SOCIO-ECONOMIC, INSTITUTIONAL AND ECOLOGICAL DYNAMICS OF CROCODILE RANCHING IN LOWER RIVER TANA, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfillment of the Requirements for the Doctor of Philosophy Degree in Natural Resources Management of Egerton University

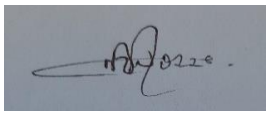
EGERTON UNIVERSITY

MARCH, 2024

DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in this university or any other for the award of a degree.

Signature  Date 27th March 2024

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Recommendation

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DEDICATION

This work is dedicated to my late sister Elizabeth Mose, late father Zephaniah Mose and late mother Mary Mose who all passed on in the course of this study. I am beholden to their humility, encouragement and value for hard work.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to all people who helped me in my PhD journey. I thank Egerton University for granting me the opportunity to undertake this study. I am greatly indebted to my supervisors, Dr. Wilfred Odadi and Dr. Grace Kibue for their excellent supervision, patience and dexterity in provoking thought. I appreciate the partial financial support from the Crocodile Specialist Group of the IUCN-Species Survival Commission Crocodile Specialist Group under the Student Research Assistance Scheme (SRAS).

I appreciate invaluable mentorship from Dr. Kirsten Davies through the International Support Network for African Development (ISNAD-Africa) and Prof. Simiyu Wandibba during this study programme. I also appreciate the technical assistance and advise of Merceline Ojwala and Robert Kimutai, both from the Department of Resource Surveys and Remote Sensing, Peter Hongo and Faith Muchiri both from the Wildlife Research and Training Institute (WRTI) and Solomon Kyalo of Kenya Wildlife Service (KWS). I thank Calvince Ngaji for his help in data analysis. I appreciate logistical support received from the late Mark Cheruiyot- KWS County Warden for Tana River, Miraji Ruga- the Warden for Tana Delta and the rangers from Hola, Tana Delta and Garissa Stations. Further logistical support was received from Dr. Norah Mose and Benson Ibrahim, Nile Crocodiles Limited and Galaxy Croc Farm. I would like to thank Rose Abae, Celytah Komora, Edith Gwito, Guyo Yusuf, Rahma Hamisi and Omar Said for the support in collecting data during the social survey. This study would not have been possible, without the participation of the local people whose livelihoods are intertwined with the lower River Tana.

I received advise and encouragement from Dr. Patrick Mose, Dr. John Ambuchi and Dr. Elisha Ogada at different stages of this study. I am grateful to my colleagues at KWS, Esther, Sarah, Fridah, Margaret, Natalie, Dickson and Neema for the understanding and flexibility they accorded me. This study would not have been possible without the love and patience of my husband, Winstone and sons Baraka and Ongubo. I thank the entire Mose family for all the encouragement. Above all, I thank God for making it all possible. To Him be the glory.

ABSTRACT

Crocodiles are known for their important ecological and socio-economic values globally. However, crocodiles and their habitats continue to face over-exploitation and human-induced threats, leading to unprecedented declines in their populations. Crocodile ranching aims to address these threats by concomitantly promoting sustainable use of crocodiles by local communities. This study evaluated the socio-economic, institutional and ecological factors influencing involvement in Nile crocodile (*Crocodylus niloticus*) ranching-related activities and performance of crocodile ranching activities. The study employed both social and ecological surveys. Two sets of questionnaires were administered: one to 365 households and another on 26 egg collectors. Seven key informant interviews and 4 focus group discussions were conducted. The ecological survey involved mapping the crocodile egg nests to determine their location and distribution and analyzing four scenes of Sentinel 2 satellite images of 2015 and 2018 of the egg collection zones to provide information on land cover types and changes. Image processing was done using ArcMap software, whereas statistics for each land cover category were generated in Earth Resources Data Analysis System (ERDAS) software. Quantitative survey data were analysed using the Statistical Package for Social Sciences. Age, annual income, gender, ethnic group, religion and main sources of livelihood (all $p \leq 0.021$) significantly influenced involvement in crocodile ranching-related activities. Benefitting from community projects derived from crocodile ranching significantly reduced the likelihood of being involved in illegal crocodile use practices ($\chi^2_{(1)} = 23.97$, $p < 0.001$). There was rapid expansion of cropland, and settlements between 2015 and 2018 by 213% and 61%, indicating that crocodile habitat along lower River Tana is highly vulnerable to expanding human activities associated with these land cover types. The results show that there was a significant positive impact of community incentives on involvement in crocodile ranching-related activities. Ironically, the observed high levels of tolerance towards crocodiles did not translate to positive outcomes for crocodile ranching. The study recommends the development and implementation of a crocodile ranching strategy for allocating egg collection quotas and egg collection zones based on the objectives, capacity and egg hatching success of the crocodile ranches. The study also recommends enhanced implementation of benefits and incentives from the crocodile ranching programme to improve local communities' involvement in legal crocodile utilization practices.

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LIST OF ABBREVIATIONS AND ACRONYMS

CAMPFIRE	Communal Areas Management Programme for Indigenous Resources
CBD	The Convention on Biological Diversity
CBNRM	Community-based Natural Resources Management
CBO	Community-based Organization
CFANT	Crocodile Farmers Association of the Northern Territory
CITES	The Convention on International Trade in Endangered Species of Wild Flora and Fauna
CPR	Common-pool resources
CSG	Crocodile Specialist Group
CWCC	County Conservation and Compensation Committee
CWS	Community Wildlife Service
DPSIR	Drivers- Pressures- States- Impacts- Responses
EIA	Environmental Impact Assessment
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GIS	Geographical Information System
GoK	Government of Kenya
GPS	Global positioning system
IAD	Institutional Analysis and Development
ICDP	Integrated Conservation for Development
IPCC	Intergovernmental Panel on Climate Change Land Cover Groupings
IUCN	International Union for the Conservation of Nature
KES	Kenyan Shilling
KFS	Kenya Forest Service
KII	Key Informant Interviews
KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Service
MAXQDA	Max software for Qualitative Data Analysis
MDG	Millenium Development Goals
MENR	Ministry of Environment and Natural Resources
MPA	Marine Protected Area
NTG	Northern Territory Government
PES	Payment for Environmental Services

PSR	Pressure- State- Response
RF	Random Forest algorithm
SD	Standard Deviation
SDG	Social Development Goals
SE	Standard Error
SES	Socio-economic systems
SLEEK	System for Land-based Emissions Estimation in Kenya
TRPNR	Tana River Primate National Reserve
UNDP	United Nations Environment Programme
USA	United States of America
USAID	United States Agency for International Development
US $	United Stated Dollar
WCMA	The Wildlife Conservation and Management Act
WMA	Wildlife Management Areas
WSD	Wuyishian Scenery District

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Crocodilians are mostly large, predatory, semi-aquatic reptiles of the order Crocodilia (or Crocodylia). They are categorized into three families namely, Alligatoridae, Crocodylidae and Gavialidae (King & Burke, 1989). Crocodilians are ectotherms (or "cold-blooded" animals) which occupy freshwater lakes, rivers, brackish coastal swamps and fresh water swamps . Crocodilians are thought to have positive effects in their environments as "keystone species" that maintain ecosystem structure and function by their activities (Cott, 1961; Hutton, 1989; Thorbjarnarson, 1992; van der Ploeg *et al*., 2011a; Wallace & Leslie, 2008). They are also considered as useful indicators for the health of the ecosystems they occupy (Somaweera *et al*., 2020).

The Nile crocodile (*Crocodylus niloticus*, Laurenti, 1768) which is in the family Crocodylidae is one of the most studied crocodile species (Eaton *et al*., 2010; Fergusson, 2010; Murray et al., 2020). It is endemic to Africa, and is quite widespread throughout the sub-Sahara, occurring mostly in the central, eastern, and southern regions of the continent (Aust, 2009; Eaton *et al*., 2010; Fergusson, 2010; A. C. Pooley, 1982; Ross, 1998). The global Nile crocodile population in the wild is estimated to be between 250,000 and 500,000 distributed throughout sub-Saharan Africa (Fergusson, 2010; Ross, 1998). The International Union for the Conservation of Nature (IUCN) “Red List” of 2017 describes the status for Nile crocodile as that of “least concern” (Isberg *et al*., 2019). Despite this, they face human-induced population declines in some parts of Africa (Crocodile Specialist Group[CSG], 2018; Fergusson, 2010; Isberg *et al*., 2019).

Nile crocodiles are known to occupy still or slow-moving freshwater ecosystems with sandy banks and shade for shelter (du Preez *et al*., 2018; Ross, 1998; Salem, 2013). Their diet and habitat utilization differ depending on the age, prey availability and threats of predation (Bhattarai *et al*., 2022; Calverley & Downs, 2014; Cott, 1961; Hutton, 1989; Wallace & Leslie, 2008). Crocodile existence is threatened by massive destruction of eggs and high mortality of hatchlings and sub-adults, phenomena largely attributed to predation by Nile monitor lizards and mongooses, among others and flooding on nesting sites (Cott, 1961; du Preez *et al*., 2018; Kofron, 1989, 1990; Nishan *et al*., 2023; Ross, 1998; Salem, 2013; Thorbjarnarson, 1992). Therefore, harvesting crocodile eggs and hatchlings for ranching makes good use of a resource that would largely have been wasted and is less impactful than

harvesting breeding-sized individuals for ranching (Fukuda *et al*., 2011; Manolis & Webb, 2016; Thorbjarnarson, 1992).

Globally, widespread human exploitation of crocodilians from the 1960s to late 1970s, fueled by commercial demand for their skins and finished products during the 19th to 20th centuries severely endangered their existence (Aust *et al*., 2009; Aust, 2009; Luxmoore, 1992; Staton, 1992; Thorbjarnarson, 1992; Weber *et al*., 2015). There were 6 to 8 million crocodilian skins in world trade annually in the 1960s, the majority of which were illegal or unregulated and an estimated 1.5 to 1.8 million in world trade annually as at 2013 (Jelden *et al*., 2014). This reduction resulted from increased awareness of endangered species and implementation of national and international laws to protect the over-exploited crocodilians (Aust *et al*., 2009; Fergusson, 2010; Staton, 1992; Thorbjarnarson, 1999; Weber *et al*., 2015). Such measures include the listing of 16 crocodilian species, including Nile crocodiles, in Appendix 1 of the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES) in 1975, thereby banning international trade in their live forms and their products (Jelden *et al*., 2014; Thorbjarnarson, 1999).

The recovery of many Nile crocodile populations was realized in the late 1990s (Fergusson, 2010). This resulted in dual listing of specific Nile crocodile populations in both Appendix I and II to allow for international trade in ranched specimens (Aust *et al*., 2009; Jelden *et al.*, 2014; R. W. G. Jenkins *et al*., 2004; Luxmoore, 1992; Staton, 1992; Weber *et al*., 2015). In the meantime, all states utilizing wild species of crocodilians were required to demonstrate that such trade is not harmful to the survival of species (Convention on International Trade in Endangered Species of Wild Fauna and Flora [CITES], 2010a; Thorbjarnarson, 1999). Crocodile ranching was adopted in Kenya in 1992 (CITES, 2010a).

Sustainable yield utilization programmes for crocodilians include captive breeding and ranching, both of which allow for their use and conservation. Ranching involves rearing of crocodilians in a controlled environment initially taken as eggs or juveniles from the wild, where they would otherwise have had a very low probability of surviving to adulthood for commercial purposes (CITES, 2010c). Captive breeding of crocodiles is a form of crocodile farming where the breeding stock was obtained from the wild as adults or eggs and managed in a controlled environment to produce second- and subsequent generations for purposes of trade, exchange or any other form of economic benefit (CITES, 2002; Thorbjarnarson, 1992). Both ranching and captive breeding programmes relate to the collective term ‘crocodile farming’ (Luxmoore, 1992).

Crocodile ranching, which is the subject of this study, is obtains eggs or hatchlings from the wild which, thereby necessitating maintaining a healthy breeding population in the wild (CITES, 2010). Crocodile eggs and juveniles in the wild have a very high mortality rate due to predation and cannibalism, (du Preez *et al*., 2018; Kofron, 1989, 1990; Salem, 2013). Therefore, harvesting crocodile eggs and juveniles for ranching is more beneficial than removal of breeding-sized individuals from the wild for ranching (Fukuda *et al*., 2011; Manolis & Webb, 2016; Thorbjarnarson, 1992). The release of a proportion of harvested eggs back to the wild as juveniles is often done as a precautionary measure (CITES, 2010a; Manolis & Webb, 2016; Thorbjarnarson, 1992). The basis for sustainable-use programmes is provided for by the crocodile ranching programme, and not the captive crocodile breeding programme (Thorbjarnarson, 1999; Weber *et al*., 2015). The former links the maintenance of wild populations and their habitats with the economic incentive for conservation. On the other hand, the captive breeding operation does not have any need to continue maintaining links with the local communities for access to eggs from the wild once the operation has established the needed breeding stock.

The main reason for practicing crocodile ranching is to provide skins for the global exotic market for making assorted products like shoes wallets and hand bags, and to some extent, provide live crocodilians for zoo use, pets, meat, medicinal, religious and decorative products (Dzoma *et al*., 2008; Hoffman *et al*., 2000; M. Jenkins & Broad, 1994; Luxmoore, 1992; Manolis & Webb, 2016; Nisagurwe, 2017; Revol, 1995; Thorbjarnarson, 1999). Crocodile ranching is expected to be a commercially viable strategy offering conservation and socio-economic advantages in the areas where the eggs are sourced (Austin & Corey, 2012; Corey *et al*., 2017; Espinosa-Blanco *et al*., 2013; Luxmoore, 1992; Sine *et al*., 2008). Other advantages include, accessibility to a reliable supply of eggs from the wild, provision of incentives to local people who stay with crocodiles, reduction of egg and hatchling mortality rates and achieving profitability through sale of crocodile products (CFA & NTG, 2015; Manolis & Webb, 2016; Thorbjarnarson, 1992).

Nile crocodile skin is valued because it is soft and supple, lacks bony plates in the ventral area and has large scale patterns which are aesthetically pleasing when processed for the luxury fashion industry (Ashley & Crocodile Specialist Group, 2008; M. Jenkins & Broad, 1994; Nisagurwe, 2017). It is the third largest in the average global gross quantities of skins exported annually after *Caiman crocodilus fuscus*, and *Alligator mississippiensis*, in this order. A gross total of 1,845,934 Nile crocodile skins were exported from Africa during the years 2012-2018 (CITES, 2020) with Kenya claiming only 3% of this number. This made

Kenya the fourth largest exporter after Zimbabwe, South Africa and Zambia, in this order. The annual average number of Nile crocodile skins that Kenya exported during the same period was 7,786 (CITES, 2020).

Kenya hosts some of the largest populations of the Nile crocodile in nearly all fresh water systems, including Lakes Baringo, Turkana and Victoria; rivers Mara, Ewaso Nyiro, Tana River, Ramisi and Athi/ Galana/ Sabaki; and, Lorian Swamp and is listed as one of the important range states for Nile crocodiles in East and Southern Africa (Aust, 2009; Kyalo, 2008b). Among these Nile crocodile range areas, the lower Tana River, which is one of the key fresh water systems with the largest Nile crocodile populations has been meaningfully surveyed to help estimate the population (CSG, 2003). During the 1988 total count of Nile crocodiles on 300 kilometres of lower River Tana, an estimate of 2,667 individuals with a density of 8.89 individual per kilometer (CSG, 1988) were realized. In 2003, an estimated 2,285 crocodiles were surveyed on 228 kilometers of the lower parts of the river (CSG, 2003). This part has remained the major source of crocodile eggs for ranching hitherto.

Kyalo (2008a) argues that most Nile crocodile populations in Kenya are healthy and the aim for their conservation is to control the population and to mitigate against human-crocodile conflicts through the designation of specific zones on lower Tana River for egg collection. The lack of a more recent crocodile census causes uncertainty over the basis for the annual crocodile eggs harvest programme which has operated for over 26 years. This is exacerbated by the increasing human-crocodile conflicts and human-induced loss of crocodile habitat. In addition to providing habitats for crocodiles and being the main source of crocodile eggs for ranching in Kenya, the lower Tana River is a vital source of water and livelihoods for local Pokomo farming community and Orma and Wardei livestock-keeping communities who rely on the floodplains for receding farming systems and dry season resources for livestock (Government of Kenya [GoK], 1992; Ministry of Environment and Natural Resources [MENR], 2012; Mohamed, 2015). There has been an increase in the number of settlements and farmlands and competition for water and scarce floodplains resources along River Tana basin which have resulted in human-crocodile conflicts, human-human conflicts and a threat to the survival of crocodiles (Kyalo, 2008b; Mohamed, 2015; Terer *et al*., 2004). This has in turn resulted in a decline in crocodile ranching-related activities. The effects of high concentrations of livestock, crop cultivation and humans along the river on crocodile ranching and conservation have not been accorded much attention.

Most studies have outlined broad-scale threats to the survival of crocodiles such as human/ crocodile conflict, illegal hunting practices, illegal trade, severe habitat loss, pollution

(Kahler *et al*., 2013; Kahler & Gore, 2012; Kyalo, 2008b; Salem, 2013; Somaweera *et al*., 2019; Thorbjarnarson, 1992; Utete, 2021). Many authors argue that the provision of economic incentives to landowners and local residents can help modify local harmful behaviour to ones that promote sustainable utilization and increased tolerance to crocodilians which can endanger human lives and livestock (Bolton, 1978; Jyrwa *et al*., 2020; Kyalo, 2008b; Luxmoore, 1992; Staton, 1992; Than *et al*., 2020; Thorbjarnarson, 1999; Weber *et al*., 2015). However, no systematic attempt has been made to determine and quantify the influence of specific socio-economic, institutional and ecological factors on crocodile ranching activities.

The *Wildlife Conservation and Management Act*, (2013), lists crocodiles in the schedule of animals for which game farming may be allowed in Kenya (GoK, 2013c). The Act provides for sustainable use of crocodiles through farming for trade and recreation. There are three Nile crocodile ranches in Kenya established at different times since the mid- 1990s and all rely on the lower River Tana for crocodile eggs. Nile Crocodiles Limited was established in 1997, Galaxy in 2006 and Kazuri in 2014. The ranchers operate field units for collection and holding of the crocodile eggs at the river before transporting them to the main ranches in Malindi, Mtwapa (both in Kilifi County) and Sagana in Kirinyaga County.

With 75.6 % of the human population in Tana River County living below the poverty line (Kenya National Bureau of Statistics [KNBS], 2013, 2015), it is expected that local people would readily adopt crocodile ranching which ties up with their heavy reliance on the River Tana to improve their livelihoods. This is on the strength that the possibility of developing a vibrant local tourism economy cannot be achieved due to poor security, poor infrastructure, and absence of attractive landscapes and flagship wildlife species found in other parts of Kenya. The economic pillar of Kenya's development blueprint aims at achieving Gross Domestic Product (GDP) growth rate of 10% per annum up to the year 2030 through use of the nation's resources efficiently and supporting the informal economy which employs 75% of the Kenyan human population (GoK, 2013a).

The involvement and exploring more opportunities for local communities to participate in various aspects of crocodile ranching can help improve their well-being and livelihoods, divert conflicts among local people for floodplains resources and to pacify human-crocodile conflicts and human-human conflicts. The local people in the study area are yet to meaningfully exploit the opportunity. Crocodile ranching programmes are not only intended to encourage local people living near crocodiles to conserve them and their habitats but to also provide economic incentives and other benefits to local communities while earning

foreign exchange to the nation. This is in line with Kenya's blueprint for economic development- Vision 2030 (GoK, 2013a). Therefore, more strategic attention on the potential for crocodile ranching activities for local communities' development is needed.

1.2 Statement of the Problem

The lower River Tana hosts one of the largest populations of Nile crocodiles in Kenya, is the major source of crocodile eggs for crocodile ranching-related activities and a significant source of livelihood for the local communities, including the farming Pokomo and the pastoralist Orma and Wardei communities. The dependence of both the crocodiles and local community on this river presents an opportunity for the local people to engage in crocodile ranching-related activities to enhance their livelihoods and is also a source of conflict between the community and the crocodiles and their habitats. Crocodiles play an important role in maintaining the structure and function of aquatic and associated riparian ecosystems and conferring livelihood benefits to the local communities through consumption and/ or sale of their skin and meat, among other products. However, crocodiles maim or kill members of the local communities and attack their livestock, resulting in human-crocodile conflicts. Crocodile numbers continue to decline due to illegal hunting/ trade for meat and skin, habitat loss through encroachment, pollution and retaliatory killing as a result of human-crocodile conflicts. Crocodile ranching has been practiced in Kenya for nearly three decades. However, despite the potential for the sustainable use of crocodiles through ranching in the lower River Tana and similar freshwater ecosystems, Kenya's participation and claim of this multi-million-dollar international industry is below 3%. Its performance since its inception, and the factors influencing such performance in Kenya remain poorly understood. In addition, there is little information on the explanatory factors for the existing levels of involvement in and performance of crocodile ranching-related activities in such systems.

1.3 Objectives of the Study

1.3.1 Broad Objective

To contribute towards enhanced sustainable use and conservation of crocodiles and improved human livelihoods through assessment of socio-economic, institutional and ecological factors affect local communities' involvement in and performance of crocodile ranching-related activities in lower River Tana basin.

1.3.2 Specific Objectives

The specific objectives of the study are to:

i) examine anthropogenic threats and socio-economic factors influencing the involvement in crocodile ranching- related activities

ii) assess perceptions of local people towards involvement in crocodile ranching-related activities

iii) assess the institutional factors influencing involvement and performance of crocodile ranching-related activities

iv) assess and compare the performance of select attributes of crocodile ranching within and among the crocodile ranches in the study region during the period 2014-2018 and compare it with the international standard

v) assess select biophysical factors influencing the performance of crocodile ranching-related activities.

1.3 Research Questions

The study responded to the following research questions:

i) what anthropogenic and socio-economic factors influence involvement in crocodile ranching-related activities?

ii) what are the perceptions of local people towards involvement in crocodile ranching-related activities?

iii) which institutional factors influence involvement in crocodile ranching-related activities and performance of crocodile ranching-related activities?

iv) what is the performance of the select aspects of crocodile ranching within the crocodile ranches and how do they compare in the study region and with the international standard?

v) what biophysical factors influence the performance of crocodile ranching-related activities and how?

1.5 Justification of the Study

Crocodile ranching was conceived in the early 1990's as a sustainable-use programme to enhance the conservation of crocodiles in the wild and to improve local people's livelihoods (CITES, 2010a; Hutton *et al*., 2002). The ranching programme is in line with the United Nations Sustainable Development Goals (SDGs) 14 and 15. Goal 14 aims to achieve

conservation and sustainable use of the oceans, seas and marine resources for sustainable development while goal 15 aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss (UNDP, 2012). It is also in line with Article 69 (1 & 2) of the Constitution of Kenya which requires the State to ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources, and ensure equitable sharing of the accruing benefits (GoK, 2010). Furthermore, the economic pillar of Kenya's development blueprint aims at achieving a GDP growth rate of 10% per annum up to the year 2030 through use of the nation's resources efficiently and supporting the informal economy which employs 75% of the Kenyan human population (GoK, 2013a).

Therefore, an understanding of the factors that explain the involvement in crocodile ranching-related activities and performance of crocodile ranching activities will be useful for guiding the County Government of Tana River, KWS and the Crocodile Specialist Group (CSG) in developing appropriate intervention and development measures. This will also contribute to the body of knowledge on crocodile ranching which can serve as a model for ranching of other species.

1.6 Scope

This study assessed socio-economic, institutional and ecological factors influencing the involvement in crocodile ranching-related activities and performance of crocodile ranching activities in lower Tana River. It was conducted at lower Tana River in areas designated for crocodile egg collection for the three crocodile ranches. The study focused on crocodile ranching only due to its link with the local people for accessing wild eggs.

1.7 Limitations

Although this study made reference to the "Drivers-Pressures-State-Impacts- Response" (DPSIR) theoretical framework for quantitative evaluation and measurement of socioeconomic biodiversity drivers, it did not involve the testing of the theory. The theoretical framework was used in structuring this study and to guide the interpretation of the study findings. The study anchored on the link with the local community as an important component for crocodile conservation, and therefore only focused on the ranching mode as opposed to the captive breeding mode. The nest survey was done only on the zone designated to Galaxy Croc Farm. Although the nest survey intended to cover the entire lower River Tana, it was not possible to access the Kazuri and Nile egg collection zones due to government security restrictions. The land cover assessment was confined to 2015 and 2018.

Ozi, Furaha, Ngao and Gulbanti villages which had initially been selected at the Nile Crocodile Limited egg collection zone were substituted with Galili, Hewani, Maziwa and Bilisa. This is because the course of the river had changed, making Ozi, Furaha, Ngao and Gulbanti villages no longer relevant for egg collection.

1.8 Definition of Terms

Adoption of crocodile ranching encompasses the involvement of local people in legal uses of crocodiles, that is, harvesting of crocodile eggs for ranching and engagement in practices that do not harm crocodiles and their habitat.

Captive breeding of crocodiles is a form of crocodile farming where the breeding stock was obtained from the wild as adults or eggs and managed in a controlled environment to produce second- and subsequent generations for purposes of trade, exchange or any other form of economic benefit (CITES, 2002).

Crocodile farming- a collective term which refers to both ranching and captive breeding of crocodiles (Luxmoore, 1992).

Crocodile ranching- the rearing in a controlled environment of animals taken as eggs or juveniles from the wild for commercial purposes (CITES, 2010a).

Consumptive wildlife use- refers to uses of wildlife in which wildlife is killed for food, sport, recreation or as a source of products for personal use, a source of products for commercial use and sale, as a means to control damage to property and as a population management tool (Council for Environmental Education, 1992).

Game farming- means the rearing of wildlife in an enclosed and controlled environment for wildlife conservation, trade and recreation (GoK, 2013c).

Incentives- mechanisms that positively impact on an individual's attitude and behaviour, which then motivates their active participation in collective arrangements for improved governance and management of their resources (S. Adhikari *et al*., 2014).

Institutions- systems of established and prevalent social interactions structured by social rules, norms and shared strategies as well as by their physical world (Crawford & Ostrom, 1995; Hodgson, 1988) including their enforcement characteristics and punishment mechanisms (North, 1998).

Perceptions- interpretations, understandings and observations that people make of their environment and natural resources and which influence their thoughts and conservation behaviour (Bennett, 2016).

Performance of crocodile ranching activities- refers to outcomes of the links established by the crocodile ranching operations with the local people and the international market for crocodile skins. It is based on a number of considerations revolving around access to a reliable supply of eggs from the wild, providing incentives to local people who stay with crocodiles, reducing egg and hatchling mortality and achieving profitability through sale of crocodile products (CFA & NTG, 2015)

Sustainable use programme for crocodile ranching- refers to the link established between the international leather industry and the local people living near crocodile habitats through the provision of economic incentives when the crocodile ranch accesses crocodile eggs. The economic incentives are aimed at encouraging local communities to adopt practices that benefit the conservation of crocodiles (Thorbjarnarson, 1999; Tosun, 2013).

Tolerance- refers to different perceived abilities of sharing landscape with wildlife. It also entails satisfying the interests of both humans and wildlife or agreeing to a compromise to allow for the existence of humans and wildlife (Frank, 2016) or applying appropriate mitigation measures to address human/ wildlife conflicts (Dickman, 2010).

CHAPTER TWO
LITERATURE REVIEW

Crocodilians have historically been exploited by people as a source of food, medicinal products, or killed when viewed as a threat to the human residents or their livestock (Combrink *et al*., 2011; Duffett *et al*., 2000; Thorbjarnarson, 1992). Although crocodilians are valued for their luxury skins internationally, they are disliked due to the danger they pose to lives of local people and the livestock losses they cause. Crocodilians therefore face persecutions due to retaliatory killings and attrition of their habitats in retaliation and or to pave way for other human activities (Combrink *et al*., 2011; Duffett *et al*., 2000; Raley, 2016; Thorbjarnarson, 1992; Treves & Bruskotter, 2014). There is also the danger of over-exploitation as was experienced between 1950 and 1970 (Fergusson, 2010). Crocodile ranching works on the recognition of the need to place value on habitats for the benefit of local communities in order to enhance sustainable management of the species and the associated ecosystems (Bolton, 1997; CITES, 2010a, 2019; Thorbjarnarson, 1992; Weber *et al*., 2015). This link was realized through the inception of the crocodile ranching programme in various countries, including Kenya, where meaningful efforts towards achieving recovery of the populations have been achieved.

There has been increasing realization that crocodilian sustainable-use management programmes can have a positive impact on the conservation of crocodilian or other species (Fukuda *et al*., 2011; Staton, 1992). Sustainable use of crocodiles as a conservation tool is largely dependent on the creation of economic incentives to local communities and others and thus ensure the long-term survival of the species and ecosystems (CITES, 2004; Revol, 1995; Staton, 1992; Thorbjarnarson, 1999; Weber *et al*., 2015). Crocodilian populations that had previously been depleted are known to recover where effective conservation measures have been applied. The economic importance of crocodilians is argued to often lead directly to stronger institutional arrangements for their conservation and ongoing management (Staton, 1992). Papua New Guinea, Venezuela, Bolivia, Zimbabwe and Botswana are some of the countries which have crocodilian conservation programmes which support their economic exploitation for the benefit of local landowners (Dzoma *et al*., 2008; Ovando, 2008; Revol, 1995; Staton, 1992; Thorbjarnarson, 1992, 1999).

Crocodiles are valued for their role as apex predators (Cott, 1961; du Preez *et al*., 2018; L. J. Evans *et al*., 2016; Thorbjarnarson, 1992) and are thought to be useful indicators for the health of the ecosystem (Somaweera *et al*., 2020). Despite this, crocodilians and their habitats face a number of challenges which are a threat to their survival (Calverley & Downs,

2017; Champion & Downs, 2017; Combrink *et al*., 2011; Duffett *et al*., 2000; L. J. Evans *et al*., 2016; Kyalo, 2008b; Salem, 2013; Sine *et al*., 2008; van der Ploeg *et al*., 2011a; Villamarín *et al*., 2011). Measures put in place to enhance the conservation of crocodiles and their habitats include the introduction of sustainable-use programmes, such as crocodile ranching. Such programmes aim to enhance the conservation of crocodilians and other species and their habitats, while providing economic incentives that promote local people's and other stakeholders tolerance to crocodiles and thus contributing to the survival of the species and associated ecosystems (CITES, 2004; Fukuda *et al*., 2011; Revol, 1995; Staton, 1992; Thorbjarnarson, 1992, 1999; Weber *et al*., 2015).

While the Nile crocodile population was considered to have recovered in the early 1990s in Kenya, human-crocodile conflict was becoming a significant issue and the egg collection programme was embraced as a measure to mitigate against human-crocodile conflict (Kyalo, 2008b). The success of the crocodile ranching programmes is dependent on involvement in practices and uses that do not harm crocodiles and crocodile habitat. Crocodiles, like other natural resources are subject to illegal extraction and uses. Hunting of wild crocodiles for subsistence or direct trade is not allowed by the current wildlife legislation in Kenya but use of ranched or captive-bred crocodiles is allowed (GoK, 2013c). The potential for poaching (non- legal extraction) may be more in larger areas with less enforcement targeted at detection of wildlife crime (Kahler & Gore, 2012) like outside protected areas (Conover, 2001).

Drivers and motivations for non-compliance may differ from those for compliance (Arias, 2015; Kahler & Gore, 2012). Numerous factors interact to influence the location, timing, and scale of non-compliant behaviors (Arias, 2015; Kahler & Gore, 2012; Solomon *et al*., 2015). Drivers for the conservation behaviour vary at the individual level, group level and institutional level (Epstein *et al*., 2014; Kahler & Gore, 2012; Kollmuss & Agyeman, 2002). Drivers impacting Nile crocodiles and other species inhabiting fresh-water ecosystems include habitat loss as the landscape is modified for agriculture and to meet other human needs for resources including water, fish and sand, income generation, retaliatory killings as human population densities increase in riparian environments, indirect anthropogenic effects from pollutants, illegal hunting practices and illegal trade in crocodile products (Fergusson, 2010; Kahler & Gore, 2012; Kyalo, 2008b; Salem, 2013; Somaweera *et al*., 2019). Lack of incentives and tangible benefits from wildlife resources have also been associated with the destruction of wildlife and their habitats to make way for other land uses (Robinson & Redford, 1991).

Arias (2015) asserts that effective conservation relies on peoples' compliance to rules regulating human use of natural resources. Illegal resource use not only depletes opportunities for legal users to benefit from natural resources (Kahler *et al*., 2013; Lindsey *et al*., 2013) but undermines conservation goals and have wide-ranging impacts on the social-ecological systems (Solomon *et al*., 2015). Therefore, understanding the drivers of non-compliance and compliance of natural resource extraction provides helps in preventing, mitigating and adapting to future unwanted changes in the socio-ecological systems (Arias, 2015; Golden *et al*., 2015). An assessment of strategies for resource conservation, especially within the context of crocodile ranching, is not complete without examining socio-economic factors influencing the extraction and extent use of the resources (Agrawal, 2001). Conservation initiatives should consider and understand the complex social structures of activities that amount to traditional land use and hunting and how they affect resource extraction over time (Bitanyi *et al*., 2012; Reuter *et al*., 2018).

The history of conservation of crocodilians and use of their products is associated with common- pool problems: subtractibility and difficulties in excluding non-contributors or potential beneficiaries (Aggarwal & Dupont, 1999; Hardin, 1968; Ostrom, 1990, 1994, 2003). The antecedent to crocodile ranching as one of the sustainable-yield management programmes for crocodilian conservation is the global history of heavy exploitation of crocodilians to supply the international leather industry in the 1940s, 1950s, 1960s and early 1970s (Fergusson, 2010). This resulted in unprecedented big declines of crocodilian populations, including Nile crocodiles to near-depletion (Aust *et al*., 2009; Aust, 2009; Luxmoore, 1992; Staton, 1992; Weber *et al*., 2015). As a result of the big declines in crocodilian populations, the international community listed all crocodilian species in Appendix I of *the Convention on International trade in Endangered Species of Wild Fauna and Flora* (CITES) in 1975, the same year this international convention came into force. This listing effectively banned international trade in crocodilian products. Recovery of specific crocodilian populations in States that had demonstrated deliberate efforts in protecting and managing culminated in the transfer of those populations to Appendix II to pave way for farming to supply various crocodile products for trade (Aust *et al*., 2009; Aust, 2009; Fergusson, 2010; Luxmoore, 1992; Staton, 1992; Weber *et al*., 2015).

CITES Res. Conf. 11.16 (Rev. CoP 15) provides for ranching and trade in ranched specimens of species transferred from Appendix I to Appendix II. Populations of species listed in Appendix I that occur within the jurisdiction of Parties and are considered no longer endangered and can benefit by ranching with the intention of trade can be included in

Appendix II (CITES, 2010a). These include the Nile crocodiles and other crocodilian species. This resolution requires the Party that has been allowed to ranch Appendix 1- listed animal species to maintain some information. This includes an estimate of the proportion of the annual wild production of eggs and the mortality rate in the ranching operation and causes of such mortality (CITES, 2010a).

2.1 Factors Influencing Involvement in Crocodile Ranching-Related Activities

2.1.1 Socio-economic and Household Demographic Factors

Socio-economic factors and household demographic characteristics such as age, education levels, gender, ethnic group, religion, levels of income and sources of livelihoods are thought to influence the decisions to extract natural resources as well as the extent of such extraction and use. Age positively (Mustapha *et al*., 2012) and negatively (Mogomotsi *et al*., 2020; Nguyen *et al*., 2015; Ntuli & Muchapondwa, 2018) influence biodiversity outcomes. Biodiversity outcomes worsen as the age of the household head increases (Akinsorotan *et al*., 2020; Mogomotsi *et al*., 2020; Nguyen *et al*., 2018; Ntuli *et al*., 2019). However, hunting of wild animals decreases with increasing age of the household head (Akinsorotan *et al*., 2020; MacMillan & Nguyen, 2014). Some authors argue that education has significant positive influence on conservation outcomes (Bandyopadhyay & Tembo, 2010; Mustapha *et al*., 2012; Yang *et al*., 2010) while others associate higher education levels to negative biodiversity outcomes (Ntuli & Muchapondwa, 2018; Songorwa, 1999). Yet Nguyen *et al*. (2018) found household heads extracting natural resources characterized by low levels of education. A higher education is thought to accord people more opportunities to earn better incomes and to result in less dependence on wildlife resources for survival (Akinsorotan *et al*., 2020).

The influence of gender on use of natural resources cannot be ignored (Valdivia & Gilles, 2001). Women have been found to be involved in preserving and enhancing biodiversity (Abdelali-Martini *et al*., 2008). The male gender has been significantly associated with more awareness of illegal hunting than women (Bitanyi *et al*., 2012). Several authors have reported hunting of wildlife and fishing as male-dominated responsibilities while women predominantly engaged in agriculture for subsistence (Akinsorotan *et al*., 2020; Kümpel *et al*., 2010; Mawaya & Kalindekafe, 2010; Nguyen *et al*., 2018; Yang *et al*., 2010). The involvement of young adult males in bushmeat hunting results in negative outcomes for biodiversity and deprive the food production sector of their attention, and affects the provision of food security (Akinsorotan *et al*., 2020). Religion has been used to evoke

feelings and beliefs which connect humans and environmental systems (Chunhabunyatip *et al*., 2018; W. Jenkins & Chapple, 2011; Kala, 2017). A number of authors have described the usage of taboos to protect wildlife and sanctions meted out on persons violating the taboos (Baker *et al*., 2014; Brackhane *et al*., 2019; Daltry *et al*., 2005; Reuter *et al*., 2018).

Ethnicity has been identified as an important factor in local communities' conservation behaviour due to varying customs and livelihood practices (Akinsorotan *et al*., 2020; Kiffner *et al*., 2015; Li *et al*., 2016; Yang *et al*., 2010). For example, relative abundance of the endangered musk has been observed in non-protected areas occupied by the nomadic and transhumance agro-pastoralist Tibetans (Li *et al*., 2016). However, high hunting pressure was observed in areas occupied by the hunting and gathering Lisu people (Li *et al*., 2016). The Mosuo people of China protect macaque because they believe it is a god who protects their livestock from plague (Yang *et al*., 2010). The choice of wild animals which can be hunted is determined by cultural aspects, such as the taste of meat or taboos and the threats they pose to human lives and livelihoods rather than the perceived abundance of the animals among the Funi-ô of Brazil (da Silva *et al*., 2020; Yang *et al*., 2010). Kiffner *et al*. (2015) report cultural acceptability of bushmeat and beliefs that consumption of elephant trunks increased male virility among some Nilotic agro-pastoralist groups in Tanzania.

Persons with high per capita incomes and consumption are not usually associated with extraction of natural resources (Nguyen *et al*., 2018). Lack of alternative sources of food and cash incomes accounts for high dependence of rural vulnerable groups on wildlife and forest resources for their existence (Golden *et al*., 2015; Kümpel *et al*., 2010; MacMillan & Nguyen, 2014) while incomes from wildlife constitute a fraction of household incomes (Gordon & Ayiemba, 2003; Lindsey *et al*., 2013). The opportunity of earning additional cash income has been cited as a major motivation for hunting valuable wild animals like pangolins, wild pigs and monkeys in Vietnam (MacMillan & Nguyen, 2014). However, other authors have associated relative wealth with proclivity to extract more environmental resources. For example, in Madagascar, people who had a long history of earning money from natural resources have been found to be more likely to extract natural resources (Reuter *et al*., 2018). In addition, according to Nguyen *et al*. (2018), rich people extract more natural resources due to an observed positive association between the absolute environmental income and the asset value. Kahler *et al*. (2013) underscore animal mortalities through illegal hunting and legal hunting for commercial or subsistence uses and retaliation as a notable risk to wildlife in Caprivi Region of Namibia. Salem (2013) outlines threats facing Nile crocodiles

as illegal hunting practices, destruction of natural habitat and illegal trade of hatchlings and/or skins.

2.1.2 Extent of Extraction of Resources

Natural resources and associated knowledge are essential for the livelihoods of most of the world's rural families (Valdivia & Gilles, 2001) since the income from agriculture and other sources might not suffice (Nguyen *et al*., 2015). Such uses of wildlife as subsistence; local trade; wildlife farming or ranching and sport hunting, have implications for the conservation and management of wildlife populations and for human well-being (Robinson & Redford, 1991; Tangvitoontham *et al*., 2015). Over-extraction of wildlife, forest and water resources results in degradation of natural resources and deterioration of rural livelihoods (Nguyen *et al*., 2018; Tangvitoontham *et al*., 2015). Harvesting and consumption of wildlife products to provide meat for rural people constitutes several billion dollars globally (Brashares *et al*., 2011). Kumpel *et al*. (2010) reveal that in Equatorial Guinea, bush meat was an important, but not major, component of household meat consumption and that on average, hunters sold 89% of their bushmeat. Eating wild animal meat has been found to be widely practiced in the surroundings of Betampona Strict Natural Reserve in Madagascar (Golden *et al*., 2015). The knowledge of the roles of the resources to rural livelihoods, the socio-economic factors affecting the extraction and use, and the implications on rural welfare is relevant for successful rural livelihoods and conservation initiatives.

2.1.3 Perceptions of Local People Towards Involvement in Crocodile Ranching-related Activities

The perceptions of local communities on the importance of conservation vary and they include relevance in their life such as economic, environmental benefits, promoting tourism activities, road maintenance, food resource and to create jobs (Allendorf *et al*., 2012; Dolisca *et al*., 2007; Jyrwa *et al*., 2020). Many authors have established that positive perceptions towards natural resources conservation are useful in garnering the support of local people in conserving that resource and its sustainability programmes (Bennett, 2016; Dickman, 2010; Khumalo & Yung, 2015; Kross *et al*., 2018; Nelson, 2008; Pannell *et al*., 2011). Studies of perceptions provide important understandings and interpretations of social and ecological effects of conservation programmes (Bennett, 2016). Rule compliance can be enhanced and community perceptions of wildlife improved through wildlife benefits (Ntuli *et al*., 2018). In

China, according more protection through listing of Wuyishan Scenery District as a World Heritage Site resulted in disparate perceptions of benefits among local people (You *et al*., 2014). Several contextual factors (such as culture, politics, socio- economics and livelihoods) and individual and collective attributes such as gender, values, norms, beliefs, preferences, knowledge, expectations and motivations mediate and influence perceptions (Bennett, 2016; Dickman, 2010).

2.1.4 Perceived Uses of and Benefits and Incentives from Crocodile Ranching-related Activities

The perspectives that people have of facts and personal experiences, as well as societal experiences, norms, expectations and beliefs, nature of law enforcement and economic benefits are shaped by their perceptions towards human-wildlife interactions (Conover, 2001; Dickman, 2010; Frank, 2016; Madden, 2004). For instance, in Sri Lanka, local farmers have resorted to vigilante hunting due to low tolerance to wild crocodiles and the danger they pose to human lives and livestock (Raley, 2016). Khan *et al*. (2020) found that people who had been affected negatively by saltwater crocodiles tended to be negative toward their conservation. The local people's perception of the value wildlife as provision of bush meat and medicinal values has been projected to continue posing hunting pressure on wildlife populations threatening their nature's beauty and therefore wildlife should be protected for future generations (Jyrwa *et al*., 2020; Njukang *et al.*, 2019).

Conservation has been seen as a denial of access rights to bush meat in the Bakossi area of Cameroon where the majority of the local people depended on wildlife as a source of protein (Ebua *et al*., 2011). According to Than *et al*. (2020), the willingness to support saltwater crocodile conservation is strongly associated with the perception of benefits in Myanmar.

2.1.5 Tolerance Towards Crocodile Ranching

Tolerance entails satisfying the interests of both humans and wildlife by agreeing to a compromise to allow for the existence of humans and wildlife (Frank, 2016). Interactions between humans and wildlife are often described in terms of conflict and coexistence (Knox *et al*., 2020). Appropriate mitigation measures are often applied to address human/ wildlife conflicts (Dickman, 2010). A human- wildlife conflict occurs whenever an action by humans on wildlife has an adverse impact upon the other (Conover, 2001; Woodroffe *et al*., 2005).

These conflicts may involve crop raiding, injury or killing domestic animals and human death or injury (Madden, 2004; Woodroffe *et al*., 2005). When such conflicts occur, communities or individuals may resort to lethal control of wildlife (Woodroffe *et al*., 2005). Human-wildlife conflict also refers to how people perceive risks associated with wildlife (Jordan *et al*., 2020). The terms "tolerance", "coexistence" and "acceptance" are used interchangeably in conservation to describe different perceived abilities of sharing landscape with wildlife. Factors that motivate behavior aimed at coexisting with or eliminating the threats posed by wildlife have been a subject of interest to researchers in wildlife conservation and management (Slagle & Brukskotter, 2019).

2.2 Performance of Crocodile Ranching Production System

Crocodilians are mainly ranched for their skins, while meat, live animals and teeth are important by-products (Dzoma *et al*., 2008; Hoffman *et al*., 2000; Revol, 1995; Staton, 1992; Thorbjarnarson, 1999). Ranching is a commercially strategy for crocodile farming which is practiced due to the conservation advantages it provides (Luxmoore, 1992). The performance of crocodile ranching is based on a number of considerations revolving around access to a reliable supply of eggs from the wild, providing incentives to local people who stay with crocodiles, reducing egg and hatchling mortality and achieving profitability through sale of crocodile products (CFA & NTG, 2015; Thorbjarnarson, 1992). Ranched crocodiles are crocodiles kept on farms for commercial purposes, that either hatched from eggs harvested from the wild or were collected from the wild as hatchlings (Huchzermeyer, 2003).

Husbandry practices for commercially reared crocodilians involves breeding, incubation of eggs, hatchling management (Veldsman, 2019), increasing survival rates and age at slaughter (Luxmoore, 1992). It also involves managing problems associated with intensive crocodile rearing operations including, increased population densities, artificial environmental temperatures and varying water and feed qualities (Ganswindt, 2012; Huchzermeyer, 2002; Luxmoore, 1992; Manolis & Webb, 2016). Crocodilian food intake is variable due to the influence of temperature (Ainul, 1999; Huchzermeyer, 2002, 2003; Hutton, 1987b; Piña *et al*., 2007; A. C. Pooley & Gans, 1976; Webb & Cooper-Preston, 1989). Crocodile ranching is a capital intensive and long-term project. Management objectives include reducing losses of eggs to predators or flooding through egg collection and artificial incubation in order to provide crocodilian hatchlings for ranching or restocking (Chabreck, 2006; CITES, 2010a; Luxmoore, 1992; Manolis & Webb, 2016) and costs (egg

collection, hatching and growers mortality) in order to maximize profits. Conditions on the farm often account for mortality and crocodile-specific infections (Huchzermeyer *et al*., 1994; Huchzermeyer, 2002, 2003; Luxmoore, 1992).

The financial and technical commitments required of a crocodile ranching business is illustrated by attempts to facilitate a network of over 200 small crocodile farms for New Guinea freshwater crocodiles (*Crocodylus novaeguineae*) in Papua New Guinea (Bolton, 1978; Bolton & Laufa, 1982; Cox, 2010). The project was initially designed to allow villagers to harvest hatchlings and rear them to slaughter age for export of skin and sale of other products. Its later design involved egg harvesting and rearing of hatchlings for sale by villagers.

2.2.1 Crocodile Egg harvesting

Kenya's model for sustainable use of crocodiles by wild harvest of eggs for rearing is expected to take place throughout the existence of the ranching operation. This is tied to the need to continue mitigating against human-crocodile conflicts and to provide economic incentives to local people for enhanced human tolerance towards crocodiles (Kyalo, 2008b). Nile crocodiles attain sexual maturity at a length of about 2.9 to 3.3 metres in the male, and about 2.4 to 2.8 metres in the female, and at an estimated age nineteen years or more (Cott, 1961) or may take up to 30 years (Hutton, 1987a; Luxmoore, 1992). Nile crocodiles nest in a hole made in the ground (Kofron, 1989, 1990; Leslie & Spotila, 2001; Luxmoore, 1992; Modha, 1967; A. C. Pooley & Gans, 1976; Swanepoel *et al*., 2000) at about 1m above water levels (Luxmoore, 1992).

Egg size and egg numbers per clutch are species-dependent but increase with the size and age of the female (Huchzermeyer, 2003). Egg laying in the East African region is reported to occur between August and December (Kofron, 1990; Modha, 1967; Nisagurwe, 2017). There is evidence that some adult females do not nest in consecutive years (Kofron, 1989). Egg harvesting is done using boats, canoes and helicopter drops and retrieval, with each of these done often in combination with foot surveys (Calverley & Downs, 2017; Combrink *et al*., 2011; Sine *et al*., 2008; Swanepoel *et al*., 2000; Webb *et al*., 1983a; Webb *et al*., 1983b). Egg and hatchling mortality is known to be high in the wild (Ainul, 1999; Cott, 1961; López-Luna *et al*., 2015; Modha, 1967; Thorbjarnarson, 1992). There is high natural mortality among the very young in the wild, with most dying within the first year or two, mainly from flooding (Bolton, 1978; Cott, 1961; du Preez *et al*., 2018; Kofron, 1989, 1990; Thorbjarnarson, 1992).

Egg collection from the wild for ranching has been found to be efficient and economically feasible due to the high tolerance of wild populations to egg harvesting and the value to conservation (Chomba *et al*., 2013; Luxmoore, 1992).

Yearlings and hatchlings occupy marshy habitat and vegetated banks of water bodies close to nesting sites to avoid predation (Hutton, 1989; Wallace & Leslie, 2008). Threats to crocodile eggs include human predation and other human activities, predation by animals and flooding (Champion & Downs, 2017; Combrink *et al*., 2016; Sine *et al*., 2008; Webb *et al*., 1983a). Luxmoore (1992) and Dzoma *et al*. (2008) advise that eggs should be collected and moved within 24 hours as this allows total control over the complete incubation period. Early collection reduces losses to predators, desiccation, flooding and sub-optimal temperatures. Eggs at later stages are more sensitive to mechanical injury and therefore more care is needed in collecting and transporting eggs at later stages (Luxmoore, 1992). Eggs should not be kept in dry, exposed positions where they are likely to dehydrate (Luxmoore, 1992). Eggs can be packed in a variety of containers and together with nesting media or vermiculite packed around the eggs to prevent them rolling and to maintain temperature and humidity (Luxmoore, 1992). Egg temperature, and not the temperature at some place in the incubator, determines embryonic development rate and should ideally be in the 31-33^{o}C range but should never exceed 33^{o}C during collection, transportation and incubation (Luxmoore, 1992; Manolis & Webb, 2016).

Farms that are situated close to the natural habitat of the crocodile are preferable for ease of harvesting of eggs and hatchlings in instances where no breeding stock exists on the farm (Dzoma *et al*., 2008). Eggs laid in the wild had higher mean clutch sizes than those for farms in Zimbabwe (Khosa *et al*., 2012). Khosa *et al*. (2012) also found out that the proportion of unviable eggs was higher among farm eggs (18.63%) than wild eggs (6.68%). This implies that the supply of crocodile eggs from the wild will play an important role in the crocodile leather industry.

An examination of egg harvesting programmes at Maningrida region in the Northern Territory of Australia has shown that the organization of egg collection activities and the capability of the management regime contributes to the ability of ranching operations meeting the required egg quotas. During one period, an external agent, Wildlife Management International harvested a mean of 2,359 eggs per season (range = 1272 – 4748). In comparison, at another period, a local agent, the Bawinanga Aboriginal Corporation harvested a mean of 1416 eggs per season (range = 269 - 2287) (Corey *et al*., 2017).

Predation

Although adult crocodilians have few predators (mostly humans and other crocodilians), their eggs are consumed by a wide range of invertebrates, fishes, anurans, reptiles, birds, and mammals (Somaweera *et al*., 2013). Monitor lizards are a major predator of crocodile eggs in Africa (Chibeba, 2003). The mode of nesting (hole- or mound- nesters), nest site selection, and the existence of nest protection by adults influence the level of predation on crocodilian eggs (Somaweera *et al*., 2013; Somaweera & Shine, 2013). Somaweera *et al*. (2013) suggest that oviposition site selection affects vulnerability of the nest to predation, with higher levels of predation being observed among nests in more exposed sites or sites with easier access to predators. Knowledge of threats facing crocodilian nests is essential in estimating recruitment and determining population trends (Calverley & Downs, 2014) and the performance of crocodile ranching operations.

Predation was found to affect most (86%) Nile crocodile nests in Ndumo Game Reserve in South Africa during the 2009/2010 and 66% during the 2011/2012 breeding season (Calverley & Downs, 2017). Combrink *et al*. (2016) observed water monitor lizards (*Varanus niloticus*) and marsh mongooses (*Atilax paludinosus*) as the main egg predators for Nile crocodiles. A predation of over two-thirds of 61 nests of Australian freshwater crocodile (*Crocodylus Johnstoni*) was recorded on the McKinlay River (Chibeba, 2003) during the nesting season.

Nest guarding

Nest defense, or the active aggressive nest defense by the mother against non-human predators, is said to be characteristic of most crocodilians (Murray *et al*., 2020). Hunt and Ogden (1991) illustrate the importance of nest guarding by female American alligator (*Alligator mississippiensis*) at Okefonekee Swamps, USA, in reducing egg depredation by non-human predators. Their study reveals that guarded nests were less likely to be depredated, whereas both unguarded and attended nests were more likely to be depredated. Adult *Crocodylus johnstonii* along Mckinlay River at the Northern Territory of Australia did not generally attend nests during incubation but they were very active at nest site when hatching was imminent (Webb *et al*., 1983a). Some *Crocodylus johnstonii*, however, basked on nesting banks (Webb *et al*., 1983a). At Kinabatangan River in Malaysian, nest sites could not be attributed to specific *Crocodylus porosus* females and no instances were recorded of females guarding their nests (L. J. Evans *et al*., 2016). There was, however, evidence of

females spending time at the nest site, and of excavation of eggs during hatching (L. J. Evans *et al*., 2016).

According to Combrink *et al*. (2016), female Nile crocodile defended nests aggressively against non-human intruders at Lake St. Lucia in South Africa. They further revealed that diurnally females were seldom on the nest, except during cool/cloudy weather or rain, preferring to guard from nearby shade. One female Nile crocodile was observed to closely guard a nest and refusing to move from the nest site in Ndumo Game Reserve (Calverley & Downs, 2017).

The importance of nest guarding for crocodile ranching lies in the thinking that the attendance of the nest by the female crocodile is expected to deter non-human predators from the nest. This in turn helps increase the yield in number of eggs available for harvesting for crocodile ranching. There is paucity of information on the nest guarding behavior of crocodiles at the egg collection zones. In the absence of a crocodile census for over 20 years, a survey of nests was expected to give useful information on the number of adult breeding female crocodiles. The ability to get a sufficient and reliable supply crocodile eggs from the wild is important for a crocodile ranching operation (Manolis & Webb, 2016).

2.2.2 Crocodile Egg Hatching Success

Manolis and Webb (2016) define hatching success as the proportion of live eggs incubated that produce healthy and viable hatchlings. Hatching success is affected by deformed embryos together with those which hatched but died soon after (Luxmoore, 1992). Hatching success should exceed 80% (Manolis & Webb, 2016) but may be lower where eggs collected from the wild are incubated before being graded to remove infertile eggs, eggs containing dead or compromised embryos (Luxmoore, 1992; Webb & Cooper-Preston, 1989). Through grading of eggs before incubation, it is possible to identify the nature of the problem if it arises, as either a problem with the adult crocodiles for bad quality eggs or a problem with the incubation environment (Luxmoore, 1992). Younger females lay small eggs from which fewer, smaller and more slowly growing hatchlings are produced (Huchzermeyer, 2003). The most important clutch effect is egg size and consequently hatchling size, as small hatchlings are generally poor growers (Huchzermeyer, 2003).

The incubation takes about 90 days, with incubation temperatures maintained between 31 to 33^0 C in order to minimize stress and enhance survival in a commercial farming situation (Luxmoore, 1992; Manolis & Webb, 2016). The incubation environment is extremely

important as it influences the rate of embryonic development and growth, hatching time, embryonic mortality rate and sex and subsequent growth and survival (Deeming, 2004; Luxmoore, 1992; Veldsman, 2019).

Chomba *et al*. (2013) reported a hatching success of between 61- 85% for wild- harvested eggs in Zambian Nile crocodile farms, whereas Luxmoore (1992) reported an overall hatching success ranging between 75% and 90% in crocodile farms in Zimbabwe. Chabreck (2006) observed a hatching success of 76% for artificially incubated crocodile eggs. Incubation success rates have been reported to vary depending on the management regime in Australia, with an indigenous management system achieving lower mean success rate of 14.9%, and an external management regime achieving 84.3% (Corey *et al*., 2017). They attributed the low success rates at the indigenous management system to the absence of suitably qualified and committed personnel who could constantly monitor the incubation process.

2.2.3 Skins and Other Products From Crocodiles

The most valuable product from the crocodile is the skin used in the exotic leather trade (Dzoma *et al*., 2008; Hoffman *et al*., 2000; M. Jenkins & Broad, 1994; Manolis & Webb, 2016; Nisagurwe, 2017; Revol, 1995; Thorbjarnarson, 1999). The number of eggs accessed, rate of success in hatching, and hatchling survival are linked to the number of skins the rancher can supply to the international market. Farmers generally slaughter animals of 1.2-1.5m length or less, beyond this size, very few farmers find it feasible to produce animals as large as 1.8-2.0m (Luxmoore, 1992). Nile crocodiles are slaughtered at around 2-3 years of age which corresponds to an average age of 2.5 years (Dzoma *et al*., 2008; Revol, 1995).

Nile crocodile skin is described as one of the classic skins in terms of the quality of the leather which are derived from species which lack or have poorly developed bony plates in the ventral area (M. Jenkins & Broad, 1994). They produce soft, supple leather and have large scale patterns which are aesthetically pleasing when processed (Ashley & Crocodile Specialist Group, 2008; M. Jenkins & Broad, 1994). The leather is manufactured into a wide variety of products such as belts, briefcases, shoes, handbags, wallets and watchstraps consumed in the luxury fashion industry (Nisagurwe, 2017). The Nile crocodile leather ranks second in skin value on the world market, while the estuarine crocodile is the first and the American alligator and the new Guinea fresh water crocodile rank third and fourth, respectively (Revol, 1995). Ashley (2008) estimates the global annual skin value,

manufactured value-added products and the retail value of finished classic products to be at 100 million, 400 million and one billion US dollars, respectively.

The Nile crocodile skin ranks third in the average global gross quantities of skins exported annually after *Caiman crocodilus fuscus*, and *Alligator missipiensis*, in this order (Figure 2.1). A gross total of 1,845,923 Nile crocodile skins were exported from Africa during the period 2012- 2018 (CITES, 2020). Kenya was the fourth largest exporter of Nile crocodile skins in Africa after Zimbabwe, South Africa and Zambia, in this order, during the years 2012-2018, exporting an annual average number of 7,786 skins or 3% of the total number of skins exported by these 4 countries (Figure 2.2) (CITES, 2020).

In Zimbabwe, the meat is sold locally to restaurants, butcheries and supermarkets while other crocodile items such as heads, feet, teeth, claws and back strips are processed and retailed as curios (Revol, 1995). Blood (pharmaceuticals), bones, fat (traditional medicines) are other parts of crocodiles that are used while there is minor trade in live crocodilians between zoos and for pet trade where it is licensed (Tosun, 2013). The main species used for meat are American crocodiles, Nile crocodiles and Siamese crocodiles (Tosun, 2013). Revol (1995) however notes that the diversified products are not a consistent income earner.

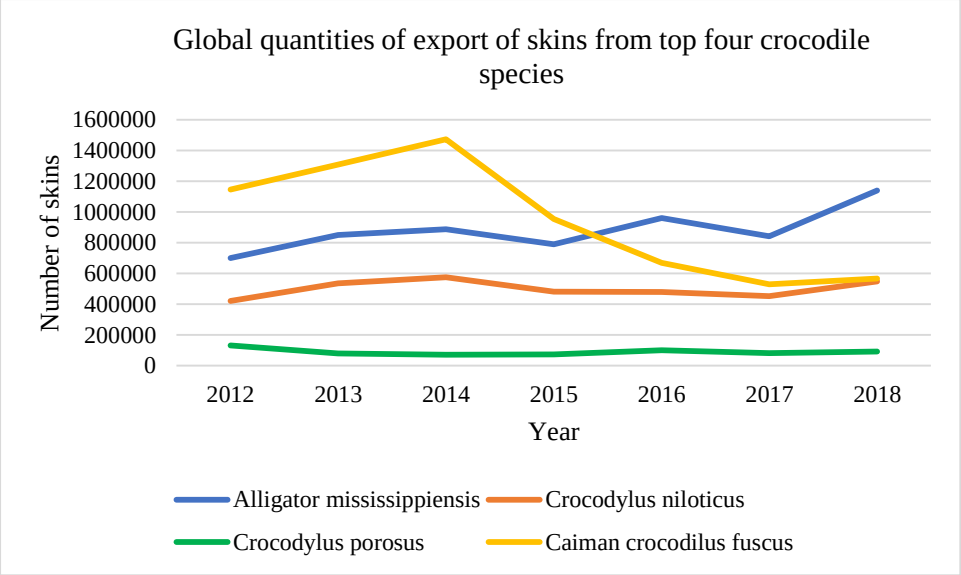

Figure 2.1: A comparison of gross annual exports of skins from top four crocodilian species for the period 2012-2018

(Data obtained from the CITES Trade Database https://trade.cites.org/, interpretation and figure are own work)

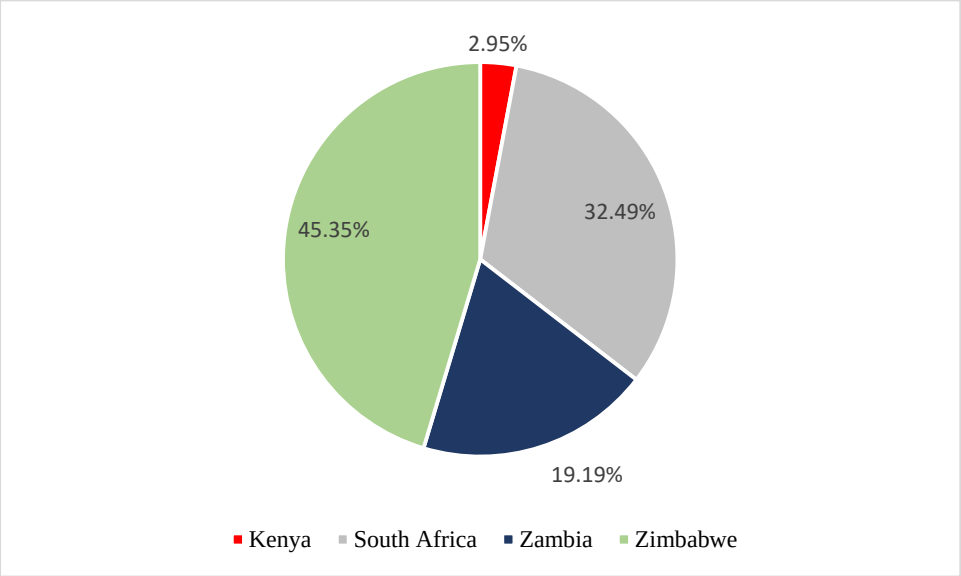

Figure 2.2: A comparison of number of crocodile skins exported from four leading African countries in Africa during the period 2012-2018

(Data obtained from the CITES Trade Database https://trade.cites.org/, interpretation and figure are own work)

2.2.4 Benefits and Incentives

Incentives are defined as those mechanisms that positively impact on an individual's attitude and behaviour, which then motivates their active participation in collective arrangements for improved governance and management of their resources (S. Adhikari *et al*., 2014). Article 11 of the *Convention on Biological Diversity* (CBD) urges each contracting State to adopt economically and socially sound measures that act as incentives for the conservation and sustainable use of components of biological diversity (CBD, 1993). Incentives are key to attracting and maintaining participation in sustainable community-based natural resource management (CBNRM) initiatives (Suich, 2013) and in improving livelihoods and security of local people, empowering them, and enhancing conservation efforts (J. R. Adhikari, 2001).

The recognition that livelihoods drive conservation and the need to accord local stakeholders opportunities to benefit directly from the biodiversity is considered an incentive to stop external threats to the biodiversity (Salafsky & Wollenberg, 2000). Gordon and Ayiemba (2003) illustrate an income-earning project from butterfly farming which is dependent on Arabuko Sokoke Forest Reserve which has helped preserve the forest from encroachment from farmers and settlements and change community attitudes to the forest by giving them a stake in its conservation. Incentives are instrumental in fostering alternative livelihoods in order to turn the local people's attention away from unsustainable use of wildlife and other natural resources (Bandyopadhyay & Tembo, 2010).

According to Campbell *et al*. (2013), the provision of community incentives such as improvement of local infrastructure, development of mari-culture and tourism industries as alternative sources of income for coastal communities have boosted the conservation of marine protected areas in Indonesia. The incentives have also helped build an enabling environment for local stewardship, enhancement of rights of local fisheries users through zonation, self-policing of the marine protected area and promoting community participation in park planning (Campbell *et al*., 2013). Well-defined and enforced property rights is a key incentive that influences resource users' participation in resource governance and management (S. Adhikari *et al*., 2014). Ntuli and Muchapondwa (2018) demonstrate that the benefits from wildlife conservation significantly and positively affect biodiversity outcomes in a community and that without the benefits, the cost of organizing and maintaining a self-organized system may not be worth the effort.

Nisagurwe (2017) identified benefits local people gained from Kaole Crocodile Farm in Tanzania included limited employment and occasional selling cow meat to the farm for feeding the crocodiles. Human behavior is influenced by various motivations (Fehr & Falk, 2001) and the effects of payments in inducing behavioral changes can vary substantially, depending on how the social meaning of such payments is constructed (Kerr *et al*., 2014). Although PES services do not induce behavioural change amongst users in the short term (S. Adhikari *et al.*, 2014), direct payments given for a longer period, tend to significantly raise awareness on payments for environmental services to the detriment of intrinsic motivations for conservation (Fehr & Falk, 2001; García-Amado *et al*., 2013; Kerr *et al*., 2014). In Philippines, the intrinsic and cultural values such as pride, love and curiosity have been established to offer motivation for the preservation of the Philipine's crocodile (van der Ploeg *et al*., 2011c)**.**

2.3 Legal, Institutional and Policy Frameworks for Crocodile Ranching

Institutions are systems of established and prevalent social interactions structured by social rules, norms and shared strategies as well as by their physical world (Crawford & Ostrom, 1995; Hodgson, 1988) including their enforcement characteristics and punishment mechanisms (North, 1998). Institutions further define both what individuals are prohibited from doing and sometimes, under what conditions some individuals are permitted to undertake certain activities (Colding & Folke, 1997; Hodgson, 1988; North, 1998). Members of the relevant community share explicit knowledge of rules and can identify breaches of the rules (North, 1998). To the extent that institutions are regarded as legitimate, people comply without (or with fewer) inducements and sanctions (Uphoff, 1992).

Preserving or instituting practices that are environmentally sound requires individual incentives and persuasions, as well as regional natural resource management bodies which can harness the power of the community to change an individual's priorities about the environment (Stanley & Clouston, 2012; Uphoff, 1992). Therefore, the knowledge of how people understand rules and choose to follow them is anchored on the incentives and disincentives involved and how people interpret and value them (Hodgson, 1988).

Legal, institutional and policy frameworks fall under the "Response" component of the Drivers, Pressures, State, Impacts and Responses (DPSIR's) theoretical framework adapted for this study, which involves three measures. The first response is the implementation or adoption of a sustainable use management programme for crocodile ranching to allow

conservation of the wild crocodile populations for ranching and supporting local people's livelihoods through such access. The second response is putting in place and adopting conservation measures or policies to enhance crocodile conservation. The third is the enactment and implementation of legislation for the conservation of crocodiles and other biodiversity. These responses have been translated into three institutional variables namely: rules and norms; awareness of rules and regulations for crocodile ranching and governance mechanisms, all of which this study hypothesizes influence the involvement in crocodile ranching-related activities and performance of crocodile ranching activities. Institutional factors are seen as responses aimed at mitigating drivers and pressures on the involvement in crocodile utilization activities (whether through legal or illegal) and the impact of such involvement on the performance of crocodile ranching activities. The following sections focus on literature review on these three aspects: norms (formal and informal), governance mechanisms and incentives relevant to adoption of crocodile ranching-related activities.

2.3.1 Institutional Framework

Kenya Wildlife Service

The Kenya Wildlife Service (KWS) is established as a state corporation through an Act of Parliament, the *Wildlife Conservation and Management Act*, 2013 to manage and conserve wildlife. Some of its functions include, promoting and undertaking extension service programmes intended to enhance wildlife conservation, education and training; identifying wildlife user rights and advising the Cabinet Secretary; granting permits; developing mechanisms for access to wildlife and benefit sharing with communities living in wildlife areas; and, monitor the compliance of terms and conditions of licenses (GoK, 2013c). The Government of Kenya has designated KWS as the Management Authority for purposes of implementing provisions of the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES) as required by the member states (CITES, 2023). Management Authorities should grant export permits for specimens of species listed in Appendix I and II only when the Scientific Authority of the State of export has advised that such export will not be detrimental to the survival of the species (CITES, 1973, 2016, 1975).

The Wildlife Training and Research Institute and the National Museums of Kenya

The Government of Kenya has designated the Wildlife Research and Training Institute (WRTI) and the National Museums of Kenya (NMK) as the Scientific Authorities to advise

the Management Authority on sustainability of trade in listed species and specimens of wildlife and other scientific matters in the implementation of the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES) (CITES, 1973, 2016, 1975, 2023). The Wildlife Research and Training Institute (WRTI) is established as a state corporation through an Act of Parliament, the *Wildlife Conservation and Management Act*, 2013. The functions of the WRTI include to: collect and analyze wildlife data and information, to support planning and decision making by different stakeholders for sustainable conservation and management; undertaking research through remote sensing and geographic information system to enhance wildlife conservation and management; and, undertake wildlife research and related emerging areas (GoK, 2013c). The National Museums of Kenya (NMK) is a state corporation established by an Act of Parliament, the Museums and Heritage Act 2006. The functions of the NMK include, to serve as a place where research and dissemination of scientific and technological is undertaken with the aim of enhancing the conservation and sustainable utilization of the biological diversity for the benefit of Kenya and the world (GoK, 2012c; NMK, 2006).

The County Wildlife Conservation and Compensation Committee

The *Wildlife Conservation and Management Act*, 2013 (WCMA) provided for the establishment of regulatory roles of the County Wildlife Conservation and Compensation Committee (CWCCC) for each county. The roles included to: i) implement the registration and establishment of wildlife user rights as provided for under this Act; ii) oversee the preparation and implementation of management plans on community and private land under the provisions of this Act; iii) ensure that benefits derived from the use of wildlife resources are distributed in accordance with the provisions of this Act; iv) bring together all relevant stakeholders within the County to actively harness their participation in the planning and implementation of projects and programmes related to the protection, conservation and management of wildlife resources in the County; and, (v) undertake education, extension services and public awareness (GoK, 2013c). With the exception of deliberation on human-wildlife conflicts, the CWCCCs were not able the other roles during their five years of existence. This has been attributed to budgetary constraints, logistical and competence challenges (personal communication with former Chairman of Tana River CWCCC and KWS officers). Following an amendment of the WCMA, the CWCCC was renamed into the Community Wildlife Conservation Committee (CWCC) and its mandate reduced to human-wildlife conflict issues and harnessing the participation of relevant stakeholders in

conservation and management programmes of wildlife (GoK, 2019b), effectively stripping it of the devolved regulatory roles.

2.3.2 Legal Framework

The *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES)

This is an agreement between governments to cooperate to safeguard certain species from over-exploitation through international trade. All import and export of species covered by the Convention in its three Appendices has to be authorized through a licensing system (CITES, 1973). The Convention also requires parties to prohibit trade in specimens in violation of provisions of the Convention and to penalize trade in, or possession of, such specimens, or both (CITES, 1973). Lastly, parties are required to provide for the confiscation or return to the State of export of such specimens (CITES, 2010c). Appendix I includes species threatened with extinction and their trade is not permitted while Appendix II includes species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilization incompatible with their survival (CITES, 1973).

Nile crocodiles have a dual listing in both Appendix I and II, for purposes of conserving this species in the wild and ranching for trade (CITES, 2010a). The Convention reckons the challenge that dual listing of crocodilian species in Appendix I and II may subject several crocodilian species to some levels of illegal trade. The Convention therefore made a provision for crocodilian specimens of species listed in the Appendices to be marked to assist in identifying them (CITES, 2010b). The Convention requires the maintenance of a universal tagging system for the identification of raw, tanned, and/or finished crocodilian skins by the general application of non-reusable tags to all crocodilian skins entering international trade from the countries of origin and that crocodilian skins and flanks be individually tagged before export (CITES, 2010b).

The Constitution of Kenya

The Constitution makes a number of provisions that apply to land, environment and natural resources and mandates Parliament to enact several legislations to give effect to the provisions of the Articles (GoK, 2010). This is seen in the subsequent amendments to the *Wildlife Conservation and Management Act* (GoK, 2013c), the *Environmental Management and Coordination Act* (GoK, 2015) the amalgamation of various sectorial land laws into three

legislations: The *Land Registration Act* (GoK, 2012b); The *Land Act* (GoK, 2012a) and The *Community Land Act* (GoK, 2016).

Article 69 of the Constitution bestows a number of obligations to the State and public of Kenya with regards to natural resources. The State is mandated to: ensure sustainable exploitation, utilisation, management and conservation of the environment and natural resources; ensure the equitable sharing of the accruing benefits; encourage public participation in the management, protection and conservation of the environment; protect genetic resources and biological diversity; eliminate processes and activities that are likely to endanger the environment; and, utilise the environment and natural resources for the benefit of the people of Kenya. This Article also mandates every person to cooperate with State organs and other persons to protect and conserve the environment and ensure ecologically sustainable development and use of natural resources (GoK, 2010). The Fourth Schedule of the Constitution of Kenya lists the protection of wildlife as a national function.

Article 61 of the *Constitution of Kenya* categorizes land in Kenya into three classes, namely private, community and public. Article 62 lists all rivers, government game reserves, national parks, wildlife sanctuaries and specially protected areas as public land. The Article further states that such land shall vest in and be held by the national government in trust for the people of Kenya and shall be administered on their behalf by the National Land Commission (GoK, 2010). Thus, Tana River Primate National Reserve and River Tana, being public land, are vested in the national government. In reference to Article 63 of the *Constitution of Kenya*, land in the study area and the majority of Tana River County is community land. This is by virtue of it being lawfully held as trust land by the county government of Tana River or being unregistered community land and therefore, it is held in trust by the County government on behalf of the communities. The same Article vests community land to communities identified on the basis of ethnicity, culture or similar community of interest. The Article required Parliament to enact legislation to give effect to this Article (GoK, 2010). This legislation was enacted in 2016 as *The Community Land Act*.

The Wildlife Conservation and Management Act

The *Wildlife Conservation and Management Act*, 2013 (WCMA) is the principal national legislation which governs crocodile ranching programmes and all other wildlife conservation and farming activities in the country. The Act establishes Kenya Wildlife Service (KWS) to conserve and manage wildlife in Kenya. KWS is mandated to perform a number of functions,

including: i) developing mechanisms for benefit sharing with communities living in wildlife areas, ii) promoting and undertaking extension service programmes intended to enhance wildlife conservation, education and training; iii) identifying wildlife user rights and advising the Cabinet Secretary thereon; iv) granting permits; and v) monitoring the compliance of terms and conditions of licenses (GoK, 2013c). The WCMA outlines four principles that are relevant to this study, namely the devolution of wildlife conservation and management, where possible and appropriate, to owners and managers of land where wildlife occurs; the recognition of wildlife conservation and management as a form of land use on public, community and private land; the derivation of benefits of wildlife conservation by landowners to offset costs and to ensure the value and management of wildlife do not decline; and, the observance of the principles of sustainable utilization in wildlife conservation and management for the benefit of present and future generations.

The Environmental Management and Coordination Act

The *Wildlife Conservation and Management Act* stipulates that the *Environmental Management and Coordination Act* shall apply to the conservation, protection and management of wildlife. In particular, crocodile ranching as a wildlife use right is a major land use change and involves commercial exploitation of natural fauna and flora for which an environmental impact assessment should be done before commencing the project. The proponent of the crocodile ranch shall undertake a full environmental impact assessment (EIA) study and submit an environmental impact assessment study report to the National Environment Management Authority prior to being issued with any license by the Authority (GoK, 2015). The presentation of the EIA report and license are a requirement in the application process for a permit from KWS to ranch crocodiles.

Land Laws

Past land laws regarding Trust Lands are traced back to the colonial period where they were defined as any land other than private land within the "Special Areas" held in trust by the Trust Land Board in accordance with the Trust Land Ordinance for the persons ordinarily resident in those areas. Such land was subject at all times to such groups, tribes, families or individuals by virtue of existing native law and custom and was set aside for native people (Colony and Protectorate of Kenya, 1960; GoK, 1963b). At independence from the British Colony, the Constitution of Kenya retained and defined the Trust Lands as those lands situated outside Nairobi Area before 12th December 1964 and registered in the name of the

Trust Land Board (GoK, 1963a). The state of land and natural resources management under the Trust Land Act, Chapter 288 and the post- independence Constitution of Kenya can at best be described as one that took away property rights from local people and placed them on the executive arm of the Government, and the study area is no exception. This effectively rendered local people passive as the management and control rights were exercised by other authorities outside their community, thereby making the natural resources open access.

The establishment of Tana River Primate Reserve and the expansive irrigation project under Tana River Development Authority exemplify the insecurity of natural resource property rights facing local people in the study area. Article 118 of this Constitution and Section 7 of the Trust Land Act gave the President the power to direct the local authority to set apart land in the Trust Land for use and occupation of the Government (GoK, 1939, 1963a). Article 117 of this Constitution and Section 13 of the Trust Land Act, gave powers to County Councils to set apart an area of Trust Land vested in that County Council for use and occupation by a public body or authority for public purposes, extraction of minerals or mineral oils, prospecting or by any person(s) which Councils deems will benefit the residents of that area of Trust Land through revenue from rent (GoK, 1939, 1963a).

For the first time in Kenya's history, community land rights were accorded recognition, protection, adjudication and registration through the current Constitution of Kenya in 2010 and the subsequent legislation of *The Community Land Act* in 2016. This Act aims to govern the management and administration of community land and to provide for the role of county governments in relation to unregistered community land. It requires natural resources found on communal lands to be used and managed sustainably and productively with due regard to inter- and intra- generational benefit of the whole community with transparency and accountability and, for equitable sharing of accruing benefits (GoK, 2016). A salient feature in this Act is that it gives customary land rights equal recognition and force in law like freehold or leasehold rights. The Act confers the County government the duty to hold in trust all unregistered community land on behalf of communities but prohibits it from selling, transferring, disposing or converting for private purposes any such land.

Two provisions of *The Community Land Act* are relevant to this study. First, a registered community may set aside special purpose areas for farming, community conservation and cultural and heritage sites among other uses. Second, it establishes devolved governance mechanisms for discharging a number of functions including, running the day-to-day functions of the community, formulating rules to govern the land and prudent management of the land on behalf of the community. Decisions are made in the community assembly through

a prescribed democratic process. Such a devolved governance mechanism could be useful in conserving natural resources, including use of crocodiles for the benefit of the community. It is not yet known how the local people and the County government of Tana River have made use of this provision.

2.3.3 Policy Framework

Crocodile ranching as well as other wildlife-based enterprises are a product of strategies the KWS put in place in the early 1990's as a response to the challenges wildlife management and conservation was facing outside the protected areas. KWS started community wildlife service (CWS) programmes based on the principle that local people shall participate in and benefit from wildlife conservation and on the recognition that the support of local people is important for the success of wildlife conservation in non-protected areas (Kenya Wildlife Service [KWS], 1991a, 1991b, 2000). However, these well-intended strategies were not translated into wildlife legislation until 2013. Although the crocodile ranching programme had long been provided for under the CITES Convention, it is only in 2013 that the enactment of *The Wildlife Conservation and Management Act, 2013* made provision for game farming of a limited number of wild animal species, including crocodiles (GoK, 2013c).

Sessional Paper Number 3 of 1975 titled "Statement on the future of wildlife management policy in Kenya" was the National Wildlife Policy up to the year 2019. This policy sought to optimize returns from both consumptive and non-consumptive uses of wildlife (GoK, 1975). However, the government ban on hunting in 1977 (GoK, 1977) and dealership in wildlife products in 1978 (GoK, 1978) as a reaction to poaching and dwindling numbers of rhinos and elephants was a setback to the vibrant wildlife industry envisaged in this policy. In March 2018, the Government established a Task Force on Consumptive Wildlife Utilization to assess and advise on ways in which wildlife resources in Kenya can be used to provide benefits to wildlife, the national economy, and individuals and communities living with wildlife (GoK, 2019a). The Task Force noted that although both the 1975 wildlife policy and the *Wildlife Conservation and Management Act* of 2013 provide for access to wildlife resources, there are uncertainties on user rights, responsibilities and liabilities especially on lands that are under private and communal tenure (GoK, 2019a).

This observation led to the revision of the 1975 policy to Sessional Paper No. 1 of 2020 as the current National Wildlife Policy for Kenya. It aims to ensure equity in sharing of benefits, promote partnerships and incentives for wildlife-based enterprises and promoting collaboration for effective governance and financing of the wildlife sector between

stakeholders, including, communities and private and government entities. In order to achieve this, the government undertakes to promote wildlife conservation as a land-use option; provide incentives to support individuals, communities and other stakeholders to invest in wildlife conservation and management; and, empower land owners and communities in wildlife areas to participate effectively in decision-making on wildlife resources, as well as to benefit from the use of the resources (GoK, 2020).

2.3.4 Norms and Sanctions

Norms are behaviors and attitudes that most members consider to be normal, right, correct, acceptable, proper and/or appropriate (Colding & Folke, 1997). Norms are understandings which reflect what people should do (an injunctive norm) in a given situation (Jacobs *et al*., 2014). Sanctions associated with norms include informal and internally imposed (for example, feeling good or guilty), formal and externally imposed (such as public recognition or being publicly ostracized) (Manning, 2013). Social norms have been widely used in promoting conservation behaviour (McDonald *et al*., 2014). Since individuals are members of multiple social groups, the possibility that the norms of these different groups may conflict should be acknowledged (McDonald *et al*., 2014). Individuals breaking these rules may be sanctioned formally, if the norm is written into law for example, or informally through social disapproval (Kingston, 2016).

Three types of norms are identified: customs- social norms; taboos- a larger set of social and religious sanctions, which inhibit, ban or guide human conduct toward the natural environment; and laws- norms that are written down and enforced (Berkes *et al*., 2000; Colding & Folke, 1997; Diawuo & Issifu, 2015; Kingston, 2016). Customs and taboos are informal and are passed from one person to another verbally (Hodgson, 1988). Norms are also described through the purposes they serve. Descriptive norms influence behaviour via how other people would behave while injunctive norms influence behaviour via perception of how and what other people approve/ disapprove of (Cialdini *et al*., 1991; St John *et al*., 2010). Injunctive norms are likely to result in beneficial social conduct across the greatest number of societies and situations (Cialdini *et al*., 1991). Behaviour can be predicted and rule- breaking deterred through norms (St. John *et al*., 2015). Social norms are enforced through informal institutions, which do not depend on government statutes (North, 1994). In this study, norms include both the unwritten rules such as customs and taboos and written

laws such as the CITES Convention and the national legislative and policy framework relevant to crocodile ranching.

Knowledge of existing conservation norms and sanctions is an important prerequisite for compliance. In Namibia, nearly all local people were found to be aware of both codified and sociocultural wildlife norms within their conservancies (Kahler & Gore, 2012). However, a many of these wildlife norms were culturally and socially enforced as opposed to enforcement by statutory laws enforced by legislated institutions (Kahler & Gore, 2012). Totems and taboos have been used by different groups of people for different reasons (Diawuo & Issifu, 2015). Taboos play a key role in conservation by regulating when, who and how resources can be accessed and restricting or allowing access to certain resources and habitats (Colding & Folke, 2001). Two sets of prohibitions which play an important conservation role have been observed in the eastern rain forests of Madagascar (Jones *et al*., 2008). These were, extremely strict prohibitions (taboos) that could not be broken under any circumstance and a class of prohibitions determined on the basis of what society would accept (social norms). Taboos have played an important role in protecting threatened species while social norms have helped limit the level of exploitation of other species (Jones *et al*., 2008). Strict prohibitions on eating of certain animals and limiting the access into sacred forests to an approved society group only are seen as important cultural practices that aid wildlife conservation in Nigeria (Jimoh *et al*., 2012).

In Ghana, rules, regulations, totems and taboos have been found to help in protecting particular ecosystems and habitats, particular animals or plant species and to regulate the exploitation of particular natural resources (Sarfo-Mensah & Oduro, 2007). Diawuo and Issifu (2015) exemplify how rules associated with taboos and totems as belief systems have been used successfully to promote natural resource conservation and management among the Sankana and Tongo-Tengzuk communities in northern Ghana. It is taboo to kill or injure a sacred crocodile because the Tongo-Tengzuk communities belief that crocodiles are the incarnation of their important ancestors. The water, plants and other animals living in the water are protected from indiscriminate harvesting due to the presence of crocodiles in the water. Protection of sacred places and prohibitions were the most commonly applied norms in the conservation of the various elements of the biophysical environment among the Iteso community in Kenya (Dominics & Fuchaka, 2016). For example, the Iteso greatly recognized the importance of rivers, marshes and swamps as important dwelling places for ancestors and various species of plants and animals and therefore had strong rules and beliefs to conserve them as well as sanctions for violators.

Many humans find the eating of crocodiles and most reptiles disgusting (Jones *et al*., 2008) and have an intrinsic aversion that drives them to kill them (Raley, 2016). However, it is not peculiar in some cases to find conflicting or contradictory codified and customary rules on the same issue existing simultaneously (A. Fischer *et al*., 2007). Pooley (2016) notes that diversity in cultural attitudes to crocodiles is apparent from the wide variety of purposes for which crocodile body parts were (and are) used by various communities across Africa. He describes them as ranging from hunting them for food and their body parts as artefacts, for leather work, for medicines or magic, as aphrodisiacs and for their musk. The Wapokomo people in Kenya and one of the communities in this study eat crocodile meat and are fearless towards crocodiles (S. Pooley, 2016).

The traditional reliance on natural resources has been identified as integral to rural and ethnic identity among many local communities (Commerçon *et al*., 2021). People may not always observe taboos or mores, or practice their nominal religion where there is conflict with utilitarian or cultural use of the animal (Kingston, 2016). The introduction of external practices and institutions has contributed to change in traditional regulations, together with inner conflicts about leadership and community cohesion (Commerçon *et al*., 2021). For example, the effectiveness of taboos in protecting wildlife has been undermined by intrusion by other tribes, westernization and improved hunting techniques (Jimoh *et al*., 2012). The tendency to disregard the local community approach to conservation has been seen to negatively affect the integral conservation of biodiversity in the Amazon region (Yoamara *et al*., 2020). There is evidence that respect for socially enforced prohibitions was breaking down where local people no longer have the right to manage their resources (Jones *et al*., 2008). Nevertheless, investment in conservation law enforcement is effective (St. John *et al*., 2015) and perhaps the fallback where customs and taboos have been disregarded.

In remote landscapes like Tana River which have poor infrastructure and poor wildlife-based tourism, conservation law enforcement may be costly and scanty. In such places, it is other factors which encourage compliance and which when harnessed may supplement or even reduce reliance on conventional and costly enforcement (St. John *et al*., 2015). Whereas the state bears the responsibility to monitor and enforce national laws, its capacity to do so may not be adequate (Jones *et al*., 2008). Locally defined and enforced prohibitions therefore play a central conservation role because they may be the only effective rules governing the use of natural resources (Jones *et al*., 2008). This study undertook to establish prevailing norms and sanctions for crocodile ranching and conservation and how they have influenced the adoption of crocodile ranching-related activities.

2.3.5 Awareness of Rules and Regulations for Crocodile Ranching

Local people rely on wildlife resources for their different livelihood needs (Akande *et al*., 2019; Robinson & Redford, 1991; Valdivia & Gilles, 2001; Zhang *et al*., 2008). Yet destruction and loss of habitats, illegal use of wildlife, over-exploitation of resources and lack of conservation awareness impact negatively on biodiversity and ecosystems and, therefore, sufficient understanding and corrective measures are needed in order to avoid affecting human well- being (Akande *et al*., 2019; Meadows, 2011; Pal, 2006; Tangvitoontham *et al*., 2015).

Because people often poach wildlife and overharvest forests despite knowledge of the environmentally correct thing to do (Jacobson, 2009), there is necessity to contextualize people's behaviour within the socio-economic environment they operate in. Low levels of awareness of wildlife laws and consequences of breaking such laws has been reported by several authors (Keane *et al*., 2011; Momanyi, 2015; St. John *et al*., 2015). They attribute illegal hunting and other negative environmental outcomes to lack or low level of awareness of wildlife laws. Momanyi (2015) recommend inclusion of local communities in conservation affairs. Lack of awareness of benefits and risks of crocodile conservation led to the failure of an ex-situ breeding programme for the endangered endemic Philippine crocodile (*Crocodylus mindorensis*) for re-introduction into suitable wetlands (van der Ploeg *et al*., 2011a). However, a later alternative approach for in-situ conservation of the Philippine crocodile incorporating intense public sensitization, community consultations by the local government and the participation of local people contributed to the reduction of anthropogenic threats to crocodiles like deliberate killing and a decrease in the use of destructive fishing methods (van der Ploeg *et al*., 2011b).

In Mexico, despite being aware of regulations for wildlife use, the same communities have the need to hunt for food (Oliva *et al*., 2014). Gandiwa *et al*. (2014) illustrate high levels of awareness among local communities in Zimbabwe of about the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) while the knowledge of a much older community conservation programme around Gonarezhou National Park was limited. They attributed the cause of low community awareness to poorly structured community conservation outreach programmes. Awareness of Malagasy poaching laws was associated with the belief that people do not poach because local rules are well enforced (Rizzolo *et al*., 2017). Eliason (2004) describes situations where violators deemed to have

good knowledge of wildlife laws violate them on grounds of forgetfulness or ignorance. In addition, despite having knowledge of wildlife laws, local communities illegally took wildlife to rebel against the state or protest against regulations against regulations governing resource use or to exercise perceived traditional rights to land tenure and resource use (Muth & Bowe, 1998).

It is imperative to focus on changing people's awareness and sensitivity to wildlife conservation and ultimately, their behavior because solutions to conservation problems lie with them (Akande *et al*., 2019; Jacobson, 2009). Further, rules are fundamental to the implementation of conservation policies, but must be known or understood if they are to change behavior (Keane *et al*., 2011). There is recognition that lack or low conservation awareness can lead to harmful practices and unsustainable natural resource extraction and use (Kahler *et al*., 2013; Kahler & Gore, 2012).

2.4 Biophysical Factors Influencing the Performance of Crocodile Ranching-related Activities

The performance of crocodile ranching depends on access to a reliable supply of eggs from the wild. This in turn depends on the physical state of the egg collection sites along the zones assigned to the crocodile ranches for egg collection. There exists extensive literature on crocodilian nesting ecology (Calverley & Downs, 2014, 2017; Combrink *et al*., 2011, 2016, 2017; Kofron, 1990; Swanepoel *et al*., 2000; Webb *et al*., 1983a; Webb *et al*., 1983b). Differences in Nile crocodile habitat utilization depends on the age and sex of the crocodile and prey availability and dispersals occur when they attain a length of 1.2 metres (Calverley & Downs, 2014; Hutton, 1989). Suitable areas for Nile crocodiles include those with permanent water, high, sunny, sandy banks above flood levels and sufficient vegetation to provide shade and shelter (Salem, 2013). Females lay eggs between September- January in nests on dry river beds, river banks and sandy shores in clutch sizes of 20-60 eggs (Kofron, 1989).

Nesting surveys aid in recording nest site locations, identifying physical characteristics that define suitable nesting habitat, estimating the breeding percentage of a population and are thus important for the future protection of crocodilians (Villamarín *et al*., 2011). There is potential for terrestrial resources needed by animals like crocodilians whose earliest life-history stages are the only ones that require terrestrial habitats to be in short supply relative to aquatic resources (Somaweera & Shine, 2013). Studying reproductive ecology helps in

assessing the population dynamics of an unstudied population, as reproductive output is thought to be a measure of population health (Champion & Downs, 2017). According to Refsnider (2016), the need to ensure the survival of the nesting female, maximize the survival of the offspring produced, place new hatchlings close to suitable juvenile habitat and promote natal philopatry of daughters drive the evolution of nest site choice among oviparous animals.

Physical alterations to suitable habitat shaped by natural processes such as floods or anthropogenic interference alter the quality and quantity of habitat available for crocodilian nesting purposes and need to be quantified (Calverley & Downs, 2014, 2017; Swanepoel *et al*., 2000). This is because such changes affect the long-term viability of the Nile crocodile population (Calverley & Downs, 2017). Evans *et al*. (2015) note that spatial analyses, or assessments of the distribution of crocodile nests in any given area, have not been the focus of any studies.

2.4.1 Land Cover Types and Changes

Land cover refers to the attributes of the earth's land surface and immediate sub-surface such as the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other (Lambin & Geist, 2008; Meyer, 1995; Meyer & Turner, 1996). The term is closely related to the term "land use", which describes the socio-economic or functional purposes and ways in which humans exploit the land cover for human resource demands (Canada, 2008; Lambin & Geist, 2008; Meyer, 1995; Meyer & Turner, 1996). Land cover changes are defined as the changes occurring to the land cover over time (Canada, 2008). Such changes have been attributed to human actions (Meyer & Turner, 1996) and biophysical forces (Canada, 2008; Lambin & Geist, 2008). Biodiversity loss resulting from overharvesting, habitat destruction, and species transfer are now in a magnitude to warrant concern over their extinction (G. Fischer *et al*., 1996; Meyer & Turner, 1996; Turner *et al*., 1994). Remotely sensed images, GIS, aerial photographs, modelling and ground validation techniques with or without reference to historical nest data have been used in mapping crocodile nesting habitats in Egypt, Ghana and Northern Territory- Australia (Agyemang *et al*., 2007; Duffett *et al*., 2000; Gibson, 2014; Harvey & Hill, 2003; Salem, 2013).

Nile crocodiles as well as a few other crocodilian species are needed in the ranching industry mainly because of the commercial value of their skin. Therefore, the management and expansion of this industry in conjunction with conservation priorities requires knowledge of the location and extent of areas suitable for crocodile nesting (Duffett *et al*., 2000). It is also important to assess how human activities which manifest in land cover changes influence

crocodile ranching. There is considerable potential for scarcity of terrestrial resources needed by animals like crocodiles, whose earliest life history stages are the only ones that require terrestrial habitats (Somaweera & Shine, 2013). The ability of a species to utilize disturbed habitats depends upon satisfying the requirements of all life history stages, and often, the egg stage will be the weakest link (Somaweera & Shine, 2013). Salem (2013) argues that the abundance and progress or regress of the Nile crocodile depends on the availability of suitable vegetation and soil types and shoreline areas with less or no human disturbance.

Habitat destruction, settlements and disturbance along rivers and other natural corridors (e.g. floodplains) has resulted in fragmentation between sub-populations and the possible loss of genetic diversity (Combrink *et al*., 2011). Selective land conversion for agricultural purposes raises a number of potential issues for crocodile nesting even into previously remote areas, often forcing crocodiles to nest in areas of medium to high anthropogenic disturbance (L. J. Evans *et al*., 2016). Further, disturbance by cattle and human activity near nesting areas affect nesting effort, abundance, distribution and embryo survival (Combrink *et al*., 2017).

Increases in human induced habitat alterations have also created shifts in preferred crocodilian habitat availability (Gibson, 2014). The number of adult crocodiles decreased per kilometer of river covered, when the proportion of human-induced land cover change (conversion to farmland) increased (Gibson, 2014). Salem (2013) identifies suitable habitats as those areas currently being used by the Nile crocodile and the areas which were in close proximity to natural vegetation, while unsuitable habitats for crocodiles included the settlement and agriculture areas, fishermen camps, steep and rocky shorelines. Unfortunately, high sandy river banks, essential for crocodile ecology, are needed for fishing camps and village sites, therefore fishermen activities inevitably influence the nesting success of crocodiles and the crocodiles themselves (Salem, 2013).

2.4.2 Location and Distribution of Nesting Sites

Nile crocodiles are hole nesters, i.e., they excavate holes in the substrate where they lay eggs (Calverley & Downs, 2017; Combrink *et al*., 2017; Murray *et al*., 2020; Refsnider, 2016). Crocodiles nesting sites need to be on high, sunny sandy banks above flood levels and enough vegetation to provide shade and shelter (Salem, 2013; Webb *et al*., 1983a). This enables the female to guard against predators throughout the incubation period and to protect the eggs from overheating (Calverley & Downs, 2014, 2017; Swanepoel *et al*., 2000).

Hole nesters are thought to be communal nesters, i.e., conspecifics deposit their egg clutches in a clamped distribution at a scale visible to an observer, unlike mound-nesters (Doody *et al*., 2009; L. J. Evans *et al*., 2016; Murray *et al*., 2020; Swanepoel *et al*., 2000; Webb *et al*., 1983a). However, this nesting behaviour has not been observed among Nile crocodiles since the distances between two nests ranging from 1 to 100 metres apart (Calverley & Downs, 2017; Swanepoel *et al*., 2000). Scarcity of suitable nesting habitat can force crocodiles to nest in whatever less suitable nest habitat is available (Calverley & Downs, 2017; Somaweera & Shine, 2013; Swanepoel *et al.*, 2000).

Crocodile nesting sites have been reported to have consistent habitat features of substrate and distance from water Somaweera and Shine (2013). Breeding female Nile crocodiles have exhibited a tendency to repeatedly use nesting sites Combrink (2017) and Champion and Downs (2017). Another argument holds it that for hole-nesters, the distance of a nest from permanent water may be based on availability of suitable, friable substrates rather than protection from predators (Chibeba, 2003; Somaweera *et al.*, 2013; Somaweera & Shine, 2013). The distance from water at which nests are constructed is important (Refsnider, 2016). The close proximity of a crocodile nest to water provides brooding females the safety of the water when alarmed and cooling needs as well as increase the survival chances of a nest as they are tended by females (Calverley & Downs, 2017; Cott, 1961; Kofron, 1989; Modha, 1967). Several studies on the nesting ecology of Nile crocodiles indicate that the majority of nests are located within 20 metres from the water (Champion & Downs, 2017; Hutton, 1989; Kofron, 1989; Swanepoel *et al*., 2000). The same authors however Nile crocodile nests have been found at distances greater of 20 to 40 metres. Hutton (1989) and Champion & Downs (2017) observe the average distance for the location of Nile crocodile nests located from permanent water as 7.7 and 9.8 metres, respectively.

Knowledge of the distribution and abundance of crocodilian nests and threats facing them is essential in estimating recruitment population trends as well as habitat use by the breeding crocodiles (Calverley & Downs, 2017; Villamarín *et al*., 2011). Villamarin *et al*. (2011) and Refsnider (2016) further argues that nest distributions shed light on habitat use by breeding populations, which might be used as a basis for monitoring and management (Villamarín *et al*., 2011). Studies in reproductive ecology have been used to assess crocodile population dynamics and health (Calverley & Downs, 2017; Champion & Downs, 2017; Refsnider, 2016; Somaweera & Shine, 2013; Villamarín *et al*., 2011).

2.6 Research Gaps

Although a number of studies have addressed the influence of norms and sanctions on promoting natural resource conservation and the effect of the intrusion of other cultures on the effectiveness of such norms and sanctions (Commerçon *et al*., 2021; Diawuo & Issifu, 2015; Dominics & Fuchaka, 2016; Jimoh *et al*., 2012; Kahler & Gore, 2012), the focus of these studies has been on homogenous communities. Similarly, several studies have assessed the effects of various socio-economic factors such as age, gender, ethnicity, education and levels of income on biodiversity outcomes (Akinsorotan *et al*., 2020; Brackhane *et al*., 2019; Li *et al*., 2016; Mogomotsi *et al*., 2020; Mustapha *et al*., 2012; Nguyen *et al*., 2018; Ntuli *et al*., 2019; Reuter *et al*., 2018). However, there has been limited focus on how these factors influence biodiversity outcomes where sustainable use programmes have been implemented among heterogeneous communities.

Several studies have focused on crocodile nest distribution and threats facing them (Calverley & Downs, 2017; Champion & Downs, 2017; Chibeba, 2003; Murray *et al*., 2020; Refsnider, 2016; Villamarín *et al*., 2011). However, a few studies have incorporated the identification of crocodile nest sites with the use of remotely sensed data and GIS techniques to assess habitat suitability and disturbance (Duffett *et al*., 2000; Harvey & Hill, 2003; Salem, 2013). Calverley and downs (2014) and champion and Downs (2017) conducted a studies on habitat suitability and disturbance of crocodile nesting sites using historical knowledge of such sites. However, studies on habitat suitability and disturbance of crocodile nesting sites which are a subject of sustainable use programmes, like crocodile ranching, in combination with historical knowledge of such sites are limited (Shacks, 2006). A review of literature (Kyalo, 2008b; Obare, 2019) on crocodile ranching in Kenya indicates that there is little information on the location and distribution of crocodile egg nests amidst the various human altered land covers yet wildlife managers, wildlife policy makers, the crocodile ranches and local communities require this information for effective management and conservation of crocodiles and the associated ecosystems.

The study contributes to the understanding of some related variables that have not been explored in-depth in previous literature relating to involvement in crocodile ranching-related activities and performance of crocodile ranching. This study makes a theoretical contribution by explaining the processes by which socio-economic, institutional and ecological factors influence the involvement and performance of crocodile ranching-related activities. This addresses the need to understand how the "Drivers- Pressures- State- Impacts- Responses" theoretical framework can be used to understand sustainability challenges and help organize

research on interacting ecological and societal processes and predict change (Lewison *et al*., 2016).

2.7 Theoretical Framework

A critical review of three theoretical frameworks was done in order to settle for one that would guide the study. These frameworks are the Institutional Analysis and Development Framework, Social- ecological Systems and the Drivers- Pressures- States- Impacts- Responses.

2.7.1 The Institutional Analysis and Development Framework

The earliest framework for studying common-pool resources is the Institutional Analysis and Development (IAD) framework (Ostrom, 1990, 1994). The framework links the characteristics of a physical world, for example, forests, with those of the general cultural setting (the villages and harvesters that use forests): the specific rules that affect the incentives individuals face in particular situations (how forest products can be harvested, utilized and maintained); the outcomes of these interactions (regeneration or deforestation) and the evaluative criteria applied to these patterns and outcomes (efficiency, equity, sustainability). A major characteristic of this IAD framework is that it focused on community-based natural resources, something which in essence, limits its application to study of resources that are communally held and managed under collective action. In real life, communities no longer live in isolation as there are other actors as well (Agarwal & Gibson, 2001; Ojha *et al*., 2016; Thondhlana *et al*., 2015).

2.7.2 Social-ecological Systems (SES)

Further development of the IAD resulted in the framework for social-ecological systems consisting of six core subsystems namely, resource units, resource systems, governance systems, users, interactions and outcomes (Ostrom, 2007; Ostrom *et al*., 2007). The framework is tailored for, but not limited to, understanding collective action in a shared common-pool resource system (Partelow & Winkler, 2016). Thomson (1992) applied and expanded the IAD framework to study community forestry in Niger to include different classes of actors and their incentives as well as the patterns of interactions given particular incentives. However, Berkes (2007) and Fischer *et al*. (2007) note that socio-ecological systems often involve multiple actors at local, national and international levels and deal with

multiple objectives. At the same time, international agreements and national Action Plans, which normally address governance issues at a very general level need to be translated into strategies which respond to the actual situation at a local level. The framework adopted for this study here tries to address these needs.

Simple and linear frameworks for analyzing resource use and sustainability have been challenged (Andersson & Ostrom, 2008; Ostrom, 2007, 2009; Ostrom *et al*., 2007). Ostrom (2007) built on variables identified by Agrawal (2001) to develop a nested, multi-tier framework focusing on how four attributes may affect or may be affected by the socioeconomic, political, and ecological settings in which they are embedded. The attributes are the resource system, the resource units generated by that system, the users of that system, and the governance system. She further says that the conceptual hierarchy can be enhanced depending on the specific empirical or policy question being investigated. She asserts that many interactions and outcomes depend on the specific combination of several variables at one or multiple levels. The framework is largely intended to enable researchers to develop cumulative, coherent and empirically supported answers to patterns of interactions and outcomes in relation to governance arrangements, resource users, resource systems and resource units. The framework is found to be complex and does not readily render itself to address the nature, issues and intention of crocodile ranching as a sustainable use programme. However, this study has adopted some of its variables, namely, spatial and temporal distribution of the crocodile nesting sites, socioeconomic attributes of households, norms, knowledge of socio-ecological systems (perceptions), levels of harvesting crocodiles and eggs by local people and ranches and benefits to the local people.

2.7.3 Drivers- Pressures- States- Impacts- Responses

This study anchored on the "drivers-pressures-states-impacts-responses" (DPSIR) theoretical framework for quantitative evaluation and measurement of socio-economic and biodiversity drivers and pressures. The DPSIR framework was adapted from the Pressure-State-Response (PSR) structure initially developed by Rapport and Friend in the late 1970s (Carr *et al*., 2007; Patrício *et al*., 2016). The PSR structure has been, since the 1990s, used in conceptualizing marine ecosystem risks analysis and translating these for researchers, environmental managers and stakeholders (Patrício *et al*., 2016). The DPSIR as a framework for integrated environmental reporting and assessment was developed by the European Environmental Agency in 1999 and has since been widely adopted in the study of

environmental problems (Carr *et al*., 2007). In this framework, social and economic developments (Driving forces, D) exert Pressures (P) on the State (S) of the environment and these, in turn, Impact (I) on the economic, physical, cultural, and social well-being of humans through a loss or gain of ecosystem goods and services (Cooper, 2013; Maxim *et al*., 2009; Tscherning *et al*., 2012; Xue *et al.*, 2015). The impact elicits a societal Response (R) that feeds back on Drivers, State or Impacts via various mitigation, regulation, policies, adaptation or curative actions (Maxim *et al*., 2009; Tscherning *et al.*, 2012; Xue *et al.*, 2015).

Many studies have used the DPSIR theoretical framework to conceptualize sustainability challenges and help organize research on interacting ecological and societal processes and predict change (Lewison *et al*., 2016). The framework has been used in China to identify factors and human activities likely to affect ecosystem goods and services from tea plantations and to delineate potential cause and effect relationships between these factors (Xue *et al.*, 2015). The DPSIR framework has been used to guide research on socio-economic biodiversity pressures and drivers and to serve as a basis for the development of formal quantitative models in the Danube Delta Wetland System in Romania and Donana National Park in Spain (Haberl *et al*., 2009). It has been used in Burkina Faso to assess drivers and of farmers' decisions in integrating trees into agricultural practices (Sanon *et al*., 2020). Patricio *et al*. (2016) identified at least 27 research projects focusing on coastal and marine habitats having used the DPSIR framework and/ or derivatives as part of their conceptual development phases. The framework is liked due to its simplicity and transparency, focus on causal relationships, and ability to integrate socio-economic factors and biological and physical sciences with the decision-making process (Lewison *et al*., 2016; Maxim *et al*., 2009).

This study developed a comprehensive DPSIR structure to identify dynamics likely to influence the adoption and performance of crocodile ranching-related activities in lower Tana River, Kenya and to demonstrate likely cause and effect relationships between these factors (Figure 2.3). In this study, Drivers include household demographic and socio-economic characteristics and the international demand for exotic crocodile leather. Pressures are anthropogenic factors that diminish what humans get from the environment (Lewison *et al*., 2016; Maxim *et al*., 2009) and are direct environmental effects of drivers. Pressures induce socio-economic and environmental changes (Impacts) which include the use of resources, the intensity or efficiency of human activities and socio-economic performance of society (Haberl *et al*., 2009; Lewison *et al*., 2016; Maxim *et al*., 2009). Drivers are thought to create pressures which in this study include, killing crocodiles for meat, retaliatory elimination of

crocodiles as a result of conflicts with crocodiles, harvesting crocodile eggs for consumption and for crocodile ranching. These practices either support or undermine crocodile ranching. State is defined as the condition of the natural and socio-economic systems (Maxim *et al*., 2009). In this study, State includes, nature and extent of use of crocodile and crocodile products, prevailing land cover types at the egg collection zones, number of hatchlings returned to the river to boost the wild crocodile population, incomes and other benefits from egg collection to the local people and quantities of skins and other crocodile products sold.

Impacts are consequences of changes in the State of the environment. Maxim *et al*. (2009) give a further elaboration of impacts in two ways. In bio-sciences, an Impact can refer to effects on living beings and non-living compartments of ecosystems (aquatic, terrestrial and atmospheric). The term Impact in socio-economic sciences is used with focus on effects on the human systems associated with changes in environmental functions, such as resources provision. The impacts in this study include a decline in crocodile population or their extinction, low supply or inability to supply exotic crocodile skins and closure of the crocodile ranch, land cover changes at the egg collection sites that have a negative influence on the breeding behaviour of crocodiles, loss of incomes from egg collection at the households, loss of employment at the field egg collection units or the main ranches and an end to community projects.

Responses may seek to control Driving Forces or Pressures (prevention, mitigation), to maintain or restore the State of the environment, to help to accommodate Impacts (adaptation) or even deliberate "do nothing" strategies (Maxim *et al*., 2009). Two groups of Responses are identified: one associates Responses uniquely to policy action; the other identifies Responses from different levels of the society, represented both by groups and by individuals, from the government, private or non-governmental sectors (Lewison *et al*., 2016; Maxim *et al*., 2009). For application on biodiversity, they include measures to protect and conserve biodiversity (in- situ and ex- situ), and include, for example, measures to promote the equitable sharing of the monetary or non-monetary gains arising from the utilisation of genetic resources" (Cooper, 2013; Maxim *et al*., 2009). Indicators in this study which relate to Responses include the implementation of a sustainable use management programme crocodile conservation (crocodile ranching), enactment and implementation of legislation for the conservation of crocodiles and other biodiversity, adopting conservation measures to enhance crocodile conservation and putting in place institutional measures including local governance mechanisms, norms and incentives.

The DPSIR theoretical framework does not incorporate perceptions. This study however identified that perceptions (the interpretations, understandings and observations that people make of their environment and natural resources) influence their thoughts and conservation behaviour (Bennett, 2016; Munhall, 2008; Nelson, 2008). Since perceptions were thought to influence human behaviour in involvement in uses and practices which could harm or support crocodile ranching-related activities, they were incorporated in the theoretical framework as mediating between drivers and pressures.

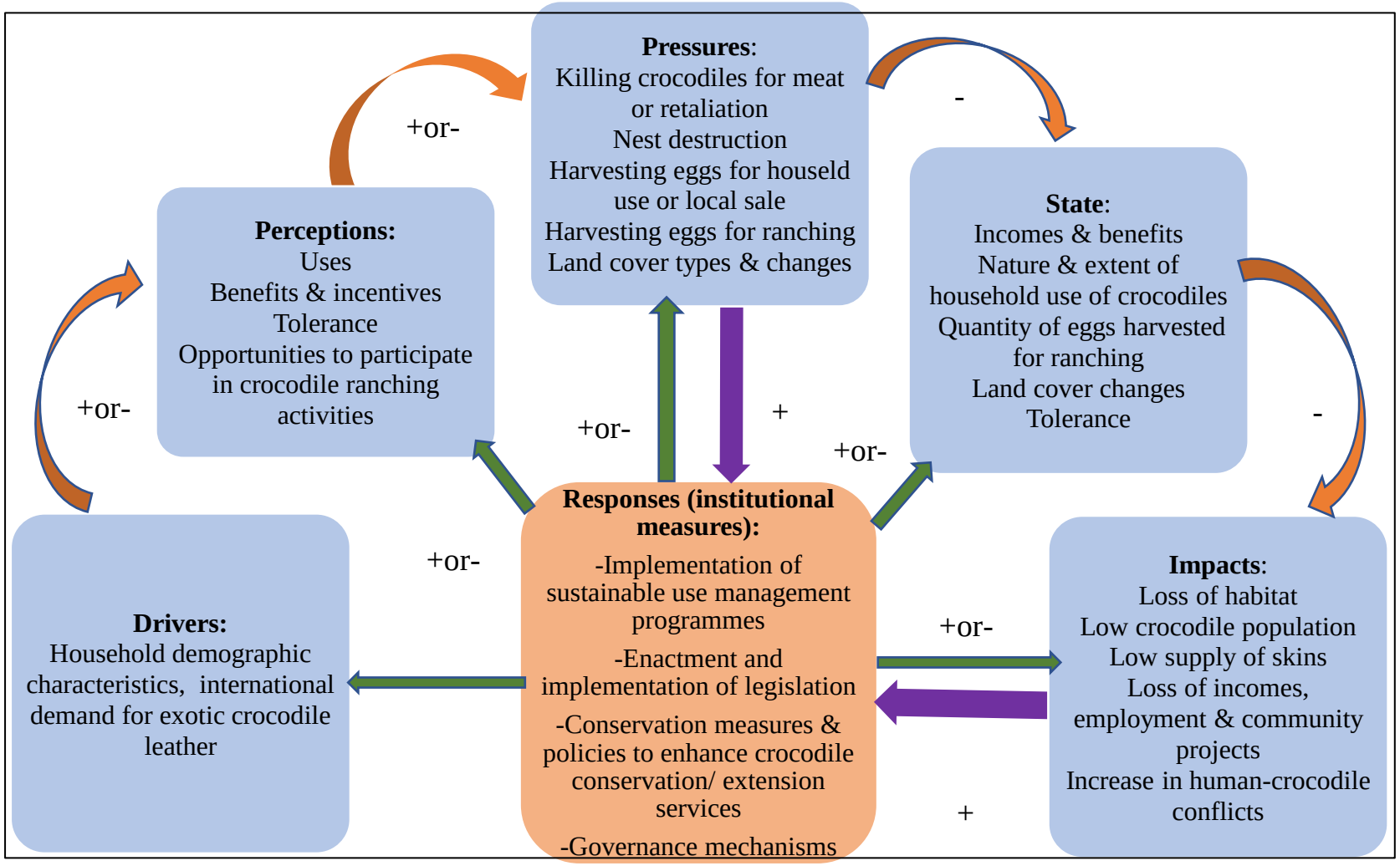

Figure 2.3:Theoretical framework for crocodile ranching. (Visual representation adapted from "Applying DPSIR to sustainable development," (adopted from E. R. Carr *et al*. (2007) with permission from Taylor & Francis through CCC RightsLink).

2.8 Conceptual Framework

The conceptual framework showing the study variables and the linkages amongst them is presented in Figure 2.4. The independent variables are socio-economic factors, perceptions, institutional factors and bio-physical factors while the dependent variables are involvement in and performance of crocodile ranching-related activities. The adoption of crocodile ranching-related activities happens when the local communities get involved in legal uses of crocodiles such as harvesting crocodile eggs for ranching, rearing live crocodiles and sale of skins and other products; and, involvement in practices that are not harmful to crocodiles and their habitat.

The adoption of legal uses of crocodiles and their products is expected to lead to a desired performance of crocodile ranching-related activities such as ability of crocodile ranches to access eggs for ranching, sell crocodile skins, incomes for local egg collectors, implementation of community projects and local community support for crocodile conservation. The illegal uses of crocodiles through their killing for meat and harvesting eggs for consumption as well as engagement in practices that harm crocodiles and crocodile habitat contribute to changes in the stability of the crocodile population and the quantity of eggs available for crocodile ranching.

Religion, formal education, ethnicity, age, gender, level of income and source of livelihood were likely determinants of local people's involvement or non-involvement in practices that either support or undermine crocodile ranching-related activities. For example, local communities with higher levels of education and higher incomes are not likely to engage in non- legal uses of crocodiles and practices that harm crocodiles and crocodile habitat. Local communities' perceptions about uses of crocodiles and benefits and incentives derived from crocodile ranching activities are thought to influence their involvement in crocodile ranching-related activities. Changes in land covers induced by human and natural factors influence the availability of resources needed in the different life stages of crocodiles. This in turn influences crocodile breeding behaviour and availability of eggs needed by the ranches and recruitment of juveniles into the population. Local people who have higher levels of awareness of crocodile ranching and conservation regulations are less likely to be associated with illegal uses of crocodiles. Local people who get incentives from crocodile ranching are likely to support legal uses of crocodiles.

The international demand for exotic crocodile leather supports the legal use of crocodiles through the crocodile ranching programme. In order to access eggs, the crocodile ranch provides incomes to egg collectors, and community projects to local people living near crocodiles.

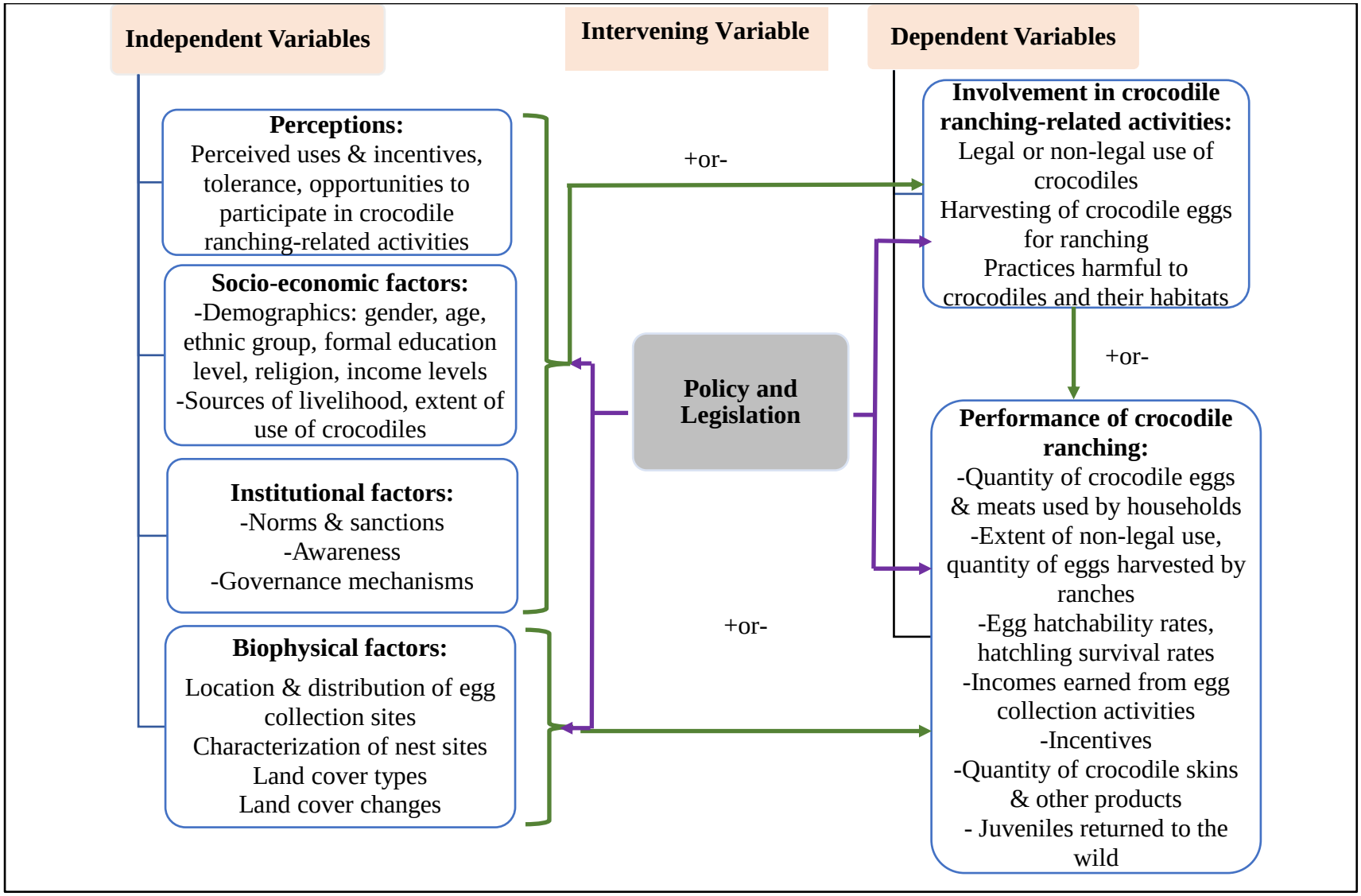

Figure 2.4: Conceptual framework for crocodile ranching

2.9 Operationalization of Variables

Adoption of crocodile ranching referred to involvement in crocodile ranching-related activities. The term also refers to involvement in legal uses of crocodiles and practices that do not harm crocodiles and crocodile habitat.

Biophysical factors referred to the state of the egg collection areas measured through four variables: land cover, land cover changes, and location and distribution of egg collection sites. Land cover refers to the area under each land cover category of the classification used. This involved identification of existing land cover types both on the Sentinel 2 image and validation on the ground and the area in hectares occupied by each of the identified classes of land cover types.

Land cover changes were represented by the changes which occurred to the land cover over time observed as the difference in hectares occupied by the identified land cover types between 2015 and 2018.

The location of egg collection sites was measured as the geographical location of the crocodile nest in co-ordinate pairs and recorded using a hand-held global positioning system (GPS). Location was also measured as the direct distance of the nest containing eggs to the water's edge measured in metres.

Distribution of egg collection sites was observed as the spatial arrangement and display of the geographical locations of crocodile egg nests at the egg collection zones along the river. This was observed as where the nests are and how sparsely or densely packed the nests are from each other.

Institutional factors were represented by three variables: norms and sanctions; governance mechanisms; and, benefits and incentives. Norms were measured through a set of statements on behaviour or actions considered acceptable or not acceptable towards crocodiles, and an assessment of how the community addresses unacceptable behaviour towards crocodiles.

Legal uses included the involvement of study participants in one or more of the crocodile ranching-related activities which are legal and which do not harm crocodiles and crocodile habitat. From the local communities' perspectives, legal uses included collecting crocodile eggs for ranches at a fee, locating crocodile egg nests for ranches at a fee, incubating crocodile eggs and selling hatchlings to ranches at a fee, training egg collectors and being employed at the ranch or at field incubation unit. Other legal uses of crocodiles included

rearing crocodiles, harvesting eggs for ranching, exporting crocodile skins and local sale of crocodile meat which were practiced by the crocodile ranches. Such uses resulted in positive outcomes for crocodile ranching and conservation.

Illegal uses included the involvement of the participants in one or more of the crocodile uses and practices which are not legal and which can harm crocodiles and crocodile habitat. These were eating crocodile eggs obtained from the wild, eat crocodile meat hunted from the wild, hunting crocodiles, using crocodile meat for fishing, selling crocodile eggs to villagers, selling crocodile meat to villagers and selling crocodile meat to fishermen, humans damaging crocodile egg nests and poisoning crocodiles. Such uses resulted in negative outcomes for crocodile ranching. The local people's engagement in practices that harm crocodiles and crocodile habitat was measured qualitatively.

Perceptions were represented by sets of questions which addressed local people's levels of tolerance towards crocodiles, perceived uses of crocodiles, benefits and incentives from crocodile ranching and perceived opportunities from crocodile ranching measured on a 5-point Lickert scale.

Performance referred to how the crocodile ranches were achieving the expected outcomes of the crocodile ranching-related activities. These are outcomes from legal uses of crocodiles: number of crocodile eggs accessed for ranching, egg collection capability, rates of hatching success, efforts to minimize egg mortality, release of sub-adult crocodiles back to the river, number of crocodile skins exported and quantity of meat sold locally and benefits and incentives paid by the ranches to the local communities.

Socio-economic factors included age of the primary respondent in years, gender, religion, ethnic group, level of formal education, annual income and major source of livelihood for the respondent. Socio-economic factors also include the extent of the illegal uses of crocodiles. The extent of non- legal uses of crocodiles was measured as: number of eggs eaten in the household during the 2017/18 egg-laying season, how often crocodile meat is eaten at the household, quantity of crocodile meat in kgs used for fishing in a month and number of crocodile eggs sold to villagers during the 2017/18 egg-laying season.

CHAPTER THREE
METHODOLOGY

3.1 Study Area

3.1.1 Location and Size

The study was conducted in the lower stretches of River Tana in Tana River County, Kenya. The study specifically covered the segment of the river stretching from the boundary between Garissa and Tana River County to Kipini where the river empties its water into the Indian Ocean (Figure 3.1). Tana River County lies between the latitudes 0^0 0'53"30" and 2^0 0'41" South and longitudes $38^0$30' and $40^0$15' East (Odhengo *et al*., 2014). It borders Garissa to the North, Isiolo to the Northwest, Lamu to the Northeast, Kilifi to the Southeast, Taita Taveta to the South and Kitui to the West. The study focused on local communities living along the lower river Tana basin and the three crocodile ranches, namely, Nile Crocodiles Limited, Kazuri London and Galaxy Croc Farm, hereafter referred to as "Nile", "Kazuri" and "Galaxy", respectively, which are located away from the lower River Tana basin. These three crocodile ranches have been allocated egg collection zones along the lower River Tana.

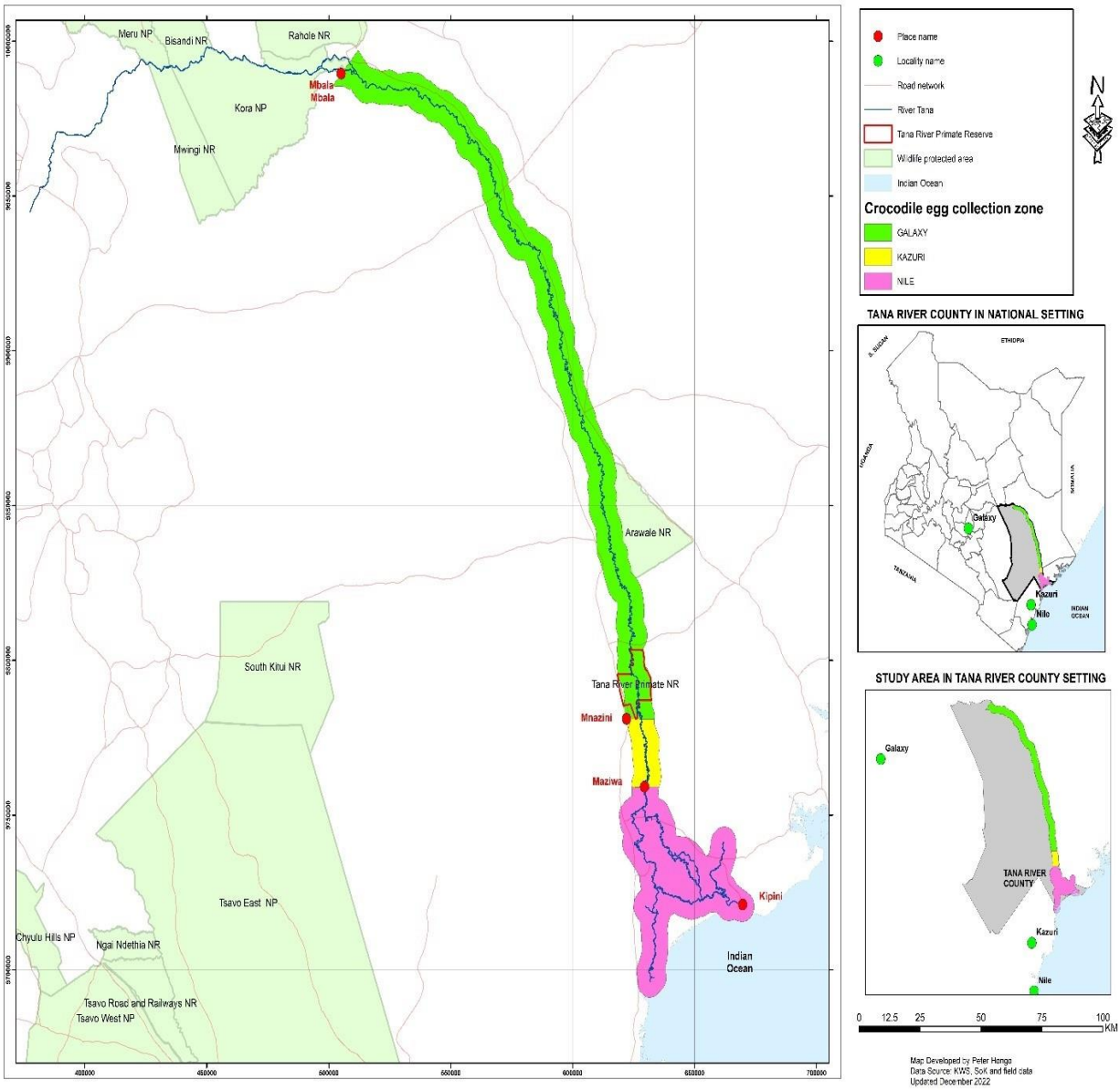

Figure 3.1: Map of the study area showing the different egg collections zones and location of the crocodile ranches

3.1.2 Climate

The county is generally dry and prone to drought. Rainfall is erratic, with rainy seasons in March–May and October–December. Annual rainfall ranges from 400 to 750mm per annum. Mean annual temperatures range from 23^{o} to 33^{o} Celcius (Odhengo *et al*., 2014). Flooding is common in the area, caused by heavy rainfall in upstream areas of the Tana River.

3.1.3 Hydrology

River Tana, whose catchment stretches from Mount Kenya and the Aberdare Mountain Ranges (Ministry of Environment and Natural Resources, 2012), traverses the county into the Indian Ocean. It is the longest river in Kenya covering over 750 kilometres (Odhengo *et al*., 2014). As the river approaches its end, it forms the Tana Delta, a large floodplain of wetlands, fresh and brackish lakes and estuaries (Maingi & Marsh, 2002).

3.1.4 Vegetation and Soil Types

The soils in the upper portions of lower River Tana range from sandy, dark clay and sandy loam to alluvial deposits (GoK, 2013b). The soils are deep around the riverine environments but highly susceptible to erosion by water and wind (GoK, 2013b). The soils in the Tana Delta are generally black cotton soils with clay, loam and alluvial deposits. High fertility soils are found along natural depressions and along the flood plains of River Tana. The fertility is due to accumulated silt or clay brought about by flooding. In the meander belt, the soils are stratified comprising of yellowish-brown sands and clay deposits that are rich in micas. The textures of top soil range from sand to clay while the sub-soil is usually firm clay. The rate of infiltration of water is slow in areas with clay top soil, and fast where sand forms the upper layer (Odhengo *et al*., 2014).

There is a riverine vegetation along the banks of the Tana River from Mbalambala to the Tana Delta at Kipini (Maingi & Marsh, 2002). The vegetation ranges from scrubland to thorny thickets within the riverine area while shrubs and annual grasses dominate most parts of the region. However, there are enclaves of trees and perennial grasses dominating wetter parts. An invasive tree species, *Prosopis juliflora*, has colonized most of the areas that are not cropped. Open vegetation to closed vegetation, with sparse trees and shrubs dominate the range lands (GoK, 2013b). There are about 71 distinct forests which lie on both sides of River Tana, ranging in size from 1–1,100 ha and covering 3, 700 ha in total (Odhengo *et al.*, 2014). Tana River Primate National Reserve consists of scattered patches of riverine forests, most of which are remnants of continental forests which resemble West African forests, woodlands, bushlands, mangroves and grasslands (Odhengo *et al*., 2014) .

3.1.5 Biodiversity

Tana River Primate National Reserve (TRPNR), located in the lower areas of the river, is the only government-protected wildlife conservation area in Tana River County (Odhengo *et al*., 2014). It is home to many endemic and range-restricted plants, primates, amphibians and reptiles (MENR, 2012; Odhengo *et al*., 2014). For example the Reserve is home to the Tana River red colobus (*Colobus badius rufomitratus*) and the Tana River Crested Mangabey (*Cercocebus galeritus*) as well as specialized habitats for many plants and animals (GoK, 1996). Arawale National Reserve is situated at the eastern side of the river in what is Garissa County. This reserve is home to hirola antelopes *Beatragus hunter*, a critically endangered species endemic to south-east Kenya and south-west Somalia, cheetah (*Acinonyx jubatus*) (Butynski, 2000; Njoroge *et al*., 2009). Vegetation in Arawale consists of grassland, bushland and open wood land dominated by acacia, commiphora and combretum species (Njoroge *et al*., 2009). The Tana River Delta is an Important Bird Area (IBA); a Ramsar Site, a Key Biodiversity Area (KBA), a Global Biodiversity Hotspot and is also part of the Coastal Forests of Eastern Africa Hotspot (Odhengo *et al.*, 2014).

River Tana is known for its high concentration of Nile Crocodiles and is thought to have the biggest living population of crocodiles in Kenya (Kyalo, 2008a; Odhengo *et al*., 2014). The lower Tana River is the main crocodile egg collection zone in the country (Kyalo, 2008a). Galaxy had made previous attempts to harvest crocodile eggs from Lake Turkana and Baringo but abandoned the sites due to limited success and logistical challenges.

3.1.6 Human Inhabitants and Socio-economic Activities

The total human population in Tana River County by 2019 was 314,710 (KNBS, 2019). Average household size was 4.6 persons and the population density was 8 persons per square kilometer (KNBS, 2019). This was projected to increase 343,662 persons by 2022 (GoK, 2023). It is Kenya's fifth poorest County after Turkana, Mandera, Wajir and Marsabit with 75.6 per cent of its inhabitants living below the poverty line (KNBS, 2013, 2015). The area is mainly occupied by the Pokomo, Orma and Wardei. Pokomo mainly practice farming and fishing while the Wardei and Orma combine livestock keeping with some shifting cultivation (GoK, 2018; Mohamed, 2015; Terer *et al*., 2004). The area experiences ethnic conflicts between the farmers and nomadic pastoralists over natural resources (Mohamed, 2015). River Tana and several seasonal rivers support livestock during the dry season. The total road network in the county is 3,377 km with only 449 km of these having bitumen surface. The land in the county is mainly non-arable covering 29,798.7 km^2. The rest is either under forest

3,457 km^2, arable land covering 2,547 km^2, and 3,059.5 km^2 under national reserves (GoK, 2018). The county irrigation potential areas cover about 200,000ha, out of which only 2% has been put under irrigation development. Farmers in the county mainly rely on rain fed and flood recession farming systems with only a few practicing irrigated farming to grow subsistence crops (Terer *et al*., 2004). Fishing activities are carried along the River Tana and at the ocean at Kipini, Ozi and Chara. Mining of sand, murram and gypsum is also practiced in the County (GoK, 2018).

3.2 Research Design

The study employed a mixed methods research design. A mixed methods design was selected to provide a better understanding of the research problem and multiple viewpoints (Creswell, 2012). Cross-sectional primary qualitative and quantitative survey data and longitudinal secondary sources of data were used. Secondary data on wild crocodile egg collection quotas and egg hatchability rates, and quantities of skins and meat sold was obtained from the crocodile ranches and corroborated with ranch returns made to KWS. Triangulation of data sources, types and methods were used to strengthen the study by providing cross-validity and consistency checks (Patton & Patton, 2002).

3.3 Target Population and Unit of Analysis

The target population was households and crocodile egg collectors in villages situated within two kilometres at the non-delta segment and within five kilometres at the delta segment of the lower River Tana, Tana River County. The coverage was wider around the delta due to the influence of the delta. These distances were selected due to the limited home range of Nile crocodiles from the river bank and the fact that households tended to be concentrated along the river banks. There were 35,099 households in Tana River County and 4,363 of these were in the study area. Data on the number of households in the study area was obtained from information available at the office of the County Commissioner for Tana River and the Red Cross, a humanitarian organization operating in the area. The unit of analysis for the quantitative household survey was the household. The qualitative approach had a number of actors involved in the crocodile ranching programme in Tana River County (Patton & Patton, 2002).

3.4 Sample Size and Sampling Procedure

For the household survey, the overall sample size was calculated in accordance with Israel (1992) as cited in Jaskow and Yamane (1965):

Sample size = $n = \frac{N}{1+N(\varepsilon)^2}$

where, n is the sample size,

N is the population size (total number of households along the river at the three egg collection zones which is 4,363) and

ε, the desired level of precision (± .05)

$$n = \frac{4363}{1 + 4363(0.05)^2}$$

n= 364.52

Using this formula, the sample size consisted of 365 households. These households were drawn from a total of ten villages selected purposively based on their importance for crocodile egg collection and existing modes of livelihoods in the study area. Four villages in Galaxy, two in Kazuri and four in Nile egg collection zones were selected. The sample size was proportionately allocated to the selected villages based on the number of households (Table 3.1). Lists of households in the participating villages were prepared with the help of the chiefs and village elders. Households were randomly drawn from these lists for interview.

All egg collectors who could be located at the segments of the river where crocodile egg collection has been going on in the last five years were interviewed. The known high turn-over of egg collectors in all the three egg collection zones and the seasonality of the egg collection exercise presented difficulties in locating egg collectors. Some of the egg collectors for Nile were located at the Ngao-Oda river channel and Ozi- Kipini segment both of which had long stopped egg collection activities in the areas due to a change in the river course and unavailability of crocodile eggs caused in what appears to be harmful fishing practices. These collectors had been inactive for over five years and were not expected to have updated information on crocodile ranching-related activities.

Table 3.1: Sample size allocation for household survey

Zones	Villages	Total number of households	Number of households selected
Galaxy	Baomo	493	42
	Sala	200	17
	Majengo- Chini ya Hola	400	33
	Makere	295	25
	Sub-total	1388	116
Kazuri	Bubesa	204	17
London	Hasakanyacha	72	6
	Sub-total	276	23
Nile	Galili	1000	83
Crocodiles	Maziwa	800	67
	Bilisa	416	35
	Hewani	483	41
	Sub-total	2699	226
Grand total		**4363**	**365**

A total of seven key informants were selected for KII. These were managers of the three crocodile ranches (one per ranch), the KWS County Warden, the KWS officer in charge of coordinating the implementation of CITES Convention, the Chairman of Tana River County Conservation Committee and County Executive Officer for wildlife affairs at the Tana River County Government. The key informants were selected based on their knowledge and experience of various aspects of crocodile ranching activities. A total of four FGDs consisting of six to eight discussants were held: two FGDs each for household heads and egg collectors. The key informants and discussants were purposefully selected from information-rich cases due to the need for in-depth focus (Baxter & Eyles, 1997; Coyne, 1997; Klenke, 2016; Patton & Patton, 2002). The small sample size for both key informants and FGDs was deemed appropriate because credibility in qualitative studies is not affected by low sample size since "saturation", (that is, no new themes occurring), is achieved even with small samples (Baxter & Eyles, 1997; Klenke, 2016).

3.5 Data Collection

3.5.1 Social Surveys

Quantitative primary social data was obtained through use of two sets of semi-structured questionnaires for household heads (Appendix A) and crocodile egg collectors (Appendix B) to get data on demographic characteristics, socio-economic and institutional factors. Questionnaires were administered face-to-face with the help of enumerators (field assistants). The questionnaire contained four parts. The first part elicited information on demographic and socio-economic background of the participant including age, gender, ethnicity education, religion sources of income and annual income. The second part elicited information on crocodile utilization practices. The third part elicited information on perceptions towards crocodile ranching-related activities, whereas the fourth solicited information on institutional factors. The enumerators were trained before conducting interviews (Plate 3.1). Face-to-face interviewing was chosen because it yields highest response rates in survey research and it gives room for the researcher to clarify ambiguous responses (Bernard, 2013).

Qualitative surveys were conducted through key informant interviews (KII) and focus group discussions (FGDs) using interview guides (Appendix C, D and E). To obtain qualitative data from KII and FGDs, the researcher interviewed the key informants and moderated the focus group discussions with the help of an assistant taking notes. Additionally, a digital voice recorder was used to record discussions and interviews.

Plate 3.1: Training field enumerators in Danisa. Own picture.

3.5.2 Ecological Survey

Crocodile Nest Survey

Topographical sheets for the study area were acquired from Survey of Kenya for geo-referencing. Necessary data for the river and existing road networks were then extracted by digitization to develop a base map on which primary data for crocodile nesting sites were overlaid. Nesting sites and boundaries for zones allocated crocodile ranches for egg collection were identified with the help of ranch workers, egg collectors and village elders for mapping. The nest survey was conducted during an active egg collection season and was planned to be done in late December 2018 and January 2019 which coincided with active egg-laying and harvesting season. A 40 HP boat was used for the nest survey in combination with foot surveys. This approach is consistent with other studies (Calverley & Downs, 2017; Combrink *et al*., 2017; Swanepoel *et al*., 2000).

Designing nest survey to coincide with an active egg collection season enabled the researcher benefit from local knowledge of the egg collectors and ranch supervisors to locate historical nesting sites. In most cases, the search for nests was made much easier by the knowledge of the ranch supervisors and egg collectors of the physical location where the crocodiles repeatedly laid eggs over the seasons. The presence of a nest was often made known by a fleeing crocodile when observers approached (Champion & Downs, 2017). A combination of historical knowledge of nesting sites and observation of the female plunging into the river increased the chances of locating nests sites. The research crew members were then guided to the location of the nest by visible and distinct trails the female crocodiles made on the embankment heading to the nests. The nest site was identified by an indent or signs of soil disturbance, accompanied by imprints where the crocodile had been lying near or on the nest (Champion & Downs, 2017). Historical knowledge of nesting sites has been used by various researchers in locating and mapping crocodile nesting sites (Calverley & Downs, 2017; Champion & Downs, 2017; Harvey & Hill, 2003).

Once nesting sites had been identified, a steel rod was used to determine the exact location of the eggs (Plate 3.2a). The presence of a nest and eggs was discerned by the characteristic cracking sound made by the metal rod coming into contact with the top egg inside the nest. The confirmation of eggs was done by removing the top soil to view the first top eggs (Plate 3.2b) after which the geographical location was recorded using a hand-held global positioning system (GPS). The direct distance of the nest to the river bank was measured to the nearest metre using a flexible measuring tape. The use of stainless steel rods

to probe in order to locate nests has been considered a reliable method (Calverley & Downs, 2017; L. J. Evans *et al*., 2016; Swanepoel *et al*., 2000; Webb *et al*., 1983a; Webb *et al*., 1983b). Hand-held GPS has been employed to record locations of nests elsewhere (Calverley & Downs, 2017; Champion & Downs, 2017; Combrink *et al*., 2011). The egg collectors then removed eggs from the nest and counted the number. Viable eggs were then carefully placed inside Styrofoam boxes by the egg collectors. The researcher recorded the way point for the geographical location, the number of eggs and the attributes for each of the identified nest site using a data collection sheet (Appendix F). The attributes included egg damage by humans, female observed tending the nests, number of females present, extent of egg predation, eggs collected by collectors or non-collectors, nest overrun by floods and nest soil type.

Geographical positioning system (GPS) data were downloaded into a computer using DNR Garmin software and thematic maps for the egg collection sites developed. The location of nesting sites was overlaid on the land cover map of the area to indicate the spatial distribution and crocodile nesting areas. Geographical Information System data and number of eggs harvested by the ranchers during the active egg collection season during which field data for this study were collected were overlaid on the land cover map to assess the egg harvesting potential. Thematic maps for the egg collection sites were developed using a GIS software.

Plate 3.2: Locating a crocodile egg nest

(a) At left foreground are visible and distinct claw marks made on the embankment by the nesting female crocodile heading to the nest. (b) Egg collectors probing an area identified as a crocodile nesting site to identify the location of a nest using steel rods. (c) Crocodile egg nest with top nest substrate removed to show eggs at Bobwaini in Galaxy egg collection zone. Own pictures.

Land Covers and Changes

Image quality assessment was carried out before downloading the best quality images for the study area. The study area was fully covered by four scenes of Sentinel 2 satellite images: MFU, MEV, MFT and MFU. These scenes were therefore downloaded and processed using ENVI software involving cloud removal, band compositing and scenes re-projection. Areas covered with clouds were removed as the clouds block whatever land cover is beneath and thus affecting the interpretation process. This resulted to an image with data gaps which is then gap filled later on with another image of almost the same time period but with no data gaps as shown in Figure 3.2.

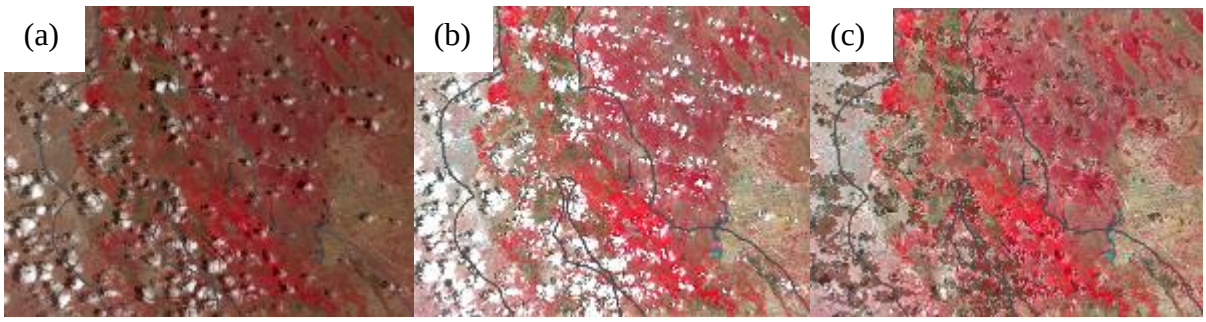

Figure 3.2: Figures showing (a) portion of image with cloud cover (b) cloud cover masked out and (c) gap filled image

For the mapping exercise, the Intergovernmental Panel on Climate Change Land Cover Groupings (IPCC) classification scheme was adopted because the land cover categories are reasonably mappable by remote sensing methods due to the high-level groupings it provides (Milne *et al.*, 2003). The mapped classes included; forestland, grassland (which was subdivided into open grassland and shrubland), cropland, settlement, other land and wetlands (water bodies) (Canada, 2008) (Appendix G). An analysis of the satellite images was to be done for two years (2018 and 2013) to show changes that had occurred over a 5-year timescale. However, the 2013 data was not available for downloading and this could possibly be attributed to the fact that Sentinel 2 satellite image was launched in the year 2013. Therefore, the available images for analysis for all the scenes were for the year 2015 and 2018. Supervised image classification method was adopted for the study with Random Forest (RF) algorithm as the classifier (GoK, 1990) (Appendix H). The use of the RF algorithm was adapted from System for Land based Emissions Estimation in Kenya (SLEEK) project (GoK, 1990). The main advantages of RF over other classifiers such as Maximum Likelihood (ML) is that it provides measures of confidence for each pixel for each class, it provides accuracy

and variable importance information with the results and training requirements are less demanding than other classifiers SLEEK (2019). The script used in this process (Appendix H) was developed by Ned Horning in R software (http://www.amnh.org/our-research/center-for-biodiversity-conservation/biodiversity-informatics.).

Training sites were picked from groups of pixels that were identified as having a particular land cover class (Figure 3.3). They were thus defined as polygons which were digitized on the image and labeled using the land cover codes shown in Appendix G and saved as a shapefile. Selection and coding of training sites was done in ArcMap (Briem *et al*., 2002) and an already developed Random Forest Script (Appendix H) used to run the classification. The script was configured in order to locate the training sites shapefile, input image and location of the outputs as well as the margin files.

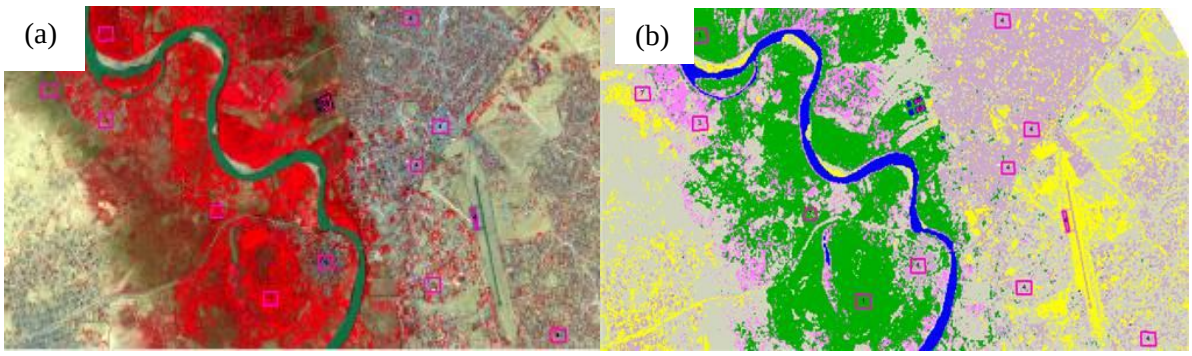

Figure 3.3: Picking of the training sites

(a) groups of pixels identified as having a particular land cover class; (b) groups of pixels digitized on the image and labeled using land cover codes

The classified image output a *.tiff* format was then density sliced and color mapped using ENVI software to assign visible colors. Statistics of each landcover category were generated in Earth Resources Data Analysis System (ERDAS) software. Classification was therefore done separately on each of the four scenes of Sentinel 2 satellite images with training sites picked per scene to avoid spectral overlap. Picking of training sites for the first draft map was done based on the image interpretation skills of the interpreter and with aid of the auxiliary datasets that were available. Once the picking of training sites was done for each stratum, the classification was run using the RF algorithm written in R-script (Appendix H). Once training sites were selected for each scene, the operator ran the classification using the R-script and got an output which was then colour-coded for visualization. The classification outputs were

then clipped based on the study area boundary and mosaicked to have a complete map (Figure 3.4).

After generation of the first draft map, there was need to validate the land cover classes on the ground. Thus, a sampling scheme was designed to sample out points for ground-truthing purposes and this was based on the following criteria: accessibility was considered as a factor and thus roads were used in the sampling process; a sampling zone was generated within the 3 km buffer along the river which formed the study area; stratified random sampling was adopted whereby the area (in ha) for the generated land cover classes was calculated and points to be validated were based on the total area of a land cover class in proportion to the total area of study area. A total of 100 points were randomly generated for validation (Table 3.2 and Figure 3.4). The points were traced on the ground using a GPS and data collected in each and every point as shown in Plate 3.3 and Figures 3.4 using a data sheet (Appendix I and J). The 100 points were then divided into half and 50 used to retrain the satellite image to obtain a final classification and the remaining 50 for the final accuracy check. A quick accuracy check was done on the draft classified image with all the 100 validated points, and an overall accuracy of 66% was obtained with a Kappa Coefficient of 0.5857.

After field validation exercise, the 100 points that had been validated were divided into two halves. One half was used to retrain the classification and the other half was used to run the final accuracy assessment. After retraining and re-running the classification with a gap-filled image a final output image for 2018 was generated with an overall accuracy and Kappa statistic of the classification are of 84% and 78%, respectively as shown the Table 3.3. The result of the accuracy assessment of the classified map shows that there is moderate agreement of reference data with the classified maps and is therefore suitable for this study. According to Congalton (2004), coefficient values greater than 0.80 represents strong agreement; a value between 0.4 and 0.8 represents moderate agreement and 0.4 represents poor agreement.

Table 3.2: Number of points per class for field validation

Landcover category	**Points to be validated**
Forest land	20
Open Grassland	15
Crop land	10
Settlement	10
Other land	10
Wetland	10
Shrub land	25
Total	**100**

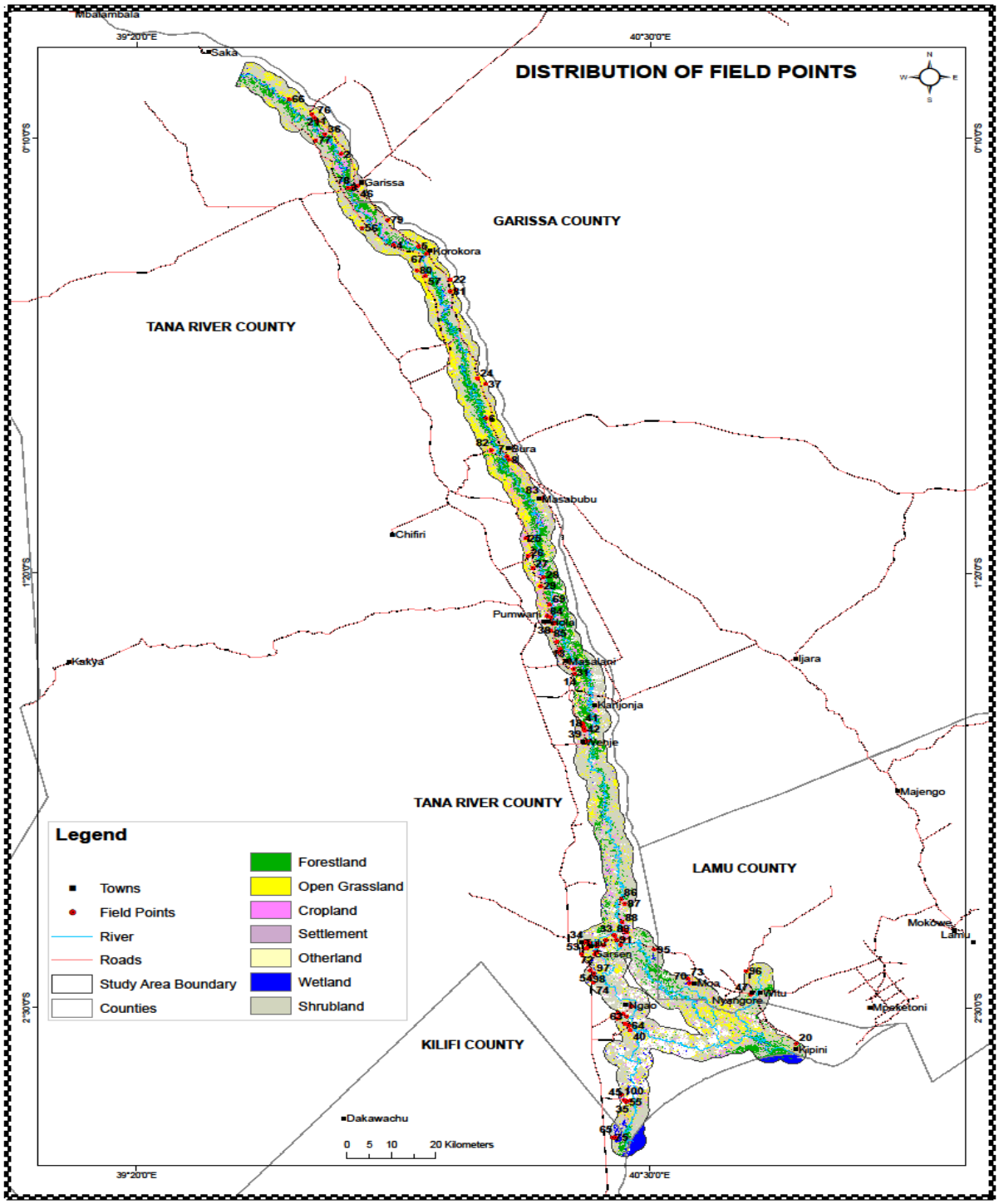

Figure 3.4: Complete map of the study area showing land cover types and field

Plate 3.3: Ground validation exercise

(a) Searching for a sampled point for validation (b) Confirming a sampled point in Sombo area

(c) Taking a picture at a point in Moa during ground validation exercise. Own pictures

Table 3.3: Accuracy assessment results

Overall Accuracy	84%	(42/50)* 100						
Kappa Coefficient	0.783							
Land cover class		Validated Points						
	Forestland	Open Grassland	Cropland	Settlement	Other land	Water bodies	Shrubland	Total
Forestland	4	0	0	0	0	0	0	4
Open Grassland	0	4	0	0	0	0	0	4
Cropland	0	1	2	0	0	0	0	3
Settlement	0	0	0	4	0	0	0	4
Other land	0	0	0	0	3	0	0	3
Water bodies	0	0	0	0	0	5	0	5
Shrubland	1	2	3	1	0	0	20	27
Total	**5**	**7**	**5**	**5**	**3**	**5**	**20**	50
Land cover class		Validated Points (%)						
	Forestland	Open Grassland	Cropland	Settlement	Other land	Water bodies	Shrubland	Total
Forestland	80	0	0	0	0	0	0	8
Open Grassland	0	57.14	0	0	0	0	0	8
Cropland	0	14.29	40	0	0	0	0	6

Settlement	0	0	0	80	0	0	0	8
Other land	0	0	0	0	100	0	0	6
Water bodies	0	0	0	0	0	100	0	10
Shrubland	20	28.57	60	20	0	0	100	54
Total	100	100	100	100	100	100	100	100

3.6 Data Analysis

3.6.1 Quantitative Data

Quantitative survey data were processed and analyzed using the Statistical Package for Social Sciences (SPSS) computer programme.

Objective 1: Socio-economic factors influencing the involvement in crocodile ranching-related activities

A multinomial logistic regression was fitted to investigate the effects of seven socio-economic factors (i.e., age, level of formal education, annual income, gender, ethnic group, religion, main source of livelihood and egg collection zone) on involvement in crocodile use (neutral [non-use], legal and illegal). For the response variable, the neutral category was used as the reference category. The reference categories for the explanatory variables gender, ethnic group, religion, main source of livelihood and egg collection zone were male, Ilwana/Malakote Muslim, others (bee keeping, remittances from children and masonry) and Nile, respectively.

Objective 2: Local perceptions towards involvement in crocodile ranching-related activities

Three separate multinomial logistic regression models were fitted to assess the relationships between involvement in crocodile use (outcome carriable) and each of the three predictor variables, namely, level of tolerance towards crocodiles, perceived benefits and incentives, and, perceived opportunities for crocodile ranching.

Objective 3: Institutional factors influencing involvement in crocodile ranching-related activities and performance of crocodile ranching-related activities

Three separate multinomial logistic regression models were fitted to assess the relationship between various institutional factors and involvement in and performance of crocodile ranching-related activities. The first model assessed the relationship between norms and sanctions (predictor variable) and involvement in different crocodile uses (outcome variable). The predictor variable was binary (yes/no), with “no” being used as the reference category. The second model assessed the relationship between egg collection zone (predictor variable) and the likelihood of benefitting from the crocodile egg collection programme (outcome variable). The predictor variable was egg collection zone (Galaxy, Kazuri and Nile), with Nile as the reference category. The categories in the outcome variable were personal direct income, community project and none (no benefit) with the latter as the reference category.

The third model assessed the relationships between the two predictor variables (i.e., awareness of legally accepted ways of using crocodiles and awareness of various rules for crocodile ranching, and involvement in different crocodile uses (outcome variable). The crocodile use categories were neutral (non-use), legal uses and illegal uses, with the neutral group as the reference category in the model. For each of the three predictor variables, "no" was used as the reference category in the model.

The influence of institutional factors on performance of crocodile ranching was evaluated by performing correlation analyses. The first analysis was between number of crocodile eggs harvested by the crocodile ranches during the period 2013 to 2018 at the three egg collection zones along lower River Tana and collection fees paid by the crocodile ranches to local egg collectors over the same period. The second analysis was between crocodile hatching rate in each of the crocodile ranches and total fees paid by the ranches to the egg collectors during the period 2013 to 2018.

Objective 4: Performance of select aspects of crocodile ranching production system

Descriptive statistics were used to summarize crocodile hatchability, and the quantities of crocodile eggs harvested, skins produced and exported, and meat sold during the period. This involved analyses of the performance of egg harvesting, egg hatchability, and skins produced and exported, and meat sold during the period 2014 to 2018. Correlation analyses were performed to investigate the relationship between: 1) the number of eggs harvested and the number of nests, 2) the number of eggs harvested and the number of boats deployed, and, 3) the number of eggs harvested and number of egg collectors engaged.

Correlation analysis was performed to examine the relationship between the egg hatching rate and the egg collection fees paid to the egg collectors. A *t*-test was performed to test differences between Galaxy and Nile in the quantities of crocodile eggs collected, skins sold and meat sold.

A model to examine the relationship between incentives and benefits derived from crocodile ranching (predictor variable) and involvement in different crocodile use categories (outcome variable) was fitted. The predictor variables were personal direct income, community project and none (i.e., no benefit) with the latter as the reference category.

Objective 5: Bio-physical factors influencing the performance of crocodile ranching

Descriptive statistics for area occupied by each land cover type for the years 2015 and 2018 were generated and for land cover changes during the period 2013 to 2018. The spatial distribution of nests was assessed by overlaying nest locations on map of the study area.

3.6.2 Qualitative data analysis

Qualitative data were analysed using the Max software for qualitative data analysis (MAXQDA) (Kuckartz & Stefan, 2019). Audio data from the interviews was transcribed and imported as pdf files into MAXQDA software. The documents were organized into document groups, namely, key informant interviews and focus group discussions. A systematic study of the files was conducted in order to understand the whole text and to aid the process of categorizing contents of the documents into codes (McLeod, 2011) (Appendix K.1). Sixteen themes were classified. Each code was assigned its own colour to change the background colour of the marked text (Kuckartz & Stefan, 2019; McLeod, 2011). The code clouds in Appendix K.2 illustrate the most frequently assigned codes among the different documents in the study. An overview of the codes was done to determine how many times each code was assigned to individual or multiple documents as visualized in the code matrix browser (Appendix K.3). The size and colour of the clusters in the matrix show how many document segments in each document have been assigned each particular code and subcode. The larger the cluster, the greater the number of segments that were assigned this code or category in this document. The document portrait was used to visualize all the coded segments of each document in terms of the order and colour of the codes (Appendix K.4). These are the listed codes and colours in the first column of code matrix overview but are now weighted in the document portrait to have large sizes representing large segments. Such a display helped identify the basic tone of each document (MAXQDA, 2020).

The code relations browser was used to assess the relationships between codes by showing the number of co-occurrences of any given two codes in the documents (Appendix K.5). Using the code map, codes used in the study were displayed in order to visualize the similarity and relationships in the data (Appendix K.6). Each code was represented by a circle. Larger circles were indicative of more assignments to that code and the distance between codes was indicative of how similarly the codes were applied in the data. Connecting lines between codes were indicative of co-occurrence of codes. Thicker connecting lines were indicative of more co-occurrences between two codes. The code “Rules and regulations” had no relations and has therefore been left out of the code map (MAXQDA, 2020).

Lastly, the data in each of the documents was systematically analysed and summarized (Kuckartz & Stefan, 2019). Exemplary quotes were identified and used to illustrate the themes (Kuckartz & Stefan, 2019; McLeod, 2011). The analysis entailed looking for

similarities and differences between the texts and explanations for crocodile ranching-related phenomena.

3.7 Validity and Reliability

A pilot study was conducted to pre-test the questionnaires to determine their adequacy to collect the required data, identify any logistical problem which could have to be addressed (Babbie, 2013; Gomm, 2009). Piloting helped identify any mistakes in the design of the questionnaire and interview schedule, guided in restructuring ambiguous questions, the order of questions and rephrasing unclear instructions (Babbie, 2013; Bernard, 2013). It also guided precoding responses in the questionnaire which were used in the main study (Babbie, 2013). The questionnaire was administered on 30 household heads on a different population with similar characteristics. These respondents were not interviewed during the main survey. The Cronbach's alpha was used to assess the internal consistency of responses to perception questions which were in a scale (Bernard, 2013). A value of 0.707 for internal consistency of responses to perception questions was realized, which was within the acceptable minimum coefficient of between 0.7 and 0.8 (Bernard, 2013; de Vaus, 2002).

Rigour and credibility in the qualitative component of this study was ensured through the researcher's lens (Creswell & Miller, 2000). This was achieved through triangulating with quantitative methods and use of quotations from several respondents, providing information on respondent selection, presenting different perspectives from interviewees, providing information on the appropriateness of methodology, applying appropriate methodology and presentation of direct quotations (Baxter & Eyles, 1997; Creswell & Creswell, 2007; Creswell & Miller, 2000).

3.8 Ethical Issues

The approval of the research project was sought from the Graduate School and Ethical Review Board at Egerton University prior to going to the field to collect data (Appendix L). A research permit was obtained from both the National Commission for Science, Technology and Innovation (Appendix M). Permission to access and use secondary data on crocodile ranching was obtained from Kenya Wildlife Service (Appendix N). The County Commissioner and County Police Commander for Tana River County were notified for security reasons. The researcher was introduced through the local leadership structures such as the chiefs and village elders prior to commencing interviews and nest surveys on the river.

The purpose of the study was disclosed to the participants, their confidentiality assured and their consent to participate in the study obtained. (Appendix O, P and Q). No live crocodiles were captured, or eggs harvested or nests destroyed for purposes of this study.

CHAPTER FOUR

RESULTS

4.1 Demographic characteristics of the study participants

4.1.1 Household Survey

A total of 365 household heads participated in the household survey. Various characteristics of these participants are presented in Figure 4.1. A vast majority (68%, *n*=249) of these participants, were males. The dominant age categories were 30-39 years (23%, *n*=84) and 40-49 years (23%, *n*=84). Islam (as opposed to Christianity) was the more dominant religion with 61% (*n*=224) of the household survey participants reporting to be Muslims. In terms of ethnicity, Pokomo (63%, *n*=230) were the most dominant, followed by Orma (23%, *n*=83), Watta (9%, *n*=36) and Ilwana/Malakote (4%, *n*=16).

Slightly less than half (47%, *n*=173) of the participants had primary level of formal education, whereas less than 20% and less than 10% of the participants had secondary and tertiary education levels, respectively. Slightly less than a quarter (24%, n=87) of the participants had no formal education. The vast majority (70%, *n*=255) of the participants had an income lower than Kenya Shillings (KES) 250,000 per annum. An overwhelming majority (88%, *n*=321) of the participants were not members of any community environment or conservation group. In addition, most (79%, *n*=288) did not hold any leadership positions in the community.

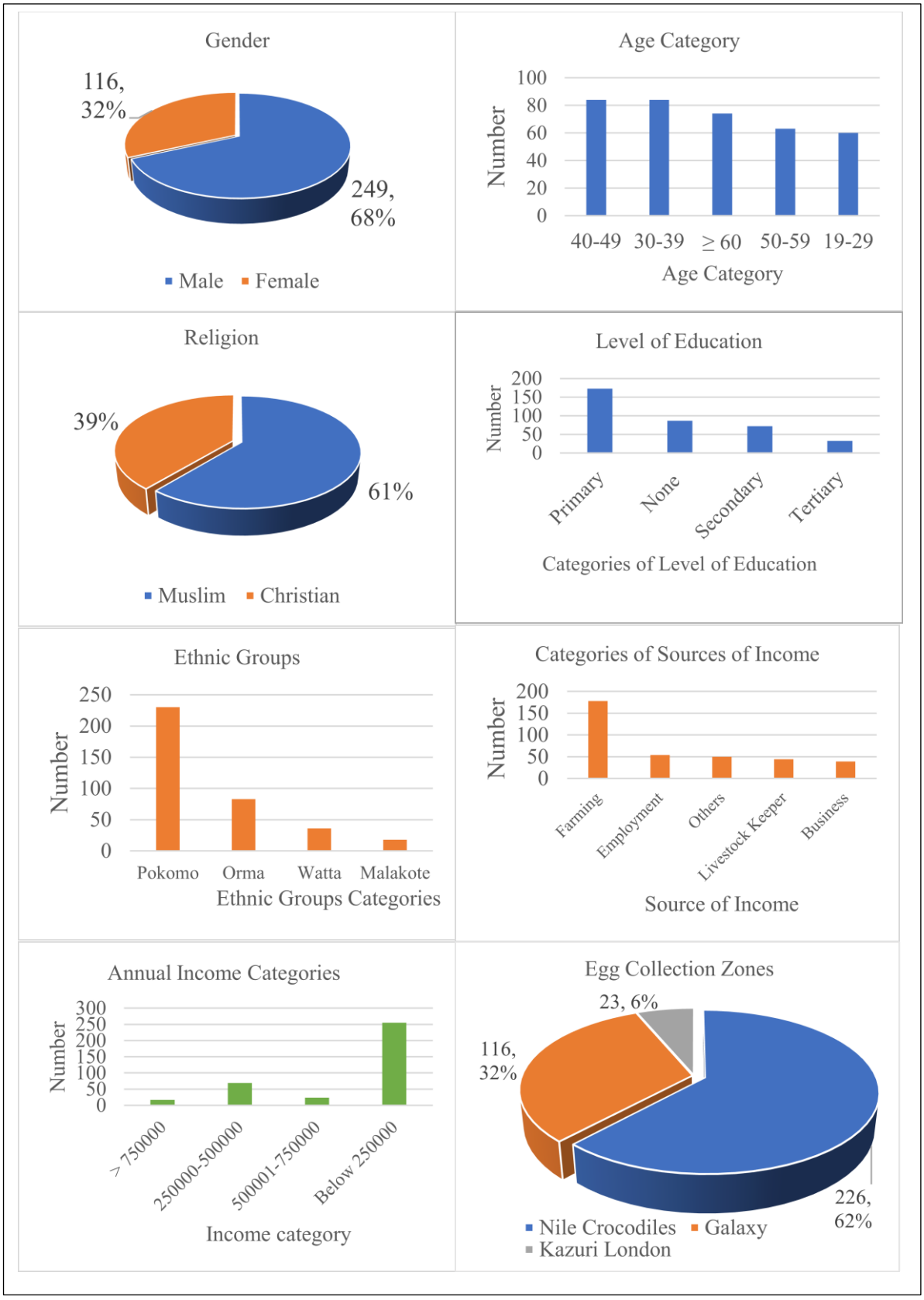

Figure 4.1: Various demographic characteristics of household survey participants

4.1.2 Egg Collectors Survey

Figure 4.2 shows the demographic characteristics of the egg collectors who participated in the study. Slightly over half (i.e., 54%, *n*=14) of the egg collectors were from the Nile egg collection zone followed by Galaxy egg collection zone (31%, *n*=8). About 69% (*n*=18) of the egg collectors had household sizes of 6-10 members. A majority (73%, *n*=19) of the respondents were Muslims. With regards to formal education, nearly two-thirds (62%, *n*=16) of the egg collectors attained primary education. On ethnic background, 42% (*n*=11) of the egg collectors were from the Pokomo ethnic group. The dominant age category of the egg collectors was 40-44 years of age (62%, *n*=16). All the egg collectors were males.

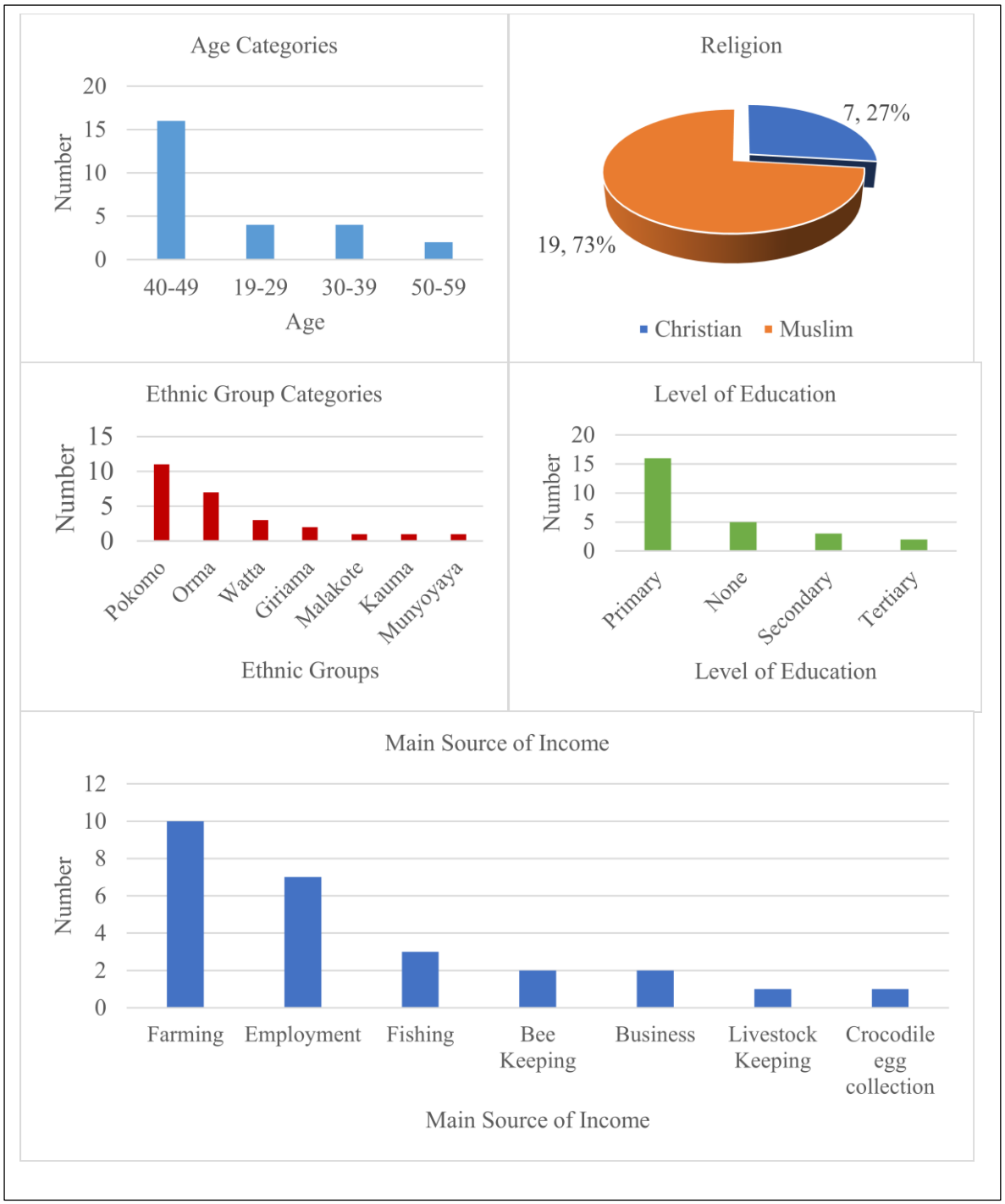

Figure 4.2: Demographic characteristics of the egg collectors

4.2 Socio-economic Factors Influencing Involvement in Crocodile Ranching-related Activities

Males (as opposed to females) were the most dominant gender in all the three categories of crocodile uses (neutral, illegal use and legal use); they comprised 65-94% of the respondents in all categories (Table 4.1). Survey participants from the Muslim religion were mainly in the neutral and the legal categories of crocodile use, while Christians dominated illegal use category (Table 4.1). Participants with primary level of education dominated in all the three crocodile use categories (45-59%; Table 4.1). Farming was the primary source of livelihood in all the three categories of crocodile use (65-96%; Table 4.1). Pokomo was the most dominant ethnic group, accounting for 63% of the participants.

Table 4.1: Socio-economic characteristics of household participants by crocodile use category

Socio-economic characteristics	Categories	Crocodile use category		
		Neutral (non-use) %	Illegal use %	Legal use %
Age category	19-29	18.8	8.4	41.2
	30-39	25.3	20.2	11.8
	40-49	20.5	26.1	35.3
	50-59	15.3	21.8	11.8
	>=60	20.1	23.5	0.0
Level of formal education	Primary	50.7	39.5	58.8
	Secondary	10.9	37.8	11.8
	Tertiary	5.2	16.0	11.8
	None	33.2	6.7	17.6
Annual income category	Below 250K	69.9	68.9	70.6
	250-500K	21.4	16.0	17.6
	501-750K	4.8	8.4	11.8
	Above750K	3.9	6.7	0.0
Gender	Male	65.1	70.6	94.1
	Female	34.9	29.4	5.9
Ethnic group	Pokomo	46.7	97.5	41.2
	Orma	32.8	0.0	47.1
	Watta	14.0	1.7	11.8
	Ilwana/ Malakote	6.6	0.8	0.0
Religion	Christian	15.3	87.4	11.8
	Muslim	84.7	12.6	88.2
Main source of income	Farming	41.9	59.7	64.7
	Livestock keeping	18.3	0.0	11.8
	Employment	13.5	19.3	5.9
	Business	11.4	10.1	5.9
	Others	14.8	10.9	17.7

Egg collection zone	Galaxy	35.4	26.1	23.5
	Kazuri	8.7	0.8	11.8
	Nile	55.9	73.1	64.7

Multinomial logistic regression analysis showed that age, annual income, gender, ethnic group, religion and main sources of livelihood significantly influenced (all p≤ 0.021) involvement in crocodile use, whereas education and egg collection zone had no significant influence (both (χ^2>0.002, df=1, p>0.0.082) on such involvement (Table 4.2 and Appendix R.1). Specifically, a unit increase in age increased the likelihood of being involved in illegal uses (as opposed to non-use) of crocodiles increased by 44% with increase in age, whereas it reduced the likelihood of engaging in legal use practices by 57% (both χ^2<9.3, df=1, p<0.017 Table 4.2). One unit increase in annual income doubled (χ^2=8.5, df=1, p=0.004) the likelihood of engaging in illegal uses but did not significantly alter (χ^2=0.7, df=1, p=0.421) the likelihood of engaging in legal uses. Key informant interviews and FGDs revealed that older participants are likely to have the needed courage and experience to undertake the risky and tough exercise of hunting crocodiles and searching for their nests unlike younger participants who have little or no experience. It was further revealed that the expectation and need for income and family responsibilities increase with age.

Additionally, a participant whose main source of livelihood was livestock keeping was 91% times less likely than those with other sources of livelihood (bee keeping, remittances from children and masonry) to be involved in legal uses (as opposed to non-use) of crocodiles (χ^2=4.048, df=1, p=0.044). However, there was no significant influence (χ^2< 0.1, df=1, p=0.996) of livestock keeping on the likelihood to engage in illegal uses. A male participant was five and 12 times more likely (χ^2>12.9, df=1, p<0.001 and χ^2=5.2, df=1, p=0.023) than a female to be involved in illegal and legal uses, respectively. Key informant interviews and FGDs revealed that harvesting crocodile eggs from nests, and hunting crocodiles are tasks that are largely performed by men.

Regarding religion, a Christian participant was 20 times more likely than a Muslim participant (χ^2=26.5, df=1, p=<0.001; Table 4.2) to be involved in illegal uses but not (χ^2< 0.6, df=1, p=0.441) legal uses of crocodiles. Key informant interviews and focus group discussions revealed that Muslims were prohibited from killing crocodiles and eating crocodile meat and eggs, and that violators were excommunicated. With regard to ethnicity, participants from the Pokomo and Orma participants were more likely than Ilwana/Malakote

participants to be involved in legal uses (as opposed to non-use) of crocodiles (χ^2>155.8, df=1, p<0.001) but not (χ^2=<0.2, p>0.718) illegal uses. Results from KIIs and FGDs showed that the traditional indigenous knowledge, beliefs and cultural practices of the Orma and Pokomo promoted human-crocodile co-existence. It was revealed that the Pokomo have a rich indigenous knowledge of the behaviour of crocodiles and have devised ways of co-existing with crocodiles. Focus group discussions and KIIs revealed that it was due to the Orma's belief that their prosperity was connected with the river (River Tana) and its animals, including crocodiles, that they protected the river ecosystem. Education and egg collection zone were not significant (all χ^2>0.19, df=1, p>0.082) for involvement in either legal or illegal uses of crocodiles.

Key informant interviews (KII) and focus group discussions (FGDs) revealed that engagement in illegal crocodile utilization practices differed across and within ethnic groups. Specifically, it was revealed that engagement in hunting crocodiles and harvesting of crocodile eggs was practiced by a section of the Pokomo ethnic group due to body protein needs, pride and identity, and medicinal and virility values and it was locally considered normal. One of the Galaxy egg collectors stated, "not all Pokomos eat crocodile meat. *Mila Chini* Pokomos who live at the areas of Garsen going down the river eat the meat and eggs". It was revealed that such illegal practices were not practiced among Orma, Watta and Ilwana/ Malakote. In addition, it was revealed that Muslims are prohibited from killing crocodiles and eating crocodile meat and eggs, and that violators are excommunicated. A discussant from Sala FGD summed up this view by stating, "crocodiles are *haram* as per Islam and therefore we are not allowed to kill them or eat their meat or eggs".

Table 4.2: Effects of various socio-economic factors on the likelihood of involvement in different categories of crocodile uses

Categories of crocodile uses	Socio-economic Factors	Coefficient	Std. Error	Wald χ^2	Sig.	Odds Ratio
Illegal uses	Age	.367	.153	5.733	0.017	1.443
	Annual income	.806	.277	8.470	0.004	2.239
	Gender (Male)	1.529	.428	12.781	<0.001	4.615
	Religion (Christian)	2.996	.582	26.494	<0.001	19.996
	Ethnic group (Pokomo)	.442	1.224	.130	0.718	1.555
	Ethnic group (Orma)	-19.236	2537.59	.000	0.994	0.000
	Ethnic group (Watta)	-2.355	1.486	2.512	0.113	0.95
	Main source of income (Livestock keeping)	-15.386	3022.3	.000	0.996	0.000
	Education	-.119	.187	.402	0.526	0.888
	Egg collection zone (Galaxy)	-.875	.502	3.033	0.082	0.417
	Egg collection zone (Kazuri)	-1.825	1.206	2.288	0.130	.161
Legal uses	Age	-.854	.281	9.256	0.002	.426
	Annual income	0.295	.367	.649	.421	.744
	Gender (Male)	2.499	1.097	5.191	0.023	12.175
	Religion (Christian)	0.901	1.169	.594	.441	2.462
	Ethnic group (Pokomo)	18.928	1.516	155.809	<0.001	$1.66x10^8$
	Ethnic group (Orma)	20.804	.971	458.652	<0.001	$1.08x10^8$
	Ethnic group	19.563	0.000	.	.	$3.13x10^9$

(Watta)					
Main source of income (livestock keeping)	-2.400	1.193	4.048	.044	0.091
Education	-.010	.247	.002	0.969	0.990
Egg collection zone (Galaxy)	.511	1.296	.156	0.693	0.132
Egg collection zone (Kazuri)	.583	1.587	.135	.713	1.792

4.2.1 Human-induced Threats to Crocodile Ranching-related Activities

Key informants and focus group discussants identified two major anthropogenic threats to crocodile habitat, namely, expansion of agricultural activities and overutilization of natural resources along the river (Plate 4.1- a, b and c). It was revealed that these human activities were major sources of disturbances to crocodiles and their habitats, especially nesting sites. Key informants indicated that crocodile habitat in some areas like the Tana Delta was still in relatively good condition. They however expressed fear that this state would not last for long because livestock keepers were increasingly shifting to crop cultivation, a practice that results in clearance of crocodile habitat.

Other harmful practices identified by key informants and focus group discussants included killing of crocodiles through poisoning (Plate 4.1d), spearing and trapping, and destruction of crocodile egg nests by livestock keepers to retaliate against livestock losses caused by crocodiles (Plate 4.1 f). For instance, some of the discussants revealed that crocodiles are commonly poisoned using *Aloe ruspoliana* plant (locally called "*rasai*'). The leaves are cut into small pieces and wrapped in a skin and placed at the crocodile basking sites along the river banks as baits (Plate 4.1d and e) for crocodiles to die when they swallow this poison thinking it is meat. Several such baits were sighted during nest mapping in one of the egg collection zones studied. It was also revealed that some livestock keepers kill crocodiles using poisoned meat in the areas where livestock drink water. Key informant interviews revealed that no compensation had been paid for any reported and verified livestock depredation by crocodiles.

It was revealed that fishermen use fishing rods to capture crocodiles. Once a crocodile swallows the rod, it is pulled out of the water, speared to death and its meat used as fishing

bait. Further, it was revealed that some fishermen tie crocodile meat to fishing nets which entangle crocodiles, making them easy to be caught, killed and used as fishing bait. Some livestock keepers were sighted opening up nests and destroying eggs with pangas (machettes) (Plate 4.1f). The key informants also identified the consumption of crocodile eggs and meat by some community members as a threat to crocodiles in the study area due to reduction of the number of eggs available for harvesting by crocodile ranches. These positions were stated as follows:

> "*The crocodiles lay eggs at the same time and egg collection must be done quickly since I compete with Pokomos and monitor lizards for the eggs. I now have less and less to do with Pokomos because there are no eggs available for collection in their areas*". (Manager- Nile Crocodiles Limited).

The key informants and group discussants were all of the general opinion that the number of breeding crocodiles has declined over the years. One of the key informants asserted that "in the year 2005, it was possible for one egg collector to get 2000 eggs but now even an intense search may not yield 300 eggs". Key informant interviews and FGDs generally associated the declines in numbers with the aforementioned threats to crocodiles.

Plate 4.1: An illustration of human activities along lower River Tana

(a) and (b)- an island on the river now encroached for crop cultivation but hitherto considered a refuge for crocodile breeding; (c) sand harvesting at the river; (d) poison wrapped in goat skin at the riverbank targeted at crocodiles. (e) *Aloe ruspoliana* plant, locally called "*rasai*' used to poison crocodiles; (f) crocodile nest destroyed using machetes. Own pictures

4.2.2 Extent of Illegal Uses of Crocodiles

Eating of crocodile meat and eggs were the most common illegal uses of crocodiles, with 31% and 27% of household survey respondents reporting being engaged in these practices, respectively (Figure 4.3). However, other illegal practices, namely, using crocodile meat for fishing, selling crocodile eggs to villagers, selling crocodile meat to villagers for consumption and selling crocodile meat to fishermen, were far much less common: less than 3% of the participants reported being involved in each of these practices (Figure 4.3).

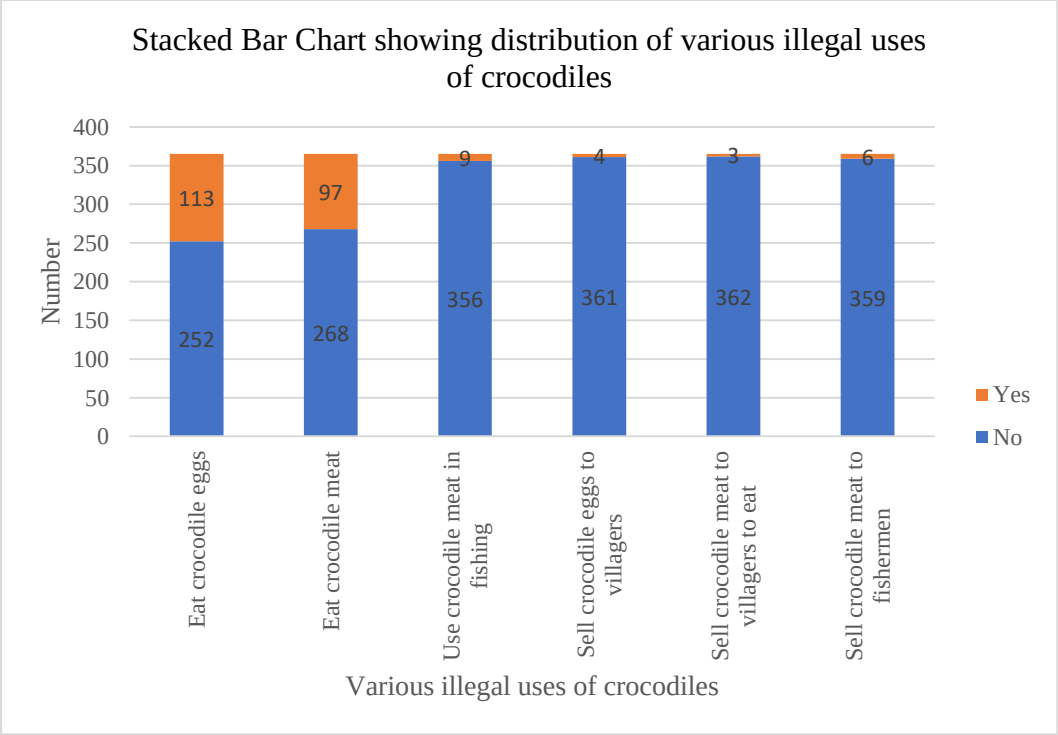

Figure 4.3: Number of households engaged in various illegal uses of crocodiles

The number of crocodile eggs eaten in 106 households during the 2017/2018 season totaled 416, giving a mean of 3.9 eggs ± 8.6 (SD) per household. Only one participant reported selling eggs to villagers during the 2017/2018 egg collection season with a total of 70 eggs being sold. A majority (>66%) of households in the three egg collection zones reported that they did not 1) eat crocodile eggs, 2) use crocodile meat as bait for fishing, and, 3) sell crocodile meat to fishermen for use as fishing baits during the year 2018 (Figure 4.4). Further, a vast majority (>94%) of the households at both Galaxy and Nile egg collection zones reported that they rarely ate crocodile meat during the year 2018. No crocodile egg and meat eating or use of crocodile meat for fishing was reported at Kazuri egg collection zone.

Approximately 17% and 21% of households in Galaxy and Nile egg collection zones, respectively, ate one to five crocodile eggs, whereas less than 5% of households in these egg collection zones ate more than 5 eggs during the 2018/2019 egg collection season. Little quantities (below 5 kg) of crocodile meat were used by participating households as bait for fishing (<1% of households in both Galaxy and Nile egg collection zones) during the year 2018. Selling of crocodile meat below 5 kg to fishermen to use as fishing bait was reported only at the Nile egg collection zone (<1% of households).

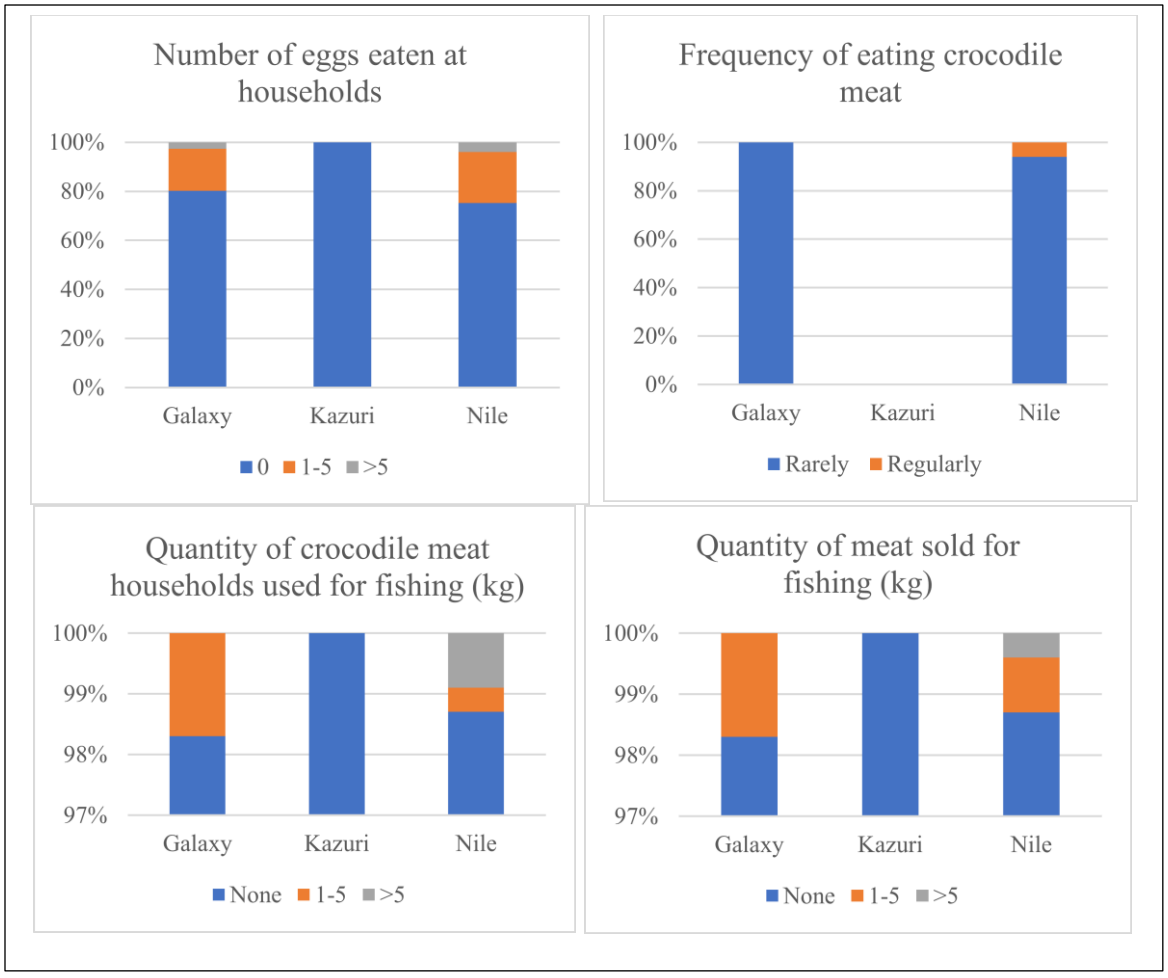

Figure 4.4: Illegal uses of crocodiles by egg collection zone during the 2017/2018 crocodile breeding season

4.3 Local Community Perceptions Towards Involvement in Crocodile Ranching-related Activities

4.3.1 Influence of Perceptions on Involvement in Crocodile Ranching-related Activities

Overall, the majority of the participants were not concerned about crocodile use. Only 6% of the participants perceived benefits derived from crocodile ranching-related activities (Table 4.3). Out of these, 25% participants were in the legal use category. Overall, the perceptions of opportunities to participate in crocodile ranching-related activities were high *n*=189 (51.8%), with 45% being involved in illegal use of crocodiles and 5.3% of the participants in legal uses. Overall, 63.3% of the participants had high levels of tolerance towards crocodiles, with 5.7% being involved in legal uses and 45.5% in illegal uses.

Table 4.3: Various perceptions of household survey participants and different crocodile use categories

Perceptions and tolerance	Responses	Crocodile use categories			Total %
		Neutral (non-use) %	Illegal use %	Legal use %	
Perceived incentives and benefits	Disagree	57.8	39.9	2.3	65.8
	Neutral	70.6	24.5	4.9	27.9
	Agree	55.0	20.0	25.0	6.3
Opportunities to participate in crocodile ranching	Low	96.2	1.9	1.9	14.5
	Neutral	69.5	25.8	4.7	35.1
	High	49.7	45.0	5.3	51.8
Level of tolerance towards crocodiles	Low	90.9	6.1	3.0	18.1
	Neutral	82.4	14.7	2.9	18.6
	High	48.9	45.5	5.7	63.3

Multinomial logistic regression analysis showed that perceived incentives and benefits derived from crocodile ranching as well as tolerance towards crocodiles significantly influenced the likelihood of engagement in different categories of crocodile uses, both $p<0.05$ (Appendix R.2). Participants who perceived incentives and benefits derived from crocodile ranching were less likely (χ^2 = 8.1, df=1, p=0.004; Table 4.4) to be involved in illegal uses but more likely (χ^2 = 14.8, df=1, $p<0.001$) to be involved in legal uses of crocodiles (as

opposed to non-use) of crocodiles. Further, participants who had high levels of tolerance towards crocodiles were more likely to be involved in illegal uses (as opposed to non-use) of crocodiles, χ^2 = 29.3, df=1, p<0.001. However, perception of opportunities to participate in crocodile ranching activities were not a significant predictor for participants' engagement in the different categories of crocodile uses (all, χ^2>1.2, df=1, p>0.110; Table 4.4).

Table 4.4: Effects of perceived incentives and benefits, awareness of opportunities to participate in crocodile ranching activities and tolerance towards crocodiles on the likelihood of influencing involvement in different categories of crocodile uses

Categories of uses	Perceptions and tolerance	Coefficient	Std. Error	Wald χ^2	Sig.	Odds Ratio
Illegal uses of crocodiles	There are incentives and benefits derived from crocodile ranching activities	-0.581	0.204	8.085	0.004	0.559
	There are opportunities to participate in crocodile ranching activities	0.202	0.185	1.197	0.274	1.224
	Tolerance towards crocodiles	1.084	0.200	29.248	<0.001	2.957
Legal uses of crocodiles	There are incentives and benefits derived from crocodile ranching	1.254	0.326	14.825	<0.001	3.505
	There are opportunities to participate in crocodile ranching activities	0.631	0.395	2.549	0.110	1.879
	Tolerance towards crocodiles	-0.286	0.362	0.626	0.429	0.751

4.3.2 Influence of Perceived Uses of Crocodiles Towards Involvement in Crocodile Ranching-related Activities

Most (53-99%) of the study participants in all the three crocodile use categories did not perceive most of the various uses of crocodiles as ways crocodiles could be used (Table 4.5). The perception among the majority (86%) of the participants in the illegal use category that crocodile meat obtained from the wild could be eaten was however an exception. Further, a majority (88%) of participants in legal-use category perceived that crocodile meat from the wild can be used as fishing bait and a majority (88%) of participants in legal use category perceived that crocodile eggs could be collected for ranches.

Table 4.5: Household survey participants perceived uses of crocodiles and crocodile use categories

Perceived crocodile uses	Response	Categories of crocodile uses		
		Neutral (non-use) %	Illegal uses %	Legal uses %
Crocodile meat from the wild	No	69.9	14.3	52.9
can be eaten	Yes	30.1	85.7	47.1
Crocodile meat from the wild	No	95.6	87.4	11.8
can be used as fishing bait	Yes	20.5	18.5	88.2
Collecting eggs for ranches at a	No	79.5	81.5	11.8
fee	Yes	20.5	18.5	88.2
Ranch hatchlings and sell meat	No	94.3	86.6	76.5
	Yes	5.7	13.4	23.5
Ranch hatchlings and rear to sell	No	93.9	84.9	76.5
skins	Yes	6.1	15.1	23.5
Sell meat from hunted crocodiles	No	96.5	94.	94.1
to community	Yes	3.5	5.9	5.9
Sell wild crocodile eggs to	No	97.8	93.3	100.0
community	Yes	2.2	6.7	0.0
Crocodiles are a tourism	No	88.6	63.9	70.6
attraction	Yes	11.4	36.1	29.4
Crocodile skins used to make	No	91.7	72.3	64.7
items	Yes	8.3	27.7	35.3
Crocodile teeth make ornaments	No	98.7	95.8	94.1
	Yes	1.3	4.2	5.9
Crocodile bile is used as poison	No	96.1	85.7	94.1
	Yes	3.9	14.3	5.9

The multinomial logistic regression showed that perceptions that crocodile eggs obtained from the wild at a fee for ranches, can be eaten and crocodiles being a tourism attraction were all found to significantly influence involvement in crocodile ranching-related activities (all $p<0.001$; Appendix R.3). Specifically, participants who perceived that crocodile eggs harvested from the-wild could be eaten were 42 times more likely ($\chi^2 = 46.7$, df=1, $p<0.001$;

Table 4.6) to be involved in illegal uses of crocodiles (as opposed to non-use) of crocodiles. However, the perception that crocodile eggs harvested from the wild could be eaten marginally influenced participants' involvement in legal uses (χ^2=4.1, df=1, p=0.043).

Further, participants who perceived that crocodile eggs could be collected for ranchers at a fee were 20 times more likely (χ^2 = 13.4, df=1 p<0.001) to be involved in legal uses and 69% less likely (χ^2 = 6.5, df=1; p=0.011) to be involved in illegal uses (as opposed to non-use) of crocodiles. Participants who perceived that crocodiles could be used as a tourism attraction were 7.5 times likely crocodiles (χ^2= 14.8, df=1, p<0.001) to be involved in illegal uses (as opposed to non-use) of crocodiles. However, the influence of the perception that crocodiles could be used as a tourism attraction did not significantly influence the likelihood of perceiving crocodiles as a tourist attraction. The perceptions that Crocodile meat can be used as fishing bait, crocodile nests can be located for the ranches at a fee, crocodile eggs can be incubated and hatchlings sold to ranches, hatchlings can be reared into slaughter age and their meat and skins sold, crocodile skins used to make leather items for sale and crocodile bile could be used as poison had no significant influence χ^2 > 0.001, df=1 p>0.086; Table 4.6) on the likelihood of the participants involvement in either legal or illegal uses of crocodiles.

Table 4.6: Influence of perceptions of various crocodile uses on involvement in crocodile ranching-related activities

		Coefficient	Std. Error	Wald χ^2	Sig.	Odds Ratio
Legal uses	Crocodile eggs can be eaten (Yes)	1.713	.845	4.111	0.043	5.547
	Crocodiles are a tourism attraction (Yes)	0673	.771	.763	0.382	1.961
	Collecting eggs for ranches at a fee (Yes)	3.018	.824	13.418	<0.001	20.453
Illegal uses	Crocodile eggs can be eaten (Yes)	3.738	.547	46.714	<0.001	42.002
	Collecting eggs for ranches at a fee (Yes)	-1.156	.452	6.544	0.011	.315
	Crocodiles are a tourism attraction (Yes)	2.009	.523	14.750	<0.001	7.457

Focus group discussants in Hewani revealed mixed perceptions towards opportunities for local communities to participate in crocodile ranching and the egg collection programme. Some felt that they did not have the technical expertise needed in incubating eggs and taking care of hatchlings. Discussants in Sala indicated that local people were not aware of the opportunity for egg collection and the possibility to incubate eggs, rear hatchlings and slaughter crocodiles for sale of skins. Egg collectors from the Nile zone felt that the cost involved in crocodile ranching was beyond their means and they also did not have sufficient knowledge of the market for the products. In addition, they cited lack of electricity for heating water in crocodile ponds at night, logistical difficulties and high cost of getting and transporting crocodile feeds. Some of the discussants' opinions on awareness of opportunities for crocodile ranching are reflected in the following quotes:

> "*How will you feed the hatchlings? What do they eat*?" (Hewani focus group discussion for household heads).

"*We hear boats moving up and down during the crocodile breeding season but none of us is involved. Unfortunately, the majority of the local people do not know about this opportunity. The few who know do not share information*." (Sala focus group discussion for household heads).

"*When you keep animals, you want to sell them at some point and get money. If we rear crocodiles, we can only take them back to the river because we do not know where we may sell them. We do not know where to market crocodiles*." (Nile Crocodiles egg collectors).

Egg collectors suggested that they could optimize their benefits from crocodile ranching by forming community-based organizations and if they are permitted by KWS to collect crocodile eggs and sell to the ranchers. Some egg collectors indicated that they had worked in the field incubation units for the crocodile ranches and thus had some skills and experience in incubating eggs and taking care of hatchlings. They also indicated that they were able to train other members of the local community in crocodile ranching. A manager at one of the crocodile ranches recommended the establishment of small-holder community groups to collect eggs, incubate them and sell hatchlings to ranchers despite the difficulties that communities may have in assuring quality standards.

key informant from one of the local organizations noted that some local community members in upstream areas did not perceive that crocodile eggs could be sold to ranchers, something which limited local community benefits from the egg collection programme. The key informant further recommended increased deliberate efforts in sensitizing local people. Further, it was revealed that residents of Hewani had not benefitted much from the egg collection programme since the river changed its course at Mnazini.

Key informants from Tana River County asserted that all land in the County was unadjudicated. However, they indicated that the County was in the process of documenting traditional claims and rights by different clans, families and tribes occupying different areas of Tana River County in order to register them as required in the new Community Lands Act of 2016. They asserted that local people interested in using land for crocodile ranching or other purposes could request the County Government for allotment through the elders and chief. However, they averred that such requests had not been made by the time of the

interview. The key informants also indicated that the County Government also helps the local people register community-based organizations in order to engage in various projects of their choice, including crocodile nature-based enterprises. The County Director for Environment affirmed that poverty levels and low technical know- how among the local people hindered local people from engaging in any other activity in the crocodile ranching value chain apart from collecting eggs and selling them to the ranchers.

4.3.3 Local Communities Initiatives to Coexist with Crocodiles

Focus group discussions (FGDs) revealed that the Pokomo community have knowledge of the behaviour of crocodiles and have devised ways of coexisting with crocodiles. Some of the discussants averred that "*crocodiles do not just attack a person; they study their victim's behaviour and attack when least expected or when the victim is not alert*". They advised people to be careful when they are at the river as crocodiles are dangerous.

> *"Crocodiles conceal themselves in water, leaving only the eyes out and can be mistaken for floating logs. People are advised to be careful when at the river. When crossing the river, the person needs make noise, like hitting the water. The crocodiles will hear the noise made by hitting the water with a rod and disappear since they are known to keep away from disturbances"* (Hewani household heads).

The FGDs also revealed that the Malakote/ Ilwana people in Sala area had knowledge of the suitable areas for crocodile nesting: (that is, soft sandy soils) which they preserved these areas since they are not suitable for crop cultivation. They also revealed that "all crocodiles disappear from a site in which one of them had taken a human being due to fear of fury and retaliation from crowds looking for them", and that "the crocodiles do not flee from an area when they take livestock".

During key informant interviews and FGDs with egg collectors it was established that local people had observed that crocodiles hunted early in the morning between 6 to 8 am and late in the evening. Consequently, they indicated that people should be advised to be careful when at the river at these times. Based on their belief that crocodiles need to eat more food during the hot season between September and March, they advised that people should avoid going to the river during the hot season. The egg collectors further averred that local people

should reduce their reliance on and visits to the river if they were to be safe and crocodiles were to continue surviving.

> *"Where I stay, people are taken mostly during the dry season in the evenings. In order for us to be safe and the crocodiles to continue surviving, we are supposed to reduce our reliance and visits to the river. Too much contact with the river exposes one to the danger of crocodiles"* (One of Galaxy egg collectors)

Group discussions with egg collectors also revealed that the Orma livestock keepers construct barriers using sharp sticks which are stuck to the floor of the river and joined using binding wire to protect livestock from crocodile attacks. Some of the egg collectors felt that only a few people benefitted from the egg collection programme while the rest of the community hated crocodiles due to the losses they cause.

> *"Other than the few people here who benefit from egg collection, the rest of the community hates crocodiles. Personally, although I get benefits from egg collection, I would be happy to congratulate someone who kills a crocodile. This is because the crocodile eats my livestock too and I do not get paid compensation. The crocodile can kill a member of my family"* (Nile Crocodiles egg collectors).

Group discussions with egg collectors revealed that cattle keepers from the Wardei community had low tolerance towards crocodiles, and that "it was not unusual to find seven to twenty crocodile carcasses floating in the river in the morning after eating poisoned meat". However, some egg collectors revealed from the same zone revealed the cultural importance of crocodiles:

> "*Among the Orma, the river is not complete without the hippo and crocodile in it. We even have a song in praise of the crocodile. Ormas will not be able to live and prosper without the crocodiles (nyacha). Ormas do not want crocodiles being exterminated from River Tana. We believe if this happens, the river will dry up*" (Nile Crocodiles egg collectors).

The egg collectors indicated that they educated local members of the community on the need to conserve crocodiles. Further, they indicated that they negotiated with the ranchers to construct boreholes in the villages to reduce human- crocodile contacts.

> "*We formed a conservancy group to tell villagers to stop poisoning crocodiles and how to co-exist with crocodiles. Such groups are very helpful, not local norms, sanctions or rules or governance structures*" (Nile Crocodiles egg collectors)

Some key informants from local organizations revealed that one of the purposes of crocodile ranching is to encourage human-crocodile coexistence in order to enhance tolerance towards crocodiles. They indicated that through crocodile ranching, communities have been able to get benefits from the egg collection programme and this had helped in having communities appreciate and coexist with the crocodiles. Whereas they acknowledged that loss of life through conflict caused by the crocodiles is still a serious problem, they believed that the situation is better than it used to be before crocodile ranching was allowed. One of the key informants opined,

> "*The communities have realized that in as much as crocodiles kill, they are also beneficial. They recognize that the egg harvesting programme helps reduce the crocodile population as well as crocodile attacks*."

The key informants from local organizations also revealed that the tolerance of the local people towards crocodiles is higher in the areas where egg collection is being done. One of them averred, "Here, the local people get benefits from crocodile ranching and therefore have high levels of awareness and there is little or no poisoning of crocodiles". However, the key informants opined that "there is less tolerance towards crocodiles in the upper areas of the river where the benefit to the communities is not well structured". The key informants further indicated that there was more poisoning of crocodiles and destruction of nests especially in the areas occupied by livestock keepers since KWS was not paying any compensation for livestock losses. One of them said:

> "*Tana River is a dry County and the livestock keepers want to water their livestock and they see the crocodiles as a big enemy to their livestock and themselves and as a result, the crocodiles are being killed*."

However, some key informants indicated that there is more tolerance towards crocodiles among livestock keepers at the Tana Delta due to payment of benefits to the local people.

4.3.4 Action Taken When Crocodiles Attack People and Livestock

The various actions taken by household survey participants in response to crocodile attacks on people and their livestock are presented in Table 4.7. The study participants indicated that the local communities mainly (over 61%) reported to KWS when crocodiles caused human injuries and death. However, 53% of the participants indicated that local communities mainly took no action when crocodiles caused livestock losses while 36% reported to KWS.

Table 4.7: Action taken by study participants when crocodiles attack people and livestock

Type of crocodile attack	Action taken	N	%
Crocodile causing human injury	Report to KWS	222	60.8
	Report to Police	18	4.9
	Take injured person to hospital	111	30.4
	Report to Chief	10	2.7
	Kill the crocodile	2	0.6
	Take no action	2	0.6
Total		**365**	**100.0**
Crocodile causing human death	Report to KWS	301	82.5
	Report to Police	23	6.3
	Report to Chief	10	2.7
	Kill the crocodile	27	7.4
	Take no action	4	1.1
Total		**365**	**100.0**
Crocodile causing livestock loss	Report to KWS	131	36.0
	Report to Police	3	0.8
	Report to Chief	26	7.1
	Kill the crocodile	11	3.01
	Take no action	194	53.1
Total		**365**	**100.0**

4.4 Institutional Factors Influencing involvement in crocodile ranching-related activities and Performance of Crocodile Ranching-related Activities

4.4.1 Norms and sanctions about crocodiles and their influence on crocodile ranching-related activities

Most (>82%) of the participants in both the neutral (non-use) and legal crocodile use categories reported that the practices of eating crocodile eggs and eating crocodile meat were not viewed as acceptable, whereas most (>80%) of those in the illegal use category reported that these practices were acceptable (Table 4.8). Most (62-93%) of participants in each of the

three crocodile use categories reported that hunting crocodiles and selling their meat was not viewed an acceptable practice (Table 4.8). Whereas most (60-77%) of participants in the legal and illegal use categories reported that killing a crocodile which had killed or injured someone was considered acceptable, most of those in the non-use category reported otherwise (Table 4.8). However, most (88-95%) of participants in each of the three crocodile use categories reported that destruction of crocodile egg nests was not viewed as an acceptable practice (Table 4.8).

Table 4.8: Norms and views of acceptable behaviour towards crocodiles and crocodile uses

		Crocodile use categories		
Norm	Response	Neutral (non-use) (%)	Illegal uses (%)	Legal uses (%)
Eating crocodile meat is normal	Yes	7.9	80.7	11.8
	No	92.1	19.3	88.2
Eating crocodile eggs is normal	Yes	10.5	89.9	23.5
	No	93.4	62.2	82.4
Hunting crocodiles and selling their meat is normal	Yes	6.6	37.8	17.6
	No	93.4	62.2	82.4
Killing a crocodile which has killed or injured someone is normal	Yes	48.0	59.7	76.5
	No	52.0	40.3	23.5
Destroying crocodile egg nests is normal	Yes	5.2	10.1	11.8
	No	94.8	89.9	88.2

Multinomial logistic regression analysis revealed that norms regarding various crocodile use practices significantly influenced involvement in crocodile use (p=0.035; Table 4.9 and Appendix R.4). Specifically, participants who viewed the eating of crocodile meat hunted from the wild was normal were 5.4 times more likely to be involved in illegal uses (as opposed to non-use) of crocodiles (χ^2 = 9.210, df=1, p=0.002; Table 4.9). Similarly, participants who viewed eating crocodile eggs harvested from the wild as normal were 24.9 times more likely to be involved in illegal uses (χ^2=40.933, df=1, p<0.001). Further, participants who viewed hunting crocodiles and selling their meat as normal were 3.9 times more likely to be involved in illegal uses of crocodiles (χ^2= 6.5, df=1, p=0.01). Participants

who viewed destroying crocodile nests as normal were less likely to be involved in illegal uses of crocodiles (as opposed to non-use) (χ^2 = 3.98, df=1, p=0.05; Table 4.9). On the other hand, participants views on hunting crocodiles and selling their meat and killing a crocodile which had killed or injured someone as normal did not influence their likelihood of being involved in illegal uses (as opposed to non-use) of crocodiles (all χ^2 >0.42, df=1, p>0.05; Table 4.9). Similarly, participants' views on hunting crocodiles and selling their meat, eating crocodile meat obtained from the wild, eating crocodile eggs obtained from the wild, and hunting crocodiles and selling their meat and destroying crocodile egg nests did not influence their likelihood of being involved in legal uses (as opposed to non-use) of crocodiles (all χ^2> 0.01, df=1, p>0.07; Table 4.9).

Discussants in the Nile egg collection zone and at Sala village revealed certain sanctions backed by Islam religion customs and sanctions among the Orma, Watta and Ilwana/ Malakote which were used to protect crocodiles and the river. Islam prohibits the killing and eating of crocodile eggs and meat and provides for the sanctioning of deviants by banning them from entering the mosque and refusing to accord them religious funeral rites when they die. It was said that such sanctions were effective in preventing anyone from engaging in harmful practices against crocodiles. According to the customs of the Orma, the river is not complete without crocodiles and hippopotamuses in it and their prosperity is intertwined with crocodiles, "*nyacha*".

Table 4.9: Influence of norms on acceptable behaviour towards crocodiles on involvement in crocodile uses

Categories of uses	Norms	Coefficient	Std. Error	Wald χ^2	Sig.	Odds Ratio
Illegal uses	Eating crocodile meat hunted from the wild is normal	1.680	.553	9.210	0.002	5.364
	Eating crocodile eggs obtained from the wild is normal	3.213	.502	40.933	<0.001	24.860
	Hunting crocodiles and selling their meat is normal	1.365	.535	6.504	0.011	3.916
	Killing a crocodile which has killed or injured someone is normal	-.298	.424	.494	0.482	.742
	Destroying crocodile egg nests is normal	-1.380	.692	3.980	0.046	.252
Legal uses	Eating crocodile meat hunted from the wild is normal	-1.221	1.178	1.076	0.3	.295
	Eating crocodile eggs obtained from the wild is normal	1.269	.846	2.251	0.134	3.558
	Hunting crocodiles and selling their meat is normal	.103	1.004	.011	0.918	1.108
	Killing a crocodile which has killed or injured someone is normal	1.107	.611	3.288	0.070	3.026
	Destroying crocodile egg nests is normal	.391	.942	.173	.678	1.479

4.4.2 How the Community Addresses Unacceptable Behaviour Towards Crocodiles

Data on how participants addressed unacceptable behaviour towards crocodiles are presented in Table 4.10. The results indicate that a majority (56%) of the respondents did nothing when a member of the community committed an unacceptable behaviour or action

against crocodiles. Others indicated that they consulted the council of elders (11%), gave warning (9%), informed KWS (7%) and reported to the chief (10%). Several other avenues were mentioned less commonly (< 5%).

Table 4.10: How community addresses unacceptable behaviour towards crocodiles

How community addresses unacceptable behavior towards crocodiles	Egg collection zone			
	Galaxy (%)	Kazuri (%)	Nile (%)	Row Total (%)
Community does nothing	27	7	66	55.9
Advising that person on how to take care of crocodiles	19	0	81	4.4
Warning	38	9	53	8.8
Consult council of elders	46	0	54	11.2
Excommunicate that person	30	0	70	2.7
Report to Chief	40.1	13.5	45.9	10.1
Inform KWS	33	4	63	6.6
Curse that person	0	0	100	0.3

Key informants and focus group discussants revealed the application of religious sanctions among Muslims which include reporting the person to the village elders or chief, to warning the person, banning the person from entering the mosque and being denied burial rites. The key informants and discussants indicated an absence of religious sanctions in areas occupied by Christians against persons who engaged in illegal uses of crocodiles and harmful practices against crocodiles.

4.4.3 Influence of Awareness of Legally Accepted Ways of Using Crocodiles on Involvement in Crocodile Ranching-related Activities

Overall, a majority (all over 53%) of the study participants from the three categories of crocodile use (non-use, legal and illegal) were not aware that crocodiles are a tourism attraction (Table 4.11). Further, the majority of the participants from both the neutral and the illegal use categories were not aware that crocodile ranching (both >65%) and harvesting and selling crocodile eggs to ranches (both > 58%) were legally acceptable. However, the

majority (both over 64%) of participants in the legal use category were aware of these two uses.

Table 4. 11: Household survey participants awareness of legally accepted ways of using crocodiles and involvement in crocodile ranching-related activities

Awareness of legally accepted crocodile uses	Response	Neutral (non-use) %	Illegal uses %	Legal uses %
Crocodile ranching is legally acceptable	No	81.7	65.5	35.3
	Yes	18.3	34.5	64.7
Harvesting and selling eggs to ranches is legally acceptable	No	72.9	58.8	5.9
	Yes	27.1	41.2	94.1
Crocodiles are a tourism attraction	No	84.3	53.8	58.8
	Yes	15.7	46.2	41.2

Multinomial logistic regression analysis showed that the awareness of legally accepted ways of using crocodiles significantly influenced involvement in crocodile use ($p<0.001$; Table 4.12 and Appendix R.5). Participants who were aware that harvesting and selling crocodile eggs to ranchers was legally acceptable were 28.8 times more likely to be involved in legal uses (as opposed to non-use) of crocodiles ($\chi^2 = 9.48$, df=1, $p=0.002$; Table 4.12). However, participants who were aware that crocodiles are a tourism attraction were 4.1 times likely to be engaged in illegal uses (as opposed to non-use) of crocodiles ($\chi^2 = 25.47$, df=1, $p<0.001$; Table 4.12).

Table 4.12: Influence of survey participants' awareness of various legally acceptable uses of crocodiles on involvement in crocodile ranching-related activities

Category of use	Awareness of various legal uses of crocodiles	Coefficient	Std. Error	Wald χ^2	Sig.	Odds Ratio
Legal uses	Crocodile ranching is legally acceptable (Yes)	.585	.589	.986	0.321	1.795
	Harvesting and selling eggs to ranches is acceptable (Yes)	3.362	1.092	9.483	0.002	28.843
	Crocodiles are a tourism attraction (Yes)	.404	.562	.518	0.472	1.498
Illegal uses	Crocodile ranching is legally acceptable (Yes)	.306	.334	.841	0.359	1.358
	Harvesting and selling eggs to ranches is acceptable (Yes)	.083	.307	.073	0.787	1.086
	Crocodiles are a tourism attraction (Yes)	1.399	.277	25.466	<0.001	4.051

Reference category for categories of use was "Neutral". Reference category for the predictor variable was "No".

4.4.4 Influence of Awareness of Rules and Regulations of Crocodile Ranching on Involvement in Crocodile Ranching-related Activities

Overall, a vast majority (>80%) of the study participants, were aware of the various rules and regulations for crocodile ranching (Table 4.13). In all cases, the number of study participants who were not aware of the various rules was more (ranging from 1 to 20%) among the neutral category as compared to the category of participants involved in illegal uses (ranging from 1 to 14%). Overall, the greatest proportion (>94%) of participants who were aware of the various rules of crocodile ranching were those involved in legal uses of crocodiles.

Table 4.13: Household survey participants' awareness of various rules and regulations for crocodile ranching-related activities

Rules and regulations for crocodile ranching	Response	Neutral (non-use) (%)	Illegal uses (%)	Legal uses (%)
Aware harvesting crocodile eggs from the wild for domestic consumption is illegal	No	10.5	7.6	5.9
	Yes	89.5	92.4	94.1
Aware hunting crocodiles for domestic consumption is not allowed by law	No	11.4	5.0	5.9
	Yes	88.6	95.0	94.1
Aware hunting crocodiles for meat for fishing is illegal	No	17.0	12.6	5.9
	Yes	83.0	87.4	94.1
Aware poisoning of crocodiles is not allowed by law	No	19.7	14.3	11.8
	Yes	80.3	85.7	88.2
Aware capturing crocodiles from the wild is illegal	No	14.4	10.9	5.9
	Yes	85.6	89.1	94.1
Aware crocodile meat and eggs from crocodile farms can be eaten	No	11.4	2.5	5.9
	Yes	88.6	97.5	94.1
Aware license is needed before harvesting crocodile eggs	No	2.2	0.8	5.9
	Yes	97.8	99.2	94.1
Aware license for crocodile ranching is needed	No	1.3	0.8	0.0
	Yes	98.7	99.2	100.0

Multinomial logistic regression revealed that participant's awareness of rules and regulations of crocodile ranching significantly influenced involvement in crocodile ranching-related activities (both $p<0.012$; Appendix R.6). Specifically, participants who were aware that crocodile meat and eggs from the crocodile farms can be eaten were 5 times more likely to be involved in illegal uses (as opposed to non-use) of crocodiles than participants who were not aware of these rules ($\chi^2= 6.062$, df=1, $p=0.014$; Table 4.14). Further, participants who were aware that a license was needed before harvesting crocodile eggs were more likely to be involved in illegal uses than participants who were not aware of this rule ($\chi^2=132.031$, df=1, $p<0.001$; Table 4.14). Participants' awareness that hunting crocodiles for meat to use as fishing bait, poisoning of crocodiles is not allowed by law, capturing of crocodiles from the wild is illegal, a license for crocodile ranching is needed did not influence their likelihood of involvement in illegal uses (as opposed to non-use) of crocodiles (all $\chi^2 > 0.047$, df=1, $p>0.363$; Table 4.14). Participants' awareness that hunting crocodiles for meat for fishing is illegal, poisoning crocodiles is not allowed by law, and that a license for crocodile ranching is needed did not influence their likelihood of being involved in legal uses (as opposed to non-use) of crocodiles (all $\chi^2 > 0.003$, df=1, $p>0.06$; Table 4.14).

Table 4.14: Influence of participants' awareness of various rules for crocodile ranching on involvement in crocodile ranching-related activities

Category of use	Awareness of rules for crocodile ranching	Coefficient	Std. Error	Wald χ^2	Sig.	Odds Ratio
Illegal use	Aware crocodile meat and eggs from crocodile farms can be eaten= Yes	1.610	.654	6.062	0.014	5.002
	Aware license is needed before harvesting crocodile eggs= Yes	13.762	1.198	132.031	<0.001	947539.276
Legal use	Aware crocodile meat and eggs from crocodile farms can be eaten= Yes	1.221	1.485	.677	0.411	3.391
	Aware license is needed before harvesting crocodile eggs= Yes	-3.047	1.658	3.377	0.066	.048

Reference category for categories of use and predictor variable were "Neutral" and "No", respectively.

4.4 Performance of Select Aspects of Crocodile Ranching Production System During the Period 2014-2018

4.4.1 Performance of Egg Harvesting

Analysis of secondary data at KWS reveals that Nile requested for a quota (permit to harvest) of 15,000 eggs for each season during the period 2014-2018, while Galaxy requested for 10,000 eggs during each of the first two seasons and 5,000 during the next two seasons (Table 4.15). The data also showed that both ranches were granted the quotas they requested for. The quantity of eggs the ranches harvested varied temporally. Secondary data at Galaxy shows that the ranch harvested over 68% of their quota of eggs during the four seasons. Secondary data at Nile revealed that the ranch achieved 161% of egg harvest during the 2016/2017 season, and below 57% during the rest of the seasons. Focus group discussions and KII revealed that egg collectors and communities at Kazuri zone refused to sell crocodile eggs to Kazuri ranch. It was revealed that the ranch failed to meet with the community to

discuss benefits payable to the local communities. Results from the FGDs revealed that Kazuri egg collectors instead sold the eggs to Nile and Galaxy. Analysis of secondary data at the ranches revealed that the number of nests from which crocodile eggs were harvested at the Galaxy zone ranged from 119 to 221 during the 2014-2018 period, while that at Nile zone ranged from 186 to 586 over the same period (Appendix R.7).

Table 4.15: Distribution of number of crocodile egg quotas requested for and permitted and number of eggs harvested by Nile and Galaxy between 2014-2018

Ranch	Season	Requested quota	Permitted quota	Number of eggs harvested	% egg harvest achieved
Nile	2014/2015	15000	15000	5224	34.8
	2015/2016	15000	15000	5107	34.0
	2016/2017	15000	15000	24104	160.7
	2017/2018	15000	15000	8550	57.0
Total		60000	60000	42985	
Galaxy	2014/2015	10000	10000	6953	69.5
	2015/2016	10000	10000	6819	68.2
	2016/2017	5000	5000	4299	86.0
	2017/2018	5000	5000	4018	80.4
Total		30000	30000	24431	

Analysis of secondary data shows that during the period 2014-2018, the mean annual number of crocodile eggs harvested by Nile was greater than that for Galaxy (10,746.3 ± 4,523.5 [SE] vs. 6,108 ± 1,034.7) but this difference was not statistically significant (t (df=6) =-1.0, p= 0.36; Appendix R.8). The number of nests from which crocodile eggs were harvested at the Galaxy zone ranged from 119 to 221 during the 2014-2018 period, while that at Nile zone ranged from 186 to 586 over the same period (Appendix R.7). The mean number of eggs per nest at Galaxy egg collection zone during the same period was 42.1 while that for Nile egg collection zone was 31.1 over the same period (Appendix 19.7).

4.4.2 Efforts Put in Egg Collection

Analysis of secondary data obtained from the ranches and KWS revealed that Nile had a bigger share of the number of eggs collected, number of egg collectors engaged and number of boats deployed for egg collection during the 2014-2018 egg collection season (Figure 4.5). The data also showed that Nile had more nests and harvested more eggs compared to Galaxy during the 2016/2017 and 2017/2018 egg collection season. The data showed that Galaxy had more nests and harvested more eggs compared to Nile during the 2014/2015 and 2015/2016 egg collection season.

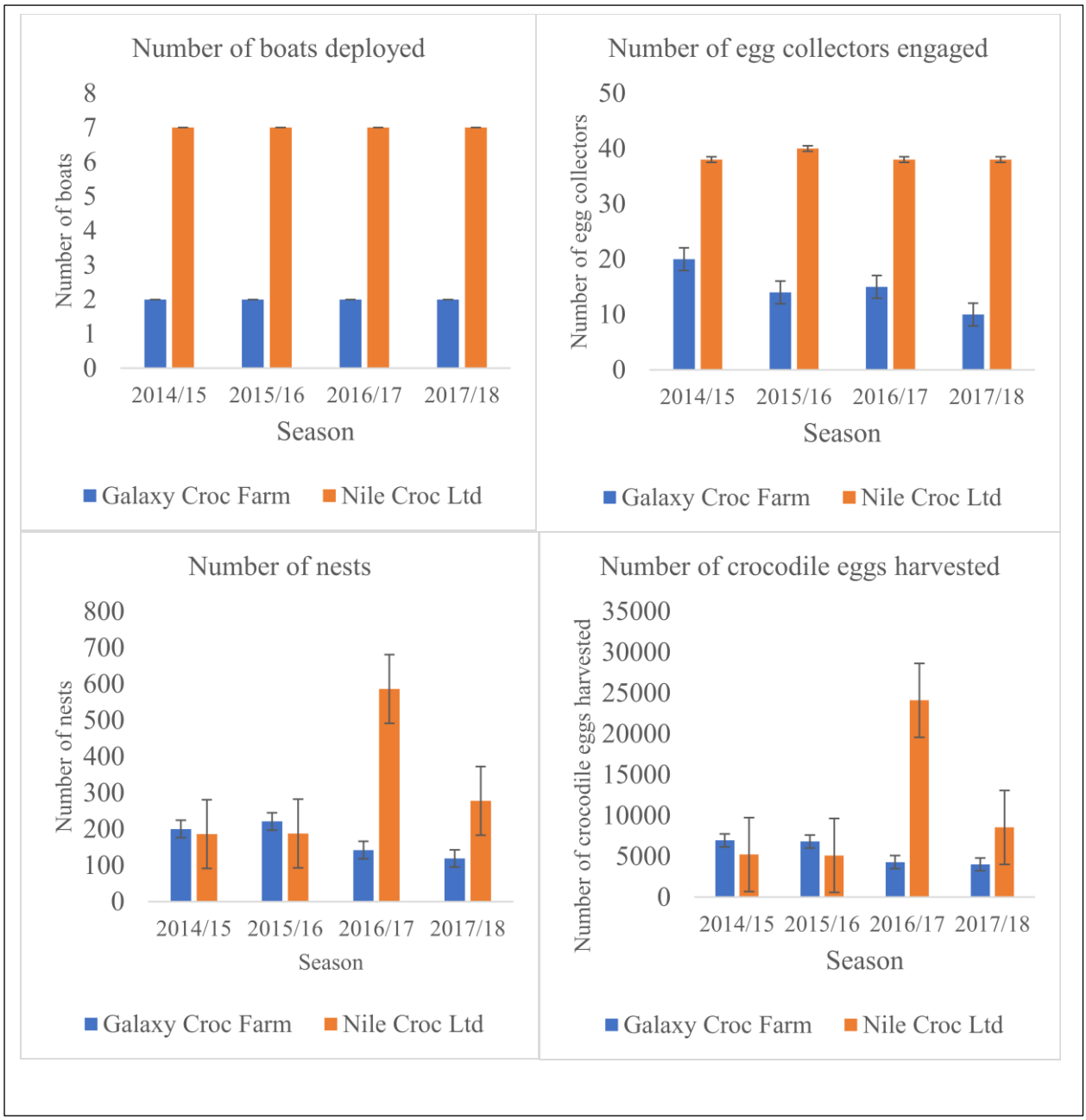

Figure 4.5: Efforts put in egg collection and performance of egg harvesting during the seasons 2014-2018.

There was a strong positive correlation between the number of crocodile eggs harvested and number of crocodile nests (R^2=0.983, p<0.001) (Figure 4.6a). However, correlations between the number of eggs harvested and the number of egg collectors engaged as well as between the number of eggs harvested and the number of boats deployed were not significant (both R^2< 0.17, p=0.30; Figures 4.6b and c).

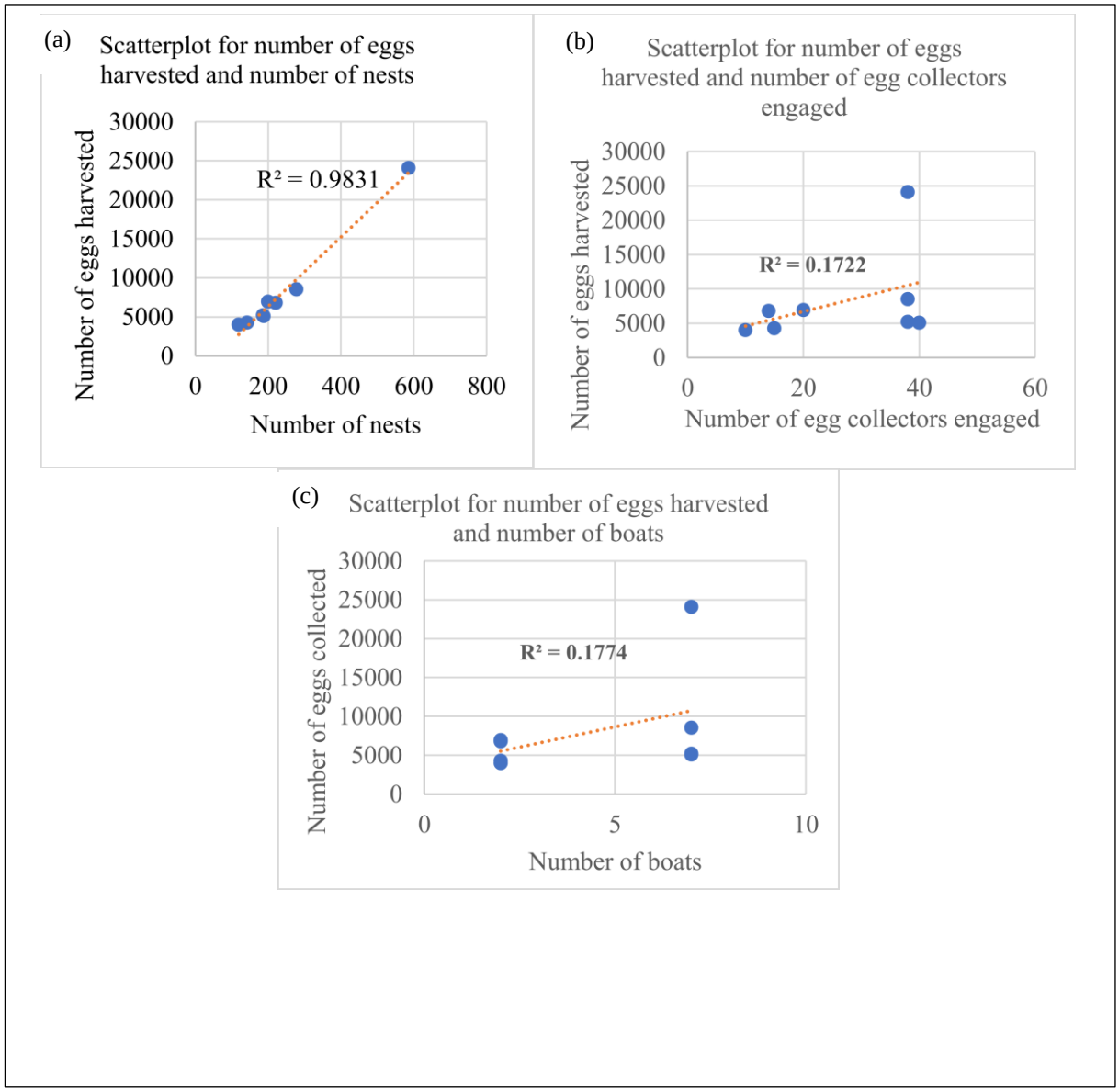

Figure 4.6: Scatter plots showing correlations between various egg collection factors

4.4.3 Crocodile Egg Hatching Performance

A comparative analysis of secondary data on egg incubation and hatching rates between Galaxy and Nile during the period 2014-2018 is presented in Figures 4.7. The data reveals that out of the four seasons studied, Nile achieved the highest number of eggs (17,582) incubated in 2016/2017 (Figure 4.7a). However, the data shows that egg hatching rate at Nile was lowest during this period than any other season (62% vs 83-92%, Figure 4.7b and c). Galaxy maintained a comparatively steady egg hatching rate of between 58 and 70% during each of the four seasons. The average hatching rate at Nile and Galaxy was 81% and 63%, respectively. A Chi-square test of independence revealed that the egg hatching success was dependent on the crocodile ranch, with Nile recording a higher hatching rate than Galaxy (χ^2 =188.053, df=1, p<0.001). Findings from direct observations and informant interviews reveal that Galaxy constructed makeshift incubators every season and did not deploy any devices to monitor temperature and humidity inside the incubators to assure optimal egg incubation conditions. It was further revealed that Nile had invested in a permanent incubation centre with humidifiers, thermometers and hygrometers and attending staff. It was further revealed that Nile graded the eggs upon arrival at the field incubation unit, whereas Galaxy graded the eggs at the nest prior to transportation to the field incubation unit. It was also revealed that due to the limited number of boats that Galaxy had and competition among egg collectors, Galaxy's egg collectors took crocodile eggs to their homes to await collection by the ranch agent.

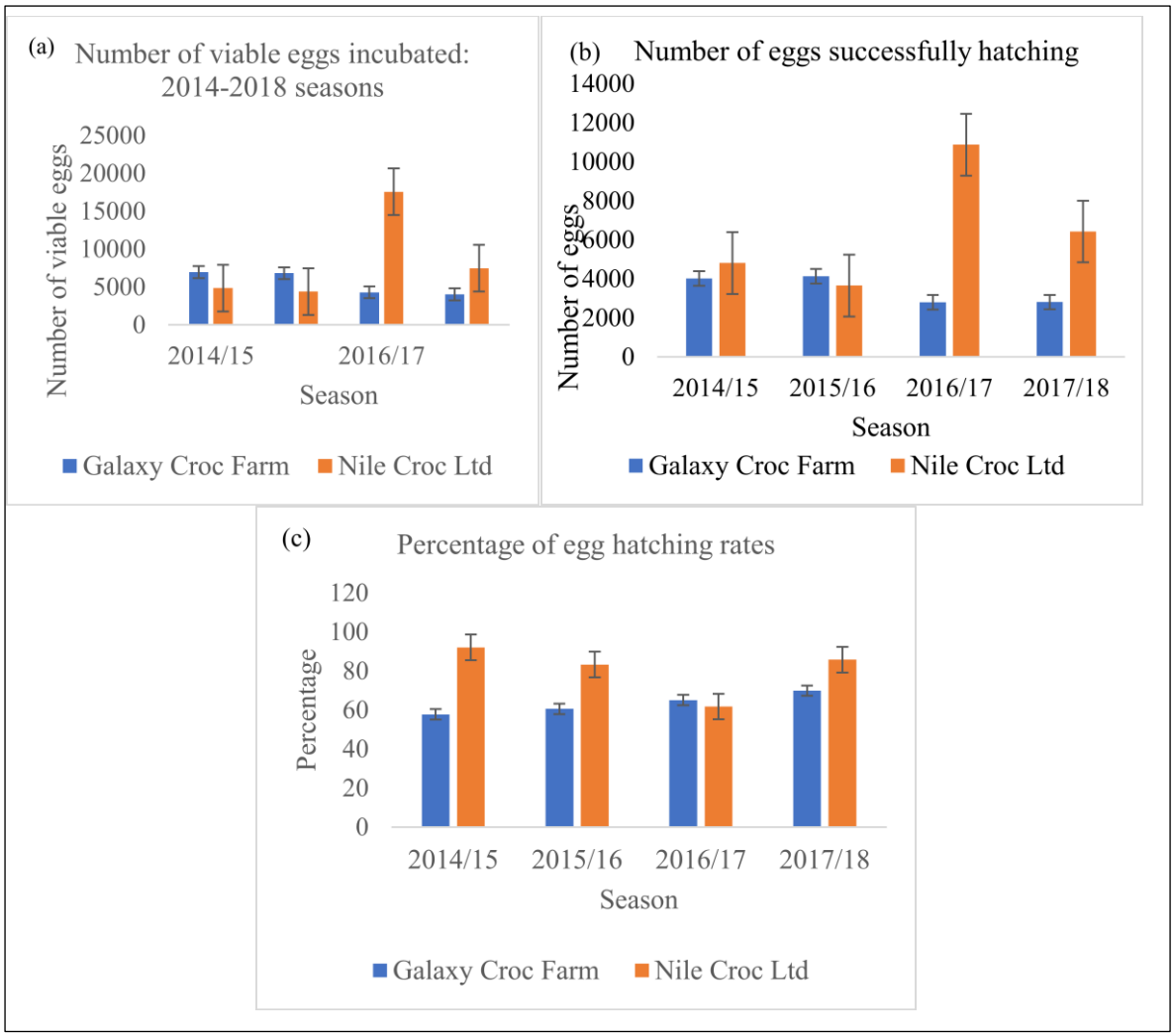

Figure 4.7: Crocodile egg hatching rates in two of the studied ranches during the period 2014-2018

4.4.4 Mechanisms for Preventing or Minimizing Egg Mortality

The majority of the egg collectors revealed that they transported the crocodile eggs mainly using canoes as opposed to boats (65% vs 35%, respectively; Table 4.16). The egg collectors survey revealed that most (58%), of the egg collectors took eggs home after harvesting to await picking up by the ranch agents. However, the survey revealed that this practice varied among egg collection zones, being the highest (100%) in Galaxy and lowest in Kazuri (25%). Fourteen percent of the egg collectors further revealed that the ranch agents picked the eggs immediately after the collectors had harvested them. This was mainly practiced by Nile, with 64% of the egg collectors in this egg collection zone indicating immediate picking up of eggs by the ranch. Galaxy egg collectors revealed a week-long or unpredictable intervals of picking up of harvested eggs by ranches 25% and 50%, respectively. Overall, the majority 65.4% of the egg collectors indicated that they had received training in feeding hatchlings (Table 4.16).

Table 4.16: Various factors affecting egg and hatchling mortality at the three egg collection zones

Factors affecting egg and hatchling mortality		Egg collection zone			
		Galaxy %	Kazuri %	Nile %	Total %
Does the egg collector at times take eggs home awaiting collection?	No	0.0	75	57.1	42.3
	Yes	100	25	42.9	57.7
How long does the egg collector wait for harvested eggs to be picked by the ranch?	Collected immediately	25	50	64.3	53.8
	At the end of the day	0.0	25.0	23.1	15.4
	Weekly	25	25.0	7.7	15.4
	Variable	50	0.0	0.0	15.4
Is the egg collector trained in egg incubation skills?	No	12.5	50	28.6	26.9
	Yes	87.5	50	71.4	73.1
Is the egg collector trained in feeding hatchlings?	No	25	50	35.7	34.6
	Yes	75	50	64.2	65.4

Key informant interviews revealed that ranch managers and supervisors at Galaxy and Kazuri crocodile ranches did not have any formal training or experience in crocodile husbandry. It was revealed that the manager of Nile who is also the proprietor, had formal training in aquaculture, had undergone apprenticeship in a nearby ecotourism facility which kept crocodiles and had 26 years of crocodile ranching experience. It was further revealed that the ranch supervisors had gained on-job training and experience in behaviour of breeding crocodiles, nest identification, egg harvesting and transportation skills, egg incubation, crocodile slaughter, skin curing, feeding crocodiles and pond management.

Plates 4.2a-g show egg collection and handling procedures by one of the three crocodile ranches studied. Key informant interviews revealed that all the three ranches studied maintained field units for egg collection and incubation at their egg collection zones. Kazuri maintained a makeshift field unit at Mikameni, while Galaxy maintains three makeshift field units at three strategic locations (Mororo near Garissa town, Hola and Mnazini). It was revealed that Nile maintains only one permanent camp at Mwanapaka for egg collection and incubation. All the three ranches and their respective egg collectors transported eggs on the river to the field incubation units using boats and canoes. This helped avoid shaking up the eggs and killing the embryos. It was further revealed that the eggs were gathered at the incubation units and transported at once to the ranches in Sagana, Malindi and Kikambala. By the time of transporting to the ranch, the eggs were normally well-formed or most had hatched and this reduced mortality. Both personal observation and KII revealed that eggs are not turned or placed on hot sand during collection to avoid killing the embryo. The eggs are sheltered under an umbrella as they are being harvested in order to avoid exposure to high temperatures and minimize egg mortality.

Plate 4.2: Photos showing crocodile egg collection and egg handling procedures

(a)Egg collectors harvesting and marking eggs during the 2018/2019 egg collection season. Note use of an umbrella to protect the eggs from ambient temperatures which could be higher than nest temperature. (b) Packing eggs in Styrofoam boxes with nest soil substrate. (c) Eggs packed in boxes awaiting collection (d) Loading boxes containing eggs in a boat (e) A temporary incubator at one of the incubation units in Hola (f) Hatchlings pipping out of eggs at one of the incubation units in Mororo (g) A new hatchling at an incubation unit. Own pictures

4.4.5 Returning Sub-adult Crocodiles Back to the River

The egg collectors' survey revealed that some attempts had been made by the three crocodile ranches to return sub-adult crocodiles back to the river, with 21% and 75% of the respondents having been engaged to do so by Nile and Kazuri, respectively (Table 4.17). On the need to return a proportion of hatchlings back to the river, some key informants revealed that the management plan for crocodile ranching prescribes that crocodile ranches should return a proportion of sub-adult crocodiles back to the river but this had not been possible. It was also revealed that local communities do not want to see live crocodiles being brought back to the river as this works against the aim of the egg collection programme to reduce human-crocodile conflicts at the river:

> *"The community does not want murderous crocodiles being brought back in the river. If KWS says there is an area which is depleted of crocodiles, we will always abide to the 4% requirement"* (Manager, Nile Crocodiles Limited).

The KWS CITES Implementation Officer indicated that the last census on crocodiles in Kenya was done in 1995. He said arrangements are being made to raise the resources required for such an exercise. In the meantime, KWS is using indirect methods like a general assessment based on the egg collection efforts to estimate the crocodile population which indicates that the population is stable.

Table 4.17: Crocodile ranches returning sub-adult crocodiles back to the river

Have you ever been engaged by ranch to return sub-adults to the river	Egg collection zone		
	Galaxy %	Kazuri %	Nile %
No	66.7	25.0	78.6
Yes	33.3	75.0	21.4

4.4.6 Inter-ranch Differences in Quantities of Skins and Meat

Analysis of crocodile skin export data at KWS revealed that during the period 2014-2018, Nile exported more raw salted skins annually compared to Galaxy (5,334.5 ± 730.6 [SE] vs.

1,278 ± -442.7; t = 4.7, p= 0.001; Figure 4.8a and Appendix R.9). Key informant interviews revealed that skins were the main product for both ranches. Secondary data at KWS showed that Nile crocodile ranch exported to one buyer in Singapore, three in Italy and one in Zimbabwe while Galaxy exported skins to its own leather factory in South Korea. During the same period, Nile reported a higher quantity of meat sold annually compared to Galaxy (23,270.5 ± 3061.8 vs. 531.0 ± 214.0; t = -7.4, p = 0.001; Figure 4.8b and Appendix R.10).

The key informant from Nile revealed that Nile mainly sold meat to high end hotels and restaurants in the Coast and Nairobi while Galaxy sold to licensed eateries along Sagana-Nairobi highway. He revealed that its attempts to tan crocodile skins locally had failed due to the poor output which could not meet the quality in the international luxury crocodile leather market. It was established that local value addition could earn the ranches more sales revenue than exporting raw crocodile skins. He revealed that it was difficult to penetrate the crocodile leather industry as a new ranch since the tanneries maintained long-term buyer-seller relationships with established crocodile ranches.

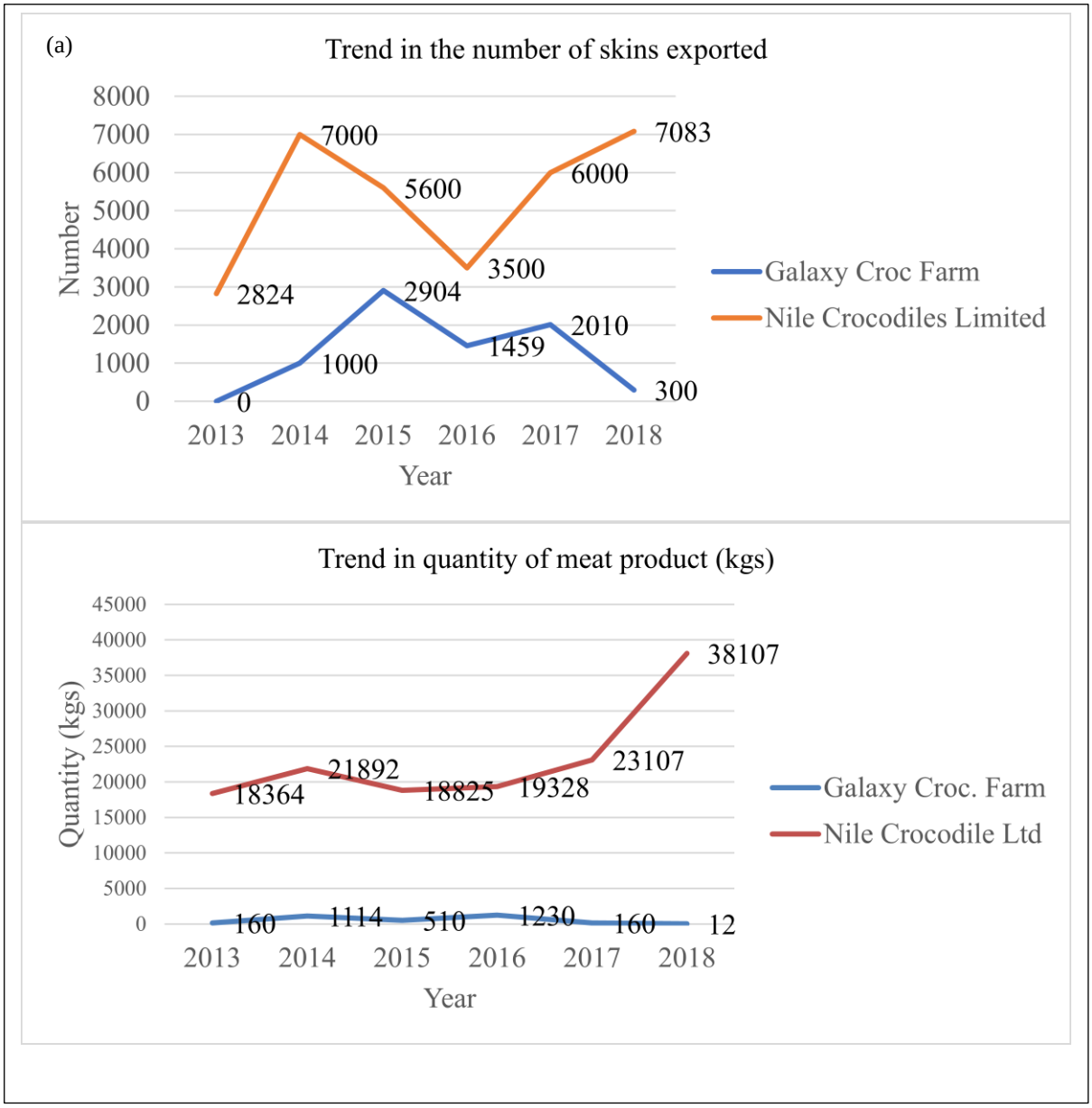

Figure 4.8: Trends of (a) number of skins exported and (b) quantity of meat sold by two crocodile ranches in the study area during the period 2013-2018

Source: Secondary data from Galaxy Croc Farm and Nile Crocodiles Limited, 2019

4.4.7 Influence of Benefits and Incentives on Involvement in Crocodile Ranching-related Activities and Performance of Crocodile Ranching-related Activities

Descriptive statistics reveal that a vast majority (72%, *n*=263) of the participants had not benefited from the crocodile egg collection programme (Table 4.18). However, more participants had benefitted from community projects (26%, *n*= 96) than from direct personal incomes (2%, *n*=4%).

Table 4.18: Household involvement in crocodile ranching-related activities and benefits from the egg collection programme

Crocodile use categories	Benefits from crocodile ranching		
	Direct personal income %	Community project %	None %
Neutral (non-use)	0.4	36.2	63.3
Illegal uses	0.8	5.0	94.1
Legal uses	1.6	26.3	72.1
Total	1.6	26.3	72.1

Multinomial logistic regression revealed that benefitting from community projects derived from crocodile ranching significantly influenced participants' involvement in crocodile use ($p<0.001$; Table 4.19 and Appendix R.11). Participants who had benefitted from community projects were 99.8% less likely to be involved in illegal uses (as opposed to non-use) of crocodiles ($\chi^2_{(1)} = 23.97$, $p<0.001$; Table 4.19). However, benefitting from crocodile ranching-related community incentives and benefits did not influence participants' likelihood of being involved in legal uses (as opposed to non-use) of crocodiles ($p>0.3$; Table 4.19). Further, direct personal income did not influence participants' likelihood of being involved either in legal or illegal uses (as opposed to non-use) of crocodiles ($p>0.3$; Table 4.19).

Table 4.19: Influence of incentives and benefits derived from crocodile ranching on involvement in crocodile ranching-related activities

Crocodile use categories	Benefits from crocodile egg collection programme	Coefficient	Std. Error	Wald χ^2	Sig.	Odds Ratio
Illegal uses	Direct personal income	492.955	.000	.	0.287	$1.224x10^{214}$
	Community projects	-1.649	.337	23.972	<0.001	.192
Legal uses	Direct personal income	-961.291	37.681	.	0.381	.000
	Community projects	.584	.553	1.114	0.291	1.793

Overall, 2% and 26% of participants reported that they had benefitted from the crocodile egg collection programme through personal income and community projects, respectively, whereas a vast majority (72%) of participants reported that they had not benefitted (Table 4.20). The proportion of participants reporting direct personal income benefits was greater in Kazuri than in each of the other egg collection zones, whereas the proportion of participants reporting benefits through community projects was greater in the Nile and nil in Kazuri (Table 4.20). Key informants and discussants in one egg collector group indicated that no community project had come forth from Kazuri. It was also revealed that Kazuri had never gone to the ground to talk with the community and to make agreements on benefits for the community. However, the key informant from Kazuri said that the ranch had paid money to leaders of Ndera and Tsampani conservancy groups, once each, meant for communities. The manager was not certain how much money was paid to the leaders of Ndera Conservancy group. It was revealed that Kazuri donates crocodile meat to feeding programs in schools with needy children through a US charity organization based in Nairobi.

Table 4.20: Community benefits from the egg collection programme and the egg collection zones

		Egg collection zone							
		Galaxy		Kazuri		Nile		Total	
		N	%	N	%	N	%	N	%
Benefit from egg collection programme	Direct personal income	1	1	3	13	2	1	6	2
	Community projects	16	14	0	0	80	35	96	26
	None	99	85	20	87	144	64	263	72

Multinomial logistic regression revealed that the egg collection zone significantly influenced participants' likelihood of deriving benefits from the crocodile egg collection programme (χ^2=46.891, *df*=4, p<0.001; Table 4.21 and Appendix R-12). Compared with participants from the Nile egg collection zone, participants from Galaxy and Kazuri egg collection zones were less likely to have benefitted from community projects derived from the crocodile egg collection programme (both χ^2=14.67, df=1, p<0.003; Table 4.21). However, the likelihood of deriving direct personal income benefits was not influenced by egg collection zone (χ^2= 0.67, df=1, p>0.1; Table 4.21).

Table 4.21: Influence of incentives and benefits derived from crocodile ranching at the egg collection zones

Benefit from egg collection programme	Egg collection zone	Coefficient	Std. Error	Wald χ^2	Sig.	Odds Ratio
Direct personal income	Egg collection zone (Galaxy)	-0.318	1.232	0.067	0.796	0.727
	Egg collection zone (Kazuri)	2.380	0.944	6.360	0.12	10.800
Community project	Egg collection zone (Galaxy)	-1.235	0.303	16.563	<0.001	0.291
	Egg collection zone (Kazuri)	-21.729	0.000	14.671	0.003	$3.659x10^{-10}$

The average direct income earned per egg collector per season ranged from KES 11,464-20,090 and KES 8,364- 31,100.3 in Galaxy and Nile, respectively (Figure 4.9). Further analysis showed that the lowest and highest direct income earned per egg collector engaged by Galaxy were recorded during the 2016/17 and 2017/18 egg collection seasons, respectively. The lowest and highest average direct income earned per egg collector engaged by Nile were recorded during the 2015/16 and 2016/17 egg collection seasons, respectively.

Key informant interviews and focus group discussions with egg collectors revealed that local people got seasonal incomes from collecting eggs for the crocodile ranches and regular incomes from employment at the field egg incubation units as well as regular incomes if employed at the main ranches. Nile had employed 80 people directly and permanently at the main ranch and another 70-80 indirectly at different times at the egg collection zone. Galaxy engaged 8-20 egg collectors and incubator attendants while Kazuri engaged up to 8 egg collectors. Kazuri paid Kenya Shillings (KES) 30 per egg on delivery and additional KES 30 for every successfully hatched egg. Nile egg collectors were paid KES 50 per egg on delivery and additional bonuses based on hatchability rates. It was revealed that the additional payments made by Kazuri and Nile were intended to motivate the egg collectors to handle the eggs carefully to minimize wastage. Galaxy graded eggs when they were delivered by the collectors and paid KES 50 per viable egg.

Egg collectors and the ranches revealed that the maximum number of eggs that could be collected in a season per collector had been reducing due to a decline in crocodile numbers and an increase in the number of egg collectors who competed for the limited eggs. Key informants asserted that a decline in the number of eggs implied lower incomes for the local egg collectors. Egg collector focus group discussants for both Nile and Galaxy noted that benefits from egg collection were limited since crocodile egg collection was not only a tough exercise which meant only few eggs could be harvested, but was also a seasonal activity. A discussant in the Nile egg collector group expressed this as follows:

> "*Egg collection is seasonal. Without another source of income, one will continue to stay in the same old house. We do not get many benefits from crocodiles. This at times makes one angry and wish that the crocodiles should be destroyed completely*."

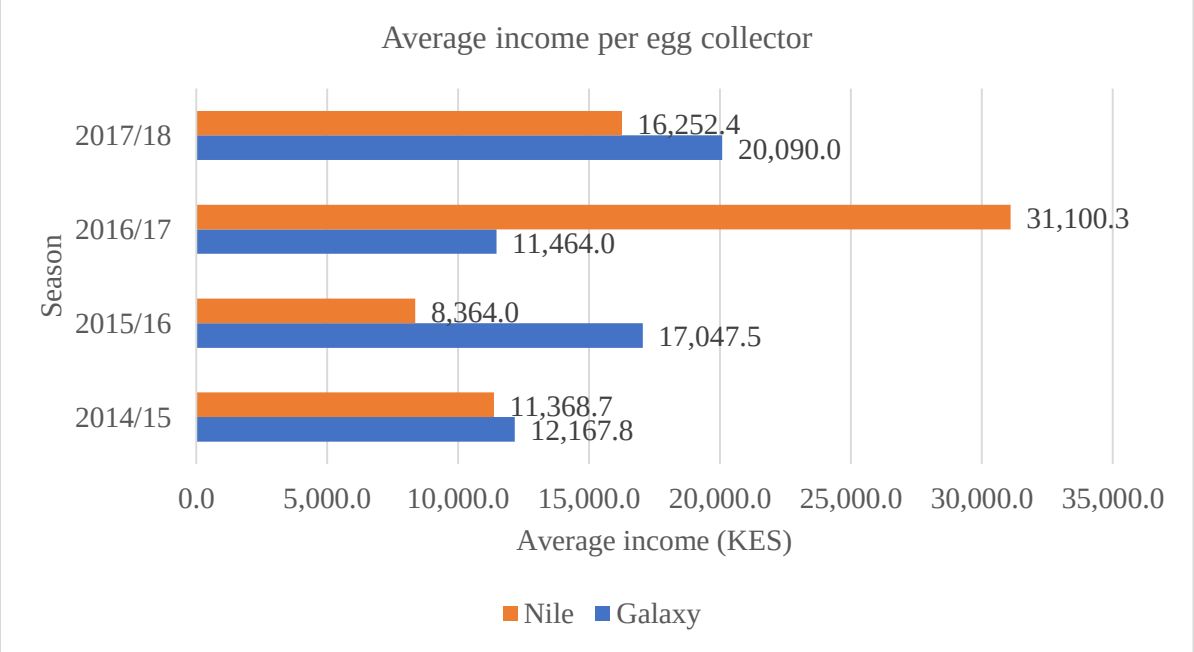

Figure 4.9: Average direct income earned per egg collector for four seasons

**Source: Secondary data from Galaxy Croc Farm and Nile Crocodiles Limited, 2019*

There was a strong positive correlation between the number of eggs harvested and egg collection fees paid to egg collectors (R^2=0.887, p<0.001) (Figure 4.10a). However, there was no correlation between the egg hatching rates and total egg collection fees paid to egg collectors (R^2= 0.001, p=0.94) (Figure 4.10b).

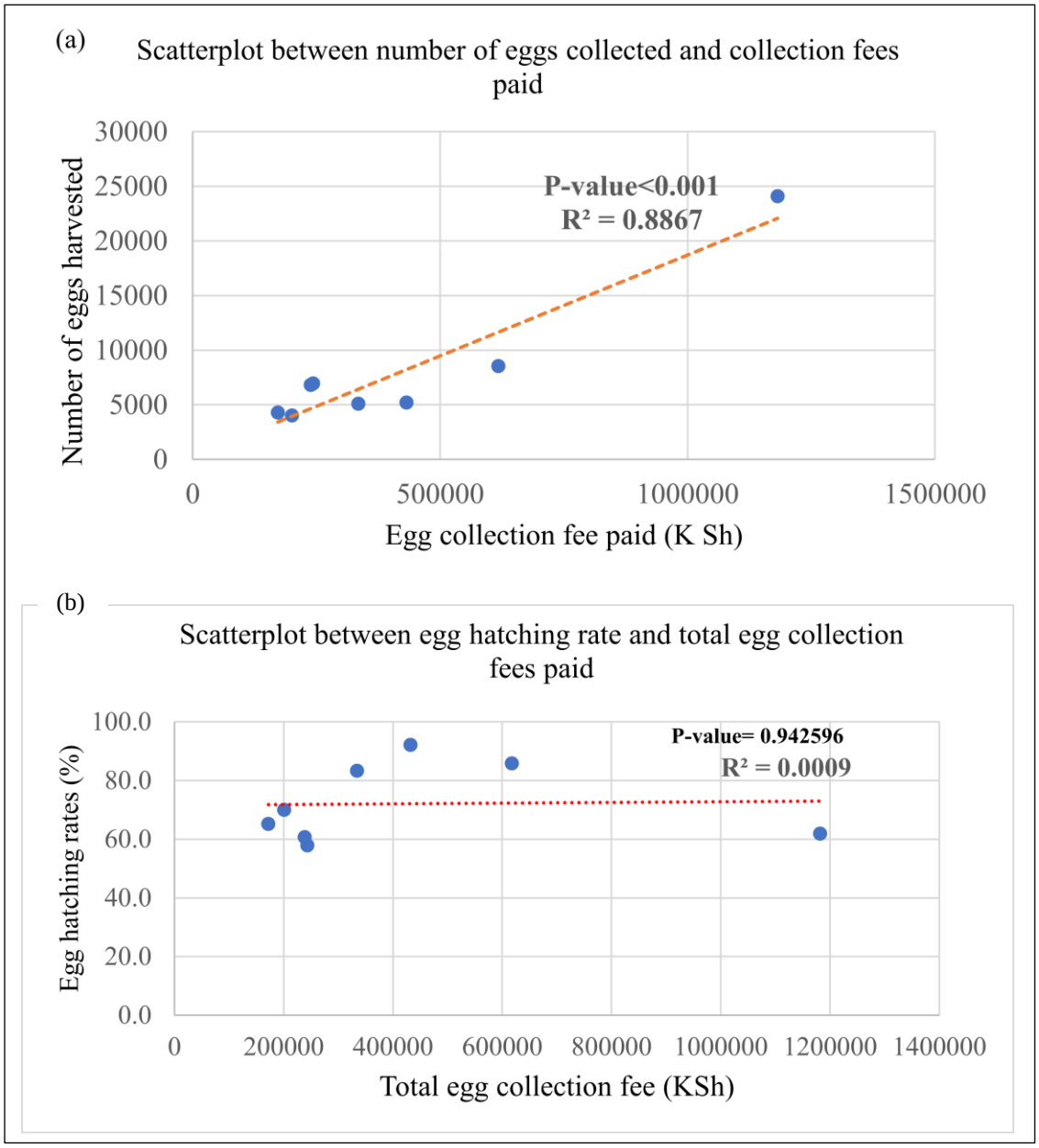

Figure 4.10: Relationship between: (a) quantity of eggs harvested and egg collection fees, and (b) egg hatching rate and total egg collection fees paid

Key informants from KWS and the County Government said that the local communities were required to be organized into government-registered community-based organizations (CBOs) that would then negotiate with the ranchers for benefits from the egg collection activities and to perform other roles to support crocodile ranching. Benefits from ranches to the community would be channeled through community groups that were recognized by the government. Results from all the FGDs revealed that the majority of the communities and egg collectors were not formally organized to participate in the egg collection activities. It was revealed that where local communities had formed CBOs, they were able to negotiate with the ranches for benefits and incentives and to control the egg harvesting exercise than those who did not have CBOs.

The Sala and Galaxy egg collector focus groups and local key informants said that there were no CBOs in the upper segments of lower River Tana and that the local communities had not benefitted from egg collection. Galaxy ranch employees were observed directly harvesting eggs from the nests during the nest mapping exercise for this study. The Hewani focus group discussants were not aware of any benefits from crocodile ranching but had only heard that egg collection was going on. Some of the Sala discussants were not even aware that they could get income from crocodile eggs:

> *"We hear boats moving up and down during the crocodile breeding season but none of us is involved. Here we have an island where the crocodiles like nesting and every year the rancher's agent come to collect eggs accompanied by KWS officials and don't engage the local people. They say they have a permit to collect eggs. The ranchers benefit by taking eggs. We have received benefits from other sources, not crocodile ranching"* (Sala household heads group).

Key informant interviews and FGDs revealed that Galaxy had donated seven hand water pumps to youth groups and 25 water pumps to egg collectors to irrigate to help them generate incomes from crop farming and to augment incomes from egg collection near the river. It was further revealed that Galaxy had donated 150 roofing iron sheets to Kitere and Baomo primary schools each in the year 2015. It was also reported that two local people from Mnazini and Baomo were employed at the ranch in Sagana. The KIIs and FGDs revealed the existence of an agreement for Galaxy to pay Ndera Conservancy an initial KES 20,000 in 2012 and another KES 30,000 every egg collection season. Key informant interviews

indicated that Galaxy had donated a camera, a boat, an engine and one water pump to the Ndera Conservancy and paid KES 1,000 sitting allowance for meetings of the Conservancy in the year 2013-14.

Key informants indicated that Nile had operated along River Tana the longest. Therefore, the impact of community benefits was felt much more at the Nile zone than at the other two egg collection zones. Both KIIs and FGDs indicated that Nile had over the years donated pit latrines, a maternity building in a local hospital and solar lighting system in it, boreholes, boats for community use, beehives, water pumps and a cattle crush to the communities in the designated zone.

It was revealed that egg collectors who occupied Onkolde and Galili areas of the Nile egg collection zone did not have any formal organization. Here, there was a disagreement among egg collectors about donations of boats and canoes to local egg collectors, with some acknowledging that Nile had donated 5 canoes to egg collectors for egg collection, transport and fishing, while others denied receiving any canoes from Nile. The key informant from Nile stated the egg collectors still had his two fiberglass boats and two canoes which they still used for egg collection and local transport. The Nile egg collector group revealed that the local people who were using canoes to collect eggs could not match the number of eggs collected by ranch workers who were using motorboats to collect eggs.

However, the situation was different at the Tsampani and Abadhani areas where egg collectors had CBOs. Nile had donated six canoes to egg collectors in Mwina, Salama, Bilisa, Tsampani and Abadhani Conservancies groups for egg collection and other transport and evacuation needs for the community and their property and for fishing. It was revealed that only known group members who were allowed to collect eggs from the nests. Here, Nile agents could only get eggs from known conservancy members. The canoes were shared equally among egg collectors from the Pokomo and Wardei communities. The number of days in egg collection season were shared among the egg collectors based on the number of serviceable canoes. They collected the eggs from the nests in advance of time and kept them safely. When the ranch workers came up in motorboats, they could only pick the eggs from the egg collectors, not from the nests. Members of the community could hire the canoes to transport crops and timber across the river and this was additional income to the conservancy groups. Nile bore the cost of constructing, maintaining and replacing the canoes if they got damaged.

Key informants from the County Government and ranches revealed that the County Government of Tana River County collected revenue from the ranches during the egg

collection season. They averred that this revenue forms part of the taxes the County sends to the National Treasury as part of the required quota of revenue that Tana River County should contribute to the national basket. They also revealed that the County Government in turn benefits from funds disbursed from the National Treasury to all Counties.

Key informants and group discussants revealed that local people who had received money as egg collectors or workers at the field egg incubation units or main ranches had used money for crop cultivation, to acquire livestock, pay school fees for their children or in other self-development projects. They also averred local people refrained from engaging in activities that were harmful to crocodiles and crocodile habitat due to the current benefits and anticipated gains from crocodile ranching. Discussants from Galaxy egg collectors' group and two key informants revealed the presence of retaliatory killings of crocodiles and destruction of crocodile eggs in the upper stretches of the Galaxy zone where little or no incomes from egg collection had been realized by the local people.

4.5 Bio-physical Factors Influencing Performance of Crocodile Ranching-related Activities

4.5.1 Land Cover Types in 2015 and 2018

The coverage of the various on land cover types at the studied egg collection zones during the years 2015 and 2018 are shown in Figure 4.11 and 4.12. Shrubland and forestland had the largest coverage, with 239,418.77 ha (82%) & 31,291 ha (11%), respectively, while cropland and settlement covered an area of 2,373 ha (1%) and 264.8 ha (0.8%), respectively (Figures 4.11a and 4.12a) during the year 2015. Shrubland and forestland covered 226,136 ha (77%) and 33,457 ha (11%) of the total area, respectively, in 2018 (Figures 4.11b and 4.12b). Cropland and settlements occupied 7,437 ha (3%) and 426 ha (0.1%) of the total area, respectively, in 2018.

The least coverage was other land which accounted for 434 ha (0.2%) of the total area. The area under cropland increased the most (213%) during the period 2015-2018, followed by the area under other land type (110%) (Figure 4.13). Areas under open grassland and settlement also increased substantially during this period (each 61%; Figure 4.13). Conversely, however, shrubland and water bodies shrunk by -5.6% and -10.8%, respectively, during this period (Figure 4.13).

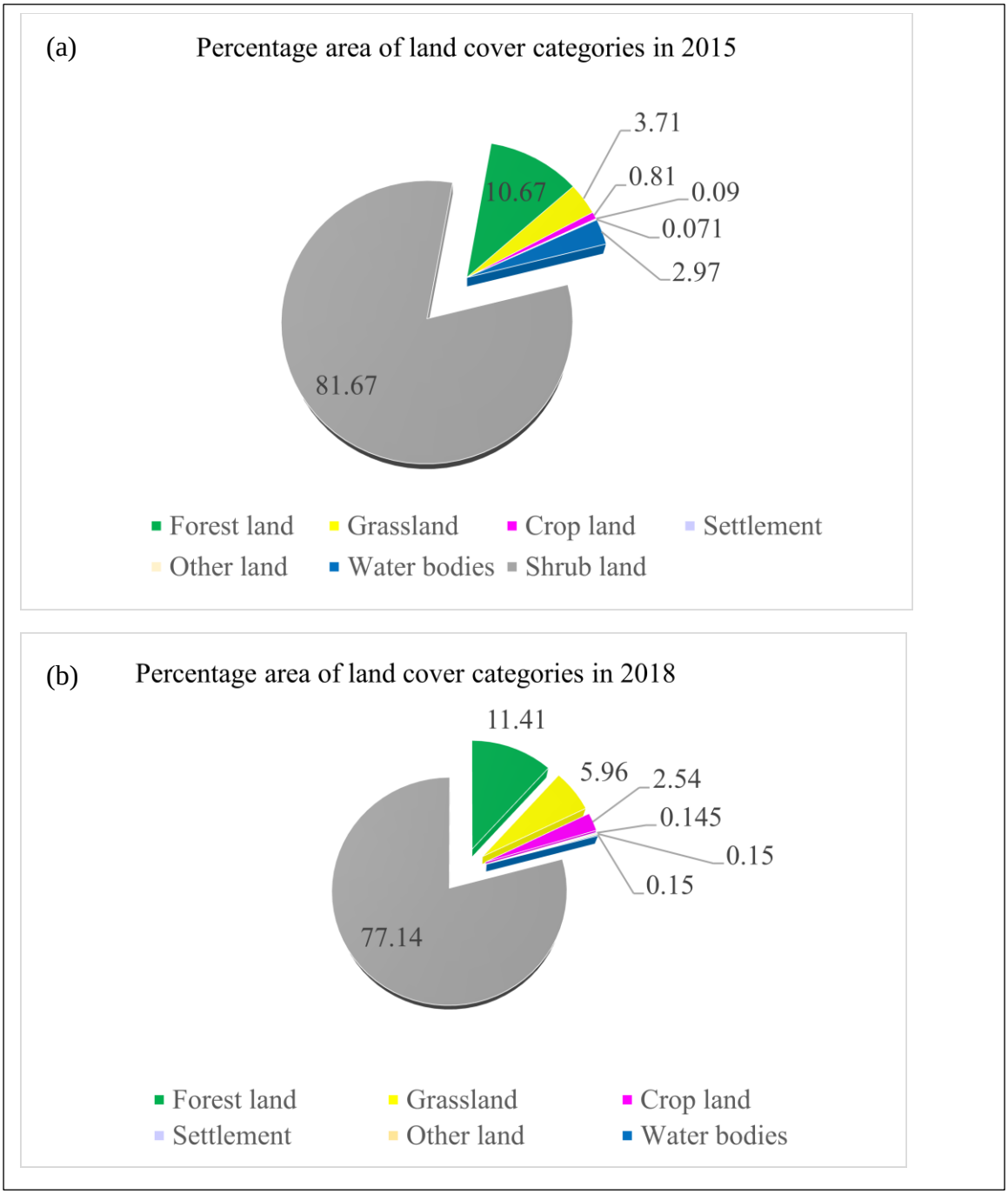

Figure 4.11: Percentage coverage of land cover types in 2015 and 2018

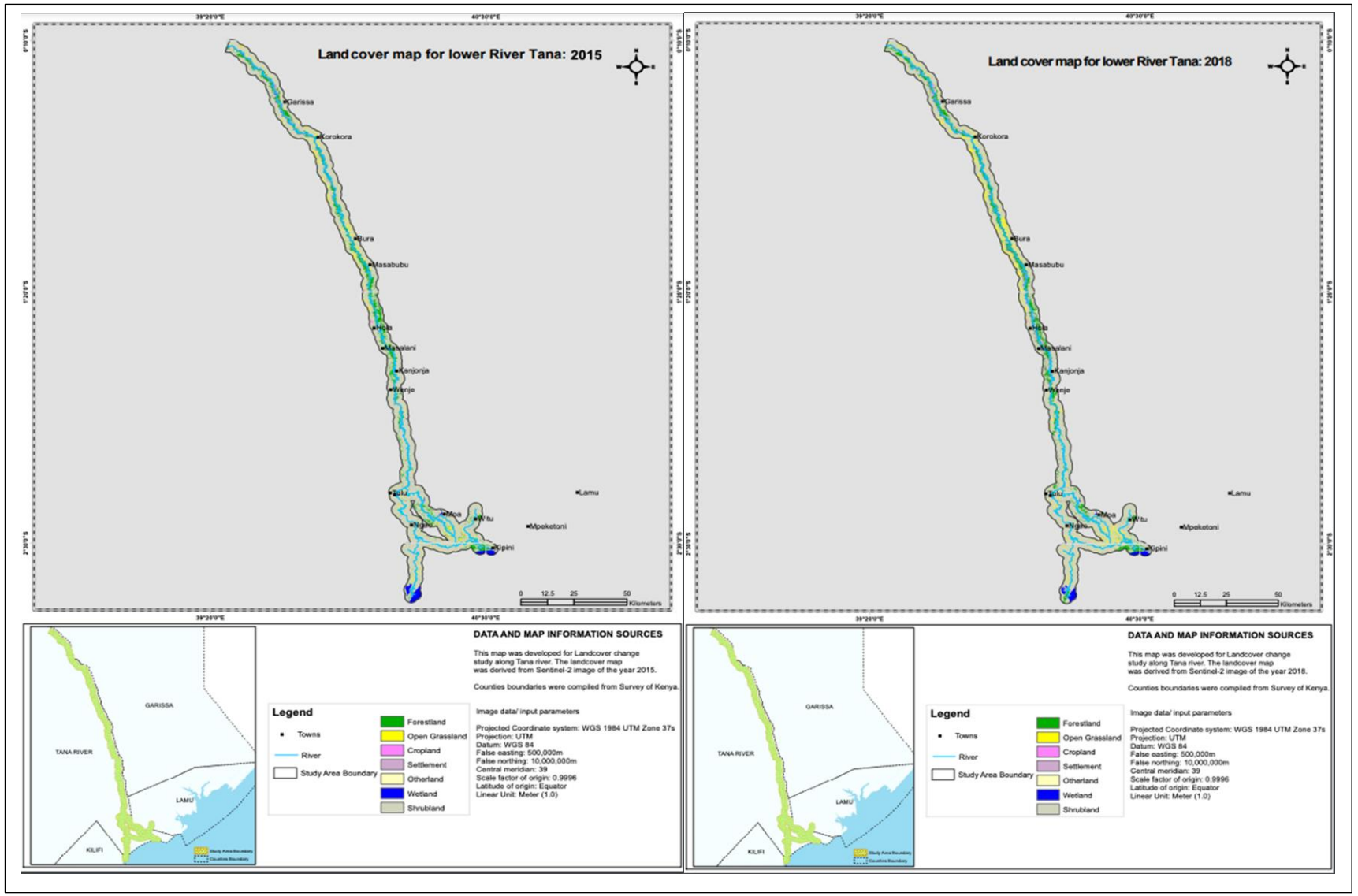

Figure 4.12: Land cover maps for the study area for the years 2015 and 2018

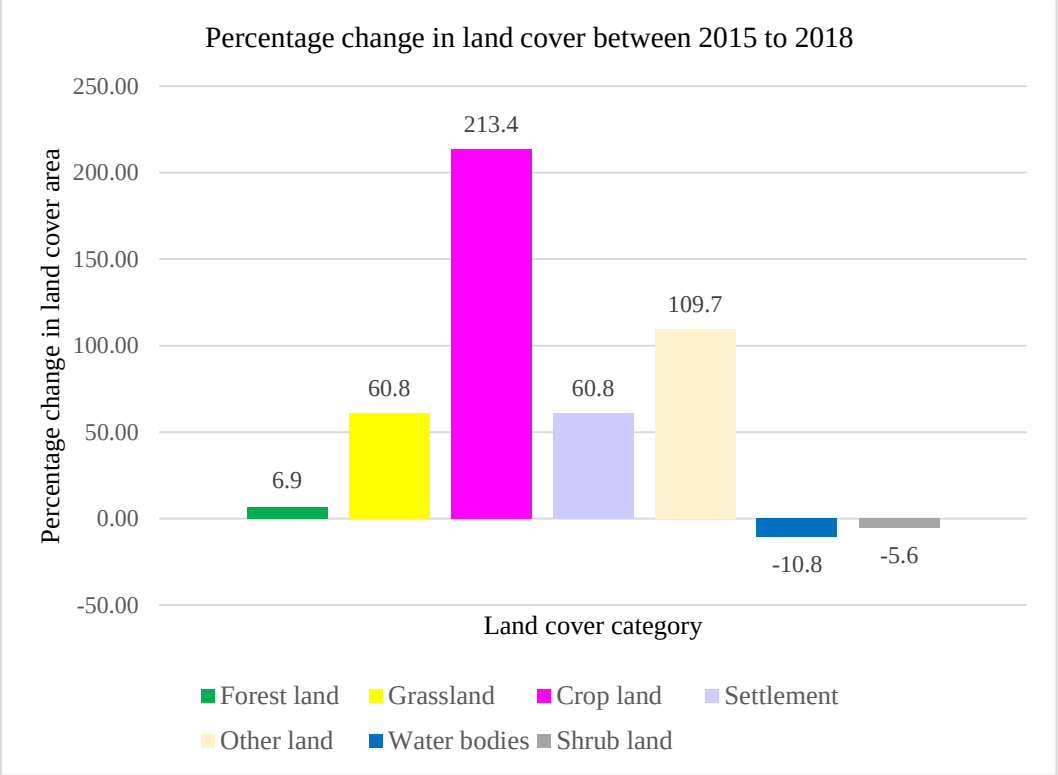

Figure 4.13: Percentage change in land cover categories between 2015 and 2018

4.5.2 The Nature and Extent of Change of Land Covers Between 2015 and 2018

Land cover change statistics and matrix between 2015-2018 are presented in Table 4.22 and Appendix S, respectively. Approximately 20,049 of what was forestland in 2015 was still remaining as forestland in 2018. A total of 13,394 ha was converted into forestland from other land cover categories, mainly shrubland and cropland from 2015 to 2018. Although an area of 110.5 ha of what was settlements in 2015 still remained as settlement in 2018, there was a conversion of 314.6 ha from water bodies, forestland, open grassland, other land, shrubland and cropland into settlements between 2015 and 2018. An area measuring 1,388 ha which was occupied by cropland in 2015 was still cropland in 2018. However, there was a conversion of 6,044 ha of forestland, open grassland, settlements, other land, water body and shrubland into cropland, with forestland and shrubland contributing 2,023 and 3782 ha, respectively. An area of 206,400 ha covered by shrubland in 2015 was remaining as shrubland in 2018. There was a conversion of

19,515 ha of grassland, forestland and cropland into shrubland between the two periods. However, there was a simultaneous conversion of 28,638 ha of shrubland into forestland, open grassland, cropland, settlement, other land and water body over the same duration of time. Regarding open grassland, an area of 4,401.1 ha remained as open grassland in 2018. However, 13,042.37 ha of other land covers were converted into open grassland with shrubland being the main (12,404.8 ha) contributor.

Table 4.22: Land cover change statistics

No.	Class Name	Area in Ha
1	Forest land remaining forest land	20,049.42
2	Grassland remaining grassland	4,401.06
3	Crop land remaining crop land	1,388.34
4	Settlement remaining settlement	110.25
5	Other land remaining other land	162.47
6	Water bodies remaining water bodies	6,812.96
7	Shrubland remaining shrubland	206,399.95
8	Changes to Forestland	13,393.96
9	Changes to Grassland	13,042.37
10	Changes to Cropland	6,044.24
11	Changes to Settlement	314.59
12	Changes to Other land	271.52
13	Changes to Water bodies	961.54
14	Changes to Shrubland	19,515.09

4.5.3 Influence of land Cover Changes on Location and Distribution of Crocodile Nesting Sites

The nest survey in 2018/19 egg collection season was done only on the egg collection zone assigned to Galaxy. The rest of the river from Kitere to the Indian Ocean could not be accessed as it was barricaded for national security reasons from 20th November 2018 to around 23rd February 2019, a time that coincided with the crocodile egg collection season and the nest survey. A total of 99 nests were located on 335.5 kilometres of the Galaxy egg collection zone. The mean number of eggs per nest at the Galaxy egg collection zone during the 2018/2019 season was 33 eggs per nest (N= 99, SD = 17.8, range = 0-64). The distance

from water to the nest point ranged from 1 to 50 meters with an average of 10.3 metres (*SD*=8.4 metres) and the farthest nest being 50 metres away (Appendix R.13). The majority (66%, *n*=63) of nests were located within 0-10 meters of the water, while only one nest, 1.0% (*n*=1) was located more than 49 meters from water.

Figure 4.15 shows a land cover change map produced from post-classification comparison of detected changes between the years 2015 and 2018. The map illustrates that changes to cropland were mainly concentrated between Masabubu and Wenje, while moderate changes to cropland were observed from Korakora/ Sala area westwards. There was moderate conversion to forestland from Bura westwards and Wenje down to the Ocean through the river course on the east. Moderate conversion to forest land was observed between Hola and Wenje amidst simultaneous conversion to crop land.

Figure 4.14 also presents an overlay of the nest locations (points) surveyed at the Galaxy egg collection zone during the 2018/19 on the map for land cover changes that occurred between 2015 and 2018. The results show three main segments for crocodile egg nest locations. The first segment stretches from Gubantu to Sala, the second segment covers Tune, Bobwaini, Masalani, Rhoka and Makere, while the third segment covers Wenje-Baomo-Kitere areas which are inside the Tana River Primate Reserve. The stretch of the river between Wenje and Kitere had a high concentration of crocodile egg nests. This segment of the river had remarkably limited land cover conversion which was mainly conversion into grassland. The map indicates that the segments of the river between Tune and Bura; Mji wa Wazee and Bondeni and Wenje and Kitere are available and favourable for crocodile nesting. The areas between Magedo and Madogo; Poza and Sala; and, Rhoka and Makere had a low concentration of crocodile egg nests. No nests were found in the areas between Madogo and Poza; Sala and Nanighi; Makere and Mji wa Wazee; and, Bondeni and Bububu.

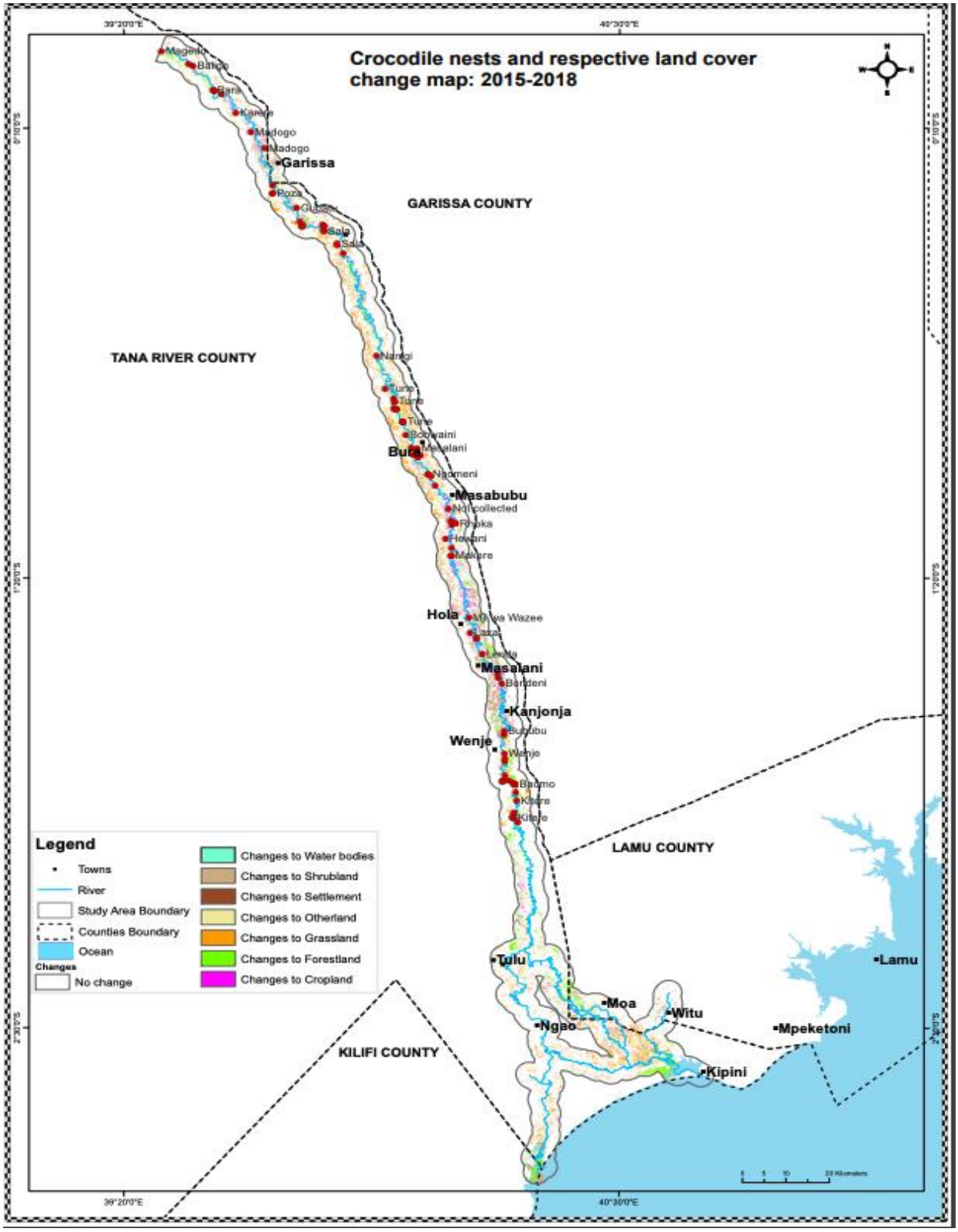

Figure 4.14: An overlay of the location (points) of surveyed nests during the 2018/2019 season at the Galaxy egg collection zone on the land cover change map

CHAPTER FIVE

DISCUSSION

5.1 Socio-economic Factors Influencing Involvement in Crocodile Ranching-related Activities

This study found that age, annual income, gender, ethnic group, religion and main source of livelihood significantly influenced involvement in different categories of crocodile use. However, formal education and egg collection zone were not significant determinants of involvement in crocodile use. Specifically, older participants, those who earned more annual income, males and Christians were more likely to be involved in illegal uses (as opposed to non-use) of crocodiles. In agreement with the present study, other studies have shown that involvement in illegal resource extraction increases with increase in the age of the household head (Akinsorotan *et al*., 2020; Mogomotsi *et al*., 2020; Nguyen *et al*., 2018). This is because certain extraction activities are demanding and require participants of higher age who are associated with more experience (López-Feldman, 2014). The finding that older participants were more likely to be involved in illegal uses (as opposed to non-use) of crocodiles can be explained by two findings from KIIs and FGDs. First, it was revealed that it is the older participants who are likely to have the needed courage and experience to undertake the exercise of hunting crocodiles and searching for their nests unlike younger participants. Second is the expectation that the need for income and family responsibilities increase with age.

The study revealed that participants who earned more annual incomes were more likely to be involved in illegal uses (as opposed to non-use) of crocodiles. This can be attributed to the possibility that these participants have greater capacity to derive their incomes from one or more natural resources along the river. Such activities contribute to loss of suitable habitat needed for the different crocodile life stages and in turn negatively affect the availability of eggs for ranching. Consistent with this finding, the rich have been found to extract more environmental resources (Nguyen *et al*., 2018). This finding contradicts other studies which show that low levels of incomes account for high dependence of rural vulnerable groups on natural resources for their existence (Harrison *et al*., 2015; Kümpel *et al*., 2010; MacMillan & Nguyen, 2014). These authors focused only on hunting for bushmeat in and around protected areas. However, the present study focused not only on hunting crocodiles for meat and eating crocodile eggs but also on other practices that affect crocodile populations, habitat and the sustainability of crocodile ranching-related activities.

The study revealed that male participants were more likely to be involved in both legal and illegal uses (as opposed to non-use) of crocodiles than female participants. The observed gender disparity in crocodile use can be attributed to the tough and risky nature of the tasks of obtaining crocodile meat through hunting and eggs from nests, which men (as opposed to women) tend to undertake. Key informant interviews and FGDs in the present study revealed that harvesting crocodile eggs from nests, and hunting crocodiles are tasks that are largely performed by men. This finding is consistent with several other studies indicating that tasks such as wildlife hunting and extraction of other forest products are predominantly performed by men as opposed to women (Akinsorotan *et al*., 2020; Kümpel *et al*., 2010; Mawaya & Kalindekafe, 2010; Sunderland *et al*., 2014). However, the present finding is distinguished that of these authors where the animals hunted for subsistence do not largely pose such risk as that faced when hunting crocodiles or harvesting crocodile eggs which can be fatal.

The study showed that participants from the Pokomo and Orma ethnic groups were more likely to be involved in legal uses (as opposed to non-use) of crocodiles than the Ilwana/ Malakote. This is consistent with other studies indicating that ethnicity plays a role in influencing natural resource utilization practices (Cuni-Sanchez *et al*., 2016; Kiffner *et al*., 2015). However, the finding from KII and FGDs that a section of Pokomos also engage in illegal crocodile utilization practices such as eating crocodile meat and eggs for body protein needs, medicinal and virility values as well as a source of pride and identity is likely because this is considered a normal tradition among the Pokomo despite it being outlawed. Several indigenous communities have been reported to hunt crocodiles for food, medicines and aphrodisiacs (Bolton & Laufa, 1982; Chomba *et al*., 2013; Corey *et al*., 2017; S. Pooley, 2016; Salem, 2013). The present study however revealed that the eating of crocodile meat and eggs is practiced by the *mila chini* Christian Pokomo who occupy the lower segments of the river and that these practices accord them pride and identity. Consistent with this finding, Pooley (2016) reported the nutritional, medicinal and virility value of crocodile meat among the Pokomo.

Another probable reason for the observed likelihood of participants from the Pokomo and Orma ethnic groups to engage in legal crocodile uses is related to existence of a more robust crocodile egg collection programme in the areas occupied by these communities. Both ethnic groups occupy the lower segments of lower River Tana much longer than the upper segments of lower River Tana where egg collection has been done for a relatively long time (Kyalo, 2008a). This finding is comparable with the study of Ntuli and Muchapondwa (2018) which showed that the longer a community is involved in wildlife conservation, the more likely it is

to develop robust institutions adapted to local conditions and to achieve positive conservation outcomes. Further, findings from

KIIs and FGDs that the existence of traditional indigenous knowledge and existence of cultural practices on crocodile conservation among the Orma and Pokomo living along the lower stretches of lower River Tana promoted human-crocodile co-existence support this argument. For example, the Orma believed that their prosperity was connected with the River Tana and the hippopotamuses and crocodiles in it. They therefore found it necessary to protect the river and the animals in it. The Pokomo on the other hand, have knowledge of the behaviour of crocodiles and have devised ways of co-existing with crocodiles. It appears that the long exposure of these two ethnic groups to crocodile ranching-related activities and the associated incentives and their traditional indigenous knowledge about crocodile conservation could have enhanced their adoption of legal uses of crocodiles.

Findings from both qualitative and quantitative findings showing that religion played a key role in influencing involvement in crocodile ranching-related activities is consistent with other studies (Baker *et al*., 2014; Brackhane *et al*., 2019; Ceppi & Nielsen, 2014; Reuter *et al*., 2018). The observed higher likelihood of Christians than Muslims to be involved in illegal uses of crocodiles can be attributed to religious differences in practices and norms regarding crocodile use. Both KIIs and FGDs established that Islam religion (unlike Christianity) prohibits its followers from eating crocodile meat and eggs, with stiff penalties such as ostracization and denial of burial rites being meted out as punishment for violation. Thus, the finding that Muslims were less likely to be involved in illegal uses of crocodiles suggests that such penalties are effective in deterring local people from engaging in practices that are harmful to crocodiles.

The present study revealed that while livestock keeping as the main source of livelihood reduced the likelihood of engaging in legal crocodile uses, it marginally altered the likelihood of engaging in legal uses. This is likely because livestock keeping was a more important source of livelihood as opposed to opportunities available to local communities from legal uses of crocodiles. Livestock keepers may therefore be reluctant to venture into new, risky and tedious less rewarding crocodile ranching-related activities. This therefore implies that the depredation on livestock by crocodiles would be meted out by retaliation, which in illegal. Lack of tolerance and retaliation for livestock depredation by carnivores has been reported in other studies (Hazzah *et al*., 2009; Treves & Bruskotter, 2014).

Human-induced threats to crocodile ranching-related activities

The results indicate four major human-induced threats to crocodile conservation. These are: the expansion of agricultural activities and overutilization of natural resources along the river, retaliatory killing of crocodiles and consumption of crocodile meat and eggs obtained from the wild. The finding that illegal consumption of crocodile meat and eggs is linked to the observed remarkable decline in the number of eggs available for legal utilization is consistent with other studies indicating that illegal resource use only depletes opportunities for legal users to benefit from natural resources (Kahler *et al*., 2013; Lindsey *et al*., 2013) but undermines conservation goals (Solomon *et al*., 2015). The finding that retaliatory killing of crocodiles due to the threats crocodiles pose on livestock keepers' livelihoods could undermine the conservation of crocodiles is consistent with others (Combrink *et al*., 2011; Kahler *et al*., 2013; Raley, 2016; Treves & Bruskotter, 2014) which show that killing of wildlife in retaliation poses remarkable risk to wildlife. The present study however further indicates that such retaliatory killing of crocodiles undermines the sustainable utilization of crocodiles. It also highlights the deliberate destruction of crocodile nests by humans as a less known phenomenon which is a threat to crocodile conservation as it reduces the number of eggs available for ranching and for recruitment into the wild crocodile population.

This study reveals that retaliatory killing of crocodiles did not happen uniformly across the lower River Tana. It was more pronounced at the upper segments which had no association and benefits from legal crocodile utilization benefits. On the contrary, there was hardly any retaliatory killing of crocodiles at the lower segment of lower River Tana due to the long association of the Orma livestock-keeping community with legal crocodile utilization practices and related benefits and their belief that their prosperity is associated with the river and its animals including crocodiles. The results further underscore absence of compensation for livestock losses despite the Wildlife Conservation and Management Act, 2013 making such a provision (GoK, 2013c) as an aggravating factor to retaliatory killing of crocodiles and nest destruction. Studies have shown that compensation schemes significantly reduce retaliatory killing of livestock predators (Hazzah *et al*., 2014; Treves & Bruskotter, 2014).

5.2 Local Community Perceptions Towards Involvement in Crocodile ranching-Related Activities

The present study showed that the participants' perceptions of benefits and incentives derived from crocodile egg collection programme was associated with increased likelihood of involvement in legal uses and decreased likelihood of involvement in illegal uses (as opposed to non-use) of crocodiles. The finding that perception of benefits increases the likelihood of involvement in legal uses of crocodiles is consistent with other studies (García-Amado *et al*., 2013; Ntuli *et al*., 2018; Oburah *et al*., 2021; Than *et al*., 2020) which have shown a strong association between willingness to support wildlife conservation with the perception of benefits.

In the present study, participants perceived three different uses of crocodiles, namely, crocodile eggs obtained from the wild can be eaten, crocodiles are a tourism attraction and collecting eggs for ranchers at a fee. These perceived uses of crocodiles were associated with positive and negative outcomes for crocodile ranching and conservation. The finding that participants who perceived that crocodile eggs obtained from the wild can be eaten were likely to be involved in both legal and illegal uses (as opposed to non-use) of crocodiles is counter-intuitive. This is because the involvement in harvesting eggs from the wild for subsistence is an illegal use and it should lower the participants' likelihood of being involved in legal uses of crocodiles. The engagement in illegal uses of crocodiles is attributed to the traditionally accepted consumption of meat and eggs among the Pokomo community. The finding on involvement in illegal consumption of crocodile meat and eggs is consistent with Chomba *et al*. (2013) and Pooley (2016) who have reported the consumption of crocodile eggs and meat and the cultural association with crocodilians. However, these authors do not associate the practice with perceptions of the concerned communities.

The engagement in both legal and illegal uses of crocodiles compares with Njukang *et al*. (2019) and Ebua *et al*. (2011) who found the possibility that conservation is at times perceived as a denial of traditional access rights to protein. In the present study, the expectation of receiving more socio-economic benefits appears to be another driving factor for the engagement in illegal crocodile uses. Consistent with this finding, generation of income and subsistence have been reported as reasons for poaching (Kahler *et al*., 2013; Kahler & Gore, 2012). In addition, there is an apparent incumbency by the local community to ensure sustainable use of this resource, whether legal or illegal. This is supported by findings from by KIIs and FGDs which revealed that the Pokomo and Orma have indigenous knowledge, beliefs and cultural practices which promote human-crocodile co-existence.

The present study revealed that participants who perceived that crocodile eggs could be collected for ranches at a fee were likely to engage in legal uses (as opposed to non-use) of crocodiles. This perception and engagement in legal crocodile utilization practices is attributed to the benefits and incentives the local communities had received from the crocodile egg collection programme. This finding is consistent with other studies (Allendorf *et al*., 2012; Holland *et al*., 2021; Oduor, 2020; Stem *et al*., 2003; Than *et al*., 2020) which report that the willingness to support conservation is strongly associated with perception of benefits. This suggests that the positive perception of the crocodile egg collection programme can be anchored on for positive outcomes for crocodile ranching and conservation.

Further, participants who perceived that crocodiles could be used as a tourism attraction were likely to be involved in illegal uses (as opposed to non-use) of crocodiles. The present study revealed that participants' perceptions that crocodiles are used as a tourism attraction did not necessarily prevent them from engaging in illegal uses of crocodiles. This finding could be attributed to two factors. First is the near-absence of wildlife-based tourism economy in the entire county of Tana River (GoK, 2013b, 2018; KNBS, 2015; Mohamed, 2015) through which they could connect crocodile conservation to tourism. Secondly, KIIs and FGDs revealed the needs of the local communities include access to crocodile eggs and meat for subsistence and trade, access to areas near the river for farming by irrigation or receding floods and water and pasture for livestock, and, mitigating against human-crocodile conflicts through destroying crocodile egg nests and poisoning crocodiles. However, it is through their need to address these needs that they are seen to be involved in illegal uses of crocodiles. This finding agrees with that of Dolisca *et al*. (2007) who found that local people see the importance of conservation through its relevance to their day-to-day life.

The study revealed a significant negative relationship between high level of tolerance towards crocodiles with participants' involvement in illegal uses of crocodiles. This finding is counter-intuitive because high levels of tolerance towards crocodiles should lower the likelihood of involvement in illegal uses of crocodiles. The finding is supported four findings from KIIs and FGDs. The first is that human-crocodile conflict was still a problem in the study region and could explain the prevalence of illegal uses of crocodiles and practices harmful to crocodiles and crocodile habitat. The second is the existence of diverse indigenous knowledge and cultural beliefs about crocodile behaviours among the Pokomo and Orma communities which enhanced their co-existence with crocodiles. The third is the finding that the local communities tolerated crocodiles because they knew some of their members derived benefits from egg collection. The finding concurs with a reported relation between high

incidences of poaching with human-wildlife conflicts (Ntuli *et al*., 2021). However, the finding differs from observations made elsewhere which show that people who had been affected by crocodile attacks on human lives and their livestock were unlikely to tolerate proximity to wild crocodilians (Khan *et al*., 2020; Raley, 2016). This could be due to the fact that the present study was done in a non-protected area where crocodile ranching was allowed while that of Khan *et al*. (2020) study was based inside a national park with village settlements in it. The fourth is that the cultural approval of the consumption of crocodile meat and eggs among the Christian Pokomos appears to explain the observed high tolerance towards crocodile and the involvement in illegal uses of crocodiles. This community therefore perceives this practice as normal despite it being proscribed by the wildlife law (GoK, 2013c).

5.3 Institutional Factors Influencing Involvement in Crocodile Ranching-related Activities and Performance of Crocodile Ranching-related Activities

This study revealed that participants who viewed illegal crocodile use practices (e.g. eating crocodile meat and eggs from the wild and hunting crocodiles) as an acceptable and appropriate thing to do were more likely to be involved in illegal uses (as opposed to non-use) of crocodiles. Although the practice of hunting crocodiles for meat and harvesting eggs from the wild for consumption is proscribed by the *Wildlife Conservation and Management Act, 2013*, the practice is not considered illegal among the local Pokomo. The present study established that the norms varied across the local ethnic and religious communities in the study area, with Islam prohibiting the consumption of crocodile eggs and meat while Christianity did not. Although the use of crocodile meat and eggs for food and medicinal purposes and as aphrodisiacs among the Pokomo and other communities has been reported elsewhere (Bolton & Laufa, 1982; Chomba *et al*., 2013; Corey *et al*., 2017; S. Pooley, 2016), the present study established that this practice was prevalent only among Christian Pokomos who occupy the lower stretches of lower River Tana. The existence of simultaneous contradictory customary norms and rules on the same issue have been reported elsewhere (A. Fischer *et al*., 2007; Kingston, 2016; McDonald *et al*., 2014).

Key informant interviews and FGDs revealed the existence of injunctive norms against this practice (i.e. the prohibition of eating crocodile meat and eggs and ostracization and denial of religious rites to contravening members) among Muslims in the study area. The injunctive norms and sanctions among the local Muslim communities on uses of crocodiles were found to have deterrent effects and positive outcomes for crocodile ranching and

conservation. Consistent with this finding, norms and religious prohibitions have been used to protect particular species, ecosystems and habitats in various places (Diawuo & Issifu, 2015; Dominics & Fuchaka, 2016; Reuter *et al*., 2016), whereas deterrent effects have been achieved by withholding social support or excluding someone who contravenes a norm from the collective society (Gezelius, 2002; Manning, 2013; Wenzel, 2004).

Key informant interviews and FGDs revealed the absence of norms disapproving retaliatory killing of crocodiles through poisoning and destroying crocodile nests especially among local communities living at the upper segments of lower River Tana. This was happening despite awareness among the local people that such practices were prohibited by rules and regulations for crocodile ranching. Further findings from KIIs and FGDs revealed that some members of the Orma community would congratulate one of their own who killed crocodiles. This situation could be explained by the inherent intolerance of loss of livelihoods through livestock losses to crocodiles and the need to retaliate. As such the local communities do not associate their behaviour of breaking crocodile ranching rules with the moral obligation to conserve crocodiles where their source of livelihood is undermined by crocodiles. Consistent with this finding, the aversion that drives people to kill crocodiles (Raley, 2016) and rewarding by social affirmation of skilled hunters despite the presence of legal disincentives (Commerçon *et al*., 2021) have been reported elsewhere.

This study revealed that study participants largely did nothing when a community member committed unacceptable behaviour or action against crocodiles or crocodile habitat. This finding could be suggestive of tolerance of the practice of eating crocodile meat and eggs from the wild, which was found to be a normal practice among the Pokomo Christians. This finding is generally indicative of local community indifference towards crocodile conservation. This is probably because such behaviour, by negatively influencing crocodiles and their habitat, actually helped to reduce crocodile-related negative impacts on humans and their livestock. Consistent with this finding studies (Commerçon *et al*., 2021) have shown local community tolerance to hunting by discouraging their members from cooperating with law enforcement.

Qualitative surveys revealed that a small proportion of the community members would advise or warn the person committing unacceptable deeds against crocodiles and crocodile habitat or consult elders or excommunicate the person. This indicates that some traces of cultural and religious systems of natural resource governance systems still exist and could be applied to prevent local people from engaging in illegal uses of crocodiles and practices which harm crocodiles. Other studies however show robust cultural and religious prohibitions

and sanctions in natural resource use (Baker *et al*., 2014; Brackhane *et al*., 2019; Daltry *et al*., 2005; Diawuo & Issifu, 2015; Dominics & Fuchaka, 2016; Reuter *et al*., 2018).

The study revealed that study participants who were aware that harvesting crocodile eggs and selling to the ranches was legally acceptable were more likely to be involved in legal uses of crocodiles. Key informant interviews and FGDs demonstrated that the knowledge among local community members that their community benefitted from projects and egg collection fees from crocodile ranches influenced the local communities' restraint from engaging in behaviour harmful to crocodiles and their habitat. This finding suggests that promoting awareness of crocodile ranching and conservation rules and regulations among the local communities would yield better conservation outcomes. Consistent with this finding, the awareness of conservation value of biodiversity and being beneficiary of incentives from conservation have been associated with engagement in activities that support conservation (Montana & Mlambo, 2019; van der Ploeg, *et al*., 2011a; van der Ploeg *et al.*, 2011b; van der Ploeg *et al*., 2011c).

Further, this study showed that the awareness among participants that crocodiles are a tourism attraction did not necessarily translate to adoption of behaviour that could result in positive conservation outcomes for crocodiles. Although tourism plays an important role in the Kenyan economy, its impact is yet to be felt in the local economy in Tana River county due to limited tourism products, underdeveloped road and tourism infrastructure (GoK, 2013b, 2018; KNBS, 2015; Mohamed, 2015). This finding differs with (Holland *et al*., 2021; Stem *et al*., 2003) who associated the engagement in pro-conservation behaviour with the actual engagement of local communities in tourism-related livelihoods. This is because the inability of local communities to connect the conservation of crocodiles and associated habitats for tourism with their day-to-day lives plays a role in their involvement in illegal practices which undermine crocodile ranching.

This study found that participants who were aware that crocodile meat and eggs from crocodile farms could be eaten, and those who were aware that a license was needed before harvesting crocodile eggs, were more likely to engage in illegal uses of crocodiles. A number of reasons can explain this situation. Firstly, the local communities find it impractical to access crocodile eggs and meat at the three crocodile ranches which are far (over one hundred kilometres) away from the river basin. Secondly, the local communities which have traditionally obtained crocodile meat and eggs freely from the river may be reluctant to buy the eggs and meat from crocodile ranches. Thirdly, Kenya Wildlife Service (KWS) only grants licenses to harvest crocodile eggs to licensed crocodile ranches. Since harvesting of

crocodile eggs and hunting crocodiles for subsistence or sale to villagers is proscribed by the *Wildlife Conservation and Management Act*, 2013 (GoK, 2013c), local communities have to resort to illegal uses of crocodiles. The finding differs with other studies (Kahler *et al*., 2013; Kahler & Gore, 2012; Keane *et al*., 2011; Momanyi, 2015; St. John *et al*., 2015) which show that low levels of awareness of negative environmental consequences of decisions, practices or action can result in negative conservation outcomes. This is because the rules and regulations for crocodile ranching appear to have interfered with the culturally accepted practices with regard to using crocodiles. These findings are consistent with the studies of Jacobson (2009) and Rizzolo (2017) who reported that violators deemed to have good knowledge of wildlife violate wildlife rules and regulations. Other studies have reported that local communities would still need to hunt for food despite being aware of regulations for wildlife use (Oliva *et al*., 2014) and to exercise traditional rights to resource use (Muth & Bowe, 1998).

5.4 Performance of Egg Harvesting, Egg Hatchability and Skin and Meat Sales and Benefits and Incentives

The strong positive correlation between the number of eggs harvested and the number of nests indicates that minimizing clearance of crocodile habitat could be key to increasing nesting sites and egg harvesting performance. This finding is consistent with other studies (CITES, 2019; Oburah *et al*., 2021; Weber *et al*., 2015) which reveal the importance of local community participation in enhancing support for management of natural resources. The mean number of 31 eggs per nest observed at Nile egg collection zone during the 2014-2018 period is an improvement from the mean of 25 eggs per nest in the year 2007 at the Nile egg collection zone (Kyalo, 2008a). This is possibly due to aging of the breeding females. This finding concurs with Cott (1961) who observed that older crocodiles lay larger clutches (Cott, 1961).

The present study found that the number of crocodile nests ranged from 378 to 728 during the period 2014-2018. This number differs with the 1451 and 1406 nests reported during the 2005/2006 and 2006/2007 seasons, respectively (Kyalo, 2008b). The finding indicates that the female breeding population has declined by about a half from between the years 2005 and 2018. This assertion is made on the basis of two observations made during the 2018/2019 nest survey. First is that the egg collectors were observed harvesting crocodile eggs in Tana River National Primate Reserve. Second, is that egg collectors were observed harvesting all

eggs from all identified nests. Due the need for the ranches and egg collectors to harvest the maximum number of crocodile eggs, it is probable that these two practices could have prevailed during the previous seasons.

The study found a significant association between the egg hatching success rate and crocodile ranching entity, with Nile having a significant higher crocodile egg hatching rate than Galaxy. This indicates that formal training and experience in crocodile husbandry and post-harvest egg management practices can influence crocodile egg hatchability. The better egg hatching performance at Nile can be attributed to formal training and experience in crocodile husbandry possessed by the Nile manager and better post-harvest egg management practices at Nile. The lower hatching rates at Galaxy could be attributed to damage in the course of transportation from the nest sites to the egg collectors' homes and to field incubation units. The lower hatching rates at Galaxy may also have been caused by failure to deploy basic equipment such as thermometers and hygrometers needed for monitoring and ensuring provision of optimal egg incubation requirements. Further, by grading eggs upon arrival at the incubation unit, Nile ensured that only viable eggs were incubated. However, it is probable that Galaxy incubated some eggs that got damaged in the course of transportation after they had been graded at the source. This finding differs with Corey *et al*. (2017) who attribute low crocodile hatching success rates to the absence of suitably qualified and committed personnel who could constantly monitor the incubation process. The isolated lowest egg hatching performance at Nile during the 2016/2017 season could be attributed challenges in transportation prior to being sold to Nile and Nile's capacity to incubate the unusually higher number of crocodile eggs (161% of allocated quota).

The present study reveals an improvement from the rates previously reported. Previous crocodile egg hatching success rate was reported at 39% for Galaxy and 63% for Nile in 2007 (Kyalo, 2008b). The egg hatching success rates (>80%) reported at Nile during the 2014/2015, 2015/2016 and 2017/2018 seasons are within acceptable industry standard, whereas the rates (<63%) reported at Galaxy are below this standard (Manolis & Webb, 2016). The egg hatching rates observed in this study (63-81%) are generally comparable to rates (61-85%) previously reported for ranching operations in Zimbabwe and Zambia (Chomba *et al*., 2013; Dzoma *et al*., 2008).

The observed higher quantity of crocodile skins and meat sales at Nile compared to Galaxy could partly be attributed to the fact that Nile had been in operation for a longer time (26 years) compared to Galaxy which had been operational for only 17 years. The longer time that Nile had been operational suggests more capital outlay and more experience in ranching

and established markets for skins. In addition, Nile aimed to produce more skins to reach a wider global market while Galaxy aimed to solely supply skins to its own leather factory in South Korea. Consequently, this study shows that the scale of production and sale of crocodile skins may be dictated by the objectives of the ranching operation. This study also shows that crocodile ranches could earn more sales revenue if the skins are tanned locally to acceptable international market standards than from the current practice of exporting raw salted skins. The finding that despite local sales of crocodile meat to hotels and butcheries, skins were the main product for both ranches.

The study revealed that benefitting from community projects (as opposed to direct personal incomes) derived from crocodile egg collection positively influenced involvement in crocodile ranching-related activities (i.e., involvement in legal uses of crocodiles). This could be attributed to the fact that incomes from egg collection are specific to individual egg collectors, whereas benefits from community projects flow to the community as a whole. Another reason is that incomes paid by the ranches to egg collectors were limited to the egg collection season which lasted up to 4 months and were not major incomes for the egg collectors. Consistent with this finding, benefits from wildlife invested in community projects such as schools, health centres and water have been reported to be more impactful than individual or household benefits (J. R. Adhikari, 2001; S. Adhikari *et al.*, 2014; Ntuli & Muchapondwa, 2018; Suich, 2013).

The present study further demonstrates that the possibility of earning more income from egg collection provides an incentive for individual egg collectors to work hard to harvest and deliver more eggs to the rancher. This finding is supported by the observed strong positive correlation between the number of crocodile eggs harvested and egg collection fees paid to egg collectors. However, KIIs and FGDs revealed that not only was egg harvesting exercise difficult, but the number of crocodile eggs that each collector could harvest in one season had declined over time and competition among egg collectors had increased. The finding is consistent with other studies (Austin & Corey, 2012; Corey *et al.*, 2017) who found that competition with other egg collectors and seasonal variation in the number of nests laid as contributing factors to varying income received by egg collectors. This may imply that the egg collectors may increasingly turn to other sources of income which may not be favourable to crocodile ranching to supplement income from egg collection.

The study revealed that the existence of well-organized and vocal community-based organizations (CBOs) can lead to better outcomes for local communities and crocodile ranching and conservation. Specifically, out of the entire stretch of the river where egg

collection was being done, it was only at the segments occupied by Tsampani, Mwina, Salama, Bilisa and Abadhani community groups where the egg collectors and local communities were able to exercise their legitimacy and authority to exclude non-local people and ranches from collecting eggs due to existence of active CBOs. These CBOs negotiated with the ranches and received more benefits from crocodile egg collection with the mediation of KWS and local Chiefs, and were effective in preventing local people from engaging in behaviour that could be harmful to crocodiles and crocodile habitat. The study further revealed that, in the absence of such CBOs, the local communities were reduced to spectators and crocodile eggs became an open-access resource, with increased risk of overharvesting. These findings are supported by the study of Campbell *et al*. (2013) and Keane *et al*. (2011) who illustrate the link between the involvement of local organized groups in natural resource management with positive conservation outcomes, including improved stewardship, local users rights and promoted community participation in monitoring and enforcement. The observed disparity in benefits from crocodile ranching among local communities at the lower segments of lower River Tana occurred despite the fact that all the local communities and egg collectors associated with Nile had been involved in the egg collection programme a similar period of 26 years.

This study established a significant relationship between participants' egg collection zones and their likelihood of having benefitted from the egg collection programme. In particular, participants from Galaxy and Kazuri egg collection zones were less likely to have benefitted from community projects compared to participants from Nile egg collection zone. This finding is supported by three findings from KII and FGDs. First is that local communities in the Nile and Galaxy egg collection zones benefitted from community projects implemented by these two ranches, with the impact being felt much more widely at the Nile egg collection zone. It was revealed that Nile, being the oldest ranch in the study region, had implemented various community projects in its respective egg collection zone. Secondly, the presence of CBOs in some parts of Nile and Galaxy egg collection zones, as opposed to the other parts of lower River Tana where local communities were not organized into CBOs, was found to be instrumental in negotiating for incentives and benefits payable to the local community members. Thirdly, local communities in Kazuri egg collection zone had not benefitted from any community projects donated by Kazuri. This latter finding can be attributed to revelation that Kazuri was the newest ranch and was facing a number of challenges due to community dynamics. Consistent with this finding, Ntuli and Muchapondwa (2018) show that community cooperation, and conservation benefits are more

developed among communities that joined such arrangements earlier than where arrangements are entered into later.

The household survey revealed that more than two-thirds of respondents had not benefitted from the crocodile egg collection programme, something which is suggestive of a limited outreach of the crocodile egg collection programme to the local communities. The household survey also revealed that benefitting from crocodile ranching-related community projects and direct personal incomes did not influence likelihood of involvement in legal uses of crocodiles. It therefore appears that there was inherent non-economic motivation for crocodile conservation among the Pokomo and Orma which had played an important role in crocodile conservation. This finding is supported by observations from KIIs and FGDs which revealed the cultural value of crocodiles among these two communities and the existence of intricate indigenous knowledge that enabled human-crocodile co-existence. Consistent with this finding, Gordon and Ayiemba (2003) and Corey *et al*. (2017) demonstrate that the motivation of local communities to conserve the forest and saltwater crocodiles, respectively, transcended the accruing economic incentives.

This study revealed that crocodile ranches give various benefits and incentives to local communities to support crocodile ranching and conservation. However, these benefits and incentives could yield mixed outcomes. For instance, Galaxy's donation of water pumps to the egg collectors with a view to supplementing their income through irrigated crop farming could be counter-productive to crocodile ranching. This is because it would encourage an increase in crop cultivation along the river thereby increasing disturbance to crocodiles and alteration to their habitat. Conversely, sinking of boreholes by Nile in the village centres helps reduce the need to fetch water from the river for domestic use, thereby partly mitigating against human-crocodile conflict. In addition, Nile's support of apiary activities could reduce farming activities along the river, thereby yielding positive outcomes for crocodile ranching. Other studies (Bandyopadhyay & Tembo, 2010; Campbell *et al*., 2013; Gordon & Ayiemba, 2003; Ntuli & Muchapondwa, 2018; Suich, 2013) have documented community benefits from wildlife which aimed to provide alternative sources of income and divert their attention from unsustainable uses of wildlife. However, it is not enough to provide alternative sources of income and divert local communities from unsustainable wildlife uses. This study therefore suggests that the community projects should be compatible with conservation of wildlife.

5.5 The Influence of Biophysical Factors on the Performance of Crocodile Ranching-related Activities

The study revealed that 95-96% of the egg collection sites were covered by natural vegetation types (i.e., shrubland, forestland and open grassland), underscoring the importance of these vegetation types in crocodile conservation and ranching. However, a substantial increase in coverage of cropland, other lands (bare soil, rock, and unmanaged land) and settlements was revealed. The observed rapid growth of cropland by 213% between 2015 and 2018 was largely due to conversion from forestland, settlements, other land, water bodies and shrubland. This represents a rapid extensive growth of cropland within a short period compared to 9% growth of cropland reported elsewhere between 1986 and 2016 (Abebe *et al*., 2022) and 34% between 1990 and 2015 (Chilagane *et al*., 2020). These two studies focused on general land cover/land use changes while the present study focused on how land cover changes impacts on crocodile ranching. As such, the observed ongoing expansion of human activities such as crop cultivation, sand harvesting, settlement and livestock keeping appear to be major contributors to alteration and reduction of crocodile habitat as well as disturbance of crocodile behaviour. This finding is consistent with other studies (Kyalo, 2008a; Salem, 2013; Somaweera *et al*., 2018, 2019; Utete, 2021) which show that vast alteration of crocodile habitat and physical disturbance of crocodiles negatively affects crocodile populations.

This study attributes the increase in coverage of forest land by 6.9% between 2015 and 2018 to the spread of *Prosopis juliflora* tree species which have been reported to be highly invasive in floodplains, swamps, river basins and irrigation schemes in Tana River County (Mwangi & Swallow, 2005; Ngunjiri & Choge, 2004), an invasive tree in the area. The observed rapid increase (by 110%) in other land between 2015 and 2018 can largely be attributed to an observed development of a new irrigation scheme in Tune area, overgrazing and land degradation. A much longer rate (15%) of increase of bare land over a much longer period (30 years) has been reported elsewhere (Abebe *et al*., 2022). Studies have attributed decrease in extent of grassland coverage and increase in degraded land to human population pressure which cause extensive conversion of open grazing land into crop land and to overgrazing (Abebe *et al*., 2022; Bewket, 2002).

The observed rapid land cover changes and conversions can also be explained by the human population increase experienced in the study region. The total human population in Tana River County increased by 32% during the period 2009-2019 (KNBS, 2009, 2019) and much of this is concentrated along the lower River Tana (GoK, 2018; MENR, 2012;

Mohamed, 2015; Odhengo *et al*., 2014; Terer *et al*., 2004). Land conversion for agriculture negatively affects crocodile nesting behaviour, forcing them to nest in areas which have medium to high anthropogenic disturbance (I. J. Evans *et al*., 2015). The presence of irrigated farms and livestock close to the river account for the observed long distance for the 10 nests located over 20 metres from the water. Key informant interviews, FGDs and direct observations revealed that the areas between Bura and Madogo were occupied by the Ilwana/ Malakote community who practice small scale rice and banana farming using receding flood waters. It was further revealed that members of pastoral communities from the neighbouring Garissa County had leased land from the local Ilwana/ Malakote and were growing fruits and vegetables at a large scale using mechanized irrigation along the river.

The study revealed a gradient of crocodile nest concentration across the Galaxy egg concentration zone during the nest survey. Specifically, the highest concentration was observed in the Wenje and Kitere segment of the river, whereas the lowest concentrations were in the Madogo and Poza; Sala and Nanighi; Makere and Mji wa Wazee; and, Bondeni and Bububu segments. The high concentration of nests in the Wenje and Kitere segment is likely due to the fact that this segment is within the Tana River National Primate Reserve, with remarkably limited land cover conversion. Due to protection by KWS, the reserve is free from settlements, crop land and other changes induced by overgrazing by livestock, all of which cause disturbances to crocodiles and loss of their habitat. This finding is consistent with that of Wallace (2011) who reported that crocodile density increases in areas which have higher levels of wildlife/habitat protection.

Key informant interviews revealed that a shift in the river at Sala-Sombo and the Ngao-Oda channels had resulted in degradation of suitable crocodile habitat into bare land. In particular, it was revealed that the shift of the Sala-Sombo channel had displaced female crocodiles that were known to nest in the area. As such, female crocodiles have been forced to move much further away in search for nesting areas. For example, this is evidenced by the existence of a single nest at 24 metres away from water at Sombo. This situation could have implications on nest predation and the safety of the female as it traverses longer distances to search of nesting sites and to tend the nest. Studies have shown the importance of the proximity of the nest to permanent water, availability of suitable substrate and shade as important for the brooding female crocodile's needs for safety and nest tending (Calverley & Downs, 2017; Chibeba, 2003; Cott, 1961; Kofron, 1989; Modha, 1967; Refsnider, 2016; Somaweera *et al*., 2013; Somaweera & Shine, 2013). Compared with other studies (Champion & Downs, 2017; Hutton, 1989; Swanepoel *et al*., 2000) which found most nests

situated at distances of up to 20 metres from water, the present study however found most nests at half this distance from water.

Four factors account for the observed low concentration of nests in various segments of the river. First, is the conversion of crocodile habitat into cropland at the Madogo- Poza; Sala- Nanighi; Makere- Mji wa Wazee; and, Bondeni- Bububu segments. Second, is settlements as was observed in the Madogo- Poza; Sala- Nanighi; Makere- Mji wa Wazee; and, Bondeni- Bububu. Third is killing of crocodiles through poisoning and destruction of crocodile nests due to low tolerance of crocodiles by the local livestock-keeping communities at the Sala- Tune segment of the river. Fourth is the livestock activity at the eastern bank of the river from Bura to Sala segment. This finding is consistent with other studies (Combrink *et al*., 2011, 2017) which show that settlements and crop land, which are associated with developments, human and livestock disturbance and habitat destruction negatively affect crocodile breeding success. The present study however further observes that such anthropogenic activities would potentially affect the crocodile ranching-related activities as a result of a decline in the number of eggs available for harvesting.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

i. The various socio-economic factors had varying effects on the study participants' involvement in the various categories of crocodile uses (legal, illegal or non-use).

All-inclusive strategies that promote the mitigation of human-crocodile conflicts and the involvement men and women, communities from all local ethnic groups, older participants, those with higher annual incomes, Christians and livestock keepers will provide plausible measures for sustainable use and conservation of crocodiles and associated habitats.

ii. The perceptions that crocodile eggs could be collected for ranches at a fee and that there were benefits derived from crocodile ranching-related activities influenced participants involvement in legal crocodile utilization practices.

The counter-intuitive significant negative relationship between high levels of tolerance towards crocodiles with participants involvement in illegal uses was attributed to the existence of human-crocodile conflicts, diverse indigenous knowledge and cultural beliefs about crocodiles and the knowledge that a section of the community benefits from the crocodile egg collection programme.

iii. The involvement in illegal uses of crocodiles was attributed to various norms which prescribed the hunting of crocodiles and harvesting of crocodile eggs from the wild for consumption, trade and aiding in fishing as acceptable practices. The involvement in these practices had negative outcomes for crocodile ranching-related activities and conservation.

Islam prohibitions and sanctions with regard to eating crocodile meat and eggs and were effective in deterring local Muslim community members from engaging illegal crocodile utilization practices and had positive outcomes for crocodile ranching and conservation.

The awareness that crocodiles are a tourism attraction did not influence study participants from not engaging in illegal crocodile utilization practices. The lack of connection between tourism-based on crocodiles and the associated habitats to the livelihoods of the local communities was attributed to participants' involvement in illegal crocodile utilization practices.

iv) Post-egg harvest management practices determined the egg hatching success rate at the crocodile ranching operations.

The quantities of crocodile skins produced for export were largely dependent on the scale and objectives of the ranching operation.

Benefitting from community projects derived from crocodile ranching (as opposed to direct personal incomes) derived from crocodile ranching decreased the likelihood of being involved in illegal uses of crocodiles.

v) There was rapid increase in cropland, grassland, settlements and other land (bare soil, rock, unmanaged land) with forest land, grassland, shrubland and water bodies being the main contributors. The increase in coverage by cropland and settlements was attributed to human activities and developments which cause degradation of crocodile habitat and disturbance to crocodile behaviour.

The study shows a gradient of three crocodile nest concentration zones, namely high, medium and low, with the high nest concentration segment being inside the Tana River National Primate Reserve.

6.2 Recommendations

6.2.1 Management Implications

i) This study recommends provision of extension services to the diverse local communities to enable them engage in value addition of crocodile ranching like egg incubation and selling hatchlings and dissuade them from engaging in practices that are harmful to crocodiles and to their natural resource base.

ii) The enhanced implementation of the egg collection programme and benefits and incentives from the crocodile ranching programme in order to improve local communities' perceptions of crocodile ranching and tolerance towards crocodiles and to enhance their involvement in legal crocodile utilization practices.

iii) Implementation of sensitization programmes aiming at dissuading local communities from engaging in various crocodile utilization practices that are currently viewed as acceptable but which undermine crocodile ranching and conservation objectives.

iv) Development and implementation of a national strategy for crocodile ranching by introducing a system for allocating egg collection quotas and egg collection zones based on the objectives, capacity and egg hatching success of the crocodile ranches.

Development of a strategy for implementation of incentives and benefits from crocodile ranching in order to promote the involvement of the diverse local communities in legal and sustainable uses of crocodiles.

v) Sensitization of local communities on implications of rapid expansion of cropland, settlements, and other land (bare soil, rock, unmanaged land) on crocodile ranching-related activities and the stability of the natural resource base.

Development and implementation of a strategy to protect the areas which were found to be favourable for crocodile nesting as evidenced by the high concentration of crocodile nests and restoring the areas which had a low concentration of crocodile egg nests.

6.2.2 Areas for Further Research

i) Undertake an assessment of human-crocodile conflicts to understand the extent and impact on human lives, local communities' livelihoods and implications for crocodile ranching- related activities and conservation.

ii) Undertake an assessment of human-crocodile conflicts to understand the extent and impact on human lives, local communities' livelihoods and implications for crocodile ranching- related activities and conservation.

iii) Undertake regular census of crocodiles to determine the numbers of crocodiles in lower River Tana, the density and sex and age structure to provide a basis for planning and implementing the crocodile egg collection programme and any conservation and management measures that may be needed.

iv) Undertake long-term monitoring of the performance of crocodile egg harvesting assessment integrating use of GIS and land cover/land use changes.

Undertake studies on husbandry practices within the crocodile ranches and their influence on egg hatching success and hatchling survival rates.

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APPENDICES

Appendix A

Questionnaire For Household Survey
Interviewer's Name _____Serial No. _____
Egg collection zone 1. Galaxy 2. Kazuri London 3. Nile Crocodiles
Village name _____

I am conducting a field study on crocodile conservation in lower Tana River as part of my PhD studies at Egerton University. You are requested to participate by responding to questions in this survey about your experience and knowledge about conservation of crocodiles in Tana River County. Your participation is completely voluntary and the information you provide will be kept in confidence. The responses will be recorded in a questionnaire. Your name will neither be recorded in the questionnaire nor in preparing any report.

A. DEMOGRAPHIC INFORMATION

1. Age _____yrs
2. Gender 1. Male 2. Female
3. Marital status 1. Married 2. Not Married 3. Widow(er) 4. Divorced/ separated
4. Household size _____
5. Ethnic group 1. Pokomo 2. Orma 3. Wardei 4. Other, Specify_____
6. Religion 1. Christian 2. Muslim 3. Other, specify _____
7. What is your level of formal education level?
   1. Primary 2. Secondary 3. Tertiary 4. None

B: SOCIO-ECONOMIC INFORMATION

8. What are your sources of income? (**Circle responses**).
   i) Farming ii) Livestock keeping iii) Crocodile egg collection
   iii) Fishing iv) Welding v) Employment
   vi) Business vii) Bee keeping viii) Depend on children
   ix) Charcoal burning x) Masonry xi) Carpentry
9. What is your main source of livelihood? (**one of the responses circled above**)

_____

10. What is your annual income in K Sh? (**interviewer to bring each of the circled responses in 10 and indicate annual income for each)**

Source of income	Annual Income (K Sh)
_____	_____
_____	_____
_____	_____

_____ _____

11. The following statements relate to benefits obtained from crocodile conservation and ranching. Please state which one applies to you and the reasons:

		Statement	1. Yes 0. No	Reasons for engaging in it
A	1	Eat crocodile eggs		1. Protein source 2. Crocodile fats are medicinal 3. Medicinal 4. Sell to community
	2.	Eat crocodile meat		1. Protein source 2. Boosts immunity 3. Crocodile fats are medicinal 4. Reduces heart disease 5. Cures asthma 6. Good body builder 7. Gives pride and sense of belonging 8. Fat used for cooking 9. Sell to community
	3.	Use crocodile meat in fishing		
B	4.	Sell crocodile eggs to villagers		
	5.	Sell crocodile meat to villagers to eat		
	6	Sell crocodile meat to fishermen		
C	7.	Collecting eggs for crocodile ranchers at a fee		
	8.	Locate crocodile egg nests for ranchers at a fee		
	9.	Incubate crocodile eggs and sell hatchlings to ranchers		
	10.	Ranch hatchlings to sell crocodile meat		
	11.	Employed by rancher at the field incubation unit		
	12.	Train egg collectors		
	13.	Lease land to crocodile rancher		

12. (For those who eat crocodile eggs (A. 1 above). How many eggs did you eat during the last egg-laying season? _____

13. (For those who eat crocodile meat (A. 2 above). How often do you use eat crocodile meat?

    1. Rarely 2. Regularly 3. As often as needed

14. (For those who use crocodile meat for fishing (A. 3 above). How much crocodile meat do you use for fishing in a month? ……. kg

15. (For those who sell crocodile eggs to villagers, B4 above). How many crocodile eggs did you sell to villagers during the last egg-laying season? _____

16. (For those who sell crocodile meat to villagers, B5 above). How often do you sell crocodile meat to villagers? 1. Rarely 2. Regularly 3. As often as needed

17. (For those who sell crocodile meat to fishermen, B6 above). How much crocodile meat did you sell to fishermen last year? _____kgs (approx.)

18. How many members of your household are engaged in crocodile conservation (and use)?

_____

19. Have you benefited from the crocodile egg collection programme in your community?

1- Yes, state how. 0- No. ***(Interviewer to write response given against stated benefit below)***

Direct personal income _____

Community project, describe _____

Other, describe _____

_____

__

20. Are you aware of any legally acceptable ways of conserving and using crocodiles? ***(Interviewer to circle response given)***

1. Yes 0. No

If Yes, please list them:

1.Ranching
2.Collecting eggs and selling to ranchers
3.Tourist attraction
4.Other, explain ……

B. PERCEPTIONS

21. In which ways can crocodiles be used? **Interviewer to prompt the respondent to list and the interviewer to circle the mentioned use.**

1. Eating their eggs
2. Eating their meat
3. Using their meat as bait for fishing
4. Collecting eggs for crocodile ranchers at a fee
5. Locating crocodile egg nests for ranchers at a fee
6. Incubating crocodile eggs and selling hatchlings to ranchers
7. Ranching hatchlings to sell crocodile meat
8. Ranching hatchlings to sell crocodile skins
9. Sell meat from hunted crocodiles to the community
10. Sell crocodile eggs collected from the wild to the community
11. Tourism attraction
12. Crocodile skin used to make items for use
13. Crocodile teeth are used to make ornaments
14. Crocodile bile is used as deadly poison

22. The following statements relate to crocodile conservation and use in your community. Please state your level of agreement or disagreement with them as per the corresponding scale:

Statement		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Incentives to conserve wild crocodile populations						
1.	We should conserve crocodiles and their habitats for present and future generations.					
2.	Members of my household derive monetary benefits from crocodile conservation and use.					
3.	Members of my household derive non-monetary benefits from crocodile conservation and use					
4.	Members of my community derive monetary benefits from crocodile conservation and use					
5.	Members of my community derive non-monetary benefits from crocodile conservation and use					
Opportunities and how to participate in crocodile ranching						
6.	Crocodile ranching is a form of wildlife use and is allowed					
7.	A license is needed prior to engaging in crocodile ranching					
8.	Crocodile use is an acceptable practice in my community					
9.	Any local person can engage in crocodile ranching					
10.	Villagers can form groups to run full cycle crocodile					

	ranching					
11.	Villagers can form groups for crocodile egg collection and hatching for sale to ranchers					
Tolerance to crocodiles						
12.	Crocodiles need to be conserved to maintain the diversity of species.					
13.	Crocodiles are important animals for maintaining ecological balance for supporting life					
14.	They should be conserved to avoid scarcity					

23.What course of action should be taken by someone whose household member suffers the following damages caused by crocodiles:

	Damage	Perceived course of action
1	Human injury	Report to KWS & Police 2. Report to KWS 3. Report to Police 4. Report to police who then report to KWS 5. Report to KWS, Police or Chief 6. Take injured person to hospital then report to KWS 7. Report to KWS for compensation 8. Report to Chief 9. Take to hospital & report to Police
2	Human death	Report to KWS & Police 2. Report to KWS 3. Report to Police 4. Report to police who then report to KWS 5. Report to KWS, Police or Chief 6. Kill the crocodile when found 7. Kill the crocodile & report to KWS 8. Report to KWS, Police or Chief 9. Report to KWS for compensation 10. Report to Chief
3	Livestock loss	Report to KWS & Police 2. Report to KWS 3.Report to Police 4. Kill the crocodile with poisoned meat 5. Take no action 6. Report to Chief & KWS 7. Seek compensation from KWS 8. Report to the Chief 9. Report to KWS, Police or Chief

E. INSTITUTIONAL FACTORS

24.Do you hold a leadership role in your community?

1. Yes, Role(s) 1- Chairman of youth affairs 4- Village elder
2- Coordinator of youth affairs 5- Reconciliation elder
3- Chairman peace committee 6- Imam

0. No, go to Question 26

25. Are you a member of a community based environmental or conservation group?
1 Yes, What are the activities of the group?_____
_____
_____
_____
_____
_____
_____

0 No.

26. What institutions, whether local or public, have organized meetings in your community during the last four years? Interviewer to pick responses from the following options-
Name of institution- 1- Kenya Red Cross 2- PFF 3- Action Against Hunger 4- USAID 5- KWS

Name of institution- 1- Kenya Red Cross 2- PFF 3- Action Against Hunger 4- USAID 5- KWS 6- Muhuri 7- WFP 8- County Government 9- Nature Kenya 10- Rock 11- KECOSCE 12- Department of Agriculture 13- WELT Hunger 14- NDERA Conservancy 15- Team & Team

Agenda of meeting- 1- Food security 2-Floods and safety 3- Food relief 4- Community development project 5- Rights of citizens 6- Farming 7- Security 8- Wildlife conservation 9- Children rights 10- Human crocodile conflicts 11- Health 12- Environmental sanitation 13- Peace 14- Crocodile farming 15- Fish farming 16- Tourism 17- Wildlife Security

	Name of institution	Agenda of meeting	Number of meetings
1.			
2.			
3.			
4.			

27.What actions or behaviour towards crocodiles are considered normal and acceptable in your community customs? Interviewer to read each statement to respondent.

	Statement	1 - Yes, 0- No
1.	Hunting crocodiles and eating their meat	
2.	Eating crocodile meat	
3.	Eating crocodile eggs	
4.	Killing crocodile and hanging tail on chest as a symbol of heroism	
5.	Hunting crocodiles and selling their meat	
6.	Killing crocodiles which have killed or injured someone or taken livestock	
7.	Not disturbing crocodiles which are basking at the river banks	
8.	Chasing away crocodiles which come close to people at the river bank	
9.	Use of crocodile bile to hunt animals	

10.	Destroying crocodile egg nests	
11.	Keeping crocodiles at home	
12.	Disposing crocodile dead body on the road	

28. How does your community address unacceptable actions or behaviour against crocodiles?

Interviewer to circle given response-

1. Community does nothing 2. Advising that person on how to take care of crocodiles 3. Warning 4. Consult council of elders
5.Excommunicate that person 6- Report to Chief
7.Report to Chief then KWS 8- Inform KWS
9. Curse that person

29. Please state your awareness of the following government wildlife rules relating to crocodile conservation and ranching:

Rule	1.Yes 2. No
Harvesting of wild eggs for domestic consumption is illegal	
Hunting of crocodiles for domestic consumption is illegal	
Hunting crocodiles for meat for fishing is illegal	
Poisoning crocodiles is not allowed by law	
It is illegal to capture wild crocodiles	
Crocodile meat and eggs can be consumed from farmed crocodiles	
A KWS license is required before harvesting eggs	
A KWS license is required for farming crocodiles.	

END

Thank you for participating in this survey

Appendix B

Questionnaire For Those Engaged In Crocodile Egg Collection As An Economic Activity

Interviewer's Name _____Serial No. _____

I am conducting a field study on crocodile ranching in lower Tana River as part of my PhD studies at Egerton University. You are requested to participate by responding to questions in this survey about your experience and knowledge about crocodile ranching in Tana River County. Your participation is completely voluntary and the information you provide will be kept in confidence. The responses will be recorded in a questionnaire. Your name will neither be recorded in the questionnaire nor in preparing any report.

A. DEMOGRAPHIC INFORMATION

1. Zone: 1. Galaxy Crocodiles Limited 2. Kazuri London Limited 3. Nile Crocodiles Limited
2. Village name_____ Division_____
3. Age _____ years old
4. Sex 1. Male 2. Female
5. Marital status 1. Married 2. Not Married 3. Widow(er) 4. Divorced/ separated
6. Household size _____
7. Ethnic group 1. Pokomo 2. Orma 3. Wardei 4. Other, Specify_____
8. Religion 1. Christian 2. Muslim 3. Other, specify _____
9. What is your level of formal education level?
   1. Primary 2. Secondary 3. Tertiary 4. None

B: SOCIO-ECONOMIC INFORMATION

10. What are your sources of income? (**Circle responses**).
    ii) Farming ii) Livestock keeping iii) Crocodile egg collection
    iii) Fishing iv) Welding v) Employment
    vi) Business vii) Bee keeping viii) Depend on children
    ix) Charcoal burning x) Masonry xi) Carpentry
11. What is your main source of livelihood? (**one of the responses circle above**)

_____

12. What is your annual income in K Sh? (**interviewer to bring each of the circled responses in 8 and indicate annual income for each)**

Source of income	Annual Income (K Sh)
_____	_____
_____	_____
_____	_____
_____	_____

13. The following statements relate to benefits obtained from crocodile conservation. Please state which one applies to you:

		Statement	2. Applicable 3. Not applicable
A	1	Eat crocodile eggs	
	2.	Eat crocodile meat	
	3.	Use crocodile meat in fishing	
B	4.	Sell crocodile eggs to villagers	
	5.	Sell crocodile meat to villagers to eat	
	6	Sell crocodile meat to fishermen	
C	7.	Collecting eggs for crocodile ranchers at a fee	
	8.	Locate crocodile egg nests for ranchers at a fee	
	9.	Incubate crocodile eggs and sell hatchlings to ranchers	
	10.	Ranch hatchlings to sell crocodile meat	
	11.	Employed by rancher at the field incubation unit	
	12.	Train egg collectors	

14. (For those who eat crocodile eggs (A. 1 above). How many eggs did you eat during the last egg-laying season? _____

15. (For those who eat crocodile meat (A. 2 above). How often do you use eat crocodile meat?

    1. Rarely 2. Sometimes 3. Regularly

16. (For those who use crocodile meat for fishing (A. 3 above). How much crocodile meat do you use for fishing in a month? ……. kg

17. (For those who sell crocodile eggs to villagers, B4 above). How many crocodile eggs did you sell to villagers during the last egg-laying season? _____

18. (For those who sell crocodile meat to villagers, B5 above). How often do you sell crocodile meat to villagers? 1. Once in a while 2. Sometimes 3. Regularly

20. (For those who sell crocodile meat to fishermen, B6 above). How much crocodile meat did you sell to fishermen last year? _____kgs (approx.)

21. For how many years have you engaged in the crocodile use forms(s) you mentioned?
    Interviewer to check forms of utilization indicated by respondent in Question 11, and for each, ask the number of years the respondent has engaged in it.
    a) Collecting eggs for crocodile ranchers at a fee _____
    b) Locating crocodile egg nests for ranchers at a fee _____
    c) Employed by rancher at the field incubation unit _____
    d) Training egg collectors _____

22. How was the price set/ decided? _____

23. Do you have an agreement with the crocodile farm? _____

24. How many crocodile eggs did you collect and deliver in the following years?

Year	Total no. of eggs collected	Rate paid per viable egg delivered (Sh)	Rate paid per egg as bonus after successful hatching (Sh)	Total income from egg collection	Total income from paid bonuses
2013/14					
2014/15					
2015/16					
2016/17					
2017/18					

25. Have you worked for any other crocodile rancher since the year 2013?
    1. Yes 2. No, go to Question 32
26. How many crocodile ranchers have you worked for since 2013? _____
27. What are your reasons for the changes in 29 above?
    1.Rancher 1 _____
    _____
    2.Rancher 2 _____
    _____

28.Have you ever collected crocodile eggs for two ranchers during any one egg-collection season?
    1. Yes 2. No
29. How else have you benefited from the crocodile egg collection programme in your community?
_____
_____
_____

30. How else can crocodiles be used? (traditional, medicinal value, religious)
_____
_____

C: INSTITUTIONAL FACTORS

31. Have you received training in egg collection and handling?
    1. Yes 2. No

If Yes, explain **(interviewer to prompt respondent to list and probe further for the additional information below)**:

	Type of training	**No of times trained**	**Mode of training-** **4. Seminar** **5. On the job**	**Trainer** **1. Galaxy** **2. Kazuri** **3. Nile Crocodiles**
1.	Identification of nesting site			
2.	Egg handling			
3.	Egg incubation skills			
4.	Feeding hatchlings			

5.	Feeding sub-adult and adult crocodiles			
6.	Other, specify _____			

32. How many other people have you individually trained to be egg collectors? _____

33. Are you a member of any association for crocodile egg collectors?

1. Yes, Name of association _____

Is it registered? _____

2. No

34. What are the activities of this association? _____

_____

_____

35. Do you verify that the crocodile rancher has a valid egg collection permit when he engages you for egg collection?

1. Yes, Go to Q36.
2. No, Go to Q

36. How do you verify? 1. By being informed by the rancher's agent

2. By checking the rancher's permit

36. How do you identify a crocodile egg nest?

1. By chance 2. Observation 3. Through other people

37. How do you decide the quantity of eggs to harvest from a crocodile egg nest?

1. Take all eggs from the nest 2. Take as stipulated by a quota
3. Indiscriminate

38. How do you decide the quantity of nests to harvest eggs from at the nesting sites?

1. Harvest from all identified nests 2. Harvest eggs from some of the identified nests
3. Indiscriminate

39. How do you avoid double harvesting/ overlapping egg collection zones for other ranchers?

1. Informed zone boundary by ranch supervisor
2. Confirm zone by checking egg collection permit
3. Do nothing/ not sure

40. How is your egg collection quota set?

1. By self 2. By rancher 3. No quota

41. How is field crocodile egg collection supervision conducted?

1. By rancher 2. By KWS
3. By the County Conservation and Compensation Committee 4. No supervision

42. Have you ever been engaged by the crocodile rancher to return crocodile hatchlings or sub-adults back to the river?

1. Yes, How many times? _____
2. No

43. What means of transport do you use to access the egg collection sites? _____

_____

_____

44. How long after you have harvested eggs from the nest are they picked by the ranch supervisor?

1. Immediately 2. At the end of the day

3. Weekly 4. Other, explain _____

45. Are there times you take the eggs to your home to await collection by the ranch supervisor?

1. Yes, how many times have you done this during the last five years? _____
2. No

46. Please state your awareness of the following government wildlife rules relating to crocodile conservation and utilization:

Rule	1.Yes 2. No
Harvesting of wild eggs for domestic consumption is illegal	
Hunting of crocodiles for domestic consumption is illegal	
Hunting crocodiles for meat for fishing is illegal	
Poisoning crocodiles is not allowed by law	
It is illegal to capture wild crocodiles	
Crocodile meat and eggs can be consumed from farmed crocodiles	
A KWS license is required before harvesting eggs	
A KWS license is required for farming crocodiles.	

47. Do you know the boundaries for the egg collection zones assigned to the rancher who has engaged you?

1. Yes 2. No

48. The following statements apply to how egg harvesting is done. Which one applies to you?

1. I harvest crocodile eggs from all visible nests in site allocated to me
2. I do not harvest from all nests that I identify in the egg collection site allocated to me

49. The following statements relate to crocodile conservation and use in your community. Please state your level of agreement or disagreement with them as per the corresponding scale:

Statement		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Incentives to conserve wild crocodile populations						
1.	We should conserve crocodiles and their habitats for present and future generations.					
2.	Members of my household derive monetary benefits from crocodile conservation and use.					
3.	Members of my household derive non-monetary benefits from crocodile conservation and use					
4.	Members of my community					

	derive monetary benefits from crocodile conservation and use					
5.	Members of my community derive non-monetary benefits from crocodile conservation and use					
Awareness of opportunities for participation in crocodile ranching						
6.	Crocodile ranching is a form of wildlife use and is allowed					
7.	A license is needed prior to engaging in crocodile ranching					
8.	Crocodile use is an acceptable practice in my community					
9.	Any local person can engage in crocodile ranching					
10.	Villagers can form groups to run full cycle crocodile ranching					
11.	Villagers can form groups for crocodile egg collection and hatching for sale to ranchers					
Tolerance to crocodiles						
12.	Crocodiles need to be conserved to maintain the diversity of species.					
13.	Crocodiles are important animals for maintaining ecological balance for supporting life					
14.	They should be conserved to avoid scarcity					

50. What course of action should be taken by someone whose household member suffers the following damages caused by crocodiles:

	Damage	Perceived course of action: 1- Report to KWS & Police 2- Report to KWS 3- Report to Police 4- Report to Police who then inform KWS 5- Report to KWS, Police or Chief 6-Take to hospital then report to KWS 7- Report to KWS for Compensation 8- Report to Chief 9- Take to hospital & report to Police
1	Human injury	
2	Human death	
3	Livestock loss	

END

Thank you for participating in this survey

Appendix C

Interview Guide For Crocodile Ranchers

I am conducting a field study on crocodile conservation in lower Tana River as part of my PhD studies at Egerton University. You are requested to participate by responding to questions in this survey about your experience and knowledge about conservation of crocodiles in Tana River County. Your participation is completely voluntary and the information you provide will be kept in confidence.

1.Why did you start crocodile ranching? How do you currently use crocodiles? Reasons? How else can you use crocodiles?

2.What is your current live crocodile stock by age and sex? What is your optimum capacity?

3. Area occupied by ranch? No of ponds?

4. Equipment deployed in the field for egg collection?

5. Do you have access to sufficient and timely supply of eggs?

6. Information on egg collection permits: application date, date grant (5yrs), quota requested for vs granted quota?

7. Number of egg collectors engaged (5years)? Is there training offered to egg collectors? How often are the egg collectors trained?

8. How do you minimize risks of mortalities to collected eggs and hatchlings?

9. What are your farm products? meat, skins, live, skulls? (quantities in 5 years), local sales vs export.

10. What and how do you pay your egg collectors? Do you have an agreement with them?

11. What benefits have you given to the local people at the egg collection zones?

12. Have you ever returned a proportion of hatchlings back to the river?

13. Are you a member of crocodile ranchers' association?

14. Qualifications of ranch owner and ranch manager? Experience in crocodile ranching and marketing of crocodile products?

Appendix D

Question Guide For Focus Group Discussion With Household Heads

I am conducting a field study on crocodile conservation in lower Tana River as part of my PhD studies at Egerton University. You are requested to participate in this discussion by responding to questions in this survey about your experience and knowledge about conservation of crocodiles in Tana River County. Your participation is completely voluntary and the information you provide will be kept in confidence.

1. What are the benefits and uses of crocodile ranching? Who can do crocodile ranching?
2. What are considered wrong things to do at the river and riparian area that are harmful to crocodile conservation?
3. Please state what is considered correct or incorrect in your community/ group you belong to:
    a. Eating crocodile meat Eating crocodile eggs
    b. Using crocodile meat for fishing baits
    c. Protecting crocodile nesting site(s)
    d. Preserving crocodile basking sites
    d. Killing a crocodile which attacks humans
    e. Killing a crocodile which attacks livestock
    f. Harvesting crocodile eggs Selling crocodile eggs Farming crocodiles
4. Are there rules and sanctions which help oversee the above norms within your community/ group?
5. Please list rules and sanctions in your community/group for governing crocodile use. How are they enforced?
6. What social structures exist in your community/ group which help in governance of use of crocodiles? What are their roles?
7. What government rules or regulations do you know with regard to crocodile use?
8. What benefits has your community/ group received from crocodile ranching?
9. Do crocodile numbers and well-being depend on human activities on areas close to the river?

Appendix E

Question Guide For Focus Group Discussion With Crocodile Egg Collectors

I am conducting a field study on crocodile conservation in lower Tana River as part of my PhD studies at Egerton University. You are requested to participate in this discussion by responding to questions in this survey about your experience and knowledge about conservation of crocodiles in Tana River County. Your participation is completely voluntary and the information you provide will be kept in confidence.

1. What forms of crocodile uses exist for economic benefits?
2. Which ones of these are you engaged in?
3. What are your reasons for not engaging in the others you mentioned above?
4. What other uses of crocodile can you engage in?
5. Have you been able to collect the desired quota of crocodile eggs?
6. What local rules and sanctions exist in your community to guide crocodile utilization?
7. Name local governance structures that enable or prevent crocodile conservation and utilization? What are their roles?

Appendix F

Data Sheet For Egg Collection Sites

Crocodile egg collection zone ☐ Galaxy ☐ Kazuri London ☐ Nile Crocodile Sheet No.____

Location Name	X-proj	Y-proj	Way point no	Eggs present?	Total no of eggs in nest	No of viable eggs	No of unviable eggs	No of broken eggs	No of unfertilized eggs	Damaged: human-croc conflict Yes No	Tended by female 1.Yes 2. No	No. of females present	No of nests	Predation 1.Nil 2.Medium 3.Severe	Soil type 1.Coarse river sand 2.Alluvial deposits 3.Clay	Distance from water (m)	Remarks

Appendix G

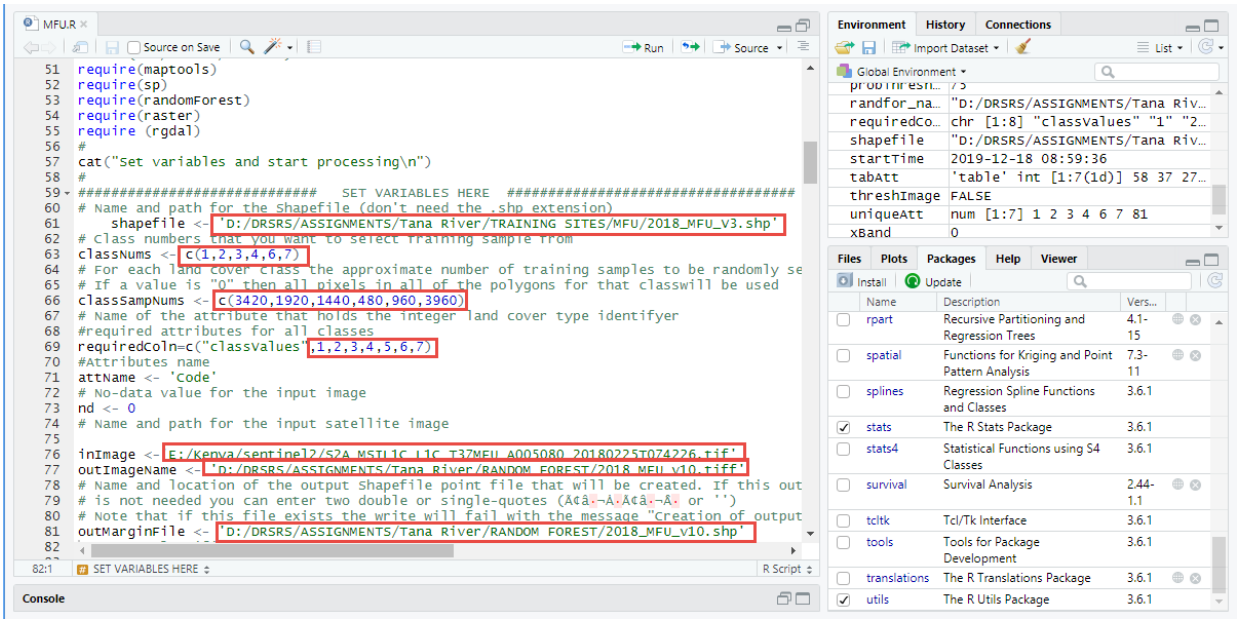
Definition Of Land Cover Categories

Land cover class	Description	Code	Colour
Forestland	Forest land according to Kenya's definition (Kenya Forest Service [KFS], 2013) are; *'areas occupied by forests and characterised by tree crown cover ≥ 15%, an area ≥ 0.5 ha and a tree height ≥ 2m. It also includes areas managed for forestry where trees have not attained 2m height but with potential to do so, and areas that are temporarily destocked'.* In the study area, forest lands mostly include the riverine vegetation which contains woody vegetation that is consistent with the national forest definition.	1	
Open grassland	This refers to rangelands and pasture land that is not considered as cropland. It includes grasslands without trees and are areas that mostly support pastoralism in the study area.	2	
Cropland	This category refers to land that is purposely managed for agricultural activities. It includes areas with annual herbaceous crops where crops grow in one or more seasons in a year and at times are bare due to tillage. It also includes agro-forestry systems which however were not mapped in the study area. Agroforestry is defined as the deliberate growing of woody perennials/trees on the same unit of land as agricultural crops (Somarriba, 1992).	3	
Settlement	Settlement includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under the other categories.	4	

Other land	This includes any unidentified land. It could be bare soil, rock, and all unmanaged land areas that do not fall into any of the other categories at a specific time.	5	
Wetland (water bodies)	This refers to either water bodies or vegetation found in wetlands. Water bodies refer to areas covered or saturated by water that is observable by remote sensing including lakes, oceans, dams, reservoirs, and rivers. While vegetated wetland contains the vegetation associated with these water bodies including papyrus and reeds and riverine trees. In this study only the water bodies were mapped under this category. The wetland vegetation was mapped according to whichever category they fell.	6	
Shrubland	Shrub land was mapped as areas with vegetation that fall below the thresholds used in the forest land category and are not expected to exceed the threshold used in the forest land definition. They are mainly areas with a mixture of trees, shrubs and grasses. The biomass content here is very different from the open grassland and due to the canopy closure of the woody component; it is possible to differentiate these areas from the open grasslands.	7	

Appendix H

Random Forest Clip Used To Run The Supervised Classification



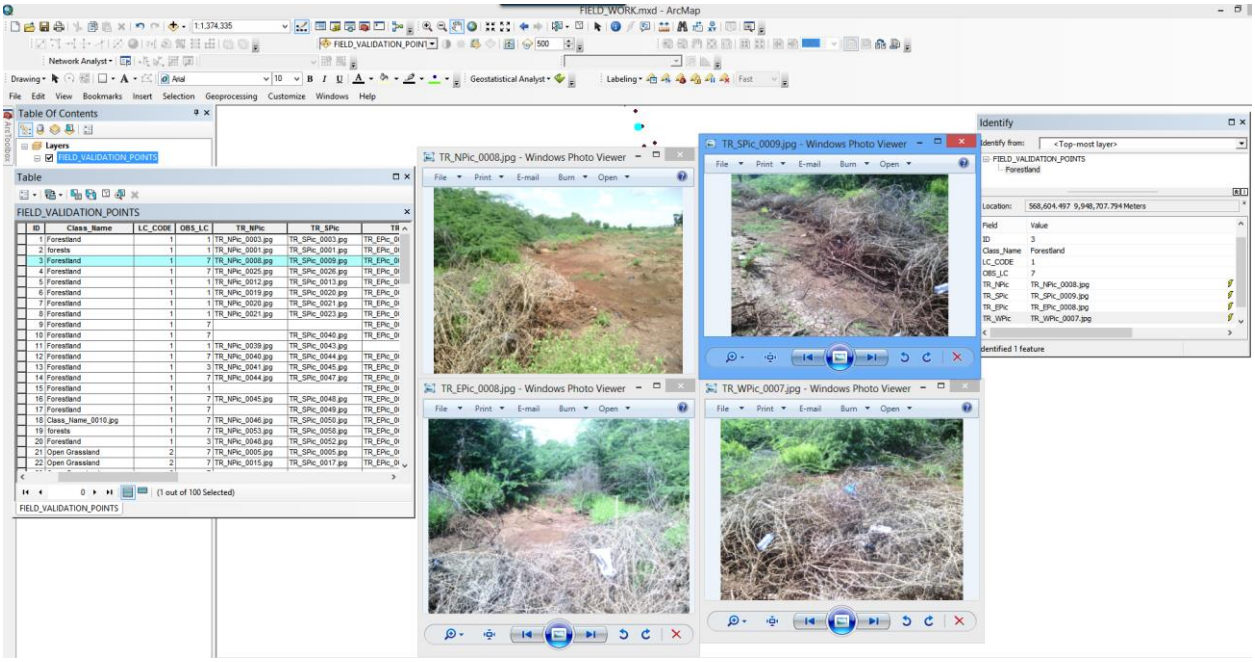
Appendix I

Field Data Collection Sheet Used During Ground Validation Of Sampled Points

ID	Class Name	LC_Code	Observed land cover	North picture	South picture	East picture	West picture	Remarks
1	Forestland	1	1	Y	y	y	y	
2	Forestland	1	1	Y	y	y	y	
8	Forestland	1	1	Y	y	y	y	
15	Forestland	1	1	Y	y	y	y	
95	Shrubland	7	1	Y	y	y	y	
25	Open Grassland	2	2	Y	y	y	y	
28	Open Grassland	2	2	Y	y	y	y	
29	Open Grassland	2	2	Y	y	y	y	

Appendix J

North, South, East and West Photos As Picked During Ground Validation Exercise



Appendix K

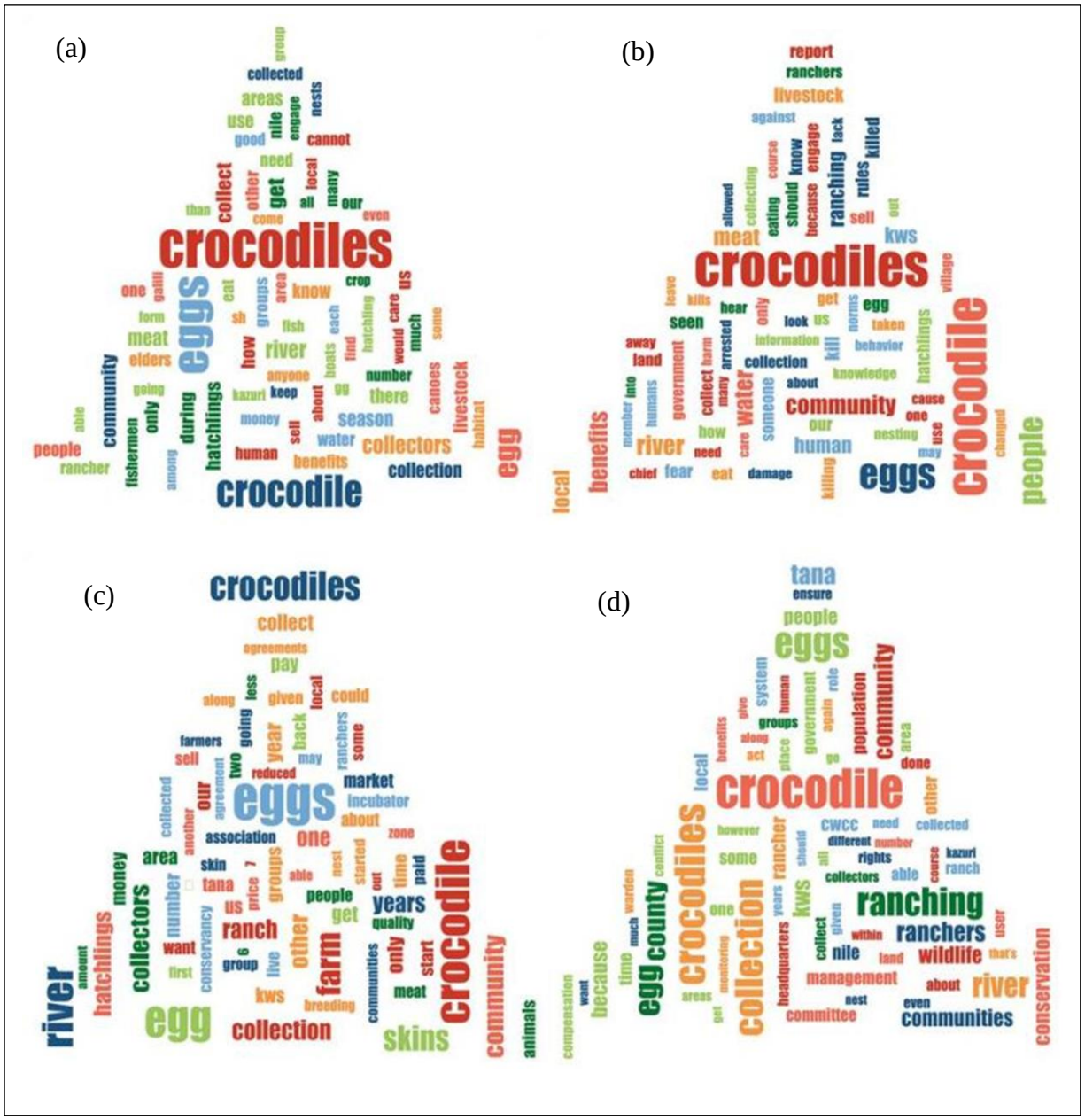
Qualitative Data Analysis Process And Outputs Using Max Software For Qualitative Data Analysis

K.1: Legend for coding qualitative data analysis

	Code	Legend
1.	Training	Training given to egg collectors on nest identification, crocodile behaviour, egg handling, incubation skills and taking care of hatchlings
2.	Performance	Objective of ranch, equipment deployed for egg collection and at ranch, egg collection levels, egg and hatchling mortality, live crocodile stocking levels, number of skins produced
3.	Governance	Strategies, structures, processes and traditions put in place to bring together various actors in the management of the crocodile ranching in order to attain its objectives as a sustainable- use management programme. Prevent harm caused by crocodiles to humans and livestock, prevent non- legal uses of crocodiles, rancher access to eggs for ranching, local people to get economic incentives, supply exotic crocodile leather to the international market, maintaining viable crocodile populations and ecological integrity at the river, avoiding use of crocodiles that may endanger their survival
4.	Coexistence and tolerance	Different perceived abilities of sharing landscape with wildlife
5.	Action taken	Action taken when a crocodile injures or kills someone or when it takes livestock
6.	Awareness of written laws/ rules for crocodile use	Discussants' awareness of written rules and regulations regarding crocodile use
7.	Norms	Bahaviour and practices that most members consider to be normal, right, correct, or appropriate. This behaviour, is however not compulsory.
8.	Rules and sanctions	Include religious rules and local unwritten (informal) rules and sanctions. They prohibit or prescribe behaviour and processes and sanctions against those who contravene the rules.
9.	Physical factors	Physical factors influencing adoption and performance of crocodile ranching-related activities.
10.	Normal behaviour towards crocodiles	Human behaviour or action towards crocodiles and their habitat that is considered normal or correct
11.	Harmful behaviour or action towards crocodiles	Human behaviour or action that is considered harmful to crocodiles and their habitat
12.	Awareness of crocodile ranching and	Awareness of opportunities for local people to be involved in legal uses of crocodile ranching through egg collection, incubation, rearing hatchlings for sale to ranchers, rearing hatchlings to slaughter age for

	opportunities	sale of skins and meat.
13.	Illegal uses of crocodiles	Involvement in uses of crocodiles that are not allowed by wildlife law and which are harmful to crocodile conservation and ranching.
14.	Legal uses of crocodiles	Permissible uses of crocodiles by law: egg collection for ranching, employment in ranch and field incubation unit. involvement in crocodile uses that are permitted in law for crocodile ranching.
15.	Reasons for non- legal uses of crocodiles	Reasons for engaging in the stated non- legal uses of crocodiles
16.	Benefits and incentives from crocodile ranching	Monetary and non- monetary benefits and incentives obtained from crocodile ranching Payments made by crocodile ranchers to the County Government as levies upon egg collection along lower River Tana. Payments paid as fees to local egg collectors and other non- monetary benefits/ incentives paid or given to egg collectors and communities living at the egg collection zones along the river. Payment received as fees from egg collection, other non- monetary benefits to the egg collector and his/ her community. incentives paid as fees to egg collectors, monetary and non- monetary incentives paid to egg collectors and communities living at the egg collection areas along the river.

K.2: Code Clouds Illustrating The Most Frequently Assigned Codes Among The Different Document Groups



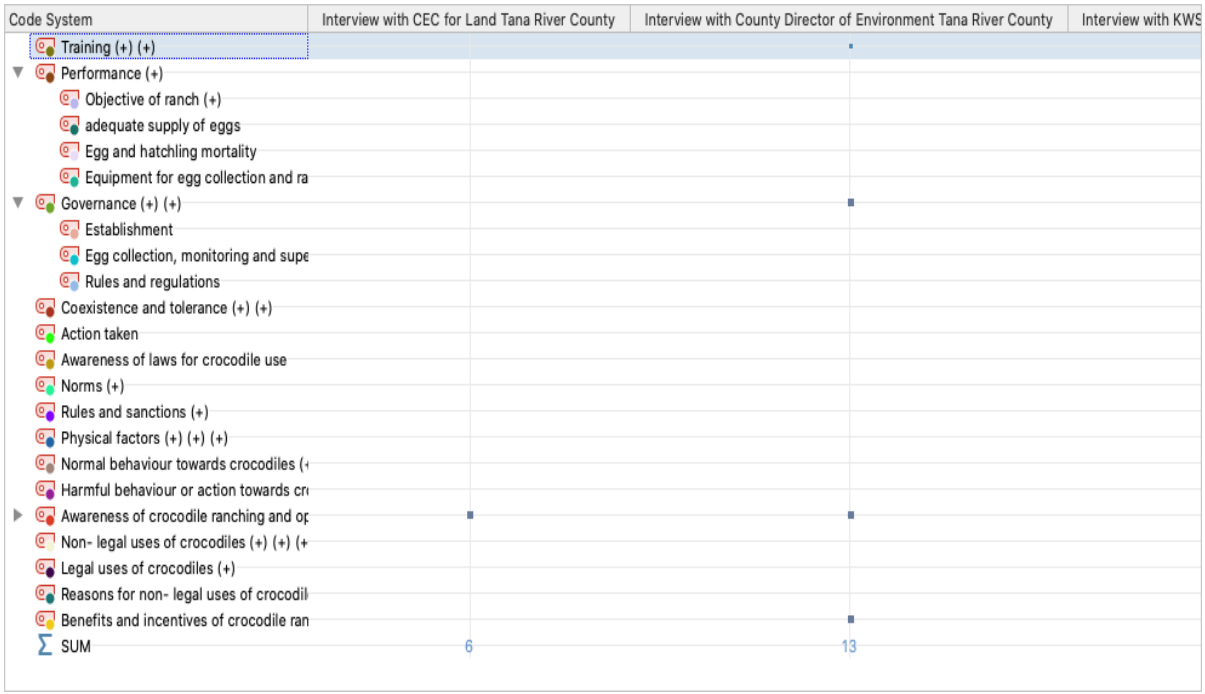
(a) Egg collectors group interviews, (b) Household heads group interviews, (c) Crocodile ranch managers, (d) Governance key informants

K.3: Code Matrix Browser An Overview Of How Many Times Each Code Appears In Individual / Multiple Documents

1. Key Informant Groups: ranch managers

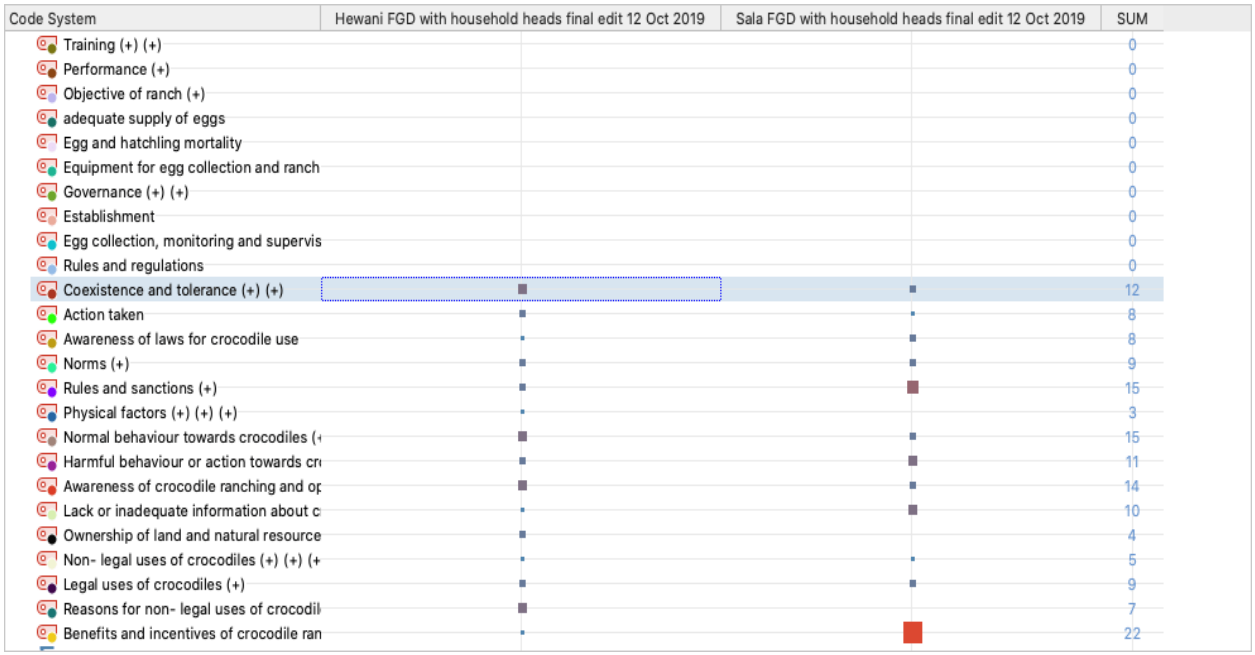
Code System	uri London key informant interview final	Nile crocodile key informant interview_2	Galaxy Croc Farm key informant interview	SUM
Training (+) (+)				5
Performance (+)				24
Objective of ranch (+)				6
adequate supply of eggs				7
Egg and hatchling mortality				9
Equipment for egg collection and ra				11
Governance (+) (+)				22
Establishment				0
Egg collection, monitoring and supe				0
Rules and regulations				0
Coexistence and tolerance (+) (+)				3
Action taken				0
Awareness of laws for crocodile use				0
Norms (+)				0
Rules and sanctions (+)				0
Physical factors (+) (+) (+)				3
Normal behaviour towards crocodiles (+				0
Harmful behaviour or action towards cr				3
Awareness of crocodile ranching and op				1
Non- legal uses of crocodiles (+) (+) (+				4
Legal uses of crocodiles (+)				0
Reasons for non- legal uses of crocodil				1
Benefits and incentives of crocodile ran				11
SUM	45	51	14	110

2. Governance key informants



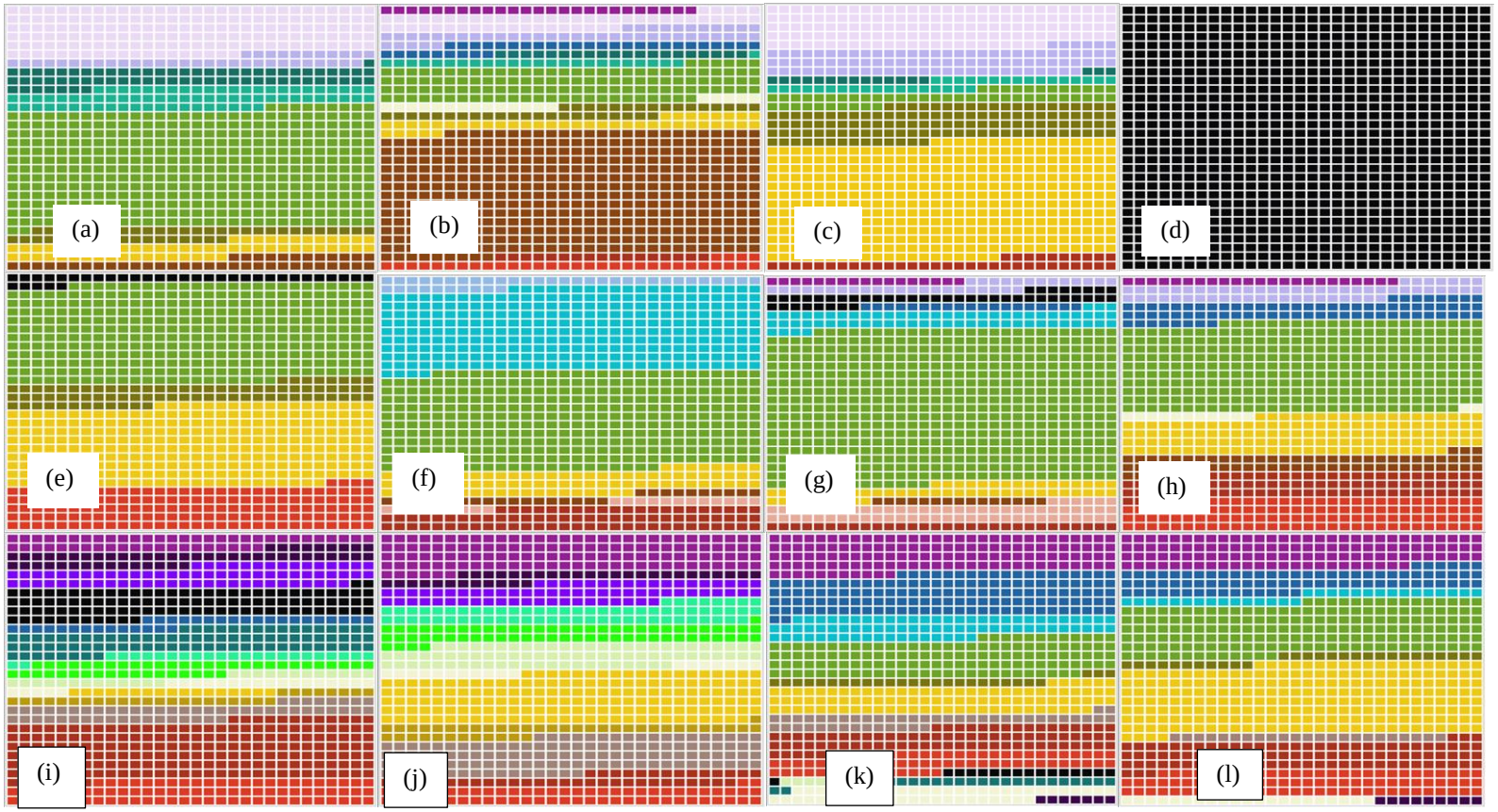
Code System	Interview with CEC for Land Tana River County	Interview with County Director of Environment Tana River County	Interview with KWS
Training (+) (+)			
Performance (+)			
Objective of ranch (+)			
adequate supply of eggs			
Egg and hatchling mortality			
Equipment for egg collection and ra			
Governance (+) (+)			
Establishment			
Egg collection, monitoring and supe			
Rules and regulations			
Coexistence and tolerance (+) (+)			
Action taken			
Awareness of laws for crocodile use			
Norms (+)			
Rules and sanctions (+)			
Physical factors (+) (+) (+)			
Normal behaviour towards crocodiles (+			
Harmful behaviour or action towards cr			
Awareness of crocodile ranching and op			
Non- legal uses of crocodiles (+) (+) (+			
Legal uses of crocodiles (+)			
Reasons for non- legal uses of crocodil			
Benefits and incentives of crocodile ran			
SUM	6	13	

3. Focus Group Discussions



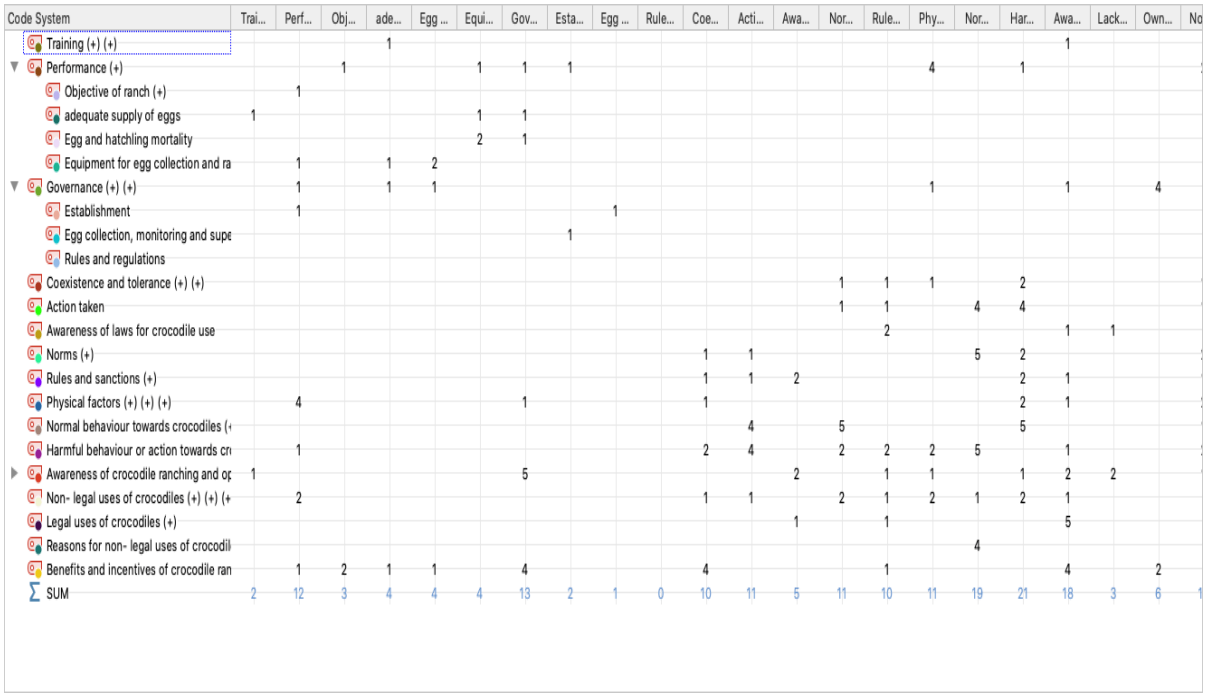
Code System	Hewani FGD with household heads final edit 12 Oct 2019	Sala FGD with household heads final edit 12 Oct 2019	SUM
Training (+) (+)			0
Performance (+)			0
Objective of ranch (+)			0
adequate supply of eggs			0
Egg and hatchling mortality			0
Equipment for egg collection and ranch			0
Governance (+) (+)			0
Establishment			0
Egg collection, monitoring and supervis			0
Rules and regulations			0
Coexistence and tolerance (+) (+)			12
Action taken			8
Awareness of laws for crocodile use			8
Norms (+)			9
Rules and sanctions (+)			15
Physical factors (+) (+) (+)			3
Normal behaviour towards crocodiles (+			15
Harmful behaviour or action towards cr			11
Awareness of crocodile ranching and op			14
Lack or inadequate information about c			10
Ownership of land and natural resource			4
Non- legal uses of crocodiles (+) (+) (+			5
Legal uses of crocodiles (+)			9
Reasons for non- legal uses of crocodil			7
Benefits and incentives of crocodile ran			22

K.4: Document Portraits Used To Visualize All The Coded Segments Of Each Document To Aid In Identifying The Basic Tone Of Each Document



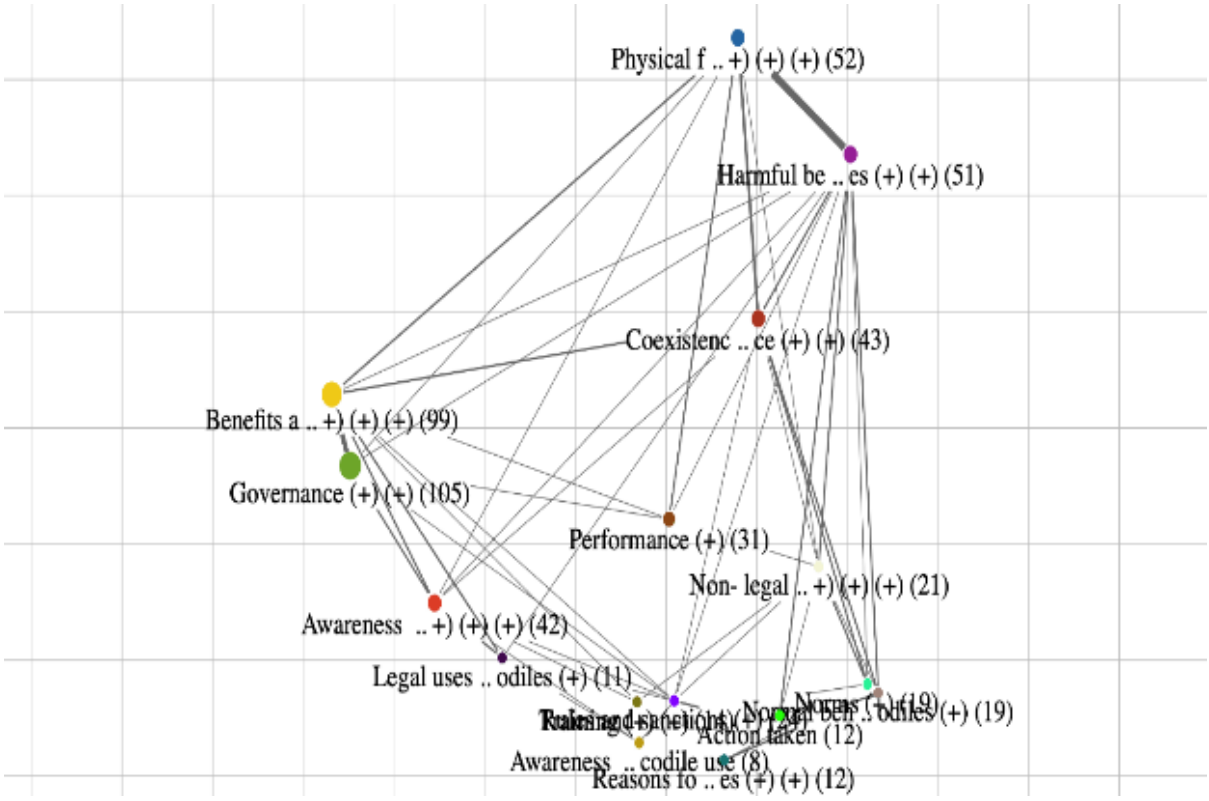
a) Kazuri London Limited manager, (b) Nile Crocodile Limited manager, (c) Galaxy Croc Farm manager, (d) County Executive for Land, (e) County Director for Environment (f) KWS County Warden, (g) KWS CITES Officer (h) CWCC Chairman, (i) Hewani FGD (j) Sala FGD (k) Galaxy egg collectors (l)Nile egg collectors

K.5: Assessment Of Relationships Between Codes Using The Code Relations Browser



Code System	Trai...	Perf...	Obj...	ade...	Egg ...	Equi...	Gov...	Esta...	Egg ...	Rule...	Coe...	Acti...	Awa...	Nor...	Rule...	Phy...	Nor...	Har...	Awa...	Lack...	Own...	No
Training (+) (+)				1															1			
Performance (+)			1			1	1	1								4		1				
Objective of ranch (+)		1																				
adequate supply of eggs	1					1	1															
Egg and hatchling mortality						2	1															
Equipment for egg collection and ra		1		1	2																	
Governance (+) (+)		1		1	1											1			1		4	
Establishment		1							1													
Egg collection, monitoring and supe								1														
Rules and regulations																						
Coexistence and tolerance (+) (+)														1	1	1		2				
Action taken														1	1		4	4				
Awareness of laws for crocodile use															2				1	1		
Norms (+)											1	1					5	2				
Rules and sanctions (+)											1	1	2					2	1			
Physical factors (+) (+) (+)		4					1				1							2	1			
Normal behaviour towards crocodiles (+												4		5				5				
Harmful behaviour or action towards cr		1									2	4		2	2	2	5		1			
Awareness of crocodile ranching and op	1						5						2		1	1		1	2	2		
Non- legal uses of crocodiles (+) (+) (+		2									1	1		2	1	2	1	2	1			
Legal uses of crocodiles (+)													1		1				5			
Reasons for non- legal uses of crocodil																	4					
Benefits and incentives of crocodile ran		1	2	1	1		4				4				1				4		2	
SUM	2	12	3	4	4	4	13	2	1	0	10	11	5	11	10	11	19	21	18	3	6	1

K.6: Visualizing Similarities And Relationships In The Data Using Code Maps



Appendix L

Ethical Review Committee Clearance

EGERTON UNIVERSITY
TEL: (051) 2217808
FAX: 051-2217942
P. O. BOX 536
EGERTON

RESEARCH ETHICS REVIEW COMMITTEE

EU/RE/DVC/009
Approval No. EUREC/APP/083/2019 **9th July 2019**

Ms. Margaret Nyabwari Moose
Department of NARE
Egerton University,
P.O.Box 536,
EGERTON

Dear Margaret,

RE: ETHICAL CLEARANCE APPROVAL:
Assessment of Socio-Ecological and Institutional Factors Influencing the Adoption and Performance of Nile crocodile (crocodylus niloticus) Ranching along Lower Tana River, Kenya

This is to inform you that ***Egerton University Research Ethics Committee*** has reviewed and approved your above research proposal. Your application approval number is ***EUREC/APP/083/2019.*** The approval period is ***10th July, 2019 – 11th July, 2020.***
This approval is subject to compliance with the following requirements:

i. Only approved documents including (informed consents, study instruments, MTA) will be used
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***Egerton University Research Ethics Committee.***
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***Egerton University Research Ethics Committee*** within 72 hours of notification
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***Egerton University Research Ethics Committee*** within 72 hours
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.

vii. Submission of an executive summary report within 90 days upon completion of the study to ***Egerton University Research Ethics Committee***.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.keand also obtain other clearances needed.

Yours sincerely

Prof. J. K. Kipkemboi,
CHAIRMAN, EGERTON UNIVERSITY RESEARCH ETHICS CTTEE

JKK/BK/BK

Appendix M

Research Permit

THIS IS TO CERTIFY THAT:
MS. MARGARET NYABWARI MOSSE
of EGERTON UNIVERSITY, 1029-517
Nairobi,has been permitted to conduct research in *Kilifi , Kirinyaga , Tanariver Counties*

on the topic: *ASSESSMENT OF SOCIO-ECOLOGICAL AND INSTITUTIONAL FACTORS INFLUENCING THE ADOPTION AND PERFORMANCE OF NILE CROCODILE RANCHING ALONG LOWER TANA RIVER, KENYA*

for the period ending:
13th February,2020

.....
Applicant's Signature

Permit No : NACOSTI/P/19/11428/27775
Date Of Issue : 14th February,2019
Fee Recieved :Ksh 2000

.....
Director General
National Commission for Science, Technology & Innovation

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014.

CONDITIONS

1. The License is valid for the proposed research, location and specified period.
2. The License and any rights thereunder are non-transferable.
3. The Licensee shall inform the County Governor before commencement of the research.
4. Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies.
5. The License does not give authority to transfer research materials.
6. NACOSTI may monitor and evaluate the licensed research project.
7. The Licensee shall submit one hard copy and upload a soft copy of their final report within one year of completion of the research.
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice.

National Commission for Science, Technology and innovation
P.O. Box 30623 - 00100, Nairobi, Kenya
TEL: 020 400 7000, 0713 788787, 0735 404245
Email: dg@nacosti.go.ke, registry@nacosti.go.ke
Website: www.nacosti.go.ke

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

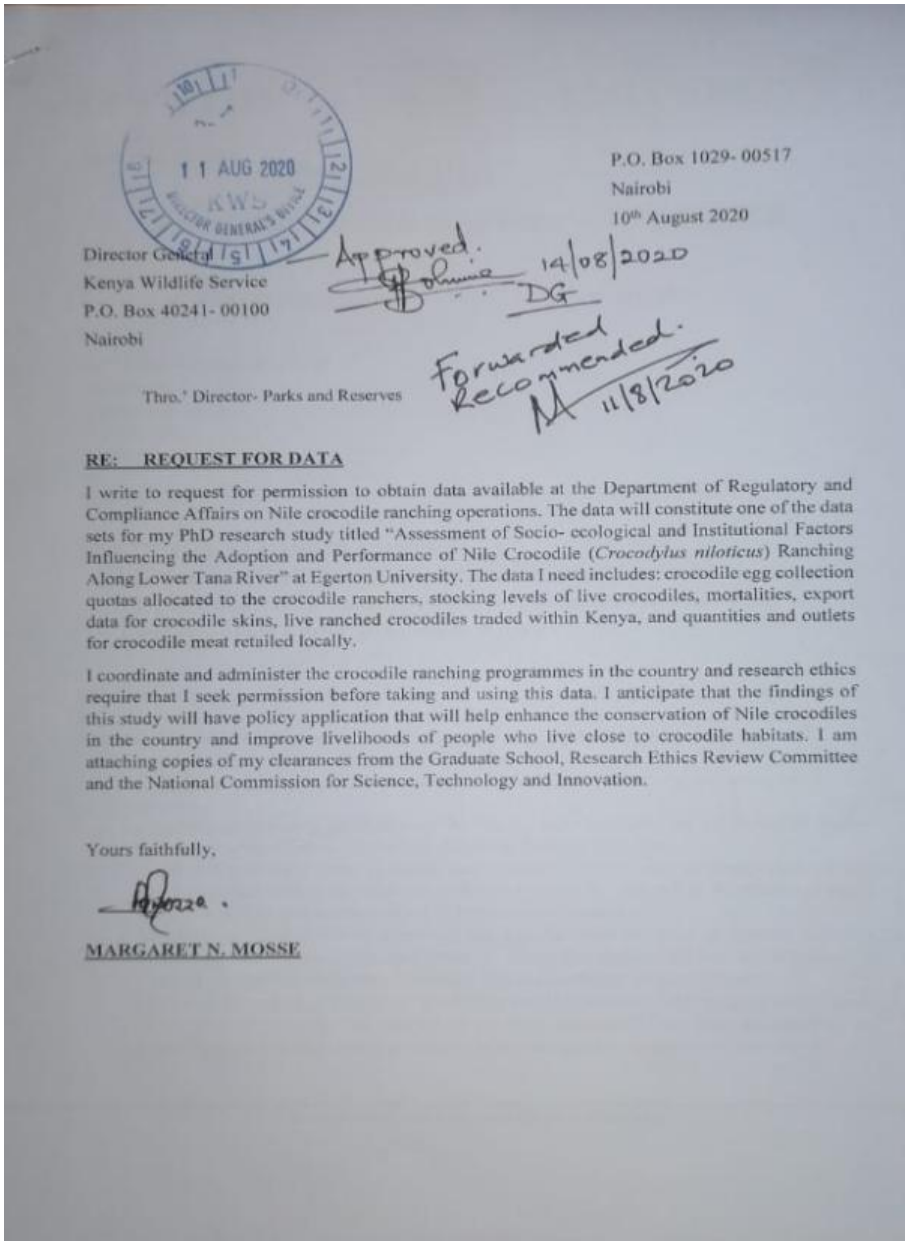
RESEARCH LICENSE

Serial No.A 23108

CONDITIONS: see back page

Appendix N

Approval From Kenya Wildlife Service To Access Crocodile Ranching Data



11 AUG 2020
KWS
DIRECTOR GENERAL'S OFFICE

P.O. Box 1029- 00517
Nairobi
10th August 2020

Director General
Kenya Wildlife Service
P.O. Box 40241- 00100
Nairobi

Approved.
14/08/2020
DG

Thro.' Director- Parks and Reserves

Forwarded
Recommended.
11/8/2020

RE: REQUEST FOR DATA

I write to request for permission to obtain data available at the Department of Regulatory and Compliance Affairs on Nile crocodile ranching operations. The data will constitute one of the data sets for my PhD research study titled "Assessment of Socio- ecological and Institutional Factors Influencing the Adoption and Performance of Nile Crocodile (*Crocodylus niloticus*) Ranching Along Lower Tana River" at Egerton University. The data I need includes: crocodile egg collection quotas allocated to the crocodile ranchers, stocking levels of live crocodiles, mortalities, export data for crocodile skins, live ranched crocodiles traded within Kenya, and quantities and outlets for crocodile meat retailed locally.

I coordinate and administer the crocodile ranching programmes in the country and research ethics require that I seek permission before taking and using this data. I anticipate that the findings of this study will have policy application that will help enhance the conservation of Nile crocodiles in the country and improve livelihoods of people who live close to crocodile habitats. I am attaching copies of my clearances from the Graduate School, Research Ethics Review Committee and the National Commission for Science, Technology and Innovation.

Yours faithfully,

MARGARET N. MOSSE

Appendix O

Informed Consent Form For Questionnaire Survey Respondents

You have been invited to participate in a questionnaire survey for a research titled "Assessment of Socio-ecological and Institutional Factors Influencing the Adoption and Performance of Crocodile Ranching-ranching Related in Lower Tana River" which is part of my PhD studies in Egerton University. The survey contains questions about your experience and knowledge about using and conserving crocodiles in Tana River County. Your participation is completely voluntary and if you decide to participate in the interview, we promise you the following:

1. Confidentiality. All information you provide us will be kept in the strictest confidence. The responses will be recorded in a questionnaire. Your name will neither be recorded in the questionnaire nor in preparing any report.
2. Voluntary Participation. Your participation is voluntary and you may pull out of the interview at any stage you feel you do not want to proceed. You also have the option of not answering a question at any one time you decide.
3. Additional Information. If you have any questions about the research, or wish to receive a copy of the report when it is completed, you may contact Margaret Mosse, P.O. Box 1029-00517 Nairobi; email: mossenyabwari@gmail.com; Telephone 0722440170. If you need information on your right as a research participant, please contact The Secretary, Egerton University Research Ethics Committee, P.O. Box 536, Egerton or Email address eurec@egerton.ac.ke.

Questionnaire Survey Consent

I agree to participate in this interview. I understand that my participation is voluntary and will not affect me in any way. I also understand that I can stop participating or refuse to answer questions at any time.

Name_____

Signature_____ Date _____

Appendix P

Informed Consent Form For Key Informant Interviews

You have been invited to participate in an in-depth interview for a research titled "Assessment of Socio-ecological and Institutional Factors Influencing the Adoption and Performance of Crocodile Ranching-related Activities in Lower Tana River" which is part of my PhD studies in Egerton University. The interview will include questions about your experience and knowledge about utilization and conservation of crocodiles in Tana River County. Your participation is completely voluntary and if you decide to participate in the discussion, we promise you the following:

1. Confidentiality. All information you provide us will be kept in the strictest confidence. The discussion will be audio-recorded and we will be taking notes also. Your name will neither be used in preparing the notes nor in preparing any report.
2. Voluntary Participation. Your participation is voluntary and you may pull out of the discussion at any stage you feel you do not want to proceed. You also have the option of not answering a question at any one time you decide.
3. Additional Information. If you have any questions about the research, or wish to receive a copy of the report when it is completed, you may contact Margaret Mosse P. O. Box 1029- 00517, Nairobi; Email: mossenyabwari@gmail.com; Telephone: 0722440170. If you need information on your right as a research participant, please contact The Secretary, Egerton University Research Ethics Committee, P.O. Box 536, Egerton or Email address eurec@egerton.ac.ke.

Key Informant Interview Consent

I agree to participate in this key informant interview. I understand that my participation is voluntary and will not affect me in any way. I also understand that I can stop participating or refuse to answer questions at any time.

Name_____

Signature_____ Date _____

Appendix Q

Informed Consent Form For Focus Group Discussants

You have been invited to participate in a questionnaire survey for a research titled "Assessment of Socio-ecological and Institutional Factors Influencing the Adoption and Performance of Crocodile Ranching-related activities in Lower Tana River" which is part of my PhD studies in Egerton University. The discussion will be centred around your experience and knowledge about on the use and conservation of crocodiles in Tana River County. Your participation is completely voluntary and if you decide to participate in the interview, we promise you the following:

1. Confidentiality. All information you provide us will be kept in the strictest confidence. The responses will be recorded in a note book and voice recorder. Your name will neither be recorded in the note book nor in preparing any report.
2. Voluntary Participation. Your participation is voluntary and you may pull out of the interview at any stage you feel you do not want to proceed. You also have the option of not answering a question at any one time you decide.
3. Additional Information. If you have any questions about the research, or wish to receive a copy of the report when it is completed, you may contact Margaret Mosse, P.O. Box 1029-00517 Nairobi; email: mossenyabwari@gmail.com; Telephone 0722440170. If you need information on your right as a research participant, please contact The Secretary, Egerton University Research Ethics Committee, P.O. Box 536, Egerton or Email address eurec@egerton.ac.ke.

Questionnaire Survey Consent

I agree to participate in this discussion. I understand that my participation is voluntary and will not affect me in any way. I also understand that I can stop participating or refuse to answer questions at any time.

Name_____

Signature_____ Date _____

Appendix R

Quantitative Data Analysis Outputs

R.1: Multinomial logistic regression- effects of various socio-economic factors on the likelihood of involvement in legal uses of crocodiles

Model fitting information

Model	Model Fitting Criteria			
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept only	545.547			
Final	250.691	294.856	30	<0.001

Likelihood Ratio Tests

	Model fitting criteria	Likelihood Ratio Tests		
Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	250.691	.000	0	.
Age	270.229	19.538	2	<0.001
Level of formal education	251.096	.405	2	0.817
Annual income	261.231	10.540	2	0.005
Gender	272.026	21.335	1	<0.001
Ethnic group	280.618	29.927	6	<0.001
Religion	282.070	31.379	2	<0.001
Main source of income	268.732	18.041	8	0.021
Member of a community environmental group	256.446	5.755	2	0.056
Level of formal education	128.085	13.065	6	0.042
Egg collection zone	255.449	4.758	4	0.313

R.2: Multinomial logistic regression- effects of perceived incentives and benefits derived from crocodile ranching, awareness of crocodile ranching and tolerance towards crocodiles on involvement in crocodile ranching-related activities

Model fitting information

Model	Model Fitting Criteria		Likelihood Ratio Tests		
	AIC	BIC	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept only	280.899	288.698	276.899			
Final	186.437	217.637	170.437	106.461	6	0.000

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	116.127	104	0.196
Deviance	105.419	104	0.443

Likelihood Ratio Tests

Effect	Model Fitting Criteria		Likelihood Ratio Tests			
	AIC of Reduced Model	BIC of Reduced Model	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	256.421	279.820	244.421	73.983	2	.000
Incentives and benefits	213.019	236.419	201.019	30.582	2	.000
Awareness	185.931	209.331	173.931	3.494	2	.174
Tolerance	220.476	243.875	208.476	38.039	2	.000

R.3: Multinomial logistic regression -effects of various perceptions of crocodile uses on involvement in crocodile ranching-related activities

Model fitting information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept only	434.295			
Final	173.867	260.428	28	<0.001

Likelihood Ratio Tests

Effect	Likelihood Ratio Tests			
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	173.867	.000	2	.
Crocodile eggs can be eaten	245.027	71.160	2	<0.001
Crocodile meat can be eaten	177.614	3.1747	2	0.154
Crocodile meat can be used as fishing bait	176.117	2.250	2	0.325
Collecting eggs for ranches at a fee	208.494	34.626	2	<0.001
Locate crocodile nests for ranch at a fee	174.060	.193	2	0.908
Incubate eggs and sell hatchlings to ranchers	173.906	.038	2	0.981
Ranch hatchlings and sell meat	176.224	2.357	2	0.308
Ranch hatchlings and sell skins	174.324	.457	2	0.796
Sell meat from hunted crocodiles to community	176.938	3.071	2	0.215
Sell wild crocodile eggs to community	175.992	2.125	2	0.346
Crocodiles are a tourism attraction	191.153	17.286	2	<0.001
Crocodile skins used to make items	176.957	3.090	2	0.213
Crocodile teeth make ornaments	173.964	.097	2	0.953
Crocodile bile is used as poison	176.864	2.996	2	0.224

R.4: Multinomial logistic regression- effects of various normal and acceptable behaviours towards crocodiles on crocodile ranching

Model fitting information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept only	354.691			
Final	94.962	259.729	12	<0.001

Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	94.962	0.000	0	.
Hunting crocodiles and selling their meat is normal	95.446	0.483	2	0.785
Eating crocodile meat in normal	108.029	13.066	2	0.001
Eating crocodile eggs is normal	137.565	42.603	2	<0.0001
Hunting crocodiles and selling their meat is normal	101.656	6.693	2	0.035
Killing a crocodile which has killed or injured someone is normal	99.502	4.540	2	0.103
Destroying crocodile egg nests is normal	99.564	4.602	2	0.100

R.5. Multinomial logistic regression- effects of various perceived legally acceptable uses of crocodiles on involvement in crocodile ranching-related activities

Model fitting information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept only	116.508			
Final	49.477	67.032	6	<0.001

Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	49.477	0.000	0	.
Crocodile ranching is legally acceptable	50.981	1.505	2	<0.471
Collecting and selling eggs to ranchers is acceptable	66.497	17.021	2	<0.001
Tourism attraction	75.839	26.363	2	<0.001

R.6: Multinomial logistic regression- effects of participants awareness of various rules for crocodile ranching on involvement in crocodile ranching-related activities

Model fitting information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log likelihood	Chi-Square	df	Sig.
Intercept only	70.472			
Final	53.194	17.277	12	0.139

Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	53.195	.000	0	.
Aware hunting crocodiles for meat for fishing is illegal	77.651	24.456	2	0.000
Aware poisoning crocodiles is not allowed by law	54.124	0.930	2	0.628
Aware capturing wild crocodiles is illegal	53.839	0.645	2	0.724
Aware crocodile meat and eggs from crocodile farms can be eaten	62.002	8.807	2	0.012
Aware license is needed before harvesting eggs	57.236	4.041	1	0.133
Aware license needed for crocodile ranching	56.280	3.085	2	0.214

R.7 Quantity of eggs and nests at Galaxy and Nile and mean number of eggs per nest during period 2014-2018

Ranch/season	Total no. of eggs	Total no. of nests	Mean
Galaxy			
2014/15	6953	200	34.77
2015/16	6819	221	30.86
2016/17	4299	119	33.76
2017/18	4018	119	33.76
Sub-total	**22089**	**682**	**32.41**
Nile			
2014/15	5224	186	28.09
2015/16	5107	188	27.16
2016/17	24104	586	41.13
2017/18	8550	278	31.78
Sub-total	**42985**	**1238**	**31.78**
Grand total	**65074**	**1920**	**32.10**

R.8 *t*-test for quantity of eggs harvested

Group statistics for quantity of eggs harvested by Galaxy and Nile during period 2014-2018

	Crocodile ranch	N	Mean	Std. Deviation	Std. Error Mean
Quantity of eggs harvested	Galaxy	4	6107.75	2069.355	1034.677
	Nile	4	10746.25	9047.088	4523.544

t-test for equality of means of quantity of eggs harvested by Galaxy and Nile ranches during the period 2014-2018

		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Quantity of eggs harvested	Equal variances assumed	-1.000	6	0.356	-4638.500	4640.367
	Equal variances not assumed	-1.000	3.313	0.385	-4638.500	4640.367

R.9 *t*-test for quantities of skins exported

Group statistics for quantities of skins sold by Galaxy and Nile ranches, 2013-2018

	Crocodile ranch	N	Mean	Std. Deviation	Std. Error Mean
Quantity of skins sold	Galaxy	6	1278.83	1084.390	442.700
	Nile Crocodiles	6	5334.5	1789.554	730.582

t-test for equality of means for quantity of skins exported by Galaxy and Nile ranches during the period 2013-2018

		t	df	Sig (2-tailed)	Mean Difference	Std. Error Difference
Quantity of skins sold	Equal variances assumed	-4.748	10	0.001	-4055.667	854.245
	Equal variances not assumed	-4.748	8.236	0.001	-4055.667	854.245

R.10 *t*-test for quantities of meat sold

Descriptive statistics for quantity of meat sold by Nile and Galaxy during period 2013-2018

	Egg collection zone	N	Mean	Std. Deviation	Std. Error Mean
Quantity of meat (Kgs)	Galaxy	6	531.00	524.132	213.976
	Nile	6	23270.50	7502.376	3061.832

t- test for equality of means for quantity of meat sold by Galaxy and Nile crocodile ranches during the period 2013-2018

		t	df	Sig. (2-tailed)	Mean difference	Std. Error Difference
Quantity of meat (kgs)	Equal variances assumed	-7.406	10	0.000	-22739.500	3070.298
	Equal variances not assumed	-7.406	5.049	0.001	-22739.500	3070.298

R.11: Multinomial logistic regression for the influence of incentives and benefits derived from crocodile ranching on involvement in crocodile ranching-related activities

Model fitting information

	Model Fitting Criteria	Likelihood Ratio Tests		
Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept only	58.850			
Final	17.701	41.149	4	0.000

Likelihood Ratio Tests

	Model Fitting Criteria	Likelihood Ratio Tests		
Effect	-2 Log Likelihood of reduced Model	Chi-Square	df	Sig.
Intercept	17.701	<0.001	0	.
Egg collection zone	58.850	41.149	4	<0.001

R.12: Multinomial logistic regression for the influence of incentives and benefits at the egg collection zones

Model fitting information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept only	91.319			
Final	126.891	26.731	4	<0.001

Likelihood Ratio Tests

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of reduced Model	Chi- Square	df	Sig.
Intercept	126.891	<0.001	0	.
Benefitted from crocodile egg collection programme	91.319	46.891	4	<0.001

R.13 Descriptive statistics for distance of nests from water

Distance from Water: Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Distance from water (M)	96	49.00	1.00	50.00	10.3095	8.34855
Valid N (listwise)	96					

Appendix S

Crosstabulation Matrix of Land Cover Classes Along the Lower River Tana

Value	2015	2018	Area of change in Ha
1	**Forestland**	**Forestland**	**20049.42**
2	Forestland	Grassland	76.06
3	Forestland	Cropland	2023.08
4	Forestland	Settlement	15.63
5	Forestland	Other land	0.18
6	Forestland	Water Bodies	33.43
7	Forestland	Shrubland	6748.56
8	Grassland	Forestland	422.00
9	**Grassland**	**Grassland**	**4401.06**
10	Grassland	Cropland	111.56
11	Grassland	Settlement	13.97
12	Grassland	Other land	20.86
13	Grassland	Water Bodies	100.46
14	Grassland	Shrubland	7655.36
15	Cropland	Forestland	1354.60
16	Cropland	Grassland	253.41
17	**Crop land**	**Crop land**	1388.34
18	Cropland	Settlement	10.34
19	Cropland	Other land	0.00
20	Cropland	Water Bodies	41.66
21	Cropland	Shrubland	3267.48
22	Settlement	Forestland	3.90
23	Settlement	Grassland	49.29
24	Settlement	Cropland	1.85
25	**Settlement**	**Settlement**	110.25
26	Settlement	Other land	0.83
27	Settlement	Water Bodies	15.28
28	Settlement	Shrubland	167.26

29	Other land	Forestland	3.36
30	Other land	Grassland	49.32
31	Other land	Cropland	2.68
32	Other land	Settlement	8.74
33	**Other land**	**Other land**	162.47
34	Other land	Water Bodies	129.60
35	Other land	Shrubland	222.63
36	Water Bodies	Forestland	117.48
37	Water Bodies	Grassland	209.49
38	Water Bodies	Cropland	123.12
39	Water Bodies	Settlement	17.40
40	Water Bodies	Other land	180.64
41	**Water Bodies**	**Water Bodies**	**6812.96**
42	Water Bodies	Shrubland	1453.80
43	Shrubland	Forestland	11492.62
44	Shrubland	Grassland	12404.80
45	Shrubland	Cropland	3781.95
46	Shrubland	Settlement	248.51
47	Shrubland	Other land	69.01
48	Shrubland	Water Bodies	641.11
49	**Shrub land**	**Shrub land**	**206399.95**

Appendix T

Abstracts Of Publications

T.1: Anthropogenic threats to crocodiles, and the level and sociodemographic determinants of their utilization in lower River Tana basin, Kenya

Tropical Conservation Science
Volume 17: 1–15

DOI: 10.1177/19400829241241457
journals.sagepub.com/home/trc
Sage

Anthropogenic Threats to Crocodiles, and the Level and Sociodemographic Determinants of their Utilization in Lower River Tana Basin, Kenya

Margaret N. Mosse[1,2], Wilfred O. Odadi[1], and Grace W. Kibue[1]

Abstract

Background and Research Aims: Globally, crocodile ranching programs are intended to generate livelihood benefits for local communities and incentives for crocodile conservation. However, there is need for their contextual scientific evaluation in many human-dominated tropical landscapes. We investigated the anthropogenic threats to crocodiles, and examined the level and sociodemographic determinants of their utilization in lower River Tana basin, Kenya.

Methods: We conducted seven key informant interviews, four focus group discussions and a quantitative household survey involving 365 respondents randomly selected from local villages. We analyzed anthropogenic threats to crocodiles and other qualitative data thematically. We summarized quantitative data using descriptive statistics and used multinomial logistic regression to analyze the association between selected sociodemographic variables and crocodile utilization.

Results: The main anthropogenic threats to crocodiles were agricultural expansion into their habitat, their retaliatory killing, and consumption of their meat and eggs. Only 5% of the respondents utilized crocodiles legally, whereas 32% utilized them illegally. Increasing age, increasing income, being male and being Christian all increased the likelihood of illegal crocodile utilization. Being male increased the likelihood of legal crocodile utilization, whereas increasing age decreased this likelihood.

Conclusions: Our study demonstrates multiple anthropogenic threats to crocodiles in lower River Tana despite a long-term ranching program. Furthermore, local community participation in this program is marginal and markedly varies among sociodemographic groups. Taken together, our findings suggest that crocodile ranching, as practiced in this landscape, is largely ineffective in achieving its intended socioeconomic and conservation goals.

Conservation Implications: To enhance their effectiveness, crocodile ranching programs in such landscapes should be tailored for local socio-cultural contexts. We recommend capacity building and awareness raising initiatives tailored for specific groups to increase local community participation in sustainable crocodile utilization and minimize their engagement in practices that are detrimental to crocodiles.

T.2: Nile crocodile nesting ecology under varying human disturbance intensities along lower River Tana, Kenya

Current Trends in Natural Sciences
Vol. 12, Issue 24, pp. 110-126, 2023
https://doi.org/10.47068/ctns.2023.v12i24.012

Current Trends in Natural Sciences (on-line)
ISSN: 2284 953X
ISSN-L: 2284-9521

Current Trends in Natural Sciences (CD-Rom)
ISSN: 2284 9521
ISSN-L: 2284-9521

NILE CROCODILE NESTING ECOLOGY UNDER VARYING HUMAN DISTURBANCE INTENSITIES ALONG LOWER RIVER TANA, KENYA

Margaret Mosse [1,2], Grace Kibue [1], Wilfred Odadi [1]

[1]Egerton University, Natural Resources Department, P.O. Box 536-20115, Egerton, Kenya
[2]Kenya Wildlife Service, P.O. Box 40241-00100, Nairobi, Kenya

Current Trends in Natural Sciences

Abstract
The Nile crocodile (Crocodylus niloticus, Laurenti, 1768) supports important ecological and socio-economic functions; however, its survival in most of its ranges in Africa continues to be threatened by anthropogenic activities. Here, we compared selected attributes of Nile crocodile nests (abundance, clutch size, distance from water, and presence or absence of eggs, tending and predation) across three human disturbance regimes (low, intermediate and high), indexed by coverage of cropland and settlement, along lower River Tana, Kenya. We conducted a crocodile nest survey in January 2019 and overlaid the resultant data on the most recent land cover map of a 1-km wide strip on both sides of the river, segmented into the different disturbance regimes using remote sensing and geographical information system techniques. The low, intermediate and high disturbance regimes comprised combined cropland and settlement coverage of 2%, 9% and 15%, respectively, and covered 28%, 27% and 47% of the surveyed river segment. We counted a total of 99 nests, with 45, 34 and 20 nests located in low, intermediate and high disturbance regimes, respectively. Nests were 56% less frequent than expected under high disturbance, whereas they were 69% more frequent than expected under low disturbance and showed expected frequency under intermediate disturbance. In addition, nests were 56% and 41% less frequent under high disturbance compared to low and intermediate disturbance, respectively. However, nest abundance was statistically similar between the latter two regimes. No significant differences were observed in other assessed attributes across disturbance regimes. Our study underscores the importance of minimizing land conversion in such human-dominated landscapes for enhanced sustainable utilization and conservation of crocodiles.

Keywords: Crocodylus niloticus, human disturbance, human-dominated landscapes, land conversion, land cover