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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

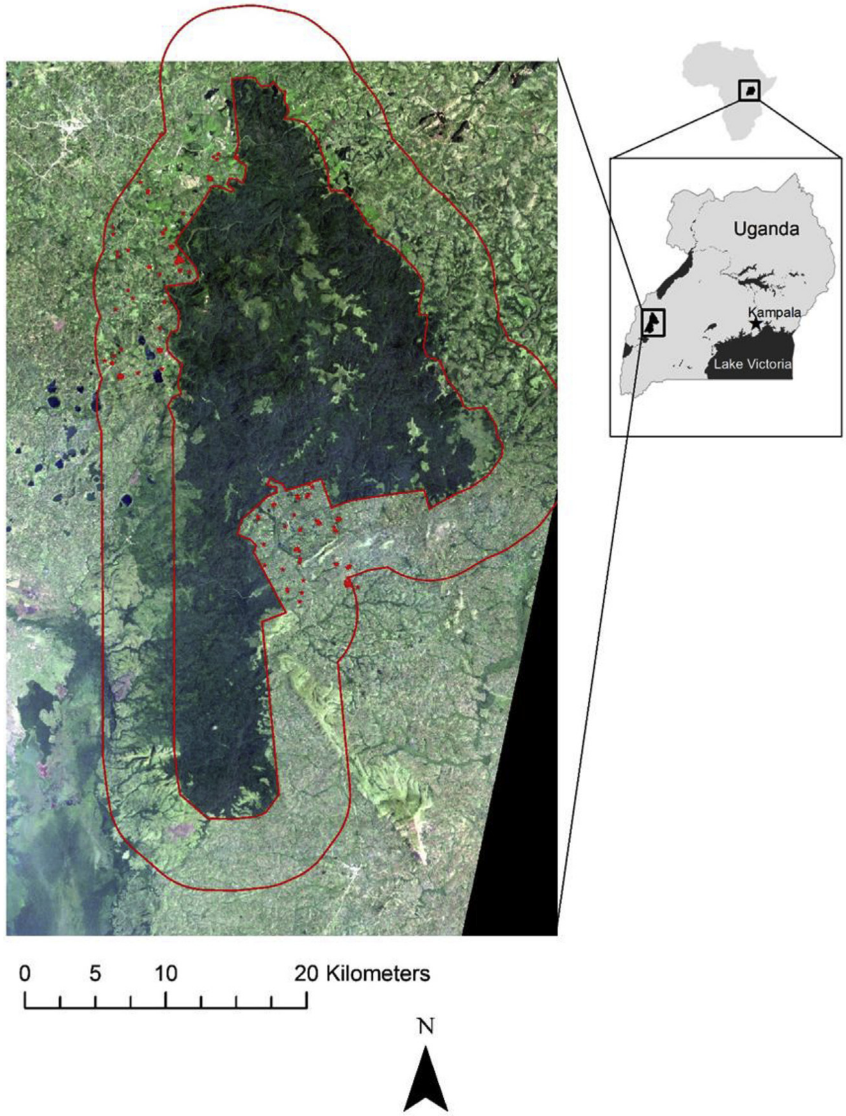

Fig. 1. Study area showing Kibale National Park, the 5-km landscape surrounding the park, and the interview locations.

belong primarily to two ethnic groups — the Batoro, less intensive farmers (west side) and the generally more intensive farmers and immigrant Bakiga (east side) (Hartter, 2007). The Bakiga have been immigrating to the Kibale area from southwestern Uganda since the 1950s seeking land and employment on the tea estates (Hartter et al. 2014a; Ryan & Hartter, 2012). Both ethnic groups plant a mixture of subsistence (bananas, maize, beans, and cassava as the main staple foods) and cash crops during the two farming seasons.

Analysis

We focused on forest and wetland patches near the Kibale boundary (<5 km) to determine whether there is a local household zone (LHZ) of influence leading to a greater rate of forest and wetland fragmentation (measured by number, size, and isolation) than in the larger landscape. Since 1.5 km is the farthest distance respondents reported they would travel to gather resources in wetland and forest patches (Hartter, 2007), we created a buffer of 1.5 km around each of 130 household interview locations to create the LHZs (Fig. 2). Although some forest and wetlands may connect to one another, we considered them separately in their fragmentation patterns since both the governance and resources supplied by each differs (Hartter & Ryan, 2010). Then we explored socioecological factors from household surveys that may drive these local processes. We modeled fragmentation as a function of household location, demography, and perceptions and attitudes about human-landscape interactions. We used a multi-model selection approach to probe the relationship between physical location, demography, and reported perceived benefits or harm from the park and forest or wetland patches.

Landscape patch analysis

Three dates of classified Landsat satellite imagery were used during this analysis: 26 May 1984, 17 January 1995, and 31 January 2003. The 1995 and 2003 images were acquired at the end of the dry season, when forests and agricultural lands can be distinguished from one another. The 1984 image was the only available cloud-free image within the necessary time period and was acquired at the end of the rainy season. Phenological differences were taken into account by performing independent image classifications. Geometric registration resulted in a Root Mean Squared Error of less than 0.5 pixels. Subsequent atmospheric correction and

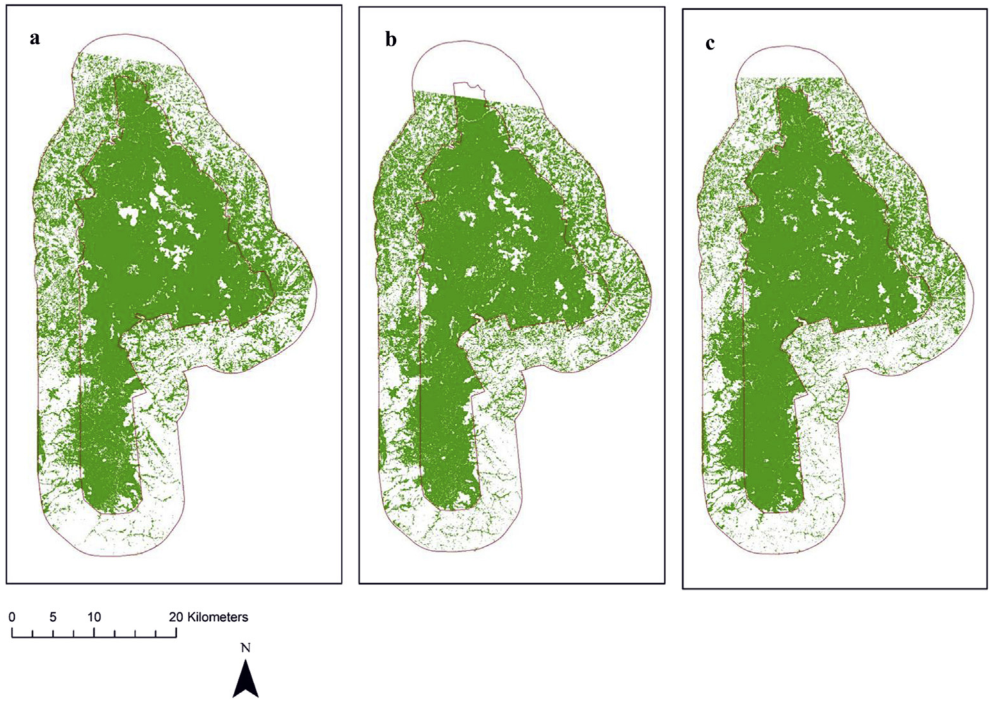

Fig. 2. Forest cover in and around (5 km) Kibale in a. 1984, b. 1995, c. 2003.

radiometric calibration was then performed. The independent classifications of each image used the Gaussian maximum likelihood classifier. The five land cover classes were (1) forest, (2) tea and shrub, (3) wetland and elephant grass, (4) crops and bare land, and (5) water. The overall accuracy of the classification was 89.1%, with a kappa of 0.867. Each classified image was recoded as (1) forest or non-forest (Fig. 3), and (2) wetland or non-wetland (Fig. 4). It is important to note that the wetland class is a mixed representation of tall grasses: papyrus (*Cyperus papyrus* L.), which is more indicative of water present, and elephant grass (*Pennisetum purpureum Schumach*), generally found in drier areas. These grasses have similar spectral signatures, and are used similarly by local people – grass collection for mats, etc. Fragments that were less than 0.5 ha were filtered out of the image using the sieve tool; more

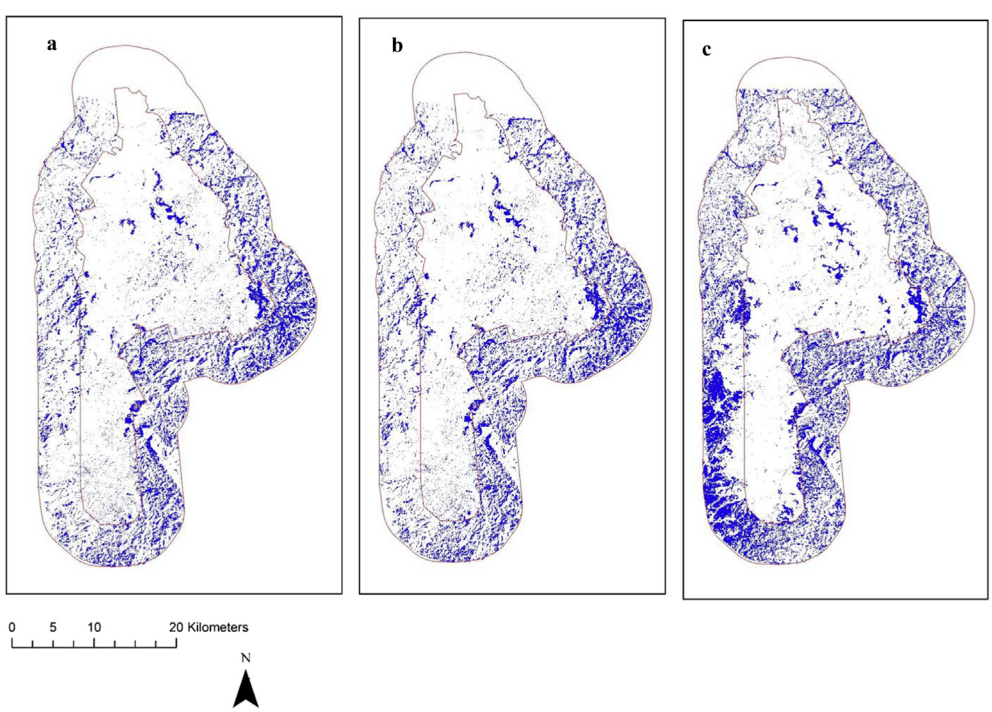

Fig. 3. Wetland in and around (5 km) Kibale in a. 1984, b. 1995, c. 2003.

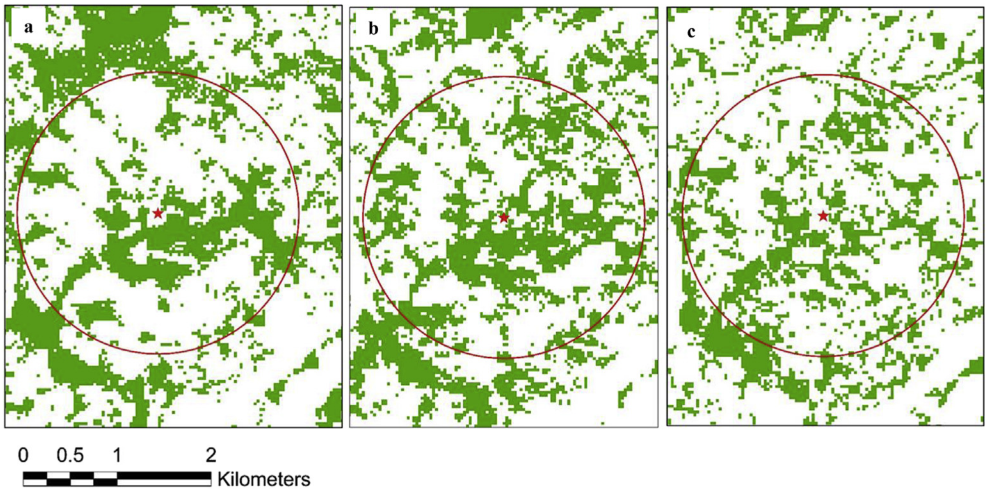

Fig. 4. An exemplar local household zone (LHZ), showing forest cover in a. 1984, b. 1995, c. 2003.

details regarding the image processing techniques can be found in Hartter and Southworth (2009).

Defining LHZ influence

Landscape change over time within the 130 LHZs was quantified using Fragstats 4.1 (McGarigal, Cushman, & Ene, 2012). Three class-level metrics were run for each individual buffered image file for the three dates: mean patch size, total number of patches, and mean patch isolation (nearest-neighbor distance). These metrics were chosen to provide direct comparisons to a prior analysis of fragmentation in the larger landscape surrounding the park (Hartter & Southworth, 2009). To understand the potential influence of park establishment in 1993 on the process of fragmentation as a function of household behaviors, we calculated the change in these metrics between 1984 and 2003, and between 1995 and 2003, to yield long term change and a proxy for change since park establishment. As such, only the regions around these LHZs were subset for the analysis.

Household survey data

Two research areas were defined within 5 km of Kibale, one on the west side (110 km^2) and one on the east side (56 km^2) of the park (Fig. 1). A set of random geographic coordinates were generated within each of these areas, and those points became the centers of 9-ha areas termed 'superpixels' (Goldman, Hartter, Southworth, & Binford, 2008), 36 on the west side and 32 on the east side. In 2006, we conducted a total of 130 household interviews within these superpixels from which land use, attitudes toward the park, and resource use was documented (Hartter et al. 2014b). A handheld global positioning system receiver was used to obtain coordinates from each respondent's house and entry point to the nearest wetland and forest fragment used by the household.

Statistical modeling

We created models of fragmentation describing the overall time span (1984–2003) and from 1995 to 2003, as a proxy for processes since park establishment in 1993. As we had many socioecological variables to explore from the household survey responses, we needed to balance our modeling approach and avoid model overfitting and overparameterization (Burnham & Anderson, 2002). We used multi-model selection in the R package 'glmulti' (Calcagno & de Mazancourt, 2010) to explore suites of variables, and to select a best fit model, based on Akaike's information criterion for small sample sizes (AICc). We conducted the model selection in two steps, taking the first step to derive a best fit model of location and demographic variables, using the smallest AICc as our criterion of best fit. In the second step, we used the criterion of AICc$\geq$ 2, as a cut off for improvement of fit over the first step model (Burnham & Anderson, 2002).

We established ten suites of variables from survey responses (given in Table 1) as candidates for logistic models of changing fragmentation metrics (mean number of patches, patch size, and isolation). The first step of model selection was conducted using a suite of physical location and demographic variables, to explore the geographic and sociodemographic relationships (Table 1). We then tested variable suites, sequentially, accounting for perceptions and attitudes such as: reported crop raiding, crop raiding from particular species (elephants, baboons, or small monkeys), perceived crop raiding emanating from fragments or the park, whether it was better to live closer to the park, benefits respondents derived from the park, and respondents' attitude towards the park (Table 1). We retained variables as model improvement increased. This two-step approach allowed us to control for geographic and demographic heterogeneity prior to assessing the role of perceptions and attitudes. Conducting multi-model selection in a hypothesis variable suite approach has proven valuable in previous work, to avoid bias or statistical 'fishing' (Gusset et al. 2008; Stewart Ibarra et al. 2013).

Results

Landscape fragmentation

At the full landscape level there has been a decline in forest patches outside the park (Fig. 2) and an increase in the wetland patches outside the park (Fig. 3), although hereafter we discuss only the LHZs as our unit of analysis. It is worth noting however, that this wetland class also includes elephant grasses and these areas have expanded, especially in the south western region outside the park (Fig. 3), but that this region is outside of the sampling of LHZs used in this analysis and so does not impact these results. We use the term wetlands in the remaining of the paper as these discussions relate more to the wetland with papyrus and bottomland forest regions which are located with the LHZ regions.

We found that there was an increase in the mean number of forest and wetland fragments in the LHZs, from 1984 to 2003,

Table 1
Ten suites of variables as hypothesized socioecological drivers of local fragmentation.

Suite	Name	Variable description
Geographic	Side	Interview locations in communities on the east or west side of Kibale National Park
	Distance	Distance from Kibale National Park (KNP) boundary (km)
	Sw_dist	Distance from interview site to nearest wetland fragment ≥ 0.5 ha (km)
	For_dist	Distance from interview site to nearest forest fragment ≥ 0.5 ha (km)
Social/demographic	Age	Age of respondent (years)
	Wealth	Wealth category 1–3 of respondent's household[a]
	Gender	Gender of respondent
	Batoro	Respondents identified themselves as Batoro (ethnic groups are mutually exclusive)
	Bakiga	Respondents identified themselves as Bakiga
	New	Respondents moved to the area within the last 5 years
Crop raiding	Cropraid	Respondents answer "yes" to "Do you and your household have problems with wild animals that raid your crops?"
Most problematic animals	Pr_bab	Baboon reported as the most problematic (currently) wild animal to the respondent's household.
	Pr_el	Elephant reported as the most problematic (currently) wild animal to the household.
	Pr_allsm	Small monkeys reported as the most problematic (currently) wild animal to the household.
	Pr_other	Other animals such as cane rats, mongoose, civets, are reported as most problematic.
Problem animals	Baboon	Baboon reported as a current problem animal to the respondent's household
	El	Elephant reported as a current problem animal to the respondent's household.
	allsm	Small monkeys (vervet, L'Hoest's, red colobus, black and white colobus, grey cheeked mangabey, redtail) reported as a current problem animal to the respondent's household
Patch problem animals	For_bab	Baboon reported as a current problem animal to the respondent's household, and believed to come from the nearby forest patch(es)
	For_allsm	Small monkeys reported as a current problem animal to the respondent's household, and believed to come from the nearby forest patch(es)
	Sw_bab	Baboon reported as a current problem animal to the respondent's household, and believed to come from the nearby swamp(s) [wetland patches]
	Sw_allsm	Small monkeys reported as a current problem animal to the respondent's household, and believed to come from the nearby swamp(s) [wetland patches]
Park problem animals	KNP_bab	Baboon reported as a current problem animal to the respondent's household, and believed to come from the park
	KNP_el	Elephant reported as a current problem animal …
	KNP_allsm	Small monkeys reported as a current problem animal …
Living closer to the park	close	Respondents believe it is better to live closer to the park rather than farther away (using self-assessed definition of "closer" and "farther")
Park attitudes	KNP_bene	Respondents believe the park provides benefits to their household
	KNP_hurt	Respondents believe the park harms their household
	KNP_stay	Respondents wish the park to remain as it is rather than dissolve it
Park services/problems	Keep_anim	Respondents believe that the park contains or reduces wild animal forays into nearby fields
	Keep_env	Respondents believe the park provides other ecosystem services
	KNP_raid	Respondents believe the park causes harm to their household because of crop raids by park wildlife

[a] Based on definitions described in Hartter et al. 2014a, 2014b.

signaling increasing fragmentation (Table 2). The number of forest patches in LHZs decreased shortly after park establishment in 1995, but increased substantially by 2003, while the number of wetland patches increased across both time periods. This suggests that fragmentation was certainly occurring in the LHZs, in a classic pattern of chopping up of the landscape. The size of forest patches was consistently smaller in the LHZs than in the overall landscape, and there was a substantial decline in size from 1984 to 2003. However, between 1984 and 1995, forest patches in LHZs increased in mean size. Taken in combination with the decrease in number in this first period, it is likely that there was a shift from many small fragments and some large, to a clearing and converting of the smaller forest fragments on the landscape, resulting in fewer, larger fragments remaining. By 2003, perhaps as a result of exclusion from woody resources in the park, these larger forest fragments were fragmented into more, but smaller fragments. This finding is similar to that seen across the landscape surrounding Kibale where many of the fragments have been completed converted to farmland over time (Chapman et al. 2013), but the effect appears to be particularly pronounced in the LHZ, suggesting a strong effect of household influence on forest fragmentation dynamics. We see a reflection of this process, although less dramatically, with the isolation measure (nearest-neighbor distance – Fig. 4a). We saw an overall increase in LHZ forest fragment isolation from 1984 to 2003, similarly to the previous studies of the larger Kibale landscape, but in the period just after park establishment (1995), isolation decreased. This points to perhaps a more complex mechanism in play, where smaller, more isolated fragments are cleared entirely, leaving clusters of remnant fragments, with nearer neighboring fragments; essentially leaving only clumps of relatively intact forest patches. Unsurprisingly, the jump in mean isolation from 1995 to 2003 within the LHZs is not as large as in the overall landscape; there simply isn't as much space in LHZs to create those distances.

The wetland patches exhibited a more complex dynamic occurring over the study period. The classic fragmentation trajectory in the LHZs shown in Fig. 3, with a steady increase in the number of wetland patches, suggests a shattering of patches. The

Table 2
Comparison of forest and wetland patch size and isolation in LHZs to those in the larger landscape (Hartter & Southworth, 2009, Table 4), in 1984, 1995, and 2003.

	1984		1995		2003	
	All[a]	LHZ (SE)	All	LHZ (SE)	All	LHZ (SE)
Forest Patch Mean Size	14.1	10.51 (0.52)	16.1	14.93 (0.99)	10.5	4.78 (0.18)
Wetland Patch Mean Size	2	7.33 (0.38)	1.4	2.71 (0.13)	2.3	3.84 (0.18)
Forest Patch Isolation	106	89.38 (1.39)	102	83.36 (1.28)	119	97.15 (2.05)
Wetland Patch Isolation	77	88.90 (1.83)	84	127.69 (3.84)	80	94.57 (1.93)

[a] As reported in Hartter & Southworth, 2009, Table 4.

Table 3
Top selected models (best fit) for each of the 12 model selection analyses. Best fit models for forest patches (F1–F6) and wetland patches (W1–W6), detailing variables, showing the variable estimate (v), standard error (SE), t-value (t), p-value (p) and significance (*<0.05,**<0.001,***<0.0001, ns – not significant); model R^2, overall f-test, and p-value.

Suite		Geog	Geog	Geog	Geog	Dem/Soc	Cropraid	Most prob	Most prob	Most prob	Park atts	Park atts	Park ES	Park ES	Most prob	Dem/Soc	Dem/Soc	Patch	Park prob
	Int	side	dist	sw_dist	for_dist	Wealth	Cropraid	pr_bab	pr_allsm	pr_other	KNP_bene	KNP_stay	keep_anim	keep_env	pr_el	age	Bakiga	for_bab	KNP_allsm
F1	Change in number of forest patches 1984–2003, $R^2 = 0.55$, $F_{8,96} = 14.52$, p<<0.001																		
Est (SE)	−3.40 (4.85)		−5.00 (0.62)	−0.02 (0.01)	0.01 (0.01)	3.17 (1.36)	5.38 (2.15)	5.60 (2.71)			−4.58 (2.18)	5.19 (1.62)							
t *sig*	−0.70		−8.11 ***	−2.92 **	1.82	2.33 *	2.50 *	2.06 *			−2.10 *	3.21 **							
F2	Change in number of forest patches 1995–2003, $R^2 = 0.66$, $F_{10,94} = 17.88$, p<<0.001																		
Est (SE)	5.18 (3.55)	−14.35 (1.48)	−0.88 (0.47)	−0.02 (0.01)	0.01 (0.01)	2.93 (1.01)	4.94 (1.63)					2.94 (1.09)	−3.80 (1.75)	−3.51 (1.46)	−3.75 (2.06)				
t *sig*	1.46	−9.71 ***		−3.24 **	2.45 *	2.90 **	3.03 **					2.70 **	−2.18 *	−2.40 *	1.82				
F3	Change in forest patch size 1984–2003, $R^2 = 0.46$, $F_{6,98} = 13.70$, p<<0.001																		
Est (SE)	−4.15 (2.06)		1.76 (0.32)		0.00 (0.00)			−6.43 (1.36)	−1.91 (0.93)		2.17 (1.13)	−1.67 (0.81)							
t *sig*	−2.01 *		5.45 ***		0.38			−4.72 ***	−2.06 *		1.92	−2.07 *							
F4	Change in forest patch size 1995–2003, $R^2 = 0.62$, $F_{9,95} = 17.15$, p<<0.001																		
Est (SE)	0.08 (3.87)	14.11 (1.44)	−1.73 (0.47)		0.00 (0.00)	−3.89 (1.08)			−3.97 (1.44)	−4.24 (2.45)	2.60 (1.66)	−1.20 (1.20)				−0.07 (0.04)			
t *sig*	0.02	9.81 ***	−3.65 ***		0.37	−3.61 ***			−2.76 **	−1.73	1.57	−1.00				−1.81			
F5	Change in forest patch isolation 1984–2003, $R^2 = 0.32$, $F_{9,95} = 4.9$, p < 0.001																		
Est (SE)	14.21 (7.86)		4.79 (1.19)	0.05 (0.02)	−0.04 (0.01)		−21.33 (5.84)	10.03 (5.45)	10.66 (5.05)	22.77 (7.24)		−4.48 (2.60)					5.72 (3.55)		
t *sig*	1.81		4.03***	3.28 **	−3.01 **		−3.65 ***	1.84	2.11 *	3.15 **		−1.72					1.61		
F6	Change in forest patch isolation 1995–2003, $R^2 = 0.22$, $F_{7,97} = 3.90$, p < 0.001																		
Est (SE)	15.73 (8.94)		4.56 (1.31)	0.06 (0.02)	−0.05 (0.02)		−11.46 (4.63)					−2.10 (2.85)						−18.12 (11.85)	9.09 (5.53)
t *sig*	1.76		3.49***	3.34 **	−2.95 **		−2.47 *					−0.74						−1.53	1.64

Suite		Geog	Geog	Geog	Geog	Dem/Soc	Dem/Soc	Dem/Soc	Crop raiding	Most prob	Park atts	Park ES	Patch prob	Park probs	Park atts	Park ES
	Int	side	dist	sw_dist	for_dist	age	Bakiga	Gender	Cropraid	pr_bab	KNP_bene	keep_env	sw_allsm	KNP_raid	KNP_stay	keep_anim
W1	Change in number of wetland patches 1984–2003, $R^2 = 0.45$, $F_{7,97} = 11.19$, p<<0.001															
Est (SE)	30.04 (5.48)		−4.57 (0.72)	−0.02 (0.01)	0.02 (0.01)			−4.54 (2.06)	−9.56 (2.71)				−6.64 (2.41)			
t *sig*	5.48***		−6.39 ***	−2.32 *	2.70 **			−2.21 *	−3.53 ***				−2.68			
W2	Change in number of wetland patches 1995–2003, $R^2 = 0.35$, $F_{6,98} = 8.94$, p<<0.001															
Est (SE)	4.44 (4.81)	−11.07 (3.38)			0.01 (0.01)		−6.70 (3.33)			6.74 (3.28)		4.56 (2.48)			0.45 (1.73)	
t *sig*	0.92	−3.28 **			2.47 *		−2.02 *			2.06 *		1.84			0.26	
W3	Change in wetland patch size 1984–2003, $R^2 = 0.17$, $F_{5,99} = 4.17$, p = 0.002															
Est (SE)	−7.63 (2.13)		1.05 (0.28)		0.00 (0.00)			1.70 (0.84)	2.47 (1.00)						−0.66 (0.62)	
t *sig*	−3.59 ***		3.81 ***		−0.41			2.02 *	2.46 *						−1.08	
W4	Change in wetland patch size 1995–2003, $R^2 = 0.27$, $F_{5,99} = 7.19$, p < 0.001															
Est (SE)	2.21 (0.70)				0.00 (0.00)	−0.02 (0.01)	1.29 (0.28)			−1.29 (0.40)					−0.10 (0.20)	
t *sig*	3.17 **				−2.44 *	−1.84	4.54 ***			−3.23 **					−0.52	
W5	Change in wetland patch isolation 1984–2003, $R^2 = 0.31$, $F_{7,97} = 6.20$, p < 0.001															
Est (SE)	−29.75 (12.20)				−0.01 (0.01)	0.25 (0.11)			21.58 (5.18)		10.41 (5.03)		15.53 (4.31)		−5.86 (3.39)	8.51 (5.26)
t *sig*	−2.44 *				−0.78	2.15 *			4.17 ***		2.07 *		3.60 ***		−1.73	1.62
W6	Change in wetland patch isolation 1995–2003, $R^2 = 0.29$, $F_{6,98} = 6.80$, p<<0.001															
Est (SE)	−32.87 (12.76)	24.70 (5.69)		−0.06 (0.03)	0.05 (0.02)							−13.08 (6.07)		13.48 (5.78)	−1.55 (4.61)	
t *sig*	−2.58 *	4.34 ***		−2.42 *	2.05 *							−2.16 *		2.33 *	−0.34	

dramatic drop in wetland fragment size from 1984 on suggests rapid wetland conversion occurring around households. Utilization pressure on wetlands is very high; not only do people obtain papyrus, tree poles, fuelwood, and water from wetlands, but there is also the threat of draining for agriculture. In addition, we found in previous work that there is likely a reactive response to legal frameworks protecting wetlands that may have increased wetland conversion to agriculture; essentially, you cannot be restricted from using the land if it is not a wetland anymore (Hartter & Ryan, 2010). This trade-off between living close to a wetland of a useful size for essential resources, with concomitant rapid rates of conversion initially, followed by a more gentle nibbling away at remnant smaller wetlands, as well as outer edges of larger ones, and dividing up larger patches, is reflected in Figs. 3b and 4b: the mean size increases a little after park establishment and the LHZ isolation distance returns to roughly pre-establishment levels. Unlike forest fragments, unless the hydrology of a wetland patch is dramatically altered by over-utilization of all its vegetative components, the renewable nature of the water supply may actually be self-serving protection in the LHZ. There is also the pervasive local belief that forests can be owned by individuals, whereas wetlands cannot. This *de facto* regulation of resources may also provide some level of protection or stewardship of wetlands (Hartter & Ryan, 2010).

Landscape models

The top selected models and variables are given, with model summaries, in Table 3; appendix A details the full model selection procedure and information measures.

Forest models

Our top selected models indicated that forest fragmentation decreased farther from the park boundary; as distance from the park appeared in all six models, and was highly significant in all but one (Table 3). We found that the side of the park was significant for both the number (west) and size (east) of forest patches post-park establishment, but not for isolation of patches. Wealthier households were associated with an increase in patches, and a decrease in patch size, post-park establishment. There was a significant association between increased fragmentation and reported crop raiding, and reporting that baboons were the most problematic animal, for several of our models. Reports of small monkeys as the most problematic animal were significantly associated with both decreasing patch size and increasing isolation.

There was a negative relationship between the number of patches and reported benefits from Kibale – suggesting decreased fragmentation with perceived park benefits – but increased patch numbers and decreased patch size, with the perception that Kibale should stay (Table 3). The perception that the park is beneficial both as a place that provides resources for animals, thus reducing forays into adjacent farms and also ‘keeps the environment’ by providing rain, fresh air and other ecosystem services (Hartter et al. 2014b), correlated with a decreasing number of forest patches in the post-park establishment period, suggesting a positive impact of these perceptions.

Wetland models

The top model for overall change in wetland patch number (1984–2003) suggested decreased numbers, and increased sizes of wetlands farther from the park. The side of the park was important for both the number (west) and isolation (east) of wetlands, after park establishment (Table 3). Respondent gender (female) was associated with decreased number of wetlands, and an increase in size over the whole period. However, identifying as Bakiga showed similar patterns only after park establishment. Reported crop raiding was significantly associated with patch number decrease, patch size increase, and isolation (Table 3). Post-park establishment fragmentation in the form of increasing patches and smaller sizes was significantly associated with reporting baboons as the most problematic animal; however, both patch number change and isolation were associated with reports of wetlands sourcing small animals as crop raiders.

The attitude that the park helps ‘keep the environment’ was negatively associated with isolation, suggesting a positive impact of this perception; and the perception that the park was a source of crop raiding was positively associated with isolation, suggesting the opposite link. Reports that the park provides benefits was significant for isolation, but opposing; the attitude that the park should stay was important but not significant in five of the six models, suggesting that these attitudes and perceptions shape local human-environment interactions, but the links are not always direct.

Socioecological drivers of fragmentation

Our models of fragmentation as functions of socioecological drivers at the household level showed in many cases, geographic location was important, either in terms of distance from the park edge, or being located west or east of the park. We found a greater change in the number of forest patches closer to the park, increasing isolation farther from the park, and increased change in patch size overall farther from the park, but the opposite post-park establishment (1995–2003), indicating greater change in patch size nearer the park. We found that the side of the park had a significant and pronounced effect on the size and number of forest patches, in the post-establishment period, although isolation appeared to be unaffected (Table 2). This suggests that geographic heterogeneity in the human-environment response leading to fragmentation in the LHZ structures much of the patterns we see. Increased forest fragmentation occurred more, nearer the park, post-establishment, with a strong signal of increased fragmentation on the west side of the park, which is settled mainly by Batoro.

We found an increase in number and decrease in size of wetland patches nearer the park, but no influence of park proximity on isolation. However, post-establishment, the side of the park proved to be important, with increased LHZ wetland patch numbers in the West, and increasing isolation to the East, where the Bakiga are the most dominant ethnic group. While the West and East are associated with the Batoro and Bakiga, respectively, this is not a strict 1:1 relationship in these data. To untangle whether fragmentation patterns were directly attributable to cultural practices, or indirectly, by the later arrival of Bakiga to the area (Ryan & Hartter, 2012), respondent identification with ethnic group was tested as a variable in the models, in addition to ‘side’. Affiliation with the Bakiga was correlated with increasing isolation of forest patches overall, but Batoro affiliation was correlated with increased number and decreased sizes of wetland patches in the post-park establishment period, perhaps reflecting decreasing availability of remnant areas. Wealthier households were associated with increased numbers of forest patches across the entire time period 1984–2003, and post-park establishment, and a decrease in patch size after 1995, but this appeared not to be important for wetland fragmentation patterns in the LHZs. Whether wealthier households are indicative of larger families requiring more fuelwood resources, or are directly tied to greater rates of land conversion, is not readily apparent from our study, but the differential impact of wealth on forests versus wetlands will have implications for management.

It was interesting to discover that the perceptions and attitudes of household respondents improved model fit in every case. We found that all the models for fragmentation of both forest and wetland patches for the entire time period (1984–2003), except changing forest patch size, included reported crop raiding. In forest patch models, the most problematic crop raiding animal reported was consistently baboons, which was associated with an increase in the number of patches, a decrease in patch size, and an increase in isolation in the LHZs. In the models of wetland fragmentation over the entire time period, the report of small monkeys coming from nearby wetlands was important for patch numbers and isolation. These associations of crop raiders with fragmentation may indicate a behavioral response to reduce patches that serve as habitat ‘stepping stones’ for crop raiders into the landscape of the LHZ.

Both over the whole time period, and after park establishment, small monkeys and elephants were important in several models, and baboons emerged as associated with changes in wetland patch size and number, after park establishment. While it is hard to point to behaviors directly (Holmes, 2003), mitigating for these perceptions is likely important to conservation in this landscape. Kibale is in no small part made famous by its primate diversity: it is home to 12 species of monkey, including critically endangered red colobus (*Piliocolobus tephroceles*), endangered chimpanzees (*Pan troglodytes* Schweinfurti), and threatened L'Hoest's monkey (*Cercopithecus lhoesti*) (Struhsaker, 1997). The fragments surrounding the park are also home to primate populations, and the loss of forest patches around the park has led to a decline in primate populations. In earlier work it was shown that between 1995 and 2003, 25% of fragments that had previously supported red colobus and black and white colobus (*Colobus guereza*) were cleared, and it was estimated that the black and white colobus population had declined by 55% in the landscape around the park (Chapman, Naughton-Treves, Lawes, Wasserman, & Gillespie, 2007).

Perceptions of the landscape surrounding the park and in the LHZs are likely strongly shaped by attitudes toward, and perceptions of, the park itself. Two important questions about the park were asked in this survey: if the respondent perceived benefit from the park, and whether they thought the park should stay. Eleven of the twelve models included ‘stay’ as an important variable explaining fragmentation, and four models included ‘benefit’ as important, and where significant, this was correlated with decreasing fragmentation in the LHZ. In addition, some named benefits, such as environmental regulation (keeps the environment), slowing crop raiding by providing habitat for the animals (keeps animals), and the hazard of the park maintaining crop raiders, emerged as important in this study, particularly environmental regulation post-park establishment. A few of these variables were significant in the final models, all suggesting associations between positive attitudes and decreased fragmentation. However, these results about perceptions and attitudes suggest that there is not a uniformly direct link between the conservation goals of the park and the perceptions of the human-landscape interaction. For example, respondents indicated that the park should stay, but it was associated with increased fragmentation in the LHZ – there is not a direct connection of ‘liking’ a park, and exhibiting behaviors to support conservation goals. However, there does appear to be a link between perceiving park benefits – ecosystem benefits – and behaviors in the LHZ that do not increase fragmentation.

Discussion

The landscape in the LHZs became more fragmented between 1984 and 2003; there was an increase in the number of patches (Fig. 5), a decrease in mean patch size, and an increase in patch isolation (Table 2). The mean size of forest patches in the LHZs was smaller than in the larger landscape in all three time steps, and decreased faster between 1995 and 2003, after park establishment. Isolation distance was smaller in the LHZs than across the larger landscape, increasing similarly over time (Table 2). In combination with the evidence for smaller patches, this suggests fragmentation occurs aggressively around households, wherein the remnant patches are being chopped up, slowing the apparent isolation, by introducing smaller inter-patch distances, but increasing in impact as time progresses. Mean wetland patch size was larger in the LHZs than across the aggregate landscape, but decreased markedly, and overall, wetland patches in LHZs became more isolated over time. This research thus shows that fragmentation was occurring more, and more rapidly, on this landscape in closer proximity to household sites than the remainder of the landscape. While the image dates used in this analysis are not current, and the interview data is from 2006, these same processes are ongoing in this landscape as fragmentation continues over time, and more households are established. As such, we need to better understand these drivers of

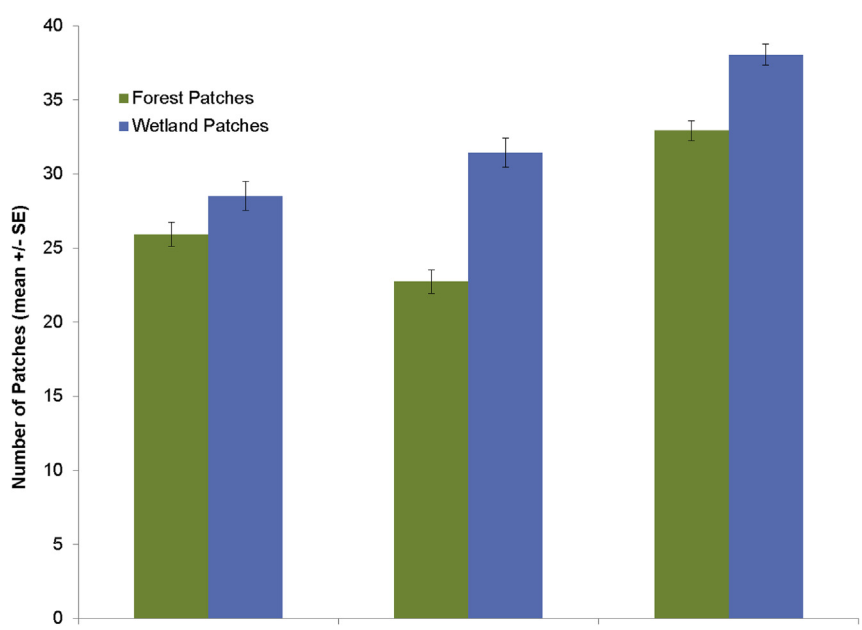

Fig. 5. Number of forest and wetland patches in local household zones (LHZs) (mean ± SE).

fragmentation in order to develop improved strategies for their study and management. People use resources more when they are found closer to their home. This research has highlighted a novel approach to integrating household surveys with remote sensing and landscape fragmentation studies, in order to better understand the social-ecological drivers of fragmentation at a household level across a park landscape. We are able to connect the perceptions which are driving action in this landscape to the process of local-level landscape fragmentation of both forest and wetland resource patches. This represents a novel integration of social and ecological information, within a multi-model selection approach, to allow us to understand landscape fragmentation processes, so we may better manage these landscapes and ideally to mitigate continued fragmentation.

Landscape fragmentation is a global problem facing biodiversity and human livelihoods (Hanski, 2005; Wade, Riitters, Wickham, & Jones, 2003), and is being linked to increasing numbers and types of issues, e.g. fire occurrence (Hantson, Pueyo, & Chuvieco, 2015), disease transmission (Marston et al. 2014; Tracey, Bevins, VandeWoude, & Crooks, 2014), declining wildlife populations (Newmark, Stanley, & Goodman, 2014), and decreasing availability of agricultural land (Bermeo, Couturier, & Galeana Pizaña, 2014). The pressure on remnant natural and protected areas from increasing human populations surrounding them is well established (Cuba, Bebbington, Rogan, & Millones, 2014; Joppa et al. 2009; Wittemyer et al. 2008). Models of deforestation suggest that, for tropical landscapes, this is not a local phenomenon, but rather it is a response to large-scale pressures and drivers (DeFries et al. 2010). However sub-Saharan Africa is thought to be an exception to this rule (Fisher, 2010). Given that rural human population growth and internal migration do occur, we might expect that there is nonetheless a highly localized impact of the establishment of households on the surrounding landscapes. Most importantly, while there is an ever increasing number of studies documenting fragmentation and its impacts on the landscape and concomitant dependent processes (e.g. wildlife population sustainability, disease vector/host maintenance, ignition potential), in order to manage for the future, we must identify the drivers – particularly social-behavioral – in order to understand what system leverage points are available for management.

Kibale National Park is part of an increasingly isolated chain of parks in the Ugandan portion of the Albertine Rift. The population surrounding the park has increased, while access to the park decreased after establishment (Ryan & Hartter, 2012). These fragmentation trends over the entire period are clearly driven by more recent processes suggesting that there is an influence of usufruct restriction occurring. As only 18 of the 130 households interviewed in 2006 were present for less than a decade, this suggests that the reduction in available land and access to forest resources since park establishment are key factors in landscape fragmentation. In previous studies, Kibale's landscape has proven the exception to the assumption that park presence necessarily induces antagonism with local people (Goldman et al. 2008). Nonetheless, there has been an inexorable decline in remnant forest and wetland habitat surrounding the park, coupled with an increase in human population density, which inevitably leads to resource pressure (Mackenzie & Ahabyona, 2012; Mackenzie, Chapman, & Sengupta, 2012). Other researchers, addressing the analysis of fragmentation around park landscapes have found direct linkages with household location, resource use and fragmentation (Munroe, Southworth, & Tucker, 2004; Nagendra, 2008; Nagendra, Pareeth, Sharma, Schweik, & Adhikari, 2008; Southworth, Nagendra, & Cassidy, 2012), although the research presented here does provide for more explicit linkages between socioecological drivers of fragmentation within the local household zone across the landscape. Such in-depth understanding of the processes driving changes and the resources being extracted by the households allows for a clear identification of fragments and their use over time, to better link to management and mitigation strategies (DeFries, Foley, & Asner, 2004; Sun, Huang, Zhen, Southworth, & Perz, 2014).

The predominant drivers of the differences in LHZ influence on fragmentation of forests and wetlands in the landscape around Kibale National Park, both during and after park establishment, are the perception of crop raiding, and attitudes about the park and its benefits/services – regardless of location, ethnicity, gender, or wealth. Thus, this study points to important points in the system that conservation managers can target – such as effective compensation schemes for crop-raiding, creating community-based resource management programs to promote sustainable use of remnant fragments of forests and wetlands, evaluating crop selection and placement in terms of palatability to wildlife, to discourage raiding while maintaining household nutrition and income flows – and presents a guide to future work. A better understanding of why local populations want the park to stay, and whether the landscape outside and inside are viewed as different types of forests and wetlands, would help better shape the links to the LHZs.

Identifying ecosystem services and translating these to applied management questions is currently under scrutiny. A recent review (Portman, 2013) highlights the complexity of combining the ecosystem service approach to addressing biodiversity loss (Daily, 1997; Daily et al. 2009; Nelson et al. 2009) with management including humans, proposing that the ecosystem-based management (EBM) approach to promoting resilience, in order to provision services to humans fits well (Levin & Lubchenco, 2008). This type of initiative has primarily been used for management of marine and coastal resources (McLeod, Lubchenco, Palumbi, & Rosenberg, 2005), and would be a practical framework for thinking about co-management of fragments between communities and parks management in this landscape.

Conclusion

In this study, spanning 20 years of land cover change, before, during, and after park establishment, in the landscape surrounding Kibale National Park in western Uganda, we found strong evidence for a local household zone (LHZ) effect on fragmentation patterns for both remnant forest and wetland patches. No doubt, as the human population grows in Uganda and around the park, fragmentation of the Kibale landscape will continue. Park-neighbor dynamics will almost certainly change as resource pools decline for both humans and wildlife and the park remains exclusive to resource extraction. We found that there were geographical and socioecological heterogeneities in the patterns of LHZ impact, influenced by wealth, and in some cases associated with tribal identity. We found strong indications that the perception of crop raiders – primarily baboons and small monkeys, but also including elephants and other animals – may largely shape human-environment interactions in the LHZ, and were associated with fragmentation. Our modeling approach allowed for an increased understanding of the socioecological drivers of fragmentation of both forest and wetland landscapes, by households, in order to provide much more constructive and targeted information for fragmentation management and mitigation, in this important park-landscape. Almost all of the best fit models included the variable of the attitude that the park should stay, but it was associated with increased fragmentation. Importantly, this suggests that the uncharacteristic non-hostile attitude about Kibale does not directly translate into conservation-friendly local human-environment interactions. Future research will continue to build upon this increased landscape understanding of the fragmentation processes and continue to contribute to the larger discussion of the effectiveness of parks as management regimes.

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Appendix A. Full model selection.

	Model	AICc	ΔAICc
Forest fragments			
F1			
Geography only	side + distance + sw_dist + for_dist	799.38	0.00
Best 1	1 + distance + sw_dist + for_dist + wealth + bakiga	794.30	5.08
Cropraid	1 + distance + sw_dist + for_dist + wealth + cropraid	788.73	10.65
overall prob animals	None		
forest animals	None		
KNP animals	None		
Most problematic animals	1 + distance + sw_dist + for_dist + wealth + cropraid + pr_bab	787.79	11.59
close	None		
park ES	None		
park attitudes	1 + distance + sw_dist + for_dist + wealth + cropraid + pr_bab + KNP_benefit + KNP_stay	765.83	33.55
F2			
Geography only	side + distance + sw_dist + for_dist	732.27	
Best 1	1 + side + distance + sw_dist + for_dist + wealth + new	728.05	4.21
Cropraid	1 + side + distance + sw_dist + for_dist + wealth + cropraid	723.38	8.88
overall prob animals	1 + side + distance + sw_dist + for_dist + wealth + cropraid + el	722.25	10.01
forest animals	None		
KNP animals	1 + side + distance + sw_dist + for_dist + wealth + cropraid + KNP_el	721.75	10.51
Most problematic animals	1 + side + distance + sw_dist + for_dist + wealth + cropraid + pr_el	721.94	10.33
close	None		
park ES	1 + side + sw_dist + for_dist + wealth + cropraid + keep_anim + keep_env	720.10	12.17
park attitudes	1 + side + distance + sw_dist + for_dist + wealth + cropraid + KNP_benefit + KNP_stay	706.59	25.67
BEST	1 + side + distance + sw_dist + for_dist + wealth + cropraid + pr_el + keep_anim + keep_env + KNP_stay	701.04	31.23
F3			
Geography only	side + distance + sw_dist + for_dist	664.31	
Best 1	1 + distance + for_dist + wealth + bakiga	659.65	4.66
Cropraid	1 + distance + for_dist + wealth + bakiga + cropraid	655.40	8.91
overall prob animals	None		
forest animals	None		
KNP animals	1 + distance + for_dist + wealth + bakiga + cropraid + KNP_bab + KNP_allsm	651.98	12.33
Most problematic animals	1 + distance + for_dist + pr_bab + pr_allsm	637.72	26.59
close	None		
park ES	None		
park attitudes	1 + distance + for_dist + wealth + bakiga + cropraid + KNP_benefit + KNP_stay	643.05	21.26
BEST	1 + distance + for_dist + pr_bab + pr_allsm + KNP_benefit + KNP_stay	625.04	39.27
F4			
Geography only	side + distance + sw_dist + for_dist	737.44	
Best 1	1 + side + distance + for_dist + age + wealth	723.15	14.29
Cropraid	None		
overall prob animals	None		
forest animals	1 + side + distance + for_dist + age + wealth + for_allsm	720.54	16.90
KNP animals	None		
Most problematic animals	1 + side + distance + for_dist + age + wealth + pr_allsm + pr_other	718.47	18.97
close	None		
park ES	1 + side + distance + for_dist + age + wealth + keep_anim	722.81	14.63
park attitudes	1 + side + distance + for_dist + age + wealth + KNP_benefit + KNP_stay	712.93	24.51
BEST	1 + side + distance + for_dist + age + wealth + pr_allsm + pr_other + KNP_benefit + KNP_stay	709.06	28.38
F5			
Geography only	side + distance + sw_dist + for_dist	921.70	0.00
Best 1	1 + distance + sw_dist + for_dist + bakiga	920.57	1.13
Cropraid	1 + distance + sw_dist + for_dist + bakiga + cropraid	917.43	4.28
overall prob animals	None		
forest animals	None		
KNP animals	None		
Most problematic animals	1 + distance + sw_dist + for_dist + bakiga + cropraid + pr_bab + pr_allsm + pr_other	917.20	4.50
close	None		
park ES	None		
park attitudes	1 + distance + sw_dist + for_dist + bakiga + cropraid + pr_bab + pr_allsm + pr_other + KNP_stay	899.20	22.50
F6			
Geography only	side + distance + sw_dist + for_dist	942.66	
Best 1	1 + distance + sw_dist + for_dist	941.88	0.77

(*continued*)

Cropraid	1 + distance + sw_dist + for_dist + cropraid	938.74	3.92
overall prob animals	None		
forest animals	1 + distance + sw_dist + for_dist + cropraid + for_bab	938.04	4.62
KNP animals	1 + distance + sw_dist + for_dist + cropraid + for_bab + KNP_allsm	937.40	5.26
Most problematic animals	None		
close	None		
park ES	None		
park attitudes	1 + distance + sw_dist + for_dist + cropraid + for_bab + KNP_allsm + KNP_stay	923.91	18.75
Wetland fragments			
W1			
Geography only	side + distance + sw_dist + for_dist	823.97	
Best 1	1 + distance + sw_dist + for_dist + gender + bakiga	821.14	2.83
Cropraid	1 + distance + sw_dist + for_dist + gender + bakiga + cropraid	817.48	6.49
overall prob animals	None		
wetland animals	1 + distance + sw_dist + for_dist + gender + cropraid + sw_allsm	810.65	13.32
KNP animals	1 + distance + sw_dist + for_dist + cropraid + KNP_allsm	816.55	7.42
Most problematic animals	None		
close	None		
park ES	1 + distance + sw_dist + for_dist + gender + bakiga + cropraid + keep_env	816.88	7.09
park attitudes	1 + distance + sw_dist + for_dist + gender + bakiga + cropraid + KNP_stay	800.00	23.97
BEST	1 + distance + sw_dist + for_dist + gender + cropraid + sw_allsm + KNP_stay	795.36	28.61
W2			
Geography only	1 + side + distance + sw_dist + for_dist	835.46	
Best 1	1 + side + for_dist + bakiga	830.16	5.30
Cropraid	None		
overall prob animals	None		
wetland animals	None		
KNP animals	None		
Most problematic animals	1 + side + for_dist + bakiga + pr_bab	827.05	8.41
close	1 + side + for_dist + bakiga + close	832.31	3.15
park ES	1 + side + for_dist + bakiga + keep_env	827.32	8.14
park attitudes	1 + side + for_dist + bakiga + KNP_stay	817.62	17.84
BEST	1 + side + for_dist + bakiga + pr_bab + keep_env + KNP_stay	813.86	21.60
W3			
Geography only	1 + side + distance + sw_dist + for_dist	624.39	0.00
Best 1	1 + distance + for_dist + gender	620.67	3.72
Cropraid	1 + distance + for_dist + gender + cropraid	617.82	6.57
overall prob animals	None		
wetland animals	1 + distance + for_dist + gender + cropraid + sw_allsm	612.22	12.16
KNP animals	None		
Most problematic animals	None		
close	None		
park ES	None		
park attitudes	1 + distance + for_dist + gender + cropraid + KNP_stay	606.08	18.31
BEST	1 + distance + for_dist + gender + cropraid + KNP_stay	606.08	18.31
W4			
Geography only	1 + side + distance + sw_dist + for_dist	392.31	
Best 1	1 + for_dist + age + bakiga	386.45	5.86
Cropraid	None		
overall prob animals	1 + for_dist + age + bakiga + baboon	383.36	8.95
wetland animals	1 + for_dist + age + bakiga + sw_bab	384.30	8.01
KNP animals	1 + for_dist + age + bakiga + KNP_bab + KNP_el	386.39	5.92
Most problematic animals	1 + for_dist + age + bakiga + pr_bab	376.41	15.90
close	1 + for_dist + age + bakiga + close	387.27	5.04
park ES	None		
park attitudes	1 + for_dist + age + bakiga + KNP_stay	381.12	11.19
BEST	1 + for_dist + age + bakiga + pr_bab + KNP_stay	372.90	19.42
W5			
Geography only	side + distance + sw_dist + for_dist	968.39	
Best 1	1 + distance + for_dist + age	965.01	3.38
Cropraid	1 + distance + for_dist + age + cropraid	955.64	12.75
overall prob animals	1 + distance + for_dist + age + cropraid + allsm	955.28	13.11
wetland animals	1 + distance + for_dist + age + cropraid + sw_allsm	946.66	21.73
KNP animals	1 + distance + for_dist + age + cropraid + KNP_bab + KNP_el	953.88	14.51
Most problematic animals	1 + distance + for_dist + age + cropraid + pr_bab	954.24	14.15
close	None		
park ES	1 + distance + for_dist + age + cropraid + keep_anim + keep_env	953.74	14.66
park attitudes	1 + distance + for_dist + age + cropraid + KNP_benefit + KNP_stay	935.26	33.13
BEST	1 + for_dist + age + cropraid + sw_allsm + keep_anim + KNP_benefit + KNP_stay	928.09	40.30
W6			
Geography only	side + distance + sw_dist + for_dist	1027.24	
Best 1	1 + side + sw_dist + for_dist	1025.18	2.06
Cropraid	1 + side + sw_dist + for_dist + cropraid	1024.62	2.62
overall prob animals	None		
wetland animals	None		
KNP animals	1 + side + sw_dist + for_dist + KNP_el	1023.63	3.60

(*continued on next page*)

(*continued*)

Most problematic animals close	1 + side + sw_dist + for_dist + pr_el	1024.26	2.98
park ES	1 + side + sw_dist + for_dist + keep_env + KNP_raid	1018.23	9.01
park attitudes	1 + side + sw_dist + for_dist + KNP_bene + KNP_hurt + KNP_stay	1003.02	24.21
BEST	1 + side + sw_dist + for_dist + keep_env + KNP_raid + KNP_stay	999.18	28.06

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