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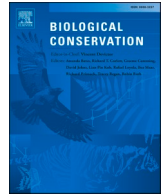
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Using the centre-periphery framework to explore human-carnivore relations

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ABSTRACT

Living alongside carnivores can incur both costs and benefits on people's lifeways. While positive outcomes of carnivore presence can foster coexistence, negative relations with carnivores can trigger carnivores' killing and undermine their conservation. In response to this, conservation efforts increasingly focus on promoting positive human-carnivore relations, most often through improvements in the flow of economic benefits from carnivores to local communities. However, there is a question mark over the effectiveness and potential consequences of market-based instruments for carnivore conservation. To understand the opportunities and pitfalls of market-based instruments for carnivore conservation, we use a centre-periphery framework to compare human-carnivore relations in two pastoral systems with uneven market-based conservation efforts across Kenya. We conducted 230 semi-structured interviews on costs and benefits, mitigation strategies and self-reported propensity to kill carnivores. Our study shows how different human-carnivore relations are enacted in areas with uneven market-based conservation efforts. We found that the extent to which benefits are attributed to alive carnivores is largely shaped by the existence of market-based conservation efforts in the area. Our results also document an openly self-reported propensity to kill carnivores in places where market-based conservation efforts are meagre at best. A more robust understanding of the effectiveness of market-based instruments for carnivore conservation is essential to sustain positive human-carnivore relations into the future.

1. Introduction

Fostering coexistence between people and carnivores is one of the most complex and central concerns for carnivore conservation in the 21st century (Ripple et al., 2014). Carnivores can impact people's livelihoods and personal safety (Broekhuis et al., 2020), which can trigger the killing of carnivores (Hazzah et al., 2009; Marchini and Macdonald,

2012) and undermine their conservation (Ripple et al., 2014). Furthermore, there is potential for an increase in negative human-carnivore relations that cause costs for people and/or carnivores (Buijs and Jacobs, 2021), as human populations expand further into previously uninhabited areas, and as some species recolonise areas of their historical range (Chapron et al., 2014).

Carnivore conservation efforts have increasingly focused on

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minimising the costs associated with living alongside carnivores by providing benefits that encourage tolerance and coexistence¹ (Broekhuysen et al., 2020). Additionally, conservation efforts could foster positive human-carnivore relations that do not present substantial problems to either people or carnivores and bring benefits to both of them (Buijs and Jacobs, 2021). Conservation efforts are largely associated with market-based instruments that support such tolerance and coexistence (Dickman et al., 2011). For instance, compensation schemes and insurance programmes that could offset the negative economic impacts of livestock losses to carnivores (Chen et al., 2013; Karanth et al., 2018) or economic activities such as wildlife tourism and recreational hunting that could eventually benefit local communities through conservation-related income (Homewood et al., 2012; Di Minin et al., 2021). The general idea behind these market-based conservation efforts is to minimise the economic shocks of losing livestock to carnivores by “making carnivores pay” (Dickman et al., 2011).

However, despite market-based conservation efforts possibly fostering positive human-carnivore relations, the scholarly literature on carnivore conservation has predominantly been biased towards negative human-carnivore relations (e.g., Bombieri et al., 2023), which is likely to overlook positive human-carnivore relations (Buijs and Jacobs, 2021). Moreover, many conservation scholars and practitioners have raised concerns about the overall effectiveness of market-based instruments for carnivore conservation (Lindsey et al., 2007; Ravenelle and Nyhus, 2017). First, conservation market-based instruments are often associated with the commodification of carnivores by mainly attributing (if not only) economic benefits to it (Vannelli et al., 2019), and overriding other ways in which carnivores contribute to human and non-human well-being (O’Bryan et al., 2018). Second, several studies have shown that economic incentives can impinge on intrinsic motivations towards conservation (Kerr et al., 2012; Rode et al., 2015), changing over time a moral or social motivation to conserve into an economic trade-off (Anyango-Van Zwieten et al., 2015; Fernández-Llamazares et al., 2020), and overlooking the complex historical, cultural, and political contexts in which human-carnivore relations are forged and negotiated (Goldman, 2011; Homewood et al., 2012). Third, critics also question the long-term market-based sustainability of these programmes (Dickman et al., 2011), and the possibility of local communities threatening to kill carnivores if economic funds dry up (Anyango-Van Zwieten et al., 2015). Finally, such economic benefits are often inequitably shared across communities (Dickman et al., 2011), unavailable to those who bear most of the costs (Lindsey et al., 2007) and unevenly distributed (Waldron et al., 2017), thereby contributing to exacerbate structural inequities in benefits distribution (Sène-Harper and Séye, 2019).

Despite growing interest in understanding the effectiveness of market-based instruments for carnivore conservation (or lack thereof), little is known about how varying levels of conservation attention shape distinct human-carnivore relations. While most studies focus on the specific place-based settings in which human-carnivore relations are enacted on a daily basis, few have attempted to situate such relations within a broader social-ecological context (Massé, 2016; Fletcher and Toncheva, 2021). In this study, we explore the social-ecological factors that drive distinct human-carnivore relations in two different settings of Kenya with different levels of conservation attention. We explore this imbalance through the use of the centre-periphery framework. This theoretical framework has been extensively applied in different

scholarly fields to examine inequalities and asymmetries of a specific factor between a ‘centre’ and a ‘periphery’ (Friedman, 1966; Lind, 2018; Klimczuk and Klimczuk-Kochańska, 2019). While centrality in a network is often associated with increasing influence, power and dominance, a position in the periphery usually relates to fewer opportunities for development, and/or marginalisation (Díaz-Reviriego et al., 2017; Rozyłowicz et al., 2017). The centre-periphery framework can shed light on how market-based instruments for carnivore conservation are inherently woven into the production of new geographies of human-wildlife relations and offers a complementary angle to explore spatial distributions of peoples’ willingness to coexist with wildlife (Vogel et al., 2023).

Here we use a categorical centre-periphery framework to explore how the positioning of two distinct pastoral systems with uneven levels of conservation attention influences the human-carnivore relations; one of them being at the centre of conservation efforts where market-based instruments are abundant, and the other at the periphery of conservation efforts where market-based instruments are largely absent. To do so, we explore three distinct indicators of local human-carnivore relations for each study site: (1) costs and benefits of living alongside carnivores in current and past times; (2) mitigation strategies suggested by respondents (hereafter, suggested mitigation strategies); and (3) self-reported propensity to kill carnivores. We then contrast the local human-carnivore relations of both sites and assess temporal changes in reported benefits. As the underlying factors associated with human-carnivore relations are complex and multi-faceted (Hazzah et al., 2009), we also evaluate different socio-economic factors that contribute to shaping human-carnivore relations in both sites.

2. Methods

2.1. Study sites

We conducted the study in Laikipia and Ileret, Kenya. We selected these two study sites for three main reasons: (1) the presence of pastoralist communities living at the edge of wildlife conservation areas; (2) the historical presence of the same carnivore assemblage (Kruuk, 1980; Frank et al., 2005); and (3) these sites have contrasting conservation efforts where we classified Laikipia as the “centre” and Ileret as the “periphery” in the centre-periphery framework of conservation efforts (see Supplementary Material 1 for more details on the study sites).

2.1.1. Centre: Laikipia

In Laikipia County in central Kenya (Fig. 1A), we collected data in two communal group ranches, Koija and Il Motiok (hereafter, Koija-Il motiok). Both group ranches are communally owned by Maasai pastoralist communities, and share similar sociocultural, economic, and ecological characteristics. The communities are bounded on the west by two conservancies (Loisaba Conservancy and Mpala Research Centre), private wildlife conservation areas set up on private land by a private individual or institution for the purpose of wildlife conservation, which for Koija-Il motiok residents inevitably entails living adjacent to carnivores (King et al., 2018).

According to the Laikipia Wildlife Forum survey in 2003, 60,605 tourists visited Laikipia in 2002, providing direct employment to 1054 people. In total, around 5100 people are directly or indirectly dependent on tourism jobs in the region (Ramser and Wiesmann, 2007). Laikipia also has an outstanding international conservation reputation as a result of several decades of conservation efforts (e.g., conservation projects on endangered species such as African wild dogs, leopards and lions; Samburu-Laikipia Wild Dog Project, Uhifadhi Wa Chui, Lion Landscapes), with numerous public and private conservation organisations (e.g., Laikipia Wildlife Forum, Mpala Research Centre, Loisaba Conservancy) operating in the area. Most conservation efforts share a synchronic focus on promoting positive human-carnivore relations by helping adjacent local communities to improve livestock protection,

¹ It is important to note that both terms coexistence and tolerance frequently appear in the literature describing human-wildlife relations, but their connotation can differ among conservationists. We follow earlier definitions of tolerance as ‘the acceptance of the perceived costs and benefits of living alongside local populations of wildlife’ and coexistence as ‘a dynamic but sustainable state in which humans and large carnivores co-adapt to living in shared landscapes’ (Carter and Linnell, 2016; Boronyak et al., 2020).

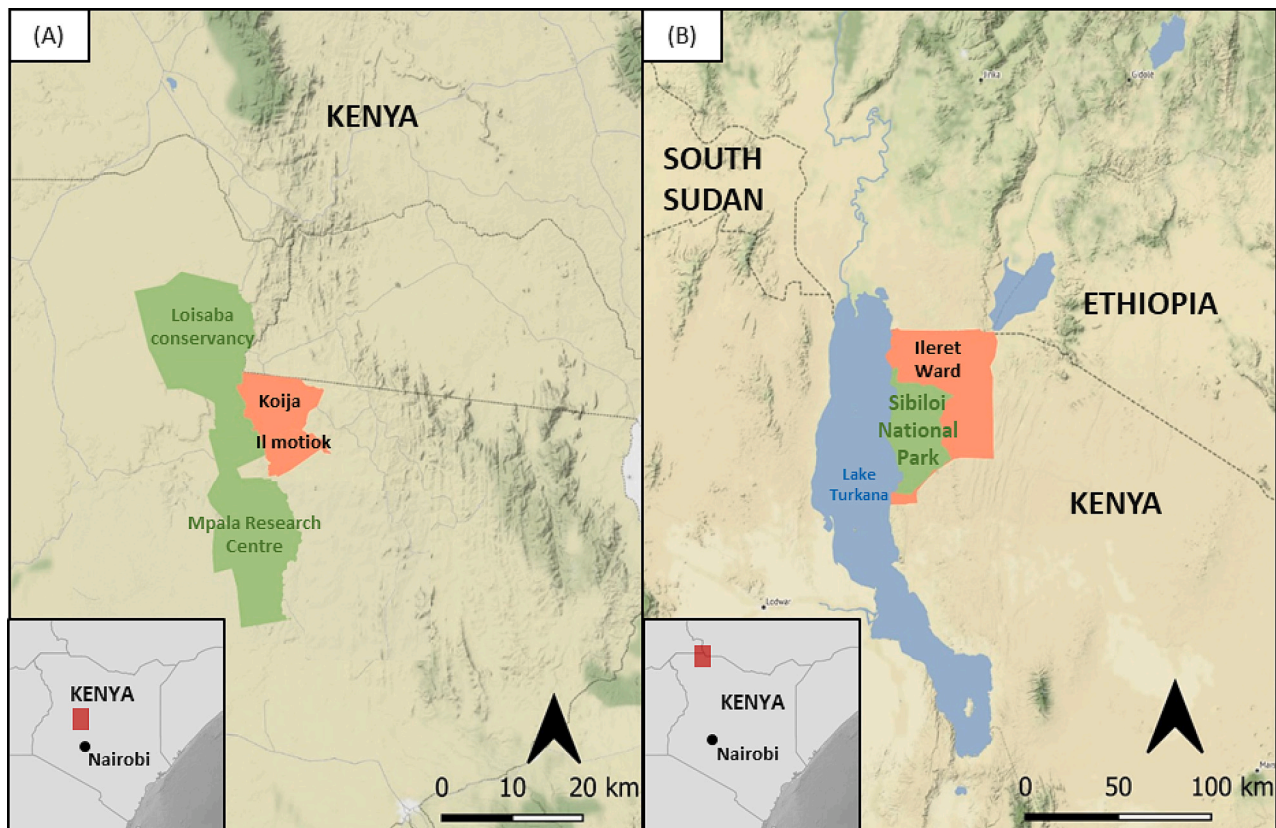


Fig. 1. Map of the two study sites: (A) Centre: Koiya-Il motiok adjacent to Loisaba Conservancy and Mpala Research Centre in Laikipia County (central Kenya); (B) Periphery: Ileret Ward bordering Sibiloi National Park in Marsabit County (north Kenya).

providing food and water, infrastructure and machinery, supporting formal education and healthcare, creating employment, and offering permission for grazing on private lands for community livestock (Lamers et al., 2014). For instance, Mpala Research Centre is seen to be the social services lifeline for several critical needs of these communities (DePuy, 2011), such as providing free canine rabies vaccination (Mpala Research Centre, 2021). In 2020, Loisaba Conservancy helped construct a girls' dormitory and currently supports four girls at the college. In addition, Loisaba Conservancy' health outreach clinics offered consultations and treatment to 2030 patients. In 2021, 500 households benefited from the drought relief grazing programme of Loisaba Conservancy (Loisaba Conservancy, 2021). Finally, 40 out of an estimated 170 employees of Loisaba Conservancy are from Koiya (Nthiga et al., 2015).

2.1.2. Periphery: Ileret

Ileret Ward in northern Kenya encompasses Sibiloi National Park (hereafter, Sibiloi, Fig. 1B). Sibiloi is co-managed by the Kenya Wildlife Service (KWS) and the National Museums of Kenya (NMK) and is situated within the traditional territory of the Daasanach pastoralist community that lives around the park neighbouring carnivores (Torrents-Ticó et al., 2021).

Ileret has been considered the epitome of an extreme periphery with low access to the power grid, lack of public infrastructures, low literacy levels and limited telecommunication networks (IUCN, 2020). Sibiloi has been reported as one of Kenya's most deficit parks, significantly under-resourced, understaffed and where conservation initiatives are meagre at best (IUCN, 2020; UNESCO, 2020). Sibiloi had a mean number of 663 tourists for about six consecutive years (since 2006; KWS (Kenya Wildlife Service), 2011). Thus, the limited funding for management is obtained from tourism revenues from other sites in Kenya (IUCN, 2020). Although local wildlife declines have long been reported in the area, the scale of its defaunation is still unknown. This lack of

conservation attention has led to Sibiloi being inscribed in the UNESCO List of World Heritage in Danger (UNESCO, 2018). Since the park's creation in 1973, Sibiloi's adjacent communities have borne many of the costs associated with the area's wildlife. In addition, the scant economic benefits resulting from the park (e.g., through tourism revenue), have mainly benefited KWS and NMK or non-local tourism businesses (NMK (National Museums of Kenya) and KWS (Kenya Wildlife Service), 2019). Thus, local people in the vicinity of Sibiloi report being alienated from the park and seeing little benefit from it, lacking access to significant revenue linked to conservation and perceiving only peripheral participation in a few research projects (IUCN, 2020). Overall, the situation is so critical, and data are so deficient that information on the scarce conservation efforts on the site is almost impossible to obtain. The Sibiloi Management Plan 2018–2028 is the main conservation initiative in the area, but its implementation is proving challenging due to limited resources (UNESCO, 2020).

2.2. Data collection

We pilot-tested the semi-structured interviews for two months at both study sites (centre: $n = 19$, periphery: $n = 18$) and made some adjustments to ensure consistency in the terminology and sampling strategy across sites. During the pilot-testing phase, we carried out simple random household sampling at the village level throughout the day. However, as we worked with semi-nomadic pastoralist communities, we realised that our sampling strategy was affected by a strong selectivity bias, given that during the day, herders searching for pastures (i.e., those individuals with the closest interactions with carnivores) were often absent. Moreover, we became aware of the difficulties in carrying out interviews during the busy morning activities, and evening milking responsibilities, when most people reported being unavailable for interviews. Based on the pilot testing, we shifted towards

opportunistic sampling within and beyond the villages. This allowed us to ensure the participation of local people herding their livestock in the pasture areas (i.e., a time when they are usually available for interviews) and those staying in their households (Newing et al., 2011). Although our sampling strategy corresponds to non-probability sampling, it allows us to represent local communities' daily realities more.

A non-Indigenous researcher (MT-T) conducted face-to-face semi-structured interviews with a Maasai co-researcher (EM) between October–November 2019 in Koiya-Il motiok, and with a Daasanach co-researcher (TTK) between March–April 2021 in Ileret. We acknowledge that interviews in Ileret were carried out during the ongoing COVID-19 pandemic. However, Ileret has extremely challenging communication networks and limited contact with other segments of Kenyan society, and Sibiloi has historically been one of Kenya's least popular tourist destinations (KWS, 2011; IUCN, 2020; UNESCO, 2020). Therefore, we are confident the pandemic's effects did not significantly influence the daily lives of the Daasanach community, neither their relations with carnivores nor their answers.

We interviewed only Maasai and Daasanach pastoralists living within the study sites. EM and TTK asked the questions in Maa and Daasanach languages respectively, translated them to English and MT-T wrote the answers onto a hardcopy of the interview. EM and TTK had received formal training in interviewing techniques and had previous experience conducting surveys (e.g., as part of the Kenyan national population census). Interviews focused on the historical carnivore assemblage (African wild dog *Lycaon pictus*, black-backed jackal *Canis mesomelas*, caracal *Caracal caracal*, cheetah *Acinonyx jubatus*, leopard *Panthera pardus*, lion *Panthera leo*, spotted hyena *Crocuta crocuta* and striped hyena *Hyaena hyaena*), included both closed-ended and open-ended questions (see Supplementary Material 2 for a sample), taking around 30 min to complete. We explained the purpose of the study and informed every respondent that we were independent of the government and that no compensation would be provided for livestock depredation to avoid misconceptions and minimise incentives for exaggerating answers. Respondents were free to indicate that they “did not know”, “did not remember” or “did not want to answer” to any question, and that they could withdraw from the interview at any time. We took detailed field notes during the interviews, recording *verbatim* perspectives and observations made by respondents. We relied on community members' quotes to add ethnographic depth to the study, and to discuss how the Maasai and Daasanach communities think and feel about carnivores, gaining deeper insight into the affective dimensions of their relations with carnivores.

2.3. Ethics

This study was authorised by Kenya Wildlife Service (KWS/BRM/5001) and the National Commission for Science, Technology and Innovation (NACOSTI/P/19/194 and NACOSTI/P/20/6994); and by the Chief and Chairman of Koiya-Il motiok, the Administrator of the Ileret Ward and the Chief of Ileret. The research design of this study is in full accordance with the guidelines of the Ethical Review Board in the Humanities and Social and Behavioural Sciences of the University of Helsinki and adheres to the Code of Ethics of the Society for Conservation Biology. We obtained verbal Free, Prior, and Informed Consent (FPIC) from each community member involved in the study (see Supplementary Materials 3). We guaranteed anonymity, confidentiality and data protection through all the phases of this project. All Maasai and Daasanach engaged in the project agreed to be part of the study under these conditions.

This study was conducted as part of a long-term participatory research project, over which we developed strong bonds of trust and reciprocity with both communities, exemplified by cooperating to document traditional wildlife stories producing a book of traditional folktales that is being used as a school material (Daasanach Community, 2019). Moreover, since 2016 and 2017, MT-T has been living and closely

interacting with Maasai and Daasanach communities for twelve months across both sites, participating in community life and attending community events. EM and TTK participated in data collection and, to the best of their ability, tried to ensure that the interpretation is correct, and reflects the perspectives shared by study participants as accurately as possible. Yet, we acknowledge that most of the authors are non-Indigenous scholars trained in conservation research, and thus, we are aware that the way data were gathered, interpreted and portrayed is primarily through a conservation lens.

2.4. Human-carnivore relations indicators

2.4.1. Costs and benefits

For the purpose of this paper, we measured economic costs by reported livestock losses to carnivores because livestock are not only a major source of income, but also include cultural relevance, which makes livestock depredation very difficult to accept (Torrents-Ticó et al., 2021). Yet, we acknowledge that our approach does not cover all the costs of living alongside carnivores, such as the indirect costs incurred by guarding livestock from predation (Dickman et al., 2011), among many others (see Braczkowski et al., 2023). First, we asked for the main cause of livestock losses (e.g., carnivores, diseases, droughts). Then, we asked respondents how much livestock they had lost to carnivores in the three months prior to the interview (i.e., livestock depredation).

To assess benefits, we asked respondents whether they thought there were any benefits, good or positive values associated with living alongside carnivores and, if so, what these were. To assess temporal changes in reported benefits, we asked respondents about these benefits in the current and past times (i.e., during the times of the grandparents' respondents). Although respondents could associate specific benefits with particular species of the carnivore assemblage, for this study, we grouped the answers into three categories: no (i.e., no benefits associated with any carnivore), unknown (i.e., did not know benefits for any carnivore), and yes (i.e., benefits associated with at least one carnivore species). From the affirmative answers, we categorised those benefits into four categories: aesthetic benefits (e.g., beautiful, nice to see), cultural benefits (e.g., used of wildlife-based products for cultural practices), ecological benefits (e.g., scavenger behaviour), and economic benefits (e.g., income, employment, paying education fees, development inputs such as roads, schools or clinics). We also classified affirmative answers into those benefits that were attributed to alive carnivores (i.e., non-consumptive benefits that are only accrued when the carnivore is alive), and to dead carnivores (i.e., consumptive benefits that are only accrued when the carnivore is dead).

2.4.2. Suggested mitigation strategies

As a proxy for mitigation strategies, we asked, ‘How would you mitigate livestock depredation?’ We coded the answers into five categories: capture and relocate, fence wildlife conservation areas, improve guarding of livestock (e.g., use of wire fences), kill carnivores and none (i.e., no strategies were suggested).

2.4.3. Self-reported propensity to kill carnivores

We specifically paid attention to avoiding bias by not asking directional questions about killing behaviours (Nuno and St. John, 2015). Thus, we asked two questions to identify possible self-reported preventive and retaliatory killing. (a) ‘How do you protect your livestock from carnivores?’ We used this question as an indicator of preventive killing. We grouped the answers to this question into seven categories: deterrents (e.g., torches, scarecrows, lighting fires), guardian dogs, human daytime shepherding, kill carnivores, night guarding, traditional fencing and wire fencing. (b) ‘What do you do after you find that your livestock has been killed by a carnivore?’ We used this question as an indicator of retaliatory killing. We grouped the answers into five categories: chase away (i.e., scare carnivores without killing), kill carnivores, nothing (i.e., doing nothing), report kills, and others (e.g., eat

livestock remaining carcass). We acknowledge that self-reports on preventive and retaliatory killing are only proxy measures and may not necessarily always reflect actual killing behaviours to the extent they occur. Yet, we still believe this proxy offers relevant information about human-carnivore relations on both sites.

2.5. Data analysis

To carry out our analysis, we calculated descriptive statistics as appropriate for each question. We used quotes to support the main findings (see Supplementary Materials 4 for some representative quotes provided by centre and periphery community members).

2.5.1. Cross centre-periphery and temporal analysis

We used a Pearson's chi-squared test to determine if killing carnivores' reports varied between centre and periphery respondents. We also analysed if current benefits attributed to dead carnivores varied between centre and periphery respondents and from past to current times.

2.5.2. Factors associated with human-carnivore relations

We used logistic Generalised Linear Models to test how socio-economic factors are associated with: i) benefits that respondents attributed to alive carnivores, ii) suggested killing carnivores as a mitigation strategy, iii) self-reported preventive killing, and iv) self-reported retaliatory killing. The predictor variables were age (≤ 30 , >30), gender (man, woman), formal education (some level of schooling or not), costs (i.e., number of livestock depredation in the three months prior to the interview), and having close family members with conservation- or tourism-related jobs (yes, no). Additionally, each predictor variable interacted with the position in the centre-periphery framework (centre, periphery).

For model selection, we used a backward manual removal procedure and recorded the AIC for each resulting model (Crawley, 2012). We ended up with 11 candidate models from which we selected the subset of models with AIC differences <2 from the lowest AIC among all candidate models considered. From this subset, we obtained a consensus model that contains the average regression estimates for each predictor variable. Finally, we calculated the 95 % confidence intervals of each factor and considered them statistically significant when those intervals did not overlap zero (see Supplementary Materials 5 for more details). We fitted the models using the *glm* function from stats package (R Core Team, 2020) and models were averages using function *model.avg* from MuMIn package (Barton, 2022). We assessed all models for dispersion and lack of extreme influence of outliers using DHARMA package (Hartig, 2022). All statistical analyses were performed in R 4.0.2 (R Core Team, 2020).

3. Results

In total, we interviewed 104 respondents (gender: 73 % men, 27 % women) from the centre community and 126 respondents (gender: 67 % men, 33 % women) from the periphery community. We identified respondents as women or men according to their socio-cultural expression of their gender. Thus, we acknowledge that our binary gender variables may not necessarily reflect our respondents' gender identities (Cameron and Stinson, 2019). All respondents were pastoralists and owned livestock. We found that the centre respondents have a higher percentage of formal education (centre = 40 %, periphery = 19 %) and close family members with tourism- or wildlife-related jobs (centre = 48 %, periphery = 7 %) compared to periphery respondents.

3.1. Costs and benefits

3.1.1. Costs

We found that despite centre respondents having fewer total losses and lower mean losses to carnivores than periphery respondents, 46 % of

centre respondents reported carnivores as the main cause of livestock losses. In contrast, the majority of periphery respondents (57 %) reported diseases as the main cause (Table 1). Overall, 64 % of centre and 96 % of periphery respondents reported at least one head of livestock being killed by a carnivore in the three months prior to the interview.

3.1.2. Benefits

The large majority of centre respondents reported economic benefits in the current times (53 %, Table 2). The current benefits attributed to dead carnivores reported by centre respondents have significantly decreased from the past (Table 2; $\chi^2 = 72.32$, $df = 1$, $p < 0.001$, Cohen $w = 0.6$). Furthermore, we found that the majority of centre respondents (54 %) that reported cultural benefits attributed to dead carnivores in the past, reported economic benefits attributed to alive carnivores in current times.

The majority of periphery respondents (99 %) currently associated carnivores with cultural benefits, which are attributed to dead carnivores. In contrast, only 14 % of periphery respondents attributed benefits to alive carnivores in current times (Table 2). We did not find significant differences between benefits attributed to dead carnivores by periphery respondents in the current and past times ($\chi^2 = 0.82$, $df = 1$, $p = 0.37$, $w = 0.09$).

Overall, current benefits attributed to dead carnivores differ significantly between centre and periphery respondents ($\chi^2 = 218.05$, $df = 1$, $p < 0.001$, $w = 0.98$).

3.2. Suggested mitigation strategies

We found a sharp contrast in reports of killing carnivores as a suggested mitigation strategy between centre and periphery respondents (Table 3; $\chi^2 = 118.49$, $df = 1$, $p < 0.001$, $w = 0.72$).

3.3. Self-reported propensity to kill carnivores

Self-reports of killing carnivores as a preventive practice between centre and periphery respondents differ radically (Table 4a; $\chi^2 = 44.67$, $df = 1$, $p < 0.001$, $w = 0.45$). Self-reports of killing carnivores after livestock depredation differ significantly between centre and periphery respondents (Table 4b; $\chi^2 = 137.09$, $df = 1$, $p < 0.001$, $w = 0.78$).

3.4. Factors associated with human-carnivore relations

For the benefits attributed to alive carnivores, we found that respondents with close family members with conservation- or tourism-related jobs were more likely to associate benefits with alive carnivores ($\beta = 1.575$, $SE = 0.379$, $p < 0.001$). While periphery respondents with formal education were more likely to report benefits attributed to alive carnivores, formal education was not a significant predictor for centre respondents ($\beta = 1.944$, $SE = 0.721$, $p < 0.05$). For the suggested mitigation strategies, we found that respondents with some formal education were less likely to report killing carnivores than those who did

Table 1

Summary of the main cause of livestock losses, and total and mean number of livestock depredation events in the three months prior to the interview.

Costs	Centre	Periphery
<i>Main cause of livestock losses</i>		
Carnivores	46 %	29 %
Diseases	40 %	57 %
Droughts	14 %	14 %
<i>Livestock depredation</i>		
Total		
Shoats	316	1800
Cattle	10	376
Mean		
Shoats	3 (range 0–20)	14 (range 0–70)
Cattle	0 (range 0–3)	3 (range 0–20)

Table 2

Summary of the benefits associated with carnivores in the current and past times (i.e., during the times of the grandparents' respondent) by centre and periphery respondents. Respondents could answer more than one answer, so the percentage indicates how many centre ($n = 104$) and periphery respondents ($n = 126$) gave this answer.

Benefits	Centre		Periphery	
	Past	Current	Past	Current
	% of respondents	% of respondents	% of respondents	% of respondents
<i>'Do you think there are any benefits, good or positive values associated with living alongside carnivores? If so, what are these?'</i>				
No	26.92	45.19	1.59	0.79
Unknown	17.31	0	1.59	0
Yes	55.77	54.81	96.83	99.21
Categories of benefits				
Aesthetic	0.96	5.77	0.79	3.17
Cultural	54.81	1	96.83	99.21
Ecological	0.00	5.77	0.00	0.00
Economic	0.00	52.88	0.00	11.11
Carnivore status (alive/dead)				
Attributed to alive carnivores	0.96	54.81	0.79	13.49
Attributed to dead carnivores	54.81	0.96	96.83	99.21

Table 3

Summary of the suggested strategies to mitigate livestock depredation by centre and periphery respondents. Respondents could answer more than one answer, so the percentage indicates how many centre ($n = 104$) and periphery ($n = 126$) respondents gave this answer.

Suggested mitigation strategies	Centre	Periphery
	% of respondents	% of respondents
<i>'How would you mitigate livestock depredation?'</i>		
Capture and relocate	0.96	0.79
Fence wildlife conservation areas	3.85	0.79
Improve guarding of livestock	50.96	5.56
Kill carnivores	1.92	73.81
None	43.27	16.67

not have it ($\beta = -1.633$, $SE = 0.470$, $p < 0.001$). Respondents living at the periphery of conservation efforts were more likely to report killing carnivores than those at the centre ($\beta = 4.958$, $SE = 0.751$, $p < 0.001$).

In relation to the preventive killing, we found that women and respondents with some formal education were less likely to self-report killing carnivores (gender: $\beta = -1.870$, $SE = 0.470$, $p < 0.001$; formal education: $\beta = -2.812$, $SE = 0.781$, $p < 0.001$). Respondents living at the periphery of conservation efforts were significantly more likely to self-report killing carnivores than respondents living at the centre ($\beta = 4.321$, $SE = 1.037$, $p < 0.001$). For the retaliatory killing, we found that while periphery respondents with close family members with conservation- or tourism-related jobs were less likely to self-report killing carnivores, it was not a significant predictor for retaliatory killing for centre respondents ($\beta = -2.144$, $SE = 0.998$, $p < 0.05$).

4. Discussion

Our study shows that human-carnivore relations differ significantly in two pastoral systems with uneven market-based conservation efforts across Kenya. The centre-periphery framework offers an original comparative approach to show that the presence of market-based conservation efforts generally fosters positive human-carnivore relations. In

Table 4

(a) Summary of the preventive practices used to protect livestock by centre and periphery respondents. (b) Summary of the behavioural responses to livestock depredation by centre and periphery respondents. Respondents could answer more than one answer, so the percentage indicates how many centre ($n = 104$) and periphery ($n = 126$) respondents gave this answer.

Self-reported propensity to kill carnivores	Centre	Periphery
	% of respondents	% of respondents
<i>(a) Preventive killing: 'How do you protect your livestock from carnivores?'</i>		
Deterrents	84.62	16.67
Guardian dogs	86.54	2.38
Human daytime shepherding	17.31	81.75
Kill carnivores	0.96	38.10
Night Guarding	12.50	61.90
Traditional fencing	96.15	92.06
Wire fencing	15.38	0
<i>(b) Retaliatory killing: 'What do you do after you find that your livestock has been killed by a carnivore?'</i>		
Chase away	16.35	0.79
Kill carnivores	11.54	89.68
Nothing	66.35	82.54
Report	17.31	1.59
Others	21.15	2.38

contrast, a lack of these impinges on carnivore populations due to a widely self-reported propensity to kill carnivores. Although these results rely on community members' openness to discuss carnivore killing and conclusions drawn from them should be considered as tentative, they still highlight the value of comparative approaches across different conservation contexts (see Marino et al., 2022). Our results also show that at the centre of conservation efforts there is a narrow report of economic benefits that can potentially undermine the importance of the myriad non-economic benefits that carnivores bring to humans. Furthermore, this study reveals the reality of periphery areas where negative human-carnivore relations remain largely unchallenged by carnivore conservation.

Findings derived from a social-ecological system at the centre of conservation efforts are encouraging from the standpoint of carnivore conservation, with low self-reports of killing carnivores. However, our study also provides four reflection points. First, only a proportion of the community members report benefits attributed to alive carnivores. Thus, some community members may not perceive benefits to alive carnivores or may perceive them, but these do not offset the costs, which could have isolated but negative impacts (Hazzah et al., 2009), on already diminished and globally threatened carnivore populations (Ripple et al., 2014). Therefore, transformative conservation actions aiming to promote positive human-carnivore relations should be first and foremost built on social justice and equity (Fletcher and Büscher, 2020). Frameworks for promoting socially-just conservation (e.g., Just Conservation, Convivial Conservation) offer important guidance in this regard (see Vucetich et al., 2018; Büscher and Fletcher, 2019). Second, economic benefits are the largest benefits attributed to alive carnivores in current times. However, economic activities, such as wildlife tourism, are largely contingent on fluctuations in the global economy (Lindsey et al., 2020). Third, cultural benefits are less reported in current times and seem to be replaced by economic benefits. The replacement of cultural benefits attributed to dead carnivores for economic benefits attributed to alive carnivores is illustrated in the following quotes by the same centre community member: "now tourists come to see the carnivores and conservancies build schools and health centres, pay school fees for our children and create jobs for us", and "in the past, during marriage ceremonies, the bridegrooms tied a piece of lion skin on the ankles, but nowadays, none wear it". Although in our study, many cultural benefits are attributed to dead carnivores, some studies show there are still some non-economic benefits associated with living wildlife that hold a substantive conservation potential (e.g., Lyver et al., 2019; Fernández-

Llamazares et al., 2021). Moreover, as cultural benefits are less reported in current times, conservation behaviour often becomes contingent upon economic reasoning, shifting how local communities relate to their local ecologies (Fernández-Llamazares et al., 2020). Fourth, centre community members are not engaged in reporting livestock depredation events and rarely suggest ways to reduce them. One reason may be that local people view someone else (e.g., government, wildlife conservation areas) as responsible for carnivores and livestock depredation, thus, reducing the feeling of local people's responsibility and stewardship (Hemson et al., 2009). Yet, it may also be a combination of not being aware of the administrative channels available, lack of incentives, not believing that an improvement is possible and being time-consuming (Blair, 2009).

The social-ecological reality at the periphery of conservation efforts is critical for the persistence of healthy local carnivore populations. Most community members attribute benefits to dead carnivores, mostly cheetahs and leopards, whose skins are used in a traditional coming-of-age ceremony (see Torrents-Ticó et al., 2022 for further details). For instance, a periphery community member manifested, “we benefit from cheetahs and leopards because we use their skins as capes in the Dimi ceremony”. In addition, livestock is part of the local pastoral identity and the primary symbol of wealth and respect, and thus, livestock losses to carnivores are very difficult to accept, particularly when considering the significant social capital invested in protecting them (i.e., human daytime shepherding and night guarding). In this case, killing carnivores is the most suggested mitigation strategy and the propensity to kill carnivores is openly self-reported and most often with an explicit sense of pride (Torrents-Ticó et al., 2021; Torrents-Ticó et al., 2022). Here, it is important to note that the establishment of Sibiloi led to the disenfranchisement and exclusion of local Daasanach communities (IUCN, 2020), which could explain the high levels of reactance towards conservation initiatives in the area (e.g., people killing wildlife as a protest against conservation regulations; see Goldman, 2011). Moreover, in the periphery, addressing livestock losses to diseases and droughts may be perceived to be beyond people's control (Hazzah et al., 2009), and thus, local people may focus on livestock losses to carnivores, despite not being the main cause of livestock losses. We found that several socio-economic factors (formal education, gender and having close family members with conservation- or tourism-related jobs) are also significantly associated with human-carnivore relations. These results sit well within the growing number of studies in political ecology showing that human-carnivore relations are complex, multi-layered and situated within a wider set of contextual factors and political-economic shifts (e.g., Margulies and Karanth, 2018; Marino et al., 2022). Therefore, future conservation efforts in the periphery must consider these factors and go hand-in-hand with effective and multi-faceted strategies tailored to the specific social-ecological system (Western et al., 2019). Future collaborative approaches in the area require mitigating livestock losses to diseases so that local people are more able to withstand livestock depredation (Ching et al., 2021), raising education and awareness about carnivores (Marker et al., 2003) and promoting plural benefits attributed to alive carnivores (Hazzah et al., 2014).

Establishing landscapes of human-carnivore coexistence requires a deep understanding of the opportunities and barriers of our current market-based approaches to carnivore conservation. Although social-ecological systems with robust conservation efforts are more likely to sustain positive human-carnivore relations, conservation actions are also crucially needed in periphery areas, in order to increase suitable habitats for carnivores. In addition, the extent to which market-based instruments alone can protect alive carnivores long into the future remains an open question. Taking seriously the literature problematising the emergence of conservation as a mere site of speculative capital accumulation (Büscher and Fletcher, 2015), future conservation actions should therefore strive to complement economic benefits among local communities with other synchronic approaches, including safeguarding traditional cultural benefits of coexistence and promoting a stronger

sense of wildlife stewardship beyond market-based terms (Hazzah et al., 2014). For instance, the Lion Guardians program in the Amboseli Ecosystem in Kenya provides training in literacy and assistance in better preventive practices. The program also employs Maasai warriors as citizen scientists using their Maasai traditional tracking systems based on their knowledge and previous experience as herders and lion hunters to monitor lions. This approach respects Maasai knowledge and helps maintain the essence of the warriors' traditional role in society (Hazzah et al., 2014; Dolrenry et al., 2016). Ultimately, a pluralistic approach would make human-carnivore relations more resilient if economic benefits dwindle due to global, national, or local economic crises, as it has been exemplified by the COVID-19 pandemic (Lindsey et al., 2020).

4.1. Study limitations

We acknowledge some potential limitations in our study. First, we recognise the exploratory nature of this study in using the centre-periphery framework only in two scenarios, potentially obscuring the complex gradient between what is hereby understood as “centre” and “periphery” (Engel, 2008). Future research should use the centre-periphery framework in a greater number of study sites in order to embrace complexity in human-carnivore relations across different conservation contexts. Second, we acknowledge that the presence of a non-Indigenous person (MT-T) in the interviews may have influenced community members' answers. However, being associated with an international university may have helped legitimise the perception of our research as independent, which enabled the author to be viewed more neutrally by communities. Third, we acknowledge that self-reported measures of livestock depredation could be exaggerated and attribute losses to carnivores even if they may have been caused by diseases (Holmern et al., 2007). Yet, we believe self-reported livestock losses cannot be ignored because they are essential to understanding human-carnivore relations and still provide a relatively reliable index of livestock depredation events (Woodroffe et al., 2005), which is particularly relevant in the nearly total absence of official data on the ground. We also recognise that asking about sensitive topics (e.g., killing carnivores) may lead to biased answers (Nuno and St. John, 2015). Therefore, the low percentage of self-reports of killing carnivores at the centre could have different interpretations. It could suggest that the long-term conservation efforts in the area have been successful (Sundaresan and Riginos, 2010). However, it could also be due to under-reporting driven by fear of law enforcement (St. John et al., 2012) or a desire to please conservationists (Sheil and Wunder, 2002), which would mislead carnivore conservation.

5. Conclusions

Assessing how uneven market-based conservation efforts in an area influence human-carnivore relations is crucial to understanding the opportunities and pitfalls of current market-based instruments for carnivore conservation. This study uses the centre-periphery framework as a novel and distinctive approach to compare human-carnivore relations from areas with uneven conservation efforts across Kenya. Our study shows how human-carnivore relations are embroiled within broader social-ecological contexts to conserve specific landscapes. Here, we show that benefits, suggested mitigation strategies and self-reported propensity to kill carnivores are highly site- and context-dependent. In the centre of conservation efforts, human-carnivore relations include a low self-reported propensity to kill carnivores. In contrast, the propensity to kill carnivores is openly self-reported in a periphery area where conservation efforts are meagre at best. Yet, current conservation efforts prioritise economic benefits over non-economic ones that may have a strong conservation potential. Carnivore conservation is likely to be best served by broadening its focus to recognise the plurality of benefits associated with carnivores, and increasing conservation attention to periphery areas where negative human-carnivore relations

remain unchallenged.

CRedit authorship contribution statement

Miquel Torrents-Ticó: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing, Funding acquisition, Project administration. **Femke Broekhuis:** Validation, Formal analysis, Writing – review & editing. **Daniel Burgas:** Data curation, Formal analysis, Writing – review & editing, Visualization, Supervision. **Mar Cabeza:** Methodology, Writing – review & editing, Supervision. **Emmanuel Miliko:** Conceptualization, Investigation, Validation, Data curation, Project administration. **Thomas Titiay Komoi:** Conceptualization, Investigation, Validation, Data curation, Project administration. **Álvaro Fernández-Llamazares:** Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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