Received: 26 July 2022 | Revised: 21 April 2023 | Accepted: 18 May 2023

DOI: 10.1111/csp2.12974

CONTRIBUTED PAPER

Conservation Science and Practice
A journal of the Society for Conservation Biology
Open Access

WILEY

Advancing protected area effectiveness assessments by disentangling social-ecological interactions: A case study from the Luangwa Valley, Zambia

Marina Frietsch[1] | Noelia Zafra-Calvo[2] | Arash Ghoddousi[3] | Jacqueline Loos[1,4]

[1]Leuphana University, Social-Ecological Systems Institute, Faculty of Sustainability, Lüneburg, Germany

[2]Basque Centre for Climate Change, Scientific Campus of the University of the Basque Country, Bilbao, Spain

[3]Geography Department, Humboldt-University Berlin, Berlin, Germany

[4]Leuphana University, Institute of Ecology, Faculty of Sustainability, Lüneburg, Germany

Correspondence
Jacqueline Loos, Leuphana University, Social-Ecological Systems Institute, Faculty of Sustainability, Universitätsallee 1, 21335 Lüneburg, Germany.
Email: jacqueline.loos@leuphana.de

Funding information
Robert-Bosch Foundation; Deutsche Forschungsgemeinschaft, Grant/Award Number: 409732304

Abstract

Protected and conserved areas (PCAs) target at biodiversity conservation and human well-being, but often reflect low levels of effectiveness. Understanding PCAs social-ecological systems in which people and nature interact in so-called social-ecological interactions is key to understanding the roots of (in) effectiveness, and to leverage change toward resilient and sustainable systems. Despite this potential, social-ecological interactions in PCAs are commonly neglected in effectiveness evaluations. To address this gap, we elaborated a thorough understanding of the social-ecological interactions in PCAs through the following steps: In a first step, we extracted from scientific literature which social-ecological interactions influence the effectiveness of PCAs in general and derived influencing factors which shape those interactions. Based on these insights, we developed an analytical framework, which, in a second step, we applied to a case study in North Luangwa, Zambia. We elucidated three dimensions of social-ecological interactions occurring in the study area: care (e.g., conservation programs), conflict (e.g., disease transmission), and use (e.g., hunting). We visualized relationships between these interactions and associated key variables in a causal loop diagram. Finally, we drew on the case study in Zambia's Luangwa Valley to propose system-specific metrics for key variables central to the social-ecological structure of the study area to make effectiveness measurable. Our approach allows for linking site-specific social-ecological interactions to PCA effectiveness. More generally, our findings call for the consideration of the relationships between people and nature when assessing conservation effectiveness.

KEYWORDS

area-based conservation, human-nature interactions, human-wildlife coexistence, impact evaluation, social-ecological systems

1 | INTRODUCTION

Protected and conserved areas (PCAs) contribute to the conservation of biodiversity, ecosystem services and functions, and to human well-being (Convention on Biological Diversity [CBD] 2020). Their importance is recognized at a global level: the most post-2020 biodiversity framework demands the conservation of at least 30% of the planet by 2030 through a "well connected and effective system of protected areas" (CBD 2020, p. 5). Although the number of PCAs increases, biodiversity and its associated benefits for all living species continue to decline (Ceballos et al., 2020; Pimm et al., 2014). This reflects a lack of effectiveness of PCAs (Coad et al. 2015, Leverington et al., 2010).

PCA effectiveness is influenced by many ecological (e.g., Geldmann et al., 2020), social (e.g., McKinnon et al., 2016; Schreckenberg et al., 2016) and social-ecological (e.g., Cumming & Allen, 2017; Palomo et al., 2014) factors. Based on these factors, various tools exist to assess the effectiveness of PCAs (dos Santos Ribas et al., 2020), with ecological and social drivers of PCA effectiveness being commonly assessed separately (Caillon et al., 2017; de Lange et al., 2016; Ghoddousi et al., 2022). This separation, as well as the rare consideration of social-ecological interactions (SEIs), disregards the diverse interplays that link human and biophysical components and processes across multiple scales (Berkes & Folke, 1998,) and their impacts on PCA performance (Martín-López et al., 2017; Muradian & Pascual, 2018; Soga & Gaston, 2020). The detailed consideration of the interactions (see Ostrom, 2009) between the resource system (PCA) and users (humans) disentangle how human-nature relationships play out in the wider social-ecological systems that PCAs are embedded in.

Social-ecological system thinking recognizes PCAs as complex coupled systems encompassing ecological processes, social processes, and their interactions (Cumming et al., 2015; Cumming & Allen, 2017; Palomo et al., 2014). Interactions between social and ecological system components are defined as the "direct interactions between individual people and nature" (Soga & Gaston, 2020, p. 1). Such interactions drive dynamics in social-ecological systems (Cumming et al., 2006; Schlüter et al., 2017) by triggering feedback, causing emergent phenomena and continuously changing patterns and structures within and across scales (Preiser et al., 2018; Schlüter et al., 2019). In the context of PCAs, social-ecological effectiveness refers to effectiveness along three complementary dimensions: ecological outcomes (e.g., biodiversity), social outcomes (e.g., well-being), and social–ecological interactions (SEIs, Ghoddousi et al. 2022). Some important SEIs are human pressures (e.g., poaching, land-use change) and nature's contribution to people (e.g., spiritual values of nature, human-wildlife conflict). SEIs, however, have been rarely considered in PCA effectiveness evaluations (Ghoddousi et al., 2022).

Because of their significance for social-ecological systems (Ramos-Quintana et al., 2019; Soga & Gaston, 2016), SEIs are crucial to understanding the roots of (in)effectiveness of PCAs (da Costa Rego et al., 2015; Sodhi et al., 2011) and leverage change toward resilient, sustainable protected systems. While specific SEIs have been used to assess PCA effectiveness in the past (e.g., anthropogenic pressures on nature; Geldmann et al., 2019), there is no research on the combined influence of multiple SEIs on social-ecological effectiveness.

Zambia's Luangwa Valley exemplifies a social-ecological system where North Luangwa National Park and four adjacent game management areas exhibit a high level of biodiversity and are home to several endangered and endemic species (Riggio et al., 2013) while people inhabit this area and have relationships with nature (Anderson et al., 2015; Watson et al., 2015). Despite years of conservation in the region, the lack of effectiveness of the study PCA system is reflected in habitat conversion and loss (Riggio et al., 2013; Watson et al., 2015), unsustainable natural resource use (Dumas et al., 2017) and human-wildlife conflict (Gross et al., 2018; Subakanya et al., 2018). Thus, this system of PCAs provides an opportunity to assess the relationship between SEIs and social-ecological effectiveness.

With this case study, we develop a novel approach that allows practitioners and policymakers to generate a comprehensive understanding of SEIs and their links occurring in PCAs. This understanding, in turn, can inform site-specific conservation strategies. In this research, we aim to answering two research questions: (1) Which factors shape SEIs and thereby influence social-ecological effectiveness in PCAs in general? (2) Which SEIs occur and how do they interact in the study area in North Luangwa, Zambia? Specifically, we develop an analytical framework in the scope of research question one, which is applied to the North Luangwa case study as part of research question two.

2 | METHODS

2.1 | Study area

Zambia designated 41% of its terrestrial surface for PCAs. One of the most remote national parks is North Luangwa National Park (IUCN category II), which is surrounded by the game management areas (IUCN category IV) Musalangu, Lumimba, Munyamadzi, and

Mukungule. Conjointly, these PCAs cover 27,705 km^2 (UNEP-WCMC, 2020) and will henceforth be referred to as North Luangwa. The Luangwa Valley is of central importance to large mammal conservation in Zambia and hosts some of the largest remaining populations of lion (*Panthera leo*) (Riggio et al., 2013) as well as several large ungulate species (Lewis et al., 2011). In Zambia, national parks are core conservation areas with minimal human impact through tourism, while game management areas serve as buffer zones and entail designated zones for sustainable use (National Parks and Wildlife Service 2018).

2.2 | Analytical framework

To answer our first research question of which factors shape SEIs and influence social-ecological effectiveness in PCAs, we developed an analytical framework. This analytical framework emerged from a purposeful literature search (Gentles et al., 2016) on the relationship between SEIs and PCA effectiveness. We obtained the literature using Web of Science and Scopus queries, the snowball method (Greenhalgh & Peacock, 2005), citation searches (Hart, 2001), and keyword searches on Google Scholar. Keywords for these searches included "human-nature interaction," "social-ecological interaction," "protected area," "national park," and different spellings of these terms (see details in Appendix 1). This literature review yielded 22 peer-reviewed journal articles on SEIs and their influence on PCA effectiveness (Figure 1).

The extent to which PCAs achieve their respective objectives determines their degree of (in)effectiveness. In North Luangwa, two types of PCAs are of central importance: a national park (IUCN category II) that seeks to protect "natural biodiversity along with its underlying ecological structure and supporting environmental processes, and promote education and recreation" (Dudley, 2008, p. 16) and four Game Management Areas (IUCN category VI), which are PCAs with sustainable use of natural resources and follow the primary objective of protecting "natural ecosystems and [using] natural resources sustainably, when conservation and sustainable use can be mutually beneficial" (Dudley, 2008, p. 22).

2.3 | Data collection: Interviews and literature search

To answer our second research question of which SEIs occur and how they interact in the study area in North Luangwa, we used two datasets (Figure 1). First, we conducted 34 nondirective interviews in 2019 (henceforth abbreviated by "I" and numbered) with people living or working in the study area to gain in-depth information on various perspectives on conservation and natural resource management. Interviewees were selected to represent a broad range of stakeholders and sectors according to a previously conducted stakeholder analysis in the study area. Interviewees included local inhabitants, rangers, women, teachers, traditional leaders and chiefs, members of NGOs active in the area, members of the community resource boards and people from the tourism sector. After explaining the purpose of our inquiry, we asked participants for their consent to take notes and explained that the provided information will be kept anonymous. Interviewees shared their experiences with living and working in North Luangwa and in the process referred to diverse SEIs that shape their daily lives.

Second, we conducted a systematic literature search on SEIs occurring in North Luangwa and in PCAs in Zambia, in general, using the Web of Science platform, citation searches (Hart, 2001), publications found via the snowball method (Greenhalgh & Peacock, 2005) and keyword searches on Google Scholar. Here, search keywords were "Zambia," "people-nature interaction," "human-nature interaction," "human-environment interaction," "social-ecological interaction," "wildlife conflict," and different spellings of these terms (see details in Appendix 2). Subsequently, we scrutinized the 54 journal articles obtained by this search as well as the 34 interviews to identify SEIs occurring in the study area. Here, the analytical framework developed in the scope of the first research question was used to systematically organize influencing factors, involved stakeholders, temporal and spatial scales, and outcomes of each SEI.

2.4 | Data analysis: Coding and causal loop diagrams

To provide a more structured overview of the identified SEIs, we inductively coded SEIs into nonhierarchical dimensions. We did this by differentiating between key characteristics of the SEIs following the analytical framework with a particular focus on stakeholders and the outcomes of the interactions between these stakeholders and the social-ecological system in which they live and operate in. We further classified different categories of SEIs within each dimension through an iterative coding process. Importantly, some SEIs can be aligned with more than one dimension. Here, the dimension fitting best for

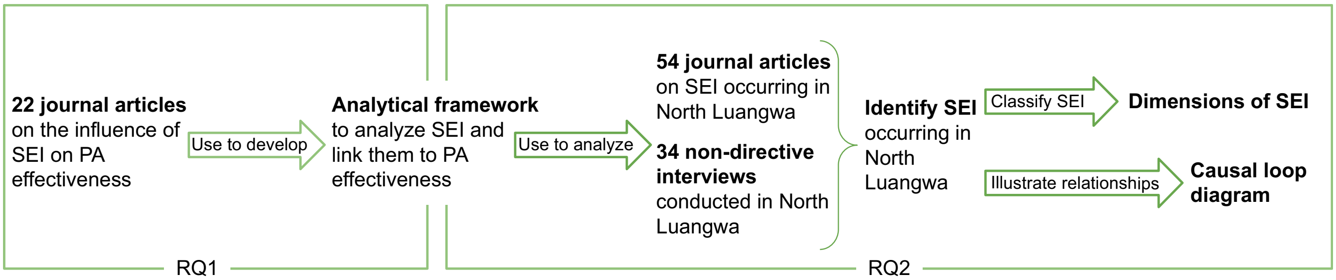

FIGURE 1 Flowchart of the step-wise approach to develop the analytical framework, identify social ecological interactions (SEIs), and develop indicators following the two research questions (RQ).

a particular SEI was identified based on the focus of the interviews and the literature. For instance, hunting is classified to be part of the *use* dimension. At the same time, hunting could be understood as a conflict because the ecological system components experience detrimental effects.

Finally, we visualized the links between the SEIs in a causal loop diagram (Rissman & Gillon, 2017; Sterman, 2001), using the system dynamics software Vensim PLE (Ventana Systems, 2015). Causal loop diagrams have been applied in social-ecological systems research to visualize links between key system elements (e.g., Coletta et al., 2021; Hanspach et al., 2014; Jiren et al., 2020). For the causal loop diagram to be simultaneously comprehensive and manageable, we included the most frequently mentioned SEIs and variables emerging from the interviews and the literature ($n = 18$; variables were mentioned by at least five different sources). We derived links between the variables from the interviews and literature and visualized these links through arrows. Closed cycles between variables indicate either balancing (self-regulating) or reinforcing (growing) feedback loops (Haraldsson, 2004). We classified the variables in the causal loop diagram as either root nodes, central nodes, or end-of-chain nodes to clarify their influence on the system. Root nodes are variables with many outgoing arrows (=causal links) that typically provide information on the source of an issue or phenomenon; central nodes exhibit multiple outgoing as well as incoming arrows and are thus connected to a particularly high number of processes and interactions occurring in the system; end-of-chain nodes are characterized by mostly incoming arrows and usually are the product of several upstream dynamics (Niemeijer & de Groot, 2008). This classification supports the identification of root causes of ineffectiveness and the determination of interactions and variables with strong leverage for change—the root nodes and central nodes with many causal links. It also illustrates how causes and links might be overlooked when solely focusing on the end products of ineffective processes.

3 | RESULTS

3.1 | The influence of social-ecological interactions on protected area effectiveness: Analytical framework

We identified diverse factors that restrict, facilitate, or otherwise shape SEIs, which in turn, influence PCA effectiveness (Table 1). The literature analysis yielded the following influencing factors: biophysical conditions such as climate and geography predetermine patterns of species distributions and ecosystem structures. Socio-cultural dynamics shape people's values of and attitudes toward nature, laws and regulations, which moderate the relations between humans and nature, and power structures that shape societies and the way they view and interact with nature. In this socio-cultural fabric, different stakeholders emerge: residents, tourists, external resource extractors, land managers, governance agencies, and conservationists. These stakeholders and their interactions with nature underlie and contribute to closely intertwined economic, socio-cultural, and ecological changes. Governance restricts or furthers many of these interactions and historical conditions shape their form and development. Finally, scales are relevant when discussing SEIs to account for temporal and spatial dynamics.

Based on these influencing factors, the analytical framework (Figure 2) comprises three building blocks that guide data collection and analysis to better understand SEIs: (1) the influencing factors provide context for identified SEIs, which are the product of preceding conditions; (2) the spatial and temporal scales, as well as relevant stakeholders, describe the manifestation of SEIs; (3) the outcomes of interactions on ecological or social system components are considered as effects of SEIs.

TABLE 1 Overview on factors influencing social-ecological interactions in PCAs as derived from the literature review

Factor influencing social-ecological interactions	Sources
Natural landscape conditions	Ruiz-Ballesteros & Ramos-Ballesteros, 2019, Soga & Gaston, 2020
Socio-cultural influences: people's values and attitudes towards nature	Fox & Xu, 2017, Ellis et al., 2019, Muradian & Pascual, 2018
Socio-cultural influences: laws and regulations	Ruiz-Ballesteros & Ramos-Ballesteros, 2019
Socio-cultural influences: power relations	Boonstra, 2016, Ruiz-Ballesteros & Ramos-Ballesteros, 2019
Actors	Cumming et al., 2015, Ellis et al., 2019, García et al., 2020, Martín-López et al., 2017, Nyhus, 2016, Ramos-Quintana et al., 2019
Governance	Ruiz-Ballesteros & Ramos-Ballesteros, 2019
Economic aspects	Ruiz-Ballesteros & Ramos-Ballesteros, 2019, Soga & Gaston, 2020
History	Nyhus, 2016, Roux et al., 2020
Temporal and spatial dynamics	García et al., 2020, Soga & Gaston, 2020

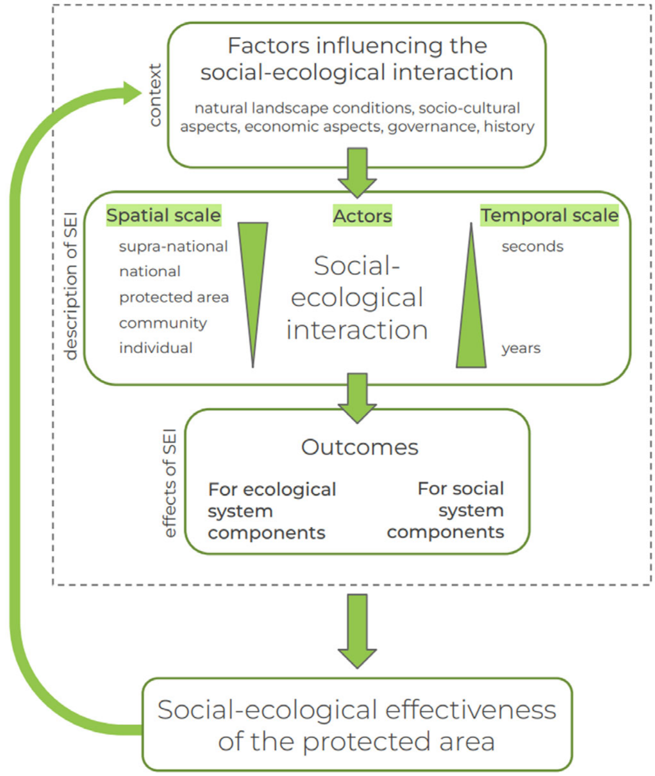

FIGURE 2 The analytical framework used for the analysis of each social-ecological interaction. The first component refers to the context in which a social-ecological interaction occurs and aims at identifying factors that influence the occurrence of this interaction. The second component concerns the social-ecological interaction itself, its scales and the involved stakeholders. The third component encompasses the effects of a social-ecological interaction on the ecological and social system components. The long green arrow indicates that the social-ecological effectiveness of a protected area, in turn, influences the context in which a social-ecological interaction occurs.

3.2 | Social-ecological interactions occurring in north Luangwa: Three dimensions of interactions

Guided by the analytical framework, we identified SEIs mentioned in the systematically collected literature and in the interviews. During this process, we inductively categorized SEIs occurring in the study into the three non-hierarchical dimensions: *care*, *conflict*, and *use* (Figure 3; see details in Appendix 3). We further classified different categories of SEIs within each dimension.

3.2.1 | Dimension care

The dimension *care* includes social system components that actively take a caring role for ecological system components. It comprises three categories (conservation, stewardship, knowledge) and six SEIs (establishment of PCAs, establishment of conservation programs, wildlife translocations, voluntary restrictions of individual actions for the sake of conservation, research, environmental education).

Conservation, stewardship and knowledge are subject to strong historical, political and societal changes accompanied by different laws and attitudes. While the Luangwa Valley has been inhabited for centuries (Anderson et al., 2015), the enforcement of European worldviews on local communities changed long-standing SEIs dramatically during the colonial era. Overall, colonial laws fractured the way people used and related to nature (Anderson et al., 2015, I13, Kaunda, 2016) and still shape the view of conservation today (Anderson et al., 2015). Today, stakeholders in conservation and stewardship are residents, government authorities, NGOs and state agencies (Anderson et al., 2015; Lindsey et al., 2014; Subakanya et al., 2018). Stakeholders in the category of knowledge differ between research and education: while mainly external groups conduct and finance research (I1, Abel and Blaikie 1986), education takes place in schools, within

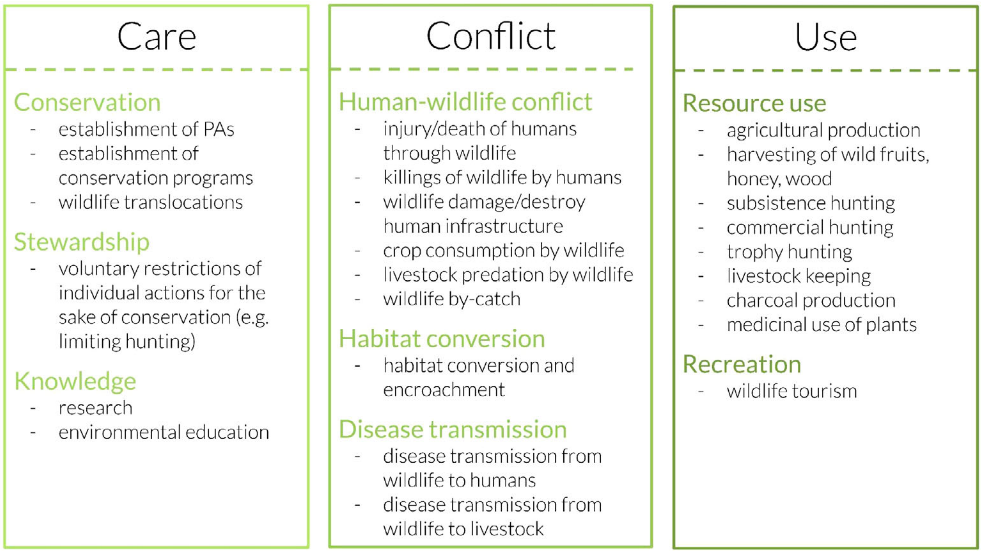

FIGURE 3 The 24 social-ecological interactions that were identified in the study area were iteratively assigned to eight categories of social-ecological interactions (green font) within three dimensions of social-ecological interactions (care, conflict, use).

communities (I26, Nyirenda et al., 2017), and in the context of conservation programs (I7). The subjects of care are mostly wildlife populations, species, or ecosystems and not individual specimens (I2, I5, Marks, 2001). For all three categories in the *care* dimension, we found no information on spatial and temporal patterns neither in the interviews nor in the literature.

To create incentives for sustainable natural resource use and simultaneously enhance the welfare of local communities, Community Based Natural Resources Management was initiated in 1988 (Milupi et al., 2020). Yet, the distribution of benefits among households tends to be uneven (Manning, 2012; Richardson et al., 2012) and the political elite frequently usurped power, decision-making capacities, and funds. Local communities, however, face strict law enforcement, restricting traditional land-use practices. This drives some people into illegal hunting to ensure their survival, which accelerates social tensions among residents. Moreover, residents harvesting renewable resources for subsistence purposes on customary land were reported to be abused and imprisoned by state conservation agents (Manning, 2012).

Formally, local communities controlled 94% of Zambian land, however, the state appropriated customary land across the country and transformed it into game management areas controlled by governmental organizations (Manning, 2012). Apart from legal aspects of land ownership, cultural factors play a role in the conservation and stewardship of land. Some interviewees reported that they proudly take care of the land, feel part of the PCA system, and acknowledge the impact of human activities on nature (I19, I21, I24). Some people supported the protection of natural resources by either joining official programs and organizations (e.g., becoming rangers, I27) or by engaging in their own projects (e.g., voluntary conservation farming to protect soil, I25). Heritage and intergenerational knowledge transfer were considered important in these forms of stewardship (I7, I21). Simultaneously, interviewees mentioned other groups of local people who were unaware of the benefits obtained from the environment or conservation, thinking that only the government profits from PCAs (I27).

3.2.2 | Dimension conflict

The *conflict* dimension includes all interactions between social and ecological system components with detrimental effects for some or all system components involved. It comprises three categories (human-wildlife conflict, habitat conversion, disease transmission) and nine SEIs (injury/death of humans by wildlife, killings of wildlife by humans, wildlife damage/destroy human infrastructure, crop consumption by wildlife, livestock depredation by wildlife, wildlife by-catch, habitat conversion and encroachment, disease transmission from wildlife to humans, disease transmission from wildlife to livestock).

Actors involved in human-wildlife conflicts commonly include individual residents or communities on the one side and single animals on the other side. In the study area, elephants (*Loxodonta africana*) cause most of the damages to crops and infrastructure, and accidentally injure or kill people (Gross et al., 2018, I4, I5, I8, I10, I19, Richardson et al., 2012, Subakanya et al., 2018). Leopards (*Panthera pardus*), spotted hyenas (*Crocuta crocuta*), and raptors mainly attack livestock (Nyirenda et al., 2017). Crop damage and livestock depredation often exhibit clear spatial and temporal patterns. For example, elephants predominantly raid the villages during harvest months and during nighttime (I12, I17). The number of incidents varies widely with the locality: some interviewees state daily conflicts with animals (I19, I26) while others do not report any major conflict with wildlife at all (I7, I13). Damage to crops and livestock by wildlife results in food shortages. The resulting food insecurity impedes socio-economic development (I20, I26, Richardson et al., 2012)—especially since no realized compensations for residents in game management areas exist (I5, I8, I20, Subakanya et al., 2018). Some people respond to human-wildlife conflict with increased illegal subsistence hunting (Lewis et al., 2011) or retaliatory killing of wildlife (I8, Becker et al., 2013).

Actors from both inside and outside the PCAs engage in habitat conversion of natural areas and cropland encroachment. Zambia has experienced rapid human population growth with high growth rates in game management areas (Rosenblatt et al., 2019; Watson et al., 2015). The associated increases in roads, railways, and infrastructure (Watson et al., 2015) as well as in agriculture and charcoal production result in habitat conversion (Lindsey et al., 2014), paving the way for more human encroachment to follow. Human encroachment, in turn, jeopardizes ecological connectivity among PCAs (Lindsey et al., 2014), restricts animal movements (Curry et al., 2019), replaces natural vegetation with cultivated land (Watson et al., 2015), reduces population densities of wildlife (Rosenblatt et al., 2016), and exposes wildlife in national parks to edge effects in the form of snaring and diseases (Watson et al., 2015). While game management area boundaries rarely halt encroachment in the Luangwa Valley (Watson et al., 2015), national park boundaries largely deter humans from invading natural areas: the annual rate of habitat loss in game management areas of 0.69% is considerably faster than in national parks (0.05%) and outside PCAs (0.51%) (Lindsey et al., 2014).

Finally, the prevalence of zoonotic diseases such as sleeping sickness (Human African Trypanosomiasis and African Animal Trypanosomiasis, henceforth HAT and AAT; Alderton et al., 2018; Leach et al., 2017), anthrax (Lehmann et al. 2017), foot-and-mouth disease, and malaria (Lewis et al., 2011) impacts the compatibility of wildlife conservation and agro-pastoralist land uses in the study area. With hot and dry climatic conditions ideal for the tsetse fly, North Luangwa is a hotspot of HAT and AAT (Anderson et al., 2015; Nakamura et al., 2019). Pronounced seasonal effects on both tsetse and wildlife populations result in changes in infection risk over the year (Leach et al., 2017). Anthrax outbreaks are associated with the food insecurity of the dry season and commonly pause during the rainy season when wildlife and humans regain access to water and food (Lehman et al., 2017). Hence, people living in the Luangwa Valley developed alternative land use and management strategies based on hunting and agriculture over the centuries (Anderson et al., 2015). Habitat conversion and deforestation lowers HAT risk because they decrease reservoirs, thereby releasing more land for human use (Leach et al., 2017). This is why attempts to control HAT historically conflicted with conservation objectives (Anderson et al., 2015). Recent intensification of farming practices, including the increased number of livestock in North Luangwa amplifies the risk of HAT and AAT epidemics (Alderton et al., 2018, Leach et al., 2017). Anderson et al. (2015) predicted that "ecological changes associated with this diversion from traditional land-use patterns will be contributing to reductions in biodiversity, ecosystem functioning and [...] ecosystem services" (p. 3).

3.2.3 | Dimension use

The *use* dimension includes all interactions where social system components use ecological system components for their enrichment. It comprises two categories (resource use, recreation) and nine SEIs (agricultural production, harvesting of wild fruits, honey and wood, subsistence hunting, commercial hunting, trophy hunting, livestock keeping, charcoal production, medicinal use of plants, wildlife tourism).

The category recreation comprises tourism, which is organized by tourism operators (White & Belant, 2015) and mostly revolves around nature in the study area (Richardson et al., 2012). Other stakeholders include tourists and residents who are employed in tourism-related economies (Lindsey et al., 2014). The category resource use encompasses eight SEIs. The literature as well as the interviewees mainly focus on agricultural production, livestock keeping, and different forms of hunting. Food security impacts the temporal patterns of these activities. While some residents are food insecure year-round, many others experience seasonal food insecurity (I19, Marks, 2001). Besides their economic importance for local livelihoods, agriculture, livestock, and resource use have fundamental societal and cultural meanings, such as being connected to certain gender roles (I17) or shaping emotional connections to wildlife (I24). Increasing demand for land drives deforestation, habitat conversion, and human encroachment (I2, Leach et al., 2017, Lindsey et al., 2014). These developments often accelerate wildlife harvest (Watson et al., 2015), which affects ecological system components: wildlife movement become restricted (Watson et al., 2013) and animal populations decrease (Becker et al., 2013;

Chomba & Matandiko, 2011; Creel et al., 2016; Rosenblatt et al., 2016).

In the Luangwa Valley, inconsistent rains (Lewis et al., 2011), floods (I21), droughts (Marks, 2001), diseases, restricted access to markets (Anderson et al., 2015; Lewis et al., 2011), and lacking infrastructure (Dumas et al., 2016) reinforce chronic poverty and food insecurity among smallholder farmers (Dumas et al., 2016). Agricultural production is the primary livelihood for an estimated 90% of households in the Luangwa Valley (Dumas et al., 2016). To supplement food supply, generate additional income, and cope with extreme climate events, many farmers use natural resources and engage in hunting, fishing, logging, and charcoal production (Dumas et al., 2017; Robledo et al., 2012) or practice livestock keeping (Dumas et al., 2018). However, livestock ownership is largely restricted to few animals per household (Dumas et al., 2018) due to the high risk of HAT and AAT, the prevalence of other diseases (Anderson et al., 2015; Dumas et al., 2018), wildlife depredation (Anderson et al., 2015, Dumas et al., 2018), poor forage, (Dumas et al., 2018), and minimal access to veterinary care (Anderson et al., 2015, Dumas et al., 2018).

Hunting in the study area mostly occurs illegally (Marks, 2001; Rosenblatt et al., 2019). Residents engage in hunting for short periods of time for cultural or subsistence reasons (I3, Marks, 2001). Importantly, some residents oppose illegal hunting categorically, while others rely on illegally hunted meat for their livelihood (Lewis et al., 2011). Moreover, organized poaching groups from outside the PCA hunt elephants and other species for commercial purposes (Watson et al., 2013). Legal ways of hunting are resident hunting (Lindsey et al., 2014; Rosenblatt et al., 2016) or trophy hunting (Curry et al., 2019; Ray-Brambach et al., 2018). Spatially, wildlife use is concentrated in game management areas (Anderson et al., 2015; Watson et al., 2013). Hunting reduces crop damage (Richardson et al., 2012) and trophy hunting generates revenues (White & Belant, 2015), which contribute to infrastructural improvements (I17) and conservation (Creel et al., 2016; White & Belant, 2015). This, in turn, reduces illegal hunting (I13; White & Belant, 2015). While residents benefit from free meat distributed by trophy hunting operators, the two parties are also in conflict over access to land (I17, I18, White & Belant, 2015).

3.3 | Illustrating links between key system elements: Causal loop diagram

The causal loop diagram (Figure 4) illustrates the links between the 18 most repeatedly reported variables describing dynamics between social and ecological system components that occur in North Luangwa (Appendix 3). While most variables depicted in the causal loop diagram are not SEIs, they represent context-specific factors that can induce SEIs, are the product of SEIs, or shape the manifestation of a particular SEIs. For instance, the causal loop diagram reveals that the SEI *crop consumption by wildlife* affects the *food security of local communities*—not a SEI itself—which in turn influences the SEIs subsistence hunting.

Additional information provided by the causal loop diagram include variables' positions as either root nodes (e.g., *extreme climate and weather events*), central nodes (e.g., *wildlife population size*) or end-of-chain notes (e.g., *human development*). This classification offers more insights on the role a specific variable plays in a given system. Finally, the causal loop diagram revealed information about the feedbacks between the variables in coupled social-ecological systems, such as feedback loops about processes and developments.

Given the high number of variables and feedbacks, we exemplarily show the additional information that the causal loop diagram contain: feedback loop "B" highlights the balancing link between *subsistence hunting*, *wildlife population size*, *crop consumption by wildlife*, and *food security of local communities* (Figure 4). A high degree of subsistence hunting reduces wildlife population densities and thereby lowers wildlife crop consumption, which in turn, causes a high level of food security, subsequently reducing the need for subsistence hunting. Hence, the cycle starts anew, this time with contrary developments. This feedback loop portrays the conflict between North Luangwa's human and nonhuman inhabitants who compete for space and food resources. Due to the balancing nature of the feedback loop, insecure conditions prevail for all stakeholders involved.

Feedback loop "R" is a reinforcing loop (Figure 4). It reveals that *habitat conversion and encroachment* are steadily increasing in North Luangwa and interest in *trophy hunting* is high. This increases the *capital of conservation programs*, which boosts the *development* of infrastructure. Again, the cycle continues, this time steadily spiraling upwards, causing ever more habitat conversion. This feedback loop shows how human development reinforces itself. Once the social system components are not the only part of the equation, however, it becomes apparent that this socio-economic development only operates at the expense of nature: human activities further erode biophysical structures and drive habitat loss and fragmentation.

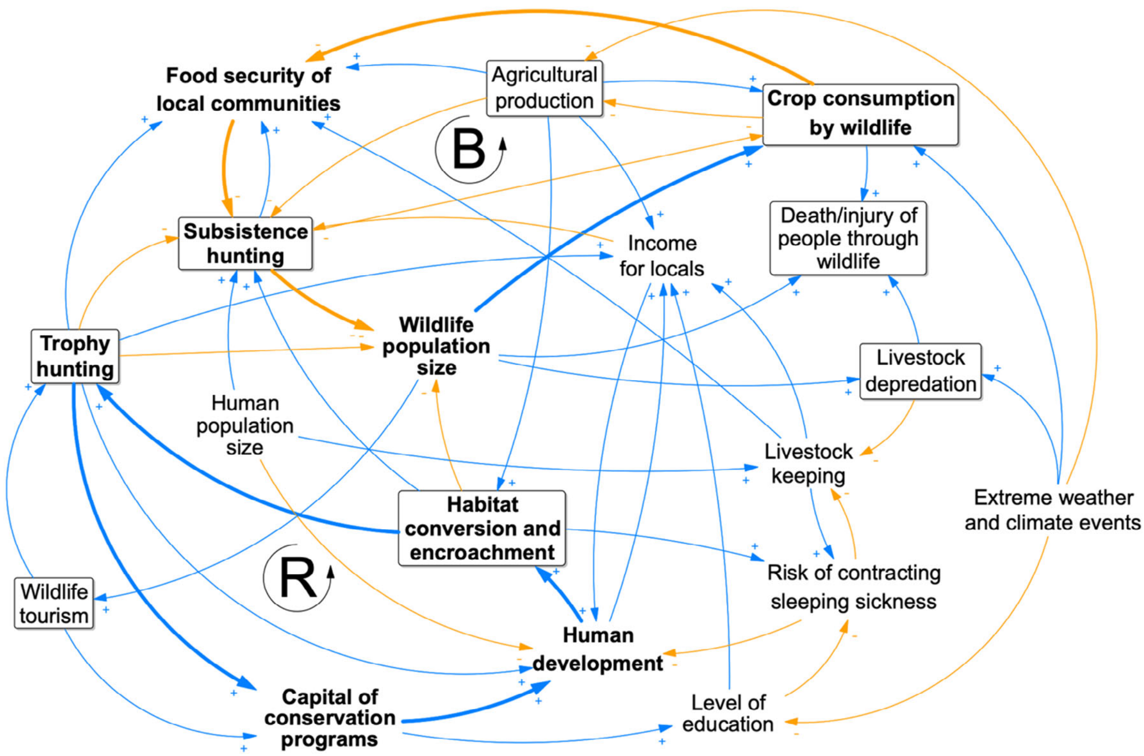

FIGURE 4 Causal loop diagram of human-nature dynamics in North Luangwa, Zambia. Blue arrows with a "+" represent relationships between variables with an enhancing effect. Orange arrows with a "−" indicate relationships with a reducing effect. Closed cycles in the diagram indicate either balancing, self-regulating (B) or reinforcing, growing (R) feedback loops. The highlighted balancing feedback loop illustrates the interaction between wildlife and human communities the highlighted reinforcing feedback loop illustrates how socio-economic development continuously increases at the expense of nature. Social-ecological interactions are highlighted with black boxes.

4 | DISCUSSION

Our study disentangles the direct interactions between the North Luangwa PCAs (i.e., a resource system; see Ostrom, 2009) and the people living and working in this socia-ecological system (i.e., the users of this resource system; see Ostrom, 2009). Our approach to explore social-ecological effectiveness of North Luwanga PCAs comprises three components: an analytical framework for the analysis of SEIs occurring in a PCA; three dimensions of SEIs that summarize interactions in the study area; and a causal loop diagram that depicts the links and feedback between SEIs and associated variables that shape the social-ecological system in North Luangwa. These three components allow researchers, practitioners, and stakeholders to enter a discussion about the social-ecological effectiveness of PCAs. While we based our work on the voices of residents and peer-reviewed articles, we acknowledge the importance of cross-checking and refining our results with the people living and working in the study area as well as the managers of the study PCAs. By asking stakeholders´ perceived relevance of SEIs, we can enhance our approach and facilitate a thorough understanding of PCA effectiveness on multiple levels. This knowledge can then be used to develop socially, ecologically, and social-ecologically effective strategies to support PCAs.

4.1 | Working with social-ecological interactions

4.1.1 | Identifying social-ecological interactions

The three dimensions of SEIs—*care*, *conflict*, and *use*—summarize the manifold SEIs that occur in North Luangwa. Potentially, SEIs belonging to all three dimensions are present in every PCA where humans and nature coexist. Hence, the three dimensions can help uncover SEIs. Scientific literature majorly presents unidimensional PCA effectiveness analyses (Geldmann et al., 2019; Kiffner et al., 2020; Lindsey et al., 2017). In accordance with Martín-López et al. (2017), Muradian and Pascual (2018), and Soga and Gaston (2020), we recommend SEIs to become routinely considered in assessing PCA effectiveness and we further recommend the considerations of SEIs belonging to all three categories.

Each dimension affects PCA effectiveness differently. First, SEIs belonging to the dimensions *conflict* and *use* comprise benefits and disbenefits that people derive from interactions with nature. This influences people's quality of life (Ramos-Quintana et al., 2019) and thereby impacts PCAs' effectiveness to contribute to human well-being. For example, material and nonmaterial services provided by nature in North Luangwa include the provision of building materials (Chidumayo, 2016), food (Anderson et al., 2015, Dumas et al., 2017, I9), and emotional connections to specific places (I4, I8). Disservices and disbenefits are human-wildlife conflicts (Gross et al., 2018, I3, I19, I26) or crop damage by wildlife (I19, I27, Subakanya et al., 2018). Negative interactions seem to outnumber positive ones in our study system. However, reports might be skewed toward detrimental outcomes for humans, which requires further investigation.

Second, SEIs belonging to the dimensions *conflict* and *use* considerably shape how people view nature. This, in turn, influences the acceptance and commitment of communities to conservation (Miller, 2005, Soga & Gaston, 2016)—and can thereby cause the emergence of SEIs belonging to the *care* dimension. In North Luangwa, attitudes toward nature vary widely. On the one hand, nature is seen as a "gift from God" (I9) and the source of everything humans need to live. This perception of nature is often linked to SEIs belonging to the *use* dimension and accompanied by support for conservation. In contrast, living near wildlife and nature entails risks: attacks on humans (e.g., I5, I10), crop-raiding (e.g., I19, I27), and destruction of infrastructure (e.g., I17, I20) threaten the survival of some people. Such SEIs result in a hostile attitude: "nature is a threat, not friendly" (I17) and farmers describe that they do not work with but rather fight against nature (I26).

Finally, SEIs belonging to the *care* dimension influence PCA effectiveness by facilitating activities to create sustainable SEIs (da Costa Rego et al., 2015; Sodhi et al., 2011), thereby supporting the long-term effectiveness of PCAs. Such activities often directly tackle conflict or unsustainable use. Examples include conservation efforts that aim to reduce human-wildlife conflict (Anderson et al., 2015; Marks, 2001) and support sustainable natural resource management (Subakanya et al., 2018), different forms of stewardship such as voluntary hunting restrictions (I19, I22), or research on ecological system components (I30, I32).

The analytical framework enables a thorough analysis of single SEI. The framework depicts a causal flow from context to SEIs to outcomes to effectiveness. However, the framework can also be read backwards: ineffective aspects of PCAs can also be related to outcomes of specific SEI, which in turn are influenced by contextual factors. This inversion of perspective presumes reciprocity between SEIs and effectiveness: dynamics in a PCA influence the context, which cascades to changes in the interactions between nature and people, resulting in new outcomes.

4.1.2 | Connecting social-ecological interactions

While the analytical framework identifies single SEI, the causal loop diagram offers insights into the links between these SEIs. Inducing change in the study system requires knowledge about such interactions that can sometimes be closed balancing or reinforcing feedback loops. For example, an oversimplified attempt to reduce subsistence hunting through laws and regulations will negatively affect the food security of local communities. The identification of outcomes and their links to interactions and contexts following the analytical framework allows drawing connections between SEIs and social-ecological effectiveness. Eventually, statements on which SEIs or which context factors support or obstruct social-ecological effectiveness in the study PCAs can be made. Similarly, the causal loop diagram can be used to track causes and effects of different variables and thereby identify places and strategies to intervene in the system.

4.1.3 | Measuring social-ecological effectiveness

Identifying SEIs and understanding interactions between them is a first step to develop site-specific conservation strategies. As a next step, the assessment of PCA effectiveness requires a site-level set of related metrics to allow for quantification. To date, social-ecological metrics that measure effectiveness beyond social or ecological spheres are lacking (Cumming & Allen, 2017). We argue that the development of such metrics is key to advance conservation research and practice. In the case of our study area, such metrics could for example include the proportion of area under direct human influence (measured by % of area exhibiting signs of human presence: infrastructure, cultivated land, livestock herds, logging sites) and the rate of conversion of natural areas for human purposes in km^2/year to measure habitat conversion and encroachment; or the average number of livestock per household and the percentage of households keeping livestock to quantify livestock keeping. The development of such metrics can benefit from the approach we present in this article: A list of SEIs occurring in a given PCA can be used to identify relevant variables for which to create metrics. Causal loop diagrams can then act as tools for working with the metrics by providing a visual portrayal of structures and links within the system that illustrates how different metrics relate to the wider system.

4.2 | Reflecting our approach and positionality

Our work explores dynamics and feedbacks in a particular social-ecological system from the perspective of people living and working in this system. This approach entails several implications regarding the positionality and scope of this study. In the past years, the need for more reflexivity in conservation science became increasingly recognized (Beck et al., 2021; Boyce et al., 2022). In agreement with this call for more self-critical and responsive conservation research (Montana et al., 2020), we reflected on three implications of our approach for the results we present from this research.

First, as we based our work on spoken and written descriptions of the processes taking place in the study area, our inferences are stemming from anthropocentric viewpoints by local stakeholders, scientists and conservationists. This is especially apparent when considering the three dimensions *care*, *conflict*, and *use*. Because we assigned different SEIs to these categories based on the interviews and literature, the resulting classification is inherently anthropocentric and does not represent these interactions from the point of view of the nonhuman inhabitants of the study area. While the nature of our data resulted in this human-centered perspective on interactions between the PCAs and the people living and working there, we acknowledge that other viewpoints on such interactions exist and are valuable. For example, several research areas have incorporated more-than-human perspectives in the past years (e.g., political ecology: Whatmore, 2013; intrinsic values of nature: O'Connor & Kenter, 2019; nature-based solutions: Maller, 2021) to account for realities beyond human perception and rationality. Such approaches have the potential to reveal new dimensions and interpretations of SEIs but were beyond the scope of this study.

Second, we acknowledge that conservation science is inextricably informed by normative values (Beck et al., 2021, Boyce et al. 2022). In our case, this has two consequences. First, the interviews we based our work on are not entirely objective assessments of the processes taking place in the study area but rather paint a partial picture that is influenced by respondents' personal experiences. Second, the literature we included in our analysis as well as the inferences we made from the data, are at least partially affected by normative values. Throughout our analysis, we paid attention to draw conclusions based on the existing data and refrain from subjective interpretations. Nevertheless, we believe it is important to acknowledge that conservation science is shaped by researchers' own background and (predominantly Western) values (Beck et al., 2021, Boyce et al. 2022) and that interview data are influenced by stakeholders' normative values, rules and knowledge (Colloff et al., 2017).

Third, because we focused on interactions between local people (users) and their environment (resource system), some elements of the social-ecological system of PCAs in North Luangwa (Ostrom, 2009) are not included in the study. This includes for instance decision-making processes about human-human interactions or about human-wildlife conflicts that are taking place in the PCAs, and which are, in fact, a manifestation of conflicts between human interests (Madden, 2004, Dickmann 2010, Redpath et al., 2015). In contrast, the three dimensions *care*, *conflict*, and *use* summarize how people relate to the PCAs and describe direct interactions between stakeholders and their environment.

In summary, our decision to base our work on interviews with local stakeholders as well as relevant literature on the topic results in an anthropocentric, normative view on interactions between humans and their environment that does not capture all processes happening in the study system. These limitations, however, do not mean that our results are irrelevant in the real world. We integrated a wide range of voices of stakeholders, scientists and conservationists that are all key voices needed to create sustainable PCAs and elicited central SEIs taking place in the North Luangwa PCAs. This knowledge can contribute to tackling conservation and sustainability challenges in the study area. In addition, the resulting framework can be applied to other social-ecological systems.

5 | CONCLUSION

Protected areas have the potential to significantly contribute to the conservation of biodiversity, the integrity of ecosystem processes, and to human well-being (CBD 2020). Promoting this potential requires the consideration of social-ecological interactions that are central to understanding the roots of (in)effectiveness of protected areas and leverage change toward resilient, sustainable systems. Here, we propose a framework that guides a thorough analysis of social-ecological interactions occurring in a given protected area. First, the analytical framework facilitates the analysis of single social-ecological interactions. Second, the three dimensions *care*, *conflict*, and *use* summarize the different types of social-ecological interactions occurring in PCAs. Third, the causal loop diagram illustrates links and feedback between social-ecological interactions. These three key results can be applied to other PCAs to varying degrees. The analytical framework can be applied to other PCAs without further adjustments; the three dimensions *care*, *conflict*, and *use* can serve as an orientation toward which SEIs might occur in a PCA; the causal loop diagram is site-specific and needs to be specifically generated for the PCA of interest. Although there are universally congruent dynamics in PCAs worldwide, reaching impactful area-based conservation measures in different contexts requires case-specific analyses of SEIs and their dynamics that actively involve local stakeholders (guided by the analytical framework and the three dimensions of interactions, and involving a causal loop diagram). The holistic understanding of dynamics and processes generated with the help of this approach can support the development of effective, resilient, and sustainable protected areas that meet the biodiversity and human well-being goals.

ACKNOWLEDGMENTS

We thank all interviewees for talking to us about protected areas and their interactions with nature and wildlife. Ethical approval has been obtained by the Ethics Advisory Board of Leuphana University. We thank P. J. Muyoma for help in the field and translations, C. Lakemann for the identification of stakeholders, V. Widawski for transcription of the interviews and E. Gross for practical advice. JL acknowledges funding through a Robert-Bosch Junior Professorship, which enabled the research project "Wildlife, Values, Justice: Reconciling Sustainability in African Protected Areas." AG appreciates the financial support of the German Research Foundation (DFG; PArCS project #409732304). We thank two anonymous reviewers for their constructive feedback on an earlier version of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available upon request from the corresponding author, [JL]. The data are not publicly available due to the privacy of research participants.

ORCID

Marina Frietsch https://orcid.org/0000-0001-5992-314X
Noelia Zafra-Calvo https://orcid.org/0000-0003-3350-0784
Arash Ghoddousi https://orcid.org/0000-0001-9605-3091
Jacqueline Loos https://orcid.org/0000-0002-7639-2894

REFERENCES

Abel, N., & Blaikie, P. (1986). Elephants, people, parks and development: The case of the Luangwa Valley, Zambia. *Environmental Management*, *10*(6), 735–751. https://doi.org/10.1007/BF01867727

Alderton, S., Macleod, E. T., Anderson, N. E., Machila, N., Simuunza, M., Welburn, S. C., & Atkinson, P. M. (2018). Exploring the effect of human and animal population growth on vector-borne disease transmission with an agent-based model of Rhodesian human African trypanosomiasis in eastern province, Zambia. *PLoS Neglected Tropical Diseases*, *12*(11), 1–26. https://doi.org/10.1371/journal.pntd.0006905

Anderson, N. E., Mubanga, J., Machila, N., Atkinson, P. M., Dzingirai, V., & Welburn, S. C. (2015). Sleeping sickness and its relationship with development and biodiversity conservation in the Luangwa Valley, Zambia. *Parasites and Vectors*, *8*(224), 1–14. https://doi.org/10.1186/s13071-015-0827-0

Beck, J. M., Elliott, K. C., Booher, C. R., Renn, K. A., & Montgomery, R. A. (2021). The application of reflexivity for conservation science. *Biological Conservation*, *262*, 109322. https://doi.org/10.1016/j.biocon.2021.109322

Becker, M., McRobb, R., Watson, F., Droge, E., Kanyembo, B., Murdoch, J., & Kakumbi, C. (2013). Evaluating wire-snare poaching trends and the impacts of by-catch on elephants and large carnivores. *Biological Conservation*, *158*, 26–36. https://doi.org/10.1016/j.biocon.2012.08.017

Berkes, F., & Folke, C. (1998). *Linking social and ecological systems: Management practices and social mechanisms for building resilience*. Cambridge University Press.

Boonstra, W. J. (2016). Conceptualizing power to study social-ecological interactions. *Ecology and Society*, *21*(1), 21. https://doi.org/10.5751/ES-07966-210121

Boyce, P., Bhattacharyya, J., & Linklater, W. (2022). The need for formal reflexivity in conservation science. *Conservation Biology*, *36*(2), e13840. https://doi.org/10.1111/cobi.13840

Caillon, S., Cullman, G., Verschuuren, B., & Sterling, E. J. (2017). Moving beyond the human–nature dichotomy through biocultural approaches: Including ecological well-being in resilience indicators. *Ecology and Society*, *22*(4), 27. https://doi.org/10.5751/ES-09746-220427

Ceballos, G., Ehrlich, P. R., & Raven, P. H. (2020). Vertebrates on the brink as indicators of biological annihilation and the sixth mass extinction. *Proceedings of the National Academy of Sciences*, *117*(24), 13596–13602. https://doi.org/10.1073/pnas.1922686117

Chidumayo, E. N. (2016). Distribution and abundance of a keystone tree, Schinziophyton rautanenii, and factors affecting its structure in Zambia, southern Africa. *Biodiversity and Conservation*, *25*(4), 711–724. https://doi.org/10.1007/s10531-016-1086-x

Chomba, C., & Matandiko, W. (2011). Population status of black and white rhinos in Zambia. *Pachyderm*, *50*, 50–55 Retrieved from: http://www.rhinoresourcecenter.com/pdf_files/133/1332550918.pdf

Coad, L., Leverington, F., Knights, K., Geldmann, J., Eassom, A., Kapos, V., Kingston, N., de Lima, M., Zamora, C., Cuardros, I., & Nolte, C. (2015). Measuring impact of protected area management interventions: Current and future use of the Global Database of Protected Area Management Effectiveness. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*(1681), p.20140281.

Coletta, V. R., Pagano, A., Pluchinotta, I., Fratino, U., Scrieciu, A., Nanu, F., & Giordano, R. (2021). Causal loop diagrams for supporting nature based solutions participatory design and performance assessment. *Journal of Environmental Management*, *280*, 111668.

Colloff, M. J., Martín-López, B., Lavorel, S., Locatelli, B., Gorddard, R., Longaretti, P.-Y., Walters, G., van Kerkhoff, L., Wyborn, C., Coreau, A., & Wise, R. M. (2017). An integrative research framework for enabling transformative adaptation. *Environmental Science & Policy*, *68*, 87–96. https://doi.org/10.1016/j.envsci.2016.11.007

Convention on Biological Diversity. (2020). Update of the zerodraft of the post-2020 global biodiversity framework. (Report No. CBD/POST2020/PREP/2/1).

Creel, S., M'soka, J., Dröge, E., Rosenblatt, E., Becker, M. S., Matandiko, W., & Simpamba, T. (2016). Assessing the sustainability of African lion trophy hunting, with recommendations for policy. *Ecological Applications*, *26*(7), 2347–2357. https://doi.org/10.1002/eap.1377

Cumming, G. S., & Allen, C. R. (2017). Protected areas as social-ecological systems: Perspectives from resilience and social-ecological systems theory. *Ecological Applications*, *27*(6), 1709–1717. https://doi.org/10.1002/eap.1584

Cumming, G. S., Allen, C. R., Ban, N. C., Biggs, D., Biggs, H. C., Cumming, D. H., De Vos, A., Epstein, G., Etienne, M., Maciejewski, K., Mathevet, R., Moore, C., Nenadovic, M., & Schoon, M. (2015). Understanding protected area resilience: A multi-scale, social-ecological approach. *Ecological Applications*, *25*(2), 299–319. https://doi.org/10.1890/13-2113.1

Cumming, G. S., Cumming, D. H., & Redman, C. L. (2006). Scale mismatches in social-ecological systems: Causes, consequences, and solutions. *Ecology and Society*, *11*(1), 1–20 https://www.jstor.org/stable/26267802

Curry, C. J., White, P. A., & Derr, J. N. (2019). Genetic analysis of African lions (Panthera leo) in Zambia support movement across anthropogenic and geographical barriers. *PLoS One*, *14*(5), 1–16. https://doi.org/10.1371/journal.pone.0217179

da Costa Rego, K. M., Zeppelini, C. G., Lopez, L. C. S., & Alves, R. R. N. (2015). Assessing human-bat interactions around a protected area in northeastern Brazil. *Journal of Ethnobiology and Ethnomedicine*, *11*(1), 80–88. https://doi.org/10.1186/s13002-015-0058-7

de Lange, E., Woodhouse, E., & Milner-Gulland, E. J. (2016). Approaches used to evaluate the social impacts of protected areas. *Conservation Letters*, *9*(5), 327–333. https://doi.org/10.1111/conl.12223

Dickman, A. J. (2010). Complexities of conflict: The importance of considering social factors for effectively resolving human–wildlife conflict. *Animal Conservation*, *13*(5), 458–466. https://doi.org/10.1111/j.1469-1795.2010.00368.x

dos Santos Ribas, L. G., Pressey, R. L., Loyola, R., & Bini, L. M. (2020). A global comparative analysis of impact evaluation methods in estimating the effectiveness of protected areas. *Biological Conservation*, *246*, 108595. https://doi.org/10.1016/j.biocon.2020.108595

Dudley, N. (2008). *Guidelines for applying protected area management categories*. IUCN.

Dumas, S. E., Kassa, L., Young, S. L., & Travis, A. J. (2018). Examining the association between livestock ownership typologies and child nutrition in the Luangwa Valley, Zambia. *PLoS One*, *13*(2), 1–21. https://doi.org/10.1371/journal.pone.0191339

Dumas, S. E., Lungu, L., Mulambya, N., Daka, W., Lewis, D., & Travis, A. (2017). Effect of sustainable poultry interventions on household food security and resilience in game management areas of Zambia's Luangwa Valley: A before-and-after study. *The Lancet Global Health*, *5*, 24. https://doi.org/10.1016/S2214-109X(17)30131-6

Dumas, S. E., Lungu, L., Mulambya, N., Daka, W., McDonald, E., Steubing, E., Lewis, T., Backel, K., Jange, J., Lucio-Martinez, B., Lewis, D., & Travis, A. J. (2016). Sustainable smallholder poultry interventions to promote food security and social, agricultural, and ecological resilience in the Luangwa Valley. *Zambia. Food Security*, *8*(3), 507–520. https://doi.org/10.1007/s12571-016-0579-5

Ellis, E. C., Pascual, U., & Mertz, O. (2019). Ecosystem services and nature's contribution to people: Negotiating diverse values and trade-offs in land systems. *Current Opinion in Environmental Sustainability*, *38*, 86–94. https://doi.org/10.1016/j.cosust.2019.05.001

Fox, D., & Xu, F. (2017). Evolutionary and socio-cultural influences on feelings and attitudes towards nature: A cross-cultural study. *Asia Pacific Journal of Tourism Research*, *22*(2), 187–199. https://doi.org/10.1080/10941665.2016.1217894

García, M. M., Hertz, T., Schlüter, M., Preiser, R., & Woermann, M. (2020). Adopting process-relational perspectives to tackle the challenges of social-ecological systems research. *Ecology and Society*, *25*(1), 29. https://doi.org/10.5751/ES-11425-250129

Geldmann, J., M. Deguignet, A. Balmford, N. D. Burgess, N. Dudley, M. Hockings, N. Dudley, M. Hockings, N. Kingston, H. Klimmek, A. H. Lewis, C. Rahbek, S. Stolton, C. Vincent, S. Wells, S. Woodley, and J. E. Watson. (2020). Essential indicators for measuring area-based conservation effectiveness in the post-2020 global biodiversity framework. https://doi.org/10.20944/preprints202003.0370.v1

Geldmann, J., Manica, A., Burgess, N. D., Coad, L., & Balmford, A. (2019). A global-level assessment of the effectiveness of protected areas at resisting anthropogenic pressures. *Proceedings of the National Academy of Sciences*, *116*(46), 23209–23215. https://doi.org/10.1073/pnas.1908221116

Gentles, S. J., Charles, C., Nicholas, D. B., Ploeg, J., & McKibbon, K. A. (2016). Reviewing the research methods literature: Principles and strategies illustrated by a systematic overview of sampling in qualitative research. *Systematic Reviews*, *5*(1), 172. https://doi.org/10.1186/s13643-016-0343-0

Ghoddousi, A., Loos, J., & Kuemmerle, T. (2022). An outcome-oriented, social–ecological framework for assessing protected area effectiveness. *Bioscience*, *72*, 201–212. https://doi.org/10.1093/biosci/biab114

Greenhalgh, T., & Peacock, R. (2005). Effectiveness and efficiency of search methods in systematic reviews of complex evidence: Audit of primary sources. *BMJ*, *331*(7524), 1064–1065. https://doi.org/10.1136/bmj.38636.593461.6

Gross, E. M., Lahkar, B. P., Subedi, N., Nyirenda, V. R., Lichtenfeld, L. L., & Jakoby, O. (2018). Seasonality, crop type and crop phenology influence crop damage by wildlife herbivores in Africa and Asia. *Biodiversity and Conservation*, *27*(8), 2029–2050. https://doi.org/10.1007/s10531-018-1523-0

Hanspach, J., Hartel, T., Milcu, A. I., Mikulcak, F., Dorresteijn, I., Loos, J., von Wehrden, H., Kuemmerle, T., Abson, D., Kovács-Hostyánszki, A., Báldi, A., & Fischer, J. (2014). A holistic approach to studying social-ecological systems and its application to southern Transylvania. *Ecology and Society*, *19*(4), 32.

Haraldsson, H. V. (2004). Introduction to system thinking and causal loop diagrams. *Reports in Ecology and Environmental Engineering*, *1*, 1–50.

Hart, C. (2001). *Doing a literature search: A comprehensive guide for the social sciences*. Sage.

Jiren, T. S., Hanspach, J., Schultner, J., Fischer, J., Bergsten, A., Senbeta, F., Hylander, K., & Dorresteijn, I. (2020). Reconciling food security and biodiversity conservation: Participatory scenario planning in southwestern Ethiopia. *Ecology and Society*, *25*(3), 24.

Kaunda, C. J. (2016). Towards an African ecogender theology: A decolonial theological perspective. *Stellenbosch Theological Journal*, *2*(1), 177–202. https://doi.org/10.17570/stj.2016.v2n1.a09

Kiffner, C., Binzen, G., Cunningham, L., Jones, M., Spruiell, F., & Kioko, J. (2020). Wildlife population trends as indicators of protected area effectiveness in northern Tanzania. *Ecological Indicators*, *110*, 105903. https://doi.org/10.1016/j.ecolind.2019.105903

Leach, M., Bett, B., Said, M., Bukachi, S., Sang, R., Anderson, N., Machila, N., Kuleszo, J., Schaten, K., Dzingirai, V., Mangwanya, L., Ntjamoa-Baidu, Y., Lawson, E., Amponsah-Mensah, K., Moses, L. M., Wilkinson, A., Grant, D. S., & Koninga, J. (2017). Local disease–ecosystem–livelihood dynamics: Reflections from comparative case studies in Africa. *Biological Sciences*, *372*(1725), 1–18. https://doi.org/10.1098/rstb.2016.0163

Lehman, M. W., Craig, A. S., Malama, C., Kapina-Kany'anga, M., Malenga, P., Munsaka, F., Muwowo, S., Shadomy, S., & Marx, M. A. (2017). Role of food insecurity in outbreak of anthrax infections among humans and hippopotamuses living in a game reserve area, rural Zambia. *Emerging Infectious Diseases*, *23*(9), 1471–1477. https://doi.org/10.3201/eid2309.161597

Leverington, F., Costa, K. L., Pavese, H., Lisle, A., & Hockings, M. (2010). A global analysis of protected area management effectiveness. *Environmental Management*, *46*(5), 685–698. https://doi.org/10.1007/s00267-010-9564-5

Lewis, D., Bell, S. D., Fay, J., Bothi, K. L., Gatere, L., Kabila, M., Mukamba, M., Matokwani, E., Mushimbalume, M., Moraru, C. I., Lehmann, J., Lassoie, J., Wolfe, D., Lee, D. R., Buck, L., & Travis, A. J. (2011). Community Markets for Conservation (COMACO) links biodiversity conservation with sustainable improvements in livelihoods and food production. *Proceedings of the National Academy of Sciences*, *108*(34), 13957–13962. https://doi.org/10.1073/pnas.1011538108

Lindsey, P. A., Nyirenda, V. R., Barnes, J. I., Becker, M. S., McRobb, R., Tambling, C. J., Taylor, W. A., Watson, F. G., & M. t'Sas-Rolfes. (2014). Underperformance of African protected area networks and the case for new conservation models: Insights from Zambia. *PLoS One*, *9*(5), 1–14. https://doi.org/10.1371/journal.pone.0094109

Lindsey, P. A., Petracca, L. S., Funston, P. J., Bauer, H., Dickman, A., Everatt, K., Flyman, M., Henschel, P., Hinks, A. E., Kasiki, S., Loveridge, A., Macdonald, D. W., Mandisodza, R., Mgoola, W., Miller, S. M., Nazerali, S., Siebe, L., Uiseb, K., & Hunter, L. T. B. (2017). The performance of African protected areas for lions and their prey. *Biological Conservation*, *209*, 137–149. https://doi.org/10.1016/j.biocon.2017.01.011

Madden, F. (2004). Creating coexistence between humans and wildlife: Global perspectives on local efforts to address human–wildlife conflict. *Human Dimensions of Wildlife*, *9*(4), 247–257. https://doi.org/10.1080/10871200490505675

Maller, C. (2021). Re-orienting nature-based solutions with more-than-human thinking. *Cities*, *113*, 103155. https://doi.org/10.1016/j.cities.2021.103155

Manning, I. P. A. (2012). The landsafe socioecological development model for the customary commons of Zambia: Evolution and formalization. *Natural Resources Journal*, *52*(1), 195–214 http://www.jstor.org/stable/24889602

Marks, S. A. (2001). Back to the future: Some unintended consequences of Zambia's community-based wildlife program (ADMADE). *Africa Today*, *48*(1), 121–141 https://www.jstor.org/stable/4187393

Martín-López, B., Palomo, I., García-Llorente, M., Iniesta-Arandia, I., Castro, A. J., Del Amo, D. G., Gómez-Baggethun, E., & Montes, C. (2017). Delineating boundaries of social-ecological systems for landscape planning: A comprehensive spatial approach. *Land Use Policy*, *66*, 90–104. https://doi.org/10.1016/j.landusepol.2017.04.040

McKinnon, M. C., Cheng, S. H., Dupre, S., Edmond, J., Garside, R., Glew, L., Holland, M. B., Levine, E., Masuda, Y. J., Miller, D., Oliveira, I., Revenaz, J., Roe, D., Shamer, S., Wilkie, D., Wongbusarakum, S., & Woodhouse, E. (2016). What are the effects of nature conservation on human well-being? A systematic map of empirical evidence from developing countries. *Environmental Evidence*, *5*(1), 1–25. https://doi.org/10.1186/s13750-016-0058-7

Miller, J. R. (2005). Biodiversity conservation and the extinction of experience. *Trends in Ecology and Evolution*, *20*(8), 430–434. https://doi.org/10.1016/j.tree.2005.05.013

Milupi, I. D., Somers, M. J., & Ferguson, W. (2020). Inadequate community engagement hamstrings sustainable wildlife resource management in Zambia. *African Journal of Ecology*, *58*(1), 112–122. https://doi.org/10.1111/aje.12685

Montana, J., Elliott, L., Ryan, M., & Wyborn, C. (2020). The need for improved reflexivity in conservation science. *Environmental Conservation*, *47*(4), 217–219. https://doi.org/10.1017/S0376892920000326

Muradian, R., & Pascual, U. (2018). A typology of elementary forms of human-nature relations: A contribution to the valuation debate. *Current Opinion in Environmental Sustainability*, *35*, 8–14. https://doi.org/10.1016/j.cosust.2018.10.014

Nakamura, Y., Yamagishi, J., Hayashida, K., Osada, N., Chatanga, E., Mweempwa, C., Chilongo, K., Chisi, J., Musaya, J., Inoue, N., Namangala, B., & Sugimoto, C. (2019). Genetic diversity and population structure of Glossina morsitans morsitans in the active foci of human African trypanosomiasis in Zambia and Malawi. *PLoS Neglected Tropical Diseases*, *13*(7), 1–15. https://doi.org/10.1371/journal.pntd.0007568

Niemeijer, D., & de Groot, R. S. (2008). A conceptual framework for selecting environmental indicator sets. *Ecological Indicators*, *8*(1), 14–25. https://doi.org/10.1016/j.ecolind.2006.11.012

Nyhus, P. J. (2016). Human–wildlife conflict and coexistence. *Annual Review of Environment and Resources*, *41*, 143–171. https://doi.org/10.1146/annurev-environ-110615-085634

Nyirenda, V. R., Musonda, F., Kambole, S., & Tembo, S. (2017). Peasant farmer–raptor conflicts around Chembe bird sanctuary, Zambia, Central Africa: Poultry predation, ethno–biology, land use practices and conservation. *Animal Biodiversity and Conservation*, *40*(1), 121–132. https://doi.org/10.32800/abc.2017.40.0121

O'Connor, S., & Kenter, J. O. (2019). Making intrinsic values work; integrating intrinsic values of the more-than-human world through the life framework of values. *Sustainability Science*, *14*(5), 1247–1265. https://doi.org/10.1007/s11625-019-00715-7

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, *325*(5939), 419–422. https://doi.org/10.1126/science.1172133

Palomo, I., Montes, C., Martín-López, B., González, J. A., García-Llorente, M., Alcorlo, P., & Mora, M. R. G. (2014). Incorporating the social–ecological approach in protected areas in the Anthropocene. *Bioscience*, *64*(3), 181–191. https://doi.org/10.1093/biosci/bit033

Pimm, S. L., Jenkins, C. N., Abell, R., Brooks, T. M., Gittleman, J. L., Joppa, L. N., Raven, P. H., Roberts, M. C., & Sexton, J. O. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. *Science*, *344*(6187), 987–999.

Preiser, R., Biggs, R., De Vos, A., & Folke, C. (2018). Social-ecological systems as complex adaptive systems. *Ecology and Society*, *23*(4), 46. https://doi.org/10.5751/ES-10558-230446

Ramos-Quintana, F., Sotelo-Nava, H., Saldarriaga-Noreña, H., & Tovar-Sánchez, E. (2019). Assessing the environmental quality resulting from damages to human-nature interactions caused by population increase: A systems thinking approach. *Sustainability*, *11*(7), 1–29. https://doi.org/10.3390/su11071957

Ray-Brambach, R. R., Stommel, C., & Rödder, D. (2018). Home ranges, activity patterns and habitat preferences of leopards in Luambe National Park and adjacent game management area in the Luangwa Valley, Zambia. *Mammalian Biology*, *92*(1), 102–110. https://doi.org/10.1016/j.mambio.2017.11.002

Redpath, S. M., Bhatia, S., & Young, J. (2015). Tilting at wildlife: Reconsidering human–wildlife conflict. *Oryx*, *49*(2), 222–225. https://doi.org/10.1017/S0030605314000799

Republic of Zambia. (2018). National parks and wildlife policy. Ministry of Tourism and Arts, 42 pp. https://www.wpazambia.com/wp-content/uploads/2019/03/National-Wildlife-Policy-2018.pdf Accessed 1 June 2023.

Richardson, R. B., Fernandez, A., Tschirley, D., & Tembo, G. (2012). Wildlife conservation in Zambia: Impacts on rural household welfare. *World Development*, *40*(5), 1068–1081. https://doi.org/10.1016/j.worlddev.2011.09.019

Riggio, J., Jacobson, A., Dollar, L., Bauer, H., Becker, M., Dickman, A., Funston, P., Groom, R., Henschel, P., de Iongh, H., Lichtenfeld, L., & Pimm, S. (2013). The size of savannah Africa: A lion's (Panthera leo) view. *Biodiversity and Conservation*, *22*(1), 17–35. https://doi.org/10.1007/s10531-012-0381-4

Rissman, A. R., & Gillon, S. (2017). Where are ecology and biodiversity in social–ecological systems research? A review of research methods and applied recommendations. *Conservation Letters*, *10*(1), 86–93. https://doi.org/10.1111/conl.12250

Robledo, C., Clot, N., Hammill, A., & Riché, B. (2012). The role of forest ecosystems in community-based coping strategies to climate hazards: Three examples from rural areas in Africa. *Forest Policy and Economics*, *24*, 20–28. https://doi.org/10.1016/j.forpol.2011.04.006

Rosenblatt, E., Creel, S., Becker, M. S., Merkle, J., Mwape, H., Schuette, P., & Simpamba, T. (2016). Effects of a protection gradient on carnivore density and survival: An example with leopards in the Luangwa valley, Zambia. *Ecology and Evolution*, *6*(11), 3772–3785. https://doi.org/10.1002/ece3.2155

Rosenblatt, E., Creel, S., Schuette, P., Becker, M. S., Christianson, D., Dröge, E., Mweetwa, T., Mwape, H., Merkle, J., M'soka, J., Masonde, J., & Simpamba, T. (2019). Do protection gradients explain patterns in herbivore densities? An example with ungulates in Zambia's Luangwa Valley. *PLoS One*, *14*(10), 1–21. https://doi.org/10.1371/journal.pone.0224438

Roux, D. J., Smith, M. K. S., Smit, I. P., Freitag, S., Slabbert, L., Mokhatla, M. M., Hayes, J., & Mpapane, N. P. (2020). Cultural ecosystem services as complex outcomes of people–nature interactions in protected areas. *Ecosystem Services*, *43*, 1–12. https://doi.org/10.1016/j.ecoser.2020.101111

Ruiz-Ballesteros, E., & Ramos-Ballesteros, P. (2019). Social-ecological resilience as practice: A household perspective from Agua Blanca (Ecuador). *Sustainability*, *11*(20), 1–15. https://doi.org/10.3390/su11205697

Schlüter, M., Baeza, A., Dressler, G., Frank, K., Groeneveld, J., Jager, W., Janssen, M. A., McAllister, R. R. J., Müller, B., Orach, K., Schwarz, N., & Wijermans, N. (2017). A framework for mapping and comparing behavioural theories in models of social-ecological systems. *Ecological Economics*, *131*, 21–35. https://doi.org/10.1016/j.ecolecon.2016.08.008

Schlüter, M., Haider, L. J., Lade, S. J., Lindkvist, E., Martin, R., Orach, K., Wijermans, N., & Folke, C. (2019). Capturing emergent phenomena in social-ecological systems. *Ecology and Society*, *24*(3), 11. https://doi.org/10.5751/ES-11012-240311

Schreckenberg, K., Franks, P., Martin, A., & Lang, B. (2016). Unpacking equity for protected area conservation. *Parks*, *22*(2), 11–26. https://doi.org/10.2305/IUCN.CH.2016.PARKS-22-2KS.en

Sodhi, N. S., Butler, R., & Raven, P. H. (2011). Bottom-up conservation. *Biotropica*, *43*(5), 521–523. https://doi.org/10.1111/j.1744-7429.2011.00793.x

Soga, M., & Gaston, K. J. (2016). Extinction of experience: The loss of human-nature interactions. *Frontiers in Ecology and the Environment*, *14*(2), 94–101. https://doi.org/10.1002/fee.1225

Soga, M., & Gaston, K. J. (2020). The ecology of human–nature interactions. *Proceedings of the Royal Society*, *287*(1918), 1–10. https://doi.org/10.1098/rspb.2019.1882

Sterman, J. D. (2001). System dynamics modeling: Tools for learning in a complex world. *California Management Review*, *43*(4), 8–25. https://doi.org/10.2307/41166098

Subakanya, M., Tembo, G., & Richardson, R. B. (2018). Land use planning and wildlife-inflicted crop damage in Zambia.

Environments, *5*(10), 110–121. https://doi.org/10.3390/environments5100110

UNEP-WCMC. (2020). Protected area profile for Zambia from the world database of protected areas. Retrieved from: https://www.protectedplanet.net/country/ZMB

Ventana Systems. (2015). Vensim [Software]. http://vensim.com/free-download

Watson, F. G., Becker, M. S., McRobb, R., & Kanyembo, B. (2013). Spatial patterns of wire-snare poaching: Implications for community conservation in buffer zones around National Parks. *Biological Conservation*, *168*, 1–9. https://doi.org/10.1016/j.biocon.2013.09.003

Watson, F. G., Becker, M. S., Milanzi, J., & Nyirenda, M. (2015). Human encroachment into protected area networks in Zambia: Implications for large carnivore conservation. *Regional Environmental Change*, *15*(2), 415–429. https://doi.org/10.1007/s10113-014-0629-5

Whatmore, S. J. (2013). Political ecology in a more-than-human world: Rethinking 'Natural'Hazards. In *Anthropology and nature* (pp. 79–94). Routledge.

White, P. A., & Belant, J. L. (2015). Provisioning of game meat to rural communities as a benefit of sport hunting in Zambia. *PLoS One*, *10*(2), 1–13. https://doi.org/10.1371/journal.pone.0117237

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Frietsch, M., Zafra-Calvo, N., Ghoddousi, A., & Loos, J. (2023). Advancing protected area effectiveness assessments by disentangling social-ecological interactions: A case study from the Luangwa Valley, Zambia. *Conservation Science and Practice*, e12974. https://doi.org/10.1111/csp2.12974