Piel, AK, Stewart, FA, Lenoel, A and Johnson, C

Deterring poaching in western Tanzania: The presence of wildlife researchers

http://researchonline.ljmu.ac.uk/id/eprint/1861/

Article

Citation (please note it is advisable to refer to the publisher's version if you intend to cite from this work)

Piel, AK, Stewart, FA, Lenoel, A and Johnson, C (2015) Deterring poaching in western Tanzania: The presence of wildlife researchers. Global Ecology and Conservation, 3. pp. 188-199. ISSN 2351-9894

TITLE: Deterring poaching in western Tanzania: The presence of wildlife researchers

Alex K. Piel,[1, 2] A. Lenoel,[3] C. Johnson,[4] F. A. Stewart[1]

[1] Department of Archaeology and Anthropology, University of Cambridge, Cambridge CB2 3QG, United Kingdom

[2] Department of Anthropology, University of California, San Diego, La Jolla, CA 92093 USA

[3] University of Montpellier II, 5 bd Henri IV - CS 19044, 34967 Montpellier Cedex 2, France

[4] College of Science, Wallace Building, Swansea University, Singleton Park, Swansea SA2 8PP, United Kingdom

KEY WORDS: Researcher presence; illegal poaching; Unprotected Area; Deterrence; Tanzania

CORRESPONDING AUTHOR: Alex Piel, akp34@cam.ac.uk,
+44 7557915813;

Abstract

Illegal poaching threatens wildlife across Africa. Historically and even today, conservationists have lobbied local and national governments to create and better manage protected lands to reduce this threat. In many cases, however, governments are either unable or unwilling to invest further resources in exclusive protected areas, such as national parks. In addition to traditional methods, or where such approaches are not feasible, a complimentary form of protection is researcher presence, which has been described recently to deter wildlife poaching. We present data over four years that assesses the impact of researcher presence on wildlife and snare encounter rate in an unprotected area in western Tanzania, where there is a mid-term chimpanzee study ongoing. We systematically collected spatiotemporal presence data on the nine, most common mammal species in the study area, as well as all snares. Snare encounter rates increased with distance from researcher base station, whilst overall mammal encounter rates decreased. Further, mammal encounter rates have increased each year since the arrival and permanence of researchers in this remote area. Our findings have implications for the benefits of researcher presence, namely in deterring poaching, especially in unprotected areas with minimal governmental surveillance.

1 Introduction

Large mammals are threatened across their distribution in Africa. From long-term studies, e.g. Serengeti ecosystem (Sinclair et al. 2007), numerous data describe mammal presence, movement, and more recently, threats, within, along the periphery, and outside of protected area (PA) boundaries. The pattern is clear: PAs that once provided a safe refuge for threatened or endangered species are failing to mitigate human-wildlife conflict (Western et al. 2009; Craigie et al. 2010). Increasingly, PAs are vulnerable to human encroachment, especially by poachers (Metzger et al. 2010), in addition to the same ecological changes and threats to adjacent, unprotected areas, especially when both are part of the same ecosystem (Hansen et al. 2011). Specifically, agriculture, logging and other forms of human land use in unprotected areas "may alter the flows of energy, materials, and organisms across the ecosystem in ways that change ecological functioning" of protected areas (Hansen & DeFries 2007: 978).

In Tanzania, where >30% of land already has some protective status (forest reserve, game reserve, etc.), but where legal and illegal exploitation of wildlife continues to cause a decline of numerous mammalian species (Stoner et al. 2007; Wasser et al. 2010), it is politically and economically complex to petition for further PAs. We argue here that whilst research provides essential knowledge for applied conservation, additionally it can provide protection that may be equally effective to that of upgrading an area to national park status. Recent studies have described the interaction between researchers and conservation, namely the role of researcher presence in deterring illegal hunting and aiding species diversity and abundance (Pusey et al. 2007; Campbell et al. 2011; Laurance 2013). Whilst mere researcher presence would have no effect on lucrative, commercial hunting for species like elephant (*Loxodonta africana*), it may deter small scale, subsistence hunting which comprises most of this illegal industry (Abernethy et al. 2013), especially if it is combined with traditional, government-facilitated patrols. Few studies, however, have systematically measured the effect of researcher presence on hunting pressure. We sought to do so by investigating changes in mammal and snare encounters over the course of the first four years of a mid-term study of chimpanzees in an unprotected area of open land in western Tanzania. We provide here empirical data that demonstrate the positive effect researchers have towards species conservation and the maintenance of ecosystem integrity.

1.1 Researcher presence and conservation

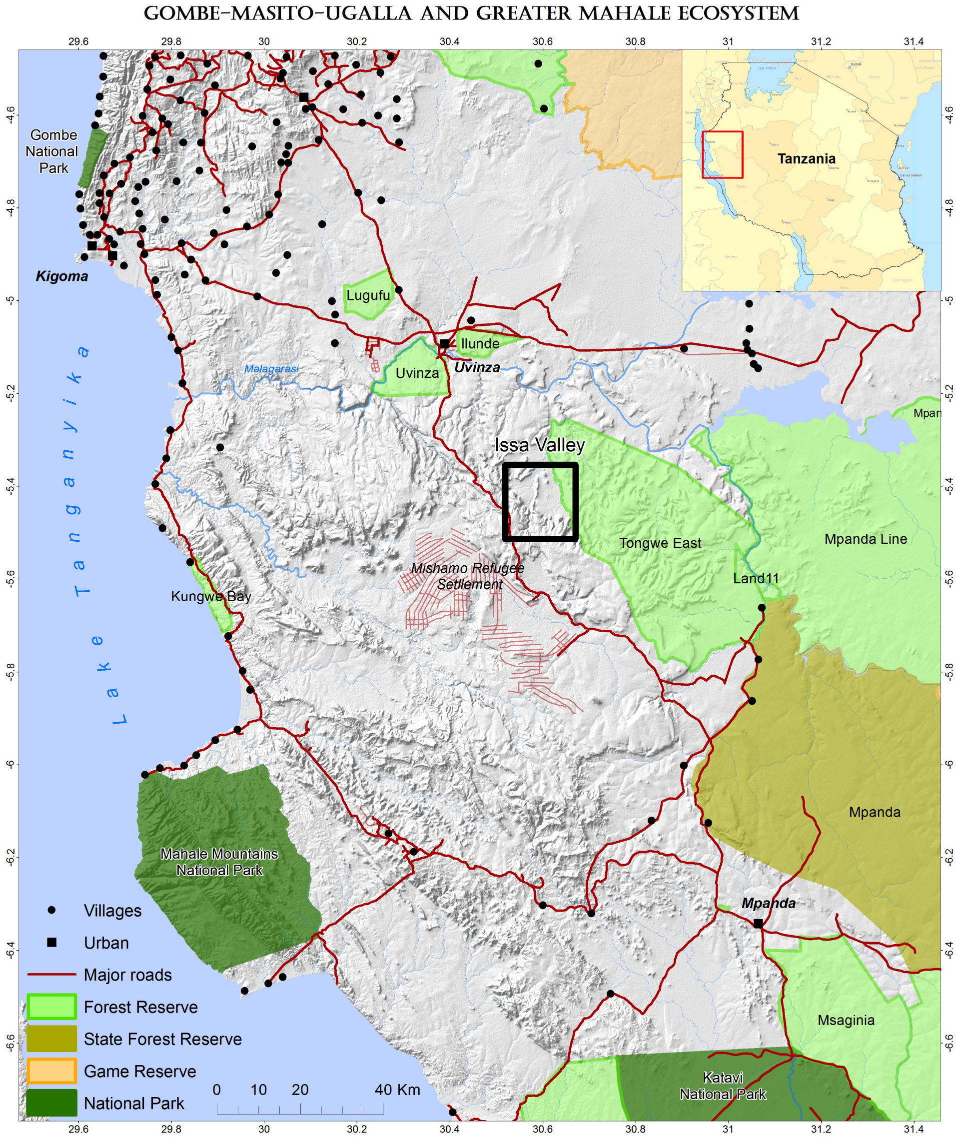
Research and conservation meet at a complex intersection. Some have argued that traditional divisions between these fields are merely "imaginary or insufficient" to prevent cooperation (Caro & Sherman 2013: 305); others have described explicit ways that scientists can contribute to providing conservation-minded results, e.g. effective population sizes (Anthony & Blumstein 2000). Others have emphasized the incorporation of data into conservation management plans (Pusey et al. 2007), although the effectiveness of specific management plans is not yet well understood

(Struhsaker et al. 2005). Some times, long-term studies themselves or just the very presence of researchers may mitigate threats to systems or species (Wrangham & Ross 2010).

In West Africa, Campbell and colleagues (2011) examined the conservation value of a long-term chimpanzee research station in Tai Forest, Cote d'Ivoire. They walked 200km of line transects and found that all primates and especially (over-harvested and endangered) duiker species (*Philantomba maxwellii; Cephalophus dorsalis*) were more abundant closer to the researcher station. Subsequent density analyses revealed that primates, irrespective of species, lived at densities up 100x larger near the research station, further demonstrating the benefit of a permanent research station, especially when researchers coordinated anti-poaching patrols with local law enforcement (Goran et al. 2012). However, as Tai Forest is a national park, law enforcement may have been greater around the researcher station. Consequently, this study could not determine whether researcher presence alone had a deterrent effect.

To better understand the role that *only* researcher presence plays in deterring poaching, ideally one studies a system with minimal government surveillance, yet with permanent researcher presence. Such contexts are rare, as it is actually the nature of PAs that encourage and foster researcher presence, providing infrastructure, safety, and often history of known wildlife populations (Sinclair et al. 2007). We measured the spatiotemporal distribution of snare and mammal encounters as a function of proximity to the researcher base station and overall search effort in the Issa Valley, Ugalla, western Tanzania. Data collection began late in the first year of the establishment of the Ugalla Primate Project – a continuous, ongoing study of woodland primates and medium-large mammals. Our study differs in three key ways from the aforementioned studies at Tai and Gombe. First, the Issa Valley lies in Open Area, belonging to Tanzania's central government, with no formal protective status. It is >30km from the nearest protected area (a forest reserve, also with no formal government surveillance). Second, data collection on snare and mammal encounters began at the onset of our Project, and thus we can monitor from baseline when there was minimal history of researcher presence. Finally, we have systematically monitored search effort, allowing us to control for this critical element in our analyses.

FIGURE 1



1.2 Regional History

The Greater Mahale Ecosystem Tanzania hosts over 90% of Tanzania’s estimated 2200 chimpanzees (Moyer et al. 2006; Piel & Stewart 2014) and most of the area is still considered Open Area. Historically, brief surveys (Moore 1994; Kano et al. 1999; Schoeninger et al. 1999; Moyer et al. 2006; Ogawa et al. 2006a, 2006b, 2012; Piel & Moore 2010) or isolated studies (Hernandez-Aguilar 2006; Moore & Vigilant 2013) have characterized research into the region, most of which have focused on chimpanzee distribution, although some also reported presence/absence of medium and large mammals as well (Moyer et al. 2006; Hernandez-Aguilar 2009; Iida et al. 2012). Until recently, there was no mid-term length study outside of the NPs, and no study that was able to assess change over time, either in mammal presence or threat intensity.

1.3 Aims and hypotheses

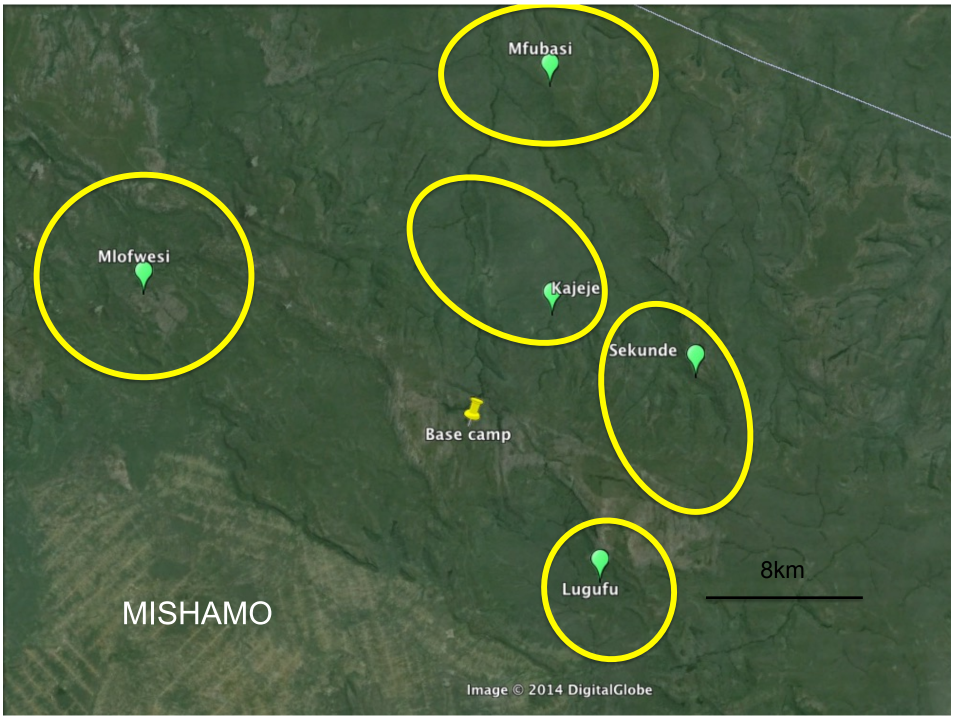
In this study we aimed to assess change over time and space in mammal density, and mammal and snare encounters, to determine whether researcher presence has a positive impact. We hypothesized that mammal densities will increase over time in the core-study area due to protective presence of researchers. In the core and peripheral areas we hypothesized that there would be spatiotemporal relationships between mammal and snare encounters as a function of the distance from researcher camp and researcher presence tenure. We expected to find more snares and fewer mammals encountered per unit effort as distance from research camp increases, and we expected the opposite relationship between mammal and snare encounters as the distance to Mishamo – a settlement home to >45,000 Burundian refugees decreased. We also investigated variation in mammal and snare encounters across regions, vegetation types, and seasons, to examine other factors that may influence poaching effort over space and time. We also expected a spatial correlation between snare and mammal encounters, if hunters know where best to target. Finally we hypothesized that if researchers are a deterrent to poachers, there would be a decreasing snare encounter rate since our Project inception and an increase in mammal-encounter rates as well.

2 Method

2.1 Study site

We collected data between January 2009-December 2012 in and surrounding the Issa Valley, Ugalla, in western Tanzania (Figure 1). The Issa Valley, lies in the west of the Ugalla region, >90km from the nearest National Park boundary (Mahale Mountains along Lake Tanganyika), ~50km from the nearest officially recognized village (Uvinza) and less than 10km from Mishamo, a Burundian refugee settlement established in the 1970s. Ugalla itself is a 3300km^2 area consisting of broad valleys separated by steep mountains and flat plateaus ranging from 900-1800m above sea level. Ugalla vegetation is dominated by miombo woodland - *Brachystegia* and *Julbernardia* (Fabaceae), although also includes swamp, grassland (together, these were classified to comprise ‘open’ vegetation), as well as evergreen gallery and thicket riverine forests (termed ‘closed’ vegetation). There are two distinct seasons: wet (mid October – mid April) and dry (late April – late September), with dry months defined as having <100 mm of rainfall. Rainfall averages ~1200 mm per annum (range: 900-1400mm, from 2001-2003; 2009-2014) and temperatures range from 11^{o}C to 35^{o}C (Stewart et al. 2011). Chimpanzees were first studied in this area from 2001-2003 (Hernandez-Aguilar 2006), and sporadically since 2005. A mid-term permanent research presence was initiated in 2008 by the Ugalla Primate Project and has been maintained since then.

FIGURE 2



2.2 Data Collection

2.2.1 Line transects:

Data for both mammal and threat distribution and density come from line transects and reconnaissance (recce) walks. We established seven line transects in Fall 2008, totaling 39.8km (range: 4.8-6.1km). From January 2009-March 2010 we walked each transect bi-weekly, at ~1km/hour, whilst from April 2010-December 2012, we walked these same transects once monthly. Researcher teams were always comprised of two experienced field assistants or researchers, who each looked for all direct or indirect (faecal, print, nest, feeding remains) evidence of mammal presence as well as for snares. We recorded perpendicular distance from the animal or object to the transect line using a measuring tape, as well as documenting vegetation type (woodland, open gallery forest, closed gallery forest, swamp), topography (valley, slope, plateau), and age (1-fresh, 2-recent, 3-old) of object. All animals in a group were counted, but we measured the distance to the first one observed (Marshall et al. 2008).

2.2.2 Recce walks:

Besides transects, we also recorded all evidence of mammals and snares from recce walks and during work on other research projects, e.g. focal follows of red-tail monkeys (*Cercopithecus ascanius*) or yellow baboons (*Papio cynocephalus*), or days spent searching for chimpanzees or snares specifically. Additionally, once monthly, we conducted a 3-day extended patrol to a peripheral area to the core study site. These patrols were designed to expand the geographical scope of our project and offer comparative data from areas less frequently visited by researchers. Each patrol destination (n=6,

Figure 2) was visited twice annually. Similar to transect methods, we recorded number, age, and type of evidence, in addition to vegetation type and topography. In addition to mammal and snare sightings, we recorded “effort” points every 30 minutes, where a GPS coordinate, vegetation and topography information were recorded.

2.3 Data analyses

2.3.1 Line transects

We used DISTANCE 6 (Thomas et al. 2010) to analyze line transect data according to standard line transect analyses in which the drop in the number of sightings with increasing distance is modeled to obtain a probability estimate of sighting an object (Thomas et al. 2002). Estimating densities from line transect survey can be done from several types of observations, e.g. direct encounters, dung samples, ape nests (Spehar & Marshall 2010; Tagg & Willie 2013). We considered only direct observations of individuals in our analyses, except in two cases. For chimpanzees, we analyzed encounter data of both individuals and nest sightings. For bushpigs (*Potamochoerus larvatus)*, because we encountered them only rarely, we used dung encounters to calculate an overall density. Previous studies have demonstrated the reliability of using dung counts to estimate overall species richness, especially at scales >25km^2 (Cromsigt et al. 2008).

To determine chimpanzee densities, nest counts can be corrected to a measure of density by dividing the density of nests by the number of days elapsed between the first and last walk of the survey (Plumptre & Reynolds 1996). This equation is accurate as long as each subsequent count occurs before the minimum time recorded for a nest to disappear. We used the mean decay rates found by Stewart *et al.* (2011), who reported a mean minimum decay rate of 83.3 days (averaged between woodland and forest rates) during the dry season in the core study area. We thus used the equation below for each year:

$$Dc = Dn/(P*n)$$

…where Dc is the density of chimpanzees (number of individuals per kilometre), Dn is the density of nests (number of nests per kilometre), P is the production rate (number of nests per individuals per day) and n is the number of days elapsed between the first and last walk. Estimates from mark nest count method will hereafter be designated as “chimpanzeenest” and estimates from individual’s sighting will hereafter be “chimpanzeesighting”.

We tested every model in DISTANCE with the uniform, half-normal and hazard-rate key functions and cosine, simple polynomial and hermite polynomial series expansions. We used the Chi-squared goodness-of-fit tests to see how well each model fit the data, which is based on a comparison of the observed and expected frequencies of observations within distance bins (Marques et al. 2009). Once only models that fit our data were selected we compared the Akaike Information Criterion (AIC) (Thomas et al. 2002) to select the best curve (lowest AIC value) to model the perpendicular distance data.

We calculated densities across four years of transects (2009-2012) for species whose sample sizes were sufficient (i.e. sufficient enough to obtain at least one DISTANCE 6 model that fit the data). For those species that were observed in more than one vegetation type, we stratified by vegetation in order to take into account the different detection probabilities between open (woodland, swamp) and closed (gallery forest) habitat. Densities were subsequently determined for each habitat. We then calculated a global density, weighted by the (manually calculated) proportion of each habitat across the core study area: 97 % for open habitat and 3% for closed habitat (unpublished data).

We then calculated densities for each year in order to assess any trends across time. We stratified by year for calculating densities from 2009 to 2012 when sample size was sufficient. Given the small sample sizes each year for all of the species (range: n=3-93 observations) we determined a global detection function for each of them instead of stratifying the detection function by year, and assumed that the type and distribution of vegetation were consistent from 2009 to 2012.

2.4 Recce walks

To assess spatial and temporal patterns of animal and snare encounter rates outside of transects, we plotted the position of all effort points in addition to all observations of wildlife and snares in ArcGIS 10.1 (Redlands, CA). We imported Google Earth imagery into ArcGIS as base maps and overlayed polygon features accordingly. We subsequently overlaid a 500m x 500m vector grid using ET GeoWizards extension and identified seven categorical variables: year, season, vegetation type, location (i.e. core study area or one of the six patrol locations). Finally, we calculated mammal and snare encounter rates per 500x500 grid cell and then measured the distance from the center of each cell to researcher base station and added this as a continuous variable into the model.

We used Kernel density plots to view the distribution of temporal and spatial variables, e.g. distance from researcher station and conducted linear regressions between the locations of each encounter (snare, mammal) and researcher camp to assess the role of camp proximity to encounter rates. To assess what variables best predicted snare and mammal encounter rates, we built a linear model (LM) that included mammal and snare presence as response variables, and the above-mentioned variables as categorical fixed effects (except distance from camp, which was continuous). Finally, to assess whether finding a snare in one location predicted a snare near-by, we conducted a Moran's I (measure of spatial auto-correlation) test (Moran 1950)

We used a p-value of 0.05 below which we rejected the null hypothesis (H_0) that snares and mammals are evenly distributed across space and time.

2.5 Habitat and mammal characterization

We defined the beginning of the wet season as 15 September, and the dry season as 15 April, based on average annual (2009-2014) onset and end of rains. To investigate whether there was more riverine forest further from the researcher station (which may explain poaching effort), we conducted a vegetation classification of the entire area (combined core and peripheral = 400 km^2), where each of the above-described cells was scored as either 0 (no forest present in the cell) or 1 (forest present). These data were then included into our model as forest presence or absence.

To examine whether (animal) encounter rates differed with animal-size or taxa level, we sub-divided animals into small (<~50kg, e.g. duikers, klipspringer, pig), medium (50-100kg, e.g. bushbuck, hartebeest, leopard, reedbuck, roan antelope) and large (over 200kg, e.g. buffalo, zebra) -sized, and also analyzed primates and chimpanzees separately. Otherwise, if not noted, analyses considered all mammals together.

3 Results

3.1 Line Transects

Despite walking over 2196km along line transects over four years, we found an insufficient number of snares encountered to include in DISTANCE. We were, however, able to analyze transect data for mammal presence.

Results revealed that within the core study area, we observed common duikers (*Sylvicapra grimmia*) the most often, followed by yellow baboons (*Papio cynocephalus*), whilst roan antelope (*Hippotragus equinus)* was the most rare (Table 1). Global densities revealed that when we controlled for habitat availability (97% woodland, 3% gallery forests) baboons actually occurred at the highest density, followed by duikers and red-tail monkeys. Densities were dramatically different across vegetation types for the only two species observed sufficiently in both forests and woodlands. Bushbuck (*Tragelaphus scriptus*) densities were 4.46 individuals/km in forest versus only 0.22 in woodlands, over 20x lower. We found a similar relationship for chimpanzees, where forest densities calculated from sightings and nests differed notably from woodland densities (Table 2).

TABLE 1

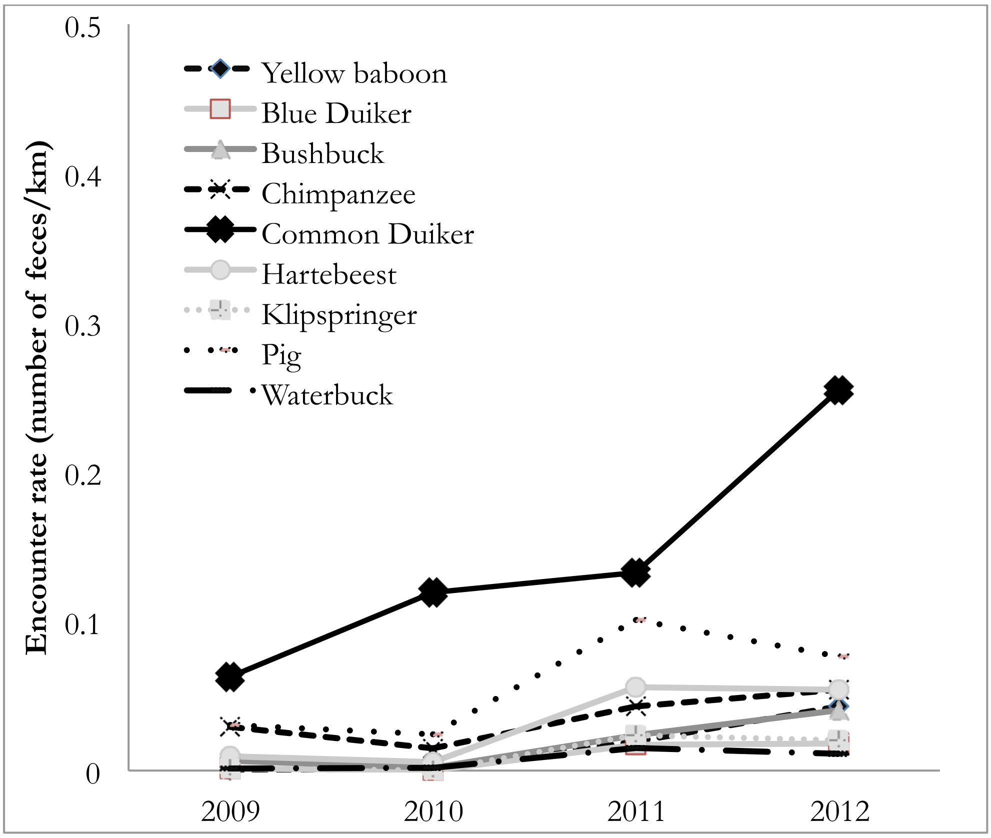
Species (common)	Density (indiv/km^2)	N	95% lower	95% upper
Yellow baboon	4.11	106	1.79	9.42
Common duiker	2.53	330	1.98	3.24
Red-tailed monkey	0.68	19	0.39	0.98
Chimpanzee $_{observation}$	0.67	30	0.20	2.22
Bushbuck	0.35	50	0.17	0.74
Klipspringer	0.33	48	0.19	0.57
Chimpanzee ^{nest}	0.25	1218	0.24	0.25
Roan antelope	0.11	12	0.05	0.16

TABLE 2

Vegetation Type	Species (common)	Density (indiv/km^2)	N	95% lower	95% upper
Gallery forests	Bushbuck	4.46	21	2.34	8.48
	Chimpanzee ^{nest}	2.56	430	2.43	2.67
	Chimpanzee $_{observation}$	6.79	17	2.28	20.17
Woodland	Bushbuck	0.22	29	0.10	0.50
	Chimpanzee ^{nest}	0.18	788	0.17	0.18
	Chimpanzee $_{observation}$	0.48	13	0.14	1.66

We were unable to compare species-specific observations between years due to low sample sizes. However, when we, instead, used dung samples/species recorded from transects to examine whether encounters were rising or declining over time, we found that an inter-annual increase for all species between 2009-2012, most dramatically for common duikers, which rose from 0.06 feces/km in 2009 to 0.26 feces/km in 2012, an increase of almost 450% (Figure 3). Other species exhibited modest and steady increases.

FIGURE 3



3.2 Recce Walks: Mammal and Snare encounters

Mammals

Overall, we encountered mammals more frequently as the distance to the researcher base station decreased, although no relationship was found with the proximity to Mishamo. Most mammal encounters were made in the gallery forests, both closed and open, despite this vegetation type representing only ~ 3% of the study area. The fewest encounters occurred in the swamps. We found that most encounters occurred in the late wet and early dry, and less encounters in the early wet seasons. Finally, most mammal encounters occurred during the later years of the study (Table 3).

Overall, a composite model revealed that seasonality, followed by vegetation type and distance to the base station were the best predictors of mammal encounters.

TABLE 3

Variable	Effect	Standard error	t-value	p-value
Distance to base camp	-0.015	0.001	-7.84	<0.001
Distance to Mishamo	0.006	0.002	2.92	0.269
Season: early dry	-0.135	0.011	-11.42	<0.001
Season: early wet	0.083	0.011	7.17	<0.001
Season: late wet	-0.147	0.012	-12.17	<0.001
Closed gallery forest	0.094	0.011	8.36	<0.001
Open gallery forest	0.078	0.013	6.02	<0.001
Swamp areas	-0.086	0.024	-3.61	<0.001
Year	-0.015	0.006	-2.47	0.013
Area: Lugufu	-0.133	0.042	-3.17	0.001
Area: Mfubasi	-0.274	0.037	-7.36	<0.001
Area: Mlofwesi	-0.270	0.033	-7.97	<0.001
Area: Mttindi	-0.294	0.036	-8.15	<0.001
Area: Sekunde	-0.124	0.030	-4.037	<0.001

When we ranked these by their Akaike Information Criterion (AIC) value, we found that the best predictor of mammal presence was year, then the distance to Mishamo, and then distance to the base camp. We then looked more closely at what types of mammals were encountered closest to the base station and found that encounters of all categories (chimpanzees, primates, small, and medium-sized mammals) exhibited increased encounters as the distance to the base station decreased (Table 4).

TABLE 4

Variable	Effect	Standard error	t-value	p-value
Chimpanzees	-0.398	0.142	-2.80	0.005
Primate	1.180	0.380	3.102	0.471
Small mammals	-0.020	0.028	-0.721	<0.001
Medium mammals	0.001	0.277	0.005	<0.996

Snares

In total, we encountered and destroyed 652 rope and wire snares between 2010-2012. We tested whether snare frequency showed a relationship to distance to the researcher base station, and found that snare encounters were significantly more frequent as the distance to the researcher base camp increased and also as the distance to the refugee settlement, Mishamo, decreased. Vegetation type was also a strong predictor of snare presence, with significantly more snares found in swamp, as well as open and closed gallery forest patches. There were also seasonal effects, with more snares encountered in the early wet season and early dry than in the late wet season, for example (Table 5).

When we compared the effect of these variables and investigated which of them best predicted snare presence, we found that the distance to the researcher base station was the best predictor of snare presence, followed by vegetation type, and then the distance to Mishamo (Table 5). We also found that snares encountered in one 500m x 500m grid cell significantly predicted snare presence in adjacent cells (Moran's I = 0.014, p<0.001)

TABLE 5

Variable	Effect	Standard error	t-value	p-value
Distance to base camp	0.005	0.000	8.70	<0.001
Distance to Mishamo	-0.005	0.000	-7.41	<0.001
Season: early dry	0.008	0.003	2.29	0.022
Season: early wet	0.002	0.003	0.655	0.512
Season: late wet	-0.003	0.003	-0.91	0.361
Closed gallery forest	0.034	0.003	9.45	<0.001
Open gallery forest	0.030	0.004	7.30	<0.001
Swamp areas	0.071	0.007	9.15	<0.001
Year	-0.004	0.001	-2.45	0.014
Area: Lugufu	-0.032	0.013	-2.43	0.015
Area: Mfubasi	0.031	0.012	2.59	0.009
Area: Mlofwesi	0.029	0.010	2.67	0.007
Area: Mttindi	0.049	0.011	4.24	<0.001
Area: Sekunde	-0.014	0.007	-3.78	<0.001

Overall, according to AIC values, we found that the best predictor of snare presence was season, then year, distance to Mishamo, and distance to the base camp. Finally, we found evidence that poachers were targeting areas where we also encountered chimpanzees and other primates (e.g. *Cercopithecus ascanius* - Table 6).

TABLE 6

Variable	**Effect**	**Standard error**	**t-value**	**p-value**
Small mammals	-0.020	0.028	-0.721	0.471
Medium mammals	0.001	0.277	0.005	0.996
Primates	1.180	0.380	3.102	0.002
Chimpanzees	-0.398	0.142	-2.802	0.005

4 Discussion

Our data reveal that whilst large mammal species [e.g. elephant, eland (*Tragelaphus oryx)*, and giraffe (*Giraffa camelopardalis)*] are entirely absent at Issa, numerous other medium to large species remain, and encounters are significantly more common closer to the research base station and farther from Mishamo, a large refugee settlement that was created in 1972. The rarity of the largest mammals at Issa is likely a recent phenomenon. Historically from the 1950s and 1960s (Suzuki 1969; Kano 1971; Nishida 1989) and as recently as 2001 (Hernandez-Aguilar 2006), many of these large species were present at Issa, although probably at low densities. Today, there remain extremely rare encounters with some (elephant, zebra), whilst others are locally extinct (giraffe). Given the recent presence of these species in the area, it is unlikely that any change in physical environment has contributed to their current absence. Rather, illegal hunting, both south of the study area (Waltert et al. 2009; Wilfred 2010; Wilfred & MacColl 2010; Martin & Caro 2012; Martin et al. 2012) and also north (Ogawa et al. 2006b), is likely the primary cause, especially for commercially lucrative species (Wasser et al. 2010).

To examine whether there was a difference between where researchers surveyed most, with those that we rarely visited, we compared the encounter rates of mammals and snares within the core study area, to those in peripheral areas, each of which was patrolled only twice annually. We found that significantly fewer snares were encountered closer to the base station, and consequently, significantly more small and medium mammal, primate, and chimpanzee encounters as well. More specifically, we found significant differences between these peripheral areas, especially in snare encounters. Whilst areas closest to (human) population areas exhibited high snaring (Mfubasi, Mlfowesi, Mttindi), areas further did not (Lugufu). Whilst Lugufu is one of the furthest areas from human settlements, it is one of the most heavily used areas by nomadic cattle-herders, who report removing snares they find to protect their cattle from being victimized (unpublished data).

Given the significant relationship between the distance to the base station and the probability of encountering a snare, we conclude that the most likely reason that we observed so few snares near the station is hunter-avoidance of researcher teams. Illegal hunting in Tanzania is risky, with jail-terms and large fines for those found guilty. Whilst researchers do not have authority to apprehend people, most people recognize that researchers have a legal right to be in the forest, and so avoid confrontations and even encounters whenever possible.

We also sought to explore the relationship between the ecological heterogeneity of the ecosystem and mammal and snare encounters. The study area, and the region as a whole, are characterized by ecological heterogeneity, dominated by vast stretches of miombo woodland that are interspersed with open and closed riverine patches, swamps, and grasslands. We observed most of these nine species in only one of either open or closed vegetation types, although two species (bushbuck and chimpanzee) were observed in both types. Forest densities were factors of two and three times larger for bushbuck and chimpanzees, respectively. This pattern is likely one of the reasons that we also found significantly more snares in forests, compared to the woodlands: Poachers knew where their best chances lay. This relationship was supported by a significant correlation between mammal and snare presence.

Results from transects suggest no clear trend in mammal densities between 2009-2012. Given the long-lived nature of these sized mammals, and their already low-density in this open, dry habitat, four years may not be sufficient to reveal change at the population level. When we looked at dung encounter rates, though, we found that all nine species that we monitored showed annual encounter increases, in some cases very dramatic ones (>450% in common duikers, Figure 3). Duikers have been shown elsewhere to respond well to disturbed areas (Remis & Kpanou 2010) and so this result is unsurprising if human (poacher and researcher alike) presence is considered a disturbance; what is more persuasive, however, of researcher-induced protection, is that species such as bushpigs and hartebeest, otherwise highly preferred by hunters (unpublished data) are also increasing steadily each year, suggesting a possible reduction in hunting for them as well. Only in subsequent years will we able to test whether these are statistically or more important, biologically significant increases. Whilst it is tempting to attribute these patterns to a growth in species-populations, it is also possible that some individuals of each species have merely grown habituated to researcher presence and/or use transect paths for ease of travel.

Alternative explanations for rising encounter rates include an increase in food availability and/or a decrease in predation pressure. Whilst we do not systematically measure food availability for non-primate terrestrial mammals, we can use rainfall as proxy for terrestrial vegetation abundance (Bourgarel et al. 2002). Our highest recorded rainfall to date is from 2009, after which total rainfall declined in 2010 by over 26% and has since remained consistent from 2010-2012 (unpublished data). Predation pressure is similarly difficult to assess. The Ugalla ecosystem has long been known to host many of Tanzania's large predators (Kano 1971; Nishida 1989; Hernandez-Aguilar 2009; Iida et al. 2012), but their abundance across time has not yet been described. Data from 2009-2011 are not available, but from 2011-2013 data from motion–triggered cameras deployed around the core study area at Issa suggest that leopard encounters have increased each year (unpublished data). It does remain possible that a decline in other top predators (e.g. lions, hyenas), however, has contributed to the rising mammal densities described above, although we have no empirical evidence to support that.

4.1 Alternative explanations for decreasing snaring

There are, of course, other possible explanations for why poaching has decreased; the most plausible is an increase in socio-economic standards. It has been established that in western Tanzania, poverty level predicts poaching frequency (Wilfred & MacColl 2010) and thus increasing household income, for example, may also contribute to lower poaching rates. As a country, Tanzania is one of the poorest in the world, although has exhibited high economic growth (>7%) over the last few years (World Bank Country profile, 2014). However, this growth is not universally distributed, and not actually represented in some of the key indicators that predict poaching. For example, between 2009 and 2012, the proportion of people living below the poverty line in Tanzania rose over 19%, from 33.6% to 40.0% (Health and Social Welfare 2013). Additionally, mean household size, which is negatively correlated with income (Lanjouw & Ravallion 1995) is 28.8% larger in Kigoma region, than the nation-wide average (Hess & Leisher 2011). Thus, whilst we cannot rule out rising socio-economic standards as an explanation for decreasing human hunting pressure in the area, it seems unlikely given these recent socio-economic figures.

An additional explanation could be a shift in hunting tactics. Whilst we have no evidence that poachers have turned more to guns than snares, shifting methods away from snares to a different method would also give us similar results. Future analyses that examine overall human activity, including logging, hunting camps, etc. may shed more light on spatiotemporal patterns of broader human activity in these areas, and reveal whether hunting tactics have changed over the years.

4.2 Conclusion

There have been multiple reports recently that describe the positive contribution that researchers play in the conservation of endangered species (Laurance et al. 2012; Laurance 2013), however few have provided empirical data to quantify this relationship. For chimpanzees, analyses from both West (Campbell et al. 2011; Goran et al. 2012) and East (Pusey et al. 2007) Africa have argued that ape study populations and sympatric wildlife benefit greatly from the presence of long-term research stations, directly in the form of deterring illegal poaching and indirectly, via promoting the value of wildlife or else supporting local communities with employment, among others.

Illegal hunting continues to be prevalent throughout Tanzania, and PAs that harbor high concentrations of wildlife attract the practice (Holmern et al. 2006; Knapp 2012). Unregulated and illegal hunting almost always result in decimated wildlife populations (Lindsey et al. 2013). A common strategy for reducing poaching pressure in PAs and NPs specifically is to increase patrol effort, or create buffer zones of varying protective status around NP boundaries, thus requiring less governmental resources while offering diversity in land use and revenue generation for surrounding villages (Brandon & Wells 1992). Where there has been delayed attention to buffering PAs, critical areas for e.g. chimpanzees such as those in the Tai Forest in Ivory Coast and Gombe National Park have become isolated, increasingly threatened from expanding surrounding human populations. In unprotected areas, however, far less is known, not only about species diversity and abundance (Caro 1999; Stoner et al. 2007), but also the nature of threats (but see Western et al. 2009). Our study demonstrates that since the inception of a mid-term research project and thus permanent researcher presence, annual encounter rates have risen with all nine mammalian species examined here.

Inundating PAs and unprotected areas alike with researchers is not the solution, however. Rather, a combination strategy of researcher presence (Campbell et al. 2011), government patrols (Goran et al. 2012), and community conservation (but see Hackel 1999; Adams & Hulme 2001) may the most effective way forward than any strategy is on its own to reducing illegal human activity. This combination is likely to be especially applicable in remote areas that are less frequently visited by tourists and thus more susceptible to illegal human encroachment, and also in places where research teams are ephemeral, and thus gaps between in their presence can be buffered with government patrols and local intiatives.

In a broad review of the relationship between researcher presence and conservation, Laurance (2013) expanded on other benefits, ranging from pioneering researchers who became ‘heroes’ in multiple disciplines (e.g. George Schaffer), or else went on even to lead ministries (e.g. Lee White) in critically important countries for conservation. Researcher presence can also play a significant role in monitoring poaching intensity (Mohd-Azlan & Engkamat 2013) and even directly confronting poachers. Additional researcher-initiated investments into infrastructure and education in villages adjacent to important areas for biodiversity (including environmental education programs or forest monitors training) can also be effective. Moreover, researchers have been instrumental in empowering local communities to defend ancestral land against multi-national companies seeking to extract and exploit resources (Herlihy 2003). Research stations also provide employment for local people who may otherwise resort to poaching for income generation. Finally, researchers and conservationists alike are often influential in overall advocacy for protection but also changes in popular attitudes towards wildlife and wilderness areas (Nash 1989).

In summary, establishing new PAs across Africa, but within Tanzania especially can be politically sensitive and financially prohibitive. As human population expands, pressure on governments to allocate more land for wildlife becomes less tenable. Our data suggest that in addition to providing data for governmental institutions on wildlife behavior and conservation, researchers offer another benefit, that of deterring illegal hunting, especially in areas with minimal protective status and low government surveillance. If, in the long-term, such advocacy leads to a higher protective status for otherwise ‘open land’ then perhaps researchers can be optimistic about the future of wildlife in these areas.

5 Acknowledgements

We are grateful to the Tanzanian Wildlife Research Institute (TAWIRI), the Commission for Science and Technology (COSTECH), and to Mpanda District government for permission to conduct research in Tanzania. Many thanks to Leslie Knapp and the Division of Biological Anthropology for hosting AL during her internship at Cambridge and to the Erasmus Programme for funding this internship to AL. CJ and Moritz Rahlfs led many of the safaris that resulted in data described here, and none of the work could be achieved without the indefatigable efforts of Shedrack and Joffrey Lucas, Busoti and Mlela Juma, Msigwa Rashid, Mashaka Alimas, and Parag Kadam. Funding was provided by the Carnegie Trust for Universities of Scotland, Harold Hyam Wingate Foundation, L.S.B. Leakey Foundation, International Primatological Society, National Science Foundation, the Ruggles-Gates Fund for Biological Anthropology, University of California, San Diego, and the Wenner-Gren Foundation. The Ugalla Primate Project is generously supported by the UCSD/Salk Institute Center for Academic Research and Training in Anthropogeny (CARTA). Many thanks to Tim Caro, Jim Moore for extremely helpful feedback on this topic to and two anonymous reviewers for improvements on an earlier version of this paper.

6 References

Abernethy, K. A., L. Coad, G. Taylor, M. E. Lee, and F. Maisels. 2013. Extent and ecological consequences of hunting in Central African rainforests in the twenty-first century Extent and ecological consequences of hunting in Central African rainforests in the twenty-first century. Philosophical transactions of the Royal Society of London. Series B, Biological sciences **368**:20130494.

Adams, W. M., and D. Hulme. 2001. If community conservation is the answer in Africa , what is the question ? Oryx **35**:193–200.

Anthony, L. L., and D. T. Blumstein. 2000. Integrating behaviour into wildlife conservation: the multiple ways that behaviour can reduce Ne. Biological Conservation **95**:303–315.

Bourgarel, M., H. Fritz, J.-M. Gaillard, M. De Garine-Wichatitsky, and F. Maudet. 2002. Effects of annual rainfall and habitat types on the body mass of impala (Aepyceros melampus) in the Zambezi Valley, Zimbabwe. African Journal of Ecology **40**:186–193.

Brandon, K. E., and M. Wells. 1992. Planning for people and parks: Design dilemas. World Development **20**:557–570.

Campbell, G., H. Kuehl, A. Diarrassouba, P. K. N'Goran, and C. Boesch. 2011. Long-term research sites as refugia for threatened and over-harvested species. Biology letters **7**:723–6.

Caro, T. 1999. Densities of mammals in partially protected areas : the Katavi ecosystem of western Tanzania. Journal of Applied Ecology **36**:205–217.

Caro, T., and P. W. Sherman. 2013. Eighteen reasons animal behaviourists avoid involvement in conservation. Animal Behaviour **85**:305–312. Elsevier Ltd.

Craigie, I. D., J. E. M. Baillie, A. Balmford, C. Carbone, B. Collen, R. E. Green, and J. M. Hutton. 2010. Large mammal population declines in Africa's protected areas. Biological Conservation **143**:2221–2228. Elsevier Ltd.

Cromsigt, J. P. G. M., S. J. Rensburg, R. S. Etienne, and H. Olff. 2008. Monitoring large herbivore diversity at different scales: comparing direct and indirect methods. Biodiversity and Conservation **18**:1219–1231.

Goran, P. K. N., C. Boesch, R. Mundry, E. K. N. Goran, P. K. N'Goran, E. K. N'Goran, I. Herbinger, F. a Yapi, and H. S. Kühl. 2012. Hunting, law enforcement, and African primate conservation. Conservation Biology **26**:565–71.

Hackel, J. D. 1999. Community Conservation and the Future of Africa's Wildlife. Conservation Biology **13**:726–734.

Hansen, A. J., C. R. Davis, N. Piekielek, J. Gross, D. M. Theobald, S. Goetz, F. Melton, and R. DeFries. 2011. Delineating the Ecosystems Containing Protected Areas for Monitoring and Management. BioScience **61**:363–373.

Hansen, A. J., and R. DeFries. 2007. Ecological mechanisms linking protected areas to surrounding lands. Ecological Adaptations **17**:974–988.

Health and Social Welfare, T. M. of. 2013. Human Resource for Health - Country Profile 2012/2013. Page 56.

Herlihy, P. H. 2003. Participatory Research Mapping of Indigenous Lands in Darién, Panama. Human Organization.

Hernandez-Aguilar, R. 2009. Chimpanzee nest distribution and site reuse in a dry habitat: implications for early hominin ranging. Journal of Human Evolution **57**:350–64. Elsevier Ltd.

Hernandez-Aguilar, R. A. 2006. Ecology and Nesting Patterns of Chimpanzees (Pan troglodytes) in Issa, Ugalla, Western Tanzania. University of Southern California.

Hess, S., and C. Leisher. 2011. Baseline study for the Tuungane Health and Conservation Project. Page 80.

Holmern, T., S. Mkama, J. Muya, and E. Røskaft. 2006. Intraspecific prey choice of bushmeat hunters outside the Serengeti National Park, Tanzania: a preliminary analysis. African Zoology **41**:81–87.

Iida, E. G., G. Idani, and H. Ogawa. 2012. Mammalian fauna of the miombo forest in the Ugalla area, western Tanzania. African Study Monographs **33**:253–270.

Kano, T. 1971. The Chimpanzee of Filabanga, Western Tanzania. Primates **12**:229–246.

Kano, T., H. Ogawa, R. Asato, and M. Kanamore. 1999. Distribution and density of wild chimpanzees on the northern bank of the Malagarasi river, Tanzania. Primate Res **15**:153–162.

Knapp, E. J. 2012. Why poaching pays: a summary of risks and benefits illegal hunters face in Western Serengeti, Tanzania. Tropical Conservation Science **5**:434–445.

Lanjouw, P., and M. Ravallion. 1995. Poverty and Household Size. The Econimic Journal **105**:1415–1434.

Laurance, W. F. 2013. Does research help to safeguard protected areas? Trends in Ecology & Evolution **28**:261–6. Elsevier Ltd.

Laurance, W. F., H. Koster, M. Grooten, A. B. Anderson, P. A. Zuidema, S. Zwick, R. J. Zagt, A. J. Lynam, M. Linkie, and N. P. R. Anten. 2012. Making conservation research more relevant for conservation practitioners. Biological Conservation **153**:164–168. Elsevier Ltd.

Lindsey, P. A. et al. 2013. The bushmeat trade in African savannas: Impacts, drivers, and possible solutions. Biological Conservation **160**:80–96. Elsevier Ltd.

Marques, T. A., L. Thomas, J. Ward, N. DiMarzio, and P. L. Tyack. 2009. Estimating cetacean population density using fixed passive acoustic sensors: an example with Blainville's beaked whales. The Journal of the Acoustical Society of America **125**:1982–94.

Marshall, A. R., J. C. Lovett, and P. C. L. White. 2008. Selection of Line-Transect Methods for Estimating the Density of Group-Living Animals : Lessons from the Primates. American Journal of Primatology **11**:1–11.

Martin, A., and T. Caro. 2012. Illegal hunting in the Katavi-Rukwa ecosystem. Journa of African Ecology **51**:172–175.

Martin, A., T. Caro, and M. Borgerhoff. 2012. Bushmeat consumption in western Tanzania : A comparative analysis from the same ecosystem. Tropical Conservation Science **5**:352–364.

Metzger, K. L., A. R. E. Sinclair, R. Hilborn, J. Grant, C. Hopcraft, and S. A. R. Mduma. 2010. Evaluating the protection of wildlife in parks : the case of African buffalo in Serengeti. Biodiversity and Conservation **19**:3431–3444.

Mohd-Azlan, J., and L. Engkamat. 2013. Camera trapping and conservation in Lanjak Entimau Wildlife Sanctuary, Sarawak, Borneo. The Raffles Bulleton of Zoology **61**:397–405.

Moore, D. L., and L. Vigilant. 2013. A population estimate of chimpanzees (Pan troglodytes schweinfurthii) in the Ugalla region using standard and spatially explicit genetic capture-recapture methods. American Journal of Primatology **76**:335–346.

Moore, J. 1994. Plants of the Tongwe East Forest Reserve (Ugalla), Tanzania. Tropics **3**:333–340.

Moran, P. A. P. 1950. Notes on Continuous Stochastic Phenomena. Biometrika **37**:17–23.

Moyer, D. et al. 2006. Surveys of Chimpanzees and other Biodiversity in Western Tanzania. Page 65. Report submitted to USF&W, Great Apes Fund.

Nash, R. F. 1989. The Rights of Natures: A History of Environmental Ethics. University of Wisconsin Press, Madison, WI.

Nishida, T. 1989. A note on the chimpanzee ecology of the Ugalla area, Tanzania. Primates **30**:129–138.

Ogawa, H., J. Moore, and S. Kamenya. 2006a. Chimpanzees in the Ntakata and Kakungu Areas , Tanzania. Primate Conservation **21**:97–101.

Ogawa, H., T. Sakamaki, and G. Idani. 2006b. The Influence of Congolese Refugees on Chimpanzees in the Lilanshimba Area, Tanzania. Pan Africa News **13**:19–21.

Ogawa, H., M. Yoshikawa, and M. Mbalamwezi. 2012. A Chimpanzee bed found at Tubila , 20 km from Lilanshimba habitat. Pan Africa News **18**:5–6.

Piel, A. K., and J. J. Moore. 2010. Monitoring Movements: Tracking Unhabituated Chimpanzees Using Real-Time Acoustic Surveillance. Proceedings of the International Primatological Society. Kyoto.

Piel, A. K., and F. A. Stewart. 2014. Census and conservation status of chimpanzees (Pan troglodytes schweinfurthii) across the Greater Mahale Ecosystem. Page 74. Report submitted to the The Nature Conservancy, USA.

Plumptre, A. J., and V. Reynolds. 1996. Censusing Chimpanzees in the Budongo. International Journal of Primatology **17**:85–99.

Pusey, A. E., L. Pintea, M. L. Wilson, S. Kamenya, and J. Goodall. 2007. The Contribution of Long-Term Research at Gombe National Park to Chimpanzee Conservation. Conservation Biology **21**:623–634.

Remis, M. J., and J. B. Kpanou. 2010. Primate and ungulate abundance in response to multi-use zoning and human extractive activities in a Central African Reserve. African Journal of Ecology **49**:70–80.

Schoeninger, M. J., J. I. M. Moore, and J. M. Sept. 1999. Subsistence Strategies of Two “Savanna” Chimpanzee Populations: The Stable Isotope Evidence. American Journal of Primatology **314**:297–314.

Sinclair, A. R. E., S. A. R. Mduma, J. G. C. Hopcraft, J. M. Fryxell, R. Hilborn, and S. Thirgood. 2007. Long-Term Ecosystem Dynamics in the Serengeti : Lessons for Conservation. Conservation Biology **21**:580–590.

Spehar, S. N., and A. J. Marshall. 2010. Estimating Orangutan Densities Using the Standing Crop and Marked Nest Count Methods: Lessons Learned for Conservation. Biotropica **6**:748–757.

Stewart, F. A., A. K. Piel, and W. C. McGrew. 2011. Living archaeology: artefacts of specific nest site fidelity in wild chimpanzees. Journal of Human Evolution **61**:388–95.

Stoner, C., T. Caro, S. Mduma, C. Mlingwa, G. Sabuni, and M. Borner. 2007. Assessment of effectiveness of protection strategies in Tanzania based on a decade of survey data for large herbivores. Conservation Biology **21**:635–46.

Struhsaker, T., P. Struhsaker, and K. Siex. 2005. Conserving Africa's rain forests: problems in protected areas and possible solutions. Biological Conservation **123**:45–54.

Suzuki, A. 1969. An ecological study of chimpanzees in a savanna woodland. Primates **148**:103–148.

Tagg, N., and J. Willie. 2013. The Influence of Transect Use by Local People and Reuse of Transects for Repeated Surveys on Nesting in Western Lowland Gorillas (Gorilla gorilla gorilla) and Central Chimpanzees (Pan troglodytes troglodytes) in Southeast Cameroon. International Journal of Primatology **34**:554–570.

Thomas, L., S. T. Buckland, K. P. Burnham, D. R. Anderson, L. Jeffrey, D. L. Borchers, S. Strindberg, A. H. El-shaarawi, and W. W. Piegorsch. 2002. Distance sampling **1**:544–552.

Thomas, L., S. T. Buckland, E. a Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. a Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. The Journal of Applied Ecology **47**:5–14.

Waltert, M., B. Meyer, and C. Kiffner. 2009. Habitat availability, hunting or poaching: what affects distribution and density of large mammals in western Tanzanian woodlands? African Journal of Ecology **47**:737–746.

Wasser, S. et al. 2010. Elephants, Ivory, and Trade. Science **327**:1331–1332.

Western, D., S. Russell, and I. Cuthill. 2009. The Status of Wildlife in Protected Areas Compared to Non-Protected Areas of Kenya. PloS One **4**.

Wilfred, P. 2010. Towards sustainable Wildlife Management Areas in Tanzania. Tropical Conservation Science **3**:103–116.

Wilfred, P., and A. D. C. MacColl. 2010. Income sources and their relation to wildlife poaching in Ugalla ecosystem , Western Tanzania. African Journal of Environmental Science and Technology **4**:886–896.

Wrangham, R. W., and E. Ross, editors. 2010. Science and Conservation in African Forests: The Benefits of Longterm Research. Cambridge University Press, Cambridge, UK.

FIGURE LEGENDS

FIGURE 1 – Map of western Tanzania, with the study site (Issa) in the center box, and the other three national parks of western Tanzania (Katavi, Mahale, Gombe) also identified (Source: Lilian Pintea/the Jane Goodall Institute).

FIGURE 2 – Map with the core study area and the peripheral areas.

FIGURE 3 – Transect dung encounter rate of nine different mammalian species over the first four years of the mid-term study.

TABLE 1 – Results from line transects, with global density and number of encounters of each species.

TABLE 2 – Results from line transects of bushbuck and chimpanzee densities in open and closed vegetation types. Chimpanzee densities are shown using both direct encounters ("Chimpanzee $^{\text{observation}}$") and nest counts ("Chimpanzee $^{\text{nest}}$").

TABLE 3 – Linear model results of the potential factors to influence mammal encounter rate.

TABLE 4 – Linear model results revealing that all categories of mammals (small, large, primates, chimpanzees) showed increased encounters closer to the researcher base station.

TABLE 5 – Linear model results of the potential factors to influence snare encounter rate

TABLE 6 – Linear model results examining whether snare presence correlated with other groups of mammals