

# **A One Health assessment of a “Herding for Health” project at the wildlife-livestock interface in western Ngamiland, Botswana**

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## Dedication

To my parents and siblings for their love and support, to the people and cultures of Africa for the inspiration and to the diversity of life on Earth for providing the motivation.

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## Declaration

I declare that the thesis, which I hereby submit for the degree *Philosophiae Doctor* at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

B C Heermans



6<sup>th</sup> October 2021

## Executive Summary

This PhD thesis titled, ‘A One Health assessment of a Herding for Health project at the wildlife-livestock interface in western Ngamiland, Botswana’, analyzed data collected from an applied Herding 4 Health (H4H) project implemented in western Ngamiland, Botswana. The H4H model was first established at the Department of Veterinary Tropical Diseases at the University of Pretoria to apply One Health principles that acknowledge the interconnectedness of human, animal and ecosystem health. The model aims to assist agropastoral communities in the transfrontier conservation areas (TFCAs) of southern Africa with the dual objectives of poverty eradication and biodiversity conservation. A mixed-methods approach was used to investigate some of the key assumptions of the H4H model. The thesis is comprised of five chapters: Chapter 1, an introduction to the H4H model and a literary review of the methodology of subsequent chapters; Chapter 2, ‘One Health profile and farmer’s perceived risk analysis for an agropastoral community in the Khaudum-Ngamiland Wildlife Dispersal Area of the Kavango–Zambezi TFCA’, that used a qualitative and quantitative survey approach to investigate community sentiments on animal and rangeland health, regional constraints to livestock husbandry and human-wildlife conflict; Chapter 3, ‘An environmental template and drivers of functional heterogeneity in communal rangelands of the western Okavango Delta’, which used community survey and rangeland sampling techniques to explore how H4H can address the piospheric nature of rangeland degradation; Chapter 4, ‘Husbandry and Herding: a community-based approach to address illegal wildlife trade’, which used a Theory of Change approach developed with input from relevant stakeholders to guide how H4H could address the current trend of diminishing wildlife populations around the Okavango Delta and Chapter 5, ‘Conclusions’, which summarizes the major findings of the dissertation and provides recommendations for H4H project interventions and for further research. Some of the key results from this thesis illustrate the importance of cattle rearing in western Ngamiland, Botswana which was the main source of household income for 97% of respondents. While most residents were satisfied with the advice supplied by local veterinary extension services, animal diseases continue to be a major challenge to farming, surpassed only by the related factor of constraints to market access due to Foot and Mouth Disease control policies. While diseases account for 7.7% of total cattle

losses, the greater loss reported is due to straying animals which account for 60.3% of total losses whereas predation accounts for 22.9%. The herding and kraaling activities promoted by H4H are ideal interventions to address losses to disease, livestock-wildlife conflict as well as stray animals. Stray cattle are a likely threat to animal disease control and may explain regional FMD outbreaks outside of buffalo (*Syncerus caffer*) ranges, which is a topic outlined for further research. The potential for planned grazing and kraaling to address rangeland health is exemplified in the environmental template which demonstrates higher wildlife utilization in abandoned kraal sites and the effect that high-density grazing has on rangeland species composition including functional attributes such as stem height, tuft basal width, the distance between tufts and grass abundance which are significantly influenced along the grazing gradient. Lastly, the H4H Theory of Change identifies three pathways based on community-level actions to address illegal wildlife trade in the region which include: increasing institutions for local enforcement, developing incentives for ecosystem stewardship and decreasing the costs of living alongside wildlife. The success of the pathways depends on underlying enabling actions related to supporting the development of institutional frameworks, building community capacity and strengthening a Conservation Agreement model to facilitate informed best farming practices targeted to increase community and ecosystem resilience to economic shocks.

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## List of Abbreviations

|       |                                                 |
|-------|-------------------------------------------------|
| BMC   | Botswana Meat Commission                        |
| CBNRM | Community-based natural resource management     |
| CBO   | Community-based organization                    |
| CBPP  | Contagious bovine pleuropneumonia               |
| FLoD  | First Line of Defense                           |
| FMD   | Foot and Mouth Disease                          |
| HEDT  | Habu Elephant Development Trust                 |
| HWC   | Human-wildlife conflict                         |
| H4H   | Herding 4 Health                                |
| IWT   | Illegal wildlife trade                          |
| KAZA  | Kavango-Zambezi Transfrontier conservation area |
| KNWDA | Khaudum-Ngamiland Wildlife Dispersal Area       |
| NGO   | Non-governmental organization                   |
| OH    | One Health                                      |
| OIE   | World Organization for Animal Health            |
| PA    | Protected Areas                                 |
| TFCA  | Transfrontier conservation area                 |
| ToC   | Theory of Change                                |
| USDA  | United States Department of Agriculture         |
| WDA   | Wildlife dispersal area                         |
| WMA   | Wildlife management area                        |

## CHAPTER 1. General introduction

Africa's savanna rangelands account for approximately half of the sub-Saharan terrestrial landscape (Bouvet et al. 2018) and are composed of an intricate socio-ecological mosaic of agro-pastoralist livelihoods and wildlife populations, setting a complex stage for conservation and rural development efforts (Tyrrell et al. 2017). Several interrelated challenges arise on rangelands of the livestock-wildlife interface that include socio-ecological linkages, high prevalence of poverty, animal disease, human-wildlife conflict, losses of biodiversity and reduced herbivore populations and rangeland degradation (Osofsky et al. 2005). Many of these challenges can be addressed through better management practices, ideally harnessing existing indigenous knowledge related to livestock management and wildlife coexistence. Additionally, communities living in proximity to wildlife populations often face further economic burden related to opportunity costs linked to biodiversity conservation (Norton-Griffiths & Southey 1993; du Toit et al. 2017; Tyrrell et al. 2020), which are likely to increase with growing food and energy demands as observed from the unprecedented growth across a range of development indices for Africa (Scheren et al. 2021). As a result, habitat loss and degradation resulting from land conversion associated with agricultural expansion presents a major threat to wildlife populations and biodiversity conservation in Africa (Williams et al. 2020; Western and Mose 2021). To garner support from communities living on the frontier of the livestock-wildlife interface, conservation initiatives such as the launch of transfrontier conservation areas (TFCAs) in the early 2000s, should aim to link the costs of farming and living alongside wildlife to the financial benefits wildlife can produce (McNutt et al. 2017). Despite a growing need for integrated wildlife-livestock systems, few working examples exist in sub-Saharan Africa. This work examines the Herding for Health (now Herding 4 Health [H4H]) model developed under the One Health programme at the University of Pretoria (Van Rooyen 2017) to address these core issues in an applied H4H project currently underway in Habu, Botswana on the western side of the Okavango Delta (hereafter referred to as, the Delta).

The Delta has been widely used by agropastoralists for centuries, which was documented by the first European expeditions to the area (Andersson 1856; Livingstone 1857). This practice continued until recent times (Basupi et al. 2017). However, at present, community access has

largely been restricted for the purpose of economic growth leveraged by the global imperative for conservation, mostly to the benefit of government and outside international investors (Magole and Magole 2009). Across Africa, communities have been displaced for the establishment of national parks, game reserves and wildlife management areas (Chatty & Colchester 2002; West et al. 2006; Adams & Hutton 2007). This type of ‘fortress’ conservation strategy (Brockington 2002; Berkes 2004) was largely driven by the western concept of wilderness as a ‘pristine’ untouched landscape and often involved the forced removal of resident human populations and reinforced a concept of division between people and nature (Adams & McShane 1992).

Holistic approaches to address the challenges posed for conservation in complex systems have gained increasing focus in the 21st century (Du Toit et al. 2003; Smith & Maltby 2003). Such approaches include interconnected goals of healthy, resilient communities, healthy animals (wild and domestic) and a healthy environment using the holistic, integrated principles of One Health in the framework of Health in Social-Ecological Systems (Zinsstag et al. 2011; Van Rooyen 2017). The One Health Initiative started in 2007 as a strategy to promote collaboration and communication by health care practitioners across the whole spectrum of the field, including humans, animals and the environment and recognizes that the health of communities, livestock, wildlife, and ecosystems are interlinked (OHI 2021). The One Health concept has been widely embraced, yet there is a lag across academic disciplines, research and policy to integrate the theory into practice (Molyneaux et al. 2011).

The H4H model was developed to address the complexity that One Health presents at the human-livestock-wildlife interface in Africa and implements lessons learned from existing frameworks of landscape approaches to conservation that endorse adaptive management, community engagement and multiple objectives (Berkes 2004; Sayer et al. 2013; Kremen & Merenlender 2018). Methods adopted by H4H are intended to be simple yet practical, integrated and holistic, and acceptable to communities living with wildlife as well as to policymakers, conservationists and development aid agencies (Van Rooyen 2017). The H4H model focuses on the health of rangelands, animals (wild and domestic), communities and governance (PPF 2018; UP 2021) and aims to demonstrate how improved communication and collaboration across multidisciplinary fields from science, business, policy and development can come together to implement the shared goals of poverty alleviation, conservation,

sustainable rangeland management and livestock production. Herding 4 Health became operational in 2017 as an implementation support programme after drawing from ten years of piloting and learning from partnerships in multiple sites in South Africa and elsewhere in southern Africa (Van Rooyen 2017; GDSA 2018; UP 2021). After the initial decade of piloting, additional H4H projects have been initiated in Botswana, Mozambique, Zambia and Zimbabwe.

The H4H model seeks to reduce risk holistically and unlock diversified opportunities to harmonize the socio-economic and ecological benefits of implementing better farming practices. Examples of socio-economic benefits include improved market access, better record-keeping of cattle, lower rates of zoonotic disease transfer and fewer stock losses from theft and depredation. Examples of ecological benefits include improved rangeland management and restoration, increased habitat connectivity through better stewardship of lands outside of protected areas, a reduction in illegal wildlife trade through disincentive mechanizations and improved collaboration between government agencies. Herding 4 Health works through collaboration with NGOs, community-based organizations (CBOs) and other stakeholders with similar objectives and strong, long-lasting relations with communities on the ground. Such multi-level stakeholder networks are key to facilitating the success of community conservation initiatives (Berkes 2007). Herding 4 Health acts as a support system offering training, guidance in practical skill sets (e.g. veterinary care, rangeland management, human-wildlife conflict mitigation, etc.) and strengthening the natural resource governance capacity of participating communities along with the livestock-wildlife interface (SAWC 2021).

Within the Kavango-Zambezi (KAZA) landscape, 75% of the land between state-protected areas falls under traditional tenure systems (Cumming 2011). This means that excluding wildlife management areas (WMAs), forest reserves and community concessions, 148,520 km<sup>2</sup> of the remaining matrix is earmarked for agropastoral uses (KAZA 2014). In northern Botswana, the majority of rural communities attribute livestock as the main source of income generation, with some communities in western Ngamiland reporting livestock as supplying as much as 95% of household income (Darkoh & Mbaiwa 2009; HEDT 2019). The regions' other major asset lies in the currently underdeveloped potential of its abundant wildlife resources which are currently in decline and threatened by illegal bushmeat hunting (Rogan et al. 2015). In recognition of the need for integrated landscapes, initiatives promoting community-based

management systems for livestock-wildlife coexistence have been in development since the 1970s (Western et al. 2020). Here we refer to coexistence as relating to both tolerances of conflict and co-occurrence, in recognition of the need to clarify from multiple interpretations that exist in the literature (Nyhus, 2016; Frank & Glikman 2019; Knox et al. 2020). Today, several livestock-wildlife coexistence projects in the east and southern Africa demonstrate that conservation of large open landscapes and rural development can be achieved through the application of well managed pastoral practices (Odadi et al. 2017; Tyrrell et al. 2017; Keesing et al. 2018; Kiffner et al. 2020).

Developing integrated livestock-wildlife systems in African communal rangelands will require understanding the key constraints that are often unpredictable and vary regionally by ecological, historical, cultural and political context (Reid et al. 2014). In Kenya's Southern Rangelands, subdivision of land and sedentarization of livestock pose critical threats to wildlife and rangeland integrity which is a phenomenon that is accelerating across the continent (Groom & Western 2003). This contrasts to northern Botswana, where much of the landscape remains intact yet livestock sedentarization still occurs at the village level. In this region, extensive veterinary fences pose impediments to resource access for both cattle and wildlife and present additional constraints to agropastoralists which arise from market restrictions due to zoonotic and other economically important transboundary diseases (TADs), such as foot and mouth disease (FMD) control policies (Osofsky et al. 2005). Such restrictions pose major challenges to farmers (de Garine-Wichatitsky et al. 2013; Musoke et al. 2015; Van Rooyen 2017) which can adversely affect community tolerance for wildlife and conservation efforts (Bedelian et al. 2007; Cumming et al. 2013; Van Rooyen 2017). The severity of consequential market restrictions that animal disease policies inflict on rural farmers is exemplified by a 2007 FMD outbreak near Habu village in Northern Botswana that resulted in a seven-year closure of the beef industry in Ngamiland (Atkinson et al. 2019). Changes to the World Organization for Animal Health (OIE) policies that relate to FMD control measures now focus on the safety of the beef commodity rather than the previously required geographical separation of livestock and wildlife, providing an opportunity for alternative risk mitigation measures (e.g. herding and kraaling) that help enable wildlife-livestock coexistence (Thomson et al. 2013b). While some countries are slow to adopt these new OIE policies, Botswana is in a current state of policy reformation, and recently drafted new guidelines for

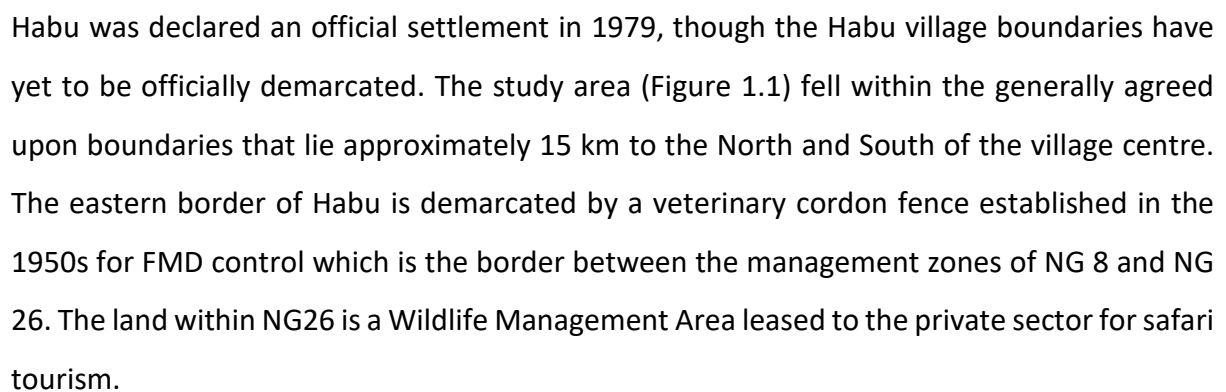
FMD control with the aspiration of reaching previously restricted beef markets. Herding 4 Health was conceptualized to aid farmers with market access through the development of alternative risk mitigation measures along the beef value chain, as well as to address related challenges on communal rangelands in southern Africa's TFCAs.

## 1.1. STUDY AREA

The Khaudum-Ngamiland Wildlife Dispersal Area (KNWDA) is one of six focal wildlife dispersal areas (WDAs) that subdivides KAZA (KAZA 2014). Though wildlife-based tourism and livestock production are the main landscape uses in Ngamiland, western Ngamiland receives few benefits from the safari industry in comparison with communities situated on the eastern periphery of the Delta (Albertson 2020).

Habu is a remote village within the KNWDA that is situated on communally-held tribal land on the periphery of the Delta and falls within the Okavango sub-District of western Ngamiland, Botswana. No official zonation plan exists for Habu, but traditional village boundaries include approximately 85,000 Ha<sup>2</sup> of semi-arid rangeland under communal tenure. Mean temperature and precipitation for the region are 20.9 degrees Celsius and 393.6 mm (GIZ 2019). The latest census bureau statistics report a population of 533 residents (Botswana Central Statistics Office 2011). Most residents have households near the village centre that are associated with approximately 126 outlying cattleposts, where household livestock is kept at night in enclosures (i.e. kraals or bomas). Being located on the distal end of the seasonal Thaoge river system of the Delta, the Habu community rarely has access to surface water outside the rainy season and general settlement patterns run North to South along the Thaoge drainage system, due to ground water availability which is accessed through artesian wells along the dry river bed.

The Habu area was first inhabited by nomadic Khoisan hunter-gatherers, the majority of which were superseded by a series of Bantu tribes that began arriving in the 1800s (Tlou 1976). The southern migration of Bayei and Hambukushu groups originating in Angola and Namibia's Zambezi Region were among the first Bantu clans to reach the region followed by Tswana speaking groups, that subsisted primarily off traditional molapo crop farming on the fertile floodplains of the Thaoge (Chief Kampomboro, pers. comm.). By the 1970s, Herero



## **1.2. RESEARCH AIM**

The Ngamiland rangelands are crucial to the livestock and wildlife economies of the region yet have been deteriorating over the past several decades and evidence indicates that the district is populated with livestock beyond the carrying capacity as a result of market restrictions stemming from animal disease control policies (Atkinson et al. 2019). These constraints pose critical development challenges to rural communities in one of Botswana's most impoverished regions (Statistics Botswana 2013). As poverty is a major determinant of human health (Stevens 2007), innovative livestock-wildlife coexistence strategies that can form the basis for livelihood and economic diversification are needed to accomplish the dual objectives of improving human health and well-being and biodiversity conservation.

The aim of this study was to analyze the drivers relating to animal (domestic and wild), human and environmental health and well-being with the ultimate aim of testing research that can help inform applied One Health work and to guide and improve upon interventions adopted by the H4H model.

## **1.3. OBJECTIVES**

The objectives of this thesis were to:

- a) Determine the animal, human and environmental health risks associated with communal livestock production systems perceived by farmers in western Ngamiland.
- b) Evaluate the drivers of rangeland condition in the communal lands on the western periphery of the Okavango Delta.
- c) Examine the role that H4H can play in combatting illegal bushmeat hunting to foster human-wildlife-livestock coexistence.

## **1.4. THESIS LAYOUT**

This thesis builds off H4H as published by Van Rooyen (2017) and previous work under the One Health programme of the Department of Tropical Veterinary Diseases at the University of Pretoria. The three main body chapters have distinct methods and have been prepared as

papers for submission to appropriate scientific journals, thus there is some unavoidable repetition on some of the key H4H principles between chapters.

Chapter Two used a mixed methods qualitative and quantitative community survey instrument that had been developed from a previous survey work conducted within the One Health framework at the University of Pretoria (Berrian et al. 2016; Van Rooyen 2017). This chapter reviews participant feedback on a host of topics that included human, environmental and animal-related health concerns, human-wildlife conflict and other economic factors including market access and prices that are related to the first research objective.

Chapter Three combines an assortment of methods including cattle surveys, habitat mapping and current rangeland surveying techniques to produce an environmental template for the Habu rangelands to examine the underlying drivers contributing to rangeland condition in western Ngamiland.

Chapter Four discusses pathways of a Theory of Change developed specifically for interventions the H4H model could promote to combat illegal wildlife crime. The chapter provides clear actions and recommendations towards regional poverty reduction and wildlife-livestock coexistence.

Chapter Five discusses the results, study limitations and provides recommendations for further research and actions for H4H in the wider context of TFCA development in southern Africa.

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## **CHAPTER 2. One Health profile and farmer's perceived risk analysis for an agropastoral community in the Khaudum-Ngamiland Wildlife Dispersal Area of the KAZA TFCA**

### **2.1. ABSTRACT**

The Khaudum-Ngamiland Wildlife Dispersal Area (KNWDA) of the Okavango-Zambezi transfrontier conservation area (KAZA) is comprised of a complex mosaic of agropastoral livelihoods close to high densities of wildlife populations. A community survey was developed using the One Health framework to better understand the underlying dynamics that affect communities' perceptions on key socio-economic and environmental factors as well as agropastoral practices to ultimately drive interventions for a Herding 4 Health (H4H) pilot project in the village of Habu. In Northern Botswana. Representatives from one hundred households voluntarily participated in in-person surveys with trained surveyors over six weeks from February to April 2019. Households were selected using a random stratified sampling method. The survey used a mixed-methods approach involving a combination of qualitative and quantitative inquiries including open-ended, Likert scale, multiple-choice and multiple selection questions to investigate community feedback related to human, animal and rangeland health, as well as regional constraints to livestock husbandry. Results from the survey illustrate the importance of cattle rearing in western Ngamiland, Botswana which was the main source of household income for 97% of respondents. While most residents were satisfied with the advice supplied by local veterinary extension services, animal diseases continue to be a major challenge to farming, surpassed only by the related factor of constraints to market access due to animal disease control policies. Herd size was determined as a significant factor associated with accessing formal markets. While diseases account for 7.7% of total cattle losses, the greater loss reported is due to straying animals which account for 60.3% of total losses, whereas predation accounts for 22.9%. The potential risk that stray animals in western Ngamiland pose to disease transmission is recommended as a critical topic for further research. Uncontrolled movements of livestock may further contribute to rangeland degradation, which is supported by a general perception that rangeland health had deteriorated in the last decade. The herding and kraaling activities promoted by H4H are

presented as ideal interventions to address rangeland health, losses to diseases and stray livestock, reduce rates of human-wildlife conflict and improve market access through protocol compliance to commodity-based trade and wildlife-friendly branding. Developing innovative methods to foster wildlife-livestock coexistence are urgently needed to improve community resilience in Northern Botswana through livelihood diversification that capitalizes on the regions primary resources, wildlife and livestock.

## 2.2. INTRODUCTION

Livestock production and wildlife tourism are the primary land uses of Ngamiland District in Northwest Botswana, which is centred in the world's largest transfrontier conservation area (TFCA) (Atkinson et al. 2019). The Okavango-Zambezi (KAZA) TFCA spans five countries, 22 protected areas and covers a land area of over 400,000 km<sup>2</sup> (Cumming 2011). The communal land between KAZA's protected areas is widely utilized for small scale pastoral and agropastoral land uses (Barnes 2013). This presents a matrix where domestic animals and wildlife converge, termed the wildlife-livestock interface, and sets an intricate stage with challenges that arise in economic development, disease control, resource utilization and biodiversity conservation (Kock 2004). To address these complex issues, development and conservation practitioners are increasingly seeking to develop innovative ideas through improved communication and cross-sectoral collaborations (Osofsky et al. 2005). The One Health (OH) initiative is one such concept that is gaining momentum and recognizes the interconnectedness between human, animal and environmental health (Conti et al. 2011). This study reports findings of a community survey designed with an OH approach with the intention of better understanding the risks that are perceived by farmers living in a community on KAZA's wildlife-livestock interface. Some of the specific aims of the survey include investigating: What are the contributions of livestock to local livelihoods?; What are the perceived constraints and risks to livestock production and sales?; What are the costs of disease mitigation to rural farmers?; What are the key impacts of wildlife on people in terms of societal and economic costs?; What are the perceived threats to rangeland condition?; Lastly, how are the above inquiries interlinked? The overall aim of this survey to holistically identify and drive specific strategies that H4H can adopt to address poverty and biodiversity conservation in one of Botswana's most impoverished regions (Statistics Botswana 2013; Magombeyi & Odhiambo 2017).

Poverty has been identified as the single largest determinant of health (Stevens 2007; WHO 2021). Poverty related diseases account for 52% of the disease burden in countries with high poverty rates yet are largely preventable and remediable with current interventions (WHO 2004, 2008). Such diseases are often associated with a lack of access to health services, education, sanitation, clean drinking water and malnutrition (Mintz et al. 1995; UN 2002; Stevens 2007; Singh & Singh 2008). Poverty related diseases include infectious diseases, 60% of which are caused by zoonotic pathogens (Taylor et al. 2001), and non-communicable diseases such as heart disease, cancer and diabetes (Niessen et al. 2018). These diseases can also create barriers to economic growth which perpetuates poverty and entraps communities further into a brutal cycle (Sachs 2008).

Another major impediment to economic development in southern Africa is related to animal disease policy (Thomson et al. 2017). Globally, foot and mouth disease (FMD) is considered one of the most significant infectious diseases due to trade policies that restrict market access in areas where the disease occurs (Jori & Etter 2016). Fences erected in Botswana in the mid 20th century to control the disease and FMD vaccination programs have been largely ineffective and the nature of FMD spread is still poorly understood (Atkinson et al., 2019). Ngamiland is notorious for the severe measures that have been taken to control animal disease outbreaks in the region such as a contagious bovine pleuropneumonia (CBPP) outbreak in 1995 that resulted in the extermination of the entire districts' cattle and an outbreak of FMD in 2007 near Habu that caused a seven-year market shut down (Atkinson et al. 2019). Regular market shutdowns in Ngamiland and the limited capacity of existing abattoirs has not only adversely affected rural farmers but has also resulted in a cattle population of poor condition and low-quality animals that exceeds even the most conservative estimates of the region's carrying capacity (H4H 2018; Atkinson et al. 2019).

Overgrazing along with climate change and variability, bush encroachment, breakdown of traditional governance systems, and agriculture-associated practices, such as slash and burn agriculture and commercial monoculture production which requires high chemical inputs, are leading contributing factors to rangeland degradation (Bolo et al. 2019). High livestock densities coupled with a lack of resting time can lead to overgrazing and soil compaction and ultimately changes to edaphic properties including soil erosion and nutrient depletion (Ralphs et al. 1990). Rangeland degradation adversely affects biodiversity at varying scales, as well as

water resources and livestock condition and productivity (Bolo et al. 2019). The financial losses associated with rangeland degradation are considerable and pose threats across scales from individuals to national economies (Dregne 1990; Yesuf et al. 2008; Bolo et al. 2019). In the wildlife-rich regions of Ngamiland, rangeland degradation has additional consequences as uncontrolled cattle that stray further into protected areas to access better grazing will likely increase rates of human-wildlife conflict (HWC) and compete with wild grazers for resources (Atkinson et al. 2019).

Human-wildlife conflict persists in many forms, some of which include: significant threats to species conservation, destruction of property, crop damage, depredation on livestock, attacks on humans, and disease transmission to livestock and people (Dickman 2010). In Ngamiland, the loss of livestock to depredation by large carnivores is common along with high rates of associated retaliatory killings of predators (LeFlore et al. 2019). A wide range of strategies has been tested to reduce HWC (Breitenmoser 2005), however, innovative measures are urgently needed for effective conflict mitigation (Dickman 2010). While there are numerous costs associated with living close to wildlife, the opportunities presented through wildlife-based economies are substantial and within Botswana, wildlife tourism has surpassed the livestock industry to become the countries' second largest contributor to GDP with a total contribution of 10.9% (World Travel & Tourism Council 2017). While tourism is susceptible to economic recessions and shocks, its potential to increase community resilience by providing a diversified revenue source is substantial. In such a context, strategies that promote the coexistence of both of Ngamiland's primary assets (wildlife and livestock), can provide an effective approach to address regional economic stability and poverty reduction.

Today, there are numerous examples of successfully integrated livestock and wildlife systems in Africa (Tyrrell et al. 2017; Keesing et al. 2018; Kiffner et al. 2020). Reported benefits from well managed wildlife-livestock systems include improved forage and economic benefits from diversified streams (Keesing et al. 2018). Another strength of integrated systems is that while many conservation methods have an underlying objective for rural development, the approaches are usually wildlife centric and driven by outsiders of the targeted communities (Western et al. 2020). A term coined by Western et al. (2020) from working with pastoral communities in East Africa is 'inside-out' conservation; a strategy that focuses on building community resilience and landscape connectivity at multiple scales through a human-centred

approach that has compatible objectives to conservation. Through a community-centred lens that prioritizes the values and concerns of pastoral communities, the inside out model aims to attain similar conservation objectives through a focus on local knowledge and strengthened informal governance structures (Western et al. 2020).

Similar to inside-out conservation is the H4H model, which is a farming systems approach with conservation outcomes (Van Rooyen 2017). Herding 4 Health was derived to address the particular and complex challenges that arise on the wildlife-livestock interface holistically through a socio-economic approach. The H4H model was first established at the Department of Veterinary Tropical Diseases at the University of Pretoria to apply the OH principles that acknowledge the interconnectedness of human, animal and ecosystem health to assist agropastoral communities in the TFCAs of southern Africa. H4H relies on multi-stakeholder partnerships with local entities that have strong working relationships with targeted communities. H4H offers assistance in the form of guidance, technical support, and financial sourcing, coupled with evidence-based mitigation practices (primarily herding and kraaling) while promoting multisector collaboration and communication to address some of the common challenges associated with communal rangelands including zoonotic disease control, market access, rangeland management and human-wildlife conflict. H4H promotes stewardship among local land users and where applicable or required may formalize stewardship agreements using the 'Conservation Agreement' model of Conservation International (Niesten et al. 2010) to negotiate incentives for implementing improved agricultural practices and ecosystem stewardship with partner communities and ensure that objectives are mutually designed and expectations are agreed upon in a highly consultative process.

This study was conducted in Habu, Botswana, an H4H site, where the implementing partners are Wild Entrust, a long-standing Botswana NGO, and a local community-based organization (CBO), the Habu Elephant Development Trust (HEDT).

## **2.3. MATERIAL AND METHODS**

The survey instrument was adapted from previous surveys designed with the intention of demonstrating the One Health principles (Berrian et al. 2016; Van Rooyen 2017). The survey

was developed with a mixed-methods approach involving cross-sectional qualitative and quantitative structured questions compiled for in-person surveys. The study used a random approach by using census data collected by members of the local community trust for all households identified in Habu's sub-village sections and assigning each household a number. Households were randomly selected using the random number generator in Microsoft Excel (Microsoft Excel, Version 15.39). A team of 8 Habu Community Scouts were trained in a 3-day course on surveying techniques and data collection using both hardcopy and digital format through SMART software on Blackview 300 smartphones. Participants were informed that the study was voluntary and confidential and was orally presented with the study purpose beforehand. Written consent was obtained for all participants of the survey. The survey was written in English and translated orally to the native language of each participant. Responses were recorded in English. A total of 100 household surveys (of an identified 126 total households residing in Habu) were completed between six weeks from February to April 2019. Where possible the household heads were chosen as survey participants. All participants were over 18 years old. The survey was conducted under Protocol REC070-18 which was approved by the Research Committee of the Faculty of Veterinary Sciences at the University of Pretoria.

The survey was designed to gather communal input on a variety of topics including village demographics, the general socioeconomic structure of Habu, human, environmental and animal-related health concerns, human-wildlife conflict and other economic factors including market access and prices. The survey included a combination of multiple-choice, Likert scale, and open-ended questions.

Data analysis for descriptive statistics including mean, median, range, standard deviation, frequency and tests for significance were conducted with Microsoft Excel (Microsoft Excel, Version 15.39) and SPSS (SPSS, Version 25).

## **2.4. RESULTS**

### **2.4.1. Demographics**

One hundred surveys were completed throughout the Habu village and outlying cattle posts. Of the respondents, 66 were household heads seconded by either a son or daughter to the household head ( $n = 25$ , 25%). The mean age of participants was in their 40s, out of a range of 19 - 79 years of age. The majority of participants were male ( $n = 89$ , 89%). The survey represented all of the major ethnic groups of Habu including, Banderu ( $n = 46$ , 46%), Herero ( $n = 25$ , 25%), Batswana ( $n = 10$ , 10%), Bayei ( $n = 9$ , 9%), Khoisan ( $n = 8$ , 8%) and Hambukushu ( $n = 2$ , 2%). This ethnic proportion corresponds to a general census of the village conducted by the Habu Community Trust in 2017 (HEDT unpub. data 2017). The level of education attained by most respondents was between Forms 1 - 3 (primary to secondary education) ( $n = 43$ , 43%) followed by primary education ( $n = 29$ , 29%), no education ( $n = 14$ , 14%), tertiary ( $n = 7$ , 7%), Form 4 - 5 (secondary education) ( $n = 5$ , 5%) and lastly pre-primary crush courses ( $n = 2$ , 2%). The majority of respondents indicated earning less than 500 Botswana Pula (BWP) per month while six respondents indicated earning a monthly wage of over 4000 BWP, one respondent reported nothing for earnings. The average monthly income was 867 BWP (standard deviation [ $sd$ ]  $\pm 1374.52$ ). The majority of respondents identified cattle keeping as their main source of livelihood ( $n = 100$ , 97%). A breakdown in sources of revenue is displayed in Figure 2.1.

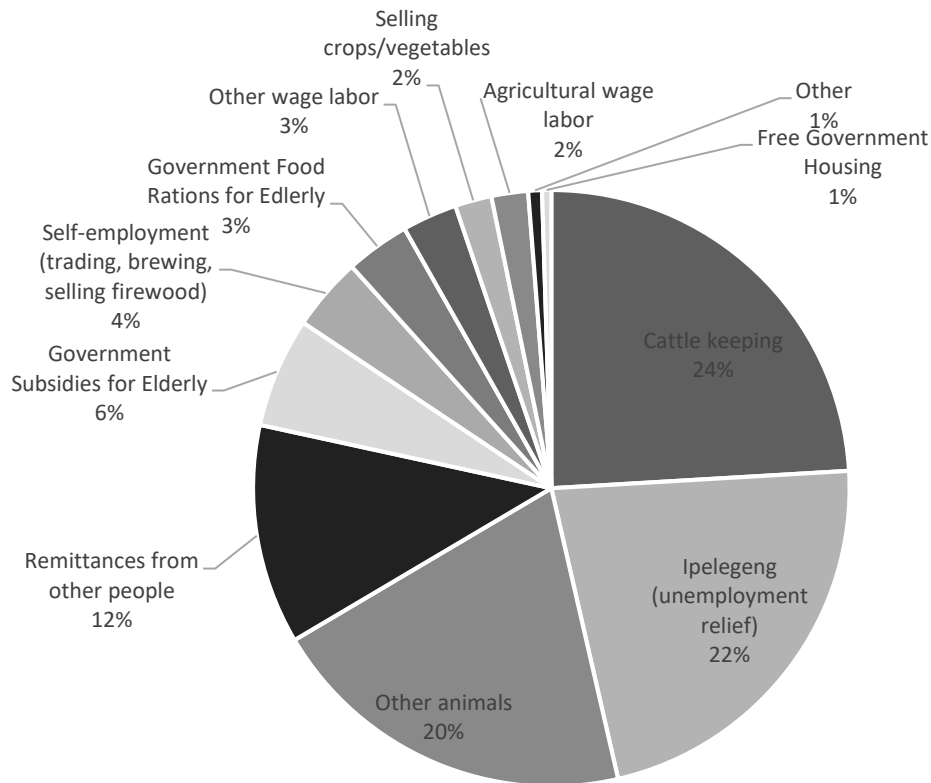


Figure 2.1. Sources of income generation by Habu survey respondents.

#### 2.4.2. Human health concerns

The majority of participants ( $n = 100$ , 86%) stated that they were satisfied with health treatment in Habu. The local Habu clinic was identified as the primary location for health treatment ( $n = 93$ , 83%) followed by primary hospitals ( $n = 7$ , 6.3%), “other” ( $n = 5$ , 4.5%), church ( $n = 4$ , 3.6%) and traditional healers ( $n = 3$ , 2.7%). Infectious diseases were the largest health challenge listed specifically for children ( $n = 71$ , 62.3%), followed by ‘other’ challenges ( $n = 13$ , 11.4%), access to treatment ( $n = 11$ , 9.6%), clean water ( $n = 10$ , 8.8%), and malnutrition ( $n = 9$ , 7.9%). Health challenges listed for the entire household are displayed in Figure 2.2.

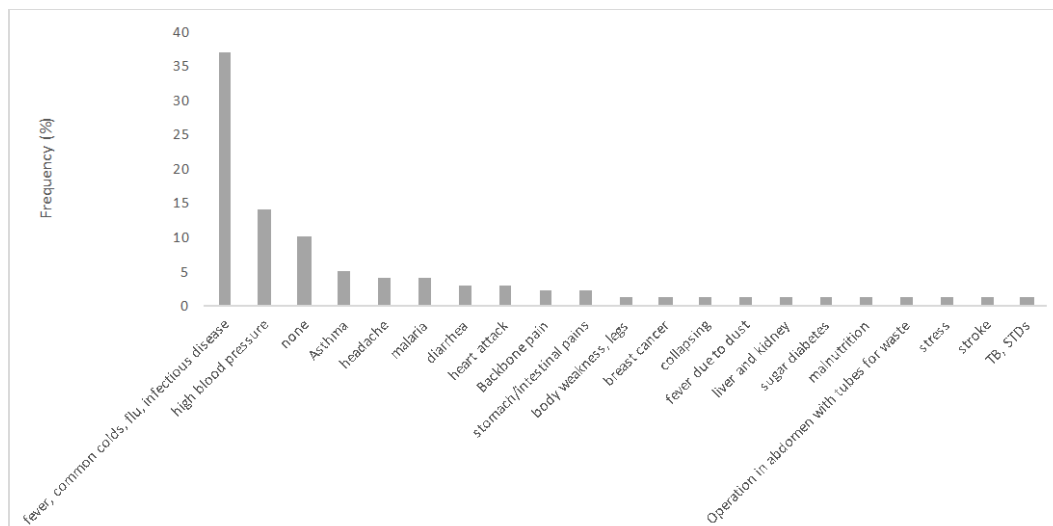


Figure 2.2. Identified human health concerns from Habu respondents.

### 2.4.3. Crop production

More than half ( $n = 57$ , 57%) of the respondents reported that they cultivate the land for crop production. Most of these crop fields range between 1 - 2 hectares ( $n = 33$ , 56.9%), followed by half a hectare and 3 - 5 hectare plots ( $n = 10$ , 17.2%), quarter hectare plots ( $n = 3$ , 5.2%) and backyard gardens ( $n = 2$ , 3.4%) as estimated by respondents. Home consumption was listed as the main reason for cultivation while 16 respondents reported production for profitmaking. Twenty-one respondents (2.3%) said they cultivated using no financial inputs towards ploughing costs, seed, fertilizer and pesticides, while 17 (1.9%) respondents estimated their costs below 2,000 BWP per annum, and 10 respondents (1.1%) estimated their inputs as between 2,000 – 5,000 BWP. One farmer listed financial inputs exceeding 7,000 BWP a year. The most common crops cultivated were maize ( $n = 57$ , 36.8%), watermelon ( $n = 29$ , 18.7%), peanuts ( $n = 19$ , 12.3%), sorghum ( $n = 16$ , 10.3%), and beans ( $n = 14$ , 9%). The vast majority of farmers reported livestock as a more important source of revenue ( $n = 95$ , 95%), while a couple ( $n = 2$ , 2%) said they were equally important and three (3%) respondents cited crops as being their major source of income.

### 2.4.4. Animal production

Cattle is the most common livestock species found in Habu and make up 55.3% of all livestock ( $n = 6,358$ ), reported by respondents followed by goats 25.9% ( $n = 2,978$ ), sheep 9% ( $n =$

1,045), donkeys 5.3 % ( $n = 620$ ), chickens 3% ( $n = 346$ ) and lastly horses which accounted for 1.3% ( $n = 157$ ) of the total livestock reported. When asked why livestock were kept the following reasons were given; dominant source of income ( $n = 99$ , 99%), selling for cash (school fees, clothes, food, etc.) ( $n = 96$ , 96%), emergency cash ( $n = 93$ , 93%), traditional reasons ( $n = 90$ , 90%), bank ( $n = 81$ , 81%), draught power ( $n = 65$ , 65%) and to start a business ( $n = 59$ , 59%).

Ninety-seven per cent of all participants indicated that cattle were the main source of household income, though one respondent held goats to be more important and another indicated government employment. Respondents gave various reasons for keeping cattle (Figure 2.3).

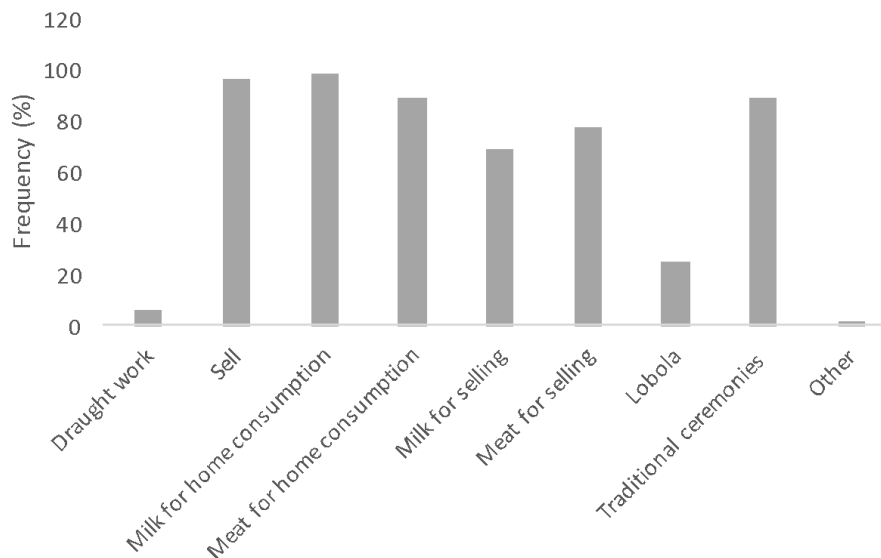


Figure 2.3. A summary of the multiple reasons given for cattle rearing in Habu ( $n = 100$ ).

Every household of the 100 participants in the survey reported cattle ownership. The household with the lowest herd size reported owning two cattle, whereas the highest was 400. The total number of cattle owned by farmers in the study is 6382. The average herd size per household was 63.82 ( $sd \pm 65.78$ ). The breakdown of cattle composition in Habu is displayed in Table 2.1 and Figure 2.4.

Table 2.1. Breakdown of herd composition as reported by Habu respondents.

| Type           | n  | Min | Max | SD    | Mean  | Sum  |
|----------------|----|-----|-----|-------|-------|------|
| <b>Bulls</b>   | 91 | 0   | 10  | 1.71  | 1.1   | 100  |
| <b>Oxen</b>    | 92 | 0   | 140 | 21.42 | 13.76 | 1266 |
| <b>Cows</b>    | 92 | 0   | 164 | 29.78 | 22.41 | 2062 |
| <b>Heifers</b> | 92 | 0   | 70  | 14.78 | 13.74 | 1264 |
| <b>Calves</b>  | 92 | 0   | 100 | 16.1  | 14.54 | 1338 |

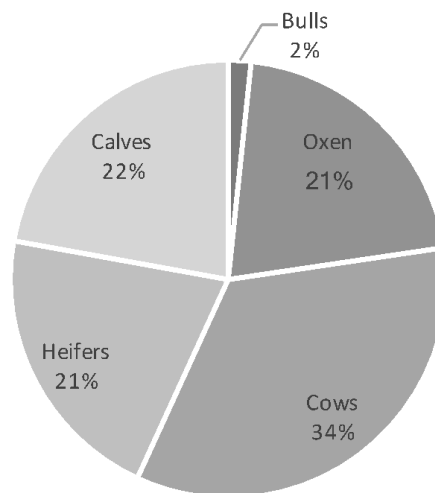


Figure 2.4. Herd composition (percentage of means) reported by respondents in Habu.

The dominant breed reported by farmers were; mixed breed ( $n = 77$ , 77%), Brahman-type ( $n = 11$ , 11%), and other breeds ( $n = 11$ , 11%). When asked which breeds are preferred by farmers, Brahman-type were strongly favoured ( $n = 63$ , 63%) followed by Simmental-type ( $n = 22$ , 22%) and other breeds ( $n = 14$ , 14%). Resistance to drought ( $n = 36$ , 36%), fast growth ( $n = 27$ , 27%), heavy weight ( $n = 11$ , 11%), and quality of dairy and meat production ( $n = 11$ , 11%) were the most desired traits in cattle breeds. Only 33 farmers reported using a specific bull for breeding.

Only 21 farmers reported buying cattle in the last 12 months. All farmers that had bought cattle had sourced them from other farmers in the region. When asked why they had not bought cattle respondents replied that it was due to lack of money ( $n = 65$ , 82.3%), they were satisfied with the number they owned ( $n = 10$ , 12.7%), there was no market ( $n = 2$ , 2.5%) or due to other reasons ( $n = 2$ , 2.5%).

When asked about cattle sales in the last 12 months, 69% ( $n = 69$ ) of respondents said they had sold cattle. Of the total cattle that were sold amongst respondents within 12 months, 53.3% ( $n = 262$ ) were sold to a local butcher, 29.5% ( $n = 145$ ) sold to BMC (Botswana Meat Co.), 6.9% ( $n = 34$ ) sold to other farmers, 6.5% ( $n = 32$ ) to agents, 3% ( $n = 15$ ) to villagers and 0.8% ( $n = 4$ ) sold to other sources. The average herd size of those who sold cattle was greater than 74 ( $sd \pm 72.70$ ), while those who didn't sell cattle in the last 12 months had an average herd size of 41.16 ( $sd \pm 39.13$ ). Mann Whitney U-Test for non-normally distributed data revealed a significant difference between the average herd size of those who sold compared to those who didn't sell cattle in the last 12 months ( $p = 0.005$ ). The association of herd size to whether farmers sold cattle or not was further investigated by binning cattle herd size and using the Fisher's exact test for small sample sizes which suggests a strong relationship ( $p = 0.014$ ).

Of the respondents who had indicated that they have sold cattle in the last 12 months, 69.6% of them ( $n = 48$ ) said that they sold cattle to a local butcher. The average herd size of those who sold to the butcher was lower than those who sold cattle to other buyers 66.48 ( $sd \pm 55.37$ ), and 91.19 ( $sd \pm 101.60$ ) respectively. Mann Whitney U-test results indicate that this difference is not statistically significant ( $p = 0.49$ ). Respondents who sold directly to BMC had the highest mean herd size of 106.71 ( $sd \pm 103.79$ ). While no significant difference was detected to support whether herd size played a role in the previous 12-month period, a significant difference was detected for the mean herd size of farmer's who never sell to BMC versus those that do sell ( $p = 0.004$ ).

Respondents were largely unsatisfied ( $n = 83$ , 94.3%) with the prices they receive for cattle largely due to low prices and poor market ( $n = 90$ , 90%) or other unspecified reasons ( $n = 6$ , 6%). Of the respondents ( $n = 11$ , 11.6%) who did not sell to BMC, their reasons included no cattle to sell ( $n = 3$ ), they had a cattle shortage ( $n = 3$ ), the prices were too low ( $n = 3$ ), or for other reasons ( $n = 2$ ).

Cattle most preferred for selling were male ( $n = 85$ , 34.4%), followed by unproductive cattle ( $n = 74$ , 30%), old ( $n = 58$ , 23.5%), medium ( $n = 21$ , 8.5%), female ( $n = 5$ , 2%) and young ( $n = 4$ , 1.6%). When asked what type of cattle gives the best meat for consumption the responses

were medium-aged ( $n = 75$ , 56.8%), male ( $n = 21$ , 15.9%), unproductive ( $n = 15$ , 11.4%), old ( $n = 10$ , 7.6%), young ( $n = 9$ , 6.8%) and female ( $n = 2$ , 1.5%).

The majority of participants slaughter their cattle ( $n = 65$ , 66.3%) either for household consumption ( $n = 58$ , 48%), use in traditional ceremonies ( $n = 21$ , 17%), selling to the butcher ( $n = 19$ , 16%), selling to friends and family ( $n = 13$ , 11%) and to give away ( $n = 10$ , 8%).

Most farmers in Habu ( $n = 96$ , 100%) milk their cows mostly for home consumption. Over a third ( $n = 36$ , 37.5%) of respondents said they also sell milk to neighbours while 67 (69.8%) respondents said that they also give milk away to their neighbours. The majority of respondents milk between 0 - 10 ( $n = 63$ ) cattle per year. More than half of Habu farmers ( $n = 55$ ) wean their cows as a general practice to induce oestrus.

Most respondents replied that they either make personal use of the hide ( $n = 34$ , 49.3%), do nothing with it ( $n = 33$ , 47.8%), use it for tanning ( $n = 1$ , 1.4%) or sell it ( $n = 1$ , 1.4%). The estimated price that a hide could fetch was largely unknown but of 5 respondents the price varied from 5 to 2500 BWP.

Participants were asked to list their principal challenges to selling cattle in Habu which are illustrated in Figure 2.5.

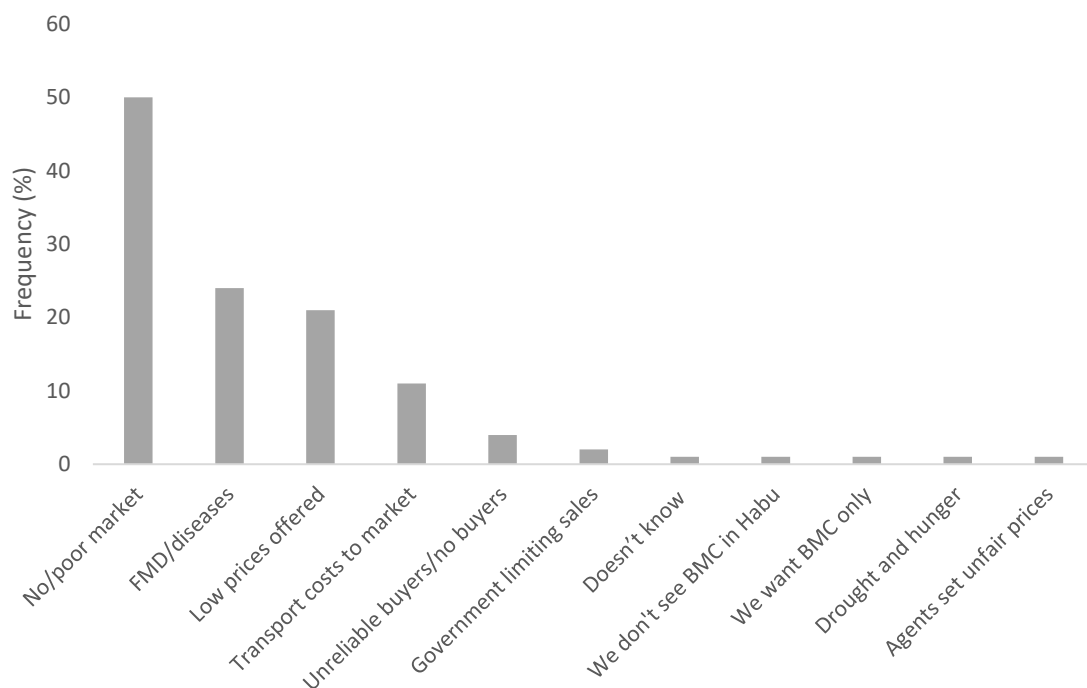


*Figure 2.5. The frequency of challenges to selling cattle reported by Habu respondents*

Similarly, to the above question participants were asked to rank the major threats to farming with cattle in Habu in the degree of importance (Figure 2.6).

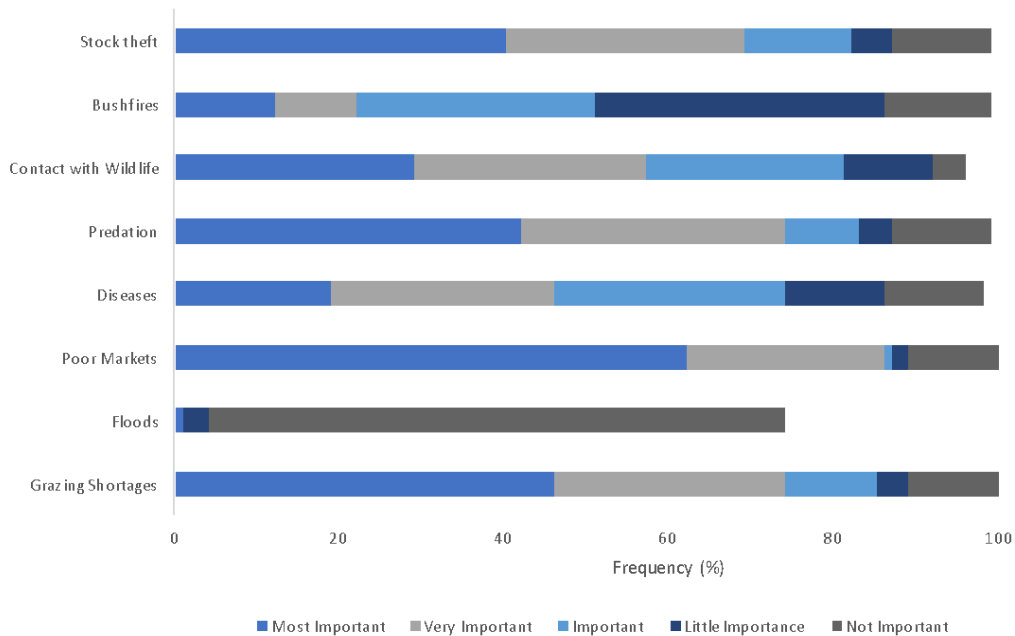


*Figure 2.6. Major threats to livestock production and their ranking of importance as reported by Habu respondents.*

The meat per kilogram is most often sold through local informal trade for between 11 to 15 BWP ( $n = 17$ , 63%) though 2 respondents claimed price ranges between 16 to 20 BWP. Beef and goat are the two most common types of meat available in Habu. Estimated relative costs of meat are displayed in Figure 2.7. Variances between estimated costs may reflect price differences between sellers and uncertainty in meat prices due to availability for purchase which is illustrated in Figure 2.8. Most preferred choice of meat by survey participants were beef ( $n = 48$ , 35%), goat ( $n = 31$ , 22.6%), chicken ( $n = 24$ , 17.5%), game ( $n = 18$ , 13.1%), lamb ( $n = 13$ , 9.5%), all ( $n = 2$ , 1.5%), or undecided ( $n = 1$ , 0.7%).

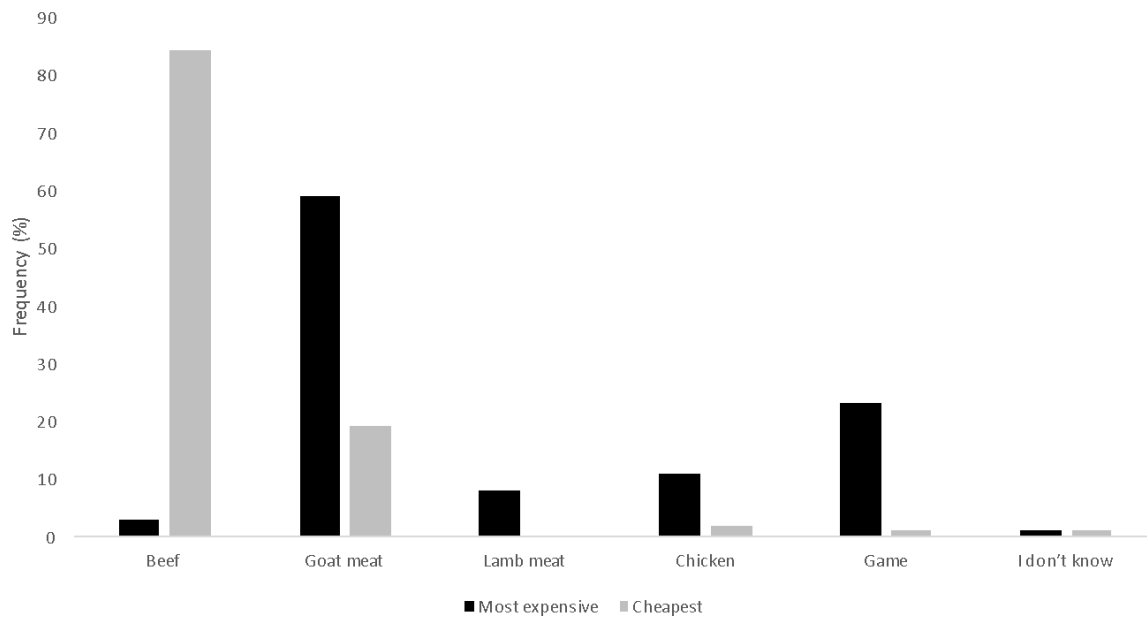


Figure 2.7. Estimated relative costs of purchasing meat in Habu. Differences in prices may be explained by differences in prices set by sellers and uncertainty stemming from the availability of meats.

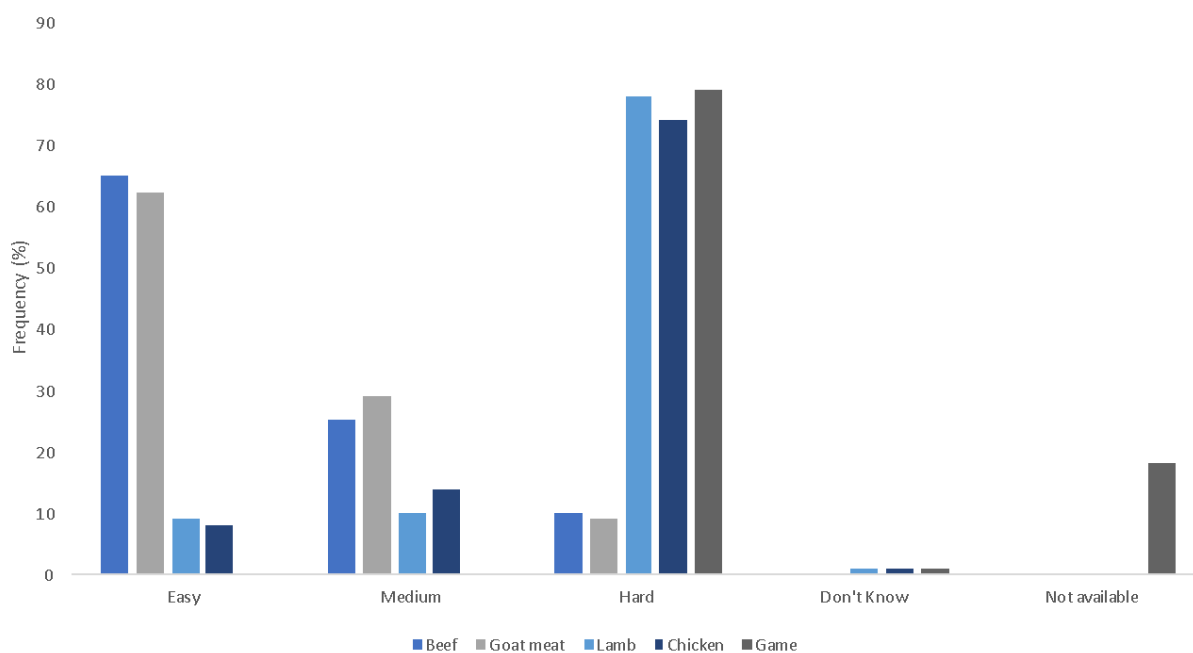


Figure 2.8. The relative degree of difficulty for purchase of different types of meat as reported by respondents in Habu.

## 2.4.5. Animal health

Perceptions on the quality of cattle in Habu were largely unfavourable with 83% ( $n = 81$ ) of farmers responding that they thought the quality of their cattle needed improvement and only 17% (17.3%) were satisfied with their current cattle quality. Most participants thought that quality could be enhanced through breeding or buying better breeds ( $n = 48$ , 57.8%) followed by artificial insemination ( $n = 32$ , 38.6%). Two respondents (2.4%) thought that quality could be enhanced through supplementary feeding while one respondent (1.2%) listed reliable water access as the best action to increase cattle quality. The majority of farmers ( $n = 73$ , 73%) were willing to change practices to improve animal quality. Twenty farmers (20%) replied that they may be willing depending on what the change may be, five farmers (5%) said they would be unwilling to change their current method of farming while two were unsure.

When asked about farming guidance they receive, 92% of farmers ( $n = 92$ ) said that they do receive advice on how to farm and most of these respondents ( $n = 72$ , 80%) were satisfied with the advice they receive. 29 respondents said they would like to receive better advice on livestock husbandry. Most guidance for animal production either comes from a government veterinary extension officer ( $n = 79$ , 79%), other farmers ( $n = 44$ , 44%) or animal health technicians ( $n = 16$ , 16%). One respondent replied that they receive their advice from programmes on the radio. Participants were further asked a series of questions focused on general perceptions on veterinary care which are demonstrated in Figure 2.9.

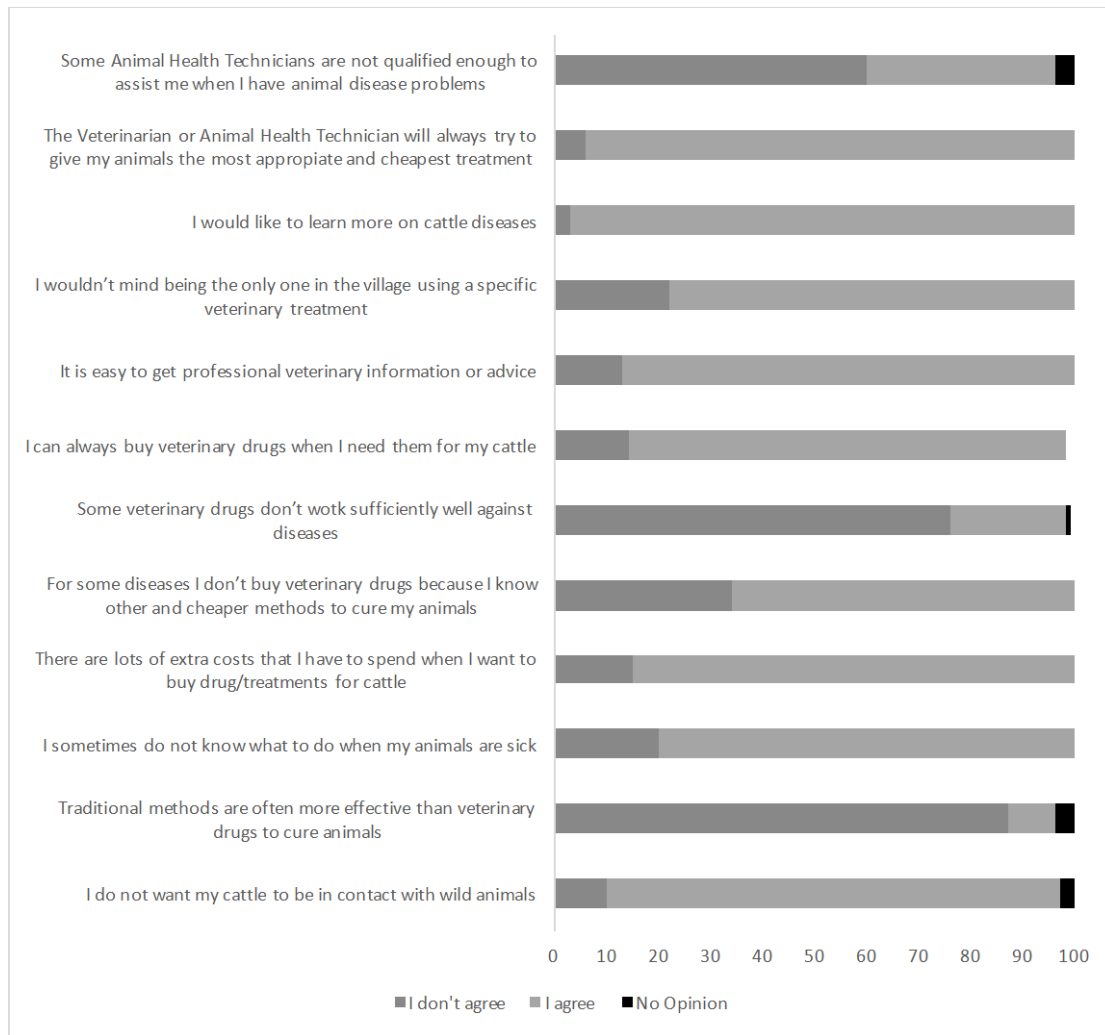


Figure 2.9. Habu respondent opinions on general questions involving animal health-related issues.

The diseases that participants' cattle were vaccinated for in the last 12 months included FMD ( $n = 99$ , 72.3%), anthrax ( $n = 26$ , 19%), lumpy skin disease ( $n = 6$ , 4.4%), black quarter ( $n = 2$ , 1.5%), brucellosis ( $n = 1$ , 0.7%), babesiosis ( $n = 1$ , 0.7%), gallsickness ( $n = 1$ , 0.7%), and pasteurellosis ( $n = 1$ , 0.7%). Most farmers ( $n = 68$ , 68%) responded that they buy some of their vaccines for cattle. Of those that did not incur expenses to vaccines, the reasons given were that vaccines were provided for free ( $n = 25$ , 64.1%), they could not afford to buy vaccines ( $n = 5$ , 12.8%), vaccines were not available in the area ( $n = 4$ , 10.3%), they did not know which vaccines to buy ( $n = 2$ , 5.1%), other reasons ( $n = 2$ , 5.1%) or that they did not find vaccines necessary to prevent diseases ( $n = 1$ , 2.6%). The mean amount spent per year on vaccines was 562.96 BWP ( $sd \pm 906.54$ ).

Most respondents stated that they actively control ectoparasites ( $n = 83$ , 83%). Methods used include dipping ( $n = 56$ , 57.1%), tick grease ( $n = 16$ , 16.3%), spraying ( $n = 16$ , 16.3%), 'other' methods ( $n = 6$ , 6.2%), and handpicking ( $n = 4$ , 4.1%). Seventy per cent of respondents treat internal parasites with methods that include oral doses ( $n = 53$ , 74.6%), deworming ( $n = 10$ , 14.1%), protein/salt blocks ( $n = 4$ , 5.6%), other unspecified methods ( $n = 2$ , 2.8%), deworming ( $n = 1$ , 1.4%), Ivermectin ( $n = 1$ , 1.4%), and traditional medicines ( $n = 1$ , 1.4%). Sixty-nine (69.7%) respondents said that they have treated their cattle for wounds and injuries in the last 12 months. The average expenditure on these treatments was 384.11 ( $sd \pm 559.53$ ). Seventy-one participants also claimed expenses for other veterinary treatments with a mean of 586.29 BWP ( $sd \pm 885.28$ ).

Most Habu farmers water their livestock through boreholes ( $n = 53$ , 53%) or artisanal well points ( $n = 40$ , 40%). Other waterpoints used are mostly seasonal including surface pans (3), springs (2) or the Thaoge river (1). Thirty-nine per cent ( $n = 39$ ) of respondents stated that there is not always enough water for their cattle. When asked when water shortages were most likely to occur, the late winter/late dry season ( $n = 37$ , 77%) was identified followed by times of drought ( $n = 4$ , 8%). When asked to estimate the average kilometres cattle walk in a day to access water, the following responses were given: 3 - 4 kilometres ( $n = 40$ ), 1 - 2 ( $n = 15$ , 5-6 ( $n = 13$ ), < 1 km ( $n = 13$ ), 7 - 8 ( $n = 10$ ), > 10 ( $n = 7$ ), 9 - 10 ( $n = 2$ ). Most respondents ( $n = 89$ , 89%) believed that the water available was healthy for their livestock, while several farmers were unsure or felt that their water supply was too dirty ( $n = 3$ , 3%), contained too much iron ( $n = 2$ , 2%), polluted ( $n = 2$ , 2%) or it made their animals sick ( $n = 1$ , 1%).

#### **2.4.6. Herding and kraaling**

Herding is currently an uncommon practice in Habu with 93% ( $n = 93$ ) of respondents reporting that they never herd their livestock and allow their cattle to roam freely. The majority of farmers ( $n = 98$ , 79.6%) indicated that if they were able they would employ a herder citing both money ( $n = 98$ , 78%) and time ( $n = 97$ , 78%) as their biggest constraints. The benefits of herding were well recognized as illustrated in Figure 2.10.

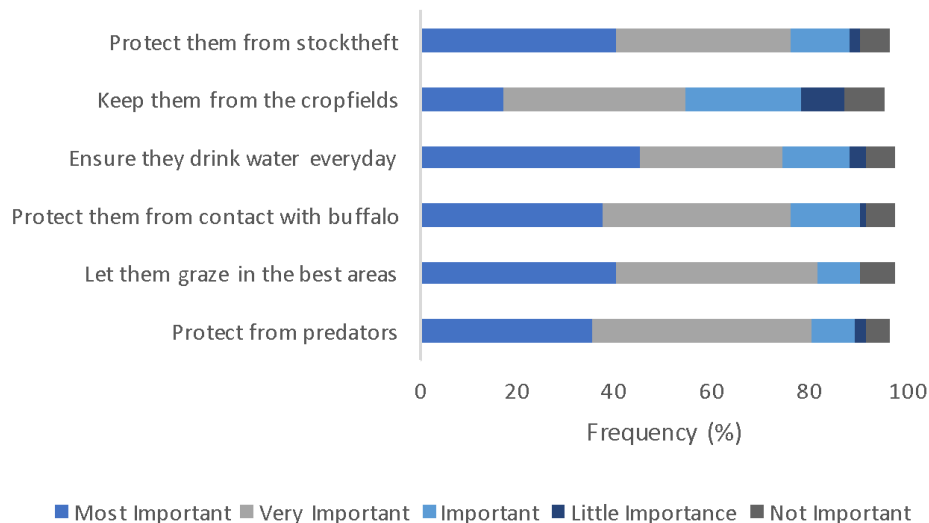


Figure 2.10. Ranked importance of the benefits of herding as reported by Habu respondents ( $n = 100$ ).

Of the respondents that herded cattle, the herder was most likely to be a family member ( $n = 12$ , 12%). Only three respondents reported hiring an employee to actively herd cattle. The respondents who do herd indicated that they were more likely to herd when there was not enough good forage in the rangelands, water was available and when their children were out of school.

Most respondents ( $n = 75$ , 76.5%) reported kraaling their cattle, though 45 of those who kraal were unsure if they kraaled all of their stock (51.1%). Seventy-two per cent of all respondents claimed they kraal whatever cattle return in the evening but that they were most likely to kraal milking cows ( $n = 30$ , 22.5%) and calves ( $n = 24$ , 18%). A large majority of farmers ( $n = 90$ , 90%) indicated that it was a family member's responsibility to kraal cattle, while five (5%) respondents said that they pay an employee to kraal their livestock. The reasons for kraaling cattle are demonstrated in Figure 2.11. Eighty-seven percent ( $n = 87$ ) of those who kraaled livestock said they kraal their livestock all year round. Those that did not state that they are most likely to kraal in the early rainy season to prevent crop damage, this period coincides with calving season and this is when they perceived higher predation rates. Reasons for not kraaling cattle included unspecified reasons ( $n = 2$ ), time constraints ( $n = 1$ ), no money to hire help ( $n = 1$ ) and one respondent who did not think that kraaling was important.

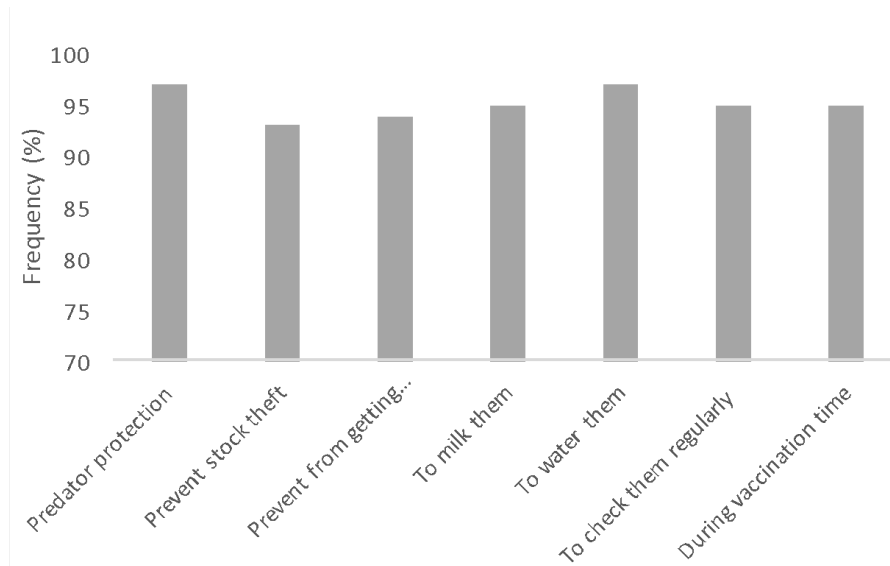


Figure 2.11. Reasons for kraaling cattle Kraaling as reported by Habu respondents. Kraaling of livestock is a common activity in Habu.

#### 2.4.7. Livestock losses and human-wildlife conflict

Most respondents reported livestock losses within the last year ( $n = 92$ , 92%). The losses of cattle reported totaled 1335 losses, accounting for 18% of the total population reported (currently owned and losses combined). Respondents largely indicated 'Lost Cattle' (cattle that stray and do not return to the boma), as the main cause which accounted for 60.3% ( $n = 776$ ) of total losses (Figure 2.12).

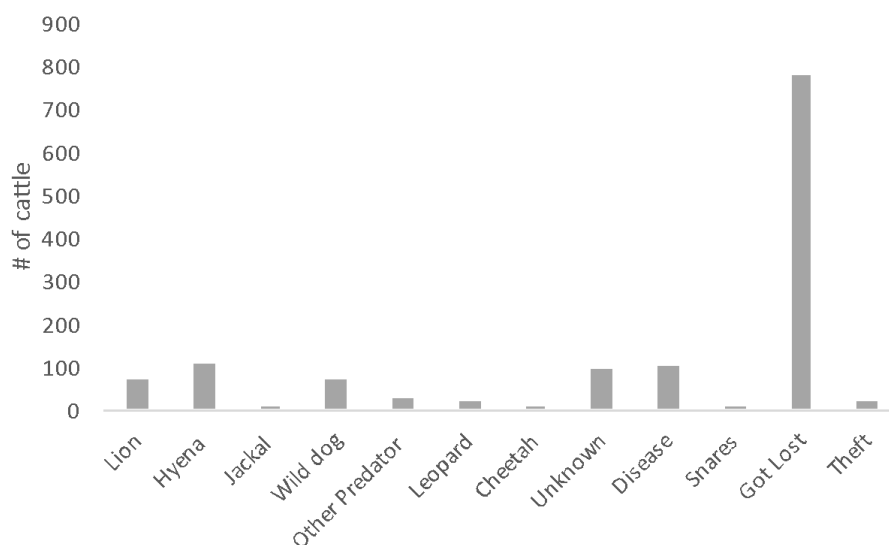


*Figure 2.12. Reported cattle losses during 12 months (March 2018 to March 2019) from Habu respondents. Cattle losses accounted for 18% of the entire reported cattle population (currently owned and losses combined).*

Straying animals was also a large cause of small stock losses as displayed in Figure 2.13. Mesopredators and 'other' or unknown causes had a higher effect on small stock in comparison with cattle. Disease had a particularly heavy toll on the goat population accounting for 4.7% ( $n = 168$ ) of the total goat population.

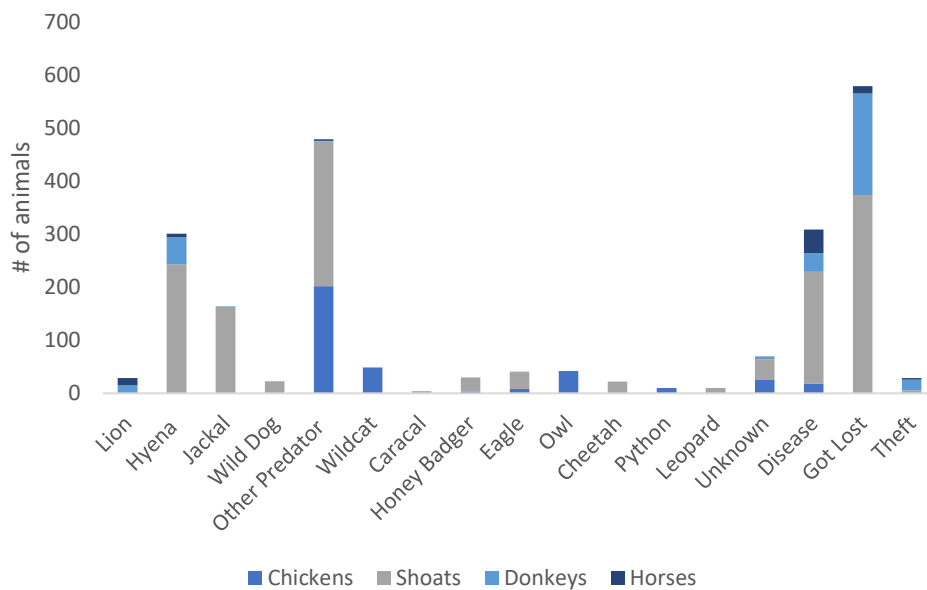


*Figure 2.13. Causes for total reported small stock losses (including chickens, shoats (sheep and goats combined), donkeys and horses) by Habu respondents for 12 months from March 2018 to March 2019.*

Most respondents ( $n = 95$ , 95%) perceived wildlife as a major threat to their livestock for reasons that included animal disease ( $n = 94$ , 30.4%), predation ( $n = 85$ , 27.5%), competition for grazing ( $n = 77$ , 24.9%) and safety ( $n = 51$ , 16.5%). The majority ( $n = 94$ , 94%) of farmers took particular issue with buffalo grazing in proximity of their cattle citing mainly animal disease ( $n = 91$ , 44.6%), competition ( $n = 64$ , 31.4%) and safety ( $n = 47$ , 23%) concerns.

The predators identified as being most problematic to livestock rearing included hyena ( $n = 83$ , 41.1%), lion ( $n = 53$ , 26.2%), leopard ( $n = 38$ , 18.8%), wild dog ( $n = 11$ , 5.4%), jackal ( $n = 9$ , 4.5%), caracal ( $n = 6$ , 3%) and other ( $n = 2$ , 1%). Predators listed as having the highest effect on small stock included jackal ( $n = 73$ , 33.2%), hyena ( $n = 57$ , 25.9%), wild dog ( $n = 34$ , 15.5%),

caracal ( $n = 21$ , 9.5%), leopard ( $n = 19$ , 8.6%), honey badger ( $n = 6$ , 2.7%), cheetah ( $n = 4$ , 1.8%), other ( $n = 3$ , 1.4%), lion ( $n = 2$ , 0.9%) and eagles ( $n = 1$ , 0.5%). The total number of livestock killed inside the kraal reported by respondents included 194 (40.7%) chickens, 186 (39%) goats, 43 (9%) cattle, 38 (8%) sheep, 9 (1.9%) donkeys, 4 (0.8%) horses and 3 (0.6%) other livestock. The most likely predators to enter kraals were leopard ( $n = 36$ , 29.8%), lion ( $n = 25$ , 20.7%), hyena ( $n = 22$ , 18.2%), honey badger ( $n = 16$ , 13.2%), caracal ( $n = 11$ , 9.1%), cheetah ( $n = 5$ , 4.1%), jackal ( $n = 4$ , 3.3%), wild dog ( $n = 1$ , 0.8%) and other ( $n = 1$ , 0.8%). When asked what action a farmer would take when a predator kills their livestock the responses were to report it ( $n = 85$ , 75%), chase it off ( $n = 11$ , 10%), kill it ( $n = 8$ , 7%), no action ( $n = 8$ , 7%) and change grazing area ( $n = 2$ , 1.8%).

#### **2.4.8. Rangeland and livestock condition**

Respondents identified the early dry season as the time of year when the rangeland is in the best condition ( $n = 73$ , 70.8%). Participants identified the late wet season as the time of year when their cattle were the healthiest ( $n = 70$ , 59.3%) and the late dry season when their cattle were in the poorest condition ( $n = 73$ , 70.8%). Most participants felt that the quality of forage in the Habu rangelands had decreased in the past decade ( $n = 66$ , 66%), while 23 (23%) respondents said that the quality increased, ten (10%) respondents said it had stayed the same and one (1%) respondent was unsure. Similarly, when asked if the abundance of forage had changed in the last 20 years 59 (59%) participants said that it had decreased, 13 (13%) responded that it had increased, four (4%) thought that it had stayed the same and one (1%) farmer was unsure. Perceived threats to the rangeland included overgrazing ( $n = 87$ , 27.4%), bush encroachment ( $n = 82$ , 25.8%), drought ( $n = 81$ , 25.5%), fire ( $n = 66$ , 20.8%), floods ( $n = 1$ , 0.3%) and other ( $n = 1$ , 0.3%).

## **2.5. DISCUSSION**

This study aimed at linking project activities with community priorities through the scope of an applied H4H project currently underway in the Okavango subdistrict of western Ngamiland, Botswana. The result is a profile of community perceptions on animal, human and environmental health risks as well as a comprehensive review of Habu's livestock production system and recommendations to guide project interventions.

The livelihood strategies in Habu are typical of villages in western Ngamiland that are adjacent to the WMAs of the Delta and bear high costs associated with living close to wildlife (depredation on livestock, crop and infrastructure damage, human safety) but receive few benefits such as the rural development projects and employment derived from CBNRM ventures in the eastern Delta where there is a functional tourism industry (Rogan et al. 2015). Livestock production is the predominant form of income generation in Habu and is consistent with agropastoral communities globally in that the indirect and direct contributions of rearing livestock to household income are diverse and complex (Smith et al. 2013). To overcome the health and livestock production related challenges demonstrated above, the following discussion proposes recommendations on how an integrated H4H model can serve to address many of the aforementioned constraints.

### **2.5.1. Human health**

Satisfaction with health services provided at the Habu Clinic was generally high. In Botswana, health services are provided by the government free of charge and the country has an extensive network of health facilities throughout its 27 health districts which prioritizes primary health care through a decentralized system (Tapera et al. 2018). The nearest hospital is located at the subdistrict capital in Gumare, situated 90 km to the north of the village and ambulance services are provided for the critically ill. Habu currently has one driver employed at the clinic but does not have a vehicle. The nearest town of Nokaneng has two ambulances that may be used throughout the region but are often predisposed or in various states of repair. Access to treatment remains a top concern among Habu residents along with infectious disease, hypertension, clean water and malnutrition. Habu residents share these poverty-related health challenges with rural villages across sub-Saharan Africa (Schneider et al. 2009; Brynard 2011). It is recommended that regional rural development initiatives should give specific attention to improving access to medical facilities, clean water, and nutrition along with health, sanitation and dietary education.

### **2.5.2. Crop production**

Sources of revenue from crop production and associated wage labour reported in this study totalled 4%. Fresh produce is difficult to come by in Habu. While crop production used to be

the main livelihood strategy for the Habu community, intermittent and delayed rains have reduced household dependence on vegetable farming (Chief Kampomboro, pers. comm.). Western Ngamiland has been identified as a region of high vulnerability to climate change and climate variability (Regional Climate Change Programme 2009; Bauer and Scholz 2010; H4H 2019). Climate change models for Botswana predict reduced rainfall and that temperature increases (+3.5°C) to be higher than regional (+3.1°C) (H4H 2019). Changes in the effective growth period for crops is driving a general shift from crop dependence to livestock dependency in many parts of sub-Saharan Africa (Thornton et al. 2006b). As subsistence agriculture in Habu becomes increasingly challenging, the imperative for alternative forms of income generation will be ever more critical. To address dietary constraints and develop alternative revenue streams, HEDT has recently developed a women's and youth cooperative that is supplied with a permanent borehole and fertilized through kraal rotation of the communal herd in the H4H program. As the effects of climate change intensify, the role of planned grazing and best practices in rangeland management concerning soil water retention will become increasingly relevant to maintain Habu's aquifers. Furthermore, malnutrition is particularly devastating among agropastoral communities due to factors of food choice that are influenced by income, market access, availability and knowledge of nutritious foods (Gebremichael & Asfaw 2019). Prioritizing community needs is a critical part of the consultative process worked into the H4H model. In the case of Habu, further support for the cooperative through garden inputs may be a relevant topic during the negotiation of stewardship agreements.

### **2.5.3. Meat consumption**

Respondents listed beef and goat meat as more readily available for purchase around Habu, however, there is no butchery or cold storage facility in the village and meat shortages are common. New sanitation laws prohibit the slaughter of animals in the traditional methods, usually under trees, however, the village has no slaughtering facility and these regulations are not strictly enforced. In recognition of this dearth of appropriate slaughtering facilities, H4H through collaborations with private enterprises has been investing in research and development of mobile slaughter facilities. The lack of meat availability may explain why the majority of Habu respondents reported slaughtering livestock for home consumption,

whereas findings in some other regions in southern Africa demonstrate that only farmers with larger herds were willing to slaughter for personal use (Van Rooyen 2017). Consumption of bushmeat, while reported as relatively scarce in supply, was still listed as the preferred meat source for 18 % of respondents. While bushmeat consumption in some regions of sub-Saharan Africa is recognized as a source of access to diverse and nutritious animal protein for impoverished communities (Brashares et al. 2011; Ripple et al. 2016; Brashares & Gaynor 2017), investigations into illegal bushmeat hunting around the Delta reported bushmeat consumption from non-hunting households were low (Rogan et al. 2018). There is scarce evidence associating bushmeat hunting in the Okavango to poverty or food security but rather it is largely an opportunistic pursuit of relatively wealthier households (Rogan et al. 2018). Bushmeat consumption may pose additional risks to human health arising from zoonotic infectious diseases (Allen et al. 2017; Pruvot et al. 2019). Furthermore, bushmeat consumption is a contributing factor to wildlife declines in Northern Botswana which may have adverse effects on the wildlife tourism industry and regional economic development (Rogan et al. 2015).

#### **2.5.4. Water**

Water availability and quality were listed as a concern for both human and livestock consumption. Water provisioning systems in Botswana are usually managed by the Department of Water Affairs. Water for household use in Habu used to be provided through a now dilapidated water reticulation system of pipes that pumped water from the neighbouring village of Nokaneng. Today water is trucked in to fill the town water tower on a biweekly basis. The government water supply in Habu is supplemented by a private donation from the leaseholders of the neighbouring Wildlife Management Area of NG26 with two additional boreholes that feed water tanks. However, drought conditions of 2019 caused livestock to destroy the fence and foundation to the water taps in the village and clean water access continues to be a primary concern for Habu residents. Most farmers water their livestock through artisanal well points dug into the dry river bed, however, the water table has dropped in recent years making it difficult to access the aquifer (Chief Kampomboro, pers. comm.). In recognition of the challenges to the access of clean water for both humans and livestock, a current mandate of HEDT is to work with private and public sectors to establish a

filtration system, rehabilitate the existing reticulation system and provide additional boreholes to farmers for livestock and household consumption. The management and maintenance of improved water access will rely heavily on improved governance structures which is an underlying priority of the H4H model. Recent support for strengthened institutions in the village have centred on democratically elected village clusters and steering committees to collaboratively plan for issues regarding grazing plans, water reticulation, garden clusters and aggregated herding programmes.

### **2.5.5. Milk and milk production**

Most cattle farmers in Habu milk their cows, which has a vital link to nutrition in Ngamiland, particularly for children under five years of age (Atkinson et al. 2019). The regional outbreak of contagious bovine pleuropneumonia (CBPP) in 1995 triggered the culling of the entire cattle population of Ngamiland as well as the erection of three additional veterinary fences to prevent the spread of the disease to the commercial farms in the south. This cattle eradication program was followed by increased malnutrition in children under 5 (Boonstra et al. 2001). However, the handling and consumption of fresh milk is a common practice in Habu and unboiled milk has been a known source of zoonotic tuberculosis and brucellosis (Marcotty et al. 2009). This health risk is preventable with proper education (Berrian et al. 2016) and as the vast majority of respondents agreed that they would like more information on bovine diseases, Habu farmers and those in the surrounding district stand to benefit from zoonotic disease education workshops focused on health risks associated with meat and dairy consumption.

### **2.5.6. Animal health and production**

In general, most farmers in this survey were satisfied with access and quality to the veterinary extension services offered by the government. There were noteworthy concerns about the qualifications of some veterinary officers and a strong desire by participants to learn more about animal disease and health-related issues. Vaccines for FMD and anthrax are provided by Botswana's Department of Veterinary Services and may explain why these were the two most commonly reported vaccines. Under the current system, many cattle are unvaccinated during governmental vaccination programs. Due to the free-roaming style of livestock

management, not all cattle can be accounted for during vaccination campaigns, which is another issue readily addressed with aggregate herding. Furthermore, average annual costs spent on veterinary care surpassed the mean monthly income which demonstrates that the costs of veterinary care are significant to Habu farmers and presents another potential benefit of communal herding towards vaccine efficacy through reducing the costs of veterinary care through collective sharing.

Cattle loss due to disease was calculated at 7.7% of total losses falling behind cattle lost to straying and predation. Disease was ranked as a relatively low constraint to farming livestock yet was the second challenge listed for selling cattle within Habu. This perception likely stems from the frequent market shutdowns in the region associated with animal disease. Losses to disease had a larger impact on small stock, which local veterinary extension officers attribute to internal parasites and low rates of deworming implemented around Habu. Farmers in Habu are restricted to market access due to the proximity to wildlife, particularly Cape buffalo, which is a known carrier of the southern African serotype of FMD (Atkinson et al. 2019). The constraint that market access poses to selling cattle is heavily reflected in this survey. After the seven-year FMD related district-wide market shutdown of 2007, the BMC abattoir in Maun reopened in 2014 with limited capacity. Without incentives for farmers to manage livestock movement or production, the Ngamiland population rose to 317,000 cattle of mostly low quality and condition (Atkinson et al. 2019). A key finding of this survey is that 'lost cattle' (ie. stray cattle) account for 60.3% of all cattle losses in Habu. In follow-up interviews, many farmers attributed this to water and forage availability that cause cattle to stray far from their cattle posts. As a result of uncontrolled movement, cattle travel across districts and subzones in search of water. Lake Ngami has a reported 15,000-20,000 stray cattle in the area (Atkinson et al. 2019). These strays may provide a much greater threat to the spread of FMD and would explain FMD outbreaks in communities that are distal from the Delta where buffalo are not found. While wildlife vectors are responsible for occasional transmissions of FMD strains to livestock, the conditions under which transmission occur are poorly understood (Jori et al. 2009; Brito et al. 2016). Some strains can persist in livestock populations where the disease has become endemic (Vosloo et al. 2002; 2009) yet the nature of these transmissions and the role that livestock and wildlife movements contribute to the spread of FMD in southern Africa is poorly understood (Teklehiorghis et al. 2014). Given the far-reaching consequences to

poverty eradication, rural development and biodiversity conservation, further research is critical and urgently recommended to understand the underlying dynamics of FMD transmission. Regarding this current situation, the aggregate herding and herd control practices promoted by H4H through the use of professional herders is an ideally suited strategy to address uncontrolled livestock movement and mitigate the risk of disease outbreaks.

Herd size was a significant factor in determining whether farmers were able to sell cattle and which markets they were able to access. This supports similar surveys done in Mnisi, South Africa and in the Zambezi region of Namibia that demonstrated that herd size acts as a precursor to whether farmers can access formal markets (Van Rooyen 2017). Herd size in Habu was higher than that of the Zambezi region and Namibia and while no other significant trends were detected when testing herd size against variables such as reasons for keeping cattle or cattle quality, these variables have shown correlations with herd size in other regions of southern Africa (Van Rooyen 2017). Selling to BMC and abattoirs requires selling enough cattle to offset high costs of transportation and animal fodder during quarantine (Atkinson et al. 2019). This is a likely explanation of why most farmers in Habu sell their livestock to local butchers where they do not incur additional costs in sales.

The majority of farmers had low perceptions of cattle quality which relate directly to concerns for market price. Most farmers thought that cattle condition could be improved through breeding or buying better breeds. The unfavourable perception of cattle quality, preference for the sale of older unproductive cattle, desire for better breeds and the discontent with prices are indicative of an under-developed livestock production system. Hides were largely discarded after slaughter which poses another potential opportunity for beef value-addition through leather products. The provisioning of desired breeding bulls and facilitating training in primary animal health care, livestock production and beef value-addition may provide powerful incentives in the negotiation of Conservation Agreements to encourage improved farming practices and environmental stewardship amongst Habu farmers.

The three main constraints identified for selling cattle were market access, disease-related constraints and low prices. Botswana has recently drafted a commodity-based trade gap analysis (Atkinson et al. 2019) to address these specific challenges through measures focused

on: accessing new markets through compliance to commodity-based trade protocols and wildlife-friendly branding and trialing new methods of animal disease control through better record keeping and mobile quarantines. The two communities selected for piloting these methods are Habu and Eretsha, which are the only two communities currently engaged in implementing the H4H model in Botswana. While H4H has provided considerable support in garnering funding, providing training, strengthening partnerships and developing the framework behind these interventions, the pilot projects are in their early stages and whether these strategies are successful in addressing the constraints identified by Habu farmers will require vigorous trialling, monitoring and evaluation.

### **2.5.7. Rangeland health**

The current cattle population in Ngamiland is nearly double the most up-to-date estimates for the regions' grazing capacity (Atkinson et al. 2019; GIZ 2019). This not only poses a major animal health risk but also threatens ecosystem health through rangeland degradation which will not only carry economic consequences for livestock condition and animal value but also revenue derived from wildlife tourism due to cascading effects of biodiversity loss. Local ecological knowledge gathered from this survey indicates a loss of Habu forage quality and quantity in the last decade, which supports the notion that rangeland degradation is a major environmental threat in western Ngamiland. Overgrazing was identified as the largest threat to rangeland condition and grazing shortages as the second major constraint to farming in Habu aside from market access. Fires were also cited as a major threat to rangeland condition and are a frequent occurrence around the Delta. A core component to the H4H model is to address issues of rangeland degradation through training in sustainable rangeland management practices and strengthening community governance through the creation of grazing committees that enable planned grazing according to the local ecological and social system, using skilled herders (SAWC 2021). Through the controlled movement of cattle and the implementation of grazing plans, the detrimental effects caused by overgrazing and lack of rest can be reversed and rangeland health restored through increased vegetation foliar cover, species richness, diversity and reduced plant basal gaps (Odadi et al. 2017). Planned grazing initiatives can have additional noted benefits to wildlife-livestock coexistence programs such as increased ecosystem stability through improved resource functional

heterogeneity, increased species richness in wild ungulates and cattle weight gain (Fynn et al. 2016; Odadi et al. 2017; Tyrrell et al. 2017).

### **2.5.8. Human-wildlife conflict**

Cattle losses to predators in Habu were reported at 3.8% of the total cattle population. This figure is higher than other areas in sub-Saharan Africa such as Tsavo, Kenya where wildlife attacks on livestock claimed 2.5% of range stock (Patterson et al. 2004) or Botswana's Central Kalahari and Khutse Game Reserves where reported losses of livestock were 2.2% annually (Schiess-Meier et al. 2007). Keeping small stock was reported as the third-largest contributor to household income in Habu apart from cattle rearing and Botswana's Ipelegeng welfare system. The costs of small stock losses to predators in Habu are substantial, accounting for a loss of 48% of the total chickens owned, 32% of the sheep and goat population and a 23% reduction in the horse and donkey population. While lethal control measures taken against predators were reportedly low in this survey, retaliatory killings have the potential to threaten Habu's aspirations for tourism development. Intolerance to carnivores and lethal control methods contribute to local, regional and global declines in carnivore populations (Woodroffe 2000). Perceptions of the degree of conflict can be greater than the actual threat and may illicit disproportional responses (Dickman 2010). While records from the HEDT Community Scout patrol data indicate that lethal control measures are used in the region mainly through the use of firearms and poison, anecdotal evidence indicates that many farmers have abandoned such methods to encourage tourism development which is supported by a recent increase in lion sighting reports and an increase in farmer requests for assistance with problem animals received by the Habu Community Scouts (HEDT unpub. data 2019). Human-wildlife conflict mitigation is one of the key interventions to the H4H model that can be addressed through minor improvements to livestock husbandry in Habu, primarily through enabling and encouraging collective action and revitalizing the traditional practices of herding and kraaling.

### **2.5.9. Herding and kraaling**

The combined actions of herding and kraaling are at the forefront of H4H activities and have the potential to address a range of the challenges that occur on southern African rangelands

including zoonotic disease control, rangeland degradation, human-wildlife conflict and cattle loss due to straying animals or theft. While herding and kraaling were once common practices in Botswana, today the herding component is nearly nonexistent. A similar situation occurs across southern Africa where a marked decline in herders was observed after governments mandated compulsory schooling (GIZ 2019). Some Habu farmers hire help to establish seasonal grazing camps. The cattle managed at these camps are usually kraaled at night and allowed to roam free during the day. Village elders of Habu recall a time of active herding in their youth before educational policies in the 1970s required that children attend school (Chief Kampomboro, pers. comm.). The benefits of herding concerning livestock husbandry were well understood by survey participants and most households indicated that they would hire herders if finances were available. The record-keeping and monthly health checks promoted by the H4H model sets an ideal platform to address related issues of animal production and disease while also accessing previously restricted markets through compliance to alternative animal disease control policies such as commodity-based trade or untapped markets associated with conscious consumers of the neighbouring safari industries in the Delta through wildlife-friendly branding (Van Rooyen 2017). HEDT currently manages a pilot community herd with approximately 150 cattle that are owned by 17 farmers. While currently the cost for the employment of herders are supported through donor funding, similar programmes in South Africa can sustain herder fees by a percentage that is taken from cattle sales in the aggregate herd (Meat Naturally 2018). This allows for farmers to share the costs of herding with confidence that their cattle have 24-hour supervision, are regularly assessed for condition, are taken to good grazing pastures and watered daily and kraaled in predator-proof bomas.

Habu has a higher reported rate of kraaling in comparison with other Botswanan communities at 75% (Weise et al. 2018) yet some African agro-pastoral landscapes report rates as high as 83% (Kuiper et al. 2015). Traditional kraals in Habu are typically built from stacking thorn bushes. The efficacy of any kraal design is dependent on durability, regular use and cost efficiency (Weise et al. 2018). Early efforts by HEDT to improve upon the kraaling method in Habu by constructing, denser, wider and taller kraals using the same traditional method has been successful in lowering the number of predator attacks inside kraals (HEDT report 2019). Though cost-effective, this method of fortification is dependent on the availability of thorny

shrubs in the immediate vicinity and requires extra labour as well as routine maintenance to keep their effectiveness over time. HEDT's communal herding program makes use of a predator-proof kraal design made from game capture material. This allows for the mobility of the kraal, which is useful in accessing distant pastures as well as fertilizing areas designated for crop production. While HEDT has been active with community sensitization on the importance of kraaling and herding, the pilot project has provided a platform for which to address associated issues of policy concern at a national level including quarantine procedures and costs, rangeland degradation, animal health and wildlife-friendly practices. It is estimated that the combined effort of herding and kraaling can save Botswana's state-funded compensation scheme for predator-induced livestock losses by up to 80% (Weise et al. 2018).

## 2.6. CONCLUSION

Livestock production in the communal lands of the livestock-wildlife interface of northern Botswana is a challenging endeavour. Current animal disease policies have thus far been costly and limit market access and alternative livelihood enhancement opportunities available to Botswana's rural poor. Furthermore, routine shutdowns of the Ngamiland beef market have inflated the region's cattle population which adversely affects ecosystem health through deteriorated rangelands which in turn affects cattle condition and the overall carrying capacity for other grazing species. Veterinary cordon fences, while ineffective at controlling FMD spread, further inhibit wildlife dispersal in one of KAZA's critical wildlife dispersal areas. This comes not only as a threat to biodiversity conservation but also to the potential for sustainable development of tourism and is one of the largest opportunities to build regional community resilience through diversified livelihoods.

The average reported annual income in western Ngamiland is below the national average (Magombeyi & Odhiambo 2017). Farmers in Habu are burdened with additional production costs due to human-wildlife conflict as well as heavy costs associated with water provisioning, quarantine and transport costs to the few abattoirs that are available to communal farmers in Botswana's red zones. In addition, farmers have lost access to traditional dry season grazing lands in WMAs, such as NG26 (Basupi et al. 2017). The combined effect of all these factors is expected to result in poorer livelihoods than the national average, as observed for the Maasai

in Ngorogoro WMA, Tanzania relative to Loliondo where there were fewer restrictions on livelihoods (Galvin et al. 2002). As marginalized communities rely more heavily on natural resources, particularly in times of global shocks such as pandemics and climate change, new approaches are urgently needed to safeguard vulnerable communities and the ecosystems they depend on. Interventions promoted by H4H, such as simple adjustments to animal husbandry practices (i.e. herding and kraaling), which will reduce cattle being lost or depredated, while improving rangeland condition and functional heterogeneity, coupled with employment opportunities for professional herders, training opportunities, investments into veterinary support and improved market access could provide the necessary incentives to negotiate ecosystem stewardship practices necessary to develop a diverse livelihood base through facilitated wildlife-livestock coexistence while also addressing many of the aforementioned challenges. The implementation of a fully functioning H4H program will depend on traditional leadership and farmers driving adoption and implementation, community capacity building, strengthening of local governance and institutional structures and ultimately continued consultation and collaboration with target communities for effective land-use planning and multi-level stakeholder, interdisciplinary partnerships and collaboration as promoted through One Health.

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## **CHAPTER 3. Environmental template and drivers of functional heterogeneity in communal rangelands of the western Okavango Delta**

### **3.1. ABSTRACT**

Rangeland degradation poses a major threat to agropastoral livelihoods in sub-Saharan Africa. Lack of a clear definition of rangeland health leaves targets of rangeland restoration efforts to the discretion and objectives of stakeholders and land-use planners. This research investigates landscape functional heterogeneity as a potential indicator for rangeland health and provides an environmental template for some of the key drivers of heterogeneity in western Ngamiland, Botswana. Using cattlepost surveys and Landsat images, a habitat classification map was generated for the rangelands around Habu village in Western Ngamiland. Cattlepost surveys were used to generate a grazing pressure map of the study area and a grazing gradient based on pixel values. Non-metric multidimensional scaling and generalized linear mixed models were used to test grazing pressure against grassland and woody vegetation structural features collected from randomized vegetation transects across the landscape. Dung surveys of abandoned cattle posts were used to identify habitat use among large mammalian herbivores. The habitat classification map elucidates heterogeneity in a matrix of five distinct habitat types around Habu. Quantile regressions of grass structural attributes indicate a significant decrease in the density of grass tufts and increase in biomass at the distal end of the grazing gradient as well as a general pattern of increased stem height, the distance between grass tufts and grass tuft basal width at sites further away from intensive grazing. Spoor surveys showed higher wildlife utilization in abandoned cattlepost sites than control sites. These results demonstrate several drivers of functional heterogeneity in the Habu rangelands. Understanding these underlying processes is critical to guide rangeland restoration efforts. The resulting environmental template is then discussed as a tool to inform interventions for a H4H pilot programme currently being implemented in the Habu area. The objective of this pilot programme was to reduce regional poverty by demonstrating a wildlife-livestock coexistence model.

## 3.2. INTRODUCTION

Land health that incorporates conservation ethics, sustainability, and biodiversity is a long-recognized yet mostly unrealized goal in the ever-demanding global economy (Leopold 1949; Western et al. 2020). Improved rangeland management and integrating livestock-wildlife coexistence and biodiverse landscapes may be critical for achieving such goals given that ecosystem health is interconnected with animal and human health (OHI 2021). In addition to land health, potential benefits from coexistence include diversified livelihoods for local communities (e.g.; opportunities in tourism, hunting, game farming) and improved livestock and wildlife production through enhancement of functional heterogeneity (Fynn et al. 2016). However, few examples of facilitated coexistence exist (Tyrrell et al. 2017). Africa's Protected Areas (PA's, parks, reserves, and wildlife management areas) have been established in part to address the conservation and biodiversity objectives, but PA's typically fail to meet the spatio-temporal variability of resources required by healthy lands that include highly mobile species (Harris et al. 2009; Craigie et al. 2010; Fynn & Bonyongo 2011; Fynn et al. 2016). In PAs, as well as in many communal lands, seasonal wildlife movements have changed or ceased altogether (Mose & Western 2015), largely due to fences and habitat degradation resulting in population declines (Hobbs et al. 2008; Løvschal et al. 2019). Livestock fencing is often blamed for southern Africa's declining wildlife populations (Osofsky 2005). Conversely, wildlife is blamed for competing with and depleting forage resources required for traditional livestock economies (Ogutu et al. 2016, 2011). Though land management decisions are often based on these basic perceptions of exploitative competition, the relationship between wildlife and livestock and the use of their requisite resources is typically more complex. Examples of integrated wildlife–livestock landscapes in parts of East Africa demonstrate that livestock can be managed to improve forage access for wildlife (Tyrrell et al. 2017; Butt & Turner, 2012; Odadi et al. 2011; Western 1982). However, applied examples are urgently needed elsewhere in the continent to illustrate how the livestock-wildlife interface can be managed to improve land health and local economies through the integration of livestock and wildlife (Odadi et al. 2017). This chapter identifies drivers of vegetation composition and animal utilization patterns using an environmental template and applied H4H principles in an agropastoral landscape in northern Botswana with a specific focus on functional heterogeneity as an indicator for ecosystem health.

### 3.2.1. Defining rangeland health

Rangeland health has been an evolving concept since the mid-20<sup>th</sup> century when it was first used to relate to community condition or successional stage based on the range succession model (Briske et al. 2005; Dyksterhuis 1949; Ellison 1949). Alternative rangeland evaluations, such as state and transition models and the threshold concept, were developed later in the 20<sup>th</sup> century to address limitations of the linear nature of the range succession model and account for the multivariate nature of vegetation dynamics (Briske et al. 2005). Further investigation into the complexities of rangeland ecology led to a shift from community composition-oriented procedures to soil and hydrology-based indicators to address rangeland health (Pyke et al. 2002). A commonly cited definition of rangeland health described by the USDA is “the degree to which the integrity of the soil, vegetation, water and air as well as the ecological processes of the ecosystem are balanced and maintained” (USDA 1997). Where integrity is defined as “the maintenance of the functional attributes characteristic of a locale, including normal variability” (Pyke et al. 2002). Although there are several critiques to applying the term ‘health’ to ecosystems (Wicklum and Davies 1995; Rapport et al. 1998) the term is commonly used in reference to ecosystem assessments in a manner interchangeable with condition (Eldridge & Koen 2003). By the early 21<sup>st</sup> century over 17 indicators had been developed for rangeland health assessments in North America (Pyke et al. 2002; Briske et al. 2005). Common criticisms to rangeland health indicators have included neglecting measures of biodiversity (Symstad and Jonas 2011), an acknowledgement that rangelands have high annual variation (Holecheck et al. 2001) and that that rangeland health assessments can be highly context-dependent and can vary due to observer experience and personal bias, e.g. while a pastoralist may be likely to value forage biomass, a conservationist is likely to be more concerned with vegetation structure and diversity (Eldridge & Koen 2003). As both biogeochemical and socioeconomic indicators are affected by environmental degradation, associations between human activities and the environmental state are important considerations for developing indicators of environmental health which vary depending on the specific management objective (Cairns et al. 1992). In developing indicators for rangeland health, Eldridge and Koen (2003) suggest including other stakeholder values and advise that “alternative management perspectives are preferred over those which are based merely on pastoralism or even the conservation of biodiversity.”

### 3.2.2. Functional heterogeneity

Functional heterogeneity is a term first described by Kolassa and Rollo in 1991 as ‘that which ecological entities actually perceive, relate to and respond to’ and thus differs from a random measurement of heterogeneity in the focal system (Owen-Smith 2004). Functional heterogeneity refers to the spatio-temporal variation in vegetation structure, composition and chemical properties that may be either induced through irregular grazing patterns, intermittent precipitation and periodic fire events or inherent and influenced by local climatic, geomorphology, edaphic and hydrological features (Western and Gichohi 1993; Owen-Smith 2004; Fryxell et al. 2005; Hopcraft et al. 2010; Fynn et al. 2016). Access to heterogeneity in African savannas affects productivity, distribution, stability and diversity of mammalian herbivore populations (Owen-Smith 2004; Fryxell et al. 2005; Hobbs et al. 2008; Fynn et al. 2016). Both high and low-quality nutrient resources are important in a heterogeneous system; the former will influence abundance, while the latter effectively serves to prevent populations from overshooting carrying capacity and can also act as a resource buffer in times of scarcity to subdue population crashes (Owen-Smith 2004). Functional heterogeneity may also provide environmental shelter and cover habitats as well as plant diversity that contains medicinal compounds and essential nutrients that aid in body condition and overall health (Owen-Smith 2002; Hobbs et al. 2008; Fynn 2012). While it is common practice to classify rangelands as productive or degraded, understanding the functional attributes of vegetation diversity demands a more complex and critical understanding of the system before prescribing management regimes, ie. a patch deemed as degraded may harbour essential functional attributes within the phytochemical components of the plant community that it supports. Through careful attention to the principles of functional heterogeneity, land managers can plan to address an array of rangeland concerns including animal health, biodiversity, productivity and interspecific competition.

Resource competition between livestock and wildlife is a concern of conservationists and pastoralists alike, which results in loss of grassland structural heterogeneity leading to an inability to adapt to drought, and from numerous examples of population crashes of large mammalian herbivore populations in degraded environments (Walker et al. 1987; Owen-Smith 2004). A mid-1990’s FAO report estimated land degradation in sub-Saharan Africa to

be as high as 230 million hectares annually with overgrazing as the main driver in successional changes of perennial nutritious grasses to less desirable annual grass species (Nana-Sinkham 1995). Interspecific competition between mammalian species is often highly contested due to limitations in the understanding between resource utilization and supply and the effect that differences in body size and mouth anatomy have on reducing competition (Murray and Illius 2000; Fynn et al. 2016). In arid and semi-arid tropical environments, such as western Ngamiland, it is known that resource scarcity in quality and abundance is common in the dry season when herbivores rely on energy stores built up from earlier in the year (Ellis & Swift 1988; Illius and O'Connor 2000). Several examples exist that illustrate how particular consideration and planning for herbivore response to spatial and temporal variation in resource quality and abundance can help to suppress population instability (Owen-Smith 2004, Fryxell et al., 2005) and may facilitate increased productivity for both livestock and wildlife populations through enhanced vegetation condition (Odadi et al., 2017). In a study looking at community conservation initiatives in rangelands in South Rift, Kenya, Tyrrell et al. (2017) witnessed how community grazing committees planned for spatio-temporal separation of livestock and wildlife between communal pastoral lands and an adjacent conservation area by creating heterogeneity throughout the landscape by limiting grazing to high-quality short grasslands in the wet season and allowing for tall grass reserves within the conservation area in the dry season to be used in times of drought or as resources in the pastoral lands diminished. Wildlife species that favour short grassland benefited from the livestock-maintained short grasslands during the growing season, while all species and cattle benefited from the conservation area as a reserve of forage during the drought. Thus, through careful planning of grazing, they demonstrated a model strategy of how livestock can coexist among populations of diverse and abundant wildlife.

### **3.2.3. Nutrient hotspots**

An additional example of how livestock and wildlife coexistence can create mutually beneficial states occurs in another form of induced functional heterogeneity generated by nutrient hotspots that result from old boma (temporary livestock enclosures) sites (Muchiru et al. 2008; Augustine et al. 2010; Porensky & Veblen 2014). Bomas redistribute nutrients in the system that create nutrient hotspots resulting from high dung concentrations (Porensky

& Veblen 2014). The enriched patches of soil and plant nutrients resulting from bomas may last from decades to centuries (Augustine et al. 2011). Hectare sized patches created from boma sites in Laikipia provide a key nutritional resource for lactation for native ungulates in the regions' phosphorous poor system while also serving as an attractant to many species that selectively chose old boma sites over adjacent relatively nutrient-poor sandy soils (Augustine et al. 2010). This concept of nutrient hotspots was tested with an experimental study in central Kenya (Porensky & Veblen 2014) that created bomas sites (occupied for one month) and analyzed soil and foliar nutrients along with plant communities and wildlife use through spoor counts of paired boma and reference sites. Their results determined that wildlife use by browsing and mixed feeding ungulates in old boma sites to be nine times higher than reference sites 32 months after abandonment. Similar results are reported from abandoned settlement sites in Amboseli where densities of 9 species of large ungulates correlated positively to old livestock settlements areas (Muchiru et al. 2008). Densities at the Amboseli sites generally increased following the first two decades of abandonment, when plant biomass was the highest, with grazers preceding browsers in response to the successional stages of grass to shrubland. This study in Amboseli showed further benefits of cattle-wildlife interactions by demonstrating the role native browsers can play in enhanced forage production through their influence over shrub encroachment (Augustine et al. 2010).

#### **3.2.4. Bush encroachment**

Bush encroachment is another related factor to rangeland condition that is prevalent in western Ngamiland and recognized in southern Africa as a threat to rangeland health and biodiversity (Soto-Schoender et al. 2018; O'Connor et al. 2014). Important drivers of bush encroachment include overgrazing, fire suppression, changes in browsing systems and increased levels of CO<sub>2</sub> in the atmosphere (O'Connor et al. 2014). Overgrazing diminishes the competitive advantage grasses have over shrub species and other woody vegetation and has adverse effects on the water cycle in the region by increasing rates of evapotranspiration through the progression of water-intensive vegetation (O'Connor et al. 2014). Though commonly referenced as a critical issue for biodiversity conservation and pastoral livelihoods, rangeland degradation through overgrazing and consequent bush encroachment have

received little attention by conservation biologists in previous decades (Spottiswoode et al. 2009).

### 3.2.5. Piospheres

Piospheres were defined by Lange (1969) as ‘an ecological system of interactions between a waterpoint, its surrounding vegetation and the grazing animal’. While historically pastoralists in Ngamiland practised a nomadic lifestyle to access water and grazing resources (Andersson 1856), current Habu settlement patterns closely align with the Thaoge river drainage system where residents use artisanal well points to provide livestock with water. Livestock prevalence in Ngamiland is closely associated with people and human settlements which is typical for livestock distribution in pastoral systems (Van Schalkwyk 2015). A study on the effects of surface water in Ruvuma, Tanzania demonstrated that the availability of dry season water has been shown to affect livestock grazing and human settlement patterns (Coppolillo 2000). Van Rooyen (2017) observed that the constraint of surface water and close association of cattle densities to human settlements is likely to render vast areas of the rangeland inaccessible to cattle thus creating a piosphere effect where rangeland condition gradually improves with distance from cattle density. Further investigation is proposed to validate this theory (Van Rooyen 2017). Similar to the sedentarization of pastoral societies, artificial water holes disrupt historic migratory and nomadic patterns of large herbivore species and alter grazing patterns, thus creating piosphere patterns with consequences for vegetation composition, plant biomass, understory cover, soil erosion, soil compaction and rangeland condition (Thrash & Derry 1999). In areas of high elephant density, canopy tree cover is directly correlated to distance from a waterpoint (Thrash & Derry 1999). Other arid and semi-arid regions have shown that piospheres also influence the organization of bird guilds and are associated with vegetation degradation (Mphinyane 2001, Macchi and Grau 2012), soil nutrients (Shahriary et al. 2012) and that the development of piospheres can be linked to drought or insecurity events (Egeru et al. 2015). Other examples demonstrate that the duration, location and quantity of water provisioning can permit livestock numbers to grow in excess of the available feed, thus there are critical spatio-temporal considerations concerning water access and rangeland management.

This study examines the aforementioned topics associated with induced and inherent functional heterogeneity in the rangelands around the village of Habu in northern Botswana. The resulting environmental template is intended to inform interventions for spatio-temporal land use planning for a H4H pilot programme in Habu. A core objective of the H4H programme is to strengthen community resilience through improved rangeland management practices that facilitate livestock-wildlife coexistence.

### **3.3. METHODS**

#### **3.3.1. Habitat mapping**

To identify the main habitat types including structure, composition and distribution around Habu, all old and existing dirt tracks were first identified with knowledge from local farmers throughout the Habu area to establish vegetation transects. Over 200 km of the back roads were surveyed at points established at two kilometres intervals. GPS and vegetation characteristics including dominant grass, shrub and tree species were recorded along with if each site was predominantly an open or closed canopy. Additional vegetation characteristic data were collected from 50 spatially randomized points selected with a random number generator in Microsoft Excel (Microsoft Excel, Version 15.39) from a 100-point grid generated within a Habu area boundary polygon created in QGIS (QGIS, Version 3.0.0-Girona). Each randomized point was buffered with a minimum of 2000 m from other points and a 1000 m buffer on each side of the Habu roads to account for the edge effect (Figure 3.1).

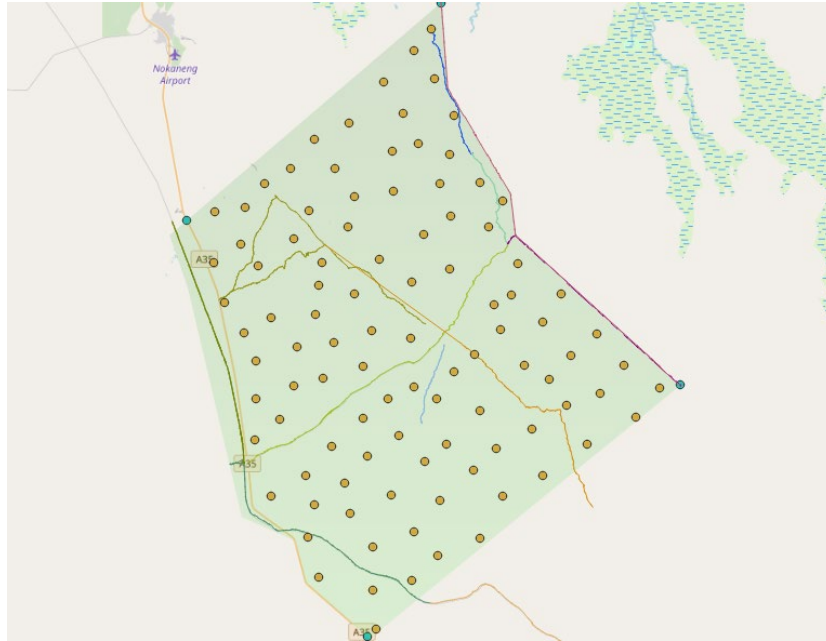


*Figure 3.1. A map of vegetation plots selected from randomized points generated in QGIS (QGIS, Version 3.0.0-Girona) with a 1000m road buffer and 2000m minimum buffer from other points. Plots were accessed by foot, vehicle, horse and donkey back in the late wet season of 2018.*

To encompass an area of interest for the entire Habu area boundary polygon, four tiles were downloaded from Landsat8 imagery. Landsat Enhanced Thematic Mapper scenes from Earth Explorer USGS of the study area were radiometrically and atmospherically corrected in ENVI (ENVI Version 5.1). Supervised and unsupervised classifications of vegetation classes were done in ENVI (ENVI Version 5.1). The Landsat images from September, 2015 were combined into a seamless mosaic using Maptiler (Version 10.3). A maximum likelihood classifier through unsupervised classification identified ten distinct vegetation classes. The ENVI file was loaded into Arcmap (Esri, Version 10.2), to assign colours to vegetation classes. Using ground-truthed data of vegetation types identified from both road vegetation transects and the randomized vegetation points, the 10 vegetation classes in the unsupervised classification were narrowed down to five final classes using a supervised classification. Ten GPS points were then randomly selected for each classification type and groundtruthed for accuracy based on structure and vegetation attributes including canopy structure and dominant species.

### **3.3.2. Abandoned boma sites/nutrient hot spots**

To investigate herbivore distribution in relation to nutrient concentration, abandoned cattle boma sites were identified with the help of local farmers and the Habu Community Scouts from the Habu Elephant Development Trust. The owner information, number of years occupied, reason for abandonment, time since abandonment and number of cattle kept at each boma site were recorded from the information provided for 30 abandoned sites. Each boma was visited once using a 'snapshot' approach, over five days in the wet season, February 2019. Data for utilization of the sites for wild and domestic herbivores were collected from dung spoor surveys that were identified to species by expert trackers. Spoor survey methodology was adapted from a similar study analyzing old boma sites in East Africa (Porensky & Veblen 2014). All dung piles present in the old boma site were identified to species, counted and the estimated age of each dung pile was recorded. To prevent repeat counts dung piles were individually removed from the site after data was recorded. The diameter of each old boma was measured using a 100 m tape measure. Vegetation structure was measured by counting the number, canopy height and species of trees and shrubs in the boma site. Matched control sites of the same diameter were identified in areas of similar vegetation structure located > 200m away from old boma sites and situated > 200m distance from any previous boma sites in the area as well as any distinct landscape features (ie. pans and riverbeds). Dung piles in the control sites were recorded using the same method done in boma sites. Using the area of each boma and the number of dung piles per species collected, the number of dung/hectare was calculated for each species for both boma and control sites. The mean and variance of dung counts per species was calculated across sites and plotted in Microsoft Excel (Microsoft Excel, Version 15.39). The effect of treatment (control vs. boma sites) was analyzed using the glmer function in the 'lme4' package (Bates et al. 2015) in R (R, Version 4.0.2. GUI 1.72). To account for the paired effect of the data, the site (1-30) was used as a random effect. As the mean for all species was considerably less than the variance (Table 3.1), a negative binomial approach (glmer.nb) was used to account for overdispersion. Goodness of fit of models were checked using the q-q plot (qqplot) package.

### **3.3.3. Grazing gradients**

All cattle posts in the Habu area were visited in March 2018 to survey farmers on cattlepost location along with the number and species of livestock owned. A GPS point was taken for

each cattlepost. A total of 128 cattleposts were identified with aid from board members of the Habu Village Development Committee. From the cattlepost survey data collected, a map of grazing pressure (Figure 3.2) was generated (Venter 2018, H4H Unpub., report) with an inverse distance calculation to interpolate values over space for each cattle post and determine the effective grazing pressure or cattle density within a five kilometre radius of the post. This assumes that cattle could travel 10 km (round trip) to forage and that the intensity of their foraging pressure will reduce linearly with distance from the cattle post. This distance was deemed appropriate to estimate grazing ranges around villages where distance measurements are unavailable (Van Rooyen 2017), however, the mean walking distance for extensive livestock production systems in Africa has been calculated at 14 km per day (de Leeuw, 1985) and as high as 20 to 30 km in more arid environments (van Raay and de Leeuw, 1974). After this statistic was calculated for each cattle post, the summed grazing pressure for all overlapping cattlepost footprints was calculated. This is then expressed as a fraction of the total Habu stocking rate (which is  $0.113 \text{ LSU ha}^{-1}$ ) which was calculated using Landsat NDVI (30 m resolution) and grazing capacity derived from the South African Grazing Capacity map (Department of Agriculture, Forestry and Fisheries 2016) for 1000 random points over SA and derived a 2<sup>nd</sup> order polynomial fit (Venter 2018). Pixel value was then extracted at the GPS location for each vegetation sampling site as a proxy for grazing pressure to examine the effects of grazing on vegetation composition and functional attributes.

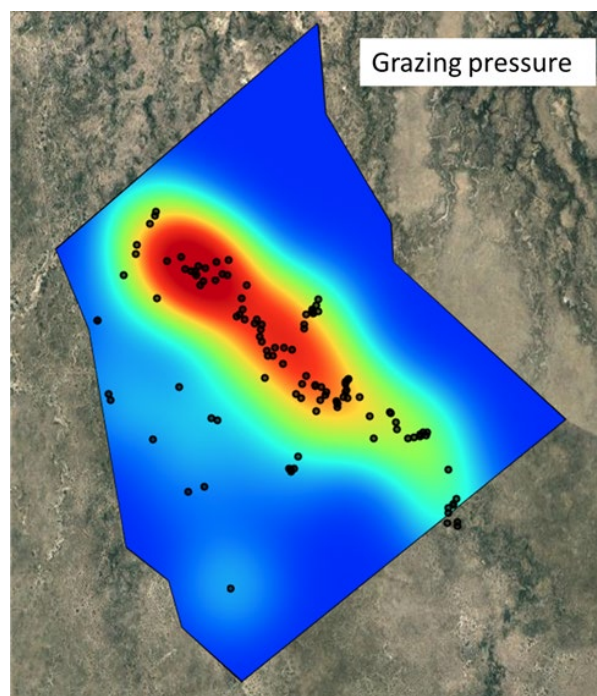


*Figure 3.2. Grazing pressure map within the Habu area generated from Landsat NDVI (Venter 2018, H4H Unpub. Report) and community cattleposts surveys assuming a 10 km per day cattle movement pattern. Black dots represent cattleposts, dark blue areas are under the average stocking rate and pure red areas are in effect 2000 times the average stocking rate.*

### **3.3.4. Vegetation sampling**

The randomized plots generated for habit mapping (See Habitat mapping methodology) were assigned vegetation point numbers and located with GPS either by foot, vehicle, donkey or horse from April to May in 2018. Vegetation sampling methods were adapted from common techniques used to monitor rangeland health in semi-arid environments (Wolfaard 2017). All woody vegetation and grasses were identified using the following field guides (van Wyk & van Wyk 2013; Roodt 2015; Van Oudtshoorn 2018).

### **3.3.5. Grass transects**

At each vegetation plot a 100 m transect, running east of the marked location, was laid out using 100 m measuring tape. On the North side of the transect line adjacent to the tape a .25 m<sup>2</sup> square made from 12 m round bar was laid down at 5 m intervals, totalling 20 replicates per transect. Inside each square data was recorded for the number of grass tufts per species, the highest grass stem, the distance between five grass tufts (starting with the 5 closest to the South-East corner of the square), the basal widths of five grass tufts (starting with the 5 closest to the South-East corner of the square), along with the number of forb species. Estimates of bare ground present in each square were also recorded. On the South side of the tape measure, grass biomass measurements were taken with a disk pasture meter (Bransby et al. 1977) dropped at two metre intervals down the length of the transect totalling 50 measurements per transect.

### **3.3.6. Woody vegetation**

Measurements for woody vegetation were recorded using width or 'belt' transects (Caratti 2006) through stem counts of woody and herbaceous vegetation that fell within a two metre width (one metre on each side of the tape) of the 100 metres transect. Each stem was

recorded to species and canopy width and height was measured with the use of a five metre measuring pole.

### **3.3.7. Analysis of vegetation sampling**

Similarities in vegetation composition across habitat types and grazing intensity were assessed using non-metric multidimensional scaling (NMDS) and the metaMDS function within the vegan package of R (Oksanen et al. 2007). The pixel value of the grazing pressure map (Figure 3.2) was used as a measurement of grazing intensity. NMDS is a leading ordination method for detecting vegetation gradients (Minchin 1987). NMDS is an iterative process that ranks Euclidean distances in ordination to reflect the most accurate similarities in sample plots then arranges the plots into two-dimensional space based on their dissimilarities (Bàez et al. 2013). As the method is only based on site similarities, it is not constrained by environmental variables that are used and may detect vegetation gradients stemming from environmental variables unaccounted for (Kantvilas & Minchin 1989). This analysis was made with two dimensions using 20 random start configurations, free permutations and the Bray-Curtis Index as a robust measurement of distance (Faith et al. 1987). The axes do not represent correlation and are interpreted by understanding similarities between the vegetation composition of shorter-inner point distances.

Generalized linear mixed models were used to demonstrate responses to the grazing gradient and test for significance for certain grass species and functional attributes of stem height, the number of grass tufts, the distance between grass tufts, tuft basal width and disk pasture meter readings. Upper quantile (95<sup>th</sup> percentile) regressions were used to examine the maximum responses of vegetation across the grazing gradient (Cade & Noon 2003). Models were run in R (R, Version 4.0.2. GUI 1.72) using quantile regressions were run using the 'quantreg' package in R (R, Version 4.0.2. GUI 1.72).

## **3.4. RESULTS**

### **3.4.1. Habitat classification**

Five distinct habitat classifications resulted from the vegetation mapping (Figure 3.3). A total of 50 randomly assigned gps points (ten per classification site) were revisited to test accuracy

of habitat classification map based on structure and vegetation attributes of which 38 sites (76%) were confirmed as appropriately classified.

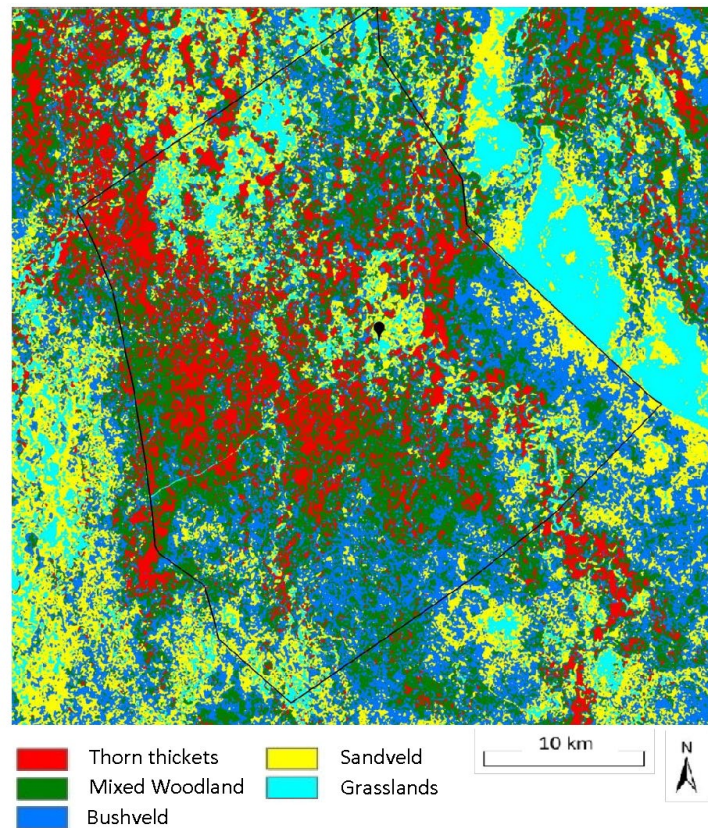


Figure 3.3. Habitat classification map of the Habu region, derived from Landsat 8 imagery, ENVI software and ground-truthed vegetation plots. The polygon represents the Habu area boundary and black marker in the centre Habu village.

Many of the woody vegetation and grass species were recorded across habitat types. The labels for each habitat classification are based on environmental features and structural attributes associated with vegetation composition.

#### 3.4.1.1. Mixed woodland

The mixed woodland community are generally closed-canopy forests proximal to the riparian regions along the Okavango Delta's channels and characterized by taller trees and shallow sandy soils. The most dominant woody vegetation found in this habitat included *Combretum hereroensis*, *Grewia flavescens*, *Terminalia sericea*, *Dichrostacys cinerea* and *Grewia flava*. Dominant grass species of the woodland were *Urochloa mosambicensis*, *Chloris virgata*, *Eragrostis viscosa*, *Pogonarthria squarrosa* and *Aristida adscensionis*.

#### **3.4.1.2. Thorn thickets**

This habitat type is characterized by dense thorny vegetation. The two most dominant species found in the thorn thickets, *Senegalia mellifera* and *Dichrostachys cinerea*, are often associated with overgrazing. *Vachellia tortilis* is another common woody species found in this habitat. Dominant grasses found in this community were *Chloris virgata*, *Aristida adscensionis*, *Urochloa mosambicensis* and *Heteropogon contortus*.

#### **3.4.1.3. Bushveld**

The bushveld habitat is characterized by shrub vegetation commonly located as a transition zone between the closed canopy of the mixed woodlands and the relatively more open canopy of the sandveld. Dominant woody vegetation in this habitat includes *Grewia flavescens*, *Searsia tenuinervis*, *Dichrostachys cinerea*, *Terminalia sericea* and *Grewia retinervis*. The most common grasses found in the Habu bushveld include *Urochloa mosambicensis*, *Chloris virgata*, *Eragrostis viscosa*, *Aristida adscensionis* and *Pogonarthria squarrosa*.

#### **3.4.1.4. Sandveld**

The sandveld habitat is generally a more open canopy environment that is often distal from seasonal rivers and featured deeper sand and more arid vegetation such as *Lonchocarpus nelsii*. The dominant woody vegetation recorded in this habitat included *Terminalia sericea*, *Senegalia nigrescens* and *Albizia harveyi*. Dominant grasses found in the sandveld include *Eragrostis viscosa*, *Chloris virgata*, *Urochloa mosambicensis*, *Aristida congesta congesta* and *Pogonarthria squarrosa*.

#### **3.4.1.5. Grassland/floodplain**

The grassland and floodplain habitats are characterized by extensive open expanses with occasional isolated woody vegetation that were commonly: *Grewia flavescens*, *Grewia flava*, *Dichrostachys cinerea*, *Vachellia erioloba*, *Gymnosporia sengalensis*. Dominant grasses in this habitat include *Aristida congesta barbicollis*, *Cenchrus ciliaris*, *Urochloa mosambicensis*.

#### **3.4.2. Abandoned boma sites/nutrient hot spots**

A total of 30 abandoned bomas and 30 matched control sites were surveyed. The average years occupied for 26 abandoned bomas were 2.5 (four sites unknown), whereas the average years from abandonment until this study took place was 7.4 (one site unknown). The average number of cattle that were kept at the bomas were 102 (four sites unknown). Reasons given for abandonment varied but were largely due to drought ( $n = 14$ ), followed by better rain and grass growth in other areas ( $n = 7$ ), unknown reasons ( $n = 5$ ), overgrazing ( $n = 1$ ), lion depredation on cattle ( $n = 1$ ), farmer fell sick ( $n = 1$ ) and farmer died ( $n = 1$ ).

Spoor from a total of thirteen mammalian species was recorded during data collection, however, only enough samples were recorded for seven species to compare between sites as excluded species were only represented by 1 sample. The most common spoor was from cattle (*Bos taurus*), followed by elephant (*Loxodonta africana*), zebra/donkey (*Equus quagga burchellii*/*Equus africanus asinus*), impala (*Aepyceros melampus*), kudu (*Tragelaphus strepsiceros*) and steenbok (*Raphicerus campestris*).

Table 3.1. Mean dung counts of combined control sites verse abandoned boma sites.

| <b>Species</b> | <b>Mean</b> | <b>Variance</b> | <b>Ratio (v/m)</b> |
|----------------|-------------|-----------------|--------------------|
| Impala         | 39.58       | 6605.93         | 166.9              |
| Elephant       | 84.98       | 4696.15         | 55.26              |
| Kudu           | 53.7        | 9923.08         | 184.79             |
| Steenbok       | 2.06        | 83.98           | 40.77              |
| Zebra/Donkey   | 53.58       | 5510.74         | 102.85             |
| Cattle         | 98.34       | 13352.5         | 135.78             |

Combined mean dung counts were higher in abandoned boma sites for all species except for zebra/donkey (Figure 3.4). Zebra and donkey counts were grouped to account for any misidentification that may have occurred during the data collection due to similarity of spoor.

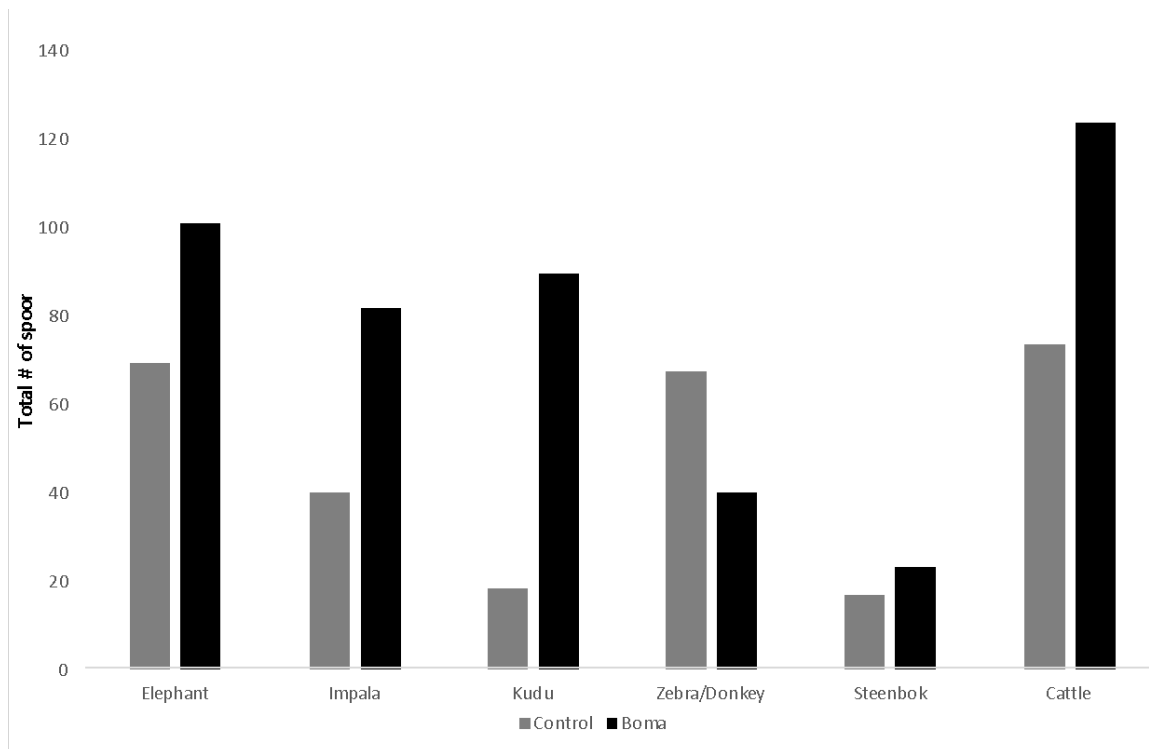


*Figure 3.4. Average dung counts for abandoned cattle bomas verse control sites in the rangelands of Habu.*

While there was a general pattern indicating a difference in mean dung counts between abandoned boma and control sites for all species, only impala, kudu and steenbok were proven statistically significant with higher dung counts observed in the abandoned boma sites, while zebra/donkey demonstrated significantly less spoor in boma sites (Table 3.2).

*Table 3.2. Comparison of mean dung counts between paired abandoned boma and control sites using a generalized linear mixed model.*

| Species      | intercept | slope coefficient | standard error | Z value | P value  |
|--------------|-----------|-------------------|----------------|---------|----------|
| cattle       | 4.6       | -0.52             | 0.32           | -1.62   | 0.11     |
| elephant     | 4.61      | -0.37             | 0.24           | -1.56   | 0.12     |
| zebra/donkey | 2.8       | 0.52              | 0.04           | 13.91   | < 2e-16  |
| impala       | 3.5       | -0.73             | 0.04           | -20.39  | < 2e-16  |
| kudu         | 4.49      | -1.58             | 0.47           | -3.35   | 0.0008   |
| steenbok     | 0.42      | -0.32             | 0.06           | -5.51   | 3.52E-08 |

### 3.4.3. Vegetation sampling

A total of 50 vegetation plots were analyzed throughout the Habu landscape from which 53 grass species and 46 woody vegetation species were identified. Grass species and relative abundance are displayed in Figure 3.5. The mean and standard deviation of functional or structural attributes per replicate were calculated as follows: Highest stem ( $476.28 \text{ mm} \pm 185.1$ ), grass species per replicate ( $8.18 \pm 2.46$ ), the average number of tufts ( $1.99 \pm 0.94$ ), the distance between tufts ( $122.44 \text{ mm} \pm 58.05$ ), tuft basal width ( $15.89 \text{ mm} \pm 10.78$ ), average forb species ( $0.40 \pm 0.31$ ), and the average number of forbs ( $0.68 \pm 0.67$ ).

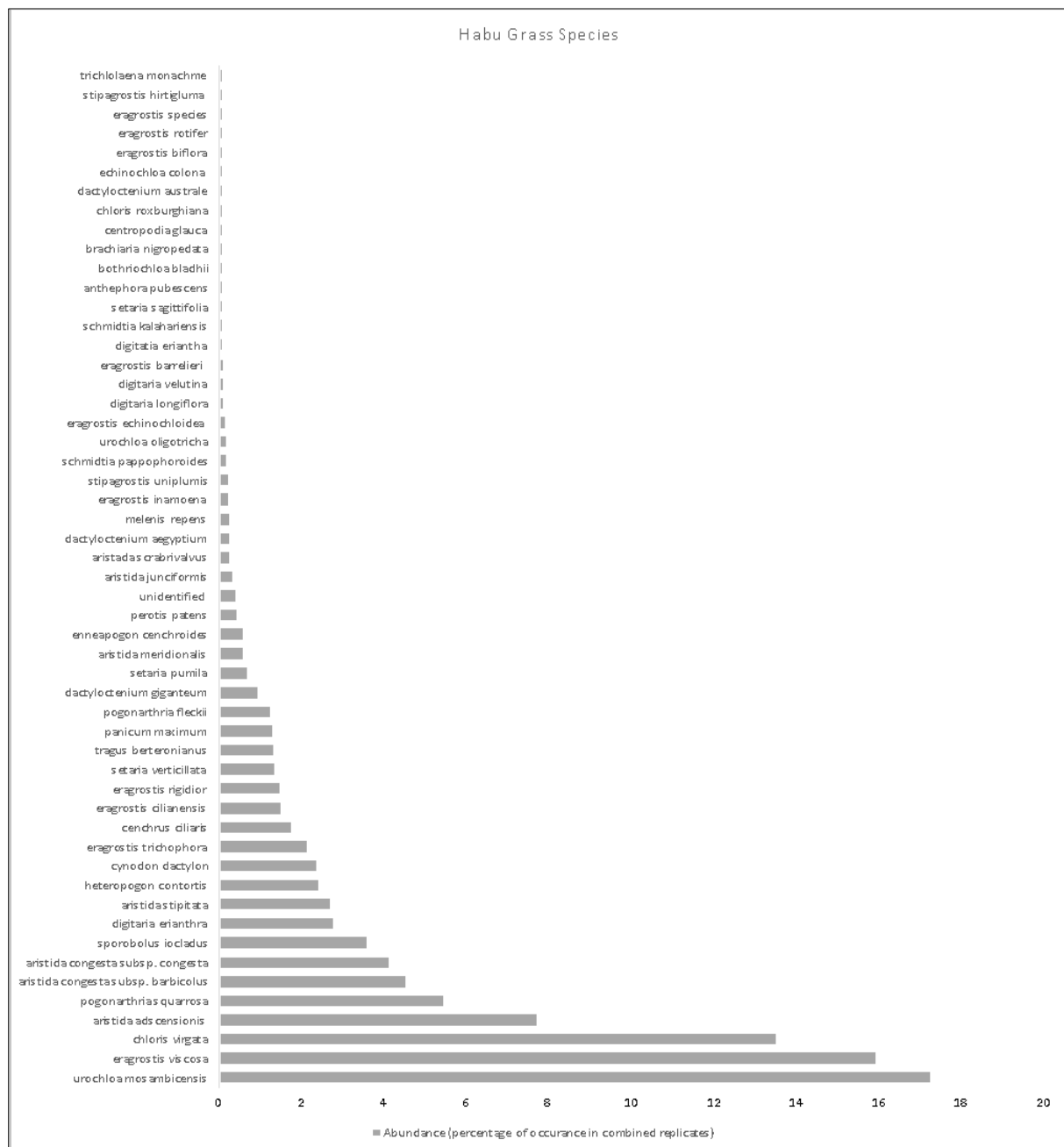


Figure 3.5. Grass species were identified from 50 vegetation sites (20 replicates/site) around Habu.

Ordination results demonstrated that grazing pressure had a statistically significant correlation with the vegetation communities for both woody vegetation (stress = 0.23,  $R^2 = 0.13$ ,  $p = 0.031$ ) and grass community composition (stress = 0.21,  $R^2 = 0.35$ ,  $p = 0.001$ ). Habitat type also confirmed significant influence on grass species composition (stress = 0.21,  $R^2 = 0.20$ ,  $p = 0.012$ ). Due to the horizontal separation of vegetation plots of distal and proximal sites to grazing intensity, axis NMDS1 appears to be associated with grazing intensity, whereas the vertical separation of more clay prone to sandy habitat types along the NMDS2 axis reflects an association to a soil gradient (Figure 3.6).

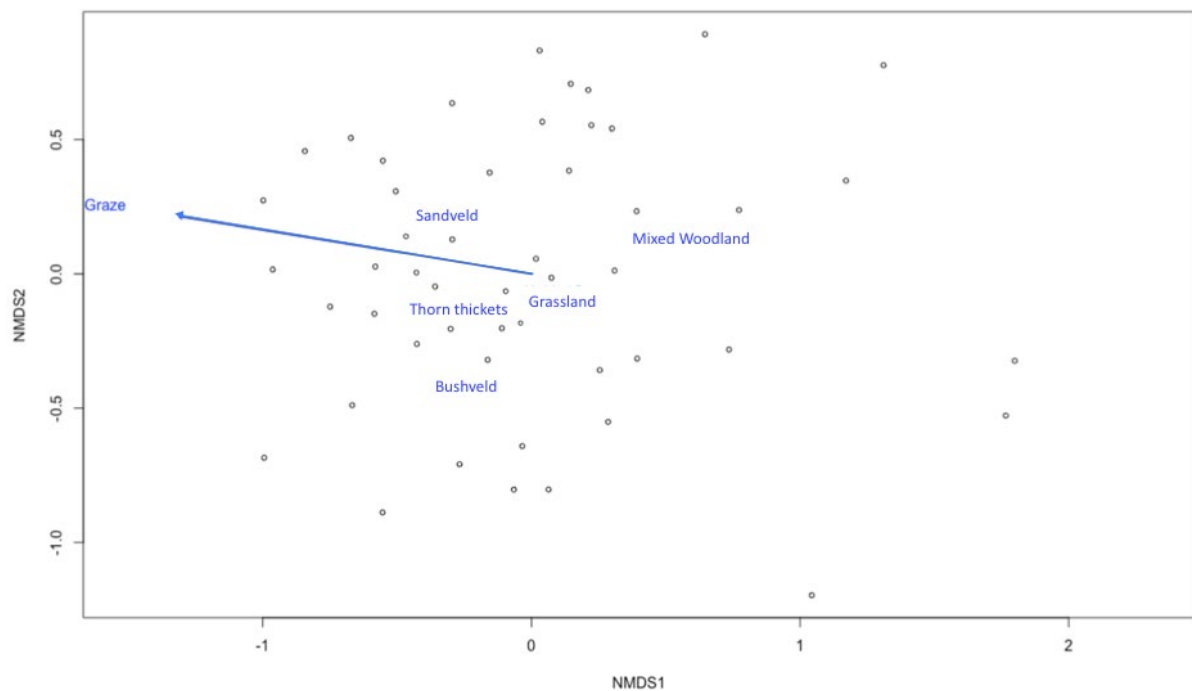


Figure 3.6. Non-metric multidimensional scaling for grass sampling sites where points in ordination space represent centroids of vegetation plots grouped in proximity to environmental variables and the vector represents grazing pressure and vector length the strength of correlation.

Models run for grassland functional attributes indicated that grazing pressure influences these variables (Figure 3.7). Grass biomass (represented by disk pasture meter readings) increased significantly with distance from intense grazing pressure while the number of tufts exhibited a significant decrease. Other functional attributes including highest stem, grass tuft basal width and the distance between tufts also followed a general pattern of increase with decreased grazing pressure however models did not support a significant correlation (Table 3.3).

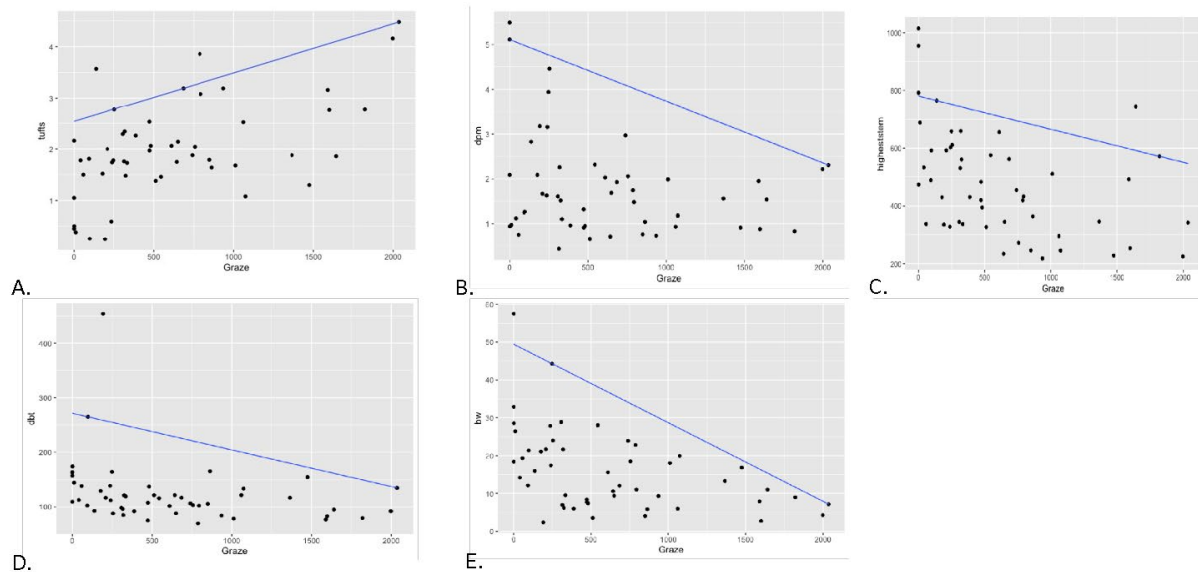


Figure 3.7. Quantile regressions ( $\text{Tau} = .95$ ) of grass functional attribute responses to a grazing gradient (where 0 represents sites more distal to grazing intensity) demonstrating a decrease in the number of grass tufts (A) per site more distal along the grazing gradient whereas there is a general pattern of increase in (B) biomass abundance (represented by disk pasture meter readings), stem height (C), the distance between grass tufts (D) and grass tuft basal width (E) at sites further away from intensive grazing.

Table 3.3. Responses of grassland functional attributes to grazing pressure quantile regressions in the ‘quantreg’ package in R 4.0.2.

| Independent variable               | Intercept Value | Std. Error | t value | Pr(> t ) |
|------------------------------------|-----------------|------------|---------|----------|
| Average number of grass tufts/plot | -0.0208         | 0.0072     | -2.8811 | 0.0059   |
| Disk pasture meter reading         | 0.0010          | 0.0003     | 2.9547  | 0.0048   |
| Highest Stem                       | -0.0003         | 0.0002     | -1.1343 | 0.2623   |
| Distance between tufts             | -0.1145         | 0.1121     | -1.0215 | 0.3121   |
| Average basal width of tufts       | -0.0672         | 0.1465     | -0.4586 | 0.6486   |

Several grass species were chosen to demonstrate how species respond differently to the grazing gradient with the use of generalized linear mixed models (Figure 3.8). Positive associations with high-intensity grazing were significant for the species of *Chloris virgata* ( $p = 0.0047$ ) and *Eragrostis viscosa* ( $p = 0.0259$ ), (Table 3.4).

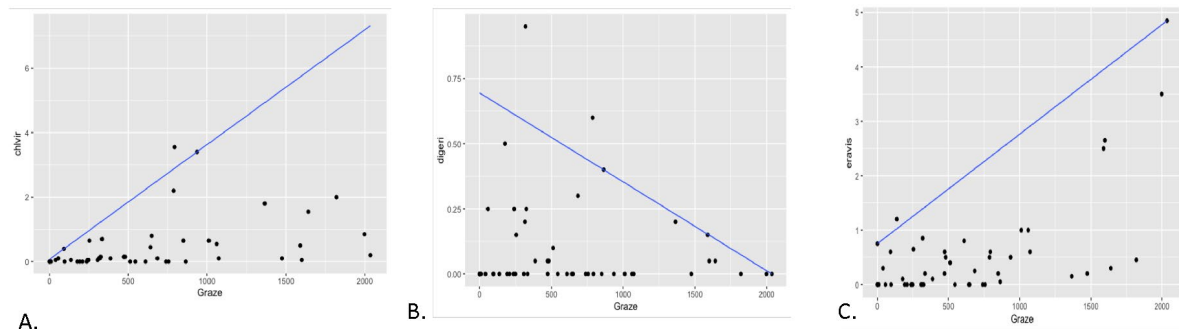


Figure 3.8. Quantile regressions ( $\text{Tau} = .95$ ) of grass functional attribute responses to a grazing gradient (where 0 represents sites more distal to grazing intensity) demonstrating a response of increased frequency with proximity to high-intensity grazing for *Chloris virgata* (A), *Eragrostis viscosa* (C), and decreased frequency with intensive grazing for *Digitaria eriantha* (B).

Table 3.4. Responses of grass species to grazing pressure derived from quantile regressions in the 'quantreg' package in R 4.0.2.

| Independent variable      | Intercept Value | Std. Error | t value | Pr(> t ) |
|---------------------------|-----------------|------------|---------|----------|
| <i>Chloris virgata</i>    | 0.0036          | 0.0012     | 2.9623  | 0.0047   |
| <i>Eragrostis viscosa</i> | 0.0020          | 0.0009     | 2.2987  | 0.0259   |
| <i>Digitaria eriatha</i>  | -0.0003         | 0.0003     | -1.3697 | 0.1772   |

### 3.5. DISCUSSION

This analysis of the environmental template identifies various drivers of functional heterogeneity in the rangelands adjacent to the wildlife management areas of the western Okavango Delta. Results from implementing the template illustrate how pastoral practices significantly influence both wildlife habitat utilization and vegetation community composition and grassland structural properties. The environmental template also provides a baseline to monitor and evaluate area-specific rangeland restoration efforts and aids management planning.

The habitat classification map generated in this study illustrates a complex mosaic of habitats typical of the Delta. These range from riverine forests to open grassland, savanna and dry woodland (Ramberg et al. 2006). The East-West transections through the major distributaries of the Delta, such as the Thaoge River which runs through the study site, are areas where vegetation variability is exceptionally high (Ramberg et al. 2006). Such variation arises from

minor elevational changes in a relatively flat gradient that cause large differences in the frequency and duration of flooding events (Ramberg et al. 2006). Other major influences on landscape heterogeneity in the Delta result from island formation resulting from Aeolian sediments and termitaria, nutrient release from fires, and shifting riverine channels due to movement of hippopotamus (*Hippopotamus amphibious*) and other large herbivores (Milzow et al. 2009). McCarthy et al. (2005) noted difficulties with habitat classifications related to the high spatial variability of vegetation cover in and around the Delta due to temporal differences in water availability and similar spectral responses of different vegetation types. Similarly, this study demonstrates an innately high degree of heterogeneity in plant community assemblages that is largely attributable to the dynamic hydrology of the Delta. This high degree of natural heterogeneity supports an abundant and diverse array of large mammals that represent significant potential for economic development to western Ngamiland. By understanding the layout of functional attributes in the habitat map, heterogeneity can be used to maximize animal production and increase resilience to climatic and episodic events (Fuhlendorf et al. 2017). For example, floodplain habitat may be retained for dry season reserve forage as seasonal pans and grazing resources are exploited in woodland habitat during the wet season, thus taking advantage of spatial variation of the contrasting hydrological regimes between the two habitat types (Owen-Smith 2004; Fynn et al. 2016). Such planning will require adaptive capacity that accounts for variation in Delta hydrology and annual precipitation and exemplifies how understanding heterogeneity within the system can result in improved spatio-temporal planning (Fynn et al. 2016). As the Habu rangelands are located at the distal end of the Delta's westernmost distributaries, an examination into the underlying factors influencing landscape heterogeneity demonstrates several anthropogenically induced factors that warrant consideration for regional land use planning.

The results of the analysis into the role abandoned livestock bomas play in creating nutrient hot spots throughout the landscape is supported by similar findings elsewhere (Muchiru et al. 2008; Augustine et al. 2010; Prensky & Veblen 2014). A clear pattern of higher dung counts was observed on abandoned boma sites for all species analyzed except zebra and donkey. A possible explanation for this is that equids require greater amounts of herbaceous forage as monogastric hindgut fermenters and tend to take advantage of readily available lower

nutrition foliage than ruminants (Sinclair 1985). Donkeys are known as non-selective grazers (Aganga & Tsopito 1998), and as both species have opposing incisors, they have higher feeding flexibility and can feed off woody vegetation, short grass and senescent long grass (Sinclair 1985; Estes 1991; Voeten & Prins 1999). Though positive associations with zebras and abandoned bomas have been observed in other studies (Prensky & Veblen 2014), findings from this study suggest that this association may not be as strong as for ruminants. Different forage requirements between these groups demonstrate how resource partitioning (Arsenault & Owen-Smith 2008) can contribute to increased landscape productivity through increased herbivore biomass.

This study analyzed abandoned bomas in Kaninangombe, (Herero word for ‘the place that swallows cattle’) in a relatively small area of the Habu landscape. Most reasons provided for boma abandonment were related to drought linked scarcity of forage and water availability highlighting the importance of mobility with accessing resources in the arid rangelands of western Ngamiland. Many more abandoned boma sites are spread throughout the landscape and, as described elsewhere in sub-Saharan Africa, recovery of these areas increases functional heterogeneity in the landscape, facilitating short grass grazing ‘lawns’, open glades important for predator avoidance, and areas of high nutrient loads attractive to wild herbivores and domestic livestock which can last for thousands of years (Augustine et al. 2010; Marshall 2018). Furthermore, mobile, predator-proof bomas, such as those used here in H4H, facilitate spatio-temporal planning that can include nutrient hotspots in the otherwise comparatively nutrient-poor soils of northern Botswana. Controlled mobility and planned grazing represent an effective tool to facilitate increased functional heterogeneity and address rangeland degradation through nutrient distribution, seed dispersal, breaking hard soil crusts, and revegetating bare patches (Augustine et al. 2010).

The results of the analysis of grassland structural features support the hypothesis put forth by Van Rooyen (2017) that a common pattern in sub-Saharan rangelands is of a piospheric nature around cattleposts resulting from increased distance from livestock concentration. This piospheric effect is illustrated in the grazing pressure heat map in Figure 3.2 while Figure 3.6 demonstrates that grazing is a driver of vegetation community composition western Ngamiland. Grass structural patterns observed in this study included a decreased number of tufts, increased stem height, basal width, biomass and distance between tufts all linked to

decreased grazing pressure. It is commonly understood that grazing (or clipping) grasses reduce root growth because the plant's resources get reallocated to above-ground growth (Tedder et al. 2011). Although grass species vary in their responses to nutrient availability through biomass accumulation and root growth patterns (Tedder et al. 2011), below-ground competition is a likely contributing factor to the lower number and wider distances between grass tufts in sites distal to grazing pressure reported here.

Grasses selected to illustrate the effects of grazing on species distributions followed expected specific responses (Van Outshoorn 2018). Both *Chloris virgata* and *Eragrostis viscosa* are categorized as Increaser II grasses that increase with the disturbing effect of overgrazing. Increaser II grasses species tend to be subclimax and pioneer grasses. *Eragrostis viscosa* is an unpalatable species with low grazing yield whereas *Chloris virgata* is valued in arid rangelands as it is a palatable pioneer species and one of few perennial species in this region to colonize bare ground, thus continuous overgrazing of *Chloris virgata* leads to severe rangeland degradation (Van Outshoorn 2018). *Digitaria eriantha* is classified as a Decreaser due to its negative response to overgrazing. Decreasers are commonly climax species that are preferred by grazing animals. While these chosen examples appropriately demonstrate responses of individual grass species to a grazing gradient, their reactions are further influenced by rainfall variability from year to year, soil conditions, interspecific competition, other environmental disturbances and the previous years' grazing history (Fynn et al. 2005; Tedder et al. 2011; Fynn et al. 2017).

The significant increase in grass biomass along the grazing gradients and changes in structural grassland features support previous studies that indicate much of the rangelands of Ngamiland are degraded (Atkinson et al. 2019; GIZ 2019). However, it is worth considering that high grazing concentrations and the associated vegetation composition may provide another form of landscape heterogeneity and functional services worthy of further examination (e.g., open glades around cattleposts may provide a service in the form of safety in high predator areas). Degraded patches are not necessarily undesirable if there are large areas of undegraded patches across the landscape. Therefore, it is essential to maintain functional heterogeneity by designing grazing intensity gradients by limiting cattlepost development in distal sites or by creating conservation zones that can serve as forage refuges in times of drought (Tyrrell et al. 2017). By understanding how grazing pressure can induce

critical vegetation changes, land use planning coupled with active herding, can effectively create desired habitat structures and vegetation compositions consistent with the objective of land health.

Another important habitat consideration and indication of land degradation around Habu is the encroachment of woody shrub vegetation which has been observed by community elders (Chief Kampomboro, pers. comm.). Encroachment of grasslands by woody vegetation has been strongly correlated with overgrazing (e.g., Roques et al. 2001; O'Connor et al. 2014; Soto-Schoender et al. 2018). The investigation into woody vegetation revealed common occurrences of shrub species heavily associated with overgrazing such as *Dichrostachys cinerea* and *Senegalia mellifera* (van Wyk & van Wyk 2013). Bush encroachment leads to an overall decline in biodiversity and carrying capacity (De Klerk 2004; Soto-Shoender et al. 2018), as well as in biomass conversion and animal productivity (i.e., reduced body condition and milk yield) (Mugasi et al. 2000). The rate of bush encroachment around Habu varies across the rangeland, with some areas reaching an increase of nine percent between 1986 and 2016 (Venter 2018, H4H Unpub., report). Strategies developed to address the trend of bush encroachment include bush clearing, fire and planned grazing (Trollope 1983; Kingdon 2005; Lukomska et al. 2010).

Developing grazing plans in communal systems of the livestock-wildlife interface through the employment of skilled herders and mobile predator-proof bomas are two cornerstones of the H4H model. Herding and planned grazing initiatives have demonstrated the maintenance of spatial and temporal heterogeneity of foraging resources leads to enhanced vegetation condition (and carbon sequestration), increased species richness (including wild ungulates), increased cattle forage intake and condition (affecting traditional economies), and increased climate change resilience (Schlecht et al. 2006; McSherry & Ritchie 2013; Odadi et al. 2017; Tyrrell et al. 2017; Crawford et al. 2018). Kraaling and controlled grazing activities employed by H4H through mobile bomas provide a method of implementing interventions necessary for sustainable land health and can play a critical role in human-wildlife conflict mitigation (Weise et al. 2018). These combined herding and kraaling practices are herewith shown to address rangeland degradation through facilitating nutrient hotspots and limiting the impacts of high-intensity grazing through careful planning.

Another intervention relevant to trends highlighted through this environmental template and currently trialled here under H4H relates to developing solutions to the scarce distribution of available surface water. Mobile water bowsers are part of a strategy to access the relatively higher biomass values located at the distal reaches of the grazing gradient. Access to these grazing areas could ultimately serve to increase productivity and ecosystem health by facilitating multi-species grazing systems and grassland heterogeneity. A potential animal health consequence can result from higher grass biomass at the distal end of the grazing gradient. This is caused by the need for livestock to walk increasing distances as forage is depleted near cattle posts. This effect is exacerbated in drought years and years of low rainfall. Walking stress that results from increased distances to forage compromises animal productivity, variously reflected in decreased milk production, reproductive performance, and growth (Maurya et al. 2012). Reduced cattle condition is a major concern to human well-being given the critical role of livestock to local economies, human health, poverty, and food security (Randolph et al. 2007).

A limitation to this study is that grazing estimates produced by pixel values derived from cattle densities around cattleposts give a probable distribution of cattle, but do not reflect temporal changes in cattle distribution as influenced by vegetation type in the absence of animal tracking data (Van Rooyen 2017). Thus, the cattle pressure map in this study provides an approximation but may not reflect accurately the cattle distribution in the landscape. Furthermore, this study focused on cattle and does not account for the added grazing pressure provided by other animals (domestic or wild) in Habu nor the trampling impact on soil that is typical of piospheres. These limitations are recommended for consideration for future research conducted in and around the rangelands of Habu.

### **3.6. CONCLUSION**

Major vegetation changes around the Habu area cattleposts and settlements investigated in this study highlight the piosphere impacts on rangeland health and their cascading consequences on animal and human health. This study highlights some of the major drivers of functional heterogeneity and rangeland condition around the village of Habu, Northwest District, Botswana, that land managers can use to help guide rangeland restoration and livestock husbandry practices in the region. Through careful land-use planning with

partnering organizations and local communities, the H4H model together with the utility of an environmental template demonstrates a locally adapted strategy that addresses the management of the drivers of land health consistent with conservation ethics and sustainable biodiversity. At the same time, this coexistence model rooted in improved management practices of environmental and animal health capitalizes on the region's predominant natural assets: livestock and wildlife, and addresses the socioeconomic imperative of poverty reduction and food security among traditional livestock communities.

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## **CHAPTER 4. Husbandry and Herding: a community-based approach to addressing illegal wildlife trade in Northern Botswana**

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### **4.1. ABSTRACT**

Illegal bushmeat hunting is a major driver of wildlife population declines in Northern Botswana. Such declines raise concerns about the principles and integrity of the Kavango-Zambezi Transfrontier Conservation Area (KAZA) and regional economic stability which is heavily reliant on wildlife-based tourism. The KAZA landscape between Northern Botswana's protected areas consists of non-state land utilized communally by small agropastoralist communities. These communities are economically challenged by international beef trade policies, restricted access to grazing in nearby wildlife management areas and high conflict costs from living in close proximity to wildlife; some of the key factors identified as drivers of bushmeat hunting in the region. Here we describe how a model called Herding 4 Health (H4H) could address these drivers. We discuss strategies using a socio-economic centered Theory of Change (ToC) model to identify the role agropastoral communities can have in addressing illegal wildlife trade (IWT). The ToC conceptual framework was developed with input from a resource team consisting of scientific and implementation experts in H4H, wildlife conservation, illegal wildlife trade and livelihood development between September and December 2018, and with a validation workshop in March 2019 with government representatives from relevant ministries, NGO's, community-based organizations and private sector participants. We identify three pathways deriving from the ToC driven by community level actions to address IWT in the region. These include: increasing institutions for local enforcement, developing incentives for ecosystem stewardship and decreasing the costs of living alongside wildlife. The success of these pathways depends on underlying enabling

actions: support for the development of institutional frameworks; building community capacity to facilitate informed best farming practices; and strengthening commitments to sustainable resource management to increase resilience to climatic and economic shocks.

## **4.2. INTRODUCTION**

The Okavango Delta in northern Botswana is a key region for biodiversity conservation and economic development in Botswana and is currently facing immediate and long-term threats including oil and gas exploration, climate change and wildlife population declines resulting from illegal wildlife trade (IWT) (Burg 2007; Magole & Magole 2009; Rogan et al. 2015; H4H 2019; Richardson 2021). IWT is a major threat to global biodiversity conservation and sustainability with consequences that affect food security and development, (Dickson 2008; Phelps et al. 2016) as well as environmental, human and animal health (Gómez and Aguirre 2008; UNODC 2020). As IWT occurs on various scales from subsistence use to organized international criminal syndicates, methods specific to the scale of illegal activities are needed to effectively counter this threat (Biggs et al. 2017).

Here we provide contextual and background information to outline key considerations to bushmeat drivers, community-based conservation, and livelihood opportunities in the Delta region of the KAZA landscape before presenting the H4H model. Finally, we present a process to which we adapt a general Theory of Change (ToC) model (Skinner et al. 2018; Biggs et al. 2017) to a community based approach to investigate the role agropastoral communities in wildlife rich Transfrontier Conservation Areas (TFCAs) can play in combatting illegal bushmeat hunting.

### **4.2.1. Bushmeat trade**

A 2011 aerial wildlife survey indicated significant declines in several ungulate species in the Delta (Chase 2012). This raised alarm for Botswana's tourism industry and conservation sector, thus motivating an increase in wildlife monitoring around the Delta as well as an investigation of the underlying drivers of this decline (Rogan et al. 2015). The results of this survey-based study funded by the FAO indicated that illegal bushmeat hunting is pervasive in the Delta with an approximation of 2000 hunters harvesting an annual take of 620,000 kg of

medium-large herbivore biomass (Rogan et al. 2017). For some ungulate species, the study surmised that hunting offtake exceeds the intrinsic population growth rate, which would imply negative ecological and economic consequences. The negative effect of the bushmeat trade on ungulate populations has been observed across sub-Saharan Africa (Lindsey et al. 2013). Declines in herbivore populations will have cascading trophic effects on predator populations which are a major draw for photographic safaris (Rogan et al. 2017).

The extent and drivers of bushmeat hunting vary by context, from cases where it is primarily a subsistence activity to those where it is done on a larger scale for commercial gain (Duffy and St. John 2013). In the Delta, bushmeat hunting is primarily an opportunistic pursuit of relatively wealthier households who use bushmeat as a form of supplementary income (Rogan et al. 2018). While exceptions in the Delta exist in the forms of syndicate organizations whose offtake exceeds 1000Kg p.a. and households that report subsistence usage, greater than half of hunters in the Delta reported an annual harvest of less than 100kg/yr. (Rogan et al. 2015). Three main drivers of bushmeat hunting identified in and around the Delta include: 1) economic opportunity, 2) lack of disincentives to hunt, and 3) negative attitudes towards wildlife (Rogan et al., 2015). Improved law enforcement and the development of alternative wildlife-based revenue streams that provide communities with conservation incentives are two recommended interventions to address illegal bushmeat hunting in the region (Rogan et al., 2018).

#### **4.2.2. Community-based conservation**

Today, there is a growing awareness that the cooperation and participation of communities living in proximity to wildlife are critical to tackling IWT (Skinner et al. 2018). This is reflected in an increasing number of international policy recommendations that promote community based approaches (Biggs et al. 2017). Despite a wide range of trialled methods, standard protocols for community engagement are not widely accepted or regarded due to inadequate monitoring of the effectiveness of community based tactics and a disconnect between policy commitments and implementation (Cooney et al. 2016; Roe & Booker 2019). Common methods that have evolved from decades of community initiatives involve; conservation awareness, development of non-wildlife based livelihoods, environmental stewardship incentives, increasing costs of participating in IWT and decreasing costs of living in proximity

to wildlife (Roe & Booker 2019). Despite a lapse in effective evaluation of such strategies, some key considerations that emerge in community engagement are: inclusivity and ownership in decision making and project design and implementation, effective governance and strengthened traditional institutions, net costs and benefits that influence community attitude either for or against conservation efforts and multilevel networks and enduring collaborations (Cooney et al. 2016; Cooney et al. 2018; Armitage et al. 2019; Roe & Booker 2019; Chan et al. 2020). Furthermore, communities are dynamic by nature and planning for successful outcomes requires understanding and sensitivity to local and social contexts (Cooney et al. 2018). For example, ethnic friction and cultural heterogeneity have been identified as challenges to community organization in Ngamiland, Botswana (Thakadu, 2005) which will have likely implications and require careful consideration for regional project design and implementation.

In Northern Botswana, community based tourism enterprises are common on the eastern, southern and northern periphery of the Delta, whereas the western side is characterized by traditional agriculture communities, underdeveloped tourism potential and greater human population density (Atkinson et al. 2019; Albertson 2020). Veterinary cordon fences west of the Delta function primarily to prevent contact between cloven-hoofed domestic livestock and Cape buffalo (*Syncerus caffer*) due to the risks of transmission of foot-and-mouth disease (FMD) (Atkinson et al. 2019). The fences effectually restrict market access for farmers living in Botswana's FMD control zones by prohibiting sales to the Botswana Meat Corporation's higher priced international beef export industry and also separate these local communities from access to the resources in the wildlife management areas of the Delta (Atkinson et al. 2019). However, the network of over 10,000 km of fencing is porous due to frequent damage by elephants and high maintenance costs (Atkinson et al. 2019). Thus, veterinary cordon fences have been ineffective spatial barriers impacting both livestock and wildlife through exacerbating disease control efforts and human wildlife conflict (Ferguson & Hanks 2010).

Together with opportunity and disease costs, human-wildlife-conflict (HWC) is another cost of conservation that is primarily shouldered by local communities and relates to tolerance to wildlife stewardship (Ceausu et al. 2020). Consequently, retaliation against wildlife responsible for HWC is common and leads to declines in wildlife populations regionally as well as globally (Woodroffe et al. 2005; Dickman 2010). Killing of lions in retaliation for livestock

losses has resulted in the removal of 30-50% of the lion population of the Delta's eastern panhandle. (LeFlore et al. 2019). Lethal mitigation measures coupled with IWT, particularly in the form of illegal bushmeat harvest, pose a threat to sustainability of Botswana's wildlife populations and the region's tourism-based economy (Rogan et al. 2015).

Government and private anti-poaching units often lack understanding of the socio-ecological landscape or a mandate on a regional scale and are often easily evaded by locally-based poaching syndicates (Fynn & Kolawole 2020). Furthermore, the para-militarization of conservation has drawn heavy criticism as a top-down approach associated with human-rights violations, enforcing exclusionary conservation practices on marginalized peoples, and deepening park-community divisions (Roe et al. 2015; Cooney et al. 2016; Massé et al. 2017). For these reasons, even proponents for militarized strategies to combat IWT, such as Botswana Defense Force's involvement in anti-poaching, advise caution with this intervention and that it should be strengthened by accountability and strategies to address local socio-economic inequalities (Cooney et al. 2018; Duffy et al. 2019). Despite extensive use of law enforcement as a method to address IWT (Roe & Booker 2019), efforts to combat poaching have proven largely ineffective when communities have not been aligned with the conservation agenda (Fynn & Kolawole 2020).

Conversely, through intimate regional, social, and ecological linkages, poaching is restricted when communities are on board with the conservation efforts, but all too pervasive when they are not (Scott 1989; Fynn & Kolawole 2020). Though communities at large are not the criminals in these cases, community sentiment can influence the prevalence of criminal activity. The unsuccessful attempts to obstruct poaching by government entities who lack the funding, manpower, local knowledge, and access to social networks represent a critical mismatch of scale (Cumming et al. 2006). At a local scale, communities are better equipped than centralized government through traditional knowledge, social networks, and human resources to effectively manage their natural resources (Murphree 2004, Ostrom 2009). Communities empowered with decision-making rights can gain significant conservation outcomes. Examples include: the increase in wildlife populations on Namibian Communal Conservancies (Muntifering 2019), designation of new community conservancies adjacent to northern Kruger National Park (Fynn & Kolawole 2020), and the decrease in elephant

poaching reported in Kenya's Northern Rangeland Trusts (Northern Rangelands Trust 2019) and in the WMAs of the Luangwa Valley (Lewis 1990).

In light of the adverse consequences that arise from overlooking societal stressors to the communities adjacent to PAs, new conservation strategies that recognize, incorporate and promote both human and environmental complexities are urgently needed. This shortfall has been widely acknowledged (Ostrom 2007) and has ultimately led to increasing complexity in conservation theory and new tools to guide the design of conservation strategy. PAs alone are inadequate to stem biodiversity loss because they are spatially-limited and consequently most biodiversity occurs outside PAs (Western et al. 2020). Thus, for large scale landscape conservation efforts (e.g., TFCAs) to be effective, the conservation scope has to widen beyond national parks and wildlife management areas to achieve habitat connectivity across the landscape (Mora & Sale 2011). The notion of 'working landscapes', that serve to conserve biodiversity while sustainably delivering the goods and services required by humanity aids to conceptualize how this connectivity within and between landscapes may be achieved (Miller et al. 2012; Kremen & Merenlender 2018; Western et al. 2020). An environment for the successful raising and keeping of livestock is one such key service, especially considering that well-managed livestock can coexist with wildlife (Tyrrell et al. 2017; Keesing et al. 2018; Kiffner et al. 2020).

#### **4.2.3. Herding 4 Health**

The methods endorsed by H4H to address such issues as rangeland degradation and the use of herding and kraaling techniques promoted for human wildlife conflict mitigation stem from widely practiced and accepted strategies (Ogada 2001; Odadi et al. 2017; Tyrrell et al. 2017; Weise et al. 2018). Prerequisite community consultation and input on program design and project implementation is a fundamental component to the model and a critical ongoing process through engagement with targeted communities. H4H uses voluntary contractual stewardship agreements based on the Conservation Agreements strategy of Conservation International (Niesten et al. 2010) as a compliance mechanism to ensure expectations and outcomes are met for all stakeholders. Conservation Agreements between communities and conservation NGOs or private enterprises work similarly to traditional institutions and communal agreements. Awards and penalties are built into the agreement to address issues

that may arise, such as noncompliance (eg. failure to curtail regional poaching may result in reduced livestock production support or pricing incentives at livestock auctions). The process is dependent on collaborative planning, designing, implementing and adjustment between target communities and partnering organizations. Conservation Agreements are currently implemented in over 20 countries globally to protect over 3 million hectares of critical biodiversity habitat (CSP 2021).

By adopting globally tested conservation approaches, such as incentive based methods to facilitate ecosystem stewardship, the initial pilot in South Africa has had success in facilitating increased market access and higher prices to farmers who apply practices of sustainable beef production on high biodiversity rangeland (Meat Naturally 2019). Further recent gains through the extension services offered by H4H include employment for communal herders, provision of vaccines, capacity building through training, support in establishing grazing plans, grazing committees, and other communal governance structures, and signing Conservation Agreements for over 240,000 hectares of communal land (CSA 2019). The implementation of H4H pilot programs in two villages characterized with large livestock numbers and high associated rates of HWC in Limpopo National Park, Mozambique, has resulted in favorable outcomes since project implementation commenced in February, 2020. Following deployment of mobile predator-proof bomas, no further incidences of livestock depredation or retaliatory killings have been observed in the pilot villages, whereas non-participating communities still experience high predation rates. In addition, park management has reported a marked improvement in relations with both communities participating in H4H (P. Leitner pers. comm.).

The H4H model is a valuable entry point for addressing IWT at local scales, as its foremost objective is to address the key concerns of agropastoral communities residing in or utilizing strategic wildlife habitat. H4H aims to overcome the opportunity costs communities face by forgoing bushmeat as a source of protein through improving livestock production systems and promoting sustainable means for communities to benefit from wildlife (e.g. tourism), thus creating a pathway for wildlife-livestock coexistence. Building community resilience is a key objective of H4H, as the tourism industry is volatile, and livestock rearing is an important source of additional livelihood support (Lindsey et al. 2020). Recent livestock sales facilitated by H4H partner Meat Naturally during COVID-19 lockdowns of 2020 demonstrate the value

of livestock during periods of vulnerability (S. Frazee pers. comm.). Greater income stream diversity resulting from mixed livestock-wildlife systems (Keesing et al. 2018) further improves community resilience to global shocks. By reducing bushmeat poaching and consumption and promoting healthy livestock practices along the beef value chain, the H4H model has the additional benefit of reducing risks for zoonotic disease emergence (Kock et al. 2009; Alexander et al. 2012).

H4H recently developed a professional herder (also called ecoranger) training curriculum at the Southern African Wildlife College, an accredited private educational facility in South Africa, which covers a range of natural resource management modules, including: primary animal health care, rangeland assessments, livestock production, HWC mitigation and livestock-wildlife contact mitigation, low stress animal handling and climate change adaptation strategies. The curriculum topics were developed after extensive consultation with livestock owners across H4H sites on the skill sets most desired for professional herders. Through multi-stakeholder partnerships, H4H sources financial assistance for students and ultimately aims to revitalize the age-old profession of herding practice through capacity building, promotion of gender equity and advancement of herders as trained professionals. Herding in the traditional form, where adolescents herded the household's herd, has been abandoned in many countries with compulsory schooling (GIZ 2019). Herders within local communities are ideally positioned to improve regional security given that their work is field-based, they have detailed knowledge of the socio-ecological landscape and are mandated to look out for community interests. Capacitating herders with relevant skillsets and fostering tighter collaboration and communication with enforcement agencies increases security and the potential to address both stock theft and illegal wildlife offtake. Ideally, this would be the approach in communities where the value of wildlife and wildlife economies are treasured alongside other livelihood strategies such as agriculture and livestock production. In such a context, we developed a Theory of Change (ToC) to guide a novel community approach centered on husbandry to explore the potential to address illegal bushmeat hunting through the core community livelihood of livestock production.

## **4.3. METHODS**

### **4.3.1. Theory of Change approach**

A Theory of Change is a framework for planning and evaluating initiatives that are designed to foster an anticipated social or environmental change (Vogel 2012). The model is a derivation of logic planning models in social practice and has advanced to become a widely used tool in the international development and aid industries (Valters 2014). This results chain approach has found relevance for conservation planners seeking to reevaluate and improve upon selected strategies (Biggs et al. 2017). The ToC is designed as a method to facilitate critical thinking in an adaptive and transparent process to ensure identified interventions lead to desired outcomes while accounting for assumptions made throughout the process.

In general, results chains are organized from actions to the consequential outputs and outcomes that achieve the overall impact. As several actions may be needed to achieve the desired impact, each action follows a linked pathway directed toward the desired outcome. Benchmarks are put in place to self-evaluate and monitor the effectiveness of each action in reaching its goals. ToC's are intended to guide an adaptive style of management that evolves over time through routine testing of the model's assumptions. Critical thinking processes that drive interventions for change are shown in ToC models as transparent and concrete strategies. This is not only beneficial for an organization's development, but for providing stakeholders and donors with a clear understanding of the complexities of change. For this reason, ToC's are becoming a mounting prerequisite for many donor organizations.

This ToC finds roots in the First Line of Defense (FLoD) framework structured for community-based conservation efforts developed in east Africa (Skinner et al. 2018). FLoD evolved into a ToC with a generalized approach to facilitate the engagement of communities in addressing IWT (Biggs et al. 2017). This generalized ToC was adapted to construct specific results chains for H4H first through a series of email-based and in person discussions in 2017-2018 with a resource team consisting of scientific and implementation experts in H4H, wildlife conservation, illegal wildlife trade and livelihood development across multiple implementation sites in the SADC region. This preliminary input was used to structure the agenda for two workshops in Cape Town (25<sup>th</sup>-28<sup>th</sup> of September, 2018 and 3<sup>rd</sup>-5<sup>th</sup> of December, 2018), attended by the resource team to draft the ToC using the Open Standards framework (CMP 2007). A final stakeholder validation workshop was held in Maun (4<sup>th</sup>-6<sup>th</sup> of March, 2019) that included participants from government, NGO's, community-based organizations and the private sector. All participants to the Maun workshop participated

voluntarily and with full disclosure as to the objectives and nature of the workshop to validate a conceptual framework. The resulting H4H ToC identifies three pathways toward an overall objective of reducing pressure on wildlife populations in the Okavango from illegal bushmeat hunting through targeted interventions with agropastoral communities on the Delta periphery (Figure 4.1).

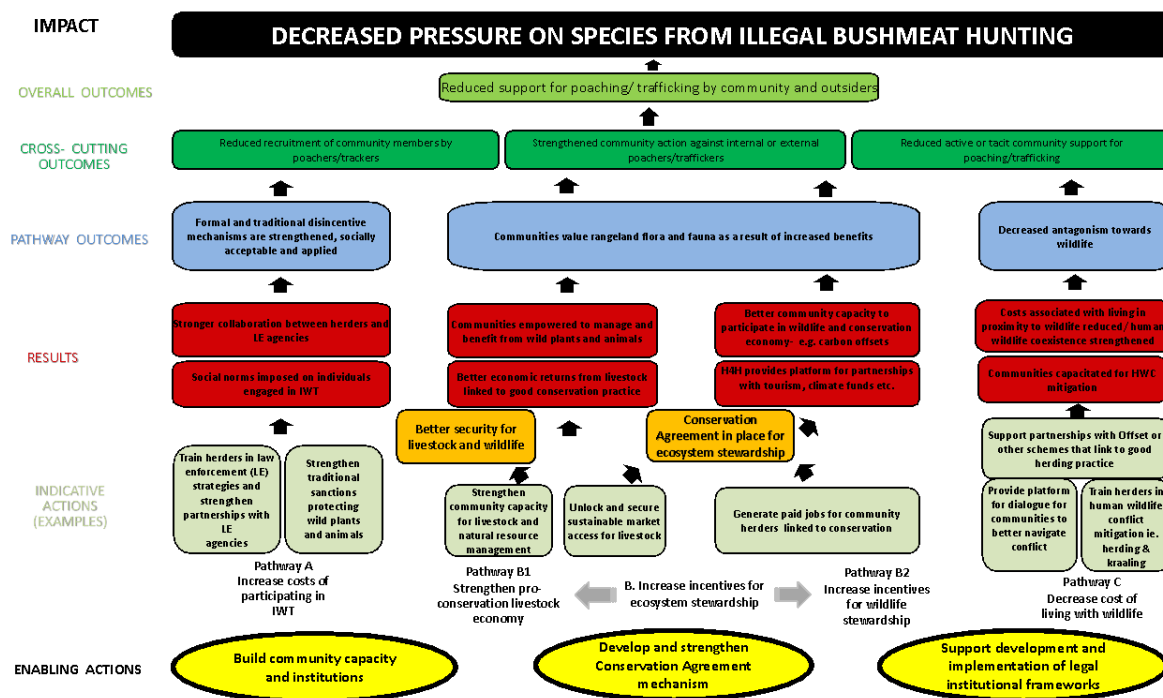


Figure 4.1. Theory of Change (ToC) developed for the Herding 4 Health (H4H) model to identify the role agropastoral communities can play in addressing illegal wildlife trade. The ToC was developed from a series of stakeholder workshops between September and December 2018. A ToC validation workshop was held in March 2019 in Maun, Botswana which included government representatives from relevant ministries, NGO's, community-based organizations and private sector participants.

## 4.4. DISCUSSION

### 4.4.1. Enabling actions

The underlying enabling actions are critical measures applicable to each pathway which serve to strengthen local governance through enhancing community capacity and providing support for institutions and institutional frameworks. Ultimately, strengthened governance will facilitate compliance with the Conservation Agreement mechanism which underpins the

model. Community capacity building is an essential and ongoing process in the H4H model which is reflected in curriculum development, and skill enhancement through training. Strengthening of the Conservation Agreement mechanism entails a highly collaborative process reached through consultative meetings with target communities to ensure expectations are agreed upon through adaptive management. H4H support for development and implementation of legal institutional frameworks (e.g. the establishment of grazing committees) speaks to strengthening local governance to ensure equitable benefit sharing, accountability and ultimately improved resource management.

#### **4.4.2. Pathways**

Actions aimed at making it more difficult and costly to participate in IWT (Pathway A) are widely recognized and practiced wildlife crime reduction strategies (Challender & MacMillan 2014). Botswana's Department of Wildlife and National Parks sub-district offices and the Botswana Defense Force are limited in resources and personnel to curb the onslaught of IWT in Botswana (Rogan et al. 2015). While private anti-poaching units have been effective in some of the WMAs of the Delta, their funding is finite, coverage is limited and mandate restricted in their areas of operation. Pathway A focusses on solidifying collaboration between local enforcement entities (e.g., community scouts, herders and farmers) through training and information sharing while also strengthening decision making rights, traditional institutions, cultural practices and social norms to wildlife utilization. Elevating the social stigma of poaching will ultimately require increasing the perceived worth of wildlife which can be realized through incentivizing mechanisms for wildlife and ecosystem stewardship (Pathway B).

Pathway B aims to motivate individuals and the community at large to take stronger action against IWT through livestock-based (Sub-pathway B1) and non-livestock based (Sub-pathway B2) incentive-based approaches to ecosystem stewardship. Sub-pathway B1 focusses on improving livestock production and market constraints to foster a pro-conservation livestock economy. Pathway B is founded on the principles of decision-making rights over, and benefits from natural resources through local community institutions, developed through decades of global research on the factors that enable robust institutions (Murphree 2009; Ostrom 2009). These actions include training and strengthening community capacity for livestock

management (community institutions) and securing sustainable market access through mechanisms that encourage wildlife friendly practices. The results include better economic returns from livestock linked to good conservation practices.

In the Delta, the tourism industry represents a vast untapped market for communal farmers, with large potential for creating incentives derived from conscious consumers who are willing to pay higher prices for goods and services that support community conservation initiatives through wildlife friendly branding schemes. While the model's preliminary aim is to establish consistent uninterrupted market access, H4H has successfully trialed facilitating higher value markets for communal farmers in Mnisi, South Africa, where the target consumers are safari lodge clientele of Kruger National Park (M. Grover pers. comm.). Through collaboration with private enterprise, farmers are awarded higher market prices linked to conservation actions such as planned grazing and other rangeland restoration techniques. This serves to highlight to farmers that wildlife can have benefits in indirect ways. The key emphasis is on linking to the robust principles of decision-making rights and benefits known to promote conservation objectives by local communities (Ostrom 2009; Murphree 2009; Persha et al. 2011).

Sub-pathway B2 focusses on developing non-livestock based incentives for wildlife stewardship through both the financial and non-financial rewards for protecting and sustainably managing wildlife and their habitats. Actions on this pathway include those focused on the development of activities like tourism, employment for communal herding linked to conservation, carbon offsets, etc., that generate benefits from wildlife conservation and build capacity in individuals and communities to participate and benefit from these initiatives. Communities are then better able to benefit from the wildlife and conservation economy through a range of mechanisms that may include professional herder and ecotourism training and employment, tourism development and carbon offset payments through improved rangeland management. In addition, H4H provides an institutional platform for the development of partnerships with communities to access climate funds, tourism enterprises and training centers. The incentive-based approaches of Pathway B are contingent on compliance with the Conservation Agreement mechanism whereby penalties to wildlife crime activities are applied by withholding incentives. Conservation Agreements can also serve to facilitate benefit sharing between communities and private enterprise. For example, tourism enterprises may opt to buy local produce and support the salaries of professional herders due

to a reduction in numbers of stray cattle in wildlife concessions, reduced retaliatory killings due to HWC and the opportunity to market social and environmental support to conscious consumers.

Finally, Pathway C focuses on reducing the costs to individuals and communities living with wildlife, in particular through improved HWC mitigation. Actions in this pathway aim at increasing the capacity of herders to effectively mitigate conflict, using techniques such as herding and protecting livestock in specially designed predator-proof boma enclosures during the night (kraaling). Successfully mitigating conflict helps reduce the cost of living alongside wildlife and helps de-escalate the conflict, which allows for dialogue with communities to explore the complex challenges of HWC. The social-ecological framework for ecosystem disservices and services (SEEDS) provides a concept for addressing HWC where the disservices (costs) of wildlife on local communities may strongly outweigh the services. For example, situations where tourism companies, national governments and the international conservation community mainly benefit from the services while experiencing little of the disservices (Ceausu et al. 2020). Pathway C explicitly aims to correct the skewed ratio of wildlife disservices to services for local communities by creating more equitable and sustainable conservation outcomes.

There are various feedback loops between the pathways. For example, success with the law enforcement strategy in Pathway A may lead to increased human wildlife conflict as predator numbers increase, which would instigate more consideration to the mitigation activities in Pathway C. Similarly, if the success of improved husbandry in Sub-pathway B1 leads to increased herd sizes, it could consequently result in increased rangeland degradation. This scenario would require a Conservation Agreement that mitigates rangeland degradation through community-driven regulation of herd size in accordance with proper rangeland management practices. In this regard, the ToC is to be taken as an adaptive decision support tool for conservation practitioners in partnership with local communities and relevant stakeholders which will require continuous reassessment, development and negotiation as it is implemented.

#### **4.4.3. Key assumptions**

The communities where H4H is implemented are often subject to fast-changing external pressures and they, along with the individuals who comprise them, vary in socio-economic, cultural and political factors. As such, the guiding pathways developed in this ToC need to be contextually assessed before implementation. Aside from the prerequisite enabling actions identified in this ToC, governance challenges from the local to international scale including transparency, corruption, elite capture, decentralization of natural resource rights, zoonotic disease and other biosafety control policies and legislation regarding wildlife crime (Frost & Bond 2008; Thomson & Penrith 2011; Rogan et al. 2015; Biggs et al. 2017) are critical factors for consideration in the attempt to address IWT in agropastoral communities.

H4H relies heavily on community confidence in the assumption that herders charged with custody of a common property (livestock) are responsible and acting on a community's best interests. The link herders can provide between livestock and wildlife security is based on the assumption that they themselves will not be lured into illicit behavior. Thus, key assumptions for a strategy that relies upon herders to assist in wildlife related law enforcement activities include: 1) Communities value wildlife and strive to benefit from its presence 2) Communities recognize that there is a poaching problem, and 3) Communities are willing to allow herders to collect data and report on illegal activity. There is empirical evidence to show that local communities are more likely to invest time and energy into forming local institutions for developing and enforcing rules about conserving natural resources if, 1) They have ownership and decision-making rights over those resources, and 2) The costs of conserving those resources are strongly outweighed by the benefits (Lewis et al. 1990; Lotter & Clark 2014; Murphree 2009; Ostrom & Nagendra 2006; Ostrom 2009; Persha et al. 2011; Muntifering 2019). When bestowed with the responsibility for making rules about wildlife conservation and community game guards are used for monitoring and enforcing these rules, local communities once notorious for poaching can become ardent conservationists (Lewis et al. 1990; Lotter & Clark 2014; Muntifering 2019). These are key and non-substitutable principles for the ToC.

Community members engaged as game guards or related roles may face open hostility, risks to personal safety and a breakdown of social cohesion within the community by members involved in wildlife crime (Painter & Wilkie 2015). In this respect, the balance of support within the community needs to be weighed so that herders do not face excessive intimidation

by those involved in illegal offtake. The level to which communities and external law enforcement are willing to collaborate, and the degree to which these strengthened relations lead to tighter action against, rather than collusion with, wildlife crime will be a paramount consideration in this decision.

In the Habu community, an H4H pilot project in the western Delta, community scouts employed by a local CBO, the Habu Elephant Development Trust, have the dual duties of wildlife monitoring and aggregate herding. While only in its third year of implementation, preliminary results have discovered linkages in criminal activity associated with stock theft and illegal bushmeat harvest which has demonstrated the critical role herders/scouts can play in reporting and acting on wildlife crime through tight associations with local law enforcement with the backing of community leadership. The Habu project was initiated with international donor support and aims to work towards sustainability through revenue generated from improved market access, livestock management and tourism levees. The dual role of skilled herders in security and livestock management has presented a few challenges, however. The pilot has been subject to the common complications of community policing, such as under-reporting of illegal activities and minor harassment. However, through continued community outreach and education, the community scouts of Habu have gained traction in garnering community support and have reduced illegal activity in a community identified conservation zone (HEDT 2019).

To dissuade community members from engaging in wildlife crime, the alternatives must be equally lucrative and appealing (Keane et al. 2008). Major assumptions for strengthening ecosystem stewardship incentives are: 1) That the target communities are on board with the H4H program, 2) That communities are willing to acquire new skill sets, 3) That the activities of improved livestock management and rangeland restoration can demonstrate positive outputs that are comparable to illicit means of livelihood enhancement, 4) That better farming practices will result in increased benefits for the farmers, and 5) That the community awareness of the H4H protocol or approach instills acceptance of a wildlife-livestock coexistence strategy.

Assumptions related to decreasing the cost of living with wildlife are: 1) That communities are willing to engage in H4H activities, and 2) That the wildlife-livestock risk and conflict

mitigation activities are effective. While the effectiveness of professional herding and kraaling and the willingness of a community to take on these activities have been tested and realized in several of the H4H sites as well as elsewhere, increased HWC mitigation measures may not always lead to increased tolerance of wildlife (Dickman 2010). Some conservation activities may result in unintended consequences. For example, a compensation scheme that is not linked to a system that enables participation in a program such as H4H as a prerequisite for compensation for livestock loss can disincentivize best practice adoption or even result in false reporting which in turn fosters greater resentment against carnivores.

Successful HWC mitigation measures alone will not be enough to keep farmers in the H4H program. Thus, economic benefits to herding, especially successful implementation of wildlife friendly beef production practices and in the long term, improved rangeland, cattle production and enhanced alternative livelihood opportunities are critical components to the model. The strength of the H4H model is that with the same activities it addresses both risk mitigation and unlocked opportunities through collective action and negotiated agreements that are context specific. Similarly, H4H can provide a platform to negotiate access and benefit sharing frameworks between protected areas and communities in a win-win, ecological and biodiversity sound way which would provide major incentives for wildlife stewardship. H4H plays a key role in providing greater resilience to community-based conservation by integrating conservation with livelihoods and co-existence of livestock with wildlife by providing a way of sustainably integrating livestock with wildlife (livelihood diversification) (Fynn et al. 2016). Through can take conservation strategy into a new multi-dimensional era beyond the one-dimensional tourism income approach that renders conservation vulnerable to global shocks that jeopardize tourism income, while also improving local community attitudes to conservation by increasing benefits to local communities of enhanced access to resources and participation in management of wildlife.

## **4.5. CONCLUSIONS**

The issues surrounding IWT are dynamic and complex (Challender et al. 2015) and require targeted interventions at multiple scales. Failure to attract or solicit community support has resulted in the underperformance of many conservation efforts in achieving their intended outcomes (Ban et al. 2013). Indirectly related to this are equally complex issues surrounding

HWC which affect community sentiments towards wildlife and pending on context can influence whether human-wildlife interactions are viewed as conflict or coexistence (Frank & Glikman 2019). Also of critical concern are prevailing power dynamics and where decision-making rights and the authority to manage conflict lie (Massé 2016) which will also influence tolerance towards conservation. The holistic, integrated approach of H4H aims to address several of the contributing factors of illegal bushmeat hunting at a community level and should be considered as a component to the broader strategy to combat IWT (Biggs et al. 2015; Biggs et al. 2017). Furthermore, in times of severe stress, rural people increasingly turn to the exploitation of nature, as observed in recent spikes of bushmeat harvest reported in Uganda and Kenya as well as the spike in the poaching of endangered green turtles in Madagascar in the past year due to effects of COVID19 lockdowns (Mupatsi 2020). The H4H model aims to build resilient communities based on livelihood diversification that can withstand stressors like global pandemics, tourism declines, recessions, or climate-related disasters, while also reducing HWC. If global-level stressors continue to increase in severity, the resulting increase of IWT will be large.

While this ToC was drawn from the experience of multiple authorities and stakeholders, many of the assumptions still need empirical validation. A common limitation to some ToCs is that they are based on ‘weak and selective’ evidence which can bolster misled confidence in a resolution without complete comprehension of the problem at hand (Valters, 2014). Thus, this ToC should be considered as an adaptive mechanism, the progression of which will require co-learning and co-management from other H4H sites, locally specific implementation in a nuanced style, targeted and applied monitoring and evaluation, and a realistic approach that accounts for the importance of different stakeholder perceptions and considers the importance of processes and relationships in achieving outcomes. Ultimately, we aim to demonstrate the use of this model, whose assumptions will be tested through monitoring, open dialogue, collaboration, and feedback with partnering communities, to strengthen the role H4H can play in community driven wildlife crime prevention.

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## CHAPTER 5. Conclusions

The wildlife-livestock-human interface characterizes the greatest management challenge to the viability of the TFCA's of southern Africa. This interface is where wildlife and livestock disease-related issues have a significant economic impact and important consequences for human health and well-being, food security, rural development, and biodiversity conservation (Kock 2004; Osofsky et al. 2008; Cummings 2011). Management of animal diseases linked to wildlife and their government control policies are costly to rural farmers and present challenges to TFCA implementation across otherwise linked landscapes by restricting animal movement and ecosystem connectivity (Osofsky et al. 2005). Movement and connectivity restrictions not only negatively impact biodiversity conservation, but also any associated diversified economic development and community resilience opportunities deriving from available wildlife-based enterprises. Given that well-managed cattle coexist very well with wildlife (Tyrrell et al. 2017; Keesing et al. 2018; Kiffner et al. 2020), more examples are needed throughout southern Africa to demonstrate the contribution that integrated wildlife-livestock systems can play in poverty eradication, economic development, ecosystem connectivity and biodiversity conservation.

This research demonstrates the interconnectedness of human, animal and environmental health as described by the principles of One Health. This research focused on traditional livestock farming, the single largest contributor to household income in the Habu village community, in an impoverished region of Northwest, Botswana with few alternative livelihoods. Market access related to restrictions imposed by animal disease control policies is one of the greatest economic challenges faced by traditional farmers in this region. In the absence of consistently reliable market access, cattle numbers in some regions of Ngamiland have swelled beyond local carrying capacity, the cost of which is a degradation of grazing areas and general rangeland condition (Atkinson et al. 2019). The current piosphere effect demonstrated in Chapter Three indicates that in times of resource scarcity, cattle will have to travel further distances to access available forage. Greater travel distances will result in loss of cattle condition and greater risk of loss of individual animals. Widely straying animals are the largest cause of livestock loss reported in the Habu farming community as revealed in Chapter Two. These straying animals also pose a threat to regional animal disease control

efforts as the nature of infection of southern African FMD variants linked to range overlap with wildlife remains poorly understood (Teklehiorghis et al. 2014). Consequently, regions characterized by uncontrolled movements of livestock can be expected to incur high rates of HWC through predation on livestock and continued market closures due to disease outbreaks. Uncontrolled livestock will also continue to contribute to rangeland degradation in a region particularly vulnerable to climate change (GIZ 2019). These conditions, unless corrected, are likely to perpetuate a cycle of poverty and food insecurity in western Ngamiland which will have damaging repercussions to human health (Stevens 2007) linked to declining natural capital and essential ecosystem services.

Herding 4 Health offers practical solutions to address many of the common challenges to agropastoral livelihoods found on the rangelands of sub-Saharan Africa. While wildlife-based economies have great potential to develop regional economic sustainability, growth, and climate change resilience, achieving this is challenging. Currently, the vast majority of Habu farmers see wildlife as a threat and a cost to their traditional livelihoods. High rates of predation on livestock and the disease risks posed by Cape buffalo in particular are the underlying drivers of this sentiment as established from the Habu community survey. While kraaling livestock at night is not uncommon in the Habu farming community, herding has been largely abandoned despite acknowledgement of its importance in addressing human-wildlife conflict, disease control, ensuring access to forage and water, and record-keeping. Both the lack of herding in local husbandry practices and the recognition of its potential importance in traditional livestock agriculture represent opportunities for skills development and employment opportunities in professional herding. Training in rangeland science and employing livestock herders equipped with grazing land management skills are the principal aims of the H4H model. Employment of trained professional herders represents targeted development ideally positioned to reverse the trend of rangeland degradation and increase landscape productivity.

Functional heterogeneity has been identified as an important factor underlying rangeland health, productivity and carrying capacity (Owen-Smith 2004; Fryxell et al. 2005; Fynn et al. 2016). The natural habitat heterogeneity characteristic of the Delta typically supports large populations of wild and domestic herbivores and the results presented in Chapter Three, identified several drivers that contribute to functional heterogeneity and rangeland condition

around Habu. Understanding these drivers in further detail can inform land-use planning efforts aimed at achieving sustainable management objectives. For example, proper training in the use of mobile predator-proof bomas may not only address human-wildlife conflict but can also be used as a nutrient cycling tool to reverse rangeland degradation and strategically plan and space nutrient hotspots to improve overall landscape productivity for both wild and domestic herbivores. Similarly, while grazing influences vegetation composition and structure, understanding the nature of this pattern in the local context advances grazing planning as an effective land management tool. Successful implementation of grazing plans can help address the primary challenge of market access through wildlife and rangeland friendly branding schemes identified in the H4H ToC.

The pathways presented in Chapter Four are aligned with commonly adopted strategies for community-based conservation but are tailored to agropastoral communities and address the specific concerns of Habu farmers. While the main actions in the ToC are commonly adopted community-based conservation tactics, insufficient monitoring and evaluation of past efforts mean that changes remain in theory only. Validation of this ToC will require developing appropriate targets and indicators for tracking progress over time. Similarly, a core output of this thesis is a series of recommendations for how the H4H model can be applied and improved in western Ngamiland, which are established in the discussion section of each body chapter and summarized in Table 5.1. Though many of these recommended interventions are already adopted by H4H and validated through previous research, some recommendations will need further investigation with an appropriate monitoring and evaluation framework. Quantifiable indicators will be necessary to demonstrate successful advances of One Health initiatives anywhere (Molyneaux et al. 2011), and the lack of such metrics in northern Botswana is recognized as a limitation to some of the focal objectives identified in this thesis.

*Table 5.1. A summary of opportunities for H4H interventions applicable to western Ngamiland, Botswana.*

| Proposed H4H Action/Mitigation Measure                                                                     | Opportunities Identified in Chapter Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Train and capacitate herders                                                                               | Skills development in:<br>Mitigating disease transmission between wildlife and livestock (Ch. 2, Ch. 4)<br>Rangeland Management (Ch. 3)<br>Animal Production (Ch. 2)<br>Primary Animal Health Care (Ch. 2, Ch. 4)<br>Human-Wildlife Conflict Mitigation (Ch. 2, 4)<br>Monitoring and Record Keeping (Ch. 4)<br>Law Enforcement (Ch.4)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Planned grazing through aggregate herding by skilled herders and kraaling with mobile predator-proof bomas | Job creation (Ch. 4)<br>Livestock losses to straying animals, theft and predation (Ch. 2, Ch. 4)<br>Decreased livestock disease transmissions and overall improved herd health (Ch. 2, Ch. 4)<br>Reduced costs of veterinary care/ increased vaccine efficacy (Ch. 2)<br>Decreased rangeland degradation from piospheric related grazing patterns (trampling, overgrazing, bush encroachment) (Ch. 3)<br>Improved functional heterogeneity (Ch. 3)<br>Improved nutrient and water cycling (Ch. 3)<br>Climate change mitigation (carbon sequestration, reduced emissions) and potential access to revenue streams through carbon markets (Ch. 3, Ch. 4)<br>Improved livestock condition from controlled movement and improved access to fodder and water (Ch. 3)<br>Increased animal productivity (Ch. 2)<br>Decreased rates of IWT and increased tolerance for wildlife (Ch. 4) |
| Health-related (animal, human and environmental) awareness workshops                                       | Health benefits from improved education on zoonotic diseases, (Ch. 2)<br>Community buy-in through improved understanding of benefits for livelihood diversification, sustainability and community resilience (Ch. 4)<br>Awareness around market development and disease control compliance (Ch. 4)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Strengthen communication and partnerships across multidisciplinary fields                                  | Improved networks with law enforcement resulting in reduced bushmeat offtake (Ch. 4)<br>Improved opportunity for community-based enterprise development (eg. livestock value chain development, beef value addition, tourism) (Ch. 4)<br>Improved disease control and animal health protocol from improved networks with Department of Veterinary Services (Ch. 4)<br>Overall policy alignment including land use planning (Ch. 4)                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Strengthen local governance through support for local institutions and frameworks                          | Improved rangeland management resulting from grazing committees (Ch. 3, Ch. 4)<br>Improved leadership, community cohesion, communication and awareness (Ch. 4)<br>Improved buy-in and coordination for best farming practices (Ch. 4)<br>Opportunities for improved market access and enterprise development (Ch. 4)<br>Improved benefit sharing among marginalized group and gender equity (Ch. 4)<br>Improved action against illicit activity (Ch. 4)                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Implement stewardship agreements centered on pro conservation livestock economy                            | Improved market access through wildlife friendly branding and commodity-based trade protocol compliance (Ch. 4)<br>Improved community-driven compliance and monitoring (Ch. 4)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Facilitate wildlife-livestock coexistence for wildlife dispersal                                           | Improved community resilience and poverty reduction through diversified livelihoods resulting from pro livestock and wildlife based economies (Ch. 4)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

The scope of this study was originally proposed to analyze the performance of the H4H model over time through measurable and quantifiable indicators related to animal, human and environmental health. These original indicators included measurements of livelihood improvement deriving from revenue generated among H4H participants, records of livestock condition of communally herded cattle, routine veterinary checkups, body condition scores

and livestock weight, and changes in rangeland condition over several years following planned grazing initiatives. The H4H programme was initiated in Habu in 2018, but only a few of these indicators were monitored due to time constraints stemming from the drought conditions of 2019. Funding delays also contributed to implementation delays, but a communal herd was established initially in 2019 and again in 2020 following the drought. While the Habu communal herd was (and continues to be) managed in accordance with rangeland restoration principles, grazing plans were still under negotiation during the study timeframe. Thus, it was not possible to track vegetation changes over the relatively short period of this research. However, in the time frame of this study, collaborating H4H projects have been implemented in other sites in southern and eastern Africa where standardized record-keeping of the focal health-related variables are currently being collected across H4H sites and which are expected to contribute to the validation of the ToC and the H4H model implemented in Habu.

The record-keeping currently being collected across H4H sites presents an ideal opportunity for further examination into the role that H4H contributes to One Health through more quantitative research. Furthermore, due to the far-reaching consequences of FMD outbreaks in southern Africa, future research is recommended on the nature of FMD spread given the current knowledge gaps in this field. Lastly, planned grazing is often cited as a potential strategy to address climate change through carbon sequestration (Godde et al. 2020), thus crucial research is required to investigate if H4H has the potential to aid rural communities in accessing financial returns through carbon markets and its conceivable contribution to planetary health.

The challenges that arise on the wildlife-livestock-human interface in the TFCA's of southern Africa are interconnected, complex and dynamic and resolving them will require innovative holistic approaches. The results of this thesis demonstrate how the interventions proposed through the One Health framework of the H4H model are ideally suited to address many of these common issues and promote multidisciplinary collaboration and strategizing in the fields of rural development and biodiversity conservation.

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## APPENDIX A. Ethics approval



UNIVERSITEIT VAN PRETORIA  
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### Research Ethics Committee

|                                   |                                                                                                                            |
|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| PROJECT TITLE                     | A One Health assessment of a Herding for Health project at the wildlife-livestock interface in western Ngamiland, Botswana |
| PROJECT NUMBER                    | REC070-18                                                                                                                  |
| RESEARCHER/PRINCIPAL INVESTIGATOR | Ben Heermans                                                                                                               |

|                                   |     |
|-----------------------------------|-----|
| DISSERTATION/THESIS SUBMITTED FOR | PhD |
|-----------------------------------|-----|

|            |             |
|------------|-------------|
| SUPERVISOR | Melvyn Quan |
|------------|-------------|

|                                        |                               |
|----------------------------------------|-------------------------------|
| <b>APPROVED</b>                        | Date <b>19 September 2018</b> |
| CHAIRMAN: UP Research Ethics Committee | Signature <i>A. M. Dineen</i> |

## APPENDIX B. Manuscript



# Husbandry and Herding: A Community-Based Approach to Addressing Illegal Wildlife Trade in Northern Botswana

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Illegal bushmeat hunting is a major driver of wildlife population declines in Northern Botswana. Such declines raise concerns about the principles and integrity of the Kavango-Zambezi Transfrontier Conservation Area (KAZA) and regional economic stability which is heavily reliant on wildlife-based tourism. The KAZA landscape between Northern Botswana's protected areas consists of non-state land utilized communally by small agropastoralist communities. These communities are economically challenged by international beef trade policies, restricted access to grazing in nearby wildlife management areas and high conflict costs from living in close proximity to wildlife; some of the key factors identified as drivers of bushmeat hunting in the region. Here we describe how a model called Herding for Health (H4H) could address these drivers. We discuss strategies using a socio-economic contoured Theory of Change (ToC) model to identify the role agropastoral communities can have in addressing illegal wildlife trade (IWT). The ToC conceptual framework was developed with input from a resource team consisting of scientific and implementation experts in IWT, wildlife conservation, illegal wildlife trade and livelihood development between September and December 2018, and with a validation workshop in March 2019 with government representatives from relevant ministries, NGO's, community based organizations and private sector participants. We identify three pathways deriving from the ToC driver by community level actions to address IWT in the region. These include: increasing institutions for local enforcement, developing incentives for ecosystem stewardship and decreasing the costs of living alongside wildlife. The success of these pathways depends on underlying enabling actions: support for the development of institutional frameworks; building community capacity to facilitate informed best farming practices; and strengthening commitments to sustainable resource management to increase resilience to climatic and economic shocks.

**Keywords:** transfrontier conservation area, illegal wildlife trade, One Health, agropastoral, community-based conservation, human wildlife conflict, coexistence

## INTRODUCTION

The Okavango Delta (hereafter referred to as the Delta) in northern Botswana is a key region for biodiversity conservation and economic development in Botswana and is currently facing immediate and long-term threats including oil and gas exploration, climate change and wildlife population declines resulting from illegal wildlife trade (IWT) [Burg, 2007; Magole and Magole, 2009; Rogan et al., 2015; Herding for Health (IHHL), 2019; Richardson, 2021]. IWT is a major threat to global biodiversity conservation and sustainability with consequences that affect food security and development [Dickson, 2008; Phelps et al., 2016], as well as environmental, human and animal health [Gómez and Aguirre, 2008; United Nations Office on Drugs and Crime (UNODC), 2020]. As IWT occurs on various scales from subsistence use to organized international criminal syndicates, methods specific to the scale of illegal activities are needed to effectively counter this threat [Biggs et al., 2017].

Here we provide contextual and background information to outline key considerations to bushmeat drivers, community-based conservation, and livelihood opportunities in the Delta region of the KAZA landscape before presenting the Herding for Health model. Finally, we present a process to which we adapt a general Theory of Change (ToC) model [Biggs et al., 2017; Skinner et al., 2018] to a community based approach to investigate the role agropastoral communities in wildlife rich Transfrontier Conservation Areas (TFCAs) can play in combatting illegal bushmeat hunting.

## Bushmeat Trade

A 2011 aerial wildlife survey indicated significant declines in several ungulate species in the Delta [Chase, 2011]. This raised alarm for Botswana's tourism industry and conservation sector, thus motivating an increase in wildlife monitoring around the Delta as well as an investigation of the underlying drivers of this decline [Rogan et al., 2015]. The results of this survey-based study funded by the FAO indicated that illegal bushmeat hunting is pervasive in the Delta with an approximation of 2,000 hunters harvesting an annual take of 620,000 kg of medium-large herbivore biomass [Rogan et al., 2017]. For some ungulate species, the study surmised that hunting offtake exceeds the intrinsic population growth rate, which would imply negative ecological and economic consequences. The negative effect of the bushmeat trade on ungulate populations has been observed across sub-Saharan Africa [Lindsey et al., 2013]. Declines in herbivore populations will have cascading trophic effects on predator populations which are a major draw for photographic safaris [Rogan et al., 2017].

The extent and drivers of bushmeat hunting vary by context, from cases where it is primarily a subsistence activity to those where it is done on a larger scale for commercial gain [Duffy and St. John, 2013]. In the Delta, bushmeat hunting is primarily an opportunistic pursuit of relatively wealthier households who use bushmeat as a form of supplementary income [Rogan et al., 2018]. While exceptions in the Delta exist in the forms of syndicate organizations whose offtake exceeds 1000 Kg p.a. and households that report subsistence usage, greater than

half of hunters in the Delta reported an annual harvest of <100kg/yr [Rogan et al., 2015]. Three main drivers of bushmeat hunting identified in and around the Delta include: (1) economic opportunity, (2) lack of disincentives to hunt, and (3) negative attitudes toward wildlife [Rogan et al., 2015]. Improved law enforcement and the development of alternative wildlife-based revenue streams that provide communities with conservation incentives are two recommended interventions to address illegal bushmeat hunting in the region [Rogan et al., 2018].

## Community-Based Conservation

Within the Kavango-Zambezi (KAZA) landscape, 75% of the land between state protected areas falls under traditional tenure systems [Cumming, 2011]. Excluding WMAs, forest reserves and community concessions, 148,520 km<sup>2</sup> of the remaining matrix is earmarked for agropastoral uses [Kavango Zambezi Transfrontier Area (KAZA), 2014]. In northern Botswana, the majority of rural communities attribute livestock as the main source of income generation, with some communities in western Ngamiland reporting livestock as supplying as much as 95% of household income [Darkoh and Mbatwa, 2009; Hahu Elephant Development Trust (HEDT), 2019]. In recognition of the need for integrated landscapes, initiatives promoting community based management systems for livestock-wildlife coexistence have been in development since the 1970s [Tyrell et al., 2017]. Here we refer to coexistence as relating to both tolerance of conflict and co-occurrence, in recognition of the need to clarify from multiple interpretations that exist in literature [Nyhus, 2016; Frank and Gikman, 2019; Knox et al., 2021]. Today, a number of livestock-wildlife coexistence projects in east and southern Africa demonstrate that conservation of large open landscapes and rural development can be achieved through the application of well-managed pastoral practices [Odadi et al., 2017; Tyrell et al., 2017; Keesing et al., 2018; Kiffner et al., 2020].

The Okavango Delta has been widely used by agropastoralists for centuries, which was documented by the first European expeditions to the area [Andersson, 1856; Livingstone, 1857]. This practice continued until recent times [Basupi et al., 2017]. However, at present, community access has largely been restricted for the purpose of economic growth leveraged by the global imperative for conservation, mostly to the benefit of government and outside international investors [Magole and Magole, 2009]. Across Africa, communities have been displaced for the establishment of national parks, game reserves and wildlife management areas [Chatty and Colchester, 2002; West et al., 2006; Adams and Hutton, 2007]. This type of "fortress" conservation strategy [Brockington, 2002; Berkes, 2004] was largely driven by the western concept of wilderness as a "pristine" untouched landscape and often involved the forced removal of resident human populations and reinforced a concept of division between people and nature [Adams and McShane, 1992].

Today, there is a growing awareness that the cooperation and participation of communities living in proximity to wildlife are critical to tackling IWT [Skinner et al., 2018]. This is reflected in an increasing number of international policy recommendations that promote community based approaches [Biggs et al., 2017]. Despite a wide range of trialed methods, standard protocols for

community engagement are not widely accepted or regarded due to inadequate monitoring of the effectiveness of community based tactics and a disconnect between policy commitments and implementation (Cooney et al., 2016; Roe and Booker, 2019). Common methods that have evolved from decades of community initiatives involve; conservation awareness, development of non-wildlife based livelihoods, environmental stewardship incentives, increasing costs of participating in IWT and decreasing costs of living in proximity to wildlife (Roe and Booker, 2019). Despite a lapse in effective evaluation of such strategies, some key considerations that emerge in community engagement are: inclusivity and ownership in decision making and project design and implementation, effective governance and strengthened traditional institutions, net costs and benefits that influence community attitude either for or against conservation efforts and multilevel networks and enduring collaborations (Cooney et al., 2016, 2018; Armitage et al., 2019; Roe and Booker, 2019; Chan et al., 2020). Furthermore, communities are dynamic by nature and planning for successful outcomes requires understanding and sensitivity to local and social contexts (Cooney et al., 2018). For example, ethnic friction and cultural heterogeneity have been identified as challenges to community organization in Ngamiland, Botswana (Thakadu, 2005), which will have likely implications and require careful consideration for regional project design and implementation.

In Northern Botswana, community based tourism enterprises are common on the eastern, southern and northern periphery of the Delta, whereas the western side is characterized by traditional agriculture communities, underdeveloped tourism potential and greater human population density (Atkinson et al., 2019; Albertson, 2020). Veterinary cordon fences west of the Delta function primarily to prevent contact between cloven-hoofed domestic livestock and Cape buffalo (*Synceus capensis*) due to the risks of transmission of foot-and-mouth disease (FMD) (Atkinson et al., 2019). The fences effectually restrict market access for farmers living in Botswana's FMD control zones by prohibiting sales to the Botswana Meat Commission's higher priced international beef export industry and also separate these local communities from access to the resources in the wildlife management areas of the Delta (Atkinson et al., 2019). However, the network of over 10,000 km of fencing is porous due to frequent damage by elephants and high maintenance costs (Atkinson et al., 2019). Thus, veterinary cordon fences have been ineffective spatial barriers impacting both livestock and wildlife through exacerbating disease control efforts and human wildlife conflict (Ferguson and Hanks, 2010).

Together with opportunity and disease costs, human-wildlife-conflict (HWC) is another cost of conservation that is primarily shouldered by local communities and relates to tolerance to wildlife stewardship (Ceausu et al., 2020). Consequently, retaliation against wildlife responsible for HWC is common and leads to declines in wildlife populations regionally as well as globally (Woodroffe et al., 2005; Dickman, 2010). Killing of lions in retaliation for livestock losses has resulted in the removal of 30–50% of the lion population of the Delta's eastern panhandle (LeFlore et al., 2019). Lethal mitigation measures coupled with IWT, particularly in the form of illegal bushmeat harvest, pose a

threat to sustainability of Botswana's wildlife populations and the region's tourism-based economy (Rogan et al., 2015).

Government and private anti-poaching units often lack understanding of the socio-ecological landscape, being mandated to operate at a regional scale, and are often easily evaded by locally-based poaching syndicates (Fynn and Kolawole, 2020). Furthermore, the para militarization of conservation has drawn heavy criticism as a top down approach associated with human rights violations, enforcing exclusionary conservation practices on marginalized peoples, and deepening park-community divisions (Roe et al., 2015; Cooney et al., 2016; Massé et al., 2017). For these reasons, even proponents for militarized strategies to combat IWT, such as Botswana Defense Force's involvement in anti poaching, advise caution with this intervention and that it should be strengthened by accountability and strategies to address local socio-economic inequalities (Cooney et al., 2018; Duffy et al., 2019). Despite extensive use of law enforcement as a method to address IWT (Roe and Booker, 2019), efforts to combat poaching have proven largely ineffective when communities have not been aligned with the conservation agenda (Fynn and Kolawole, 2020).

Conversely, through intimate regional, social, and ecological linkages, poaching is restricted when communities are on board with the conservation efforts, but all too pervasive when they are not (Scott, 1989; Fynn and Kolawole, 2020). Though communities at large are not the criminals in these cases, community sentiment can influence the prevalence of criminal activity. The unsuccessful attempts to obstruct poaching by government entities who lack the funding, manpower, local knowledge, and access to social networks represent a critical mismatch of scale (Cumming et al., 2006). At a local scale, communities are better equipped than centralized government through traditional knowledge, social networks, and human resources to effectively manage their natural resources (Murphree, 2004; Ostrom, 2009). Communities empowered with decision making rights can gain significant conservation outcomes. Examples include: the increase in wildlife populations on Namibian Communal Conservancies (Munlifering, 2019), designation of new community conservancies adjacent to northern Kruger National Park (Fynn and Kolawole, 2020), and the decrease in elephant poaching reported in Kenya's Northern Rangeland Trusts (Northern Rangelands Trust, 2019) and in the WMAs of the Luangwa Valley (Lewis, 1990).

## Wildlife-Livestock Coexistence

In light of the adverse consequences that arise from overlooking societal stressors to the communities adjacent to PAs, new conservation strategies that recognize, incorporate and promote both human and environmental complexities are urgently needed. This shortfall has been widely acknowledged (Ostrom, 2007) and has ultimately led to increasing complexity in conservation theory and new tools to guide the design of conservation strategy. PAs alone are inadequate to stem biodiversity loss because they are spatially-limited and consequently most biodiversity occurs outside PAs (Western et al., 2020). Thus, for large scale landscape conservation efforts (e.g., TFCAs) to be effective, the conservation scope has to widen

beyond national parks and wildlife management areas to achieve habitat connectivity across the landscape (Mora and Sale, 2011). The notion of “working landscapes,” that serve to conserve biodiversity while sustainably delivering the goods and services required by humanity aids to conceptualize how this connectivity within and between landscapes may be achieved (Miller et al., 2012; Kremen and Merenlender, 2018; Western et al., 2020). An environment for the successful raising and keeping of livestock is one such key service, especially considering that well-managed livestock can coexist with wildlife (Tyrell et al., 2017; Keesing et al., 2018; Kiffner et al., 2020).

Developing integrated livestock-wildlife systems in southern African communal rangelands will require addressing the key constraints that arise from market restrictions due to zoonotic and other economically important transboundary diseases (TADs), such as FMD control policies. Such restrictions pose major challenges to farmers (De Garine-Wichatitsky et al., 2013; Musoke et al., 2015; Van Rooyen, 2017) which can adversely affect community tolerance for wildlife and conservation efforts (Bedelian et al., 2007; Cumming et al., 2013; Van Rooyen, 2017). The severity of consequential market restrictions that animal disease policies inflict on rural farmers is exemplified by a 2007 FMD outbreak near Habu village in Northern Botswana that resulted in a 7-year closure of the beef industry in Ngamiland (Atkinson et al., 2019). Changes to the World Organization for Animal Health (OIE) policies that relate to FMD control measures now focus on disease prevalence in the beef commodity rather than the previously required geographical separation of livestock and wildlife, thus providing an opportunity for alternative risk mitigation measures (e.g., herding and kraaling) that help enable wildlife-livestock coexistence (Thomson et al., 2013). While some countries are slow to adopt these new OIE policies, Botswana is in a current state of policy reformation, and recently drafted new guidelines for FMD control with the aspiration of reaching previously restricted beef markets. Herding 4 Health (H4H) was conceptualized to aid farmers with market access through the development of alternative risk mitigation measures along the beef value chain, as well as to address related challenges on communal rangelands in southern Africa's TFCAs.

### Herding for Health

Holistic approaches to address the challenges posed for conservation in complex systems have gained increasing focus in the 21st century (Du Toit et al., 2003; Smith and Malby, 2003). Such approaches include interconnected goals of healthy, resilient communities, healthy animals (wild and domestic) and a healthy environment using the holistic, integrated principles of One Health in the framework of Health in Social-Ecological Systems (Zinsstag et al., 2011; Van Rooyen, 2017). The One Health Initiative started in 2007 as a strategy to promote collaboration and communication by health care practitioners across the whole spectrum of the field, including humans, animals and the environment and recognizes that the health of communities, livestock, wildlife, and ecosystems are interlinked (One Health Initiative (OHI), 2021). The H4H model was developed to address the complexity that One Health presents at the human-livestock-wildlife interface

in Africa through methods that are simple yet practical, integrated and holistic, and acceptable to communities living with wildlife as well as policy makers, conservationists and development aid agencies (Van Rooyen, 2017). The H4H model focusses on the health of rangelands, animals (wild and domestic), communities and governance (Peace Parks Foundation (PPF), 2018; University of Pretoria (UP), 2021) and aims to demonstrate how improved communication and collaboration across multidisciplinary fields from science, business, policy and development can come together to implement the shared goals of poverty alleviation, conservation, sustainable rangeland management and livestock production. H4H became operational in 2017 as an implementation support program after drawing from 10 years of piloting and learning from partnerships in multiple sites in South Africa and elsewhere in southern Africa [Van Rooyen, 2017; Gaborone Declaration for Sustainability in Africa (GDSA), 2018; University of Pretoria (UP), 2021]. After the initial decade of piloting, additional H4H projects have been initiated in Botswana, Mozambique, Zambia and Zimbabwe.

The methods endorsed by H4H to address such issues as rangeland degradation and the use of herding and kraaling techniques promoted for human wildlife conflict mitigation stem from widely practiced and accepted strategies (Ogada, 2001; Odadi et al., 2017; Tyrell et al., 2017; Weise et al., 2018). Prerequisite community consultation and input on program design and project implementation is a fundamental component to the model and a critical ongoing process through engagement with targeted communities. H4H uses voluntary contractual stewardship agreements based on the Conservation Agreements strategy of Conservation International (Nielsen et al., 2010) as a compliance mechanism to ensure expectations and outcomes are met for all stakeholders. Conservation Agreements between communities and conservation NGOs or private enterprises work similarly to traditional institutions and communal agreements. Awards and penalties are built into the agreement to address issues that may arise, such as non-compliance (e.g., failure to curtail regional poaching may result in reduced livestock production support or pricing incentives at livestock auctions). The process is dependent on collaborative planning, designing, implementing and adjustment between target communities and partnering organizations. Conservation Agreements are currently implemented in over 20 countries globally to protect over 3 million hectares of critical biodiversity habitat [Conservation Stewards Program (CSP), 2021].

By adopting globally tested conservation approaches, such as incentive based methods to facilitate ecosystem stewardship, the initial pilot in South Africa has had success in facilitating increased market access and higher prices to farmers who apply practices of sustainable beef production on high biodiversity rangeland (Meat Naturally, 2019). Further recent gains through the extension services offered by H4H include employment for communal herders, provision of vaccines, capacity building through training, support in establishing grazing plans, grazing committees, and other communal governance structures, and signing Conservation Agreements for over 240,000 hectares of communal land (Conservation South Africa (CSA), 2019).

The implementation of H4H pilot programs in two villages characterized with large livestock numbers and high associated rates of LIWC in Limpopo National Park, Mozambique, has resulted in favorable outcomes since project implementation commenced in February, 2020. Following deployment of mobile predator-proof bomas, no further incidences of livestock depredation or retaliatory killings have been observed in the pilot villages, whereas non-participating communities still experience high predation rates. In addition, park management has reported a marked improvement in relations with both communities participating in H4H (P. Leitner pers. comm.).

The H4H model seeks to reduce risk holistically and unlock diversified opportunities to harmonize the socio-economic and ecological benefits of implementing better farming practices. Examples of socio-economic benefits include improved market access, better record keeping of cattle, lower rates of zoonotic disease transfer and fewer stock losses from theft and depredation. Examples of ecological benefits include: improved rangeland management and restoration, increased habitat connectivity through better stewardship of lands outside of protected areas, and a reduction in illegal wildlife trade through disincentive mechanizations and improved collaboration between government agencies. H4H works through collaboration with NGOs, community-based organizations (CBOs) and other stakeholders with similar objectives and strong, long-lasting relations with communities on the ground. Such multi-level stakeholder networks are key to facilitating the success of community conservation initiatives (Berkes, 2007). H4H acts as a support system offering training, guidance in practical skill sets (e.g., veterinary care, rangeland management, human wildlife conflict mitigation, etc.) and strengthening natural resource governance capacity of participating communities [Southern Africa Wildlife College (SAWC), 2021].

The H4H model is a valuable entry point for addressing TWT at local scales, as its foremost objective is to address the key concerns of agropastoral communities residing in or utilizing strategic wildlife habitat. H4H aims to overcome the opportunity costs communities face by forgoing bushmeat as a source of protein through improving livestock production systems and promoting sustainable means for communities to benefit from wildlife (e.g., tourism), thus creating a pathway for wildlife livestock coexistence. Building community resilience is a key objective of H4H, as the tourism industry is volatile, and livestock rearing is an important source of additional livelihood support (Lindsey et al., 2020). Recent livestock sales facilitated by H4H partner Meat Naturally during COVID-19 lockdowns of 2020 demonstrate the value of livestock during periods of vulnerability (S. Frazee pers. comm.). Greater income stream diversity resulting from mixed livestock wildlife systems (Keesing et al., 2018) further improves community resilience to global shocks. By reducing bushmeat poaching and consumption and promoting healthy livestock practices along the beef value chain, the H4H model has the additional benefit of reducing risks for zoonotic disease emergence (Kock et al., 2009; Alexander et al., 2012).

H4H recently developed a professional herder (also called ecoranger) training curriculum at the Southern African Wildlife

College (SAWC), a SADC accredited private educational facility in South Africa, which covers a range of natural resource management modules, including: primary animal health care, rangeland assessments, livestock production, LIWC mitigation and livestock-wildlife contact mitigation, low stress animal handling and climate change adaptation strategies. The curriculum topics were developed after extensive consultation with livestock owners across H4H sites on the skill sets most desired for professional herders. Through multi-stakeholder partnerships, H4H sources financial assistance for students and ultimately aims to revitalize the age-old profession of herding practice through capacity building, promotion of gender equity and advancement of herders as trained professionals. Herding in the traditional form, where adolescents herded the household's herd, has been abandoned in many countries with compulsory schooling [Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), 2019]. Herders within local communities are ideally positioned to improve regional security given that their work is field-based, they have detailed knowledge of the socio-ecological landscape and are mandated to look out for community interests. Capacitating herders with relevant skillsets and fostering tighter collaboration and communication with enforcement agencies increases security and the potential to address both stock theft and illegal wildlife off-take. Ideally, this would be the approach in communities where the value of wildlife and wildlife economies are treasured alongside other livelihood strategies such as agriculture and livestock production. In such a context, we developed a Theory of Change (ToC) to guide a novel community approach centered on husbandry to explore the potential to address illegal bushmeat hunting through the core community livelihood of livestock production.

## THEORY OF CHANGE APPROACH

A Theory of Change is a framework for planning and evaluating initiatives that are designed to foster an anticipated social or environmental change (Vogel, 2012). The model is a derivation of logic planning models in social practice and has advanced to become a widely used tool in the international development and aid industries (Valters, 2014). This results chain approach has found relevance for conservation planners seeking to reevaluate and improve upon selected strategies (Biggs et al., 2017). The ToC is designed as a method to facilitate critical thinking in an adaptive and transparent process to ensure identified interventions lead to desired outcomes while accounting for assumptions made throughout the process.

In general, results chains are organized from actions to the consequential outputs and outcomes that achieve the overall impact. As several actions may be needed to achieve the desired impact, each action follows a linked pathway directed toward the desired outcome. Benchmarks are put in place to self-evaluate and monitor the effectiveness of each action in reaching its goals. ToCs are intended to guide an adaptive style of management that evolves over time through routine testing of the model's assumptions. Critical thinking processes that drive interventions for change

are shown in ToC models as transparent and concrete strategies. This is not only beneficial for an organization's development, but for providing stakeholders and donors with a clear understanding of the complexities of change. For this reason, ToC's are becoming a mounting prerequisite for many donor organizations.

This ToC finds roots in the First Line of Defense (FLoD) framework structured for community based conservation efforts developed in east Africa (Skinner et al., 2018). FLoD evolved into a ToC with a generalized approach to facilitate the engagement of communities in addressing IWT (Biggs et al., 2017). This generalized ToC was adapted to construct specific results chains for H4H first through a series of email-based and in person discussions in 2017–2018 with a resource team consisting of scientific and implementation experts in H4H, wildlife conservation, illegal wildlife trade and livelihood development across multiple implementation sites in the SADC region. This preliminary input was used to structure the agenda for two workshops in Cape Town (25th–28th of September, 2018 and 3rd–5th of December, 2018), attended by the resource team to draft the ToC using the Open Standards framework [Conservation Measures Partnership (CMP), 2007]. A final stakeholder validation workshop was held in Maun (4th–6th of March, 2019) that included participants from government, NGOs, community-based organizations and the private sector. All participants to the Maun workshop participated voluntarily and with full disclosure as to the objectives and nature of the workshop to validate a conceptual framework. The resulting H4H ToC identifies three pathways toward an overall objective of reducing pressure on wildlife populations in the Okavango from illegal bushmeat hunting through targeted interventions with agropastoral communities on the Delta periphery (Figure 1).

### Enabling Actions

The underlying enabling actions are critical measures applicable to each pathway which serve to strengthen local governance through enhancing community capacity and providing support for institutions and institutional frameworks. Ultimately, strengthened governance will facilitate compliance with the Conservation Agreement mechanism which underpins the model. Community capacity building is an essential and ongoing process in the H4H model which is reflected in curriculum development, and skill enhancement through training. Strengthening of the Conservation Agreement mechanism entails a highly collaborative process reached through consultative meetings with target communities to ensure expectations are agreed upon through adaptive management. H4H support for development and implementation of legal institutional frameworks (e.g., the establishment of grazing committees) speaks to strengthening local governance to ensure equitable benefit sharing, accountability and ultimately improved resource management.

### Pathways

Actions aimed at making it more difficult and costly to participate in IWT (Pathway A) are widely recognized and practiced

wildlife crime reduction strategies (Challender and MacMillan, 2011). Botswana's Department of Wildlife and National Parks (DWNP) sub-district offices and the Botswana Defense Force are limited in resources and personnel to curb the onslaught of IWT in Botswana (Rogan et al., 2015). While private anti-poaching units have been effective in some of the WMAs of the Delta, their funding is finite, coverage is limited and mandate restricted in their areas of operation. Pathway A focusses on solidifying collaboration between local enforcement entities (e.g., community scouts, herders and farmers) through training and information sharing while also strengthening decision making rights, traditional institutions, cultural practices and social norms to wildlife utilization. Elevating the social stigma of poaching will ultimately require increasing the perceived worth of wildlife which can be realized through incentivizing mechanisms for wildlife and ecosystem stewardship (Pathway B).

Pathway B aims to motivate individuals and the community at large to take stronger action against IWT through livestock-based (Sub-pathway B1) and non-livestock based (Sub-pathway B2) incentive-based approaches to ecosystem stewardship. Sub-pathway B1 focusses on improving livestock production and market constraints to foster a pro conservation livestock economy. Pathway B is founded on the principles of decision-making rights over, and benefits from natural resources through local community institutions, developed through decades of global research on the factors that enable robust institutions (Murphree, 2009; Ostrom, 2009). These actions include training and strengthening community capacity for livestock management (community institutions) and securing sustainable market access through mechanisms that encourage wildlife friendly practices. The results include better economic returns from livestock linked to good conservation practices.

In the Delta, the tourism industry represents a vast untapped market for communal farmers, with large potential for creating incentives derived from conscious consumers who are willing to pay higher prices for goods and services that support community conservation initiatives through wildlife friendly branding schemes. While the model's preliminary aim is to establish consistent uninterrupted market access, H4H has successfully trialed facilitating higher value markets for communal farmers in Mnisi, South Africa, where the target consumers are safari lodge clientele of Kruger National Park (M. Grover pers. comm.). Through collaboration with private enterprise, farmers are awarded higher market prices linked to conservation actions such as planned grazing and other rangeland restoration techniques. This serves to highlight to farmers that wildlife can have benefits in indirect ways. The key emphasis is on linking to the robust principles of decision-making rights and benefits known to promote conservation objectives by local communities (Murphree, 2009; Ostrom, 2009; Persha et al., 2011).

Sub pathway B2 focusses on developing non livestock based incentives for wildlife stewardship through both the financial and non-financial rewards for protecting and sustainably managing wildlife and their habitats. Actions on this pathway include those focused on the development of activities like tourism, employment for communal herding linked to conservation, carbon offsets, etc., that generate benefits from wildlife

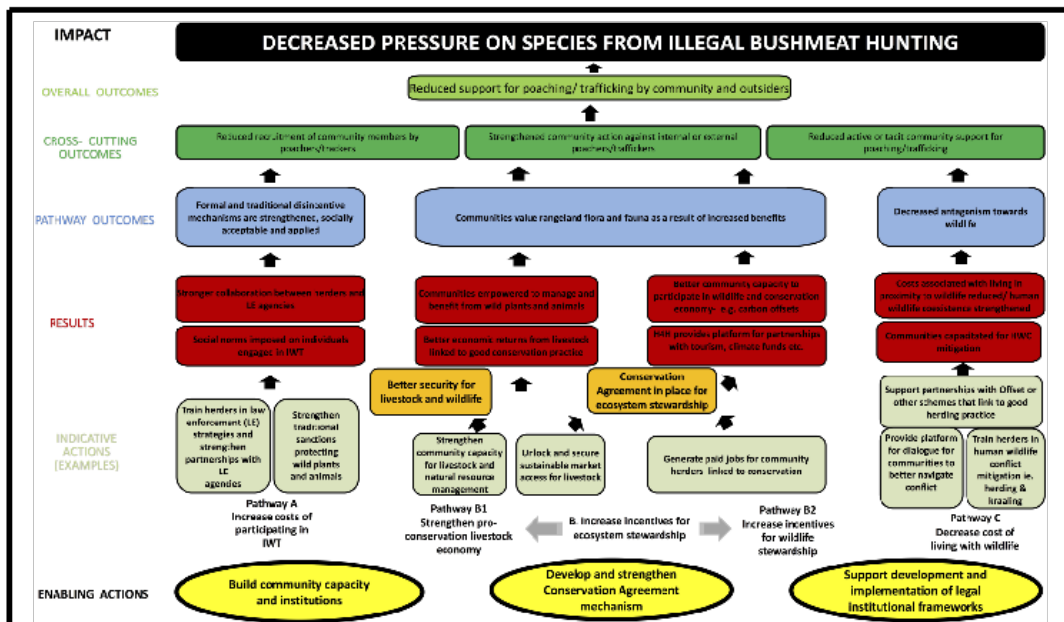


**FIGURE 1 |** Theory of Change (ToC) developed for the Herding 4: Health (H4H) model to identify the role agropastoral communities can play in addressing illegal wildlife trade. The ToC was developed from a series of stakeholder workshops between September and December 2018. A ToC validation workshop was held in March 2019 in Maseru, Botswana which included government representatives from relevant ministries, NGOs, community-based organizations and private sector participants.

conservation and build capacity in individuals and communities to participate and benefit from these initiatives. Communities are then better able to benefit from the wildlife and conservation economy through a range of mechanisms that may include professional herder and ecoguard training and employment, tourism development and carbon offset payments through improved rangeland management. In addition, H4H provides an institutional platform for the development of partnerships with communities to access climate funds, tourism enterprises and training centers. The incentive-based approaches of Pathway B are contingent on compliance with the Conservation Agreement mechanism whereby penalties to wildlife crime activities are applied by withholding incentives. Conservation Agreements can also serve to facilitate benefit sharing between communities and private enterprise. For example, tourism enterprises may opt to buy local produce and support the salaries of professional herders due to a reduction in numbers of stray cattle in wildlife concessions, reduced retaliatory killings due to IWT, and the opportunity to market social and environmental support to conscious consumers.

Finally, Pathway C focuses on reducing the costs to individuals and communities living with wildlife, in particular through improved HWC mitigation. Actions in this pathway aim at increasing the capacity of herders to effectively mitigate conflict, using techniques such as herding and protecting livestock in

specially designed predator-proof boma enclosures during the night (leavelling). Successfully mitigating conflict helps reduce the cost of living alongside wildlife and helps de-escalate the conflict, which allows for dialogue with communities to explore the complex challenges of IWT. The social-ecological framework for ecosystem disservices and services (SEEDS) provides a concept for addressing IWT where the disservices (costs) of wildlife on local communities may strongly outweigh the services. For example, situations where tourism companies, national governments and the international conservation community mainly benefit from the services while experiencing lack of the disservices (Gleason et al., 2020). Pathway C explicitly aims to correct the skewed ratio of wildlife disservices to services for local communities by creating more equitable and sustainable conservation outcomes.

There are various feedback loops between the pathways. For example, success with the law enforcement strategy in Pathway A may lead to increased human wildlife conflict as predator numbers increase, which would instigate more consideration to the mitigation activities in Pathway C. Similarly, if the success of improved husbandry in Sub-pathway B1 leads to increased herd sizes, it could consequently result in increased rangeland degradation. This scenario would require a Conservation Agreement that mitigates rangeland degradation through community-driven regulation of herd size in accordance

with proper rangeland management practices. In this regard, the ToC is to be taken as an adaptive decision support tool for conservation practitioners in partnership with local communities and relevant stakeholders which will require continuous reassessment, development and negotiation as it is implemented.

### Key Assumptions

The communities where H4H is implemented are often subject to fast-changing external pressures and they, along with the individuals who comprise them, vary in socio-economic, cultural and political factors. As such, the guiding pathways developed in this ToC need to be contextually assessed before implementation. Aside from the prerequisite enabling actions identified in this ToC, governance challenges from the local to international scale including transparency, corruption, elite capture, decentralization of natural resource rights, zoonotic disease and other biosafety control policies and legislation regarding wildlife crime (Trost and Bond, 2008; Thomson and Penrith, 2011; Rogan et al., 2015; Biggs et al., 2017) are critical factors for consideration in the attempt to address TWT in agropastoral communities.

H4H relies heavily on community confidence in the assumption that herders charged with custody of a common property (livestock) are responsible and acting on a community's best interests. The link herders can provide between livestock and wildlife security is based on the assumption that they themselves will not be lured into illicit behavior. Thus, key assumptions for a strategy that relies upon herders to assist in wildlife related law enforcement activities include: (1) Communities value wildlife and strive to benefit from its presence (2) Communities recognize that there is a poaching problem, and (3) Communities are willing to allow herders to collect data and report on illegal activity. There is empirical evidence to show that local communities are more likely to invest time and energy into forming local institutions for developing and enforcing rules about conserving natural resources if, (1) They have ownership and decision-making rights over those resources, and (2) The costs of conserving those resources are strongly outweighed by the benefits (Lewis, 1990; Ostrom and Nagendra, 2006; Murphree, 2009; Ostrom, 2009; Persha et al., 2011; Lotter and Clark, 2014; Muntifering, 2019). When bestowed with the responsibility for making rules about wildlife conservation and community game guards are used for monitoring and enforcing these rules, local communities once notorious for poaching can become ardent conservationists (Lewis, 1990; Lotter and Clark, 2014; Muntifering, 2019). These are key and non-substitutable principles for the ToC.

Community members engaged as game guards or related roles may face open hostility, risks to personal safety and a breakdown of social cohesion within the community by members involved in wildlife crime (Painter and Wilkie, 2015). In this respect, the balance of support within the community needs to be weighed so that herders do not face excessive intimidation by those involved in illegal off-take. The level to which communities and external law enforcement are willing to collaborate, and the degree to which these strengthened relations lead to tighter action against,

rather than collusion with, wildlife crime will be a paramount consideration in this decision.

In the Habu community, an H4H pilot project site in the western Delta, community scouts employed by a local CBO, the Habu Elephant Development Trust, have the dual duties of wildlife monitoring and aggregate herding. While only in its third year of implementation, preliminary results have discovered linkages in criminal activity associated with stock theft and illegal bushmeat harvest which has demonstrated the critical role herders/scouts can play in reporting and acting on wildlife crime through tight associations with local law enforcement and the backing of community leadership. The Habu project was initiated with international donor support and aims to work toward sustainability through revenue generated from improved market access, livestock management and tourism levies. The dual role of skilled herders in security and livestock management has presented a few challenges, however. The pilot has been subject to the common complications of community policing, such as under-reporting of illegal activities and minor harassment. However, through continued community outreach and education, the community scouts of Habu have gained traction in garnering community support and have reduced illegal activity in a community identified conservation zone (Habu Elephant Development Trust (HEDT), 2019).

To dissuade community members from engaging in wildlife crime, the alternatives must be equally lucrative and appealing (Keane et al., 2008). Major assumptions for strengthening ecosystem stewardship incentives are: (1) That the target communities are on board with the H4H program, (2) That communities are willing to acquire new skill sets, (3) That the activities of improved livestock management and rangeland restoration can demonstrate positive outputs that are comparable to illicit means of livelihood enhancement, (4) That better farming practices will result in increased benefits for the farmers, and (5) That the community awareness of the H4H protocol or approach instills acceptance of a wildlife livestock coexistence strategy.

Assumptions related to decreasing the cost of living with wildlife are: (1) That communities are willing to engage in H4H activities, and (2) That the wildlife-livestock risk and conflict mitigation activities are effective. While the effectiveness of professional herding and kraaling and the willingness of a community to take on these activities have been tested and realized in several of the H4H sites as well as elsewhere, increased HWC mitigation measures may not always lead to increased tolerance of wildlife (Dickman, 2010). Some conservation activities may result in unintended consequences. For example, a compensation scheme that is not linked to a system that enables participation in a program such as H4H as a prerequisite for compensation for livestock loss can disincentivize best practice adoption or even result in false reporting which in turn fosters greater resentment against carnivores.

Successful HWC mitigation measures alone will not be enough to keep farmers in the H4H program. Thus, economic benefits to herding, especially successful implementation of wildlife friendly beef production practices and in the long term, improved rangeland, cattle production and enhanced alternative

livelihood opportunities are critical components to the model. The strength of the H4H model is that with the same activities it addresses both risk mitigation and unlocked opportunities through collective action and negotiated agreements that are context specific. Similarly, H4H can provide a platform to negotiate access and benefit sharing frameworks between protected areas and communities in a win win, ecological and biodiversity sound way which would provide major incentives for wildlife stewardship. H4H plays a key role in providing greater resilience to community-based conservation by integrating conservation with livelihoods and co-existence of livestock with wildlife by providing a way of sustainably integrating livestock with wildlife (livelihood diversification) (Tynn et al., 2016). This can take conservation strategy into a new multi dimensional era beyond the one dimensional tourism income approach that renders conservation vulnerable to global shocks that jeopardize tourism income, while also improving local community attitudes to conservation by increasing benefits to local communities of enhanced access to resources and participation in management of wildlife.

## CONCLUSIONS

The issues surrounding TWT are dynamic and complex (Challender et al., 2015) and require targeted interventions at multiple scales. Failure to attract or solicit community support has resulted in the underperformance of many conservation efforts in achieving their intended outcomes (Ban et al., 2013). Indirectly related to this are equally complex issues surrounding HWC which affect community sentiments toward wildlife and pending on context can influence whether human-wildlife interactions are viewed as conflict or coexistence (Frank and Glikman, 2019). Also of critical concern are prevailing power dynamics and where decision-making rights and the authority to manage conflict lie (Massé, 2016) which will also influence tolerance toward conservation. The holistic, integrated approach of H4H aims to address several of the contributing factors of illegal bushmeat hunting at a community level and should be considered as a component to the broader strategy to combat TWT (Biggs et al., 2015, 2017). Furthermore, in times of severe stress, rural people increasingly turn to the exploitation of nature, as observed in recent spikes of bushmeat harvest reported in Uganda and Kenya as well as the spike in the poaching of endangered green turtles in Madagascar in the past year due to effects of COVID19 lockdowns (Mupatsi, 2020). The H4H model aims to build resilient communities based on livelihood diversification that can withstand stressors like global pandemics,

tourism declines, recessions, or climate related disasters, while also reducing HWC. If global-level stressors continue to increase in severity, the resulting increase of TWT will be large.

While this ToC was drawn from the experience of multiple authorities and stakeholders, many of the assumptions still need empirical validation. A common limitation to some ToCs is that they are based on "weak and selective" evidence which can bolster misled confidence in a resolution without complete comprehension of the problem at hand (Valters, 2011). Thus, this ToC should be considered as an adaptive mechanism, the progression of which will require co-learning and co-management from other H4H sites, locally specific implementation in a nuanced style, targeted and applied monitoring and evaluation, and a realistic approach that accounts for the importance of different stakeholder perceptions and considers the importance of processes and relationships in achieving outcomes. Ultimately, we aim to demonstrate the use of this model, whose assumptions will be tested through monitoring, open dialogue, collaboration, and feedback with partnering communities, to strengthen the role H4H can play in community driven wildlife crime prevention.

## DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Pretoria Research Ethics Committee. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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