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Spatial patterns of wire-snare poaching: Implications for community conservation in buffer zones around National Parks

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Wire-snare poaching is fueling the rapidly growing illegal bushmeat trade in Africa's savanna ecosystems given the region's relatively abundant wildlife, increasing commercial bushmeat demand, and burgeoning human populations; thus understanding snaring dynamics is critical to addressing this crisis. Community conservation areas often border National Parks (NPs) and are intended to serve as buffer zones wherein sustainable, wildlife-based economies exist. Yet their success is poorly-evaluated, partly due to poorly-understood poaching patterns and the impact of human development in these zones. We investigated snaring patterns in Zambia's South Luangwa National Park and adjacent community Game Management Areas (GMAs) using highly-trained four-person teams to conduct 116 snare surveys at stratified random locations across approximately 6661 km^2 from September 2011 to November 2012. We postulated that snaring would be predicted by land use, crops, roads, and permanent water. Using novel multi-logistic models, we found decisive evidence that snaring only occurred in GMAs and immediately adjacent NP areas. Within these areas, we found substantial evidence that snaring was constrained by road proximity, moderate evidence for water constraints, and equivocal evidence for crop constraints. Snare detection rates in these areas were 60%. Evaluating finer-scale GMA snaring patterns requires more data; however strong correlation between snaring and human development in protected area buffer zones necessitates increased caution and carefully planned community development initiatives, and the adoption and enforcement of well-zoned land-use plans. Incentives aimed at increasing agricultural development in buffer zones should be redirected away from these zones to reduce encroachment and poaching and protect wildlife-based economies.

1. Introduction

Wire-snare poaching and the associated bushmeat trade is an ever-increasing threat to ecosystems worldwide. While long recognized as one of the most significant conservation threats in central and western Africa (Fa et al., 2003), it is only beginning to gain attention in the more wildlife-rich savanna regions (defined as receiving between 300 and 1500 mm rainfall per year, Riggio et al., 2012) of Eastern and Southern Africa, perhaps because it has been typically regarded as a subsistence activity (Lindsey et al., 2013). While few data exist to quantify the scope and extent of bushmeat trade in the region, there are ample indications that commercial poaching is accelerating, with impacts including severe reductions or extirpations of target species, heavy by-catch of threatened and economically valuable non-target species, and the loss of entire ecological communities (Hofer et al., 1996; Lindsey et al., 2011a,b; Becker et al., 2013a; Lindsey et al., 2013). An urgent, comprehensive, and integrated response to this crisis is therefore needed that addresses a spectrum of biological, anthropogenic, legal and political factors involved in the savanna bushmeat crisis (Lindsey et al., 2013). Understanding the temporal and spatial patterns of poaching is a key component of this response given its critical importance in effectively allotting limited law enforcement resources, estimating trends, and evaluating the success of both anti-poaching and community-conservation efforts.

Protected area complexes are typically characterized by a gradient of land management ranging from strictly protected areas to buffer zones managed for combined community and conservation objectives (Wells and Brandon, 1993). While National Parks (NPs) usually prohibit human settlements or consumptive land use, buffer zones are designed to provide for sustainable wildlife use and income generation by local people, thereby encouraging

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wildlife-based economies and minimizing human edge effects (Woodroffe and Ginsberg, 1998) on the NPs themselves. Such wildlife-based uses typically focus heavily on trophy hunting given that many areas are poorly developed or ill-suited for photographic tourism (Lindsey et al., 2006, 2012). Underpinning the concept of community-based conservation is that increased revenue from wildlife encourages increased stewardship of wildlife; and thus poaching in general, and wire snare poaching in particular, can be considered an indicator of the degree of support for conservation by communities (Lewis and Phiri, 1998), although this must be considered in concert with the value of bushmeat, the historical origins of certain communities as self-managed subsistence hunting units, and individual choices in the context of poverty, community, and national policies (Gibson and Marks, 1995).

Wire-snare poaching is widespread given the easy acquisition of materials, low risk of arrest, and effectiveness of animal capture (Noss, 1998). It is also extremely difficult to evaluate trends in snaring given the difficulties in detection, relatively low densities of snares across landscapes, heterogeneous spatial patterns, and highly skewed statistical distribution of snare detection data (Becker et al., 2013a). Spatial analyses are an under-utilized means of evaluating and predicting poaching yet are heavily employed in other sectors of crime prevention (Haines et al., 2012). Few spatial analyses of snaring have been conducted save for a study by Wato et al. (2006) in and around Tsavo National Park, Kenya, who separately evaluated the effect of land use, habitat, patrol effort and distance to park boundary respectively as variables affecting snaring, and concluded that roads and human settlements were key predictors. Given that snaring likely depends on a variety of overlapping landscape and human development factors, how these influences potentially interact remains a key question, both to further understand the patterns of snaring and to enable mapping of these expected patterns across the landscape for purposes of law enforcement and land use policy (Nyirenda and Chomba, 2012). More comprehensive analyses are required from a range of different PA complexes in order to determine the factors that best determine patterns of wire-snare poaching.

Eastern Zambia's Luangwa valley is the country's most well-established wildlife tourism area, consisting of a network of NPs and Game Management Areas (GMAs) centered on South Luangwa National Park (SLNP). Zambia's NPs are classified as IUCN Category II Protected Areas, for which the primary objective is "to protect natural biodiversity along with its underlying ecological structure and supporting environmental processes, and to promote education and recreation," and its GMAs are classified as IUCN Category VI Protected Areas for which the primary objective is "to protect natural ecosystems and use natural resources sustainably, when conservation and sustainable use can be mutually beneficial" (Dudley, 2008; Chomba et al., 2011). Zambia's GMAs have long been recognized as being intended to function as buffer zones in the sense established by UNESCO's Man and the Biosphere programme (IUCN, 1976, 1992; Wells and Brandon, 1993; Simasiku et al., 2008; ZAWA, 2013). However, similar to many areas in the region, illegal poaching is a significant threat and snaring has long been recognized as a problem (Lewis and Phiri, 1998). Despite substantial investment in alternative livelihood programs and anti-poaching, there is evidence that snaring trends are increasing in the Luangwa, with heavy impacts on threatened species such as elephants and large carnivores key to local tourism economies (Becker et al., 2013a). While law enforcement patrols are regularly conducted, they are generally considered inadequate for the size of the area and the resources available, and patrols rarely provide fine-scale spatial data on poaching. Furthermore, the adaptive nature of law enforcement patrols limits their utility as a consistent source of monitoring data for use in assessing trends and patterns, in contrast to patrols targeted specifically at monitoring using standardized protocols and survey design incorporating randomized site selection. To address these problems we conducted an investigation of spatial snaring patterns in SLNP and adjacent GMAs centered around four main objectives, namely to: (1) identify key areas and predictors of snaring to enable anti-poaching patrols to more effectively allot limited resources; (2) facilitate incorporation of spatial variation into evaluations of snaring trends; (3) inform land use policy and community conservation efforts by providing rigorous evaluations of snaring; and (4) demonstrate new field monitoring, study design, statistical analysis, and spatial mapping techniques that address some of the limitations of previous approaches. Specifically, we postulated that spatial influences on the occurrence of wire-snaring are: (A) proximity to boundaries between NPs and GMAs; (B) proximity to crops, cleared land, or developed land; (C) proximity to roads; and (D) proximity to permanent water.

2. Materials and methods

2.1. Study area

The study area included most of the eastern portion of SLNP and straddled the eastern boundary with the Lupande GMA as well as the Mwanya portion of the Lumimba GMA, collectively covering 6661 km^2 (Fig. 1). The area is a mosaic of edaphic grassland, deciduous riparian forest, mopane (*Colophospermum mopane*) woodland and scrub woodland, miombo woodland, dry deciduous forest, and undifferentiated woodland (Astle, 1988; Astle et al., 1969; White, 1983). The Luangwa River forms the eastern border for most of the park; functioning primarily as a water source for wildlife and fisherman, and a partial barrier to wildlife movement, but not as a long-distance bushmeat transport corridor due to shallow depths and substantial numbers of hippopotamus and crocodiles.

2.2. Covariate data collection

Based on literature review and our knowledge of the Luangwa system from prior and ongoing work, we developed a set of four spatial covariates to evaluate as potential predictors of the occurrence of wire-snaring (Fig. 1). They included distance (km) to the nearest road (X_R), distance to the nearest cultivated or otherwise-settled area ("crops", X_C), distance to the nearest permanent water (X_W), and distance to the boundary between NPs and GMAs (X_B). Predictors X_R and X_C were included to represent roads and crops as two different forms of human influence. Predictor X_W was included to represent the influence of water either directly on wildlife distribution, or more indirectly through the presence of fishing camps and therefore human activity. Predictor X_B was included to represent the level of land protection; areas inside NPs were assigned a positive distance to the boundary, and areas inside the GMAs were assigned a negative distance, such that the distance value represented positions along what we postulated would be a continuum from more protected areas (positive values) to less protected areas (negative values).

Roads were mapped both in the field using Global Position System devices, and through manual image interpretation using Google Earth (GE) software displaying both aerial and 2.5 m SPOTMaps satellite imagery acquired in approximately 2008. Crops and other forms of development were mapped by manual image interpretation using a combination of GE imagery acquired near 2008 and true-color Landsat 5 Thematic Mapper (TM) imagery acquired in 2009 and 2010. Permanent water was mapped using supervised classification of Landsat 5 TM imagery, based on a training data set of probable permanent water bodies created through manual image interpretation of Landsat 5 imagery displayed using a Band