UNIVERSITY of BOTSWANA

FACULTY OF SCIENCE

DEPARTMENT OF ENVIRONMENTAL SCIENCE

INVESTIGATING THE BREEDING SUCCESS OF CAPE VULTURES (*GYPS COPROTHERES*) AT BONWALENONG AND MANONG YENG BREEDING SITES IN THE TSWAPONG HILLS, BOTSWANA

BY

Tsaone Goikantswemang
200604927

Supervisors: ***Prof. J.S. Perkins*** *(Department of Environmental Science)*

Co-Supervisors: Dr R. Reading *(Okavango Research Institute & Raptors Botswana)*

Dr G. Maude *(Kalahari Research and Conservation Botswana &Raptors Botswana)*

A thesis submitted to the Department of Environmental Science at the University of Botswana in fulfillment of the requirements for the Master of Science Degree in Environmental Science

SEPTEMBER 2019

APPROVAL

This dissertation has been examined and is approved as meeting the required standards of the department for the fulfillment of the requirements for the degree of Master of Science in Environmental Science.

Internal Examiner: …………..………………….Date: ………………………………..…

External Examiner: ……………………………….Date: ………………………………..

STATEMENT OF ORIGINALITY

This dissertation was carried out by the author at the University of Botswana between 2016 August and July 2018. It is an original work except where due reference is made.

Author's Signature: ______________ Date: ………………………

Supervisor's Signature: ______________ Date: ………………………

DEDICATION

I dedicate this to my beloved parents, Mr and Mrs Mothibi.

ACKNOWLEDGEMENTS

I would like to thank my supervisory team; Prof J. S. Perkins, Dr R. Reading and Dr Maude for the guidance and support you gave me throughout this remarkable journey. Specifically, thank you to Prof J.S. PERKINS who accepted me as his student in a very desperate time. Secondly, thank you to Dr R. READING for providing time to assist me in during fieldwork and giving me scientific guidance on putting the pieces together for my thesis. Thirdly, thank you Dr G. MAUDE for the encouragement and motivation you always gave to me as well as the support, notably the time you scarified to ensure that everything I needed for the field trip was in place. Not forgetting the first person I met when I started my journey in vultures' studies; Dr M. SELEBATSO, thank you for believing in me that I can make it and endure the hardships that come along studying vultures and raptors.Grateful appreciation is also extended to Mrs WENDY BORELLO for continuous support by providing professional experience on studying Cape vultures, sharing her past data and notes with me as well giving advice whenever I needed some.

Thank you to Kalahari Research and Conservation Botswana/ Raptors Botswana team, Denver Zoological Foundations and Peregrine Fund for technical and financial assistance in my project. Gigantic acknowledgements to the Department of Wildlife and National Parks and University of Botswana Research Office and the Department of Environmental science for permitting me to do this study. To the Goo-Moremi Gorge and Goo-Tau guides who helped me collect data, thank you for spending your time in the field assisting me. I sincerely appreciate the support I got from my fellow graduate students and the Department of Environmental science staff that provided and assisted in the use of geo-spatial and statistical software. Special thanks to my family and friends, without their support throughout the entire project, I would not be able to achieve this. Finally, I would like to thank GOD for the strength that sustained me throughout this memorable journey…..

ABSTRACT

The endangered Cape Vulture (*Gyps coprotheres*) breeds only in hilly areas of southern Africa. Botswana is a home of these cliff-nesting species, with its largest colonies found in the southeast (Mannyelanong Hill) and eastern (Tswapong Hill complexes) parts of the country. Out of five colonies, only two large colonies at Moremi (Bonwalenong site) and Goo-Tau (Manong Yeng site) and one small colony near Lerala (Kukubye site) villages remain. The current breeding status and population of Cape Vultures at the two large colonies (Bonwalenong and Manong Yeng) was last studied in 1999. Therefore this study used both direct observations and Generalized Linear Model to estimate the breeding population and breeding success and investigated nest site and cliff characteristics at the two large colonies remaining in the Tswapong Hills. The study results were compared with data from the 1990s.

A total of six visits were made throughout the breeding season, where a total of *n*=280 (Bonwalenong, *n*=200 and Manong Yeng, *n*=80) pairs were identified and monitored. When comparing the breeding population monitored from 1992-1999 and then not again until 2017, the results showed no significant difference in the breeding population compared to the previous studies. However, study results showed that the Bonwalenong colony has recovered from *n*=10 pairs in 1999 to *n*=200 in 2017. Over the same period, Manong Yeng had a higher number of breeding pairs *n*=158 declined to *n*=80 in 2017.

Investigations of breeding success showed that >50% of nestlings that failed to fledge occurred between June and September months which coincided with the incubation and nestling period. Breeding success estimates for 2017 at both sites significantly differed with Manong Yeng estimated at 23.8% for the 80 pairs monitored and Bonwalenong at 43.5% for the 200 pairs monitored. There was also a significant variation of breeding success among the three cliff faces especially between Bonwalenong south facing cliff and Manong Yeng cliff.

Distance of the colony to the nearest village, height of nest and aspect of cliff were found to be important for breeding success and nest site selection. Out of the total areas modeled, <20% demonstrated the suitable habitat for the nesting and breeding of Cape Vultures. These potentially habitable areas fell in the hill ranges in the Tswapong south region where the two large colonies occur. Consistent monitoring and research are required to better understand population dynamics and the key factors influencing chick survival. Results from this study are vital for governmental and non-governmental stakeholders involved in wildlife conservation and management.

Keywords: Cape Vulture, breeding success, breeding population, Generalized Linear Model, Habitat suitability, Tswapong Hills

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST ABBREVIATIONS AND ACRONYMS

BLB- BirdLife Botswana

BLI - BirdLife International

BTO- Botswana Tourism Organization

DEM- Digital Elevation Model

DWNP- Department of Wildlife and National Parks

GIS- Geographical Information System

GLMM- Generalized Linear Mixed Models

GMCA- Goo-Moremi Conservation Area

GPS- Global Positioning System

HSI- Habitat Suitability Index

HSIM- Habitat Suitability Index Model

HSM- Habitat Suitability Model

IUCN - International Union for Conservation of Nature

MCDA – Multi-Criterion Decision Analysis

USGS - United State Geological Survey

OPERATIONAL DEFINITIONS OF CONCEPTS

Table 1: Concepts and definitions

CONCEPT	**OPERATIONAL DEFINITION**
Pairs attempting to breed	Refers to two birds (male and female) observed building a nest.
Breeding	The process of bearing an offspring that occurs when an egg is laid. Since the egg could rarely be seen, it is also assumed that laying an egg had occurred when an adult is lying flat on the nest in a typical incubating position.
Nest success	The proportion of nesting or laying pairs that raise young to the age of fledging (i.e., the age when a fully-feathered offspring voluntarily leaves the nest for the first time).
Nest Failure	The proportions of nests that were abandoned or had a chick die before fledging.
Breeding Success	A ratio of successful nests to total number of nests identified and observed.
Active nest	Nest containing an incubating adult, egg or a nestling.
Nest	The structure made or place used by birds for laying eggs and sheltering young, or, structure built or occupied by the birds for purposes of breeding.
Productive nest	Nests that contained a young Cape Vulture reaching the fledging stage
Nestling	A young bird still dependent on the nest.
Juvenile	A young grown bird.
Fledging	A stage when a fully-feathered young voluntarily leave the nest for the first time.
Breeding season	The period from the start of nest building (refurbishment) or courtship to independence of the young one.
Productivity	The number of young that reach the minimum acceptable age for assessing success; usually reported as the number of young produced per territorial pair or per occupied territory in a year.
Territory	An area containing one or more nests and where no more than one pair was known to have bred at any time.

Adapted and modified from: A. S. Robertson (1986); Borello and Borello (2002); Steenhof and Newton (2007); (Pfeiffer et al., 2017a).

CHAPTER ONE

1.0 INTRODUCTION & BACKGROUND INFORMATION

Vulture populations are declining globally (Ogada et al., 2016). Currently, 14 of 23 (61%) vulture species worldwide are threatened with extinction and the most rapid declines have occurred in Asia and Africa (Ogada et al., 2016;Pfeiffer, 2016; Prakash et al., 2007). In Africa, seven out of eight species assessed have shown a decline of more than 80% (Ogada et al., 2016). The declines in vulture populations have been linked to anthropogenic pressures that account for 61% of global vulture declines (Pfeiffer et al., 2015). Despite the rapid population decline of these species, monitoring of their populations has been far from consistent, primarily due to a lack of resources to mobilize an effective monitoring effort. As a result there is inconsistency in vulture population monitoring in Botswana that result in insufficient information to quantify the current status of these birds.

1.1 STATUS OF VULTURES IN BOTSWANA

In Botswana, all resident vulture species are listed as endangered and or critically endangered by the International Union for Conservation of Nature (IUCN) RedList (BirdLife International, 2017).

Table 2: The vulture species in Botswana, IUCN Red List category and the species' current status with regard to their populations globally.

Species (English)	**Scientific Name**	**IUCN Red List category**	**Current Global Status**
Hooded Vulture	*Necrosyrtes monachus*	Critically Endangered	Rapid decline of 83% over three generations (53 years)
White-backed Vulture	*Gyps africanus*	Critically Endangered	Median estimate of 90 % declines over three generations (56 years)
Lappet-faced Vulture/Nubian Vulture	*Torgos tracheliotos*	Endangered	Rapid decline 80% in Africa
White-headed Vulture	*Trigonoceps occipitalis*	Critically Endangered	Median estimate of 96% decline in West Africa (45 years).
Cape Vulture/Kolbe's Griffon	*Gyps coprotheres*	Endangered	Declining at ~20% over three generations

Modified from: Ogada et al. (2016); BirdLife International (2017).

Restoring and stabilizing populations of vultures requires good reproduction performance in suitable habitats (Campbell, 2015; Hirschauer, 2016; Freund et al., 2016). Thus, understanding of population dynamics, reproduction ecology, and habitat requirements can help inform management and conservation strategies. However, few studies in Africa have examined population dynamics and reproduction of vulture species, such as the endangered Cape Vulture (*Gyps coprotheres*). This study focused on the breeding of the endangered Cape Vulture, which is confined to southern Africa. Botswana is home to some large colonies that were last monitored in 1999 (Borello & Borello, 2002).

1.1.1 LOCATION OF CAPE VULTURE BREEDING SITES IN BOTSWANA

In the 1980s, researchers in Botswana discovered eleven sites with assemblages of Cape Vultures, in which seven were breeding sites. Of these, about 500 pairs bred at five sites in the Tswapong Hills and close to 100 pairs bred at two sites in south-eastern part of the country in the Manyelanong and Manyana Hills (Mundy, 1982; Borello, 1985). The population of the species has fluctuated widely and declined in some sites since that time (Borello & Borello, 2002). For example, the largest colony in the Tswapong Hills, Bonwalenong collapsed in 1994-1995 (Borello & Borello, 2002) and some other colonies in the Tswapong and Manyana Hills were abandoned. The latter studies were the last conducted in the Tswapong Hills, despite the importance of this site to the breeding success of Cape Vultures. Figure 1 shows the location and status of breeding sites found and monitored in Botswana since 1985.

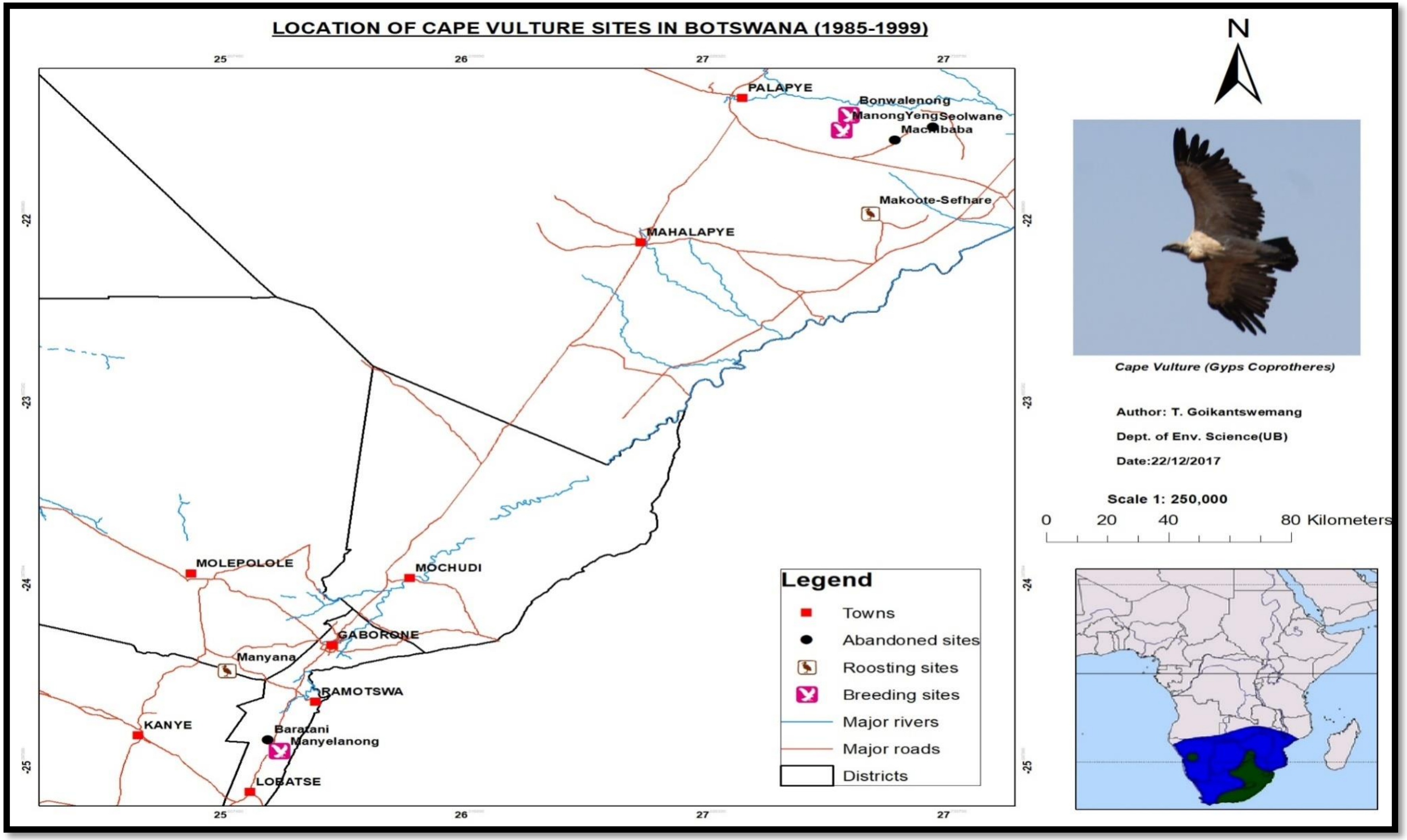


Figure 1: Location of sites of Cape Vultures (*Gyps coprotheres*) in Botswana (1985-1999). Photo taken by author on September 2017 and source of map of Africa: http://www.planetofbirds.com/accipitriformes-accipitridae-cape-vulture-gyps-coprotheres

1.1.2 THREATS FACING CAPE VULTURE POPULATIONS

While breeding success is critical to the production of fledglings and survival of Cape Vultures, their populations also face a number of other threats, including poisoning, loss of habitat, shortage of food, collision with power-lines, drowning, and persecution (Ogada, 2014a; Pfeiffer et al., 2014). These threats are a challenge to the breeding success of the Cape Vulture because they have a low reproduction rate that affects their population. Therefore it is important to understand how their breeding performance and population dynamics have fared over time to make informed decisions on their conservation. This can only be achieved through consistent breeding and population monitoring.

1.1.3 BREEDING SUCCESS OF CAPE VULTURES

Breeding success is defined as the ratio between number of pairs attempting to breed (probable breeding pairs) and number of young reaching fledgling stage (Borello, 2007). Fledgling stage is a period when are chicks can voluntarily leave a nest (~90 days) after hatching (Robertson, 1986; Steenhof & Newton, 2007). Researchers have conducted some monitoring of Cape Vulture populations to understand population dynamics and breeding success rates. Monitoring and studying populations of Cape Vultures in Botswana was conducted by Mundy et al. (1980) and Boshoff and Borello (1982) in the 1980s. In a study conducted from1992 to 1999, Cape Vultures at Manyelanong Hill near Otse village had a higher breeding population (91.4% of the population bred) with a 75% breeding success rate as compared to a 86.9% breeding population and a 69.7% breeding success at the Tswapong Hills complex (Borello & Borello, 2002). However, monitoring the population size and breeding success of Cape Vultures has not been consistent, especially in the Tswapong Hills (Borello & Borello, 2002), where the population has remained largely unstudied since 1999.

Mundy et al. (1992) emphasized the importance of population monitoring because Cape Vultures produce at most one chick per year. Population monitoring entails investigating breeding population, breeding success, and the survival of young. This provides information about the status of the breeding population and their breeding performance. Consistent monitoring enables comparison with previous data to determine population dynamics. Thus, the main focus of this research is on the breeding success of Cape Vultures in the two large colonies remaining in the Tswapong Hills.

1.2 STATEMENT OF THE PROBLEM

In Botswana, the status of the breeding population of Cape Vultures at Bonwalenong and Manong Yeng was well documented from 1985 until 1999 by Borello & Borello (2002) where seven colonies were identified and monitored. Currently, only three large breeding colonies remain in Botswana; namely two in the Tswapong Hills near Moremi and Goo-Tau villages and one in Otse at Manyelanong Hill. However, close monitoring has been only conducted at Manyelanong Hill near Otse village where 62 and 81 breeding pairs were recorded in 2014 and 2017 respectively (Wolter et al., 2016;Wolter et al., 2017). Despite their importance, the two large colonies in the Tswapong Hills have remained largely unmonitored since 1999, such that their current breeding status (success) remains unknown.

This constitutes a major gap in the research on Cape Vultures that needs to be urgently addressed, not least because the Tswapong Hills are under increasing pressure from settlement and power-line expansion at Lerala village, the construction of a dam on the Lotsane River at Maunatlala village in 2009, and increasing pressure from tourism developments and farming. Active breeding and roosting sites need protection from disturbance by, for example, increasing educational awareness of the general public and farmers (Borello, 1985; Pfeiffer et al., 2015; Pfeiffer et al., 2017) on the importance of the Tswapong Hills breeding sites. Tyler and Bishop (1998), pointed out that direct persecution and disturbance have affected breeding populations in the Tswapong Hills, with growth of the villages around the site over the last ten years contributing to abandonment of small breeding sites. They expressed concern about the small number of immature birds seen at breeding colonies, which may be due to a high mortality rate of young birds or emigration young birds from the area (Tyler & Bishop, 1998).

Other factors may also impact vulture breeding success. For example studies on the breeding performance of other colonial cliff nesting birds have shown that environmental factors such as nest site and cliff characteristics (Moreno-Opo, et al., 2013; Freund et al, 2016; Pfeiffer et al, 2017) influence breeding success. Similarly, a recent study on the Msikaba Cape Vulture colony in South Africa showed that breeding success and survival required certain cliff and nest characteristics (Pfeiffer, et al., 2017). Such information can be used to identify ideal breeding sites for reintroduction and informing conservation policies and strategies. Despite the importance of this information, little is known about the two largest Cape Vulture colonies breeding in the Tswapong Hills of Botswana.

To address this major gap in Cape Vulture research in Botswana, this study investigated the breeding success rates of Cape Vultures in the only two large breeding colonies remaining in the Tswapong Hills, as well as nest site and cliff characteristics that may influence such success. This study used the latter information to develop a GIS-based model to identify other potential suitable habitats nesting sites for Cape Vultures in the Tswapong Hills complex. The results of this study can be used to inform conservation and management strategies for both Cape Vulture populations and their habitats.

1.3 MAIN AIM AND SPECIFIC OBJECTIVES OF THE STUDY

1.3.1 MAIN AIM OF THE STUDY

The main aim of this study was to investigate the current breeding success of Cape Vultures at Bonwalenong and Manong Yeng colonies within the Tswapong Hills and compare it with that of the recent past.

Table 3: Research Objectives and Questions

Research Objectives	**Research Questions**
1. To estimate the breeding success of Cape Vultures in Bonwalenong and Manong Yeng breeding sites in the Tswapong Hills.	• What is the breeding success of Cape Vultures at the two large colonies in the Tswapong Hills? • How do current breeding success estimates of Cape Vultures differ from a previous study (1992-1999)? • Is there any significant difference between the breeding successes of the two sites?
2. To investigate the influence of nest site and cliff characteristics on the breeding success of Cape Vultures at the two large colonies in the Tswapong Hills.	• What nest site and cliff characteristics influence breeding success of Cape Vultures at the two sites in the Tswapong hills? • To what extent do these nest site and cliff characteristics affect the breeding performance of Cape Vultures?
3. To develop a GIS-Based habitat suitability model of preferred Cape Vulture nesting habitat in the Tswapong Hill complex.	• Are there other potential sites within the Tswapong Hill complex with suitable nesting habitat for Cape Vultures?

1.4 SIGNIFICANCE OF THE STUDY

Evaluating and assessing the breeding success and implications of the population status of vulture colonies provide essential information that can help direct and prioritize future conservation efforts. This study is important because it will provide:

- New knowledge on the current status of the Cape Vulture's breeding population and performance in Botswana that can be compared with that of the past (1992-1999).
- An in-depth understanding of the breeding performance of Cape Vultures at the key sites within the Tswapong Hills.
- A model that can be used to identify other potential sites for conservation.
- Data that will enrich the literature on the breeding ecology and population dynamics of vultures.

1.5 SCOPE OF THE STUDY

Studying the breeding ecology of raptors requires examining many aspects, such as population dynamics, nesting ecology, feeding and foraging patterns, habitat preference, and breeding performance (failure/success). This study focused on the breeding success of Cape Vultures, and examined how nest site and cliff characteristics affected breeding success and habitat preference. It focused on the two large breeding colonies of Cape Vultures that remain in the Tswapong Hills near Moremi (Bonwalenong) and Goo-Tau (Manong Yeng) villages. Borello and Borello (2002) previously studied these colonies using similar methodologies, permitting comparisons made between the 1992-1999 data and the 2017 data from this study. This study seized upon a unique opportunity to compare the breeding success of Cape Vultures at two spatially discrete key nesting sites over two time periods.

1.6 STUDY AREA

The study area includes the complex of the Tswapong Hills where the two remaining breeding sites with large colonies of Cape Vultures occur (Borello & Borello, 2002). These remaining breeding sites are Bonwalenong and Manong Yeng, which occur near Moremi and Goo-Tau villages, respectively (Figure 2).

1.6.1 STUDY AREA DESCRIPTION

The Tswapong Hills lie about 40 km south-east of Palapye in the eastern part of the Central District of Botswana. The hills complex stretches over 70 km east to west and about 15 km north to south, with an altitude of 850-1000 m (Borello & Borello, 1993; Ratsie, et al., 2011). This area receives an average rainfall of 440 mm annually with minimum temperatures ranging between 12.5 °C (summer) and 6 °C (winter), whereas maximum temperatures range between 21.5 °C (winter) and 40.5 °C (summer) (Geoflux, 2009). The hills are flat-topped and often sheer-sided with vertical cliffs mainly composed of sandstone and quartzites with a hard cap rock that protects the hill from erosion and results in the higher elevation from the surrounding landscape (Geoflux, 2009). Several deep gorges with cliffs and seasonal and permanent streams occur within the hills.

Natural springs feed the streams and form waterfalls with deep pools. The most accessible and spectacular waterfalls are found in the Goo-Moremi Gorge. The existence of good sources of water and soils support a relatively diverse flora and fauna in the area. The study area consists of savannah hill woodland (Ratsie et al., 2011), dominated by *Croton gratissimus* and *Acacia nigrescens*, with *Colophospermum mopane* woodland on the silt floodplains. Recent DWNP aerial surveys (DWNP, 2015) covering the project area found a wild ungulate population of kudu (*Tragelaphus strepsiceros*), impala (*Aepyceros melampus*), duiker (*Sylvicapra grimma*) and steenbok (*Raphicerus campestris*). Klipspringer (*Oreotragus oreotragus*), warthog

(*Phacochoerus africanus*), leopard (*Panthera pardus*), hyena (*Hyaena brunnea*), baboon (*Papio ursinus*) and rock dassy (*Procavia capensis*) also occur within the project area. The Cape Vulture *Gyps coprotheres* has probably bred in the Tswapong Hills for well over a century (Tyler and Bishop, 1998), with other locally rare cliff nesting birds such as Black Storks (*Cicinia nigra*), Black Eagles (*Aquila verreauxii*) and Booted Eagles (*Hieraaetus pennatus*) also found in the Tswapong Hills. The latter hill complex is home to the largest Cape Vulture colony in the country with an estimate of ~500 breeding pairs in 1999 (Borello & Borello, 2002). This study focused on the remaining two large Cape Vulture colonies that are found near Goo-Moremi (Bonwalenong) and Goo-Tau (Manong Yeng) villages in Tswapong Hill complex.

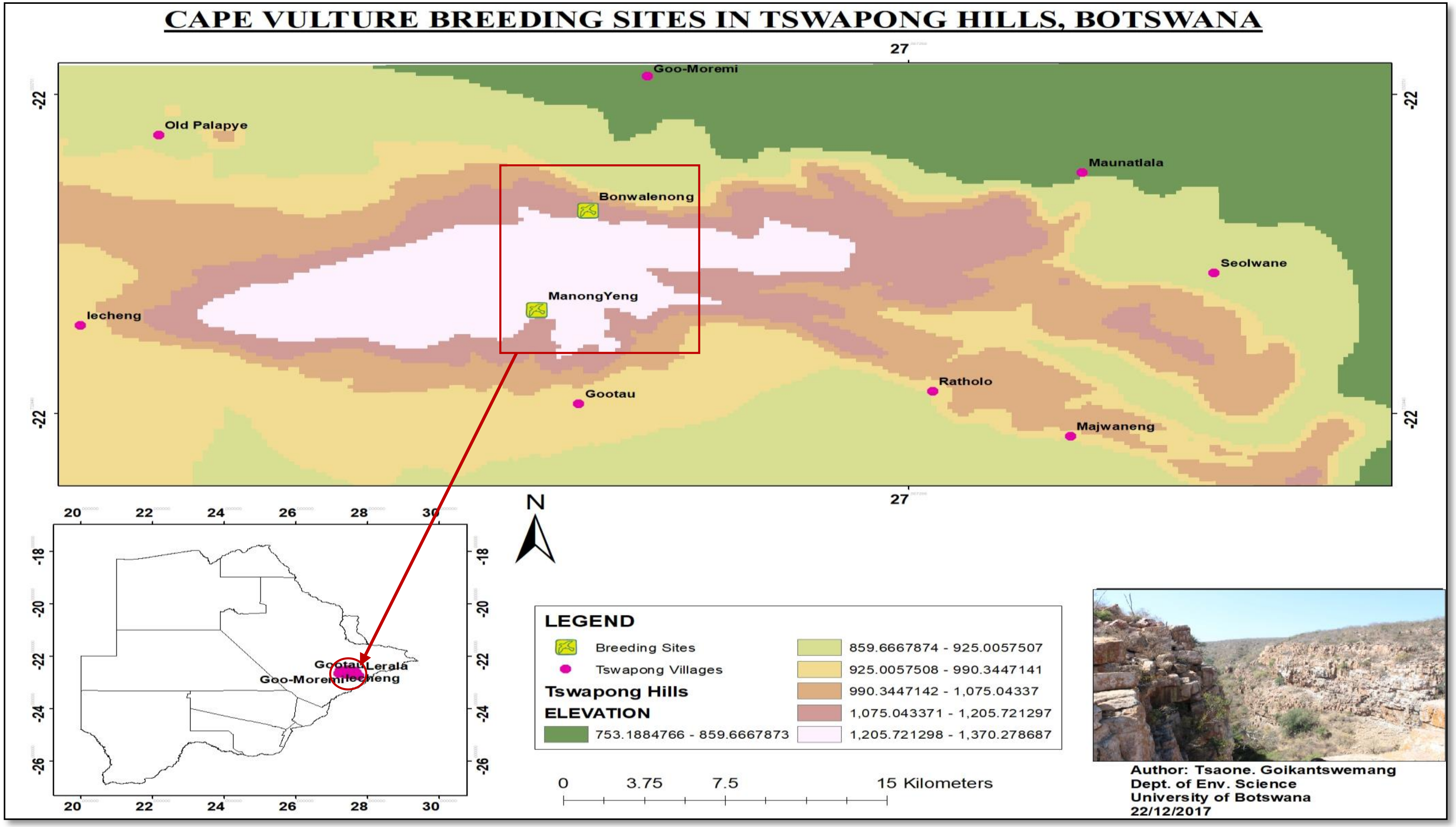


Figure 2: Map showing the study area.
Photo taken by author (September 2017).

BONWALENONG BREEDING SITE

This breeding site is located at the Goo-Moremi Gorge, about 5 km south of Moremi Village in the northern Tswapong Hills (Siphambe et al., 2017). The site has two cliff faces opposite each other (Figure 3).

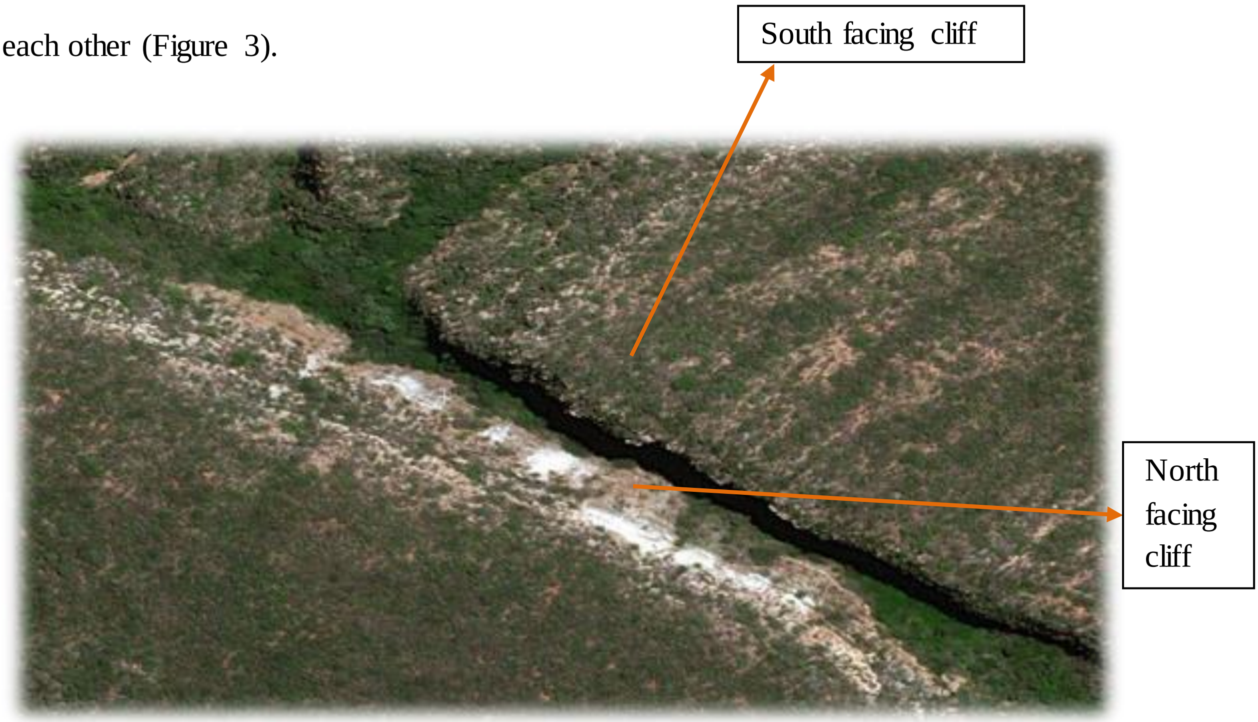


Figure 3: Aerial view of Bonwalenong breeding site showing the north and south facing cliffs. Source: Accessed from https://zoom.earth/#-22.611978,27.433008,16z,sat on the 25 January 2018

The presence of waterfalls and various wildlife species, including the endangered Cape Vulture colony has led to promotion of tourism in Moremi village, and it became a conservation area referred to as the Goo-Moremi Conservation Area (GMCA) in 2000 (Siphambe, et al., 2017). GMCA is managed by a community trust with the assistance of the Kalahari Conservation Society and Botswana Tourism Organization. The conservation area created business and job opportunities for local people. The area has been receiving a considerable number of visitors, increasing from 415 visitors in 2008 to 5,015 in 2015 (Siphambe, et al., 2017).

MANONG YENG BREEDING SITE

The Manong Yeng colony occurs north of Goo-Tau Village (Figures 4 & 5). This village lies 45 km east of Palapye off the Martins Drift road. Unlike, at Moremi village, no trust manages the Manong Yeng Cape Vulture colony. However, according to Botswana Wildlife (2016), permission must be requested from the village chief before visiting the site. The local people in Goo-Tau village are subsistence farmers who grow crops and keep livestock within walking distance of the village. During the dry season, local farmers drive their livestock into the hills where the Manong Yeng site is found, as the sand covered plateaus provide relatively good grazing. At both Moremi and Goo-Tau villages, there is no evidence of involvement of the local people in active conservation of Cape Vulture colonies.

Figure 4: Aerial view of Manong Yeng breeding site

Source: Accessed from https://zoom.earth/#-22.674953,27.409738,18z,saton 25 January 2018

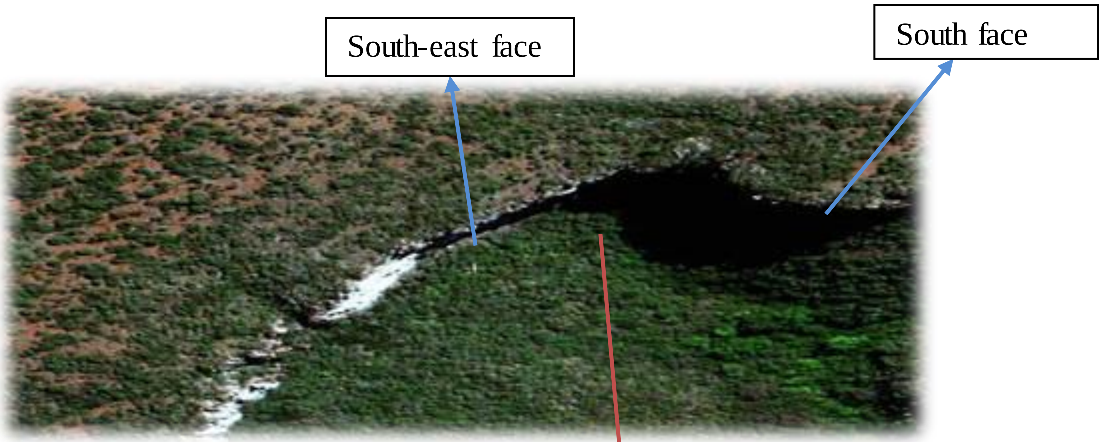


Figure 5: Cliff face at Manong Yeng breeding site (Near Goo-Tau)
Source: Author (05 August 2017)

CHAPTER 2: LITERATURE REVIEW

2.0 INTRODUCTION

This chapter outlines the status of Vultures globally, their ecological significance, key threats to their existence and examples of successful conservation measures, before focusing on factors that affect the breeding ecology of Cape Vultures.

2.1 BACKGROUND INFORMATION ON VULTURES

Globally, vulture population decline is the fastest among all groups of birds. However, research on vultures has tended to lag behind those of more charismatic birds, such as Kori Bustard (*Ardeotis kori*), especially in Africa, with some of the earliest studies carried out as recently as 2017 (Mmassy et al., 2017). In southern Africa, it is perhaps only the consequence of their severe declines that has attracted attention to their ecological importance and the urgent need to conserve their populations.

2.1.1 GLOBAL VULTURE POPULATIONS

There are around twenty-three different species of vultures throughout the world, out of which sixteen are considered threatened or endangered (Birdlife International, 2015). Regions of Asia and Africa are faced with rapid declines (Ogada, et al., 2012a). In Nepal, India, and Pakistan vulture populations have undergone dramatic declines in numbers since the mid-1990s, with declines in excess of 97% for three resident species (Prakash, et al., 2012). In India, numbers of White-rumped Vulture (*Gyps bengalensis*) have declined by 99.9% from 1992 to 2007 (Prakash et al., 2007). The decline of vulture populations is now described as a 'crisis" (Ogada et al., 2016). Six out of the eleven African vulture species had their global status worsen in the latest update of the Red Data List that shows that four species are now critically endangered (BirdLife International, 2017).

Furthermore, seven out eight species found in southern Africa have been raised to higher conservation status by the International Union for Conservation of Nature (IUCN) (BirdLife International, 2018). These include three resident species, Hooded (*Necrosyrtes monachus*), White-headed (*Trigonoceps occipitalis*), and African white-backed (*Gyps africanus*) Vultures, which are now listed as critically endangered. A recent study in Botswana showed that populations of two (Lappet-faced, *Torgos tracheliotos,* and White-headed, *Trigonoceps occipitalis,* Vultures) of four vulture species declined significantly (by 78% – 61% respectively) between 1991-1995 and 2015-2016 surveys (Garbett, et al., 2018). Also, a decline in nesting of White-backed Vultures was reported at Linyanti and Khwai colonies from 99 pairs to 46 in the space of 10 years (2007-2017) (Leepile, 2018). Virani, et al. (2011) and Ogada, et al. (2012a) have argued that declines of African vulture populations are less understood because of the diversity of threats identified. The decline of vultures globally remains a poorly understood and often ignored crisis.

2.1.1.1 CAPE VULTURE POPULATIONS

Populations of Cape Vultures are expected to decline by 92% over the next three generations (Allan, 2015; Pfeiffer et al., 2015). Since 1988, when they were first categorized as "Threatened", conservationists observed steady declines in populations of Cape Vultures leading to a change to "Vulnerable" status from 1994 until 2014 (BirdLife International, 2015). Cape Vultures have been classified as "Endangered" since 2015 (BirdLife International, 2017) and are considered locally extinct as a breeding species in Namibia, Swaziland, and Zimbabwe .

The 2013 global population was estimated at approximately 4700 pairs with 9400 mature individuals (Allan, 2015). The population of Cape Vultures declined by 66-81% over the past 50 years (Martens, et al., 2018). This decline is also evidenced by the reduced number of some breeding colonies since the 1960s, when vultures bred at 32 known colonies in South Africa as compared to 11 colonies in 2015, (Allan, 2015). In Namibia, Cape Vultures are classified as Critically Endangered because of a 98% decline from 500 birds in 1940 to 12 in 2000 and five birds in 2014 (Santangeli, et al., 2016). Similarly, the number of breeding colonies declined from five to one in the Namib Desert. Lesotho, Eastern Cape and KwaZulu-Natal Provinces and Swaziland contain 42% of the breeding pairs (Allan, 2015). The population of Cape Vultures in Botswana, especially in the Tswapong Hill complex, remains unknown since 1999.

2.1.2 ECOLOGICAL IMPORTANCE OF VULTURES

Vultures are the only obligate vertebrate scavengers that have evolved in an environment characterized by unpredictable food resources (carcasses that are scattered far and wide and only intermittently available) (López-López et al., 2014). As the latter authors emphasize, vultures provide irreplaceable ecosystem services, such as waste removal, nutrient recycling, and, by cleaning the environment of dead carcasses, also act to limit the risk of disease transmission. Both ecologically and economically (see Table 4) vultures are regarded as a priority species for conservation. In Botswana, where there is limited information documented on the importance of vultures, it is likely that their real value in terms of the essential ecosystem services they provide will be realized once they have been lost altogether.

Table 4: Summary of ecological importance of vultures

Importance	Example
Ecological	• Waste removal (Markandya, et al., 2008; Ogada, et al., 2012b; Dupont, et al., 2012). • Limit the spread of diseases (Markandya, et al., 2008; Ogada, et al., 2012b) • Nutrient recycling (Wenny, et al., 2011; Dupont, et al., 2012).
Economic	• Source of income through eco-tourism (Becker et al., 2010; Letsholo, 2015). • Helps save money in waste management such as incineration and treatment of animal remains as well as reducing emissions of CO_2. For example, the Indian government spent $34 billion on health (Markandaya et al., 2008) and $50 million on carcass removal (Morales-Reyes et al., 2015). • Source of medicine, especially in Africa (e.g. Cape Vulture and White-backed Vulture in Lesotho, South Africa; Nigeria and Benin; Ngwenya, 2001; Beilis & Esterhuizen, 2006; Mander et al., 2007; Nikolaus, 2015). • Source of food (e.g. Hooded Vulture in Ghana, (Adeola, 2009).
Cultural	• Disposal of dead human corpses (Markandya et al., 2008; Kushwaha, 2016).

2.1.3 THREATS TO VULTURES

The populations of vultures, like other raptors, are threatened by anthropogenic activities such as persecution (poisoning, shooting, and trapping) and change in land use and cover patterns through development of infrastructure (built-up areas, agricultural land, power lines, dams, wind farms and roads) near their nesting sites.

Human activities reduce the foraging range as human settlements are associated with land degradation and bush encroachment further decreasing habitat and food supplies (carcasses) (Herremans & Herremans-Tonnoeyr, 2000; Bamford et al., 2009). Land use and cover changes are the driving factor in declining wildlife population. Expansion of human settlements, farmlands (animal and crop production), ranches and cordon fences are examples of human-induced factors that alter land use and land cover resulting in declines in wildlife populations (Ogutu et al., 2011; Martinuzzi et al., 2015). Vultures are also affected by these changes. The impacts of habitat loss has been observed at the Tswapong Hill complex, where some vulture colonies collapsed and some nesting sites were abandoned as some villages expanded towards the breeding and roosting sites (Borello & Borello, 2002).

The shift from extensive cattle farming to intensive cattle farming has been cited as a threat to vulture populations through shortage of food supply (Matyeo- Tomás & Olea, 2015). The dependence of vultures on livestock has resulted in the reduction of their populations that increased with the growth in the numbers of livestock (Mateo-Tomás & Olea, 2015), but decreased with intensive farming that relies on the use of veterinary drugs, restriction of livestock movement (especially in feedlots), and the practice of burying carcass.

Poisoning has caused the majority of the decline in vulture numbers in Asia and Africa (Ogada, et al., 2016; Green et al., 2016). This can be unintentional through lead ammunition (Naidoo et al., 2012; Kenny et al., 2015; Garbett et al., 2018), exposure to veterinary drugs (Green et al., 2004; Green et al., 2016; Naidoo et al., 2017), for medicinal purpose (Groom et al., 2013), and by farmers targeting predators (Mateo-Tomas et al., 2012; Ogada et al., 2016). Poisons mostly used include carbofuran (Ogada, et al., 2016), Non-Steroidal Anti Inflammatory Drug (NSAID) especially in Asia (Green et al., 2004), and carbamate (Virani et al., 2011). In Botswana, poisoning and high lead levels are the major threats recently documented. According to Rutina et al. (2017), a total of ~ 1479 vulture species died from poisoning between 2011 and 2016 in incidences where wild animals and cattle were poisoned. Reporting of poisoning incidences in Botswana remains lacking, hence the numbers might be more.

Lead ingestion has been found as a threat facing vulture populations. According to Parish et al. (2007), lead is implicated as the leading cause of death in the Arizona population of the California Condor (*Gymnogyps californianus;* ~40% of the worldwide population). Also in a study conducted in South Africa, of 20 Bearded Vultures (*Gypaetus barbatus*) tracked 53% died due to poisoning and 80% of those that died showed high levels of lead (Krüger, 2014). In Botswana it has been found that vulture blood samples especially in hunting areas/ranches had high lead levels (Kenny et al., 2015; Garbett et al., 2018).

Climate change has also been identified as a limiting factor to the survival of Cape Vultures, especially in areas that experience high temperatures and heavy rains (Chaudhry, 2007). The presence of other species like jackals, eagles, and pythons also threatens the survival of Cape Vulture populations through competition for food and nesting sites as well as feeding on young. These impacts may lead to population reduction due to mortality or emigration to other suitable breeding sites.

Apart from the above discussed threats, there are other emerging threats of wind turbines (Rushworth & Krüger, 2014) and drowning of raptors in reservoirs (Anderson et al., 1999). For example, in southern Spain, 342 griffon vultures were found dead and this mortality increased annually near areas with wind turbines located in populated areas (Carrete et al., 2012). In South Africa, four fatalities associated with wind farms were reported in 2017 (Hazell, 2017). Also African White-backed and Cape Vultures were among raptor species frequently found in reservoirs in South Africa (Anderson et al., 1999). Moreover, in the study conducted by Borello and Borello (2002), tourism activities and disturbance from human traffic were attributed to the loss of Cape Vultures from some breeding sites. These factors were never investigated to find the extent that they affected the Cape Vulture populations. Investigation of these factors is useful to inform conservation measures and policies for vulture conservation.

2.1.4 VULTURE CONSERVATION INITIATIVES

Countries have adopted different measures towards vulture conservation. These include legislation, educational, and awareness on the use of eco-friendly products and vulture poisoning, continuous research and population monitoring, erection of vulture-friendly pylons, captive breeding and rehabilitation, and supplementary feeding or vulture restaurants (Table 5). However, the success of the majority of these efforts is influenced by several factors. For example, presence of unfriendly electric infrastructure and the use of poisonous chemicals in proximity to vulture foraging areas can hinder success. López-López, et al. (2014) , also argued that the success of supplementary feeding or vulture restaurant is influenced by their location, 'naturalistic condition'', frequency of supply, and management.

Table 5: Example of vulture conservation measures

MEASURE	STRENGTH	WEAKNESS/CHALLENGE
Legislation	• Successful banning of poisonous agro-chemicals e.g., In Bangladesh (Ramírez et al., 2014), India (Prakash, et al., 2007), Nepal (Harris, 2013).	• Not effective because vultures are migratory species and forage anywhere they can find carcass. • Lack of implementation
Supplementary feeding	• Avert the problem of shortage of food and poisoning (Piper, 2005). • Cost-effective way of disposing carcasses (Piper, 2005). • Prevent diseases such as osteoporosis • Increase breeding success (Donázar, et al., 2009). • Vulture restaurants can be used as tourists' attractions (Sharma, 2012).	• Can reduce, but not eliminate, vulture mortality where there is still use of poisonous chemicals and improper management of the restaurant (Piper, 2005; López-López et al., 2014). • Attract other scavengers (Piper, 2005). • Lack of resources hinders proper management (López-López et al., 2014)
Captive breeding and rehabilitation	• Preserve species that are threatened by extinction and allow reintroduction of lost species (Monadjem et al., 2014) . • Population restoration possible with injured birds; e.g. noted 75% successful in South Africa .	• Costly, e.g. India spend over 1 million $ a year (Prakash et al., 2007). • Sustainability of captive breeding and release depend on presence of other factors such as the use of diclofenac and lead products in the area, presence of power-lines polygons, etc. (Naidoo et al., 2011).
Education and awareness	• Influence perceptions and attitudes of public towards threatened species in their localities.	• Does not directly ensure conservation of threatened species.
Research and monitoring	• Provide useful data to inform policies (Freund, 2016).	• Lack of resources leading to inconsistent population monitoring.
Development of protected areas	• Limited to the breeding population during the breeding period (Whittington-Jones et al., 2011; Krueger, 2014; Krueger et al., 2015).	• Vultures are exposed to threats at their foraging ranges e.g. In East and West African countries (Ogada et al., 2012a; Kendall et al., 2014).

2.1.4.1 CAPE VULTURE CONSERVATION

In southern Africa where the Cape Vulture is endemic, some breeding and roosting sites are protected from human disturbance whereas some are not. For example, Cape Vulture breeding colonies are found in Mannyelanong Game Reserve and Goo-Moremi heritage site (Botswana) and within National Parks (NPs) such as Marakele, Blouberg, Magaliesberg and the Maloti- Drakensberg (South Africa and Lesotho) (Whittington-Jones et al., 2011; Krueger et al., 2015). South Africa, through Vulpro, have a consistent research and monitoring programme in place, as well as a captive breeding programme and supplementary feeding at vulture restaurants that aim to improve management and conservation of vulture populations. The national electricity provider in South Africa, Eskom, has actively participated in the monitoring of raptors, especially vultures, by ensuring that all of its power lines are raptor friendly.

Unfortunately, in Botswana the national electricity provider, the Botswana Power Corporation (BPC), has shown no such initiative, although many mining companies, such as Debswana, have adopted the use of 'raptor friendly' power lines following the recommendations of EIAs/EMPs they commissioned. Monitoring under power lines to check the incidence of raptor electrocution does not take place in Botswana, although evidence provided from such monitoring in South Africa showed alarming mortalities, which can be expected to occur across the border. It follows that there remains much to be done in Botswana, as BPC still does not have a strategy aimed at raptor conservation and lacks an explicit environmental component to its mission to provide electricity throughout the nation. The impact on conservation strategies in conserving Cape Vultures requires further investigation to inform relevant authorities (Beale et al., 2013; Phipps et al., 2013a; Phipps, 2015).

2.2 BREEDING ECOLOGY

The sustainability of vulture populations requires sufficient suitable habitat to support reproduction and survival of populations. Breeding is important for population restoration through production of offspring. Researchers therefore seek to investigate how vultures interact with one another and their natural and physical environment. Breeding performance (success or failure) and habitat suitability are important parameters in breeding ecology.

2.2.1 BREEDING OF CAPE VULTURES

Cape Vultures have a lifespan of over 30 years and reach sexual maturity between five and seven years (Pfeiffer et al., 2017). The species is monogamous, with individuals pairing for life (Mundy et al., 1992). They breed and roost on cliffs in colonies of up to ~1000 pairs. They pair in April/May and occupy old sites or construct new nests using herbaceous and woody material on cliff faces (Borello & Borello, 2002; Wolter et al., 2016). Females lay a single egg from late May to June (Mundy et al., 1997). They incubate the egg for about 57 days, with duties shared by both parents. After hatching, around August, the chick relies on its parents for food until late November (Mundy et al., 1992; Benson et al., 2004). One parent remains on the nest and waits patiently for its partner to return from foraging. The nestling to fledging period lasts between 125 to 171 days after hatching (Benson et al., 2004). Most chicks fledge in October or November (Mundy et al., 1992; Borello & Borello, 2002).

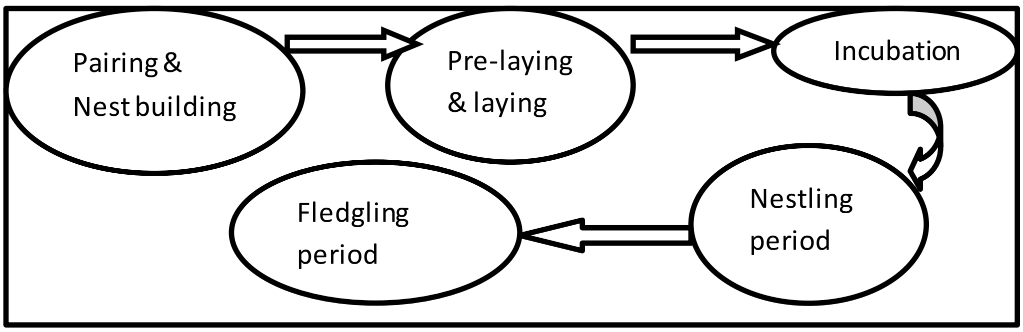


Figure 5: Breeding cycle of Cape Vulture

At around four months of age the chicks venture out of the nest to take their first flight, but they do not become fully independent until the next breeding season, and they frequently return to the nest for feeding (Mundy et al., 1992). The first year after fledging is riskiest for Cape Vultures, with survival rates estimated at 29-56%, increasing to 58-76% for immature vultures aged four years or more (Piper et al., 1999), and more than 90% for adults (Piper et al., 2005; Monadjem et al., 2014). During breeding, adults restrict their foraging to areas near their nest sites and so often experience food shortages at critical periods of chick-rearing (Martens et al., 2018). Therefore, the survival of nestlings depends on features of the foraging habitat, which includes food availability and the microclimate around the breeding site.

2.2.2 HABITAT PREFERENCE OF CAPE VULTURES

Habitat refers to an area or environment in which resources and environmental conditions support the reproduction and survival of an organism. According to Mundy et al. (1992) and Pfeiffer et al. (2015), Cape Vultures prefer to occupy a nesting environment with steep, fractured cliff faces with strong winds that promote soaring. They prefer foraging in areas of open grasslands and savanna woodlands or fairly sparse woodlands (Pfeiffer et al., 2015). Studies have shown that their foraging ranges differs according to their age (adults and juveniles) (Bamford et al., 2007; Martens, 2018). Movement of adult birds is restricted to areas near the colony especially during breeding season whereas immature birds forage far from the nesting sites (Pfeiffer et al., 2015; Phipps et al., 2013). However, vultures only roost on trees and electricity pylons when they forage away from cliffs. This exposes them to electrocution. Juveniles and immature adults usually occupy areas distant from breeding colonies which reduces competition for available food with adults (Pfeiffer et al., 2017a).

2.2.3 FORAGING AND FEEDING BEHAVIOUR OF CAPE VULTURES

Cape Vultures are carrion feeders that often travel long distance scavenging. They rely on high visual acuity to detect carcasses from long distances and their habit of moving in groups (colony) increases their searching efficiency (Mundy et al., 1992; Phipps, 2015). This behaviour has been observed among the Eurasian Griffon Vulture (*Gyps fulvus*). They do not kill their prey, but feed on the carcasses of dead animals where they take fragments of bones, soft muscles, and organ tissues (Robertson, 2015; Pfeiffer et al., 2015). Robertson (2015) observed that Cape Vultures preferred to feed on sheep as compared to cattle. They usually open a carcass with their beaks except when a dead animal has a very thick skin, requiring that they wait for other scavengers such as Bateleur Eagles (*Terathopius ecaudatus*) and the Lappet-faced Vultures (*Torgos tracheliotos)* to eat first.

During feeding, Cape Vultures usually fight for food and often stand with wings out-stretched (Phipps, 2015). Each vulture ensures that it consumes enough carrion to gain energy needed for future use during times of low food supply and or poor weather conditions when they are unable to fly (Duriez et al., 2014). This explains why they have a large body size. After feeding, they bath in ponds and pools (Robertson, 2015).

2.3 FACTORS INFLUENCING HABITAT SUITABILITY, BREEDING SUCCESS AND SURVIVAL OF NESTLINGS

Raptors select and prefer habitat with environmental factors that will support their survival. These refer to variables or characteristics of the environment that impact survival and development (Oppel et al., 2016). Several environmental factors affect the breeding success and survival rates of vultures, including climate/weather, human disturbance, vegetation cover, and characteristics of the cliff and nest site (Table 6). Therefore, vultures require a suitable habitat with good environmental conditions that will support breeding success and survival of chicks.

Environmental conditions determine food availability, level of disturbance and presence of predators which influence nesting and breeding success. For example, Agricultural practices and landscape compositions are cited as threats to the reproduction and survival of vultures because they alter food availability (Donázar et al., 2010; Margalida et al., 2014). These factors impact breeding adult survivorship and breeding success rates. In Botswana, Cape Vulture colonies occur on cliffs near villages where there are agricultural practices and tourism activities. Table 6 provides a summary of studies that investigated factors influencing breeding success of different species. A lack of information remains on the effects of vegetation structure on Cape Vulture foraging patterns (Phipps, 2015).

Table 6: Summary of literature on factors influencing habitat preference and breeding success

Factor	Author(s)	Specie	Major Finding
Disturbance	Ogada et al. (2016); Wolter, et al. (2016); Pfeiffer et al. (2017a); Borello and Borello, (1993)	Cape Vulture *(Gyps coprotheres)*	Hiking, frequent human traffic, infrastructure (power-lines, roads and reservoirs, wind farms) near breeding sites, can lead to nesting failures and even abandonment of a nesting colony (at Baratani and some cliffs in the Tswapong Hills).
Land uses and cover	Oppel et al. (2016); Mateo-Tomás and Olea, (2015)	Egyptian Vulture *(Neophron percnopterus)*	Suitability of habitat for breeding vultures in Bulgaria was linked to changes in land use such as livestock farming.
Climate change	Chaudhry, (2012); Kendall et al. (2014)	Cape Vulture *(Gyps coprotheres)*	High temperatures (exposed to the sun) and higher rainfall reduces the rate of provisioning resulting in lower breeding success (high mortality).
Vegetation Structure	Bamford et al. (2009)	Cape Vulture *(Gyps coprotheres)*	They cannot forage in areas with tree cover of more than 2600 trees·ha^{-1} and they require a take-off angle of no more than 4^{o} from the top of surrounding trees.
Nest Characteristics	Beardsell et al. (2016); Pfeiffer et al. (2017a); Djerdali et al. (2016)	Cape Vulture *(Gyps coprotheres)* White Storks (*Ciconiaciconia*)	**Nest type and position:** concealed nests had higher breeding success; nests on ledges or caves with a larger base were likely more successful **Nest dispersal/Neighbours:** 91% of Cape Vulture nests packed in one area within the same cliff face were more successful **Nest density:** medium density of nests had highest breeding success
Cliff Characteristics	Pfeiffer et al. (2017); Borello and Borello, (2002); Chaudhry, (2012)	Cape Vulture *(Gyps coprotheres)*	**Height:** preferred to nest on higher altitude and were more successful if higher **Orientation:** nests on the shady-side (more likely to be more successful if oriented south, south-west and south-east).

2.4 FOOD AVAILABILITY

Several factors influence food availability. Lack of sufficient food is attributed to some human practices, such as burying livestock and use of agrochemicals and other drugs that harm vultures. In addition, many juvenile Cape Vultures die from lack of calcium (Phipps, 2015). Poisoning leads to population declines of Cape Vultures and likely played a major role in the declining breeding population in Namibia and elsewhere (Mander et al., 2007). Poisoning and persecution of adult vultures also results in high juvenile mortality as they face lack of food provisioning due to the deaths of their parents. The distance that a breeding vulture travels to find food is also important. Availability of food within a radius of about 5 km of a nest site positively influences breeding success (Margalida et al., 2014; López-López et al., 2014). Generally, food availability for Cape Vultures depends on several factors that can be categorized into direct and indirect causes. Direct causes include size of the foraging area and presence of food sources; whereas indirect causes include the use of agro-chemicals and drugs, climate, bush encroachment, and persecution.

2.5 HABITAT SUITABILITY

Habitat loss is a major threat to reproduction and survival of any population (Haghani et al., 2016). It results from the presence of unsuitable conditions and anthropogenic activities within close proximity to the habitat. Models used to predict the suitability of habitat for a species are referred to as Habitat Suitability Models (HSM). These include a combination of statistical and spatial models such as Generalized Linear Mixed Models (GLMM) and Habitat Suitability Index Models (HSIM). Different models and techniques have been used to predict presently unoccupied, but suitable, habitats for nesting birds, such as Golden Eagles (*Aquila chrysaetos*) (Troy et al., 2014) and White-headed Woodpeckers (*Picoidesa bolarvatus*)

(Holldenbeck, et al., 2011). In southern Africa, little has been done to assess habitat suitability for Cape Vultures.

2.5.1 HABITAT SUITABILITY INDEX MODEL (HSIM)

HSIMs are commonly used. These models use a combination of numerical indices to represent the capacity of a given habitat to support a species based on the variables affecting survival. A habitat suitability index (HSI) is used to construct a HSIM. According to Block and Brennan (1993), HSIMs are comprised of a set of independent environmental variables that determine the capability of a habitat to support a species; also referred to as habitat requirements. These describe the suitability of a given habitat by combining the interactions among all key environmental variables on a species' vital rates.

HSIMs synthesize the effects of environmental variables and scale them to produce a value for each habitat variable between 0.0 (unsuitable habitat) and 1.0 (suitable/optimum habitat) (Kellner et al., 1992). Integration of geospatial techniques such as geographic information systems (GIS) and remote sensing has been useful in producing habitat maps made from HSI values to identify habitat patches for different species. Prediction of suitable habitat is important for conservation measures as well as management of habitat. However, few studies on vulture species, including the Cape Vulture, have used such models.

2.6 THEORY OF HABITAT SELECTION

Theory of Habitat Selection states that animals use habitats to meet their needs, such as breeding, roosting, and foraging. Habitat is defined as a natural environment inhabited by a particular species of an animal or plant (Abercrombie et al., 1966). This includes the surroundings that support the species. Species select a particular habitat for breeding because of its ability to provide necessary conditions and resources they need for reproduction and survival. The application of this theory therefore helps us understand the how the physical/environmental characteristics of breeding sites of Cape Vulture colonies influence breeding success.

2.7 TECHNIQUES USED IN ESTIMATING NEST SURVIVAL

For a raptor to reproduce, it must successfully pass through several stages (Steenhof & Newton, 2007). The nest must survive throughout the season, for example. Breeding is regarded as successful when a nest survives until it produces a chick. Dinsmore and Dinsmore (2007), preferred to use the term "nest survival," because success can be attained in one nesting attempt in a season that includes all stages. Population assessment requires that all breeding pairs and their nests are identified at the first stage, the nest building stage. However, Borello (2007) argued that it is not always possible to find all pairs and nests before the second stage, because species like vultures mature and pair at different times. This may reduce the sample size or misrepresent the population of breeding pairs in a breeding site. Steenhof & Newton (2007) therefore recommend that in situations where is not possible to find all pairs or nests before the egg laying stage, researcher should use nest survival models.

Furthermore, the Program Mark, and SAS software including generalized linear models are used to model results and provide better estimates of nest survival (Dinsmore et al., 2002). Findings from studies on environmental factors that affect nest survival are useful in informing policies and formulating effective conservation measures if the population is not performing well. The models used to estimate breeding success or nest survival have been mainly used in studies on waterfowl, shorebirds, and passerines that nest on or near the ground (Steenhof & Newton, 2007), but also on vulture species such as Bearded Vultures (Moreno-Opo et al., 2013). However, few studies that have examined breeding success or nest survival of Cape Vultures have employed these models.

2.8 USE OF GEOSPATIAL TECHNIQUES IN BREEDING ECOLOGY

Geospatial techniques such as GIS and remote sensing have recently received attention of wildlife managers because of their effectiveness in analyzing environmental factors. Threats towards wildlife and biodiversity at large scales, like habitat loss, pollution, invasive species introduction and climate change, are possible to assess using these two geospatial tools. Recent studies have used geospatial techniques, especially GIS and remote sensing, in modeling suitable habitat for reproduction and survival of bird species. Despite the importance of these tools, few, if any, studies have used geospatial techniques to understand the breeding ecology of Cape Vultures. Retief et al. (2013), used GIS and remote sensing tools to make recommendations for constructing wind turbine and power lines around the breeding and roosting sites of Cape Vultures. Pfeiffer et al. (2015; 2017a) used GIS tools to identify anthropogenic threats to Cape Vultures in communal farmlands and to understand their foraging space use.

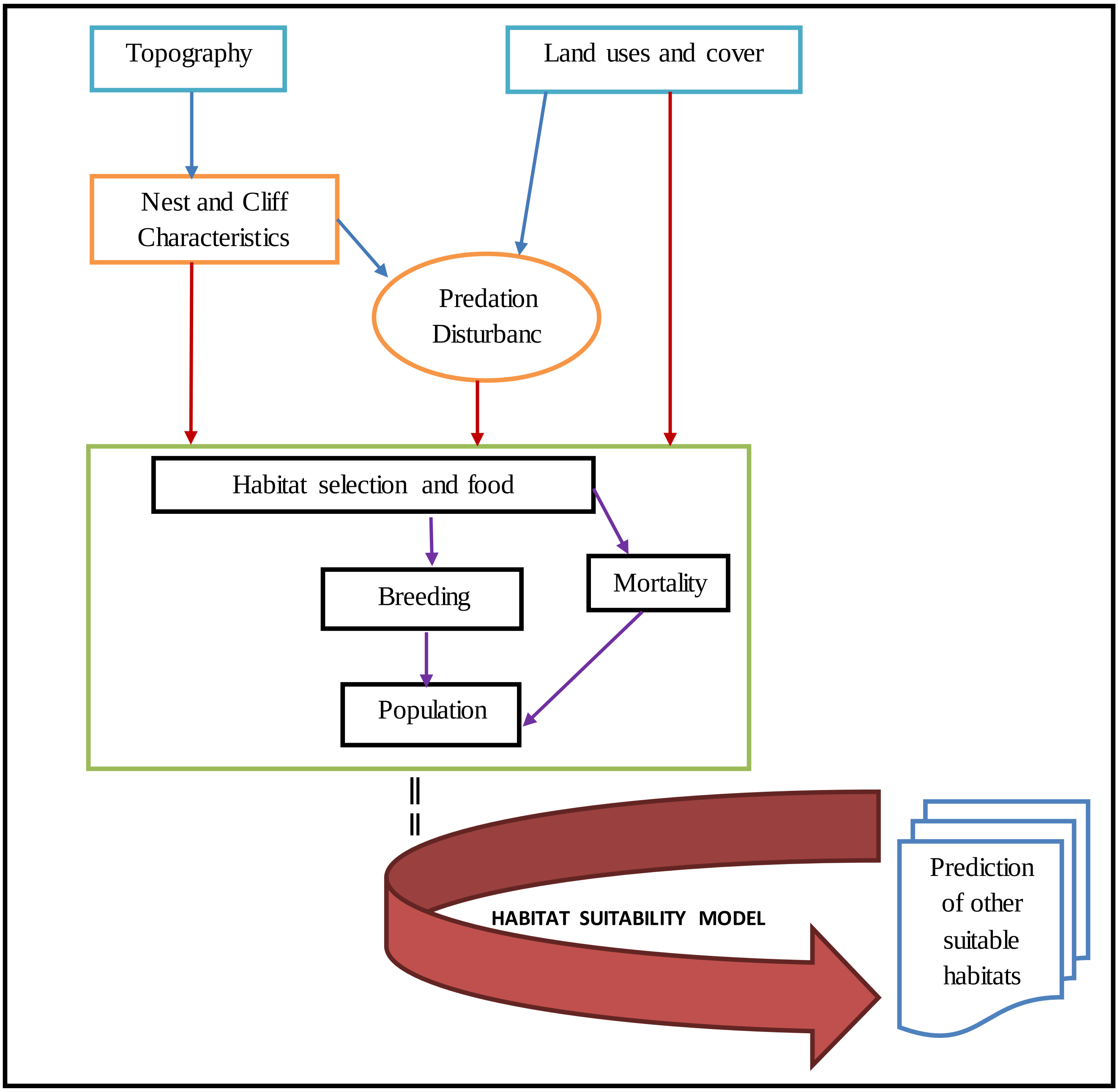
2.9 LITERATURE REVIEW SUMMARY

Populations of Cape Vultures are declining due to anthropogenic activities that pose major threats, such as loss of habitat and shortage of food. There is better information on the breeding of Cape Vultures from studies in different provinces in South Africa (Wolter, et al., 2016; Pfeiffer et al., 2017a). Continuous monitoring and conservation of breeding populations of Cape Vultures has recently given attention as a way of managing their populations. However, declines persist, such as the drop in number of breeding colonies in Botswana from five to three large colonies and one small colony. Similarly, the decline of colonies in other countries such as South Africa, Lesotho and Namibia has occurred. Despite, this situation, only South Africa has monitoring and conservation programmes that are aimed at conservation of Cape Vulture populations, whereas the latter countries lack baseline data, resulting in limited information.

Moreover, studies on breeding ecology have emphasized the importance of understanding the reproduction performance and habitat preference of vultures to develop effective conservation strategies. Literature has shown that suitable habitat forms the basis for successful breeding that will result in population recovery and restoration. It is important to assess the natural or physical characteristics of habitat occupied by Cape Vultures and determine their influence on breeding success. This study is quite different, as it adopts a comparative temporal and spatial approach, with consistent methodologies that are rarely seen in the assessment of raptors in general or Cape Vultures in particular.

2.10 CONCEPTUAL FRAMEWORK

Habitat selection and optimal foraging theories help explain the causal relationships of environmental factors and variables. Several variable linkages show the relationship between selection of preferred suitable habitat and existing environmental factors as depicted in figure 7.



Modified from; Gwalik, (2002) page 342

Figure 6: Conceptual framework

CHAPTER 3: RESEARCH METHODOLOGY

3.0 INTRODUCTION

GEOGRAPHICAL DESCRIPTION OF THE BREEDING SITES

Three active breeding sites were found in the Tswapong Hill complex, specifically: Kukubye, Manong Yeng, and Bonwalenong (Table 7 and Figure 2). However, only two (Manong Yeng and Bonwalenong) were studied for the 2017 breeding season because they had > 60 breeding pairs as compared with 6 at Kukubye.

Table 7: Geographical Description of breeding sites in the Tswapong Hill complex

LOCATION	SITE NAME	COORDINATES*
Goo-Tau	Manong Yeng	22^{o} 40’00”S 27^{o} 41’00”E
Goo-Moremi	Bonwalenong (North & South facing cliffs)	22^{o} 37’00”S 27^{o} 26’00”E

*Datum WGS84

Bonwalenong has two cliff faces, one facing north (sunny side) and the later facing south (shady side). By contrast, the Manong Yeng breeding site has one long cliff face facing south-east. This study focused on the breeding population, i.e., the number of pairs that attempted to breed in the 2017 breeding season. Non-breeding pairs were not included in the census.

3.1 RESEARCH METHODS

This study adopted a mixed methods approach whereby both qualitative and quantitative research methods were used. The combination of more than one research method provided a better understanding of the research problem. Specific research methods included: field observations, document review, and the use of geospatial techniques.

3.1.1 RESEARCH DESIGN

This study used a longitudinal survey with repeated observations of the same variables for a specified period of time. In this case, breeding populations of Cape Vultures and their breeding sites were observed throughout the breeding period (Newton, 1979; Steenhof & Newton; 2007). Observations were conducted at approximately six week time intervals and followed the methodology as undertaken by Borello (1997) starting in June and lasting until November 2017. Document review and analysis were employed to gain further insight on what other studies have covered the nesting and breeding performance of Cape Vultures in breeding colonies of the Tswapong Hills.

3.1.2 SAMPLING

To estimate the breeding success of raptors, a census of the breeding population at Bonwalenong and Manong Yeng sites in Tswapong Hills was undertaken. Cape Vultures have been found to start breeding at varying times (Mundy et al., 1992; Borello & Borello; 2002). Therefore, censuses were conducted during the laying and incubation period to avoid missing pairs that may have started laying late (Wolter, et al., 2006; Borello, 2007). All nests identified during the laying or incubation period at the cliff faces of the two sites comprised the sampled population. These included:

- nests with fresh material and still intact,
- active nests (with a bird/pair or an egg/nestling),
- old nests (with scattered old sticks), possibly from the previous season and never active throughout the breeding season were not included in the sample.

The methods used for each of the four research objectives are presented in turn below.

3.2 OBJECTIVE 1: ESTIMATING THE BREEDING SUCCESS OF CAPE VULTURES

The Cape Vulture conservation and monitoring protocols (Wolter, et al., 2006) and monitoring guidelines (Borello, 2007) were used to estimate breeding populations and breeding success of vultures found at the Bonwalenong and Manong Yeng breeding sites (see Appendix for full details).

3.2.1 DATA COLLECTION METHODS AND MATERIALS

3.2.1.1 FIELD OBSERVATION

Field observation refers to the careful and objective surveillance of particular aspects of a population or events (Neuman, 2007). Observations gather primary data by directly viewing or listening. Observation is advantageous because large quantities of data on the nesting and breeding are gathered (Neuman, 2007). An unstructured observation where the researcher is a non-participant was adopted in this study. This method allowed the researcher to collect information from an accessible point that did not disturb the birds (Baker, 2006; Neuman, 2007). However, observations from a safe distance may be inadequate to confirm the presence of an incubating bird or of young, especially if the full contents of a nest are not visible.

To estimate the breeding success of Cape Vultures at the large three colonies, a total of five visits (June to November excluding July) were made for 2017 breeding season. Observations were conducted in the early morning hours (0630-0900) when vultures were at their nests and their foraging movements reduced. All nesting and breeding activities (active and abandoned/non-active nests, fresh chicks' activity), and the state of the colony was captured. This included counting nests and recording nest occupancy on every visit. New or missed nests between June and August 2017 were also recorded.

3.2.1.1.1 MATERIALS

Binoculars (10 x 50mm) and spotting scope (15-45x60) were used to observe nesting activity and count nests in the colony. All observed nest sites were recorded in data entry sheets or log books (Driscoll, 2011) and marked using a hand held Global Position System. Guides helped record data. These data were then coded into themes. During observations the researcher took photographs of some breeding pairs and nesting sites to permit later photographic "truthing" of the data. Each vulture's nest was given a separate number (ID) (Figure 7).

Figure 7: Nest numbering at Bonwalenong (North facing cliff) in June 2017
By: Author

Sources of data on the environmental conditions of breeding sites of Cape Vultures included GPS (Global Positioning System), photographs, and satellite images from Google Earth and Flash Earth imagery. Data captured included: date of observation and nest identification; location (UTM coordinates); elevation/altitude; aspect; concealed/exposed nests; bioclimatic conditions (weather); and nest status (active, inactive, or abandoned). Active nests were confirmed by sightings of an egg, fledgling, or incubating behavior of adults, whereas inactive nests are those for which the latter was not observed. A spotting scope was used to search for any evidence of what could have happened at failed nesting attempt, e.g. dead chicks, failed egg, etc. (Wolter et al., 2006; Borello, 2007, Pfeiffer, et al., 2017a).

3.2.1.2 DOCUMENT REVIEW

A desktop literature review was conducted on the breeding ecology of Cape Vultures. This enabled the researcher to obtain more information from existing literature on breeding population trends, breeding success rates in past years, and threats to breeding populations of Cape Vultures. The literature included published research, reports and annuals from the Department of Wildlife and National Parks, Birdlife Botswana, Vulpro, and Raptors Botswana. These secondary data provided useful background for primary data gathered from observations (Vartanian, 2011).

3.2.2 DATA ANALYSIS AND PRESENTATION

Successful nests are nests that rear a chick to fledgling stage. Therefore breeding success was defined as the ratio between number of pairs attempting to breed (probable breeding pairs) and number of young reaching fledgling stage (Borello, 2007). Fledglings are chicks raised to a stage where they can voluntarily leave a nest (~90 days) after hatching (Robertson, 1986; Steenhof & Newton, 2007). In this study, success was calculated for mid-season productivity (60-80 days old nestling) (Borello & Borello, 2002), which occurred in mid-October 2017 and at the end of the season (end of November or 90+ days). This was because Cape Vultures pair and start laying eggs at different dates (Borello, 1997). The percentage of successful eggs laid and total number of successful nests was also calculated. Estimating breeding success rates was calculated using the following equation:

$$\text{Breeding success rate} = \frac{No.\ successful\ nests}{No. of\ probable\ breeding\ pairs} \times 100\%$$

Breeding failure occurred when nests with an identified pair or bird, eggs, chicks, or incubation behavior failed to produce and rear a chick to fledging. Data from the literature were qualitatively analyzed to provide comparisons. Descriptive and inferential statistics were used to analyze and summarize the breeding populations, survival rates of nests, and make comparisons with previous breeding success rates (1992-1999). Chi-square and one-way ANOVA (Analysis of Variance) with Tukey's Honestly Significant Difference (HSD) post hoc test (95% CI) test were run in R 3.5.1 (R Core Team 2018) to investigate whether there was significant variation between the two sites and among the three cliff faces in the study area, respectively.

3.3 OBJECTIVE 2: CLIFF AND NEST SITE CHARACTERISTICS AND BREEDING SUCCESS OF CAPE VULTURES

Factors that affect the breeding success of raptors include habitat characteristics (nests and cliffs). Predator disturbance was not studied in this project because it requires a lot of time or video monitoring. As the Cape Vultures nest on cliff ledges, nest site and cliff characteristics were investigated. Five visits corresponded with the following stages (Figure 9):

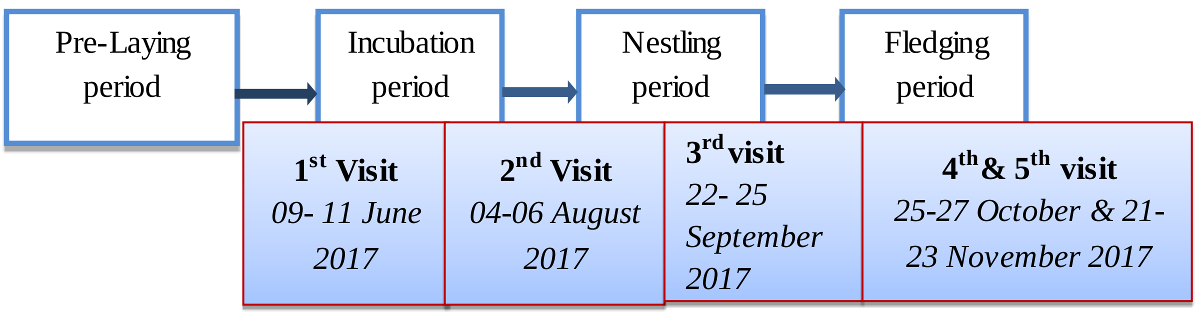


Figure 8: Breeding cycle of Cape Vultures and field observations/visitations

3.3.1 DATA COLLECTION METHODS AND MATERIALS

3.3.1.1 GEOSPATIAL TECHNQUES

Satellite imagery for 2017 from Landsat 8 OLI/TIRS was processed and used to generate topographic layers of the study areas. Data handling and processing were performed using ArcGIS10.5 and ERDAS Imagine 2016 software. GIS and remote sensing techniques are relevant because they enable creation of different map layers for easy visualization of scenarios and presentation of ideas (Chen, 2014).

3.3.1.2 FIELD OBSERVATIONS

Information about the influence nest site and cliff characteristics on the breeding success of Cape Vultures was gathered through direct observation and photographs and recorded on observation forms. Binoculars and spotting scope were used to aid observations. Photographs of cliff faces with nests were taken at each visit to further verify the nest and cliff characteristics such as nest type, dispersal and cliff formations.

3.3.2 DATA PROCESSING, ANALYSIS AND PRESENTATION

Cliff Characteristics

The characteristics of each cliff at Bonwalenong and Manong Yeng were determined and compared to evaluate their influence on breeding success. A Landsat 8 OLI/TIRS satellite image from 2017 was downloaded from the United State Geological Survey, geo-referenced, and processed to produce Digital Elevation Models (DEMs) in ArcGIS. The images and vector files were corrected to fit the real world coordinate system (Chen, 2014). Environmental layers on cliff characteristics such as aspect, slope, hill shade, and elevation were generated from Digital Elevation Models (DEMs). Information from a GPS (coordinates, elevation and orientation) helped validate the DEMs. The 3D analysis tool in ArcGIS was used to produce and display the contour map.

Nest Characteristics

The nesting cliffs were divided into sections and photographed. Photographs were then mosaicked using ArcGIS 10.5 to produce a picture of the entire cliff. Information on nest type (i.e., concealed /exposed) was derived from observations and photos. Concealed nests are those that are partially protected by side walls, roofs, or fully covered (small caves), whereas exposed nests are those that lie on exposed or uncovered on ledges (Freund et al., 2017). Photos helped show the distribution of nests on cliffs and whether they are clustered or dispersed as well as the number nearest neighbors (Pfeiffer et al., 2017a). Nests were categorized as follows: nest with >1 direct neighbor (clustered) and nests with less than two direct neighbors (dispersed). Cliff faces were further divided into sections (referred to as location in observation sheet) using geologic formations. The lack of relevant equipment for measuring the height of each nest was one of the limitations of this study. However, ArcGIS was used to measure the height (using of nests from ground level using the plotted the mosaic to give estimates of height of each nest (Figure 10).

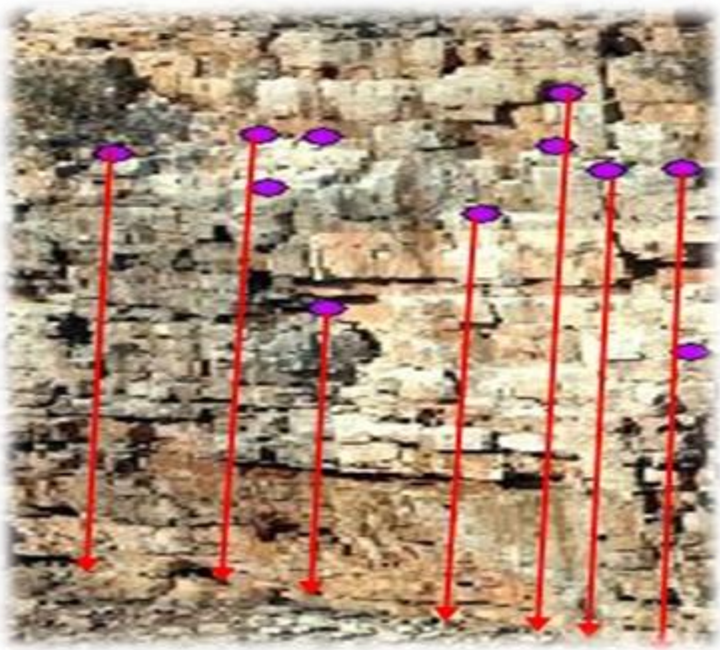


Figure 9: Nests height on a cliff
By: Author

Table 8: Descriptions of predictor variables investigated as covariates for breeding success

VARIABLE	DESCRIPTION
NEST SITE CHARACTERISTICS	
Nest type	Concealed or exposed
Dispersal	Dispersed or clustered
Height (Level)	Height of nest on a cliff (m)
CLIFF CHARATERISTICS	
Aspect	Cliff's orientation (North, South, South-east)
Hill shade	Illumination of surface from the sun's direction angle (^{0})
Distance to the nearest major road	Distance from villages (~5 Km).
Distance to the nearest village	Distance from villages (~5 Km).

Generalized Linear Models (GLM) were used to investigate the influence of predictor variables in breeding success of Cape Vultures assuming a binominal distribution (with a logit function) where successful=1 and unsuccessful=0 (Freund, 2016; Pfeifer et al., 2017a). All data from breeding sites for breeding success were included in analyses, as shown in Table 8. Breeding success was the dependent variable and nest and cliff characteristics were independent variables (predictors) whereas nest number (ID) was included as a random term (Pfeiffer et al., 2017a; Şen et al., 2017). A stepwise regression analysis was conducted to determine variables (From Table 8) that significantly correlated with breeding success through elimination of variables that had the least influence and adding those which reduced Akaike Information Criterion (AICc) (Olea & Mateo-Tomás, 2009; Pfeiffer et al., 2017). The selected variables were then used to generate possible models that were further selected based on their weights ($\Delta AIC_c \leq 2$) at 95% confidence level using packages MuMin in R (R Core Team 2018). Selection of models was conducted by starting with the highest weight and adding the model with the next highest weight until the cumulative sum of weights exceeded 0.95 (Olea & Mateo-Tomás, 2009). Using the predictors above, several possible models were generated (Table 9).

Table 9: Structure of models used to analyze the influence of predictors against the response variable, breeding success

Models
Aspect + Height + Nest Type +Distance to nearest village + Dispersal
Aspect + Height + Nest Type +Distance to nearest village
Aspect + Height + Nest Type
Aspect + Height
Height + Nest Type +Distance to nearest village + Dispersal
Height + Nest Type +Distance to nearest village
Height + Nest Type+ Dispersal
Height + Nest Type
Nest Type + Distance to nearest village + Dispersal
Nest Type + Distance to nearest village
Distance to nearest village + Dispersal

Model-averaged estimation was further carried out on the response models from GLM lsmeans to obtain β. All statistical analyses were employed in R 3.5.1 (R Core Team 2018).

3.4 OBJECTIVE 3: GIS-BASED HABITAT SUITABILITY MODEL

Selection of suitable habitat by birds is important to breeding success and survival. For cliff-nesting birds such as Cape Vultures, nest site and cliff characteristics are important. Therefore, it is important to identify other potential areas for breeding within the Tswapong Hill complex that can be used for conservation strategies. Hence this study investigated the cliff characteristics that support breeding of Cape Vultures to generate suitability model for habitat preferred by Cape Vultures in the Tswapong Hill complex.

3.4.1 DATA ACQUISITION

The study boundary for modeling was informed by locating previous and currently existing breeding sites; hence, all the hills that fell between Lotsane River and the gravel road that connects Radisele village with Tswapong villages (Figure 11). Therefore only cliff characteristics that influenced inbreeding success of Cape Vultures were used as well as others that have been cited in the literature such as hill-shade, slope, and distance to the nearest major road. ArcGIS 10.5 and ERDAS Imagine 2016 were used to map and analyze the environmental variables such as cliff characteristics (Table 8). These are factors disturbance associated with site abandonment and emigration of birds, especially, vultures (Ogada et al., 2016; Wolter et al., 2016; Pfeiffer et al., 2017a).

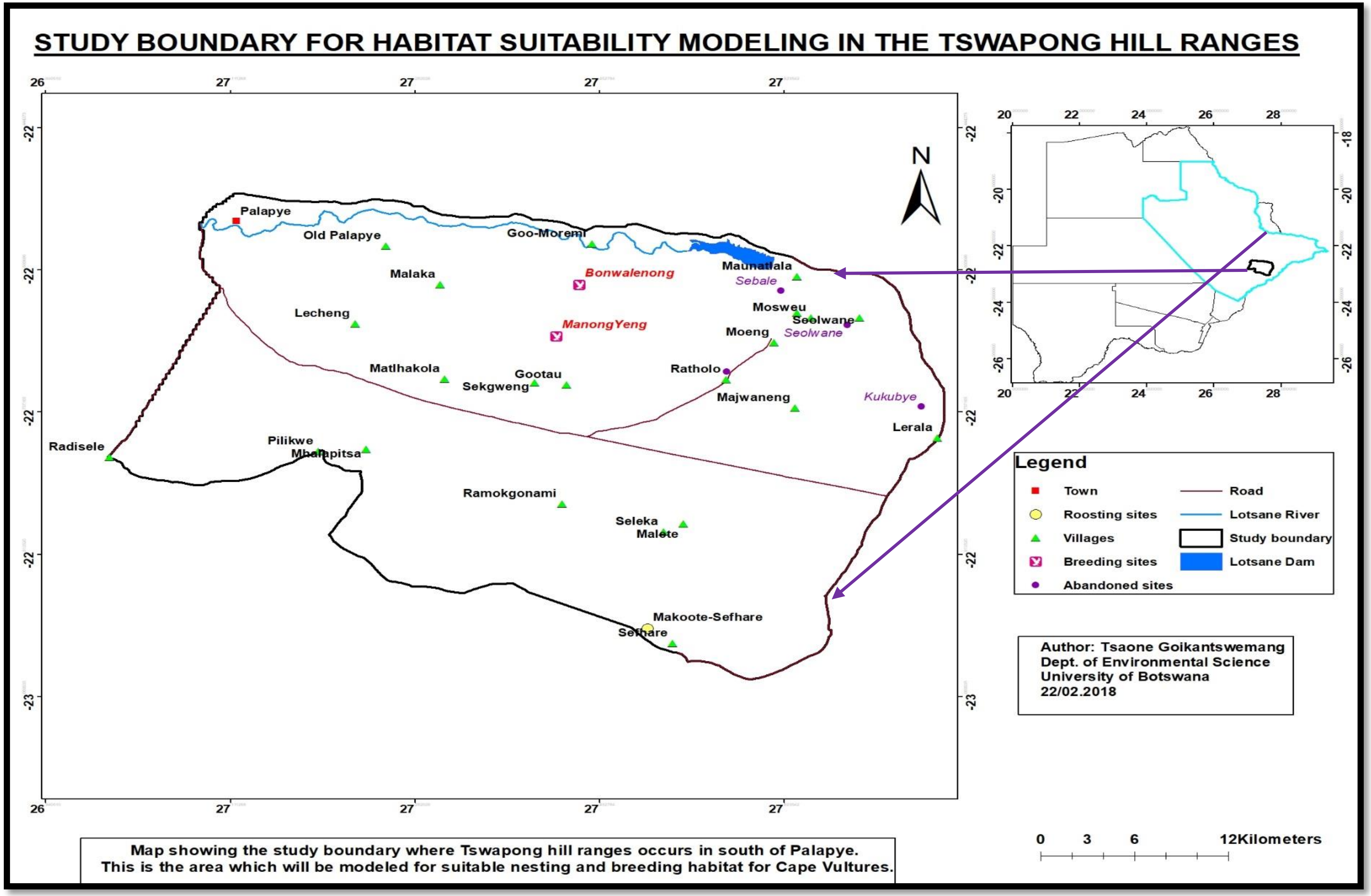


Figure 10: Study boundary

3.4.2 DATA ANALYSIS AND PRESENTATION

GIS Multi-Criterion Decision Analysis (MCDA) was adopted to build a model to predict suitable habitat for nesting areas for Cape Vultures. Data from the literature and results from the field study conducted on the cliff and nest site characteristics that influence breeding success were used as inputs. A decision evaluation using multi-criterion was employed to create or re-class layers that met the standards set for suitability. The model was built in ArcGIS incorporating the layers for: aspect, slope, elevation, hill-shade, villages and major roads (Figure 12).

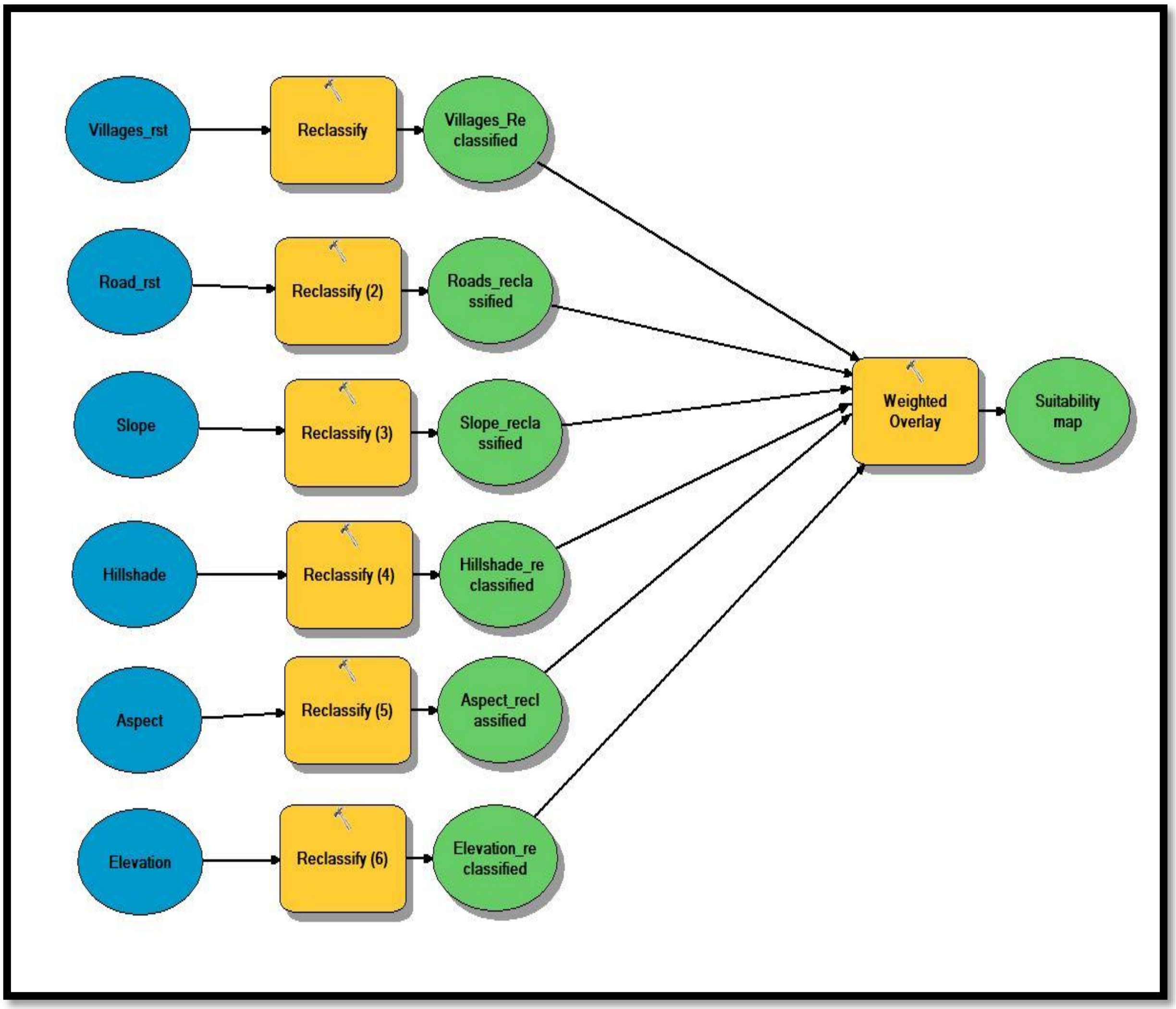


Figure 11: Model for habitat suitability of Cape Vultures

The reclassified layers were overlaid to produce a suitability map made of layers for Hill/Cliff characteristics (slope, aspect, elevation, and hill-shade) around the hills in Tswapong south locality. This model was created using the weighted sum overlay spatial analysis tool in ArcGIS 10.5 software (Table 10 and Figure 12). This type of analysis involves weighting the datasets by assigning them percentages according to their relative importance (Malczewski, 1999). For example, a dataset with higher importance in the model was assigned a higher percentage influence (weight) than the others. Qualitative and quantitative evaluations of the suitability map were made.

3.5 POST-FLEDGING OBSERVATIONS

In early December 2017, an observation was made at the bottom of the cliffs at Bonwalenong breeding site, whereas at Manong Yeng this was not done because of bush encroachment which made it inaccessible. This was done to check if there is any mortality of the fledglings. Birds found were physically examined by the researcher and a team from Department of Wildlife and National Parks and the Department of Veterinary Services. An informal interview was done with the tour guides on their observations on activities taking place at the gorge, as well as any conservation efforts and observations concerning the survival of both adults and chicks, both during and outside the breeding season.

3.6 STUDY VARIABLES

Table 10: Study variables

Variable	Dimensions	Description	Variable Type
Breeding success	Chick or nestling produced	Chick produced reaches a fledgling stage. (~ 140 days after hatching).	Dependent
Cliff site & context characteristics	Orientation /Aspect	Orientation of the cliff (N, NE, E SE, S, SW, W, NW)	Independent
	Height	Height of cliff at the level of the nest (m)	
	Elevation	Elevation above sea level, calculated as the mean value between maximum and minimum altitude of the cliff (m)	
	Slope	Slope of the nesting cliff at the point of the nests (^{o})	
	Hill-shade	Illumination of a surface given a direction and angle of the sun. Ranging from 0-255 with 0 representing complete darkness (^{o})	
	Dispersion	How nests are dispersed on a face (scattered/clustered)	
	Type	Concealed or exposed	
	Nearest neighbor	Number of direct neighbors (nests)	
Disturbance	Distance from roads	Distance from nearest busy roads (~5 Km).	Independent
	Distance from settlements	Distance from villages and settlements (~5 Km).	
Habitat preference	Presence of breeding pairs	Habitat with suitable cliff characteristics that support preference and breeding success.	Dependent

3.6.1 STUDY LIMITATIONS

Cape Vulture nests are typically located in remote and inaccessible areas, with the study limited further by several factors including:

- Lack of resources precluded obtaining exact measurements for height for each nest site and to determine if any disturbance, from humans or predators, occurred at the each breeding site. These limitations reduced the variables to investigate the influence of cliff and nest characteristics on breeding success.
- Insufficient data from previous studies hindered some analyses especially data for the Bonwalenong breeding site. Most of the data for almost all the years studied since 1984 at the Bonwalenong site were incomplete hence only the estimated pairs attempting to breed was used for comparison.

3.7 RELIABILITY AND VALIDITY

3.7.1 RELIABILITY

Reliability of this research refers to the extent to which observations will yield the same results when repeated on the same sample. This was achieved through pilot testing of the observation form. In addition, two observers were used at the same time and results compared.

3.7.2 VALIDITY

Validity of this research concerns how well the instrument measures what it is intended to measure. This applies to research design and methods of the study. This research adopted mixed research methodology in which different qualitative and quantitative methods were used to cover all areas the research intends to investigate. Moreover, the same methods as in the previous studies were used.

3.8 RESEARCH ETHICS

Research ethics were considered when conducting this research. Vultures are shy birds, hence observations were made at six weeks interval from a 100-200 m distance with a maximum of three observers to minimize disturbance. There was no direct contact or handling of birds or their nests. A research permit was obtained from the Office of the Research and Development (ORD), University of Botswana and the Department of Wildlife and National Parks. The researcher abided by University of Botswana code of research ethics as well as the research guidelines from the concerned ministry and the monitoring protocols.

3.8.1 RESEARCH MATRIX

Table 11: Research Matrix

OBJECTIVE	RESEARCH QUESTIONS	VARIABLE	SOURCES OF DATA	DATA PROCESSING AND ANALYSIS	EXPECTED OUTCOME
1. To estimate the breeding success of Cape Vultures in Bonwalenong and Manong Yeng breeding sites at Tswapong Hills.	• What is the breeding success of Cape Vultures at the two large colonies at Tswapong Hills? • How do breeding successes estimates of Cape Vultures differ from a previous study (1992-1999)? • Is there any significant difference in breeding success between the two sites?	Breeding success	-Field Observation -Document review	-Descriptive statistics -Distribution tables, Bar charts,	The current breeding success estimates significantly differ from a previous (1992-1999) study.
2. To investigate the influence of nest site and cliff characteristics on the breeding success of Cape Vultures at the two large colonies in the Tswapong Hills.	• What nest and cliff characteristics influence breeding success of Cape Vultures at the two sites in the Tswapong Hills? • To what extent do these nest and cliff characteristics affect the breeding performance of Cape Vultures?	-Nest site characteristics -Cliff characteristics	-Photographs -Satellite image (OLI/TIRS) from USGS 2017) -Flash Earth and Google earth -DEMs	- 3D Analysis -Generalized Linear Mixed Model	Environmental factors such as nest site and cliff characteristics influence breeding success.
3. To develop a GIS-Based HSIM of preferred Cape Vulture nesting habitat in the Tswapong Hill complex.	• Are there other potential sites within the Tswapong Hill complex with suitable nesting habitat for Cape Vultures?	-Habitat preference (cliff characteristics)	-Satellite image (OLI/TIRS) from USGS 2017) -Flash Earth and Google earth -DEM	-Multi-decision criteria (Re-class) -Overlay Analysis -Spatial analysis	There are other potential sites with suitable nesting habitat for Cape Vultures within the Tswapong Hill complex.

CHAPTER FOUR: RESULTS

4.1 OBJECTIVE 1: *To estimate the breeding success of Cape Vultures in Bonwalenong and Manong Yeng breeding sites in the Tswapong Hills.*

NEST MONITORING

In early June (09-11/06/2017), 197 nests were identified at Manong Yeng (*n*=78) and Bonwalenong's North facing cliffs (*n*=119). An additional 70 nests were identified at Bonwalenong's South facing cliff on 04 and 05 August 2017 with an additional 2 nests at Manong Yeng and 11 new nests found at Bonwalenong North facing cliff. Altogether, 280 nests were monitored at Manong Yeng (*n*=80) and Bonwalenong (*n*=200) breeding sites (Table 13). The Bonwalenong site had more (71.4% of 280) nests compared to the Manong Yeng (28.6% of 280). Within Bonwalenong, 65% (*n*=130) of the nests monitored occurred at the North facing cliff and 35% (*n*=70) of the nests occurred on the South facing cliff.

Table 12: Summaries of new nests monitored per cliff in the Tswapong Hills (2017)

SITE/ CLIFF	**JUNE**	**AUGUST**	**TOTAL**
Manong Yeng	78	2	80
Bonwalenong-North Facing cliff	119	11	130
Bonwalenong-South facing cliff	-	70	70
			280

Of all three cliff faces, 46% (or *n*=130) of total nests were monitored at Bonwalenong's North facing cliff, 29% (or *n*=80) at Manong Yeng Cliff and 25% (*n*=70) at South facing cliff (Figure 13).

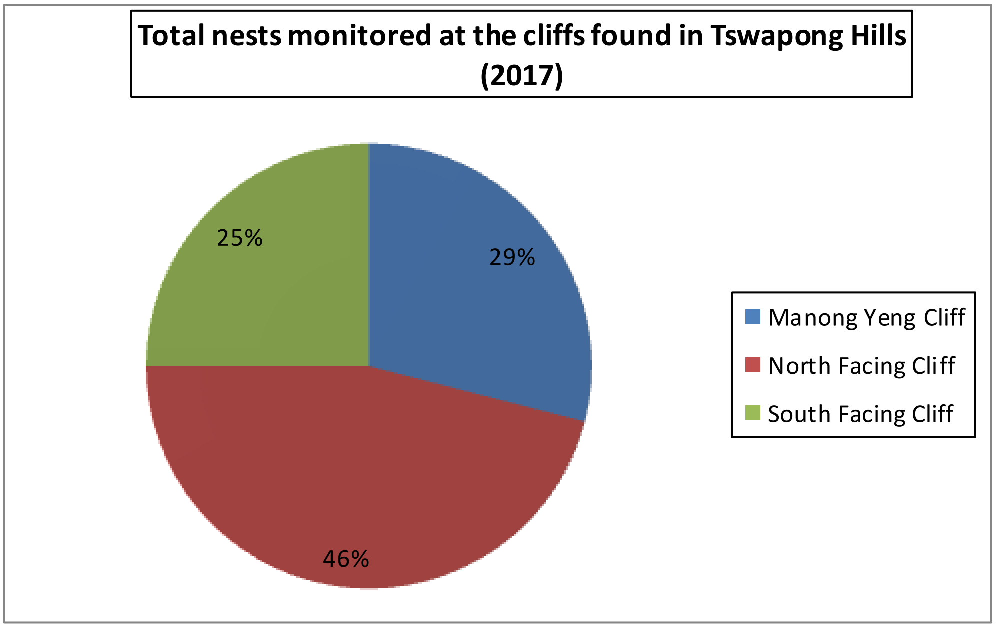


Figure 12: Percentage of nests monitored at the three cliff faces found at Tswapong Hills

BREEDING SUCCESS

4.1.1 BONWALENONG

NORTH FACING CLIFF

One hundred and nineteen (119) nests were found on the North facing cliff of Bonwalenong, of which 109 contained eggs (91.6% of total pairs observed) Table 13. By mid-season, 57 (47.9%) nests contained nestlings, but only 47 chicks reached fledgling stage, which represents 39.5% of nests (Table 13). Between August and September (between the hatching and nestling periods) 34 (37.4%) of 91 active nests became inactive, while only 10 (17.5%) of 57 active nests became inactive between September and October (after the midseason/nestling period) (Table 13).

Table 13: Number of nests (active/inactive) during monthly observations at the North facing cliff (using nests identified in June only)

	JUNE	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
ACTIVE	112	91	57	47	47
INACTIVE	7	28	62	72	72
TOTAL	119	119	119	119	119

An additional 11 new nests were identified in August, increasing the sample size to 130 nests monitored on the North facing cliff. Of those 130 nests, at least 122 (93.8%) contained eggs at some point during the monitoring period, 64 (49.2%) reached mid-season with a surviving nestling, and 54 fledged chicks (41.5% of nests) (Table 14). Out of 76 inactive/failed nests (130 nests monitored) at the end of the breeding season, 36 (43.4%) nests became inactive between August and September (mid-season period) and only 10 (13.2%) were lost thereafter (Table 14).

Table 13: Number of all nests active/inactive during monthly observations (nests identified June & August) at the North facing cliff-Bonwalenong site

	JUNE	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
ACTIVE	112	100	64	54	54
INACTIVE	17	30	66	76	76
TOTAL	119	130	130	130	130

SOUTH FACING CLIFF

Observations at the South-facing cliff at Bonwalenong began in August, when 70 nests were identified and monitored until November 2017 (Table 15). Of the 70 nests, 64 (91.4% of nests) contained eggs in August, 44 (62.9%) contained nestlings in September, 33 (47.1%) contained chicks in October and 33 (47.1%) contained fledglings in November (90+ days post hatching).

Table 14: Number of active/inactive nests during monthly observations from August (2017) at the South facing cliff at Bonwalenong site

	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
ACTIVE	64	44	33	33
INACTIVE	6	26	37	37
TOTAL	70	70	70	70

In summary, at the Bonwalenong colony, of 200 nesting pairs, at least 185 (92.5 % of pairs) laid eggs, 108 (54.0% of nests) nestlings survived until mid-season (60+ days) and 87 (43.5 % of nests) of those nestlings reached fledgling stage in November. Although the north facing cliff had more (*n*=130) pairs attempting to breed than the south facing cliff (*n*=70), the south facing cliff had a higher breeding success rate (47.1%).

4.1.2 MANONG YENG

In the Manong Yeng colony, 78 nests were identified in June 2017 and additional 2 nests in August of that year, for a total of 80 nests monitored. Of the nests identified in June, 19 (24.4%) produced a chick that survived till fledgling age, while 59 (75.6%) nests failed. Most (*n*=23; 39.0%) failures occurred between June and August, while 23.7% (*n*=14) of failures occurred between August and September (Table 16). Of the 78 nests identified in June, 63 (80.8%) contained eggs in that month, 26 (33.3% of the nests) contained nestlings in September and 19 contained fledglings in November (24.4% of nests) (Table 16).

Table 15: Number of active/inactive nests during monthly observations using nests identified on June (2017) only at Manong Yeng

	JUNE	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
ACTIVE	63	40	26	19	19
INACTIVE	15	38	52	59	59
TOTAL	78	78	78	78	78

In August, two additional nests were found. Among these 80 nests, 19 (23.8%) produced a chick that survived till fledgling and 61 (76.3%) failed (Table 17). Most (*n* = 23; 37.7%) failures occurred between June and August, followed by 26.2% (*n* = 16) failures between August and September, and 11.5% (*n* = 7) failures between September and October (Table 17). Of the 80 nests, 26 (32.5%) nestlings survived until September (mid-season) and 19 chicks reached fledgling (23.8% of nests) (Table 17).

Table 16: Number of active/inactive nests identified (using nests identified in both June & August 2017) at Manong Yeng breeding site

	JUNE	**AUGUST**	**SEPTEMBER**	**OCTOBER**	**NOVEMBER**
ACTIVE	63	42	26	19	19
INACTIVE	15	38	54	61	61
TOTAL	78	80	80	80	80

Overall, Bonwalenong south facing cliff had higher proportion percentage of nests (47.1%) which survived throughout the 2017 breeding season as compared to the other cliff faces (figure 14).

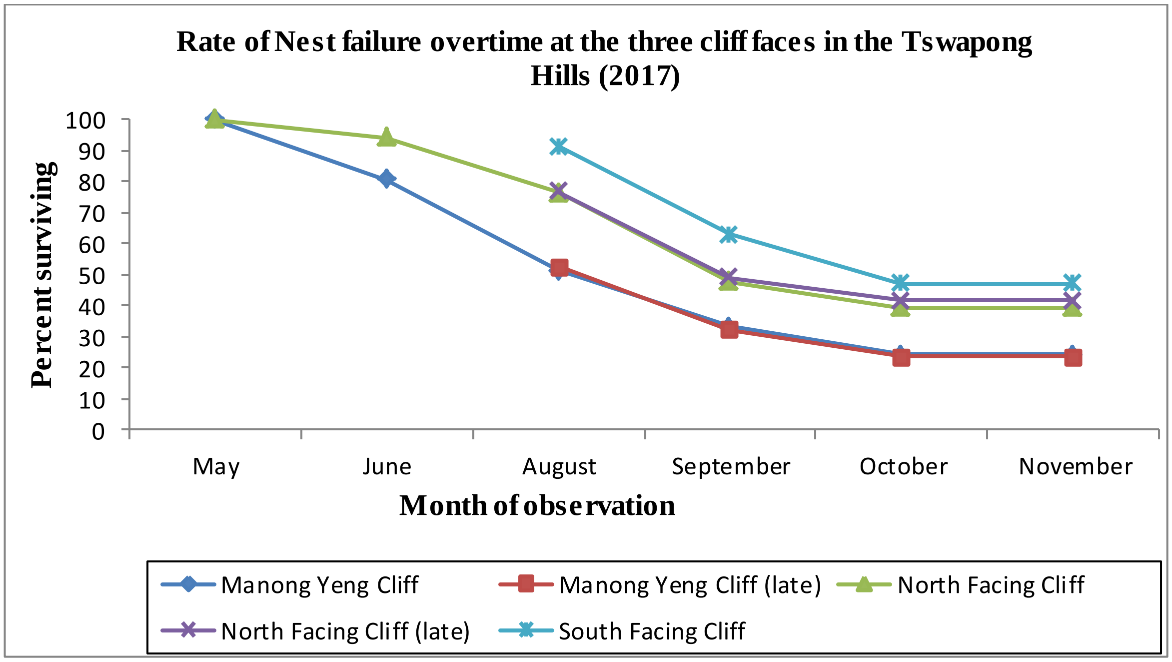


Figure 13: percent surviving overtime of nests at the three cliffs in the Tswapong Hills

Most nest failures at Manong Yeng occurred in the June to August time period, while most failures at the North and South facing cliffs of Bonwalenong occurred between August and September which both coincide with the nestling period (Figure 14). Breeding success estimates between the three cliff faces varied (Figure 15).

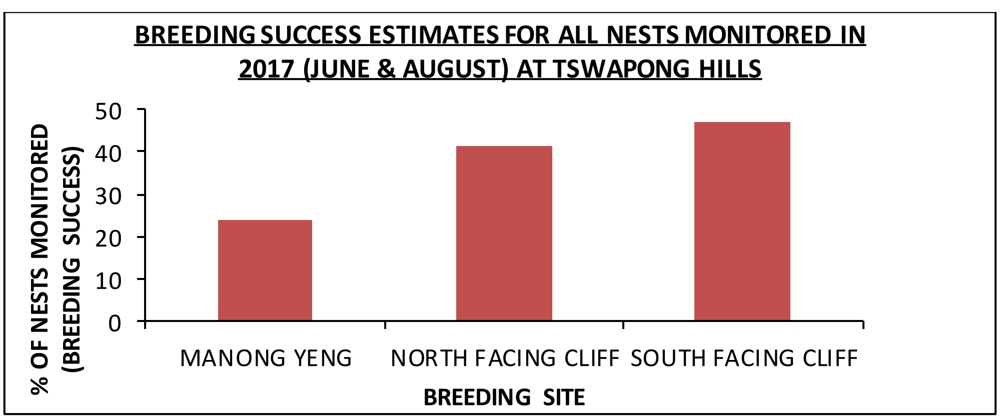


Figure 14: Breeding success estimates for each cliff face at Bonwalenong and Manong Yeng sites (2017)

A one-way ANOVA revealed that breeding success among the three cliff faces (Manong Yeng, Bonwalenong north and south) significantly varied (*F*=6.62, *df* =2, *p=0.002*). Further, post hoc tukey test showed that breeding success between Bonwalenong south cliff and Manong Yeng significantly varied (*p*=0.001), whereas breeding success between Manong Yeng and Bonwalenong north cliff (*p*=0.07) and Bonwalenong north and south (*p*=0.15) did not significantly vary (Figure 16). Overall, the difference in breeding success rates at the two sites was statistically significant (*t*=3.17, *df*= 152.29, *p*=0.002).

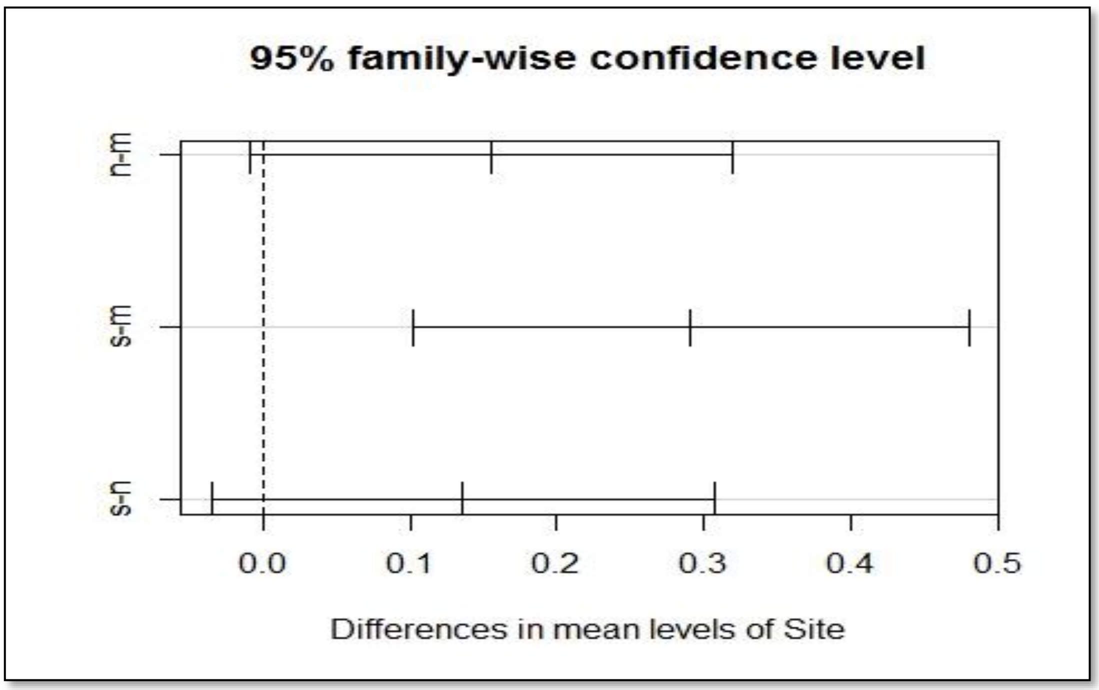


Figure 15: Breeding success variation among the three cliff faces (Bonwalenong south and north and Manong Yeng)

*[****n****=Bonwalenong north facing cliff] [****s**** Bonwalenong south facing cliff] [****m****=Manong Yeng Cliff face]*

***Significant differences are the ones which did not cross the zero value.**

4.1.3 COMPARISONS WITH PREVIOUS DATA

BONWALENONG

Bonwalenong was not monitored during the breeding season prior to 1984 (Borello & Borello, 2002). In addition, most observations were conducted only once or twice a year making it difficult to estimate breeding success. As such only data on the total number of nests built from 1984 to 1999 were collected. Between 1995 and 1999, the colony contained less than 20 nests and sometimes none (Figure 17). The most nests were built in 1991 with 248 nests (Figure 17). Breeding success was only estimated for 1988 and 1999 at 63.4% and 40% respectively.

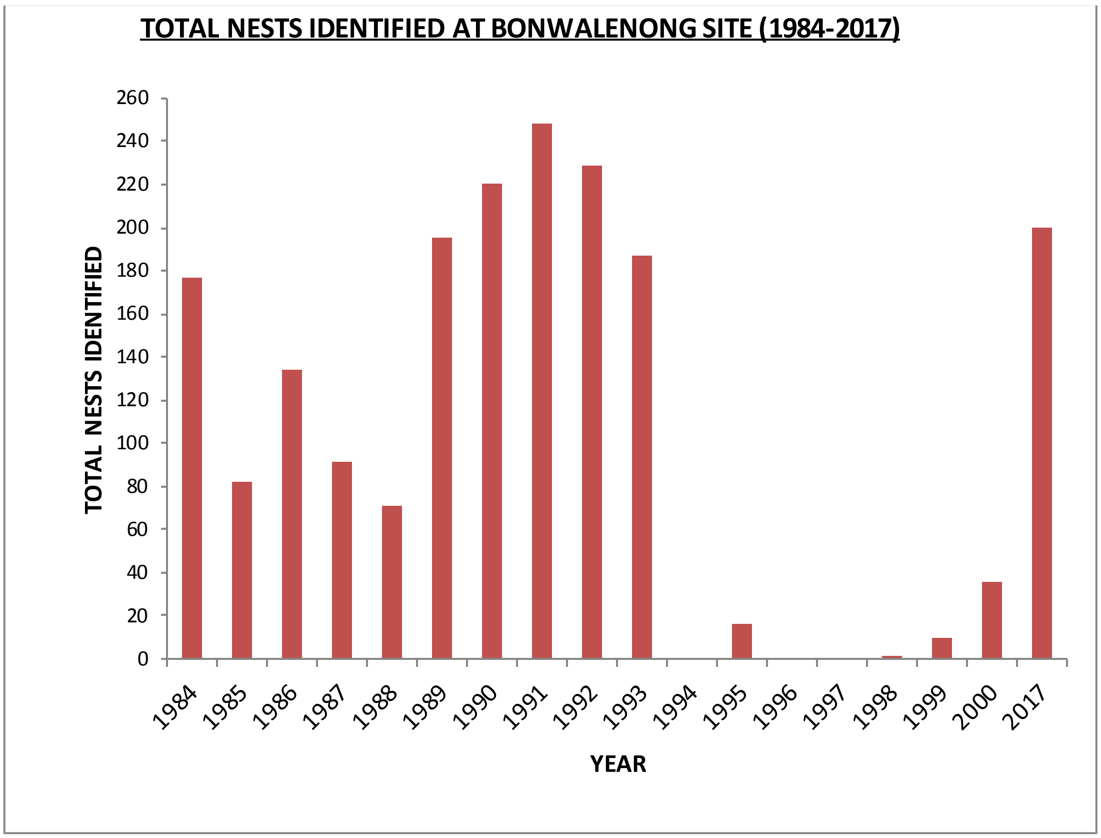


Figure 16: Comparison of total nests built between 1984-2000 & 2017 at the Bonwalenong site. The figure shows inconsistency in monitoring of the breeding population with missing data for year 1994 and also fluctuation across the years recorded.

MANONG YENG

At Manong Yeng, nest monitoring occurred from 1992-1999 and in 2017 vultures constructed fewer nests (80), with lower breeding success (23.8%) than in the 1990s (Figure 18).

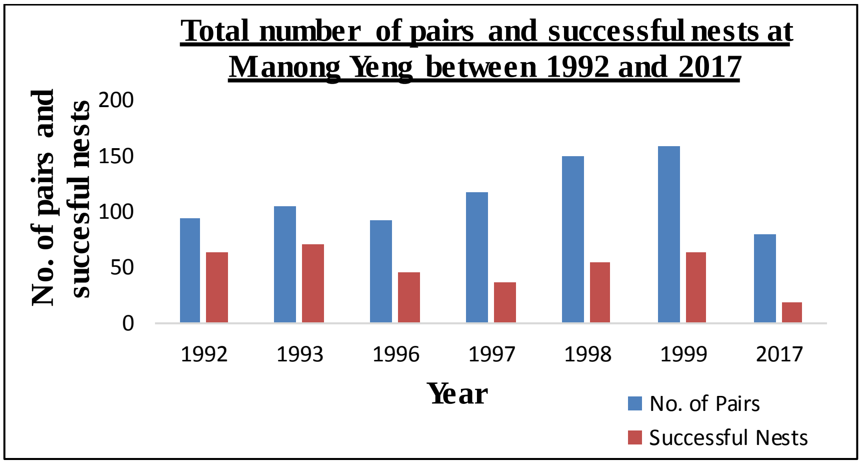


Figure 17: Total number of pairs and breeding success estimates at Manong Yeng between 1992-1999 & 2017.

When comparing number of breeding pairs at the two sites between 1992-1999 and 2017, the number of breeding pairs did not significantly differ (Manong Yeng breeding site; $x^2 = 8, p = 0.53$; Bonwalenong site; $x^2 = 9, p = 0.26$).

Table 17: SUMMARY RESULTS FOR RESEARCH QUESTIONS IN OBJECTIVE 1

RESEARCH QUESTIONS	**FINDINGS**
• What is the breeding success of Cape Vultures at the two large colonies at Tswapong Hills?	Manong Yeng : 23.8% of 80 pairs; Bonwalenong: 43.5% of *n*=200 pairs (North; 41.5% of 130 pairs and South: 47.1% of *n*=70 pairs)
• Is there any significant difference in breeding success between the two sites?	Breeding success between the two sites in 2017 (*t*=3.17, *df*= 152.29, *p*=0.002) significantly differed even among the three cliff faces also varied significantly (*F*=6.62, *df*=2, *p*=*0.002*).

• How do breeding populations and success estimates of Cape Vultures differ from a previous study (1992-1999)?	There was a lot of missing data for breeding success estimates from the previous data hence limiting the number of statistical tests. Nevertheless, results shows that there was no significant statistical difference in the breeding population compared to the previous study (x = 17, p=0.33).

4.2 OBJECTIVE 2: *To investigate the influence of nest site and cliff characteristics on breeding success of Cape Vultures at the two large colonies in the Tswapong Hills.*

Results from stepwise regression analysis showed that only height, distance to the nearest village and aspect had significant influence in breeding success and nest type had the least effect, hence they were selected to generate possible GLMs (Table 19). Hill shade, nest dispersal and distance to the nearest village were eliminated from the full model used in stepwise regression analysis. From seven GLMs constructed, only one model (bolded) resulted in $\Delta AIC_c \leq 2$ with a total weight of 1.0 (Table 20*)*. Aspect, Height, and distance to the nearest village were all represented in the model. The results further showed that all the three parameters (distance of the nearest village from the cliff, aspect of the cliff and height of nests) were very important factors in determining breeding success (*RI*=1.00). As the cliffs are orientated from north, south-east and south, the probability that breeding becomes successful increased and also breeding success increased as the height of the nest increases. However, breeding success declined as the distance between the nearest village and the cliff decreased (Table 21).

Table 18: Results from stepwise regression analysis (95% CI) showing how variables influence breeding success of Cape Vultures at the two colonies in the Tswapong Hill complex.

VARIABLE	ESTIMATE	STD.ERROR	T-VALUE	P-VALUE
Intercept	*5.87*	*1.52*	*3.85*	*0.0001*
Distance to the nearest village	-0.95	0.28	-3.45	**0.0006**
Aspect-south	0.29	0.09	3.13	**0.002**
Aspect-south-east	0.06	0.13	0.47	0.64
Height	-0.00	0.00	-2.55	**0.01**
Nest type	-0.10	0.06	-1.60	0.11

Table 19: The GLMs ($\Delta AIC_c \leq 2$) for factors influencing breeding success at Manong Yeng and Bonwalenong colonies.

Model	Df	logLik	AIC_c	ΔAIC_c	W_i
Distance to the nearest village + Aspect + Height	**5**	**-10405.1**	**20820.5**	**0.00**	**1.0**
Distance to the nearest village + Aspect	4	-10695.5	21399.1	578.64	0
Distance to the nearest village + Height	3	-10784.5	21575.1	754.56	0
Aspect + Height	4	-10874.7	21757.5	937.00	0

Df - Degree of freedom, LogLik- Models' loglikelihood value

Table 20: Relationship between breeding success and model-averaged parameters for the models (Estimates*) model parameters: Aspect (North, South, and South-east), Height of the nest and Distance to the nearest village.

Parameter	Estimate*	SE	Adjusted SE	Z	RI
Intercept	*27.11*	*0.90*	*0.91*	*29.95*	
Distance to the nearest village	-4.78	0.16	0.16	29.20	1.00
Aspect	1.33	0.06	0.06	22.96	1.00
Height	-0.00	0.00	0.00	23.37	1.00

RI =Relative importance
***Reference category for Aspect = South**

Table 21: SUMMARY RESULTS FOR RESEARCH QUESTIONS IN OBJECTIVE 2

RESEARCH QUESTIONS	**FINDINGS**
• What nest and cliff characteristics influence breeding success of Cape Vultures at the two sites in the Tswapong Hills?	• Aspect of the cliff, Height of nest, Nest type, Dispersal and Distance of the colony from the nearest village were variables that were predicted by the model to influence breeding success (Table 20 & 21).
• To what extent do these nest and cliff characteristics affect the breeding performance of Cape Vultures?	• Height of nest and Aspect were the most important variables for breeding success of Cape Vultures at the two sites. • The probability that concealed and clustered nests were success was higher than that of exposed and dispersed nests.

4.3 OBJECTIVE 3: *To develop a GIS-Based habitat suitability model of preferred Cape Vulture nesting habitat in the Tswapong Hill complex.*

The image below (Figure 19) shows the hill ranges, villages/settlements and the major road in Tswapong that falls in the study boundary.

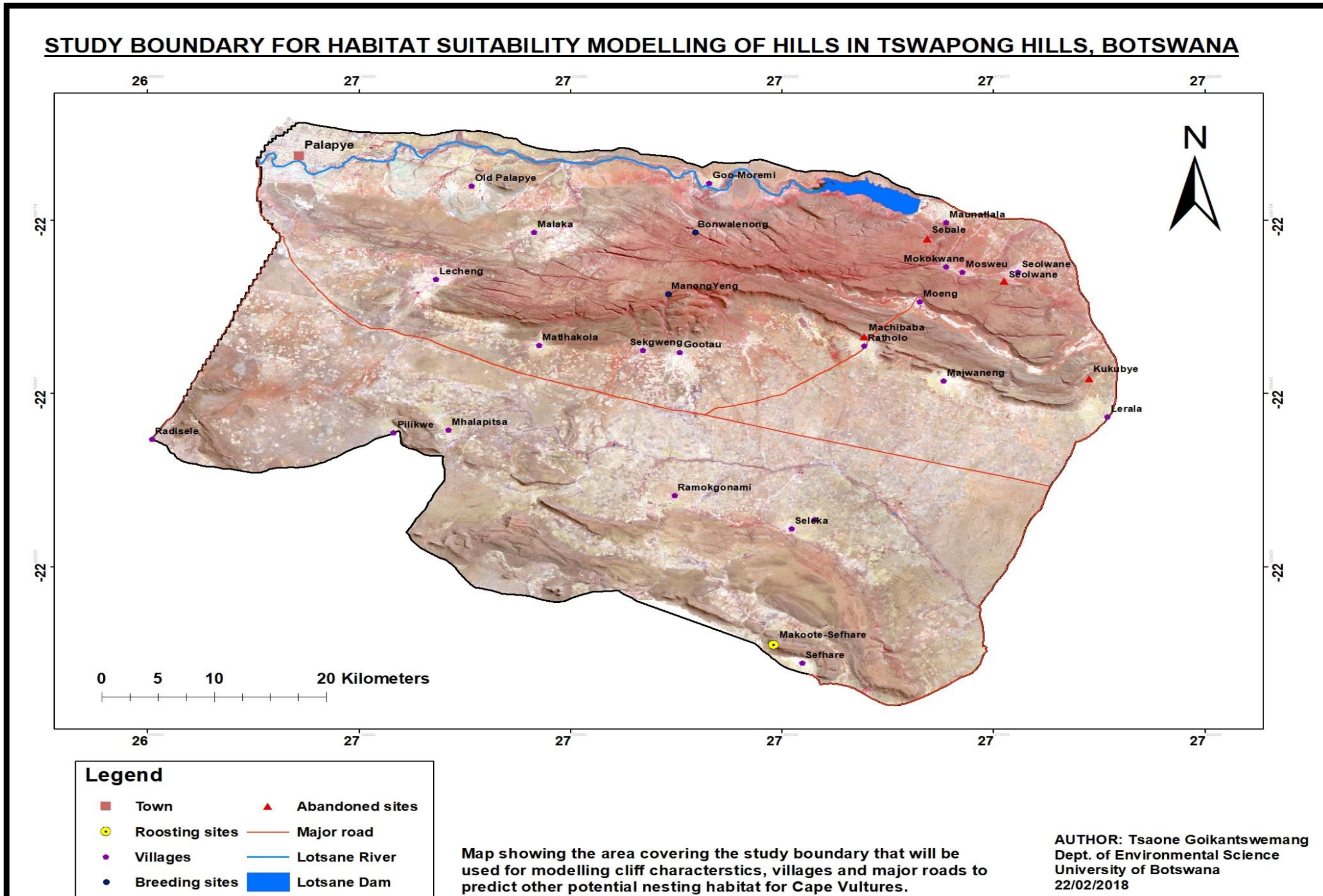


Figure 18: Landsat8 satellite image (in false color) showing the study boundary (2018)
Source: https://earthexplorer.usgs.gov

The suitability map in Figure 20, which was produced by overlaying reclassified layers in Table 24 shows that the two breeding sites lie in the most suitable areas in all layers except for the reclassified layer of distance to the nearest villages (Table 24). The maps in Figure 20 show the most suitable habitats in a dark brown color and as the color reduces to light or yellow the maps depict reduced suitability for Cape Vulture nesting and breeding success. The two current breeding sites and the roosting site as an abandoned nesting site lie on the most suitable area predicted by the model (Figure 20). Moreover the results show that from a total of 283 100 cells, only *n*=247 947 (41 543+6404) (17%) represent suitable habitat for cape Vulture nesting and breeding success (Table 22).

Table 22: Percentage of suitability per value assigned with reference figures to figure 20

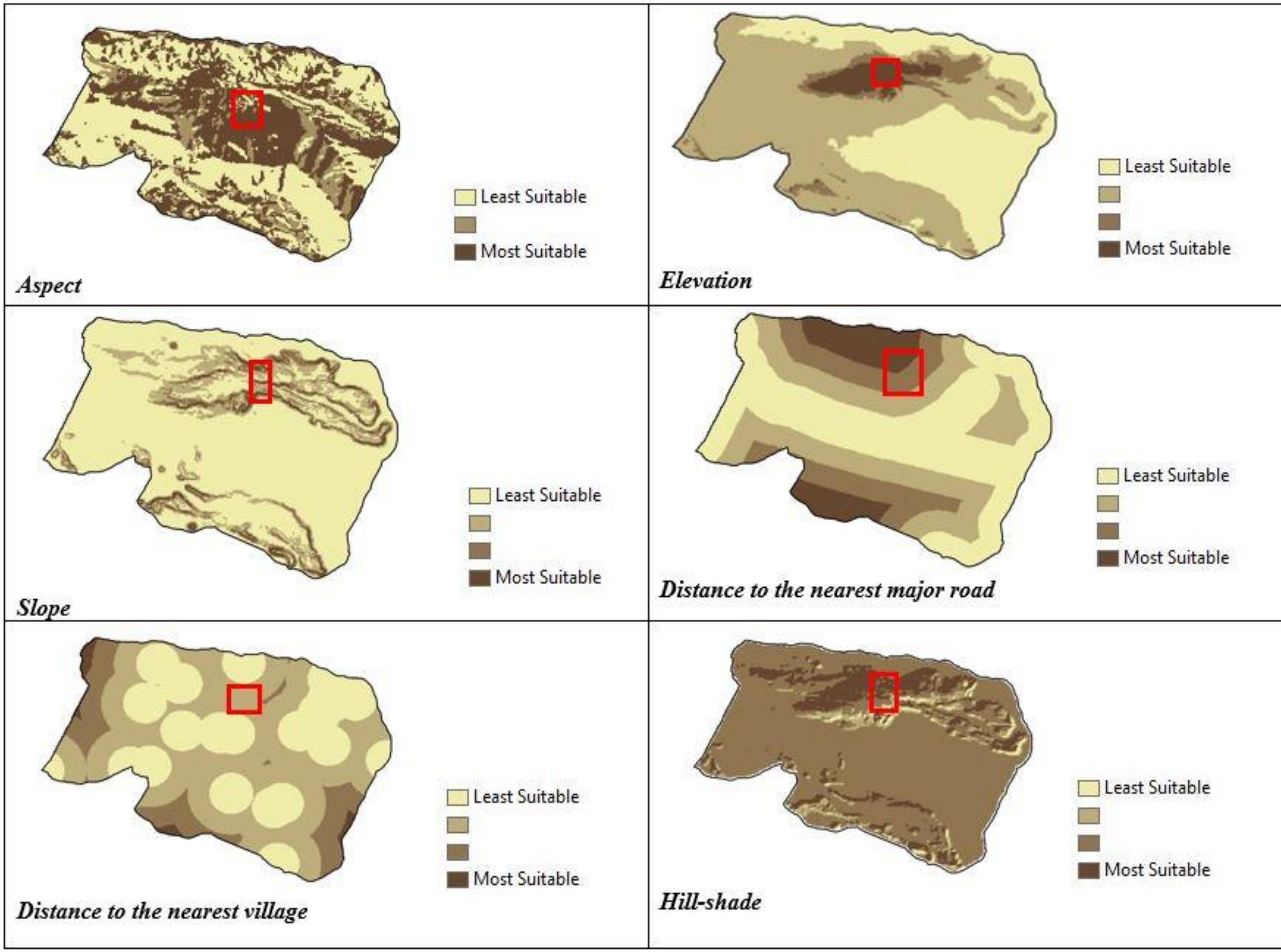
Value	Counts	%
1	87451	31
2	147702	52
3	41543	15
4	6404	2
TOTALS	**283100**	**100.00**

The hill range (Tswapong Hill complex) between Goo-Tau and Goo-Moremi villages contains the two large colonies (Bonwalenong and Manong Yeng. According to Table 23, 47% of the 7508 cells that cover the hill complex have suitable areas that Cape Vultures can use for nesting.

Table 23: Percentage of suitability per value assigned with reference figures to figure 21 (Tswapong Hill complex)

Value	Counts	%
1	64	0.9
2	3889	52
3	3012	40.1
4	543	7
TOTALS	**7508**	**100.00**

Table 24: Results from reclassification using weighted sum overlay showing level of suitability for each reclassified layer. The red marks (boxes) shows where the two large colonies in each layer.



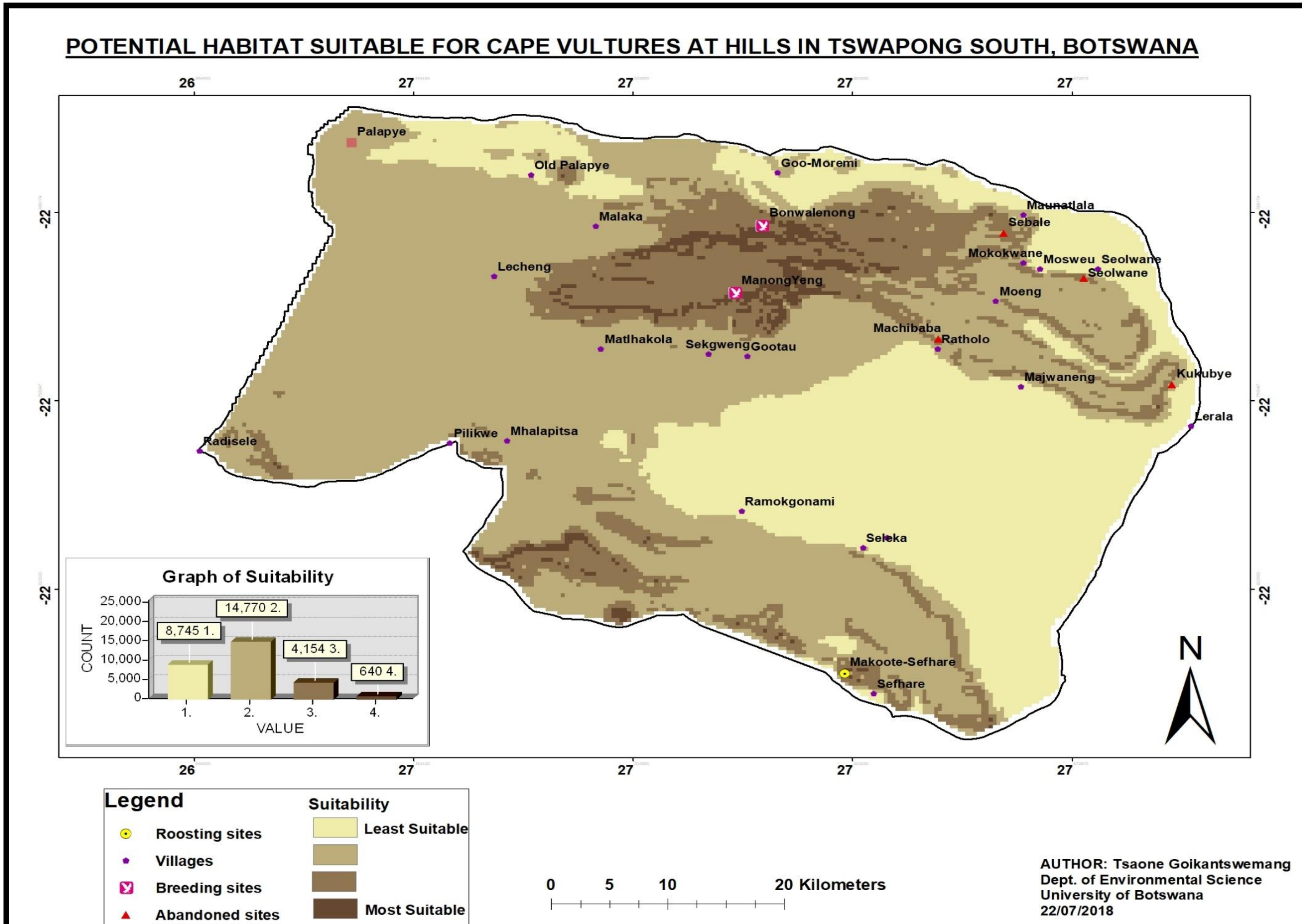


Figure 19: Suitability map created from GIS-Based Habitat suitability model for hills in Tswapong area

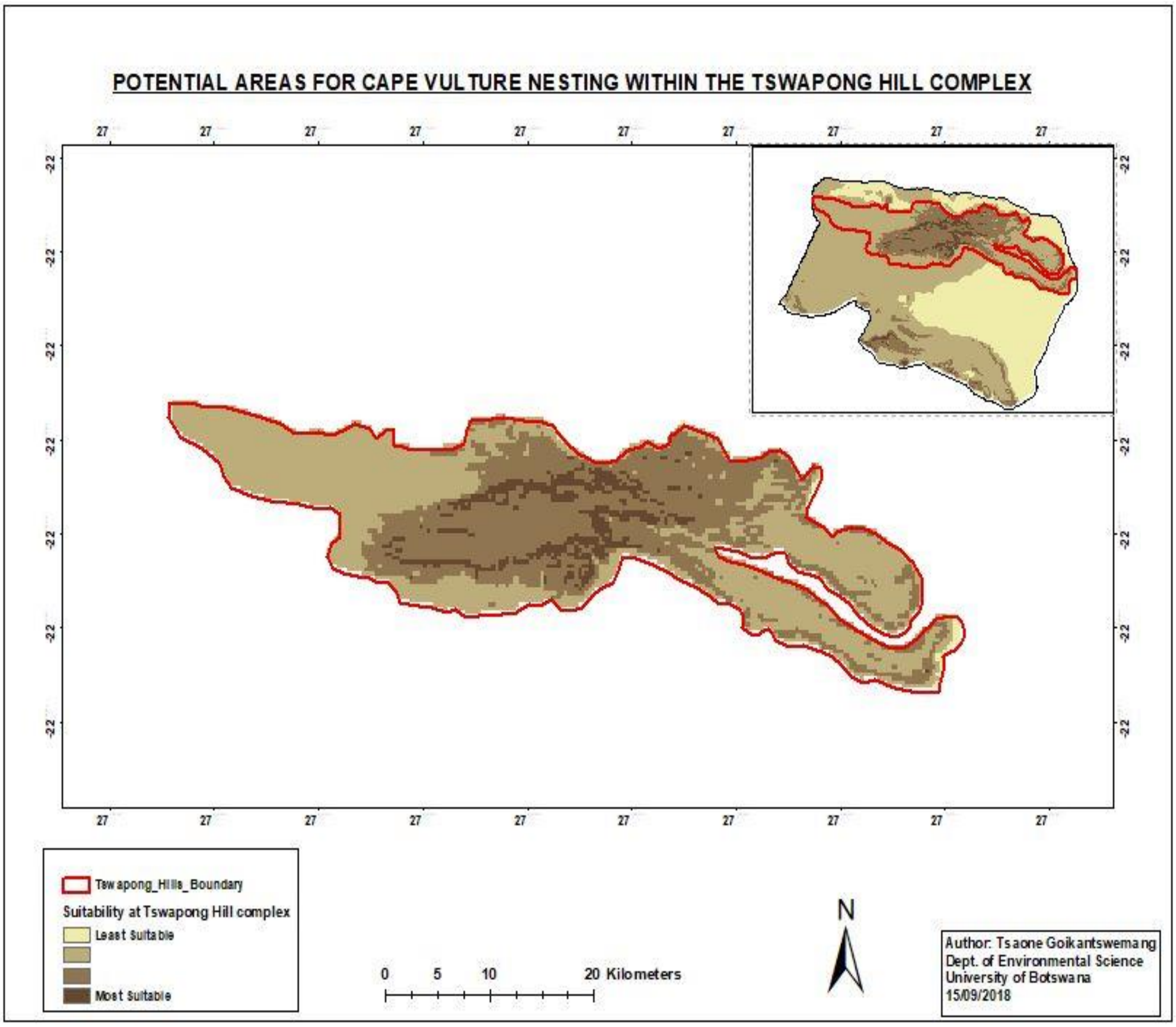


Figure 20: Potential areas for Cape Vulture nesting within the Tswapong Hill Complex

Table 25: SUMMARY RESULTS FOR RESEARCH QUESTIONS IN OBJECTIVE 3

RESEARCH QUESTIONS	FINDINGS
• Are there other potential sites within the Tswapong Hill complex with suitable nesting habitat for Cape Vultures?	• There was a small amount (3.93%) of suitable area predicted to be available from the overall area sampled by the model. However, the model showed that within the Tswapong hill ranges, where the two sites are located, there are additional potential sites for Cape Vulture nesting habitat.

4.4 OBSERVATION OF SIGNS OF CALCIUM DEFICIENCY

In December 2017, some juveniles were observed flying around the nesting cliffs at the Bonwalenong breeding site. However, three juveniles were found at the bottom of the cliffs unable to walk properly or fly. These birds presented deformed legs/feet and wings that are usually associated with a lack of calcium intake. The juveniles with deformed legs and wings were then taken to Mokolodi nature reserve for further examination and care.

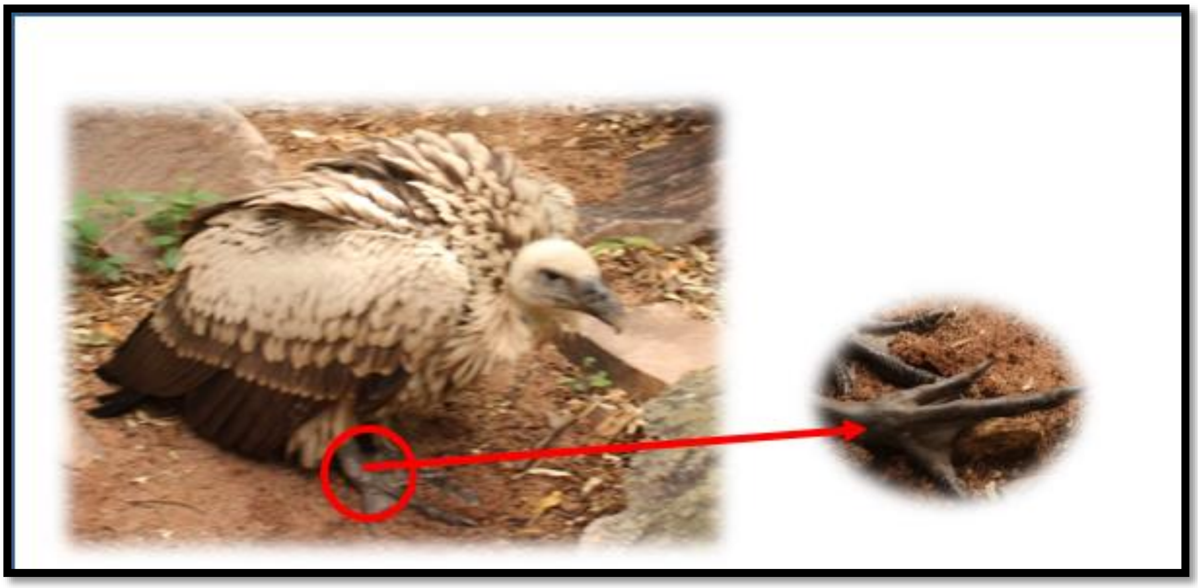


Figure 21: Deformity on the feet of the bird (juvenile)

Figure 22: Deformity on the wings and bird was unable to fly

SOURCE: Author

CHAPTER 5: DISCUSSION

Nest monitoring started early June 2017 at the north facing cliff of Bonwalenong and Manong Yeng. Later in August, more nests on the south facing cliff at Bonwalenong were identified and monitored with others until the end of November 2017. Mundy et al. (1997), Borello and Borello, (2002), and Pfeiffer et al. (2015) observed that Cape Vultures varied in their laying times between years and colonies. In the 2017 study, it was evident that some birds laid eggs very late as some new nests were found during the second visit in August. The 2017 results show that at both colonies, >90% of nests monitored were identified in June whereas <10% were found in August as new nests.

In 2017, the Bonwalenong colony had 200 pairs of which 43.5 % bred successfully whereas Manong Yeng had 80 pairs of which 23.8% were successful. Breeding success among the three cliff faces also varied significantly (Figures 15 & 16). This might be attributed to the protection of the gorge that encompasses the Bonwalenong colony and the availability of water and food sources in close proximity. Tour guides informed me that there is an open space in which they dispose of carcasses. This is not the case with the colony at Manong Yeng, although the two colonies are not very far apart. At Bonwalenong, the colony collapsed between 1995 and 1999, with less than 20 nests and sometimes none recorded (Figure 17). The researchers suggested that the massive decline in nesting was attributed to human disturbance that led to a re-distribution of birds to nearby sites (Borello & Borello, 2002). The 2017 data recorded 200 breeding pairs, which suggest that the Bonwalenong colony has recovered to approximately the level of pairs that bred there between 1989 and 1993.

Manong Yeng, on the other hand showed a non-significant decline in the number of breeding pairs, but a large decrease in breeding success when compared to results from a study conducted from 1992-1999. Borello and Borello (2002) suggested that the increase in the number of breeding pairs from 1996-1999 at Manong Yeng resulted from the collapse of the Bonwalenong colony and dispersal of birds from there into other sites such as Manong Yeng and Kukubye. Redistribution of birds to other sites has occurred in other colonies in South Africa, where an increase at one site matched a decrease in nearby sites in Kransberg, Collywobbles and Soutpansberg (Verdon & Becker, 1992; Scott 1997). The lower numbers of breeding pairs could be attributed to initiating monitoring later in 2017 than previous years (Borello & Borello, 2002). Researchers have suggested that some pairs may not breed every year (Borello & Borello, 2002). The inability to identify individual birds makes it difficult to examine these assumptions.

In other studies (Mundy et al., 1992, Boshoff et al., 1997; Borello & Borello, 2002; Anderson et al., 1999; Borello & Borello 2002; Bamford et al., 2007), predation and disturbance were identified as threats to vulture survival, especially at breeding sites. An increased tourism activity near breeding sites has also been cited as a possible threat to breeding populations (Borello & Borello, 2002). During all field observations, one pair of Black Eagles (*Ictinaetus malaiensis*) nesting at Bonwalenong colony was seen. Most tourists visited the waterfalls. The tour guides stated that primarily international tourists visit the gorges and birders who come occasionally are the ones who visit nesting sites. At Manong Yeng there was no evidence of predation and there were few kraals for cattle in the proximity.

The 2017 monitoring data shows that Cape Vultures seem to prefer nests on cliffs exposed to the sun. This is evidenced by the results in which 130 pairs bred at the north facing cliff whereas 70 and 80 pairs bred at south facing and Manong Yeng cliffs, respectively. The same observation has also been made at South African colonies, where the north and south facing cliffs had >100 pairs (Wolter et al., 2016). For example, in the south facing cliffs; Soutpansberg colony, Magaliesberg colony and Kransberg in 2016, there were 213 pairs, 390 pairs and 580 pairs respectively (Wolter et al., 2016). Also Manutusa colony, which is a north facing cliff, had 621 pairs in 2016. These aspects differ in their exposure to sunlight, which is a source of Vitamin D3. Birds need Vitamin D3 from sunlight to help them absorb calcium, which is necessary for strong egg shells and bones (Edwards, 2007). Yet, in 2017, the breeding success of the birds on the south facing cliff exceeded that of birds breeding on the north face. Chaudhry, (2012) and Kendall et al. (2014) observed that vultures nesting on sunny cliffs had less time for provisioning as they spent most their time shading the nestlings. This may result in an insufficient food supply.

Most failures occurred from June to September, or the egg laying and nestling periods. Other researchers also found that the nestling period was the most critical (Richardson et al., 1986; Mundy et al., 1992; Borello & Borello, 2002). Supplementary feeding at vulture restaurants can increase food availability during the nestling period and reduce foraging distances because breeding adults are often restricted to forage near breeding sites (Materns, 2018). Additionally, the issue of skeletal abnormalities due to insufficient calcium intake evidenced in chicks also affects their survival. After fledgling, some juveniles presented signs of osteodystrophy, which is associated with a lack of calcium in the diet. The tour guide at Goo-Moremi Gorge stated that chicks present with deformed feet bones and wings every year. Perhaps the numbers of carnivores that break up carcass bones into smaller fragments that vulture prefer to feed their chicks has decreased. To address these concerns, Richardson et al. (1986) and Menge et al. (2007) suggest supplementary feeding of bones at vulture restaurants during the breeding season. Richardson (1986) found that since the provisioning of bone fragments at vulture restaurants, the incidence of osteodystrophy declined from 17% to 2–5%. Benson et al. (2004) also stated that *Gyps* vultures usually collect bones, especially when meat is insufficient.

This study also adds to the literature on nest and cliff characteristics that support breeding success of Cape vultures. ‘Distance to the nearest village’, ‘Height of nest’ and ‘Aspect’ of the cliff were the most important variables for breeding success of Cape Vultures at the two sites. Similarly, Pfeiffer et al. (2017) found that Cape Vultures preferred to nest on higher cliffs. Şen et al. (2017) found that nests of Egyptian Vultures (*Neophron percnopterus)* at lower cliffs were more likely to fail. The study results did not show any significant influence of nest dispersal, and type (concealed or exposed) on the breeding success of Cape Vulture at Tswapong Hill complex. However, Beardsell et al. (2016) and Pfeiffer et al. (2017a) found that concealed nests and nests on ledges or caves with a larger base had a higher breeding success as compared to more exposed nests. Pfeiffer et al. (2015) showed that 91% of Cape Vulture nests situated close to each other were more successful. Wittenberger (1985), stated that nest density was the main determinant of breeding success. Clustering in colonial birds like Cape Vultures helps information sharing, which aids in finding food. Phillips et al. (1998) added that nesting in proximity to other nests improves anti-predator responses, increasing nesting success.

The 2017 monitoring data shows that as distance of the colony from the nearest village decreased, breeding success declined (Table 21). This is not a surprising finding because other studies have shown that villages or settlements near breeding sites expose those sites to disturbance, which may negatively affect breeding success (Donazar et al., 1993). By contrast at Manong Yeng with a greater distance from the village, there is less livestock farming on the outskirts which might lead to insufficient food availability in the birds' foraging range during breeding season. As such, perhaps the distance variable used in the model was influenced by carcasses availability.

The map resulting from the GIS-based habitat suitability model shows that the assumptions made about the habitat preference of Cape Vultures matched that found in the wild, with factors as distance from nearest village, aspect, and elevation having a strong influence on the breeding success of Cape Vultures (Figure 20 & 21). The model showed that within the

Tswapong Hill ranges where the two sites are located, there are potential sites for Cape Vulture nesting habitat. This suggests that these areas have the potential to support a growing population. Hence, there is a need to conserve these areas and emphasize the urgent need to conserve cliff faces that are well suited to Cape Vulture breeding.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

In 2017, the breeding success of Cape Vultures at Bonwalenong and Manong Yeng near Moremi and Goo-Tau villages respectively was monitored. Bonwalenong with two cliff faces that vultures used for nesting had more nests and significantly higher breeding success as compared to Manong Yeng. Compared to the results of a 1992-1999 study, the number of pairs and breeding success rate at Manong Yeng colony had declined since the 1990s. The number of pairs breeding pairs at Bonwalenong has recovered following a collapse of the colony between 1994 and 1998.

The two breeding sites occur near villages surrounded primarily by extensive farms that limit predator numbers and therefore bones for Cape vultures. This likely results in a shortage of calcium from crushed carcass bones, leading in turn to the chicks having weak bones, so increasing their mortality rates. Supplementary feeding of crushed bones has been suggested as a way to combat calcium deficiency (Richardson et al., 1986).

Investigation of cliff and nest site characteristics provided insight into factors influencing breeding success and selection of breeding sites. Nests on high elevations and south facing cliffs were more likely to succeed. Also, the distance of the colony from the nearest village affected the breeding success of Cape Vultures. The model of nesting sites found substantial additional suitable habitat in the Tswapong Hills that also needs conserving.

6.2. MANAGEMENT RECOMMENDATIONS

- Consistent and complete population monitoring should be conducted to understand the population status and dynamics of Cape Vultures in the Tswapong and Otse Hills. This will help understand the trends and demographic information of the population on an annual basis. Both experts and locals should participate in this monitoring.

- Supplementary bone fragments should be provided during the chick rearing period (July-December) to avoid mortality caused by a lack of calcium. This can be done at water points, feeding stations, or restaurants by engaging the community to obtain bones from abattoirs such the Jago beef abattoir near Palapye village, crush them and put them out for the vultures. This can also be achieved through partnerships with the local farming community. This practice has positively contributed to the recovery of the species in Maglisberg (Wolter et al., 2006) and significantly increased chick survival rate in the Western Cape Province in South Africa (Piper et al., 1999).
- The existing vulture rehabilitation centre at Mokolodi should be developed and resourced or equipped properly. Birds that have difficulty walking or flying should be taken to a rehabilitation centre for rehabilitation and release. This will help mitigate impacts from not only osteodystrophy, but also poisoning (Barnes, 2000).
- Initiate public education and awareness campaigns about vulture conservation, especially in villages near the breeding sites of Cape Vultures to inform people about the importance of conserving vultures and encourage them to participate in conservation measures. This can be done through reporting on new nesting sites, poisoning incidences and reporting any mortality of vultures they observe. Awareness can reduce cases of poisoning, disturbance and persecution for traditional medicine and consumption.
- Stakeholders including land managers, farmers, agro-chemists, wildlife managers, researchers, and local people, must work together to protect Cape Vultures. Minimized disturbance, monitoring of roosts and feeding sites, and reporting fatalities are some of the activities that these different stakeholders can undertake.

- Botswana Power Corporation (BPC) could act to ensure that power lines and other infrastructure in the wide vicinity of the Cape Vulture nesting areas is raptor friendly. BPC should over time ensure that any powerlines that are not raptor friendly are phased out with an initial priority around the Cape Vulture nesting areas and then across Botswana. When relevant in the shorter term "raptor guards" and other devices to reduce electrocutions and collisions should be used.

6.2.1 FUTURE RESEARCH

- There is a need for more research on the Cape Vulture movements, foraging, and the causes and effect of disturbance on them, in Botswana. Such data improve our understanding of the preferred Habitat and threats influencing the survival of the population (both adult and juveniles), thereby informing conservation strategies. Maps showing important areas used for foraging by Cape Vultures can be produced and similarly inform conservation strategies.
- Understanding key factors influencing the survival of chicks during the critical post-fledging dependence period is essential (López-López et al., 2014).
- Collaborate with other countries in research efforts to better understand population dynamics and the influence of different environments on Cape Vulture population and breeding success rates.
- Research on the power lines around the Tswapong Hills areas to assess the risk of electrocution and collision of Cape Vultures over the nesting period.
- A study to assess the risk of increasing tourism activities around the sensitive Cape Vultures nesting areas to determine if this increase in tourism is a threat to the nesting success of cape Vultures.

REFERENCES

Abercrombies, M., Hickman, C. J., &, & Johnson, M. L. (1966). *A dictionary of Biology*. London: Penguin Reference Books.

Adeola, M. O. (2009). Importance of Wild Animals and Their Parts in the Culture, Religious Festivals, and Traditional Medicine, of Nigeria. *Environmental Conservation, 19*(2), 125-134. doi:10.1017/S0376892900030605

Allan, D. G. (2015). Cape Vulture Gyps coprotheres. In M. R. P. Taylor, F.; Wanless, R. M. (Ed.), *The 2015 Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland* (pp. 174-178). Johannesburg, South Africa: BirdLife South Africa.

Anderson, D. M., Maritz, W. A., & Oosthuysen, E. (1999). *Raptors drowning in farm reservoirs in South Africa* (Vol. 70).

Anderson, M. D. (2000). Cape Vulture. In K. N. Barnes (Ed.), *The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland* (pp. 73-75). Johannesburg: BirdLife South Africa.

Baker, M. L. (2006). Observation: A Complex Research Method. *Library Trends, 1*(55), 171-189.

Bamford, A., Diekmann, M., Monadjem, A., & Mendelsohn, J. (2007). *Ranging behaviour of Cape Vultures Gyps coprotheres from an endangered population in Namibia* (Vol. 17).

Bamford, A. J., Monadjem, A., & Hardy, I. C. W. (2009). An effect of vegetation structure on carcass exploitation by vultures in an African savanna. *Ostrich, 80*(3), 135-137. doi:10.2989/OSTRICH.2009.80.3.2.965

Barnes, K. N. (2000). The Eskom Red Data Book of birds of South Africa, Lesotho and Swaziland. In B. S. Africa (Ed.). Johannesburg.

Beardsell, A., Gauthier, G., Therrien, J. F., & Bêty, J. (2016). *Nest site characteristics, patterns of nest reuse, and reproductive output in an Arctic-nesting raptor, the Rough-legged Hawk* (Vol. 133).

Becker, N., Choresh, Y., Bahat, O., & Inbar, M. (2010). *Cost benefit analysis of conservation efforts to preserve an endangered species: The Griffon Vulture (Gyps fulvus) in Israel* (Vol. 12).

Beilis, N., & Esterhuizen, J. (2006). *The potential impact on Cape Griffon Gyps coprotheres populations due to the trade in traditional medicine in Maseru, Lesotho* (Vol. 53).

Benson, P. C. (2015). A survey of Cape Vulture breeding colonies in South Africa's northern provinces (Transvaal Region) - an update 2013. *Biodiversity Observations*, 31-36%@ 2219-0341.

Benson, P. C., Plug, I., & Dobbs, J. C. (2004). An analysis of bones and other materials collected by Cape Vultures at the Kransberg and Blouberg colonies, Limpopo Province, South Africa. *Ostrich, 75*(3), 118-132. doi:10.2989/00306520409485423

Benson, P. C., Tarboton, W. R., Allan, D. G., & Dobbs, J. C. (1990). The breeding status of the Cape Vulture in the Transvaal during 1980-1985. *Ostrich, 61*(3&4), 134-142.

BirdLife International. (2004). *Threatened birds of the world, 2004. CD-ROM.* Cambridge: BirdLife International.

BirdLife International. (2015). Species factsheet: Neophron percnopterus. . Retrieved from www.birdlife.org

BirdLife International. (2017). Important Bird Areas factsheet: Tswapong Hills. . Retrieved from http://www.birdlife.org

BirdLife International. (2018). Gyps coprotheres. The IUCN RedList of Threatened Species 2017. Retrieved from http://www.birdlife.org

Block, W. M., & Brennan, A. L. (1993). The habitat concept in ornithology: theory and applications. In D. M. Power (Ed.), *Current ornithology* (pp. 35-91). New York: Plenum Press.

Borello, W. D. (1985). Poisoned vultures in Botswana: known facts. *Babbler*, 22-23.

Borello, W. D. (1997). A note on Cape Vulture Gyps coprotheres parental and juvenile behaviour at Mannyelanong, southeastern Botswana. *Babbler, 38,* 34-35.

Borello, W. D. (2007). [Conservation and population monitoring guidelines of Cape Vulture Gypscoprotheres].

Borello, W. D., & Borello, R. M. (1993). Demographic trends in Cape Griffon Gyps coprotheres colonies in Botswana, 1963–1992. In R. T. Wilson (Ed.), *Birds and the African Environment: Proceedings of the Eighth Pan-African Ornithological Congress* (Vol. 268, pp. 123-131): Annales Musée Royal de l'Afrique Centrale (Zoologie).

Borello, W. D., & Borello, R. M. (2002). *The breeding status and colony dynamics of Cape Vulture Gyps coprotheres in Botswana* (Vol. 12).

Borello, W. D., & Borello, R. M. (2002). The breeding status and colony dynamics of Cape Vulture *Gyps coprotheres* in Botswana. *Bird Conservation International, 12,* 79-97.

Boshoff, A. F., Anderson, M. D., & Borello, W. D. (1997). *Vultures in the 21st Century*. Paper presented at the Proceedings of a workshop on vulture research and conservation in southern Africa, Johannesburg, South Africa.

Boshoff, A. F., & Borello, W. D. (1982). Vultures in Botswana: The beginning of the end? *Vulture News, 8,* 7-10.

Botswana Wildlife. (2016). Goo-Tau, Tswapong Hills. Retrieved from http://www.botswanawildlife.com/gootau.html

Brown, C. J., & Piper, S. E. (1988). Status of the Cape Vulture in the Natal Drakensberg and their cliff site selection. *Ostrich, 59*, 126-136.

Campbell, M. O. N. (2015). Vultures: Their Evolution, Ecology and Conservation [Press release]

Carrete, M., Sánchez-Zapata, J., Arenas-González, R., Lobón, M., Montoya, F., & Donázar, J. (2012). *Mortality at wind-farms is positively related to large-scale distribution and aggregation in griffon vultures* (Vol. 145).

Chaudhry, M., Ogada, D., Malik, R., Virani, M., & Giovanni, M. (2012). *First evidence that populations of the critically endangeredLongbilled Vulture Gyps indicus in Pakistan have increased following the ban of the toxic veterinary drug diclofenac in south Asia* (Vol. 22).

Chen, J. (2014). GIS-based multi-criteria analysis for land use suitability assessment in City of Regina. *Environmental Systems Research., 3*(13).

De Jager Jackson, A. (n.d). *Manna in the desert. A revelation of the Great Karroo*. Johannesburg: Christian Literature Depot.

Dinsmore, S. J., & Dinsmore, J. J. (2007). *Modeling avian nest survival in program MARK* (Vol. 34).

Dinsmore, S. J., White, G. C., & Knopf, F. L. (2002). Advanced Techniques for Modeling Avian Nest Survival. *Ecology, 83*(12), 3476-3488. doi:10.2307/3072096

Djerdali, S., Guerrero-Casado, J., & Tortosa, F. S. (2016). The effects of colony size interacting with extra food supply on the breeding success of the White Stork (Ciconia ciconia). *Journal of Ornithology, 157*(4), 941-947. doi:10.1007/s10336-016-1343-5

Donázar, J., Margalida, A., & Campion, D. (2009). *Vultures, Feeding Stations and Sanitary Legislation: A Conflict and Its Consequences from the Perspective of Conservation Biology* (Vol. 29).

Donázar, J. A., Cortés-Avizanda, A., & Carrete, M. (2010). Dietary shifts in two vultures after the demise of supplementary feeding stations: consequences of the EU sanitary legislation. *European Journal of Wildlife Research, 56*(4), 613-621. doi:10.1007/s10344-009-0358-0

Donazar, J. A., Hiraldo, F., & Bustamante, J. (1993). Factors Influencing Nest Site Selection, Breeding Density and Breeding Success in the Bearded Vulture (Gypaetus barbatus). *Journal of Applied Ecology, 30*(3), 504-514. doi:10.2307/2404190

Driscoll, D. L. (2011). Introduction to Primary Research: Observations, Surveys, and Interviews. In C. Lowe & P. Zemliansky (Eds.), *Writing Spaces: Readings on Writing* (Vol. 1, pp. 153-174). West Lafayette: Parlor Press LLC.

Dupont, H., Mihoub, J. B., Bobbé, S., & Sarrazin, F. (2012). Modelling carcass disposal practices: implications for the management of an ecological service provided by vultures. *Journal of Applied Ecology, 49*(2), 404-411. doi:doi:10.1111/j.1365-2664.2012.02111.x

Duriez, O., Kato, A., Tromp, C., Dell'Omo, G., Vyssotski, A. L., Sarrazin, F., & Ropert-Coudert, Y. (2014). How Cheap Is Soaring Flight in Raptors? A Preliminary Investigation in Freely-Flying Vultures. *PLOS ONE, 9*(1), e84887. doi:10.1371/journal.pone.0084887

DWNP. (2015). *Status and Trends of Selected Wildlife Species in Botswan*. Retrieved from Gaborone, Botswana:

Edwards, H. M. (2007). Effects of u.v. irradiation of very young chickens on growth and bone development. *British Journal of Nutrition, 90*(1), 151-160. doi:10.1079/BJN2003860

Freund, M., Bahat, O., & Motro, U. (2017). Breeding Success and its Correlation with Nest-Site Characteristics: A Study of a Griffon Vulture Colony in Gamla, Israel. *Journal of Raptor Research, 51*(2), 136-144. doi:10.3356/JRR-16-15.1

Garbett, R., Herremans, M., Maude, G., Reading, R. P., & Amar, A. (2018). Raptor population trends in northern Botswana: A re-survey of road transects after 20 years. *Biological Conservation, 224*, 87-99. doi:https://doi.org/10.1016/j.biocon.2018.05.020

Garbett, R., Maude, G., Hancock, P., Kenny, D., Reading, R. P., & Amar, A. (2018). Association between hunting and elevated blood lead levels in the critically endangered African white-backed vulture Gyps africanus. *Science of The Total Environment, 630*, 1654-1665. doi:https://doi.org/10.1016/j.scitotenv.2018.02.220

Gawlik, D. E. (2002). *The Effects of Prey Availability on the Numerical Response of Wading Birds* (Vol. 72).

Geoflux. (2009). *Moremi Gorge Environmental Impact Assessment Study, Tourism Component: Final EIA Repor*. Retrieved from Gaborone:

Godfrey, R. B. (1934). Present status of the Griffon in Eastern Cape Colony. *Blythswood Review, 11*, 46-47.

Gómez-Ramírez, P., Shore, R. F., van den Brink, N. W., van Hattum, B., Bustnes, J. O., Duke, G., . . . Sonne, C. (2014). An overview of existing raptor contaminant monitoring activities in Europe. *Environment International, 67*, 12-21:https://doi.org/10.1016/j.envint.2014.02.004

Green, R., Newton, I., Shultz, S., Cunningham, A., Gilbert, M., Pain, D., & Prakash, V. (2004). *Diclofenac Poisoning as a Cause of Vulture Population Declines across the Indian Subcontinent* (Vol. 41).

Green, R. E., Donázar, J. A., Sánchez-Zapata, J. A., & Margalida, A. (2016). Potential threat to Eurasian griffon vultures in Spain from veterinary use of the drug diclofenac. *Journal of Applied Ecology, 53*(4), 993-1003. doi:doi:10.1111/1365-2664.12663

Groom, J. R., Gandiwa, E., Gandiwa, P., & van der Westhuizen, F. H. (2013). *A Mass Poisoning of White-Backed and Lappet-Faced Vultures in Gonarezhou National Park* (Vol. 59).

Haagner, A. K. (1908). The South African birds of prey: their economic relations to man. *(Supplement) Journal of the South African Ornithologists' Union, 3*(1), 76 - 116.

Haghani, A., Aliabadian, M., Sarhangzadeh, J., & Setoodeh, A. (2016). Seasonal habitat suitability modeling and factors affecting the distribution of Asian Houbara in East Iran. *Heliyon, 2*(8), e00142. doi:https://doi.org/10.1016/j.heliyon.2016.e00142

Harel, R., Spiegel, O., Getz, W. M., & Nathan, R. (2017). Social foraging and individual consistency in following behaviour: testing the information centre hypothesis in free-ranging vultures. *Proc. R. Soc. B, 284*(1852), 20162654.

Harris, R. J. (2013). The conservation of Accipitridae vultures of Nepal: a review. *Journal of Threatened Taxa, 5*(2), 3603-3619.

Hazell, P. (2017). Cape Vultures killed at wind farms. Retrieved from https://hermanusbirdclub.wordpress.com/2017/04/06/cape-vultures-killed-at-wind-farms/

Hirschauer, M. (2016). *Release success of captive bred Cape Vultures (Gyps coprotheres) in the Magaliesberg Mountains, South Africa.* (MASTERS OF SCIENCE), RHODES UNIVERSITY.

Hollenbeck, J., Saab, A. V., & Frenzel, R. W. (2011). *Habitat Suitability and Nest Survival of White-Headed Woodpeckers in Unburned Forests of Oregon* (Vol. 75).

Kellner, C. J., Brawn, J. D., & Karr, J. R. (1992). What Is Habitat Suitability and how should it be Measured? In B. R. H. McCullough D.R. (Ed.), *Wildlife 2001: Populations*. Dordrecht: Springer.

Kendall, C. J., Virani, M. Z., Hopcraft, J. G. C., Bildstein, K. L., & Rubenstein, D. I. (2014). African Vultures Don't Follow Migratory Herds: Scavenger Habitat Use Is Not Mediated by Prey Abundance. *PLOS ONE, 9*(1), e83470. doi:10.1371/journal.pone.0083470

Kenny, D., Kim, Y.-J., Lee, H., & Reading, R. (2015). Blood lead levels for Eurasian black vultures (Aegypius monachus) migrating between Mongolia and the Republic of

Korea. *Journal of Asia-Pacific Biodiversity, 8*(3), 199-202. doi:https://doi.org/10.1016/j.japb.2015.08.004

Krüger, S. C. (2014). *An Investigation into the Decline of the Bearded Vulture Gypaetus barbatusin Southern Africa.* (Phd), University of Cape Town, South Africa Percy FitzPatrick Institute of African Ornithology.

Leepile, B. L. (2018). *Changes in nesting numbers and breeding success of African White-backed Vultures in northern Botswana.* (MSc), University of Cape Town, University of Cape Town (UCT), South Africa.

Letsholo, A. (2015). Vultures have tourism potential-Birdlife Botswana. Retrieved from http://www.sundaystandard.info/vultures-have-tourism-potential-birdlife-botswana

López-López, P., García-Ripollés, C., & Urios, V. (2014). Food predictability determines space use of endangered vultures: implications for management of supplementary feeding. *Ecological Applications, 24*(5), 938-949. doi:doi:10.1890/13-2000.1

López-López, P., Ja, G., & Alcántara, M. (2014). *Post-fledging Dependence Period and Onset of Natal Dispersal in Bearded Vultures (Gypaetus barbatus): New Insights from GPS Satellite Telemetry* (Vol. 48).

Malczewski, J. (1999). *GIS and Multicriteria Decision Analysis.* Third Avenue, New York: Wiley & Sons.

Mander, M., Diedericks, N., Ntuli, L., Mavundla, K., Williams, V., & McKean, S. (2007). *Survey of the trade in vultures for the traditional health industry in South Africa*. Retrieved from

Margalida, A., Campion, D., & Donázar, J. A. (2014). Vultures vs livestock: conservation relationships in an emerging conflict between humans and wildlife. *Oryx, 48,* 172-176.

Markandya, A., Taylor, T., Longo, A., Murty, M. N., Murty, S., & Dhavala, K. (2008). Counting the cost of vulture decline—An appraisal of the human health and other benefits of vultures in India. *Ecological Economics, 67*(2), 194-204. doi:https://doi.org/10.1016/j.ecolecon.2008.04.020

Martens, F. R., Pfeiffer, M. B., Downs, C. T., & Venter, J. A. (2018). Post-fledging movement and spatial ecology of the endangered Cape Vulture (Gyps coprotheres). *Journal of Ornithology, 159*(4), 913-922. doi:10.1007/s10336-018-1564-x

Mateo-Tomás, P., & Olea, P. (2015). *Mateo Tomás and Olea 2015 Ecol Ind INFOGRAPHIC English*.

Mateo-Tomás, P., Olea, P., Sánchez, I., & Mateo, R. (2012). *Alleviating human-wildlife conflicts: Identifying the causes and mapping the risk of illegal poisoning of wild fauna* (Vol. 49).

Menge, L., Diekmann, M., Cunningham, P., & Joubert, D. (2007). Bone intake by vultures in Namibia. *Vulture News, 57*, 17-23.

Mmassy, E. C., Fyumagwa, R. D., Jackson, C. R., Bevanger, K., & Røskaft, E. (2017). Kori bustard (Ardeotis kori struthiunculus) occurrence in the Serengeti grass plains, northern Tanzania. *African Journal of Ecology, 55*(3), 298-304. doi:10.1111/aje.12351

Monadjem, A., Wolter, K., Neser, W., & Kane, A. (2014). *Effect of rehabilitation on survival rates of endangered Cape vultures* (Vol. 17).

Morales-Reyes, Z., Pérez-García, J. M., Moleón, M., Botella, F., Carrete, M., Lazcano, C., . . . Sánchez-Zapata, J. A. (2015). Supplanting ecosystem services provided by scavengers raises greenhouse gas emissions. *Scientific Reports, 5*, 7811.

Moreno-Opo, R., Fernández-Olalla, M., Margalida, A., Arredondo, Á., & Guil, F. (2013). Influence of Environmental Factors on the Breeding Success of Cinereous Vultures Aegypius monachus. *Acta Ornithologica, 48*(2), 187-193. doi:10.3161/000164513X678838

Mundy, P., Benson, P., & Allan, D. (1997). Cape vulture *he atlas of southern African birds* (Vol. 1, pp. 158-159).

Mundy, P., Butchart, D., Ledger, J., & Piper, S. (1992). *The Vultures of Africa*. London: Academic Press.

Mundy, P. J. (1982). The Comparative Biology of Southern African Vultures. Johannesburg: Vulture Study Group.

Mundy, P. J., Ledger, J. A., & Friedman, R. (1980). he Cape Vulture project in 1977 and 1978. *Bokmakierie, 32*.

Naidoo, V., Wolter, K., & Botha, C. J. (2017). Lead ingestion as a potential contributing factor to the decline in vulture populations in southern Africa. *Environ Res, 152*, 150-156. doi:10.1016/j.envres.2016.10.013

Naidoo, V., Wolter, K., Espie, I., & Kotze, A. (2011). Vulture rescue and rehabilitation in South Africa: an urban perspective. *J S Afr Vet Assoc, 82,* 24-31.

Neuman, W. L. (2007). *Basics of Social Research: Qualitative and Quantitive Approaches*. Boston: Pearson Education.

Newton, I. (1979). *Population ecology of raptors*. Berkhamsted,UK: Poyser.

Ngwenya, N. P. (2001). *mplications of the medicinal animal trade for Nature Conservation in KwaZulu-Natal. Ezemvelo KZN Wildlife.* Retrieved from unpublished report,:

Nikolaus, G. (2001). *Bird exploitation for traditional medicine in Nigeria* (Vol. 23).

Ogada, D. L., Shaw, P., Beyers, R. L., Buij, R., Murn, C., Thiollay, J. M., . . . Sinclair, A. R. E. (2016). Another Continental Vulture Crisis: Africa's Vultures Collapsing toward Extinction. *Conservation Letters, 9*(2), 89-97. doi:doi:10.1111/conl.12182

Ogada, D. L., Torchin, M. E., Kinnaird, M. F., & Ezenwa, V. O. (2012b). Effects of Vulture Declines on Facultative Scavengers and Potential Implications for Mammalian Disease Transmission. *Conservation Biology, 26*(3), 453-460. doi:doi:10.1111/j.1523-1739.2012.01827.x

Olea, P., & Mateo-Tomás, P. (2009). *The role of traditional farming practices in ecosystem conservation: The case of transhumance and vultures* (Vol. 142).

Oppel, S., Dobrev, V., Arkumarev, V., Saravia, V., Bounas, A., Manolopoulos, A., . . . Nikolov, S. (2016). *Landscape factors affecting territory occupancy and breeding success of Egyptian Vultures on the Balkan Peninsula* (Vol. 158).

Parish, C. N., Heinrich, W. R., & Hunt.W.G. (2007). Lead exposure,diagnosis, and treatment in California Condorsreleased in Arizona. In California Condors in the 21st Century. In A. Mee, L. S. L. S. Hall, & J. Grantham (Eds.), *In California Condors in the 21st Century.Series in Ornithology*. Washington, DC and Nuttall Ornithological Club: American Ornithologists Union and Cambridge, MA.

Pfeiffer, M. B. (2016). *Ecology and conservation of the Cape Vulture in the Eastern Cape province, South Africa*. University of KwaZulu-Natal, Pietermaritzburg.

Pfeiffer, M. B., Venter, J. A., & Downs, C. T. (2014). Identifying anthropogenic threats to Cape Vultures Gyps coprotheres using community perceptions in communal farmland, Eastern Cape Province, South Africa. *Bird Conservation International, 25*(3), 353-365. doi:10.1017/S0959270914000148

Pfeiffer, M. B., Venter, J. A., & Downs, C. T. (2015). Foraging range and habitat use by Cape Vulture Gyps coprotheres from the Msikaba colony, Eastern Cape province, South Africa. *Koedoe, 57,* 1-11.

Pfeiffer, M. B., Venter, J. A., & Downs, C. T. (2017a). Cliff characteristics, neighbour requirements and breeding success of the colonial Cape Vulture Gyps coprotheres. *Ibis, 159*(1), 26-37. doi:doi:10.1111/ibi.12428

Phillips, R., Furness, R., & Stewart, F. M. (1998). *The influence of territory density on the vulnerability of Arctic Skuas Stercorarius parasiticus to predation* (Vol. 86).

Piper, S. E. (2005). Supplementary feeding programmes: how necessary are they for the maintenance of numerous and healthy vulture populations? In D. C. Houston & S. E. Piper (Eds.), *Conservation and Management of Vulture Populations*. Greece: Thessaloniki.

Piper, S. E., Boshoff, A. F., & Scott, H. A. (1999). Modelling survival rates in the Cape Griffon Gyps coprotheres, with emphasis on the effects of supplementary feeding. *Bird study, 46*, 230-238. doi:- info:doi/

Piper, S. E., Mundy, P. J., & Vernon, C. J. (in prep). *Site register of the Cape Vulture Gyps coprotheres: Ancient and Modern* (None). Retrieved from Johannesburg:

Prakash, V., Bishwakarma, M. C., Chaudhary, A., Cuthbert, R., Dave, R., Kulkarni, M., . . . Green, R. E. (2012). The Population Decline of Gyps Vultures in India and Nepal Has Slowed since Veterinary Use of Diclofenac was Banned. *PLOS ONE, 7*(11), e49118. doi:10.1371/journal.pone.0049118

Prakash, V., Green, R., Pain, D., Ranade, S., Saravanan, S., Prakash, N., . . . Cunningham, A. (2007). *Recent changes in populations of resident Gyps vultures in India* (Vol. 104).

R Core Team. (2018). R:A Language and Environment for Statistical Computing. Version 3.5.1. Vienna: R Foundation for Statistical Computing.

Ratsie, M. L., Dipotso, M. F., Kootsositse, M. V., & Senyatso, K. J. (2011). *Botswana's Important Bird Areas: Status and Trends Report 2011*. Retrieved from Gaborone, Botswana

Retief, E. F., Diamond, M., Anderson, M. D., Smit, H. A., Jenkins, A., Brooks, M., & Simmons, R. (2013). *Avian Wind Farm Sensitivity Map for South Africa: Criteria and Procedures Used*.

Richardson, P. R. K., Mundy, P. J., & Plug, I. (1986). Bone crushing carnivores and their significance to osteodystrophy in griffon vulture chicks. *Journal of Zoology, 210*(1), 23-43. doi:doi:10.1111/j.1469-7998.1986.tb03618.x

Robertson, A. S. (1986). *Notes on the breeding cycle of Cape Vultures (Gyps coprotheres)* (Vol. 20).

Robertson, A. S. (2015). *The feeding ecology and breeding biology of a Cape vulture colony in the Southwestern Cape Province.*

Rushworth, I., & Krüger, S. C. (2014). Wind farms threaten southern Africa's cliff-nesting vultures. *Ostrich, 85*(1), 13-23. doi:10.2989/00306525.2014.913211

Rutina, L., Dikobe, M., & S. Perkins, J *Vultures: A Call for Research and Legal Instruments* (Vol. 49).

Santangeli, A., Arkumarev, V., Rust, N., & Girardello, M. (2016). Understanding, quantifying and mapping the use of poison by commercial farmers in Namibia – Implications for scavengers' conservation and ecosystem health. *Biological Conservation, 204,* 205-211. doi:https://doi.org/10.1016/j.biocon.2016.10.018

Şen, B., Tavares, J. P., & Bilgin, C. C. (2017). Nest site selection patterns of a local Egyptian Vulture Neophron percnopterus population in Turkey. *Bird Conservation International, 27*(4), 568-581. doi:10.1017/S0959270916000411

Sharma, P. (2012). Aceclofenac as a Potential Threat to Critically Endangered Vultures in India: A Review. *Journal of Raptor Research, 46*(3), 314-318. doi:10.3356/JRR-11-66.1

Siphambe, G., Mbaiwa, E. J., & Pansiri, J. (2017). Cultural Landscapes and Tourism Development in Botswana: The Case of Moremi Gorge in Eastern Botswana. *Botswana Journal of Business, 10*(1), 117-137.

Steenhof, K., & Newton, I. (2007). Assessing Nesting Success and Productivity. In D. M. Bird & K. L. Bildstein (Eds.), *Raptor Research and Management Techniques.* Washington, USA.: Hancock House.

Troy, J. R., Holmes, N., Veech, J., Raine, A., & Green, M. (2014). *Habitat Suitability Modeling for the Newell's Shearwater on Kauai* (Vol. 5).

Tyler, S. J., & Bishop, D. (1998). Important Bird Areas of Botswana. In K. N. Barnes (Ed.), *The Important Bird Areas of southern Africa,* (pp. 333–354). Johannesburg, South Africa: BirdLife South Africa.

Vartanian, T. P. (2011). *Secondary Data Analysis*. New York: Oxford University Press.

Verdoorn, G. H., & Becker, I. (1992). Cape Griffons of the Magaliesberg: 1991 census of nestlings and first breeding record at Nooitgedacht since 1964. *Vulture News, 27,* 19-25.

Virani, M. Z., Kendall, C. J., Njoroge, P., & Thomsett, S. (2011). Major declines in the abundance of vultures and other scavenging raptors in and around the Masai Mara ecosystem, Kenya. *Biological Conservation, 144*(2), 746-752. doi:https://doi.org/10.1016/j.biocon.2010.10.024

Wenny, D. G., Devault, T. L., Johnson, M. D., Kelly, D., Sekercioglu, C. H., Tomback, D. F., & Whelan, C. J. (2011). The Nee. (2017). *Inappropriate Use of Agro-chemicals Poses Potential Threats to Botswana* to Quantify Ecosystem Services Provided By Birds. *The Auk, 128*(1), 1-14. doi:10.1525/auk.2011.10248

Whittington-Jones, C., Wolter, K., & West, S. (2011). Monitoring of Cape vulture (Gyps coprotheres) breeding colonies in the Magaliesberg, South Africa: 2007-2009. *Vulture News, 60*(1), 6-12.

Wittenberger, J. F. (1985). The adaptive significance of coloniality in birds. *Avian biology, 8*, 1-78.

Wolter, K., Benson, P. C., Borello, W. D., Piper, S. E., Neethling, M., Vernon, C. J., . . . Neser, W. (2006). *Cape Vulture Breeding Colony Conservation and Monitoring Protocol*. Retrieved from Pretoria, South Africa.:

Wolter, K., Neser, W., Hirschauer, M. T., & Camiña, A. (2016). Cape Vulture Gypscoprotheres breeding status in southern Africa: monitoring results from 2010–2014. *Ostrich, 87*(2), 119-123.

Wolter, K., Underhill, L. G., López-Gómez, M., & Brooks, M. (2017). Bird distribution dynamics 6 – Cape Vulture Gyps coprotheresin South Africa, Lesotho and Swaziland. *Biodiversity Observations, 8*(4), 1-11.

APPENDICIES

APPENDIX 1

Vulture Monitoring Project

Cape Vulture (Gyps coprotheres):

Breeding colony conservation & monitoring protocol update (2011)

Contributors:

K. Wolter, P. Benson, S.E. Piper, M. Neethling, C.J. Vernon, A. Botha, A. Boshoff, W.D. & R. Borello, P.J. Mundy and W. Neser

Produced for the Vulture Study Group (VSG), a special interest group (SIG) of the Birds of Prey Working Group (BoPWaG) of the Endangered Wildlife Trust (EWT) and updated by the Vulture Programme (VULPRO).

Vulture Programme

Kerri.wolter@gmail.com

PO Box 285

Skeerpoort 0232

North-West

South Africa

Cape Vulture (Gyps coprotheres): Breeding colony conservation & monitoring protocol

Summary

Contents

1. Introduction

The Cape Vulture (Gyps coprotheres) is southern Africa's only endemic vulture (P. J. Mundy, D. Butchart, J. A. Ledger, & S. E. Piper, 1992) and is of special conservation concern as it has been rated as Vulnerable (M. D. Anderson, 2000) in South Africa, Lesotho and Swaziland and also as Vulnerable, globally (BirdLife International, 2004). Notwithstanding it being the most studied vulture in southern Africa and being the central focus of vulture conservation in southern Africa (P. J. Mundy et al., 1992), it has shown a consistent and continued decline over the last 30 years (le Roux, 2002).
From the earliest times when records were kept of birds in southern Africa, the status of the Cape Vulture has been the subject of much comment e.g. (De Jager Jackson, n.d); (Layard, 1867); (Godfrey, 1934); (Haagner, 1908). However, most of these records were anecdotal. With the formation of the Vulture Study Group in 1973 (P. J. Mundy et al., 1992) an attempt was made to collate everything that had been recorded for all the breeding colonies and roosts in southern Africa and this has lead to the accumulation of many published and unpublished references (S.E. Piper, Mundy, & Vernon, in prep)) for the species entire range. There are many examples of where individual researchers, or groups of interested persons have monitored individual breeding colonies or regions e.g. (W.D. Borello & R.M. Borello, 2002); (Brown & Piper, 1988); (P.C. Benson, Tarboton, Allan, & Dobbs, 1990) etc. However, the monitoring of Cape Vulture colonies has become such a massive task that the Cape Vulture Task Force (CVTF) was formed at a meeting held at Sterkfontein Dam in the Free State, South Africa on Tuesday 14th March 2006. It was decided to initiate conservation action as well as to monitor the largest and most important breeding colonies across southern Africa, starting with the 2006 breeding season. It was also decided that some of the smaller and more peripheral sites should also be the object of conservation action monitoring.

Although the Cape Vulture has been the recipient of much conservation action it is still declining and the CVTF resolved to put in place a conservation programme around each of the breeding colonies to try and halt this decline. The central aim of this programme is to halt the decline in the population and to prevent the species' range from contracting.

This document sets out in a simple and step-by-step programme to a) put in place a conservation programme at a colony and b) initiate and maintain a breeding monitoring programme for that colony.

2. Overview of protocol

There are two parallel streams: conservation and monitoring and these are to be pursued simultaneously.

To conserve the vultures at a breeding colony it is necessary to ascertain the threats faced by the vultures at that colony and within their foraging range and then to assemble the most important stakeholders for a meeting to canvas their support and to understand their attitudes to the vultures, in particular, and their conservation in general and then to take appropriate conservation actions.

To monitor Cape Vultures it is important to locate at least one viewpoint from which one can see most, if not all of the nests. Sometimes more than one viewpoint is required. From each view point a set of photographs needs to be taken and all the nests need to be marked on the photograph and numbered. Thereafter each nest can be referred to by its unique number (for photograph). A breeding colony needs to be visited three times per breeding season to be able to count:

- the number of pairs in May,
- the numbers of chicks in July/August,
- the number of fledgling in September/October,

With this data, one can estimate the number of pairs that attempt to breed and then to estimate their breeding success.

3. Background information

To understand the dynamics of conservation and monitoring at a Cape Vulture breeding colony it is useful to have as much background information as possible for that colony.Before proceeding, it is important to note that this 'background information collecting phase' can continue after or before the more important aspects of colony conservation and monitoring are taking place in the field.

The important questions to ask of any breeding colony are:

1. Has this colony ever been visited or monitored before, and if so, how many birds, pairs, nests and fledglings were counted on each visit?
2. Has anything ever been published on the colony?

3. Have the number of breeding pairs at this colony shown any long-term trends, e.g. increase or decline?
4. Have the vultures ever abandoned this colony only to return at some later date? (This is called ‘colony switching’.)
5. Have dying or dead birds ever been found at this colony, or in the near vicinity?
6. In the vicinity of the breeding site is there any evidence of poisoning, drowning, persecution, electrocution or collision with power-lines or other structures?
7. Is the colony within a conservation area? If so, is it part of a conservation or management plan?
8. Has the colony ever been part of an environmental impact assessment?

It is probable that in the vicinity of the colony there will be people who have taken an interest in the vultures over the years, these are likely to include landowners, farmers, employees of Nature Conservation agencies, teachers etc. These people need to be located and interviewed.

4. Monitoring

There are three important elements to monitoring a Cape Vulture breeding colony: documenting its physical characteristics, estimating the number of breeding pairs and estimating a number of demographic parameters, the most important of which is breeding success.

4.1Documenting the breeding site – physical characteristics

There are five aspects of a breeding colony which need to be documented: Site Description, Land tenure, Physical features, Bioclimatic characteristics and Land-use patterns. Once you have the data, check that the supplied information is reasonably correct. The data required is listed in Table A1, note that the essential items have been highlighted.

Table A1
The physical characteristics of a Cape Vulture breeding colony or roost site.

Notes: 1. Get all existing data from the Site register (available at EWT) as soon as possible as this may save you time and effort. 2. Fill in the essential items on your first visit and then get the rest on subsequent visits.

Entry	**Essential?**	**Description**
Site description		
Name	Yes	Please use the name supplied from the Site Register unless one does not already exist.
Region	Yes	Please use Country or Provincial codes
Co-ordinates	Yes	Record the co-ordinates as south and then east in the format: Dd.dddddd, i.e. -30.654865°S 26.968427°E
Locality	Yes	Say in your own words where the site is and how to get there. Mention any particular permits needed, dangerous dogs (or farmers) etc.
Photographic record		List the names of persons who have photographed the cliff faces and give file names etc, if known. Old photographs may be particularly important as a source of historical information.
Land tenure	Yes	Who owns or controls the land, e.g. private farmer, communal land etc.
Physical features		
Altitude		Height of the top of the cliffs, metres above sea level
Geology		E.g. Sandstone
Geomorphology		E.g. Sheer cliff above river gorge.
Faces		E.g. a series of separate faces
Aspect		The general direction in which the site faces.
Face height		From the top of the face to the scree slope below.
Dispersion		Describe how the nests are dispersed about the face, e.g. scattered in clumps of 2 or 3.
Bioclimatic		
Vegetation		
Bio-climatic region		(Only defined in KwaZulu-Natal)
Climatic regime		E.g. winter rainfall

Rainfall		About 650 mm p.a.
Wind regime		E.g. south-east in summer
Frost and snow		E.g. occasionally during the winter
Land-use patterns		
Immediate	Yes	Within 5 km, e.g. commercial farms, all pastoralist
Intermediate	Yes	Between 5 and 25 km, e.g. about 50% commercial farms, as above and about 50% communal lands, some cultivation, low livestock density
Distant		Beyond 25 km: e.g. 30% commercial farms, 55% communal lands (both as above) and 15% urban.

4.2 Photographing the breeding colony

For each colony, every nest at a breeding colony needs to have a unique identifier so that it can be tracked through time. There are several step procedures to do this:

1. Go to the best view point for each named section of the breeding cliff and take one or more photographs of the ledge, if this is possible. Each photograph should be at a sufficiently large scale so that individual nests can be clearly seen.

2. It is best to take the photographs at the start of the breeding season when the birds have finished, or nearly finished nest building. At this time it is usual for one bird of the pair to be standing on the nest and this makes the nest more visible.

3. The best photographs are taken at the time of day and in the weather conditions similar to what you will be monitoring in so that the photograph will resemble what you are likely to see when you are monitoring. Avoid taking documentary photographs in late winter or spring when the citizens of southern Africa, all of whom have arsonist tendencies, are burning the grasslands as this creates an impenetrable haze (Prof Piper pers. Comms).

4. When photographing a site first take one or more overview pictures showing all, or most, of the colony. Then take a series of OVERLAPPING photographs of each cliff. This is important because the first time you scan a cliff it is likely that you will miss some sections which might later be utilized.

5. Once you have selected the photographs you are to use in the field have them printed as large as possible to fit on an A4 sheet.

6. Carry your photographs in the field in a small concertina file so that all the photographs pertaining to a single face are kept together and staple the data sheets to each photograph!

4.3 Colony census

The primary purpose of the colony census is to record the contents of each and every nest and so deduce what breeding activity is taking place. It is essential that each and every nest be numbered and that the activities are recorded for each nest accordingly so that comparisons can be made between successive visits. The following step-by-step procedure is recommended.

1. Take your nest-recorded photographs, telescope, telescope tripod, sun-tan lotion, etc. and get to the first view site as soon as possible in the morning. Set up and scan the breeding cliff and take out the appropriate photographs and data recording forms. Scan the cliff to ensure that there are no nests on the cliff which are not on your photographs. If there are sections of the cliffs newly in use, then make a note to photograph them later or if the light allows, photograph straight away and add them onto your database.

2. Use your telescope to record the nest contents as best you can, it is often easiest to write in the activity codes as shown in Table C1 below. Each of these codes is clearly defined in this table.

Table C1
List of nest contents codes

Code	**Meaning**
W	Working - code often used early in season to indicate that a new nest is being constructed or an old nest being refurbished. Making a nest, usually adults flying in with sticks, grass or other nest material and actively re-arranging the materials
K	Copulation, usually at or on the nest

I	Incubating/brooding = a bird sitting tight on a egg/chick in the nest.
H	Nest is hidden, i.e. you can see or infer that a nest is there but the contents are not visible.
T	Tenanted nest, one or more adults standing on or close to the nest as if to demonstrate that they are holding the site
C	Nestling in the nest (we no longer use the term 'chick' as it is too imprecise)
F	Fledging at nest (i.e a bird that has flown at least once)
R	Ringed or marked adult at the nest
?	Code, or observation uncertain
-	Nest present but no other activity

3. Once you have finished the census of each section of the cliff fill in the totals at the bottom of the data form. Then scan that section of the cliff again and perform a visual check to make sure that you have not missed anything.

A blank census form is attached (Annexe 1) and is also available as a MS Excel file (datasheet CV monitoring southern Africa).

Once you have completed the census for a face you need to add up the totals for that visit. There are five totals to be captured: active nests, tenanted, incubating, nestlings and fledglings. The following definitions are used:

- **Tenanted**: Number of nests with a single adult, or a pair at the site.
- **Incubating**: Number of nests with an adult sitting tight on the nest.
- **Nestlings**: Number of chicks definitely seen.
- **Fledging** : Number of birds fledgings definitely seen
- **Active nests**: Total of Tenanted + Incubating + Nestlings + Fledgings

For each cliff face or sector (photo) a separate form must be completed, such as that shown in annexe 1.

On completing the annual census of all the faces that make up a breeding colony you need to complete the annual report and submit it to the CVTF co-ordinator (kerri.wolter@gmail.com). See attached format and guidelines.

4.4 The number of visits each year

You will have to undertake a visit at the start of each breeding season to take photographs of the cliffs. During the first visit you will also determine the best viewpoints and you will familiarise yourself with all the breeding faces. The same viewpoints must be used each year. Thereafter, a minimum of THREE visits are required:

- one to determine the number of breeding pairs in May,
- one to count the number of chicks in July/August,
- one to count of the number of fledging in September/October.

A minimum of 2 people is required for each count. This practice is important to reduce errors of counting. Each nest should be seen by both people as this is used to cross-check all observers.

4.5 Monitoring reports

At the end of each monitoring session ensure that all the spreadsheets have been filled in and that the totals have been captured. Check that no faces have been left out. If there is a colony guardian on site, make a copy of each census form and leave the copy with him or her for safekeeping. On returning home enter the data into the computer using MS Excel and e-mail all the spreadsheets to the Vulture Programme, Kerri Wolter (kerri.wolter@gmail.com). Print out the sheets for the next census and file the originals in your office and NEVER EVER take them out into the field again. After the last count please complete the annual report and use the reporting format (Annexe 2).

5. Colony conservation

Colony conservation is a six-step process in which you document the threats to the vultures at the colony, locate the stakeholders, assess the conservation issues, form the local colony liaison committee, institute conservation action and produce an annual report.

5.1 Document the threats to the vultures at the colony

From the background information you have collected and from at least one visit to the colony you should be able to get a rough idea of what threats face the vultures at their breeding site. There are likely to be 2 classes of threats namely; proximate and distant. Proximal threats are those that affect the vultures in the immediate vicinity of their colony. Distant threats are those that occur throughout their foraging ranges. The proximal threats may be classified into three categories:

Encroachment: The building of roads too close to the breeding colony, either below the face or above it and the building of homesteads, especially housing developments.

Disturbance: people coming too close to the colony for recreational purposes (e.g. mountain climbing, hiking, mountain biking etc.), people rolling stones down on the vultures, vehicles travelling too close to the vultures (e.g. motor vehicles, fixed-wing motorised aircrafts and helicopters), agriculture too close to the vultures and direct persecution (e.g. shooting, harvesting for food, pets or traditional beliefs).

Collisions: fixed structure built near breeding colonies, e.g. micro-wave towers, power-line structures, communication masts with stay-wires, buildings etc. can cause mortalities, mainly when birds fly into them in misty conditions.

Distant threats are those which may afflict vultures anywhere:

Poison: There are three classes of poisoning: direct poisoning = the vultures are deliberately targeted, this may be because they are seen as predators or because they are to be harvested. They can be 'collateral damage' in campaigns aimed at problem animal control and this is termed 'secondary poisoning' More recently, it has been discovered that there are a range of veterinary drugs, administered to livestock, which has a huge detrimental impact on vultures. A list of these drugs can be obtained from the Vulture Programme at kerri.wolter@gmail.com.

Drowning: vultures drown in farm reservoirs.

Electrocution and collisions: vultures are electrocuted on power-lines of many different sizes and also collide with power-lines and their supporting structures.

5.2 Setting up the breeding colony conservation breeding forum

Firstly, you need to locate the most important stakeholders in the immediate vicinity of a breeding colony and throughout its foraging range. Then you need to choose a small group of people who can adequately represent this community and arrange a time and place where you can meet. At this meeting you will need to tell them why you are concerned about the plight of the vultures and then listen to them while they tell you of their most important concerns. You need to identify a) the points of conflict between the stakeholders and the vultures, b) the important decision makers and influential persons in the local community and c) those common areas where you can work together with the community to ensure the conservation of the vultures.

5.3 Monitoring conservation action

In putting in place a conservation plan it is important to be able to record its success and failures. This can be done by recording the following:

1. The number of enquiries received from the general community concerning vultures, raptors and wildlife, in general. The better informed the community, the more they are likely to identify the ‘vulture champion’ as the person to ask about conservation issues.
2. The number of talks given to schools, farmers associations, community groups etc. All of these help raise awareness in the wider community.
3. The more people that ask, the more they learn.

7. Regional contacts

Botswana. Wendy Borello, Gaborone, E-mail: borello@sharps.co.bw

Eastern Cape. Kate Webster, Stormberg Raptor Project, Rookwood, PO Box 2429, Komani 5322. Tel nos:045 8394716 (landline, 0827025942 (cell), Email: katew@lantic.net

Free State. Mr Brian Colahan. Free State Department of Environmental Affairs and Tourism, Private Bag X01, Glen 9360, Free State, South Africa.

Gauteng Province. Ms Kerri Wolter, Vulture Programme, PO Box 285 Skeerpoort 0232. Mobile: +27-82-808-5113. E-mail: kerri.wolter@gmail.com

KwaZulu-Natal. Ms. Sonja Krüger KwaZulu-Natal Wildlife, P.O. Box 13053 Cascades, 3202. Tel: +27(0)332391516. Fax: +27(0)332391515. Mobile: +27(0)828774122. E-mail skruger@kznwildlife.com

Lesotho. Mr David HlosiMaphisa. C/o Prof. D.P. Ambrose, National University of Lesotho. P.O. Box 195, Roma 180, Lesotho. Mobile: +(266)-884-2898. E-Mail: dmaphisa@morijafest.com

Limpopo Province. Mr Johan van Wyk, Limpopo Dept. of Economic Development, Environment and Tourism. P.O. Box 69, Vivo, 0924.Tel: (015) 593-0702, Fax: (015) 593-0156, Cell: (083) 251-7071, e-mail: vanwykjs@ledet.gov.za

Mpumalanga Province.Mr Scott Ronaldson, Endangered Wildlife Trust, PO Box 107 Skukuza 1350, Cell 082-781-8783, E-mail scottr@ewt.org.za

Namibia. Ms Maria Diekmann. Rare & Endangered Species Trust, P.O. Box 178, Otjiwarongo, 9000, Namibia. Tel.: +264+(0)67-306226. E-mail: rest@iway.na

Northern Cape. Mark D. Anderson, Executive Director: BirdLife South Africa. P. O. Box 515, Randburg 2125, Tel: +27(0)11-7891122 (work), Tel: +27(0)53-8420883 (home); Mobile: +27(0)82-7880961. E-mail: **director@birdlife.org.za**

North-West Province. Ms Kerri Wolter. Vulture Programmeof R&L Wildlife Conservation. PO Box 285 Skeerpoort 0232. Mobile: +27-82-808-5113. E-mail: kerri.wolter@gmail.com

Swaziland. Dr Ara Monadjem. Department of Biological Sciences, University of Swaziland, Private bag 4, Kwaluseni, Swaziland. Tel: +(268)+518-4011, facsimile: +(268)+518-5276, mobile: +(268)+604-9248. E-mail: ara@science.uniswa.sz

Western Cape. Mr Kevin Shaw. Western Cape Nature Conservation Services. Private Bag X5014 Stellenbosch 7599. Tel: 27+(0)21-889-1560, facsimile: 27+(0)210-889-1523. E-mail: **Shawka@cncjnk.wcape.gov.za**

Zimbabwe. Dr Peter Mundy. P.O. Box FM 424, Famona, Bulawayo, Zimbabwe. Tel.: +(263)-9-74-000. E-mail: **mundy@gatorzw.com**

APPENDIX 2
OBSERVATION SHEET

VISIT NO. ______________________________ DATE: ___________________________________

COLONY: ______________________________ CLIFF FACE: ______________________________

COORDINATES: __________________________ WEATHER: _______________________________

TIME: _________________________________

LOC. SITE	NEST NO.	NN	EN	E	T	C	COMMENTS
TOTALS							

NN- No nest EN- Empty nest E- Egg seen T-Tenanted C- Chick seen

APPENDIX 3
SUMMARY SHEET

YEAR: ____________________ COLONY: ____________________________________

CLIFF FACE: ___________________

NEST NO.	TYPE	VISIT 1	VISIT 2	VISIT 3	VISIT 4	
1						
2						
3						
4						
5						
6						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
Total Nests						
Failed						
Hidden						
						Active Nests
Tenanted						
Incubating						
Nestling						

CODES	
W	Making a nest
K	Copulation
I	Incubation
H	Hidden
T	Tenanted
C	Chick seen
R	Ringed or tagged
?	Uncertain Observation
E	Egg seen
EN	Empty Nest
NN	No Nest seen
F	Fledged