



Improving Human-Lion Conflict Research Through Interdisciplinarity

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Wicked socio-ecological problems are inherently complex and require an interdisciplinary approach for mitigation. Here, we investigated the many drivers of human-lion conflict in East Africa and present a novel conceptual model illustrating the intricate interactions within and between the five main dimensions of conflict. We highlight the importance of broadening research efforts to include these multiple dimensions at all stages of the research process as well as to incorporate higher levels of diversity into research teams. We offer examples and recommendations on how to approach human-lion conflict from a more interdisciplinary perspective. However, challenges exist and will continue to arise as diverse interdisciplinary teams form. We address several main barriers to interdisciplinarity and encourage researchers and institutions to support a team science approach to solving wicked problems like human-lion conflict.

Keywords: conflict, human, interdisciplinarity, lion (*Panthera leo*), team science

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SETTING THE STAGE FOR CONFLICT

Global human-wildlife conflict has increased drastically in recent decades, and the countries of East Africa experience some of the highest rates of conflict in the world. Agonistic interactions are especially severe when involving domestic cattle and African lions (*Panthera leo*) (Franco et al., 2018; Gebresenbet et al., 2018; van Eeden et al., 2018). Cattle are often the most profitable livestock type and losses to lions can have serious financial impacts on livestock-owners (Patterson et al., 2004; Kissui, 2008; Mwakatobe et al., 2013). Moreover, within some traditionally pastoralist tribes, cattle are deeply ingrained in both religious and cultural heritage (Galaty, 1982), and owning cattle in these societies is a feature of communal identity and can be a sign of pride, wealth, and status (Hazzah, 2006; Nkiziibweki and Emmanuel, 2018). Consequently, depredation of cattle is viewed more strongly than loss of any other livestock type and can provoke a retaliatory response among affected people resulting in the killing or maiming of lions perceived to be responsible for these losses (De Iongh et al., 2009; Loveridge et al., 2010; Mponzi et al., 2014; Kuiper et al., 2015). Although the factors that threaten lion survival are many (Treves and Karanth, 2003; Karanth and Chellam, 2009; Maitima et al., 2009; Becker et al., 2013; Lindsey et al., 2013; Everatt et al., 2015), conflict with humans over livestock is one of the most pressing issues affecting lion conservation today (Bauer et al., 2018; Cushman et al., 2018). Reductions in lion populations not only have devastating ecological impacts (Miller et al., 2001; Sinclair, 2003; Ripple et al., 2014) but can also result in huge financial losses for the countries where they reside (Fayissa et al., 2008; Okello et al., 2008). Given the environmental and commercial importance of lions and the cultural and socio-economic significance of cattle in the lives of many livestock-owners, it is essential that sustainable solutions for human-lion conflict be developed and implemented.

Despite the simple label, *human-lion* conflict is far greater and more intricate than a *human vs. lion* competition for resources like cattle. Human-lion conflict is part of a complex coupled human and natural system [often abbreviated “CHANS,” an integrated system in which people and natural components inextricably interact (Liu et al., 2007)] which must be understood if the conflict itself is to be addressed. For thousands of years, the East African system has been inhabited by pastoralist tribes that migrate across vast landscapes, herding livestock alongside wildlife, and following seasonal rains (Marshall, 1990; Reid, 2012; Dong et al., 2016). In recent decades however, pastoral lifestyles and ecosystem structure have experienced dramatic changes. Human population growth coupled with subsequent infrastructure and agriculture development have led to large-scale conversion of rangelands (Borjesson et al., 2008; Msoffe et al., 2011). Consequently, many pastoralists have adopted more stationary livelihood strategies in the 20th and 21st centuries (Allsopp, 2009; Western et al., 2009). For nomadic pastoralists, more settled lifestyles contradict many long-held cultural practices with important implications for livestock herd management, livelihoods, and community structure (Homewood et al., 1987; Galvin et al., 2008). The tendency to be more settled, for instance, has changed labor allocation with youth pursuing alternative education and employment options (Tumenta et al., 2013), increased the potential for disease outbreaks deriving from large livestock congregations in confined spaces (Shiilegdamba et al., 2008), and created struggles over access to grazing lands (Fratkin et al., 1999). These evident power structures have been subsequently exacerbated by the establishment of national parks, game controlled areas, and other protected areas (Mbaria and Ogada, 2017). Alternative land-uses like these pay to exist, adding additional monetary pressures for pastoralists to seek occupations not associated with traditionally sustainable livestock husbandry practices (Coast, 2002; Balmford and Whitten, 2003; McCabe, 2003; Kideghesho, 2008). Also, tourism, the primary revenue-generator of protected areas, introduces barriers between local people and wildlife, further diminishing the traditional culture of co-existence held by many African tribes (Rutten, 2002). This can lead to changes in government policies that prioritize wildlife conservation over the livelihoods of pastoralists (Naughton-Treves, 1999). As a result of these changes in landscapes and lifestyles, rates of conflict between people and wildlife, particularly lions and other large carnivores, have increased (Ogutu et al., 2005; Muriuki et al., 2017).

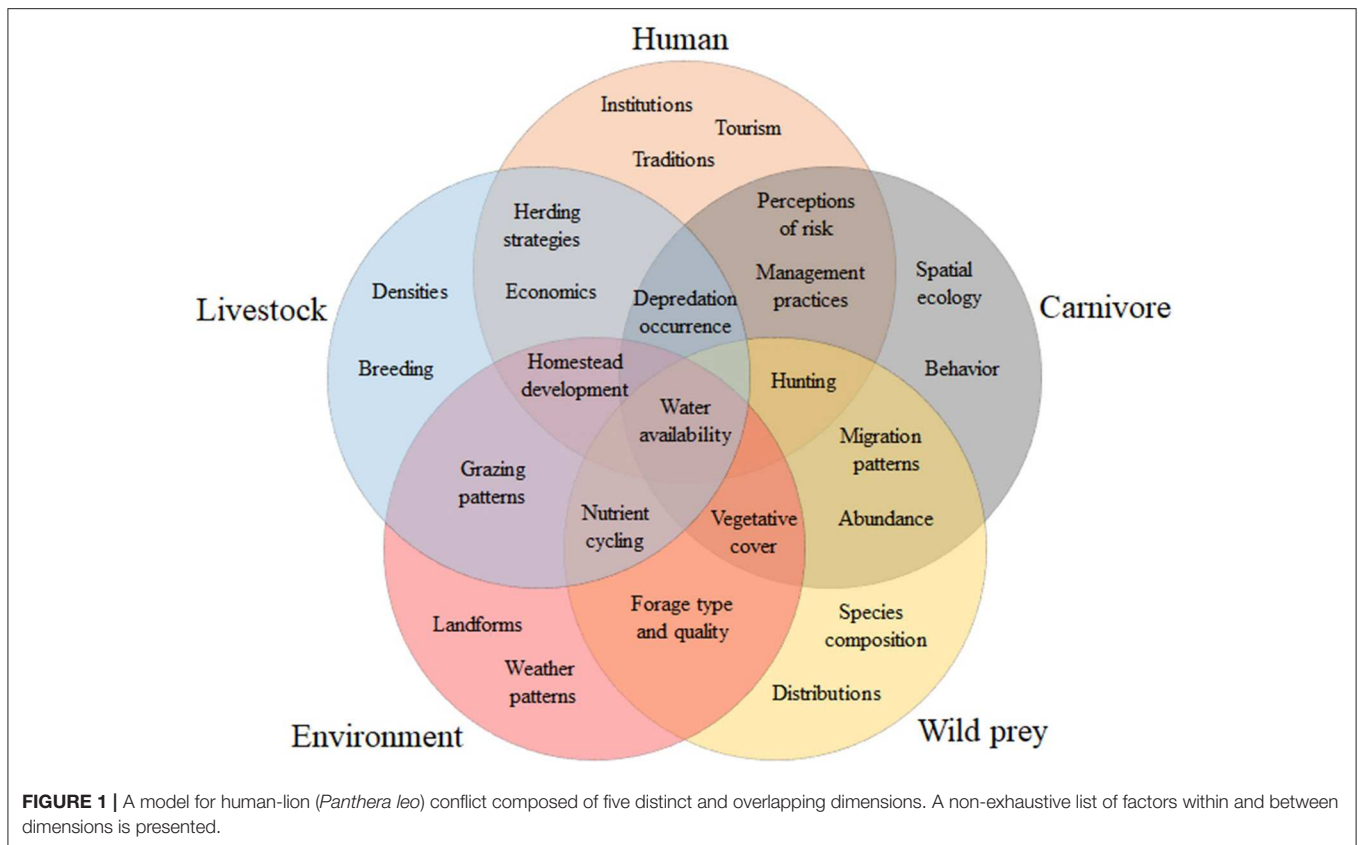
These intricacies position human-lion conflict as a wicked problem. Wicked problems are those that are extremely difficult to manage, have no clear resolution, and typically involve often-competing viewpoints among multiple stakeholders (Rittel and Webber, 1973). Wicked problems cannot be solved using conventional approaches but require partnerships with robust collaboration and transparency among a variety of researchers across the biological, physical, and social disciplines, and may even include arts, humanities, engineering, and new interdisciplinary fields (Berkes, 2004; Rylance, 2013). Collaborative science integrates the vast skills, knowledge, and perspectives needed to fully understand and address wicked

problems like human-lion conflict (Eigenbrode et al., 2007). Thus, studying these problems in an interdisciplinary way is integral to improving scientific understanding, which is the first step in the long process of effectively mitigating conflict. Much of the recent research on human-lion conflict has intended to develop sustainable solutions (Santangeli et al., 2016; Broekhuis et al., 2017; Mkonyi et al., 2017; Trinkel et al., 2017), and most conservation programs have multiple objectives, such as protecting biodiversity and improving livelihoods (Game et al., 2014). However, the suggested solutions may not actually be applicable or valid if they do not embrace the complex nature of the problem and the system from the beginning. This paper intends to (i) summarize past literature to highlight the lack of diverse, collaborative partnerships in human-lion conflict research, (ii) explain why this issue may be hampering the success of human-lion conflict resolution efforts, and (iii) present a conceptual model to help define this wicked problem and to highlight the need for interdisciplinary research teams.

A RESEARCH EVOLUTION

The first step toward skillful decision making, and in this case conflict resolution, is to define the problem (Keeney, 2004). While wicked problems are notoriously difficult to pin down (Rittel and Webber, 1973), previous studies of human-lion conflict have explained many aspects of the issue, as discussed above. Alone, each study describes a portion of the problem using its own perspective, methods, and narrative. But synthesized, this body of literature shows that human-lion conflict can actually be described by five distinct dimensions. As defined by Montgomery et al. (2018), these dimensions include (1) the carnivore dimension (e.g., the distribution, abundance, and behavior of lions), (2) the livestock dimension (e.g., the abundance, behavior, and husbandry of cattle), (3) the wild prey dimension (e.g., the distribution, abundance, and behavior of wild species that are important prey for lions), (4) the human dimension (e.g., the perceptions, practices, politics, economics, social interactions, and institutions of local people), and (5) the environment dimension (e.g., the land cover, weather, seasonality, and natural resources of the region). Each of these five dimensions is associated with spatial locations where carnivores choose to depredate livestock, and each can drive the conflict individually as well as in combination. Thus, human-lion conflict is comprised of complex layers of interacting factors within and between the five main dimensions. Here, we devised a novel conceptual model, including just some of the countless interacting factors, to illustrate the interconnectedness of all five dimensions and the complexity that is inherent to human-lion conflict (see **Figure 1**). While the model does not intend to include every aspect necessary to manage or mitigate conflict, it can be used to more fully comprehend the various factors that lead to actual occurrences of conflict and therefore to identify the types of expertise needed to address each.

Despite this complexity, human-lion conflict has historically been viewed rather narrowly within the scientific community. Montgomery et al. (2018) reviewed all studies of human-lion



conflict published between 1990 and 2015 and found that the majority of papers studied only one or two dimensions at a time, with the most common dimension studied being the human. None of the studies assessed all five dimensions simultaneously. Thus, despite the fact that research on human-lion conflict has grown exponentially since 1990, that research has had quite low levels of interdisciplinarity. Unfortunately, this lack of interdisciplinarity lies in striking contrast to the multidimensional and interrelated nature of the conflict itself and the system in which it lies, suggesting that any proposed solutions or recommendations have not taken into consideration all of the aspects of the initial problem. While it may be impractical to include all interrelationships in any one study, beginning with a systematic examination of the problem will promote communication on crucial problem features and ensure that important dimensions are not omitted (Keeney, 1982).

Just as the five dimensions of human-lion conflict overlap and interact in the model presented in **Figure 1**, so too should the research avenues pursued in the development of solutions. We contend that the complexity of human-lion conflict, as is the case with other wicked problems, is too vast to be effectively evaluated independently. Connections must be forged within the broader community of scientists to form new and flexible working teams (Norris et al., 2016). Therefore, we recommend that researchers invite interdisciplinary experts to collaborate in a team-science approach where all individuals engage in the definition of the problem and then the design,

implementation, and analysis of multifaceted research programs (Stokols et al., 2008; Bennett and Gadlin, 2012). We suggest that the unique hypotheses and methodologies of each separate research dimension inform and support the others and that the scope and scale of each dimension is periodically reevaluated by the team. Overall research objectives must continue to evolve as more data is collected and results determined. In this way, the constant interaction, adaptation, and evolution of a team's work is integral to its interdisciplinarity. Without this vital component, a research initiative may be multidisciplinary but never truly interdisciplinary, or even transdisciplinary (Eigenbrode et al., 2007; Miller et al., 2008).

Within the context of human-lion conflict, the possible interdisciplinary research pathways are innumerable. For example, a team may want to determine if and how cattle behavior is affected by the risk of lion attack. Before designing a study of this type, we recommend that the research team work to identify the ways in which the five dimensions might interact to develop patterns of human-lion conflict. Thereby, the team would need to consider, for example, if the densities of wild prey species vary across their study sites, if all cattle herds have equal access to water sources, or if herder age or tribe affiliation may impact herding strategies. This would likely require the involvement of professionals from multiple disciplines. After data collection and analysis, the team's results would also have important implications for all five dimensions of conflict. Cattle behavior might directly impact the vegetation

and soil within the grazing areas, and the team could use this information to identify habitats at risk of overgrazing, erosion, and land cover change. Through discussion and interpretation of the results, this environmental data might then feed back into the design of research questions associated with the human dimension, such as how local livelihoods are impacted by habitat degradation and environmental uncertainty. Thus, this version of interdisciplinarity provides an example of a research model that inherently examines interactions among the five dimensions before, during, and after the research is conducted and incorporates constant reevaluation of the problem by a variety of collaborators.

BUILDING BLOCKS OF AN INTERDISCIPLINARY TEAM

Montgomery et al. (2018) not only found that studies of human-lion conflict lacked diversity in their research design, but also in their co-authorship. Studies tended to have just three co-authors, most of whom derived from three highly related fields (biology/ecology/zoology, wildlife management/conservation, and environmental science). Additionally, although the human dimension was the most commonly studied component of human-lion conflict, only 4% of papers included co-authors from social science or humanities-based disciplines. Furthermore, less than a quarter of papers had authors from two or more disciplines. These metrics demonstrate again that human-lion conflict research exhibited low levels of interdisciplinarity. Similarly, Bauer et al. (2019) found an extreme lack of diversity in race, gender, and nationality of scientists conducting and publishing lion research (Bauer et al., 2019). Team diversity (in expertise, race, gender, education levels, skillsets, etc.) is a necessary attribute of interdisciplinary research and has been positively correlated with the performance of teams, as measured in a multitude of ways (Bennett et al., 2010; Read et al., 2016). For example, as team diversity increases so too does the frequency of team communication, the creation of more creative problem-solving strategies, and the implementation of higher quality decisions (Milliken and Martins, 1996; Hall et al., 2008). When these collaborations are successful, their accomplishments surpass those of any one individual (Cheruvilil et al., 2014). Thus, as more diverse teams develop, they could hold the potential to change the way human-lion conflict is studied and, ultimately, managed.

The foundation of a diverse interdisciplinary team is the makeup of the team members themselves. Here, this refers not only to each individual team member's core disciplines, but also their personal histories, beliefs, and skillsets. A team formed of people from diverse educational and professional backgrounds should perform better than one from homogeneous backgrounds given their broader range of perspectives and knowledge from which to draw (Eigenbrode et al., 2007; Bell et al., 2011; Norris et al., 2016). Also, a team with a mix of new and tenured members should be more innovative as a result of the combination of fresh ideas and established experience. Therefore, we recommend teams not only increase representation of scientists from

diverse disciplines, but also from diverse backgrounds, cultures, ranks, and education systems, as well. Thus, an effective interdisciplinary team studying human-lion conflict in East Africa, for example, might include native African scholars, team members from around the world, seasoned experts, innovative young professionals, graduate students, those with knowledge in ecology, biology, anthropology, geology, communications, history, political science, and more.

Though examples of these types of teams are becoming more common with NGOs (such as San Diego Zoo Global) and within government agencies (see the European Commission's Horizon 2020 projects or the National Science Foundation's Long Term Ecological Research Network), support for this strategy within academia is comparatively rare. We know of no current interdisciplinary academic teams publishing research on all five dimensions of human-lion conflict. One exemplary case from a different wicked problem, however, can be found in an interdisciplinary study of the Turkana people of Kenya. For over a decade, a team of ecologists, anthropologists, nutritionists, and others conducted intensive research aiming to understand human-environment interactions in grassland ecosystems (Leslie and Little, 1999). Through their research, the team determined that policies promoting the settlement of nomadic peoples were ill-informed, as the Turkana had developed sustainable land-use strategies through changes in diet, mobility, and political relations (Galvin, 1992; Leslie and Little, 1999; McCabe, 2010). This is a superb example of academic interdisciplinary research from a diverse team that was able to produce novel research outcomes from a complex coupled human and natural system. Remarkably, one consideration left out of this long-term study is the role of wildlife populations on the rangelands, especially wild ungulate species and large carnivores. Thus, despite this example, important gaps in our knowledge of these systems still exist. Nevertheless, we believe interdisciplinary teams are best suited to embrace challenges and fill the voids inherent to the pursuit of wicked problems. We recommend that future research builds on the work of this team and others, utilizing a clear conceptual model to more fully define and understand each unique dimension of their wicked problem and to incorporate the knowledge and skills needed to study them appropriately.

A CHALLENGE WORTH PURSUING

While our focus has been on highlighting the ways that increased interdisciplinarity and diversity could improve human-lion conflict research specifically, these concepts would benefit researchers studying other complex wicked problems as well. However, even with a clear but flexible definition of the problem, the guidance of a conceptual model, and an open-minded team, it is crucial to remember that there are no quick fixes for any of the complicated conservation issues emerging today. For example, interdisciplinarity is a time-consuming endeavor that may reduce short-term productivity given the extra time commitment and effort required (Pennington, 2008; Goring et al., 2014; Kwon et al., 2017). However, despite this early

investment of time, as confidence is established within long-term partnerships, the process becomes quicker and can yield higher productivity with time (Jakobsen et al., 2004). Studies have shown that interdisciplinarity increases long-term citation rates, which boosts the visibility of scholarly work and reflects its usefulness and influence (Wang et al., 2015; Leahey et al., 2017). Thus, we encourage emerging interdisciplinary teams to have patience and a clear vision of their long-term goals. Additionally, team leaders can foster morale and a sense of accomplishment by rewarding research outcomes above and beyond publications (Goring et al., 2014), and professors can encourage interdisciplinarity in their classrooms to prepare young scientists for the rigors of such collaborations.

Another possible barrier to successful interdisciplinarity is intra-team variation in theoretical constructs, judgements, and world-views, which are often directly linked to the personal values of the individuals (Lélé and Norgaard, 2005). Within the context of solving wicked problems, team members may have differing opinions on which aspects of the research are of greatest importance to society, and which are most relevant to the scientific evaluation of the problem. Furthermore, there can often be a lack of familiarity with the terminology, methods, and underlying assumptions of the various disciplines involved and a difficulty with properly communicating these terms (Heemskerk et al., 2003; Jakobsen et al., 2004). We recommend that team members attend yearly face-to-face research summits during which all proposed methodologies, research expectations, and current results are presented and discussed. Direct engagement between group members is one of the greatest predictors of productivity (Pentland, 2012), and it is through interaction and communication that trust is built within a team (Bennett et al., 2010). Therefore, we suggest that team leaders take an active role in fostering trust within the group rather than hoping it will evolve over time. Teams should hold open discussions on often-difficult topics such as authorship practices, conflict resolution strategies, and individual expectations in order to overcome challenges relating to personal values and to achieve mutual understanding. Other networking opportunities such as scientific conferences should also become more interdisciplinary in their design to facilitate communication across disciplinary boundaries and to inspire novel thinking and creative partnerships. University faculty and administrators can take an active role in breaking down barriers to interdisciplinarity by making efforts to align performance evaluations to facilitate reward systems among interdisciplinary colleagues, diversifying course offerings, and by encouraging enrollment in non-major science courses or experiential learning activities. Providing young scientists with opportunities for cross-disciplinary scholarship early in their careers will not only equip them with the tools needed to understand and incorporate diverse philosophies into their work, but doing so also has the potential to stimulate future research in ways currently unimagined.

Finally, another challenge for interdisciplinarity is cost. There are several ways to be interdisciplinary: one in which each team member is an expert in their discipline and collaborates with other experts in other disciplines through the mechanisms

discussed here, and another in which each team member seeks to attain a certain level of individual interdisciplinarity in their training so as to approach the research from multiple perspectives (Frodeman, 2010). The latter mode may be costlier, as it requires each team member to acquire a great deal of knowledge of the other collaborating fields. The former mode, however, is more challenging for putting the interdisciplinarity into operation and thus may require increased time and additional communication between members, adding to costs more indirectly (Hunter, 1999; Moran and Ostrom, 2005). Each team leader should be aware of these alternatives, and consider all options when building, maintaining, and funding an interdisciplinary team [one great resource for leaders and team members alike is the National Institute of Health's Collaboration and Team Science Field Guide Bennett et al., 2010]. Additionally, a recent study showed that research proposals with higher levels of interdisciplinarity were less likely to be funded (Bromham et al., 2016). Thus, institutional-level changes need to be made to promote and finance interdisciplinary work.

BRINGING INTERDISCIPLINARITY INTO THE FUTURE

In our increasingly globalized world, international collaborations are predicted to increase across scientific fields (Hall et al., 2008) and younger generations of PhD students are already showing higher proportions of interdisciplinary academic backgrounds than prior generations (Haider et al., 2018). Unfortunately, formal training for scientists and graduate students on how to successfully collaborate within large teams remains rare (Cheruvilil et al., 2014; Elliott et al., 2017). Increased training is needed as well as increased institutional support and funding for diverse teams that may require additional time and specific skills. We also recommend that additional research attention be devoted to evaluations of the factors that correlate with team success for interdisciplinary teams studying wicked problems and to create best practices on how to establish these teams over time. Conceptual models like the one presented here on the five dimensions of human-lion conflict can help interdisciplinary teams to better define, visualize, conceptualize, address, and readdress each dimension of their work as they move forward.

The challenges described here are just a few of many that face interdisciplinary teams. However, they are not insurmountable and interdisciplinarity still holds immense promise for the development of effective solutions to human-lion conflict. Disciplinary studies on aspects of one dimension of conflict only (e.g., local people's perceptions of depredation risk, or carnivore movement patterns) will continue to provide important scientific facts needed when designing conflict mitigation efforts. However, these efforts rely not only on credible science but also on creating an environment in which people can express their views and values through professional collaborative processes (Gregory et al., 2012). Seeking quick fixes often disregards multiple perspectives and dimensions of the problem (Rust et al., 2016) and this is likely a contributing factor as to why East African lion numbers continue to fall. Lions are among the most

scientifically studied wild felid species (Brooke et al., 2014), and levels of conflict with humans have been considered “severe” for over a decade (Inskip and Zimmermann, 2009). Thus, lions are in a unique position in that the conflict is widely studied (Montgomery et al., 2018) but sustainable solutions are not yet forthcoming. We believe that oversimplified explanations proposed through homogeneous research efforts do not hold the power to solve wicked problems situated within complex systems. Thus, there is productive space for team science to test the ways in which diverse, interdisciplinary research might be better placed to identify, validate, and scale novel solutions for human-lion conflict as well as other wicked problems. We encourage researchers to build capacity at local levels and increase data sharing so that the results of future research can be actively implemented in solving these problems (Caron and Serrell, 2009). Civil scientists, non-governmental organizations, local communities, and traditional ecological knowledge should be incorporated into studies whenever possible, in pursuit of the ultimate goal of transdisciplinarity. This paper is intended to be used as a stepping stone toward this goal offering a new

conceptual model, examples, and advice that research-informed conservation teams can draw upon when beginning the process of transitioning out of scientific “silos” and moving toward a more integrative approach to research. In this way, we hope to encourage new conservation norms where the process of solving wicked problems like human-lion conflict is not in itself a wicked problem.

AUTHOR CONTRIBUTIONS

JB and RM were the project leaders and conceived and participated in every portion of the manuscript development. ML aided in the original development of the manuscript frame and provided additions and edits to the manuscript. TM contributed significantly to writing and editing the manuscript.

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