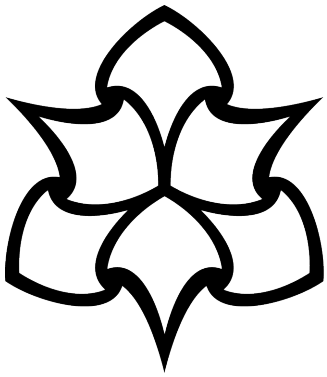

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SHORT COMMUNICATION

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A learning network approach to resolve conservation challenges in the Ngorongoro Conservation Area

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1 | INTRODUCTION

The Ngorongoro Conservation Area (NCA) is a protected area and UNESCO World Heritage Site and part of the Serengeti-Ngorongoro Biosphere reserve in northern Tanzania. It is famous for its large volcanic caldera, unique cultural heritage, early hominid fossils and significant wildlife populations. NCA has been managed as a multiple land-use area since 1959, a designation intended to foster a harmonious coexistence between indigenous residents and wildlife (Goldstein, 2004).

The NCA has international conservation prominence due to its populations of black rhinoceros (*Diceros bicornis michaeli*), African elephant (*Loxodonta africana*), and a wide range of herbivore and large predator species (Homewood et al., 2004). It supports one of the largest mammal migrations on earth, with estimates of greater than 1,000,000 wildebeest (*Connochaetus taurinus*), 260,000 plains zebra (*Equus quagga*) and 460,000 Thompson gazelle (*Eudorcas thompsoni*) (Campbell & Borner, 1995; Lembo et al., 2011). The area is also home to a large human population made up of several ethnic groups and diverse cultural traditions, including Hadzabe hunter-gatherers, and

Datooga and Maasai pastoralists (McCabe, 2003). These features attract nearly 50% of all international tourists who visit Tanzania (Melita, 2015), making the NCA by far the largest single contributor to the national economy relative to all other conservation areas in the country (accounting for 38% of park revenue in Tanzania; Busiweek, 2018). As a result, the NCA is considered a priceless and irreplaceable reserve for nature and nature's contribution to people.

Despite its enormous conservation, cultural and economic standing, there are considerable challenges in maintaining the NCA as a sustainable system for nature and people into the future. One of these challenges relates to the volume of tourists now visiting the area. Tourism has increased from approximately 50,000 visitors in 1960 to 647,773 in 2013 (Melita, 2015; Melita & Medlinger, 2013) and approaching one million more recently (Slootweg, 2016). While this rise in paying visitors has brought about significant economic benefits, stimulating considerable infrastructure development, it has also increased disturbance in and around the caldera, swelling the demand for water and natural resources. This has led to the assertion that tourism growth is incompatible with conservation objectives in the NCA (Charnley, 2005).

At the same time, unpalatable invasive plant species have spread extensively within the NCA and dominate more than half of the caldera floor (Ngondya et al., 2019), reducing rangeland quality for many wildlife species and livestock (Foxcroft et al., 2006; Ngondya et al., 2016, 2019). The resident human population has also grown dramatically from approximately 10,000 people in 1954 (displaced from adjacent areas set aside for the Serengeti National Park) to 87,851 in 2013 (Galvin et al. 2015, Masao et al., 2015) and currently approaching 100,000 (Manzano & Yamat, 2018). Associated with the expansion of the human population, livestock numbers within the NCA have increased during the same period, fostering the greater incidence and impact of diseases affecting humans, livestock and wildlife (Homewood, 2008). However, livestock populations have risen considerably less steeply than the human population (Ghosh & Uddhammar, 2013), causing a negative impact on livelihoods and well-being of the people in the NCA (McCabe, 2003). The total livestock units (TLUs) per person, a measure of food productivity for tropical pastoralists, fell from around 12.5 TLU/person in 1960 to 2.02 in 2009 (Galvin et al. 2015), well below the benchmark minimum for pastoralist food provision (~6 TLU/person). Concomitant with these changes, there is mounting evidence to show that populations of some wildlife species (i.e. gazelle species, wildebeest, kongoni (*Alcelaphus buselaphus cokii*), waterbuck (*Kobus ellipsiprymnus*) and eland (*Taurotragus oryx*) have declined in the Ngorongoro caldera (Estes et al., 2006, Moehlman et al., 2020). These species preferred the short grasslands as maintained through prescribed burning. Since the practice of burning was banned from 1975, grasslands supported taller grass stands benefitting Cape buffalo (*Syncerus caffer*, Fyumagwa et al., 2007) and elephant populations, while plains zebras have remained stable (Moehlman et al., 2020).

Mirroring a larger pattern of lifestyle change in traditional pastoral communities across Africa (Homewood, 2008), Maasai people have adapted to a more sedentary lifestyle with modern houses, increasing their reliance on garden crops and on food provided by the NCA Authority. Although it has been suggested that small-scale agriculture could be developed alongside wildlife populations in the NCA (e.g. Boone et al., 2006), it is prohibited at present and there is a complicated history associated with human rights and legal permission to farm in the NCA, which has been permitted, restricted or banned at different points in time (Goldstein, 2004; McCabe, 2003). However, were sustainable agriculture to be permitted in the NCA, the enterprise would necessarily be limited in scale due to its incompatibility with wildlife conservation. In addition, the expansion of cultivation in the NCA could clash with the tourism ideal, which perceives a benefit from the absence of development in the area (Slootweg, 2016).

While conditions for wildlife, livestock and people within the NCA have deteriorated, tourism intensity and its associated revenue have increased, thus creating a unique challenge for managers. The result is that there is no clear single causative agent or solution to improve conditions simultaneously for people, wildlife and tourism. Likewise, different stakeholders may have divergent objectives: a potential outcome for one stakeholder group may be perceived as undesirable, or even disastrous, by others. Also, the nature of issues may change through time, such as the aspirations of young people for education and jobs in urban areas instead of the pastoral lifestyle, rendering possible solutions conceived in the present ineffectual in the future. Situations like this, with uncertain, contradictory and changing requirements, have been referred to as 'wicked problems' (Rittel & Weber 1973), and it has been suggested that this may be typical of complex conservation challenges involving multiple stakeholders (DeFries & Nagendra, 2017). While there is a long history of conservation management in the NCA, in the context of similar challenges across east Africa (Reid et al., 2014), the situation continues to defy a long-term solution and has been described as a wicked problem of the utmost severity (Balint et al., 2011).

Here, we conceptualise challenges in the NCA into four categories, and we assess them for their wickedness (Table 1). Of primary importance is the sustainable livelihood and welfare of people. Specific issues include education and healthcare provision, nutrition and food sustainability, and grazing and water access for livestock. The challenge is multifarious because of human population growth, along with conflicts of interest between land use for agriculture (currently not permitted), livestock grazing and wildlife conservation. Also, there is a contradiction between romanticising the 'traditional' way of life for people in the NCA that tourists perceive versus improving living standards with modern homes and associated technologies. Another challenge is the preservation of biodiversity in the NCA. While some aspects of ecology in and around the caldera have been well studied (e.g. Sinclair et al., 2015), fundamental aspects of NCA biology outside of the caldera are less well understood, especially relating to climate change (but see Moehlman et al., 2020 for the caldera), the impact of tourism, and the interaction between humans, cattle and wildlife. The conflict of interest here is between the effects that residents and visitors have on the environment versus the economic value of increased tourism. Invasive plants are another

TABLE 1 Synthesis of principle management challenges in the NCA, management questions arising from them and reasons for wickedness

Management challenge	Management questions	Reasons for wickedness
Sustainable livelihood and welfare for local people	How can food sustainability and improved nutrition be achieved? How can education and prospects for young people be improved? How can cultural tourism be developed? How to mitigate livestock grazing, water access and cultivation rights with conservation?	• Human population growth and immigration • Differences in social values • Political sensitivity • Divergence of objectives amongst stakeholders • Cultivation, land-use change and degradation • Grazing of cattle owned by non-NCA residents • Development insults the tourist aesthetic
NCA biodiversity	Can continuous biodiversity monitoring be achieved? How resilient are crater ecosystem services? How best to mitigate and monitor poaching risk?	• The economic value of tourism and tourism growth • Potential competition between livestock and wildlife for forage and water • NCAA has limited jurisdiction and resources outside the NCA to implement strategies • Increased tourism depletes water resources • Climate change
Invasive plant species	What impact do invasive plants have on NCA biodiversity? How best to prioritise and manage invasive plant ecology in the NCA?	• Scale of the problem is large and uncertain • Reduces available forage for wildlife and livestock • Complex causality from invasion source points • Long seed bank lag time
Healthy livestock populations and zoonotic disease	How to manage and monitor risk of anthrax, Peste des Petits Ruminants, foot and mouth, rabies, rift valley fever, Brucellosis and other diseases?	• Increase in cattle population increases zoonosis risk • Increased cost of veterinary support • Epidemiology of outbreaks

Abbreviation: NCA, Ngorongoro Conservation Area

priority area, reducing rangeland quality and quantity available to wildlife and cattle. While there is awareness of the negative impacts of invasive plants (Foxcroft et al., 2006; Ngondya et al., 2017), the scale of the problem is alarming and is increasing. A final area of great concern is that of livestock and wildlife health and zoonoses. With a history of dramatic outbreaks of diseases, such as Peste des Petits Ruminants, anthrax, and foot and mouth disease, there is a looming threat to both wildlife and human welfare, exacerbated by changing land use. Meanwhile, tick-borne infections have become more common in both wildlife and livestock since the spread of taller grasses in recent decades (Fyumagwa et al., 2007).

2 | THE NCA: A FRAMEWORK FOR THE FUTURE

Processes where research and management are not closely intertwined with local communities are now considered ineffectual for nature conservation, especially in rangeland ecosystems (Reid et al., 2014). A prominent alternative approach is that of adaptive management, which emphasises knowledge creation through the scientific method (Walters & Holling, 1990) and which is favoured, perhaps unsurprisingly, by ecological scientists. However, while popular and conceptually satisfying, application of adaptive management to conservation challenges suffers inherently from a lack of spatial or temporal replication, undermining the scientific method (Sutherland, 2006). There is also a lack of evidence as to whether it has actually been widely implemented, and disagreement as to whether it is successful as a method to solve conservation problems (Reid et al., 2014; Westgate et al., 2013). A combination of adaptive management with community-based conservation, where the social and economic developments of local people are linked with the responsibility to carry out conservation goals, leveraging local ecological and traditional knowledge while building capacity, is now widely considered the way forward. While there is some evidence that community-based conservation projects tend to be successful when designed to achieve social and economic outcomes along with biological ones (Oldekop et al., 2016), there is often a fundamental conflict between sustainability of development and the preservation of nature (Berkes, 2004).

We propose a solution for the NCA that imparts responsibility and acknowledges expertise amongst stakeholder groups (Table 2). This solution is inspired by the continual engagement model (Reid et al., 2009), with an emphasis on knowledge sharing, where all principal stakeholders in the NCA are represented. These stakeholders are (a) the Ngorongoro Pastoral Council, representing NCA residents; (b) tourism industry workers from outside the NCA; (c) NCA Authority and government managers, who have direct fiscal and operational responsibility; and (d) natural scientists, social scientists and conservation organisations, both local and global, concerned with conservation of the natural resources of the NCA and human welfare. We propose a learning network solution that is characterised by knowledge exchange between stakeholders (e.g. Balint et al., 2011) and informed by continuous scenario-based assessment of outcomes (e.g. Game et al., 2014; Mason et al., 2018). For instance, a locally based wildlife manager should monitor

TABLE 2 Conventional versus learning networks approach (adapted from Mason et al., 2018)

Conventional	Learning networks	Application to NCA project
Top-down decision-making	*Distributed decision-making*	
Management decisions are made in a top-down process	Management decisions are contributed by different stakeholders	Aspects of management (e.g. monitoring, key species, invasive species, grazing) led by a local manager which takes day to day decisions within agreed parameters (legal, ethical)
Standard practice	*Creative practice*	
Standard management practices, applied elsewhere for other problems, are used	Creative management practices, suited to the specific problems, are developed	Utilise local knowledge and practices from NCA residents, evaluate ideas from similar projects worldwide, facilitate communication between project themes
Restricted expertise	*Diverse expertise*	
Management is guided by restricted expertise	Management is guided by the learning network. Challenge conventional 'best practice'. Maintain flexibility in terms of how objectives are achieved. Encourage discussion, dissent and diversity in the learning network	Establish learning network amongst NCA stakeholders. Develop a forum for the open discussion continuous knowledge exchange of management actions and outcomes
Passive management	*Predictive management*	
Management interventions are adapted over time as the system is altered	Management interventions are guided by continuous evaluation of scenario-based predictions	Management practice based on competing scenarios. For example, evaluate which management actions for forest regeneration will have the widest beneficial impact and what is the scope of potential costs? Preparation must be made to completely change strategies rather than an inflexible approach
Conventional evidence	*Pattern-based evidence*	
Management is informed by evidence from single processes	Management is informed by pattern recurrence in complex, interactive processes	Evidence-based review of existing research outcomes to inform scenario modelling (e.g. forest regeneration, rangeland management, long-term monitoring)
Strategy-focused	*Outcome-focused*	
Management strategy constrained by objectives	Focus on outcomes, strategy is flexible	Define a discrete set of specific desired outcomes for scenario modelling
Objective success	*Trade-offs in objectives*	
Focus only on management successes	Trade-offs in management success are acknowledged	Evaluate outcomes and trade-offs amongst scenario alternatives.
Avoid sharing failures	*Sharing failures*	
Management failures are not shared with stakeholders	Management failures are shared transparently with stakeholders	Full disclosure of progress including successes and failures in learning networks

Abbreviation: NCA, Ngorongoro Conservation Area.

patterns of wildlife and livestock grazing and report, on a predetermined schedule (i.e. bi-monthly), to a committee consisting of representatives of all major stakeholders. This committee, chaired by an individual with no conflict of interest, will then be able to make informed decisions about grazing management, reducing the chances of interaction and pathogen transfer between wildlife and livestock. This would allow for continuous engagement between stakeholders in the decision-making processes and for flexible management that can cope with changes in the parameters, such as those related to climate change. We believe this can be effective through generating consensus amongst stakeholders through the discussion of acceptable trade-offs between competing management objectives.

Many of the conservation and human welfare challenges in the NCA have been acknowledged and studied in the past. Yet, ongoing intensification of population growth and tourism pressures has created a unique situation at present, aggravated by the geographical, biophysical and political circumstances that have created it. While there has been a long history of conservation management in the NCA, the nature of continuous change requires continuous adaptation drawn from all-inclusive stakeholder insights. Our goal here, as representatives of each major group of stakeholders, was to propose a new process in the NCA and to document a consensus to engage in it. Therefore, we call for the immediate institution of a process of continual engagement (sensu Reid et al. 2009) and learning amongst stakeholders based on the learning networks approach leading to

a decision for action to secure the future of the NCA. Addressing conservation and development challenges in the Ngorongoro Conservation Area will necessitate creativity, persistence and long-term commitment. Our aim here was not to convey a simple solution to the huge challenge of reconciling wildlife and human conflict in the light of climate change and other land pressures imposed on the NCA, but instead to communicate a consilience amongst stakeholders on both the nature of a resolution and the will to work together to achieve it. We believe this is possible if we can echo and implement the famous words of Tanzania's first President Julius Nyerere: 'In accepting the trusteeship of our wildlife we solemnly declare that we will do everything in our power to make sure that our children's grand-children will be able to enjoy this rich and precious inheritance' (Arusha Manifesto in Watterson, 1961).

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CONFLICT OF INTEREST

The authors declare there are no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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