riparian forest), the deeper valleys (gallery forest), and the higher ground. These forests cover but a small part of Laikipia (probably <6% or <600 km²). They are mostly associated with the larger rivers that flow off of Mount Kenya (for example, Naro Moru, Nanyuki, Timau) and Aberdares Range (for example, Upper Ewaso N'yiro, Engare Ongobit, Ewaso Narok), and with the higher ground where rainfall is greatest, mainly Mukogodo Forest Reserve and Ngare Ndare Forest Reserve in the north-east and, in the south-west, with the six forest reserves to the east of the Laikipia Escarpment/Eastern Rift Valley (i.e., Rumuruti, Uaso Narok, Shamanek, Marmanet, Ol Arabel, and Lariak Forest Reserves; Fig. 2).

Three of Laikipia's primate species are restricted to closed evergreen forest above *c*. 1800 m—Kolb's monkey *Cercopithecus mitis kolbi* (Fig. 3), Mount Kenya guereza *Colobus guereza kikuyuensis* (Fig. 4), and Kikuyu small-eared galago *Otolemur garnettii kikuyuensis* (Fig. 5). While all three are widely distributed over East Africa at the species level, at the subspecies level they are all endemic to the highlands of central Kenya (which include the Aberdares Range, Mount Kenya, Ngong Hills, and Nairobi; Fig. 1). These three species (and subspecies) are ranked as 'Least Concern' on the IUCN Red List (IUCN 2014).

The geographic range and abundance of these three subspecies of primate must have been greatly reduced over Laikipia during the past 100 years, largely through fragmentation of habitats and the conversion of closed evergreen forest to cropland (mainly wheat, maize and potatoes). Although these three subspecies are typically not compatible with Laikipia's cropland agroecosystem, they all, nonetheless, remain

Figure 3. Adult female Kolb's monkey *Cercopithecus mitis kolbi* in montane forest, Mount Kenya. Photograph by Y. A. de Jong and T. M. Butynski.

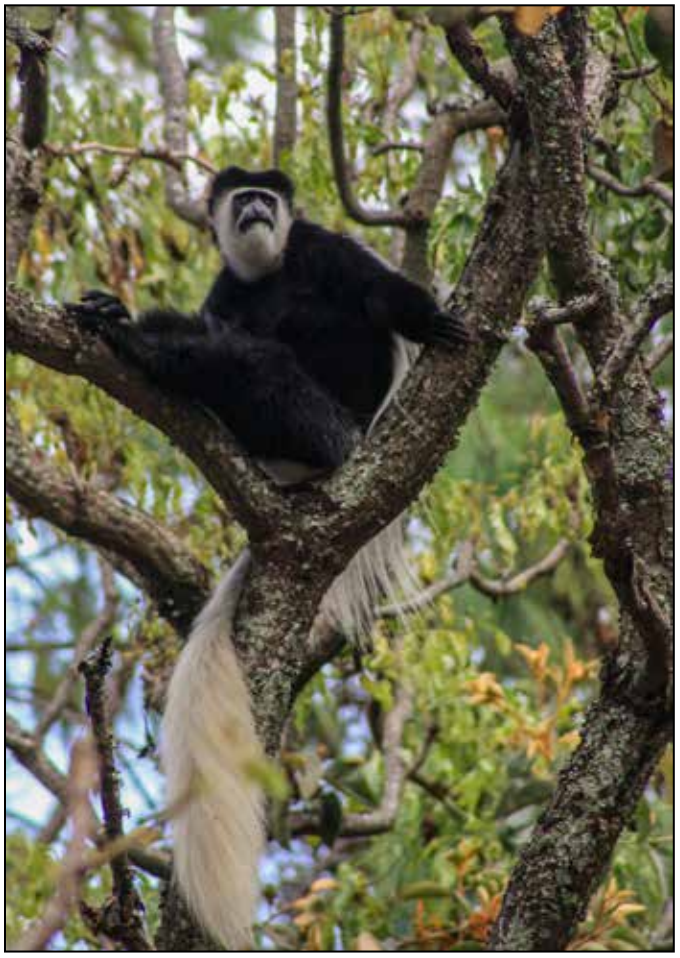

Figure 4. Adult male Mount Kenya guereza *Colobus guereza kikuyuensis* in montane forest, Naro Moru, Laikipia. Photograph by Y. A. de Jong and T. M. Butynski.

widespread and common elsewhere, particularly on the lower slopes (*c*. 1,800–2,900 m asl) of the nearby, contiguous, Aberdares Range and Mount Kenya (both of which are relatively well-protected). It is estimated that the geographic range of each of these three subspecies is >2,000 km², and that each numbers >10,000 individuals (Butynski 1999; T. M. Butynski and Y. A. de Jong pers. obs.).

Although the declining range and number of *C. m. kolbi, C. g. kikuyuensis*, and *O. g. kikuyuensis* in Laikipia is cause for concern and requires more investigation (see 'Recommendations'), the focus of this article is on the primates that occupy the other *c.* 94% of Laikipia—the primates of the rangeland agroecosystem.

Rangeland Primates of Laikipia

Four species of non-human primate inhabit the semi-arid rangeland agroecosystem of Laikipia—eastern patas monkey *Erythrocebus patas pyrrhonotus* (Fig. 6), Hilgert's vervet monkey *Chlorocebus pygerythrus hilgerti* (Fig. 7), olive baboon *Papio anubis* (Fig. 8), and Kenya lesser galago *Galago senegalensis braccatus* (Fig. 9). All four species reach their highest density where the rangeland agroecosystem is well managed (i.e., used sustainably), and where hunting and trapping of primates (for example, in retaliation for crop damage) are not threats (as is the case in Laikipia's cropland agroecosystem). All four of these species (and their subspecies) are ranked as 'Least Concern' on the IUCN Red List (IUCN 2014).

Erythrocebus patas is by far the least abundant and widespread primate in Laikipia and, therefore, the primate of greatest conservation concern. This large (adult males weigh *c.* 12 kg), diurnal, omnivorous, semi-terrestrial, fast-running monkey occurs in low densities in East Africa (Isbell 2013) but can be locally common in northern Uganda (for example, in Kidepo National Park; T. M. Butynski and Y. A. de Jong pers. obs.). In Laikipia, the area over which groups of *E. patas* occur is roughly estimated at between 700 km² and 1,000 km² (T. M. Butynski and Y. A. de Jong pers. obs.). There, home ranges are 23–40 km² (Chism and Rowell 1988; Enstam and Isbell 2004), and densities are 0.2–1.5 individuals/km² (Chism and Rowell 1988; Isbell and Chism 2007).

Figure 5. Adult Kikuyu small-eared galago *Otolemur garnettii kikuyuensis* in riparian forest, Masinga Dam, central Kenya. Photograph by Y. A. de Jong and T. M. Butynski.

Figure 6. Adult male eastern patas monkey *Erythrocebus patas pyrrhonotus* in whistling thorn acacia *Acacia drepanolobium* woodland, Ol Pejeta Conservancy, Laikipia. Photograph by R. Copeland.

Figure 7. Hilgert's vervet monkey *Chlorocebus pygerythrus hilgerti* adult females with young in mixed acacia woodland, Borana Conservancy, Laikipia. Photograph by Y. A. de Jong and T. M. Butynski.

Figure 8. Adult male olive baboon *Papio anubis* feeding from whistling thorn acacia *Acacia drepanolobium*, Lolldaiga Hills Ranch, Laikipia. Photograph by Y. A. de Jong and T. M. Butynski.

Figure 9. Adult Kenya lesser galago *Galago senegalensis braccatus* in mixed acacia woodland, Ol Pejeta Conservancy, Laikipia. Photograph by Y. A. de Jong and T. M. Butynski.

In Laikipia, the preferred habitat is open savanna woodland dominated by *Acacia* spp., particularly *A. drepanolobium* (Chism and Rowell 1988; Enstam and Isbell 2002; Isbell 2013). There, *A. drepanolobium* comprises >80% of the diet in the form of gum, flowers, seed pods, and arthropods (Isbell and Chism 2007; Isbell and Young 2007; Isbell 2013).

Erythrocebus patas populations are declining in East Africa while geographic ranges are shrinking and fragmenting. From 1996 to 2008, the geographic range of *E. patas* in Kenya declined by *c*. 46% (De Jong *et al*. 2008), and from 1995 to 2009, the geographic range in Tanzania declined by *c*. 33% (De Jong *et al*. 2009). Although Laikipia is thought to support the largest population of *E. patas* in Kenya (Isbell and Chism 2007; De Jong *et al*. 2008), the population is, nonetheless, small. This population appears to have been stable between 1979 and 2000 (415 individuals in 14–15 groups in 1979; 310–445 individuals in 13–17 groups in 2000 [Isbell and Chism 2007]). Preliminary findings from a current survey indicate, however, that this population has declined since 2000 (Y. A. de Jong and T. M. Butynski pers. obs.).

Chlorocebus pygerythrus is a medium-sized (adult males weigh *c.* 4 kg), diurnal, omnivorous, semi-terrestrial monkey, that is patchily distributed and locally common in Laikipia and over much of Kenya. It has home ranges of 10–40 ha in Laikipia (Isbell *et al*. 2002), and occurs at densities of 9–80 individuals/km² (Isbell and Enstam 2002; Isbell 2013). *Chlorocebus pygerythrus* is strongly associated with perennial and seasonal watercourses where there is *A. xanthophloea* woodland adjacent to *A. drepanolobium* bushland/woodland (Isbell *et al.* 2002). In one study in Laikipia, *A. drepanolobium* and *A. xanthophloea* accounted for *c.* 35% and 22% of the diet, respectively (Pruetz and Isbell 2000).

Papio anubis is a large (adult males weigh *c.* 22 kg), diurnal, omnivorous, semi-terrestrial monkey that is common in grassland, bushland, and woodland over much of Laikipia (Palombit 2013). There, home range size varies from <15 km² (T. M. Butynski and Y. A. de Jong pers. obs.) to >44 km² (Barton *et al*. 1992). Diet is composed of a very large number of food items, including leaves, flowers, seeds, fruits, gum, and underground parts, taken from grasses, herbs, and trees (Barton *et al.* 1992).

Galago senegalensis is a small (adult males weigh *c.* 225 g), nocturnal, omnivorous, mostly arboreal, prosimian that is widespread through the bushland and woodland of Laikipia. Limited data for this species in Laikipia indicate that the home range is roughly 4 ha and that densities are typically 40–240 individuals/km² but can be much lower and much higher than this (Nash and Whitten 1989; Off *et el.* 2008; Nash *et al*. 2013; T. M. Butynski and Y. A. de Jong pers. obs.). This species is widespread in *A. drepanolobium* bushland/woodland but reaches its highest densities in *A. xanthophloea* woodland. The diet includes mainly invertebrates and acacia gums, particularly of *A. drepanolobium* and *A. xanthophloea* (Nash and Whitten 1989; Nash *et al.* 2013).

The distribution and abundance of the four primate species in the Laikipia rangeland agroecosystem can be explained, not surprisingly, by the availability of water, food, and secure sites for sleeping and refuge. *Papio anubis*, *C. pygerythrus*, and *E. patas* require perennial sources of drinking water and will drink daily where water is readily available (Chism and Rowell 1988; Isbell and Chism 2007; De Jong *et al*. 2008). These three species probably do not occur anywhere in Laikipia where they cannot drink at least once every two days. At sites far from natural perennial sources of water, these three monkeys would not occur except for the constant presence of water at tanks and troughs placed for livestock. *Galago senegalensis* does not need to drink and, thus, its occurrence is not affected by the availability of water.

All four species require secure sites in which to rest, sleep, and take refuge from predators; in Laikipia, *P. anubis* uses tall trees and large, steep rock faces, *C. pygerythrus* uses tall trees, *E. patas* uses small to medium-sized trees (0.5–6.0 m tall) in open woodland, and *G. senegalensis* uses tree holes or trees with dense foliage in which nests are constructed (Chism and Rowell 1988; Enstam and Isbell 2002; Off *et al*. 2008; Isbell 2013; Isbell and Enstam Jaffe 2013; Nash *et al.* 2013; Palombit 2013; T. M. Butynski and Y. A. de Jong pers. obs.).

The removal by humans of natural resources from the rangelands may represent competition with one species of primate while enhancing the carrying capacity of the site for another. For example, it is likely that the partial removal of *A. drepanolobium* from a site (for firewood and the production of charcoal) reduces the carrying capacity for *G. senegalensis* and *E. patas* while increasing the carrying capacity for *P. anubis* and *C. pygerythrus*.

Benefits to Laikipia's Primates of Livestock Ranching

As mentioned briefly above, ranching in the rangeland agroecosystem of Laikipia can benefit all four species of primate or is, at worse, a neutral land use activity as concerns

primate conservation. Here are some examples of known and suspected benefits:

1. Most, if not all, large ranches have established, and maintain, water tanks and water troughs throughout the property. These perennial sources of water enable *E. patas*, *C. pygerythrus* and *P. anubis* to access these areas to forage and make use of the secure sleeping and refuge sites nearby (Chism and Rowell 1988; De Jong 2004; Isbell and Chism 2007; De Jong *et al.* 2008).
2. Most, if not all, large ranches have established, and maintain, systems of dams that serve as perennial sources of water, or, at least, maintain water for extended periods. These sites not only provide drinking water for primates and other wildlife, they also promote and support large trees (particularly *A. xanthophloea* and *Ficus* spp.) that provide important foraging, sleeping and refuge sites for all four primate species in the rangeland (Y. A. de Jong and T. M. Butynski pers. obs.).
3. *Erythrocebus patas*, *C. pygerythrus*, and *P. anubis* often seek high perches on which to rest and scan the surroundings. Fence posts are frequently used perches in open areas. In addition, *E. patas* often moves along the woodland edges that the fence lines typically create (Chism and Rowell 1988).
4. Privately-owned, government-owned, and company-owned ranches protect extensive areas of *A. drepanolobium* bushland/woodland and *A. xanthophloea* woodland. Also, the community-owned group ranches are coming to appreciate the value of these habitats, taking measures to conserve them at some sites. These are critical habitats for the primates of Laikipia.
5. Prickly pears *Opuntia* spp. (Cactaceae), introduced to Laikipia from South America in the 1950s for use as 'living fences' (Vernon 2008), are common at some sites. *Opuntia* spp. are an important source of food and water for all three monkeys, particularly during times of severe drought (Chism and Rowell 1988; Strum *et al*. in press; D. Manzolillo-Nightingale pers. comm.; Y. A. de Jong and T. M. Butynski pers. obs.). *Galago senegalensis* is also suspected of making use of *Opuntia*.
6. Predation on semi-terrestrial primates can be severe (Isbell *et al*. 2009). Predators of primates (for example, leopard, lion), although common in some parts of Laikipia, continue to be persecuted in the name of livestock protection, particularly on the group ranches (Frank *et al.* 2005; Woodroffe and Frank 2005; Frank 2011). Reduced predator densities may allow for higher primate densities, as well as enable the semi-terrestrial *E. patas*, *C. pygerythrus*, and *P. anubis* to forage more efficiently over larger areas (i.e., farther from secure retreats such as large trees and cliffs).
7. Transmission of diseases and parasites between humans and non-human primates, and the related morbidity and mortality, is of considerable concern (Butynski 2001; Chapman *et al.* 2006; Estrada *et al.* 2012; Young *et al.* 2013). Given the much lower human and domestic animal population densities in Laikipia's rangeland agroecosystem compared to the cropland agroecosystem, and the greater aridity of the rangelands, the incidence of disease and parasite transmission between humans and non-human primates is likely to be significantly less in the rangeland agroecosystem. There is, however, insufficient research on this topic for Laikipia. This is a priority area of research as concerns Laikipia's primates.
8. A large number of stakeholders concerned with the well-being of Laikipia's environment, particularly its wildlife, water and natural habitats, are promoting conservation actions. Conservation and ecotourism associations and partnerships have been created, and ecological/conservation research centers established, to work towards maintaining sustainable populations of wildlife and livestock for the long-term benefit of the people of Laikipia (Kinnaird and O'Brien 2012; Galvin and Reid 2014). At the center of these actions is the Laikipia Wildlife Forum (LWF 2011, 2013). This forum includes the owners of large ranches, group ranches, and other properties. In 2012, LWF produced a strategic conservation plan, *The Wildlife Conservation Strategy for Laikipia County (2012–2013)* (Didier *et al.* 2011; LWF 2012). The goal, as stated in this plan is "By 2030 the people of Laikipia perceive wildlife as a valuable asset and the diversity and populations of native species have been maintained or increased." Of the 21 'targets' put forth in this plan, the following six, if achieved, are likely to have the greatest positive impact on the long-term conservation of Laikipia's seven species of non-human primate:
    - By 2030 the owners of the 3,650 km² of existing habitat that currently supports most of Laikipia's wildlife are committed to wildlife conservation as a form of land use.
    - By 2030 owners of at least half of the 3,196 km² of existing high potential wildlife habitat (where wildlife is currently absent or found in low numbers) are committed to wildlife conservation as a form of land use.
    - By 2030, within the context of stable wildlife populations, more than half of Laikipia's residents view wildlife as an asset.
    - By 2030 the area under upland forest has increased by 50%.
    - By 2030 the Ewaso N'yiro River and its tributaries flow year round.
    - By 2030 wildlife is able to move unhindered within Laikipia and between Laikipia and the adjacent ecosystems.

Conflict between Humans and Non-human Rangeland Primates

The rangelands occupied by *E. patas*, *C. pygerythrus*, *P. anubis*, and *G. senegalensis* in Laikipia vary from relatively pristine and extensive (>1,000 km²) to extremely degraded

and fragmented (<1 km²). Little or no competition exists between the four primates and livestock for food and water, and, in the absence of crops, competition between the four primates and humans is low, particularly when compared to the level of conflict in the cropland agroecosystem (see above and below). That said, here are a few examples of livestock-primate and human-primate conflicts that are known to occur, or probably occur, in the Laikipia rangeland agroecosystem:

1. Habituated *C. pygerythrus* and *P. anubis* sometimes raid tourist lodges, houses, and camp/picnic sites for food (Y. A. de Jong and T. M. Butynski pers. obs.).
2. Adult *P. anubis* predation on young sheep and goats, and chickens and chicken eggs, is widespread and common, particularly on the group ranches. There is, however, considerable variation in frequency with time and place; predation on livestock seems to be most frequent during the dry season when natural foods are most scarce (Strum 2010; C. Muhoro and T. M. Butynski pers. obs.).
3. *Chlorocebus pygerythrus* and *G. senegalensis* occasionally raid beehives and extract honey, and *G. senegalensis* sometimes nests in beehives (M. Kelly pers. comm.; T. M. Butynski and Y. A. de Jong pers. obs.).
4. There are probably occasions, in times of food scarcity (for example, during droughts), when *C. pygerythrus* and *P. anubis* compete with goats for wild fruits.
5. *Papio anubis* (particularly) and *C. pygerythrus* are among the more important dispersers of the seeds of prickly pear, especially *Opuntia stricta*. These are common to abundant invasive plants on Laikipia's more degraded rangelands. As noted above, however, *Opuntia* spp. are not "all bad" as they provide important dry-season/drought foods for some species of livestock and wildlife (Vernon 2009; Strum *et al.* in press), including *P. anubis* and *C. pygerythrus*.

Primates are, overall, rather easy for pastoralists and ranchers to coexist with. There is little primate-human conflict in the rangeland agroecosystem, in strong contrast to the situation in Laikipia's cropland agroecosystem, where primate-human conflict is typically high and no species of monkey is tolerated. The hunting of primates for bushmeat is not considered a threat for any of Laikipia's primates as the people of Laikipia seldom, if ever, eat them.

Threats to Primates in Laikipia

In some parts of Laikipia the rangeland has been severely degraded and fragmented due to over-grazing and over-browsing by livestock, and by the unsustainable cutting of trees for firewood and charcoal. This over-exploitation threatens Laikipia's four species of rangeland-dependent primates.

To provide land to the growing human population of Laikipia, the Government of Kenya has sometimes purchased large ranches on which there is prime wildlife habitat and thriving wildlife populations and then subdivided these into 1–10 ha plots (Mucuthi and Munei 1996; Letai 2011). Once settled by farmers, the conservation values of these small plots rapidly decline as the conversion from a rangeland agroecosystem to a cropland agroecosystem takes place. Conversion of prime rangeland to cropland not only greatly reduces the natural foods and secure sites for all four of Laikipia's rangeland primates, it puts the three species of monkey into direct competition with humans for food (Isbell and Chism 2007; De Jong *et al*. 2008; Strum *et al*. 2008; Isbell 2013). In other words, all three species of monkey become serious crop pests for which Laikipia's farmers have no tolerance.

The water of the few perennial rivers of Laikipia (none of which is large) is increasingly exploited for the irrigation of crops. This removal of water is currently heavy and poorly managed, and greatly affects river flow. This problem is exacerbated by the considerable damage to natural vegetation in the water catchments on Mount Kenya, the Aberdares Range, and Laikipia Plateau. During the drought of 2009, the major river of Laikipia, the Ewaso N'yiro, stopped flowing for the first time in living memory; for several months the only water in this river was in widely scattered pools. The land along the perennial rivers of Laikipia comprises part of the home ranges of numerous groups of *C. pygerythrus* and *P. anubis*. Where these rivers are the only source of perennial water in the area, *C. pygerythrus* forages a few hundred meters from the river and *P. anubis* forages a few kilometers from the river. If long stretches of these rivers were to hold no water for extended periods, these two species would no longer be able to use the areas on a year-round basis. This would result in a serious decline in the abundance of both species in Laikipia.

Habitat fragmentation is one of the main threats to the conservation of species, including primates (Schwitzer *et al*. 2011; Estrada *et al*. 2012). Kenya's protected area system, as elsewhere in Africa, is not, alone, adequate to support the long-term survival of many of the large species of mammal (Craigie *et al*. 2010). As such, maintaining connectivity among Kenya's major protected areas through the conservation of lands that are not officially protected is crucial to the maintenance of the nation's large mammal biodiversity.

At present, Laikipia's rangeland agroecosystem, where well managed, provides considerable habitat connectivity among several of Kenya's largest and most important ecosystems for the conservation of biodiversity, particularly for primates and large mammals (Didier *et al*. 2011; Georgiadis 2011b). These sites include the Mathews Range and Samburu Ecosystem to the north, Meru Ecosystem to the east, Mount Kenya to east and south-east, the Aberdares Range to the south-west, and the Eastern Rift Valley to the west (Fig. 2). The current expansion of the cropland agroecosystem, together with new settlements and poorly managed rangelands on some group ranches, are reducing this connectivity. One of the several negative consequences of this loss of connectivity is that options for the movement of primates, large wild mammals, and other species, are reduced, thereby threatening the viability of their populations.

Conclusions

The wildlife in the rangeland agroecosystem of Laikipia has ecological, scientific, financial and aesthetic value (for example, Shorrocks 2007, LWF 2013), and ethical arguments can be put forth for its conservation. Large parts of Laikipia's rangeland are, however, undergoing extensive and rapid transformation due to increasing livestock and human densities, and the demand that this puts on natural resources (Vernon 2008; LWF 2012). The resulting loss of natural habitat, soil, and productivity, damage to the watershed, together with expanding villages and towns, are not only threatening human livelihoods and cultures, but Laikipia's biodiversity, including its four species of non-human rangeland primates. This degradation and loss of Laikipia's natural habitats through unmanaged human use poses an enormous challenge to the integrity of this landscape (LWF 2012).

Three of the primates remain common in this rangeland agroecosystem, while one, *E. patas*, is under threat of extirpation (not only from Laikipia but also from Kenya and Tanzania). Conversion of the rangeland agroecosystem to a cropland agroecosystem is a threat to the survival of all four species as none can thrive in a cropland agroecosystem where there are high human densities and/or intensive agriculture; *E. patas* is the least tolerant, followed by *P. anubis, C. pygerythrus*, and *G. senegalensis*. The larger primates with large home ranges are less able to survive in the cropland agroecosystem than are the smaller primates with small home ranges.

Recommendations

Concerning the long-term conservation of the seven species of non-human primate in Laikipia, our present understanding of their status, threats, and ecology/behavior leads to the following four recommendations:

1. ***Erythrocebus patas* should be the focus for primate conservation research and action in Laikipia.** In Laikipia, the most specialized primate, the one in lowest numbers, and the one under greatest threat, is *E. patas*. This small, isolated, population is judged to be vulnerable to extirpation, especially via stochastic events, particularly disease and social/political unrest. Correctly focused efforts on behalf of *E. patas* in this rangeland agroecosystem appear to be essential to increasing the size and geographic range of this population. A better understanding is needed of what limits the distribution and abundance of *E. patas* in Laikipia with the aim of determining how ranch management and other practices can be altered to promote the growth of this population (also De Jong and Butynski 2011). If conditions in Laikipia are such that *E. patas* can survive, all other species of primate on Laikipia's rangelands will also survive.
2. **Habitat conservation in Laikipia should be on water-associated vegetation types and the adjacent *A. drepanolobium* woodland, particularly along the Ewaso N'yiro River and its major tributaries.** Conservation of, and access to, the perennial water sources (springs, rivers, ponds, swamps) of Laikipia, and their associated natural vegetation types (water-edge forest and large-tree woodland), is critical to the survival of all five of Laikipia's species of monkey, as well as to humans. In addition, for *E. patas* to survive in Laikipia, large areas of *A. drepanolobium* woodland adjacent to these more mesic vegetation types need to be conserved. Conservation of the long, linear, water-associated habitats of Laikipia, and of adjacent *A. drepanolobium* woodland, would enable gene flow for all five species of monkey, as well as for the long-term conservation of most of Laikipia's other species, both animal and plant.
3. **Develop primate-based tourism in Laikipia.** With few exceptions, little attention has been given to promoting primate-based tourism in Laikipia. This activity can, however, with little effort or expense, generate additional revenue, employment, and interest in primate conservation. At present, with the exception of *E. patas* and *O. garnettii*, all species of primate in Laikipia (both diurnal and nocturnal) can been readily located and observed at multiple sites, either on foot or from a vehicle. Ample numbers of semi-habituated, readily observed primates, which could serve as the focus of this tourism activity, are already present in Laikipia. Feeding primates for the purpose of habituation should not be allowed, nor should the creation of super-habituated primates. Such primates invariably become a problem and are either removed or, more often, destroyed.
4. **Conduct primate surveys in Laikipia's eight Forest Reserves.** As mentioned above, there are eight Forest Reserves in Laikipia. These harbor most of the county's closed evergreen forest and its three species of forest-dependent primates, all of which are represented by subspecies endemic to the highlands of central Kenya (*C. m. kolbi*, *C. g. kikuyuensis*, and *O. g. kikuyuensis*). No primate surveys have been conducted in any of these forest reserves. Surveys should be undertaken to assess primate species diversity, distribution, abundance, threats and conservation status, as well as the integrity of, and threats to, these forests.

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