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# Size, shape and maintenance matter: A critical appraisal of a global carnivore conflict mitigation strategy – Livestock protection kraals in northern Botswana

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ABSTRACT

Fortified kraals are predator-proof enclosures designed to protect livestock at night. Globally, they show great promise in reducing depredation by carnivores, thus promoting co-existence with people. Their efficacy depends on effectiveness, durability, regular use, owner satisfaction, cost-efficiency, and design. We monitored 32 fortified kraals for 18 months in a high conflict area in northern Botswana ($n$ = 427 kraal months) where lions (*Panthera leo*) frequently kill cattle. Monthly kraal use was 60% and was significantly influenced by kraal type, age, and shape. When used and maintained, kraals stopped livestock depredation. Due to poor maintenance, however, kraal age had a significant, negative influence on kraal use and effectiveness, compromising sustainability and cost-effectiveness. Fortified kraals built by a non-governmental organisation cost US$1322.36 per unit ($n$ = 20) and mitigated a mean annual loss of $187.32. This suggests cost-recuperation after 7.0 years, or 2.3 times longer than observed kraal lifetime. Conversely, owner-built replicates cost $579.90 per unit ($n$ = 4), recuperating investment after 3.1 years. Owner satisfaction was significantly higher for fortified kraals when compared with traditional kraals. However, owners of fortified kraals did not kraal their cattle more frequently than owners of traditional kraals. Regionally, the mean annual kraaling rate for 29 GPS-monitored cattle herds ($n$ = 3360 nights) was 40%, leaving cattle vulnerable to depredation, and highlighting the importance of promoting vigilant herding together with kraaling to prevent losses. This combination could reduce regional livestock losses by 80%, or > $38,000 annually, however, kraal fortification alone does not provide a blanket solution to carnivore conflicts in Africa's agro-pastoral landscapes.

## 1. Introduction

Human-carnivore conflict is a global conservation issue (Inskip and Zimmermann, 2009) with important implications for the persistence of carnivores on nearly all continents (Ripple et al., 2014). In human-dominated landscapes, conflict manifests via livestock depredation (Graham et al., 2005; Baker et al., 2008) or compromised human safety (e.g. Packer et al., 2005). Linnell et al. (2012) identified 24 mammalian carnivores that regularly predate on livestock.

Whilst loss from depredation is usually low in relation to livestock numbers (Graham et al., 2005; Baker et al., 2008), it varies locally and can become economically significant in subsistence communities (Li et al., 2013; Aryal et al., 2014). The attitudes of commercial and communal land users are particularly negative towards carnivores when compared with other damage-causing wildlife like elephants, primates and ungulates (Kansky et al., 2014), even though higher losses may be incurred from disease, drought or theft (Holmern et al., 2006; Tumenta et al., 2013). Intolerance of perceived and actual threats frequently triggers retaliatory or prophylactic persecution of carnivores, contributing to their local, regional and global demise (Woodroffe, 2000; Woodroffe and Frank, 2006; Ripple et al., 2014).

Around the world, conservation stakeholders test preventative,

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reactive and *laissez-faire* conflict mitigation approaches (see Shivik, 2004; Bangs et al., 2006; Linnell et al., 2012 for reviews of available tools). Conflict prevention can be more cost-effective than lethal carnivore control (McManus et al., 2014). One globally used strategy is the night-time confinement of livestock in fortified, predator-proof enclosures (Mazzolli et al., 2002; Bauer et al., 2010; Lance et al., 2010; Reinhardt et al., 2012; Sapkota et al., 2014; Lichtenfeld et al., 2015) called either “corrals”, “pens”, “paddocks”, “bomas”, “stockades”, or “kraals”. For clarity, we will use the term kraal. Whilst traditional kraals in rural landscapes often merely contain livestock, fortification is necessary where livestock still coexist with free-ranging carnivores. Fortification can be as simple as building strong stone or thorn bush walls from locally available materials (Jackson et al., 2002; Mkonyi et al., 2017). Solutions that are more sophisticated entail portable electrified modules (Reinhardt et al., 2012) or fixed wire mesh constructions (Sutton et al., 2017). Kraaling is a culturally accepted method of livestock confinement and fortification addresses the cause of human-carnivore conflict by safeguarding domestic animals at night. Fortified kraals can be highly successful, reducing the time spent supervising livestock and decreasing nocturnal livestock losses in Africa's communal areas by > 90% (Lichtenfeld et al., 2015; Manoa and Mwaura, 2016), sometimes halting predation altogether (Frank, 2011).

Conservationists agree on the challenges of coexistence with carnivores (e.g. effective conflict mitigation), yet there is less consensus on how to facilitate and promote it (Lute et al., 2018). This may be due to a lack of rigorous monitoring of intervention outcomes (Van Eeden et al., 2017). Despite its popularity and widespread use, empirical studies assessing the effectiveness of kraals remain scarce (Okello et al., 2014; Lichtenfeld et al., 2015; Manoa and Mwaura, 2016; Sutton et al., 2017). This hampers comparisons with other conservation interventions (Eklund et al., 2017) and progression towards evidence-based conservation solutions (Van Eeden et al., 2017). Moreover, economic considerations are important in conservation management because optimal use of limited financial resources is paramount (Carwadine et al., 2008; Wilson et al., 2011). Decision-makers depend on accurate costing of conservation activities to assess cost-efficiency (Ferraro and Pattanayak, 2006) as this can determine the most feasible approaches to carnivore conservation (Rondinini and Boitani, 2007; McManus et al., 2014).

Based on our kraal building efforts (20 fortified structures) and 18 months of monitoring of 32 fortified kraals, we provide a comprehensive evaluation of kraal efficacy in a high conflict zone in the Kavango Zambezi Transfrontier Conservation Area (KAZA TFCA), the world's largest trans-frontier conservation initiative that aims to synthesise rural development with sustainable biodiversity conservation. In northern Botswana, lions (*Panthera leo*) inflict high annual livestock losses of between US dollars (hereafter $) $15,700 (2014) and $64,030 (2017) (Department of Wildlife and National Parks, Seronga office). We provide a detailed costing of fortified kraals in this area and determined their effectiveness by comparing livestock losses pre and post kraal fortification, and between fortified kraals and randomised control groups of non-fortified traditional structures. We investigated kraaling rates and drivers of kraal use from 427 direct investigations of fortified kraals and 1 year of livestock GPS-tracking. We determined the variables that influenced kraal use and evaluated kraal maintenance and utility, incorporating owner feedback. Finally, we measured financial and labour investment for this conservation strategy and review its efficacy in light of observed conflict.

## 2. Methods and materials

### 2.1. Study area

Our study focussed on communities living at the boundary of NG/11 and NG/12 multi-use areas located along the northern edge of Botswana's Okavango Delta (Fig. 1) in the KAZA TFCA. The study area partially overlaps with UNESCO's World Heritage Site (no. 1000), provides globally important wetland habitat (Ramsar site no. 879), and supports one of the few remaining strongholds of free-ranging lions (Riggio et al., 2013).

The area receives between 500 mm and 750 mm rainfall annually (Meteorological Services Botswana, 2003; Mendelsohn and el Obeid, 2004). The major dry land habitats in NG/11 are open to dense *Baikiaea-Burkea* woodlands, and mixed mopane (*Colophospermum mopane*) and *Burkea-Terminalia* woodlands on Kalahari sandveld. NG/12 is characterized by seasonally flooded grasslands and reed beds interspersed with riparian forest on islands (Mendelsohn and el Obeid, 2004; Pröpper et al., 2015; Sianga and Fynn, 2017). Floodplains are saturated from February through September, although annual variations occur.

The study area comprised five main villages and 44 remote cattle post settlements with approximately 5000 resident inhabitants. The main subsistence activities entail household-specific combinations of agro-pastoralism with small business, and most families subsist on < $500 monthly income. Non-consumptive wildlife tourism in the NG/12 floodplains offers seasonal and permanent employment opportunities.

### 2.2. Livestock management

Livestock is an important socio-cultural commodity and cattle numbers throughout the entire study area increased by 76% from about 6300 in 2006 to approximately 11,100 in 2017 (Department of Veterinary Services, Seronga office). At least 17 new cattle posts were established since 2006 and median herd size was 36 cattle (range: 2–232, $n$ = 181) in 2016/2017. Due to veterinary restrictions and the area's remoteness, owners only have irregular market access and sales opportunities. Cattle are mainly managed by their owners and younger family members but are rarely guarded during the day (9.9%, $n$ = 181). Few owners (4.4%) employ herders responsible for day-time shepherding and night-time kraaling. Others opportunistically confine cattle that are habituated to return to non-fortified traditional kraals (Fig. 2d). Cattle management is haphazard; 59.1% of owners ($n$ = 107) find and inspect their cattle < 3 times per week as herds range freely in unrestricted communal pastures in a Foot-and-Mouth-Disease endemic area (Fig. 1; Suppl. Fig. 1). Human presence near kraals during night hours varies strongly but generally decreases with kraal distance from permanent settlements. There are no artificial livestock water points; cattle depend on seasonally variable surface water for drinking. Herds primarily graze in dry land grass habitats in NG/11 during the wet season (Suppl. Fig. 1a) when seasonal pans provide drinking opportunities. Cattle range significantly farther during the dry season (Appendix 1), grazing in NG/12 wetland habitats (Suppl. Fig. 1b) when seasonal pans in NG/11 dry up and flood waters in NG/12 recede.

Livestock coexist with indigenous ungulates and five resident species of large carnivores, including lion, spotted hyaena (*Crocuta crocuta*), leopard (*Panthera pardus*), African wild dog (*Lycaon pictus*), and cheetah (*Acinonyx jubatus*). Botswana's government compensates predator-induced livestock losses using average market rates for different livestock categories (DWNP, 2013). Owners receive 100% compensation for losses to lions, whereas losses to leopard, African wild dog, and cheetah are compensated at 35% of value. No compensation is granted for losses to spotted hyaena.

### 2.3. Kraal construction

Following rampant conflict and lion poisoning in the area during 2010–2013, we built 20 fortified kraals in two phases between June 2015 and September 2017. We monitored these alongside 12 fortified structures previously built by other conflict mitigation initiatives until November 2017 (Appendix 2).

In phase 1 (until February 2016), we constructed eight wooden structures according to the fixed square design of the Africa Centre for