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Household level influences on fragmentation in an African park landscape

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ABSTRACT

The process of landscape fragmentation outside park borders occurs through the actions of people living near the boundaries. In the Kibale National Park landscape in western Uganda, human-landscape relationships are typified by small-scale subsistence agriculture, in which households rely on resources provided in forests and wetlands, whose use is in turn shaped by perceptions of resource availability. To understand and manage for fragmentation of resource pools, modeling and identifying the proximate drivers, and thus enacted resource extraction and utilization – is of fundamental importance. We combine landscape analysis at the household scale, using remotely sensed data, with household surveys, to understand the potential human drivers of local scale landscape change. We found strong evidence for a local household zone (LHZ) effect on fragmentation patterns with geographical and socioecological heterogeneities in LHZ impact. Differences were influenced by wealth, and in some cases, tribal identity. The perception of crop raiders – primarily baboons and small monkeys, but also elephants and other animals – may have largely shaped human-environment interactions, and were associated with fragmentation. Ninety-two percent of the best fit models included the attitude that the park should stay, but associated it with increased fragmentation, suggesting that the uncharacteristic non-hostile attitude about Kibale does not directly translate into conservation-friendly local human-environment interactions. This study provides insight into park–neighbor interactions and the influence of the LHZ on protected-area landscapes, and it points to important points in the system for collaborative opportunities to engage communities and conservation managers.

Introduction

Conservation biologists have long been aware of the deleterious effects of landscape fragmentation in and around protected areas ('parks' hereafter) (Brashares, Arcese, & Sam, 2001; Broadbent et al. 2008; Fearnside, 2005; Hill & Curran, 2003; Turner, 1996; Turner & Corlett, 1996). However, understanding how to implement management beyond arresting the process via protecting land in reserves, and establishing policies limiting use of remnant natural or

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protected landscapes (Hartter & Ryan, 2010), is complicated (Lindenmayer & Fischer, 2007). The factors that shape human-environment interactions in landscapes around parks occur at multiple scales (DeFries et al. 2009), driven by a combination of direct resource utilization and perceptions about the interactions themselves.

The intersection of conservation objectives of parks and human activities, such as fuelwood extraction and land conversion for agriculture, can compromise both the conservation goals of parks, and the livelihoods of people living in the landscapes surrounding them (Brandon, Redford, & Sanderson, 1998; Bruner, Gullison, Rice, & da Fonseca, 2001; Child, 2013; Naughton-Treves, Holland, & Brandon, 2005). Whether parks attract high-density populations due to increased employment opportunities (Newmark & Hough, 2000; Wittemyer, Elsen, Bean, Burton, & Brashares, 2008), or are simply subject to population increase at 'rural' density rates (Joppa, Loarie, & Pimm, 2009), recognizing the socioecological aspects of parks' roles in the landscape and people's lives is essential to understanding both attitudes and impacts to parks and livelihoods (Hansen & DeFries, 2007; Palomo et al. 2014; Wells & McShane, 2004).

While populations around savanna parks are limited by low and sporadic rainfall, which acts to severely constrain agriculture, forest parks in the African tropics are frequently surrounded by highly suitable agricultural land (Gibbes, Cassidy, Hartter, & Southworth, 2013). Deforestation across Africa has been linked to land conversion for agriculture, demand for fuelwood (Dovie, Witkowski, & Shackleton, 2004; Tole, 1998), and rising human population density, particularly in tropical montane forests (Burgess et al. 2007; Rondinini, Chiozza, & Boitani, 2006). These processes lead to increased fragmentation, particularly at the local level, in sub-Saharan Africa (DeFries, Rudel, Uriarte, & Hansen, 2010; Fisher, 2010). Near parks remnants of larger forests and wetland/grassland patches provide resources such as water, firewood, building poles, local medicines, and grasses for mats and handicrafts (Hartter, 2007). These forest patches (fragments) represent reservoirs of land, resources, and economic opportunity for people, but are also often viewed by managers as buffers for parks (Schonewald-Cox & Bayless, 1986), or stepping stones in connectivity of the larger conservation landscape (Dobson et al. 1999; Rudnick et al. 2012). The study of landscape mosaics, which are made up of patches of different land cover types, is a useful approach to the study of landscape dynamics and the changes over time. As such, in association with land cover classifications derived from satellite imagery, we can obtain landscape information on percent changes in land cover as well as the evaluation of changes in spatial pattern, organization of patches, and fragmentation over time (Forman, 1995; Southworth, 2004). These patches can present a paradox however, as sources of hazards for local farmers: crop-raiding primates, elephants, and birds seem to emanate from them, in addition to them being contained within the park (Hartter, Solomon, Ryan, Jacobson, & Goldman, 2014b). Thus, extensive conversion of fragments to grazing or cropland occurs, in part, to claim more land, but also to destroy habitat of would-be crop raiders.

We present an analysis of landscape fragmentation outside a forest park in the Albertine Rift biodiversity hotspot in East Africa, to understand the socioecological drivers of fragmentation in the local household zone (LHZ) of human-landscape interaction. Given that perceptions drive action, connecting perceptions to process – in this case, local-level landscape fragmentation – can help inform where management may be effective, and how mitigation could be implemented. Therefore, our main research hypotheses are: 1. There are identifiable local impacts of households on fragmentation patterns that are greater in the LHZ than in the larger landscape; 2. We can identify drivers of this local, measurable fragmentation impact, such as physical location, demography, or perceived benefits or harm from the park, forest, or wetland patches. Moreover, we hypothesize that we may see more impacts of these local drivers immediately following park establishment, due to exclusion from park resources. First, we explored the local household zone (LHZ) influence on forest and wetland fragmentation (patch number, size, isolation), and whether fragmentation within the LHZ is greater than in the aggregate landscape. Then, we explored socioecological factors from household surveys that may drive (or accelerate) these local processes. We modeled fragmentation as a function of household location, demography, and perceptions and attitudes about human-landscape interactions.

Material and methods

Study area

The Albertine Rift biodiversity hotspot is a region in East Africa spanning from north of Lake Albert, to the southern edge of Lake Tanganyika, comprising parts of six countries, and home to great biodiversity, and many endemic and endangered species (Plumptre et al. 2003, 2007). The western Ugandan portion of the Albertine Rift contains a chain of islandized parks, surrounded by densely populated, largely agricultural, landscapes (Hartter & Ryan, 2010). This biodiversity hotspot is ranked in the top five poverty-conservation conflict hotspots (Fisher & Christopher, 2007), making the human-environment interaction dynamics of land surrounding parks of urgent importance to conservation.

Kibale National Park (795 km^2 – 'Kibale', Fig. 1) was created by combining the Kibale Forest Reserve (455 km^2) and the Kibale Corridor Game Reserve (340 km^2) in 1993. Mid-altitude tropical moist forest covers most of Kibale with savannah grasslands and woodland in the southwest. The park itself is not fenced (though demarcated by eucalyptus trees), but is distinct in land cover from the surrounding agricultural landscape. The climate is warm (15–23 °C) throughout the year (Struhsaker, 1997). Elevation and rainfall decrease from north (approximately 1500 m elevation and 1450 mm mean annual precipitation) to south (1000 m elevation and only around 850 mm mean annual precipitation) (Diem, Hartter, Ryan, & Palace, 2014a). Rainfall is controlled strongly by the Intertropical Convergence Zone (Nicholson, 1996), with rainy seasons typically occurring during boreal spring and boreal autumn (Basalirwa, 1995). Over the past several decades there has been a significant decline in rainfall in western Uganda, and rainfall during the two rainy seasons (i.e., growing seasons) has decreased by approximately 20% (Diem, Ryan, Hartter, & Palace, 2014b). Around Kibale, the landscape is a mosaic of intensive smallholder agriculture (most farms <5 ha), large tea estates (>200 ha), and interspersed forest and wetland patches that are essentially ecologically isolated from the park (Hartter & Ryan, 2010). The wetlands regions encompass both papyrus wetland vegetation and more open grassland, such as is dominated by elephant grass. Spectrally these vegetation types are very similar and so are both encompassed in this 'wetland' category. Forest and wetland fragments range in size from 0.5 ha up to 200 ha for forests and up to 400 ha for wetlands. Since nearly all of these natural areas occur in bottomland areas, many, but not all, forest fragments and wetlands co-occur.

The human population surrounding Kibale has increased sevenfold since 1920, with density exceeding 270 people/km^2 at the western edge of the park – more than double the national average (Hartter, 2007). About 40% of the land within 5 km of the park boundary is under cultivation or pasture, and tea is found bordering much of the northwest portion of Kibale. The vast majority of people are permanent (non-mobile subsistence farmers), and