

The Ecology and Conservation Biology of Lilian's Lovebird *Agapornis lilianae* in Malawi

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ABSTRACT

Despite their popularity, parrots are the world's most threatened birds. Lovebirds (*Agapornis*) are very popular pet and aviary birds and as ecologically specialised species in the wild, they are also among the most threatened group of birds. Lilian's lovebird *Agapornis lilianae* is a mopane *Colophospermum mopane* woodland specialist. This study represents the first detailed investigation of the species ecology in the wild.

The current distribution of Lilian's lovebird in Malawi was explored. Furthermore, the extent of the largest resident population in Liwonde National Park (LNP) was investigated. Five new atlas records are reported; three within 40-56 km of the LNP population, and two were over 150 km south and north of LNP respectively. One of them in Kasungu National Park is about 66 km from the Lilian's lovebird population in Luangwa Valley, Zambia. Lilian's lovebirds occurred throughout LNP with the highest abundance in the central section. Seasonal movements to areas outside the park were recorded. A variety of vegetation types were used by the lovebirds. The strongest vegetation associations were with seasonally wet grasslands and not mopane woodlands.

The abundance and density of the Lilian's lovebird in LNP was investigated. The highest density estimates of 17 ± 4.8 lovebirds km^{-2} were recorded in LNP's mopane woodland. However, number of observations per transect differed significantly. Waterhole counts had the lowest estimates (10 ± 3.5 lovebirds). Flyway counts had the intermediate estimate (14 ± 3.0 lovebirds). The total population of Lilian's lovebirds in LNP is therefore estimated to be about 4000 individuals. The use of line transect counts at the end of the rainy season is recommended for continued monitoring of Lilian's lovebirds abundance in LNP.

Lilian's lovebird is a secondary cavity user adapted to mopane woodlands. We investigated its roost characteristics and roosting behaviour. We quantified tree and roost site variables for roost and non-roost trees. Roosting behaviour was observed during the morning and late afternoon. Lilian's lovebirds' roosts were located in large tall mopane trees with a mean diameter at breast height (dbh) of 57.4 ± 1.64 m, a mean height of 16.5 ± 0.42 m, and with a mean cavity height of 10.0 ± 0.05 m. All roosts were located in mopane trees within mopane woodland with 10 – 50 % tree cover. Non-roost areas had significantly smaller trees (mean dbh = 39.4 ± 1.72 m) and were located significantly closer together. Human disturbance was low in both areas, however, evidence of elephant *Loxodonta africana* browsing was high with large areas of stunted mopane woodland recorded in non-roost areas. We recommend that the current LNP vegetation map be updated to highlight areas of stunted mopane woodland unsuitable for Lilian's lovebird roosts. The impact of elephant browsing on large mopane trees should be assessed to understand its impact on the availability of suitable cavities for lovebirds and other tree cavity-reliant vertebrate species.

Investigations into the diet and foraging behaviour of the Lilian's lovebird revealed they fed on 30 different plant species. These occurred in six habitat types, two of which were outside LNP (agriculture fields and dambos). In the wet season majority of Lilian's lovebirds (23 %) foraged in dambo areas, whilst in the dry season (August – November) the lovebirds mainly foraged in grasslands with tree cover (18 %). In mopane woodland feeding flock sizes differed significantly between the wet (mean = 20 ± 1.0 lovebirds) and dry season (mean = 34 ± 2.3 lovebirds). Grass seeds were their main food source from December to June. Lilian's lovebirds diet was more diverse from July to November and included leaves, leaf buds, fruits, fruit seeds and herbs. Grass seeds fed on during the wet season had a high protein and energy

content. The Lilian's lovebirds foraging habitat is protected within LNP, however, early burning in areas outside the park needs to be monitored.

The breeding biology of the Lilian's lovebird was investigated. Data were collected through a combination of direct observations and infrared camera traps during three breeding seasons. Results show large similarities with the black-cheeked lovebird *A. nigrigens* in Zambia. The breeding season was from February to May. Lilian's lovebirds nested mainly in south-east oriented deep cavities (≥ 1 m) located in large mopane trees (mean dbh = 57.6 ± 2.35 cm). Nests were located in loose clusters in the areas they roosted (mean distance to nearest nest = 24.2 m). Nest fidelity was observed. Clutch size ranged from 3 – 6 eggs, (mean 5.0 ± 0.22). We recorded 49 % hatching success and 69 % fledging success. Results suggest a low breeding success mainly due to the loss of eggs to predation.

The use of poison to kill wildlife is a threat to biodiversity. In LNP illegal hunters poison naturally occurring waterholes to catch mammals and birds for food. Lilian's lovebirds are among the victims at these poisoned waterholes. Lilian's lovebird population in LNP represents about 20 % of the global population. The drinking habits of the Lilian's lovebird, the availability of natural waterholes and the occurrence of poisoning incidents in LNP were investigated. Results showed Lilian's lovebirds congregate at waterholes in the dry season with flock sizes ranging from 1 to 100 individuals. Significantly larger flock sizes were seen in the dry season compared with the wet season. The number of poisoning incidents/year ranged from 1 to 8. The dry season had the highest numbers of poisoning incidents. Lilian's lovebirds were killed at approximately four poisoning incidents each year between 2000 and 2012. The number of lovebirds found dead at a poisoned pool ranged from 5 to 50 individuals. A list of other species affected by the poisoning is provided. There is need for increased efforts in preventing this lethal activity in the park.

Avian diseases are considered to be one of the key threats to bird conservation. Psittacine beak and feather disease (PBFD) is the most significant infectious disease in psittacines. It is caused by the beak and feather disease virus (BFDV) and currently has no cure. PBFD threatens the survival of wild populations of endangered parrots in Africa. The occurrence of BFDV was investigated in wild populations of Lilian's lovebird. In addition, evidence of blood parasites presence was also investigated to determine their general health. All samples (n = 48) tested negative for BFDV. Blood parasites were observed in 13 of the 48 samples (27 %). Investigation of virus occurrence in other known populations of the species is recommended to assess the conservation risk faced.

Lilian's lovebirds (n = 55) were mist-netted and ringed in LNP. Measurements showed that females were significantly larger than males. About 50 % of the birds ringed in October were half way through their primary moult indicating that moulting starts in earlier months possibly just after the breeding season in April.

This study highlights three of the key threats (waterhole poisoning, habitat loss and predation) to the conservation of Lilian's lovebirds in LNP and provides proposed actions to address these threats.

PREFACE

The data described in this thesis were collected in Liwonde National Park, Malawi from March 2010 to June 2014. Work was carried out while registered at the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg campus, under the supervision of Professor Mike R. Perrin and Professor Colleen T. Downs.

This thesis, submitted for the degree of Doctor of Philosophy in the discipline of Ecology in the School of Life Sciences, College of Agriculture, Science and Engineering, University of KwaZulu-Natal, Pietermaritzburg campus, represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others, it is duly acknowledged in the text.



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Tiwonge I. Mzumara
September 2014

I certify that the above statement is correct and as the candidate's supervisor I have approved this thesis for submission.



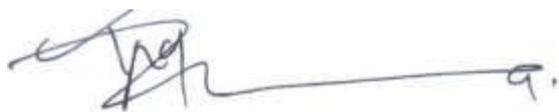
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Professor Colleen T. Downs
Supervisor
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DECLARATION 1 - PLAGIARISM

I, Tiwonge I Mzumara, declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.
2. This thesis has not been submitted for any degree or examination at any other university.
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DECLARATION 2 - PUBLICATIONS

Details of publications that form part and/or include research presented in this thesis.

Publication 1

Mzumara TI, Perrin MR & Downs CT

Distribution of Lilian's Lovebird in Malawi, Ostrich Journal of African Ornithology (in press)

Author contributions:

TIM conceived paper, collected and analysed data, and wrote the paper. MRP & CTD contributed valuable comments to the manuscript.

Publication 2

Mzumara TI, Perrin MR & Downs CT.

The drinking habits of the Lilian's lovebird and incidents of poisoning at waterholes, African Journal of Ecology (in press)

Author contributions:

TIM conceived paper, collected and analysed data, and wrote the paper. MRP & CTD contributed valuable comments to the manuscript.

Publication 3

Mzumara TI, Perrin MR & Downs CT.

Abundance of the Lilian's lovebird in Liwonde National Park, Malawi

Author contributions

TIM conceived paper, collected and analysed data, and wrote the paper. MRP & CTD contributed valuable comments to the manuscript.

Publication 4

Mzumara TI, Perrin MR & Downs CT.

Feeding ecology of the Lilian' lovebird *Agapornis lilianae* in Liwonde National Park, Malawi.

Author contributions

TIM conceived paper, collected and analysed data, and wrote the paper. MRP & CTD contributed valuable comments to the manuscript.

Publication 5

Mzumara TI, Perrin MR & Downs CT

Roosting behaviour and characteristics of cavities used by Lilian's lovebird *Agapornis lilianae* in Liwonde National Park, Malawi

Author contributions

TIM conceived paper, collected and analysed data, and wrote the paper. MRP & CTD contributed valuable comments to the manuscript.

Publication 6

Mzumara TI, Perrin MR & Downs CT

Breeding biology of Lilian's lovebird *Agapornis lilianae* in Liwonde National Park, Malawi

Author contributions

TIM conceived paper, collected and analysed data, and wrote the paper. MRP & CTD contributed valuable comments to the manuscript.

Publication 7

Mzumara TI, Perrin MR & Downs CT

Prevalence of the Beak and Feather Disease Virus in Lilian's lovebirds *Agapornis lilianae* in Malawi

Author contributions

TIM conceived paper, collected and analysed data, and wrote the paper. MRP & CTD contributed valuable comments to the manuscript.

Publication 8

Mzumara TI

Notes from ringing Lilian's lovebird *Agapornis lilianae* in Liwonde National Park, Malawi

Author contributions

TIM conceived paper, collected and analysed data, and wrote the paper.

Publication 9

Mzumara TI

Conserving the Lilian's lovebird in Liwonde National Park: A proposed conservation action plan

Author contributions

TIM conceived paper, collected and analysed data, and wrote the paper.



Signed:

Tiwonge I. Mzumara

September 2014

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CHAPTER 1: Introduction

Ecology, conservation biology and African birds

Organisms and the relationships they have with their environment provide the basis of the science of ecology (Haeckel 1866). These relationships, at both spatial and temporal scales, include organism characteristics, evolution, populations, interactions, community organization and many more (Belovsky et al. 2004). The ecology of a species is essential in planning for its conservation (Doak & Mills 1994, Snyder et al. 2000). Conservation biology addresses the biology of species, communities, and ecosystems that are in crisis (Soulé 1985). These require targeted and strategic conservation action in order to reduce the rate of loss (Hoffmann et al. 2010).

Birds have popular appeal, and are known and studied more than any other species (Brooks et al. 2008). In Africa, birds are part of many cultures (BirdLife 2013a). Nevertheless, about 10% of all African bird species are threatened with extinction, with 25 species up listed on the IUCN list between 2005 and 2012 (BirdLife 2013a). Poisoning, hunting, habitat loss and capture for the illegal bird/pet trade are some of the threats that these bird populations are facing (Eid et al. 2011, BirdLife 2013a). The need for ecological studies that can inform conservation actions cannot be over emphasized.

This study aims to elucidate the ecology of a poorly known small parrot, Lilian's Lovebird *Agapornis lilianae* in Malawi. These are needed to inform conservation measures to ensure the continued existence of this species. This is the first detailed study of this species in the wild. It also contributes to the global need for the conservation of parrots.

Parrots

Parrots (family *Psittacidae*) are represented by about 330 parrot species worldwide (Collar et al. 1994). The majority are resident in the southern hemisphere; Africa, Australasia and South America (Waterhouse 2006). However, fossil records suggest plesiomorphic parrots and parrot-like bird were once resident in the northern hemisphere, especially northern Europe (Waterhouse 2006). The oldest African fossil parrots were found in Langebaanweg (South Africa) and these fossils have led to the recent description of two new parrot species (Manegold 2013).

Parrots are a popular and easily recognised bird species (Collar 1997, Perrin 2012, Martin et al. 2014a,b). Their beautiful plumage, longevity, and some species ability to mimic human speech (Wright et al. 2001) have made them one of the most desired pet bird species in the world (Pires and Clarke 2011). They are also the world's most threatened birds (Collar et al. 1994, Collar 1997, Owens & Bennett 2000). At least 29 % (95 species) of the world's parrots are threatened (Snyder et al. 2000). A combination of habitat loss and their capture for the pet trade are the key threats to their populations (Collar 1997, Snyder et al. 2000, Perrin 2012). In 2000 an action plan was drawn with the goal to ensure the conservation of the world's parrot species (Snyder et al. 2000). This plan clearly recognized that most of the threatened parrot species lacked comprehensive field studies to plan for their conservation (Snyder et al. 2000). This has resulted in an increase of published parrot accounts worldwide (Martin et al. 2014). New information on parrot ecology and conservation status has led to a number of red list updates in the IUCN Red List (BirdLife 2013a,b; Martin et al. 2014). Parrots in Africa and its islands were previously poorly known, however, in recent years publication of parrot research, including comprehensive species accounts, books and reviews have contributed to knowledge of these species (Perrin 2012, Martin et al. 2014a,b). There

are 24 species of parrots in Africa, Madagascar and Mauritius (Perrin 2012). The African species are represented by five genera *Poicephalus*, *Psittacus*, *Coracopsis*, *Agapornis* and *Psittacula* (Perrin 2012).

Lovebirds

The genus *Agapornis* is endemic to Africa and Madagascar and comprises the smallest of all the African parrots (Perrin 2012). *Agapornis* is derived from two Greek words ‘agape’ and ‘ornis’. The word ‘agape’ is from early 17th century Greek and means ‘love’, more especially ‘brotherly love’ (Jobling 2010). The word ‘ornis’ is a classical Greek word meaning ‘bird / avifauna’ (Jobling 2010). Thus the representatives of the genus *Agapornis* are commonly known as lovebirds. Another suggested reason for this common name is their habit of indulging in mutual preening (Forshaw 1977). There are nine species, eight on mainland and one species in Madagascar (Perrin 2012). All African species have bright green plumage with facial masks of varying colours and extent. In contrast, the Madagascar lovebird species, the grey-headed lovebird (*Agapornis canus*) differs slightly from the rest having a green body and a completely grey head. The eight African species have an allopatric distribution covering a wide range of sub-Saharan Africa (Perrin 2012, Table 1).

Table 1. Summary of the threat status and distribution of the lovebird species (Birdlife International 2013b).

Species	Threat status & distribution
<i>Agapornis canus</i> (Grey-headed lovebird)	Least Concern. Native to Madagascar. It has a wide range but its population has not been quantified.
<i>Agapornis swindernianus</i> (Black-collared lovebird)	Least Concern. Native to Cameroon; Central African Republic; Congo; Congo, The Democratic Republic of Congo; Côte d'Ivoire; Equatorial Guinea; Gabon; Ghana; Liberia; Uganda.
<i>Agapornis pullarius</i> (Red-headed lovebird)	Least concern. Species has a wide range occurring in over 10 countries. Population largely unknown.
<i>Agapornis roseicollis</i> (Rosy-faced lovebird)	Least concern. Native to Namibia, South Africa & Angola. Has a wide range.
<i>Agapornis taranta</i> (Black-winged lovebird)	Least concern. Native to Ethiopia & Eritrea. Has a wide range. Population thought to be increasing.
<i>Agapornis fischeri</i> (Fischer's lovebird)	Near-threatened. Endemic to Tanzania. Population declining due to trapping for export.
<i>Agapornis personatus</i> (Yellow-collared lovebird)	Least concern. Native to Tanzania, introduced to Kenya & Burundi. Has a wide range.
<i>Agapornis lilianae</i> (Nyasa lovebird)	Near-threatened. Occurs in Mozambique, Malawi, Tanzania, Zambia & Zimbabwe. Small population suspected to be declining.
<i>Agapornis nigrigenis</i> (Black-cheeked lovebird)	Vulnerable. Endemic to Zambia. Has a small localised distribution.

Note: wide range- wide includes several countries or a whole country.

Lovebirds are popular pet and aviary birds (Collar 1997). The trapping of wild lovebirds for the illegal pet trade remains a major threat to their wild populations (Collar 1997, Martin et al. 2014a,b). In the last two decades there have been records of trade in all lovebird species apart from *A. swindernianus* (Martin et al. 2014b). Very little information exists on this species and it is largely unknown in local and international trade (Perrin 2012). *Agapornis fischeri*, *A. personatus* and *A. roseicollis* were among the most traded lovebirds in the last two decades (Martin et al. 2014b). The lack of ecological data on wild populations of lovebirds makes it difficult to estimate the impact of the illegal pet trade on them.

Several studies have investigated various aspects of lovebird biology in captivity (Dilger 1960, Kock et al. 1993, Burton et al. 2008). In the wild, only three species have been studied. Firstly, the black-cheeked lovebird, endemic to Zambia, had detailed studies of its distribution and biology investigated (Dodman et al. 2000, Warburton 2003, Warburton & Perrin 2005a,b). These highlighted the threats and areas to be protected for its conservation (Dodman et al. 2000, Warburton 2003). Secondly, the rosy-faced lovebird, endemic to Namibia, had its diet, breeding and spatial ecology investigated (Ndithia and Perrin 2006a,b, Ndithia et al. 2007). Thirdly, a study in Tanzania investigated the diet and inter-specific associations of Fischer's lovebird (Mwangomo et al. 2008). In addition to these, a study on inferences of breeding from moult of a hybrid population of lovebirds at Lake Naivasha in Kenya was undertaken (Thomson 1990). The current study focuses on Lilian's lovebird, previously little investigated in the wild.

Lilian's / Nyasa lovebird

Named after Miss Lilian Elizabeth Sclater, the British naturalist and traveller in East Africa (Shelley 1894), the Lilian's lovebird *Agapornis lilianae* (Fig. 1) was first observed in the upper Shire area of Malawi (then Nyasaland) by Sir John Kirk (Ibis, 1864, pp 329). It was initially wrongly identified as *Agapornis roseicollis* (Ibis, 1864b, pp 329), then later corrected by Captain G.E. Shelley in 1894 who described it from a voucher specimen collected in Fort Liwonde (Ibis, 1884 p466). Lilian's lovebird is red listed as a near threatened species due to its small population estimated to be less than 20 000 (Birdlife 2013b). Its population is scattered in small sub-populations along the Zambezi Valley (Warburton 2005).



Figure 1. Lilian's lovebird, adult. Liwonde National Park, Waterhole three, 14 October 2008.

(photograph by Bentely Palmer).

Lilian's lovebird occurs in south-east Zambia and southern Tanzania along the Luangwa River, into Mozambique, Zimbabwe, and along the Shire River in southern Malawi (Warburton 2005, Dowsett-Lemaire & Dowsett 2006, Dowsett et al. 2008, BirdLife 2013b, Fig. 2, Table 2). In Malawi a resident population of Lilian's lovebird occurs in Liwonde National Park (LNP, Fig. 2, 3), which lies along the Shire River. These lovebirds are often seen being sold along the roads near LNP, however, Lilian's lovebirds have never been sighted (Mzumara, pers. obs.). There are no aviaries in and around LNP, therefore all individuals seen are from the wild population (Mzumara, pers. obs.). The lovebirds continued existence in LNP is threatened by poachers who poison water pools in order to catch small mammals (pers. comm.). The communities around LNP view the lovebird as an agricultural pest and hunt them in their crop fields (Mzumara, pers. obs.). The impact of these activities on its population was unknown.

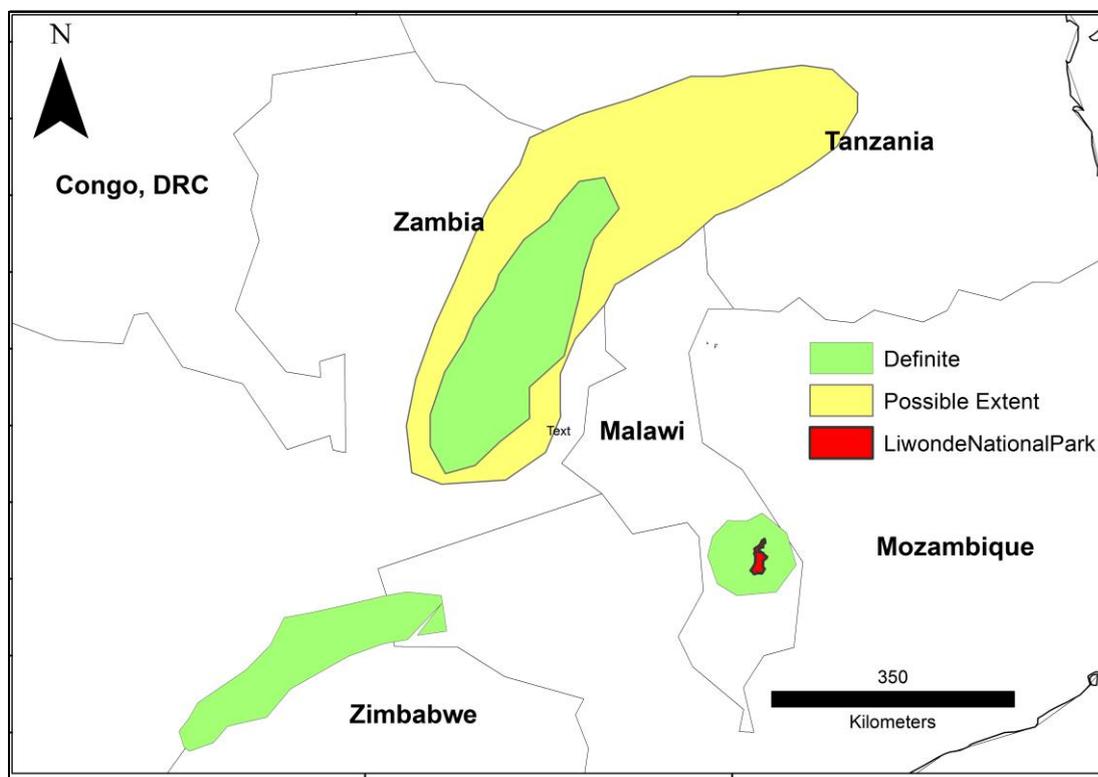


Figure 2: Map showing the distribution of Lilian's lovebird (BirdLife International 2013b).

Table 2. Distribution localities of Lilian’s lovebird according to country.

Country and area	Location
Southern Tanzania	A single observation in the Songwe area (N. Baker, pers. comm.)
Southeast Zambia	Common along the Luangwa Valley, north at least to the Muzi River & near Chama. Reported to occur in the Luano and Rufunsa Valleys (Dowsett et al. 2008)
Northwest Mozambique	Present in the drier parts of the Zambezi River Valley in Tete district, where locally common. Recorded in Chicua, Chishomba/Cachomba, and Zumbo/Alexander, & collected in Messenguense (Parker 2005)
Northern Zimbabwe	Occurs in the middle Zambezi below the escarpment from the Angwa & Hunyani Rivers westwards to Binga & Msuna, although much suitable habitat has been lost within the Kariba Basin (Irwin 1981).
Southern Malawi	Common in Liwonde National Park & surrounding areas along the Shire River, in southern Malawi. Few records from Kasungu National Park in the North of the country (this study, Dowsett-Lemaire & Dowsett 2006)

Study area

LNP is bordered by three districts Machinga, Mangochi and Balaka (Fig. 3) and is part of the Liwonde-Mangochi Protected Area Complex (LMPAC). The greater part of LNP is located in Machinga District in southern Malawi. The LMPAC comprises two protected areas, Liwonde National Park located between 14°36' to 15°03'S and 35°15' to 35°26'E, and the Mangochi Forest Reserve (MFR) to the north (Manongi 2004). LNP covers an area of 548 km² and ranges in altitude from 474 to 921 m asl. The park has a 'hard' boundary without a buffer zone along most of its length (Thomson 1998).

LNP is bound in the west by the Shire River and Lake Malombe and in the east by hills and ridges of the escarpment (Fig. 3). The topography is gently sloping, upward from the river, and is broken by two isolated groups of hills. The average annual rainfall recorded from 1977 to 1995 reported by the Research Unit at Chinguni was 999 mm with a maximum record of 1,091 mm (Happold & Happold 1990) and a minimum of 401 mm (Bhima 1998). Over nine-years (1986-1994) the same station recorded a mean maximum temperature of 31.2°C for November and mean minimum temperature of 18.5°C for July (unpublished data, Bhima 1998).

Around the borders of LNP there is a high density of villages with approximately 115-126 inhabitants km⁻² (NSO 2008). The annual human birth rate of 2.5 – 5 % (FAO 1997) indicates that the population is growing and will double by 2030 (NSO 2008). This places great pressure on land in and around LNP. This high population density imposes poaching pressure on LNP. Some of the local community members that hunt illegally in LNP now use lethal hunting methods such as poisoning waterholes (pers. comm.). These methods have a potentially devastating impact on the parks biodiversity especially on a gregarious bird like the Lilian's Lovebird (Mzumara pers. obs.). This lethal hunting is a major reason this study.

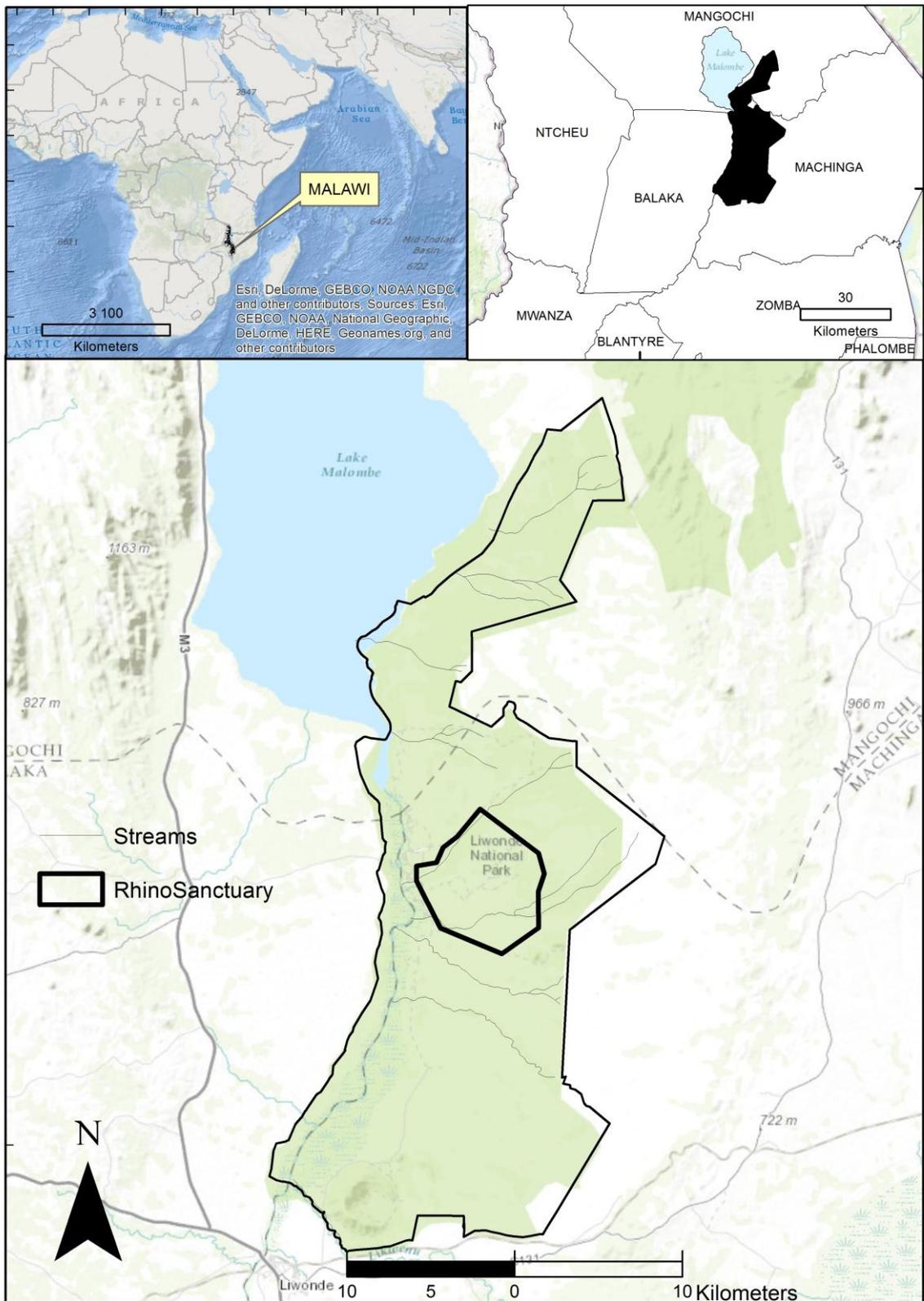


Figure 3. Location of Liwonde National Park (LNP) in Malawi.

Study objectives

This study investigated the distribution of Lilian's Lovebirds in LNP and Malawi and estimated its population density in LNP and compared this with suggested earlier population estimates (Dowsett-Lemaire & Dowsett 2006). The natural diet, drinking requirements, roosting and breeding behaviour were also investigated through field observations. The existence of threats such as disease, illegal trade, poisoning, predation and capture for food were investigated. The data chapters of this thesis have been prepared as manuscripts for international peer review journal submission. Therefore each of these chapters is formatted for a specific journal, and some overlap and repetition between chapters has been unavoidable. There is a final concluding chapter.

The data chapters are as follows:

Chapter 2: Distribution of Lilian's lovebirds in Malawi.

Chapter 3: Abundance of the Lilian's lovebird in Liwonde National Park, Malawi.

Chapter 4: Feeding ecology of the Lilian' lovebird *Agapornis lilianae* in Liwonde National Park, Malawi.

Chapter 5: Roosting behaviour and characteristics of cavities used by Lilian's lovebird *Agapornis lilianae* in Liwonde National Park, Malawi.

Chapter 6: Breeding biology of Lilian's lovebird *Agapornis lilianae* in Liwonde National Park, Malawi.

Chapter 7: The drinking habits of the Lilian's lovebird and incidents of poisoning at waterholes.

Chapter 8: Prevalence of the beak and feather disease virus in Lilian's lovebirds *Agapornis lilianae* in Malawi.

Chapter 9: Notes from ringing Lilian's lovebird *Agapornis lilianae* in Liwonde National Park, Malawi.

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CHAPTER 2: Distribution of Lilian's Lovebirds in Malawi

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Abstract

Lilian's Lovebird *Agapornis lilianae* is a Mopane *Colophospermum mopane* woodland specialist. Its global population is sparse and is spread along the Zambezi valley with little known about its current distribution and status. Consequently, the current distribution of Lilian's Lovebird in Malawi was explored. Furthermore, the extent of the largest resident population in Liwonde National Park (LNP) was investigated. Local birders and tourist guides provided distribution information from across Malawi. Transect walks were conducted to collect data from LNP. Five new atlas records are reported; three within 40-56 km of LNP population and two, were over 150 km south and north of LNP respectively. One of them, (KNP) is about 66 km from the Lilian's Lovebird population in Luangwa Valley, Zambia. New national records suggest seasonal movements. Lilian's Lovebirds occurred throughout LNP with the highest abundance in the central section. Seasonal movements to areas outside the park were also recorded. A variety of vegetation types were used by the lovebirds. The strongest habitat associations were with seasonally wet grasslands and not Mopane woodlands as would be expected. Conservation efforts should also include these vegetation types.

Keywords: Lilian's Lovebird, *Agapornis lilianae*, distribution, Mopane woodland.

Introduction

The loss of forests and woodlands in Africa is largely caused by their conversion to agricultural lands (FAO 2010). Habitat loss occurs due to deforestation and is a key threat to biodiversity (Owens and Bennett 2000). It is one of the key reasons behind the up-listing of 25 African bird species to higher categories of threat between 2005 and 2012 (BirdLife 2013). Human population growth, poverty, weak governance and political systems all contribute to high deforestation rates in Africa (Mather and Needle 2000, Lambin et al. 2001, Smith et al. 2003, Rudel 2007). However, regardless of this threat, the status and distribution of many threatened bird species in Africa is still unknown (Brooks et al. 2008). It is important to enable monitoring of populations over time, and to understand the impact of various threats (Snyder et al. 2000, Brooks et al. 2008, BirdLife 2013).

Information on status and distribution is of great importance for parrot species as they are among the world's most threatened species with a high extinction risk (Snyder et al. 2000, Martin et al. 2014). Africa, Mauritius and Madagascar are home to 24 parrot species belonging to five genera, *Poicephalus*, *Psittacus*, *Coracopsis*, *Agapornis* and *Psittacula* (Perrin 2012). Most have an allopatric distribution, covering a wide variety of habitats ranging from closed forests to arid zones (Fry et al. 1988, Perrin 2012). The genus *Agapornis*, commonly known as the lovebirds, is the smallest of all African parrots (Perrin 2012). It has nine species, eight on mainland Africa and one in Madagascar (Forshaw 1989, Perrin 2012).

Lilian's Lovebird *Agapornis lilianae* is a near Zambezian endemic with a restricted range extending downstream from the Zambezi Valley (Clancey 1996, Dowsett-Lemaire and Dowsett 2006). Isolated populations are distributed in southern Tanzania, south-east Zambia, southern Malawi, north-western Mozambique and northern Zimbabwe (Warburton 2005,

Dowsett-Lemaire and Dowsett 2006). Lilian's Lovebirds are a specialist of Mopane *Colophospermum mopane* woodlands but are reported to move seasonally to more mixed woodland (Harrison et al. 1997, Parker 2005). They are a Near-threatened species because of their small global population of < 20 000 birds which has a restricted distribution and specialised habitat (Perrin 2012, BirdLife 2014). Like most other parrots, Lilian's Lovebirds are regarded as a CITES II species, meaning that if trade is not closely monitored the species will likely face a high risk of extinction (CITES 2012).

Habitat destruction and the trapping of wild birds for the illegal pet trade are among the major threats to Lilian's Lovebird (Couto 1996, Harrison et al. 1997, Parker 2005, Perrin 2012). The creation of the Kariba Dam in Zimbabwe and the Caborra Bassa Dam in Mozambique in the 1960's and 1970's caused considerable damage and destruction to Lilian's Lovebird habitat (Parker 2005). Illegal shipments of over 3000 wild-caught Lilian's Lovebirds were seized in Zimbabwe in the 1990's (Couto 1996) and an estimated 9 938 Lilian's Lovebirds were traded between 1990 and 2009 (Perrin 2012). Despite these threats, there have not been studies to determine the habitat associations, seasonal movements, status and or distribution of Lilian's Lovebird in its range.

An accurate knowledge of a species' distribution and population trend is necessary to understand its population dynamics and design better conservation initiatives (Snyder 2000, Perrin 2012). Prior to this study, in Malawi, Lilian's Lovebirds were known to be confined to the upper Shire River valley in Liwonde National Park (LNP) and in Mbalachanda, north-western Malawi, close to the Zambian border (Dowsett-Lemaire & Dowsett 2006). A single record from the mid 1940's for the Kalembo area, west of LNP also exists (Dowsett-Lemaire and Dowsett 2006). LNP is a globally recognised Important Bird Area (IBA) (Dowsett-

Lemaire et al. 2001) on the eastern banks of the Shire River which is Lake Malawi's only outlet.

This study established the current extent of Lilian's Lovebird distribution in Malawi, in light of its historical range. We also investigated the habitat association of the LNP lovebird population. We predicted the Lilian's Lovebird distribution to be concentrated in Mopane woodland within LNP, as recorded for its closest relative, the Black-cheeked Lovebird *A. nigrigenis* in Zambia (Warburton 2003, 2005).

Methods

Study Area

LNP is located between 14°36' to 15°03'S and 35°15' to 35°26'E (Manongi 2004). It covers an area of 548 km² and ranges in altitude from 474 to 921 m a.s.l. The park has a 'hard' partially fenced boundary with no buffer zone along most of its length (Thomson 1998). The most common land use in the areas immediately bordering the park is agriculture (Mzumara, pers. obs.). To the west of the park, 1 km from the boundary, are the two major water bodies for the park; Lake Malombe and the Shire River. These two joined water bodies cover a distance of about 35 km from north to south of the park (Fig. 1 and 2).

Around the borders of LNP is a high density of villages with approximately 115-130 inhabitants per km² (NSO 2008). The annual human birth rate of 1.2 % (NSO 2008) places great poaching pressure in the protected area (Dowsett-Lemaire and Dowsett 2006). Six main vegetation communities are recognised in LNP; riverine and flood plain vegetation, tree

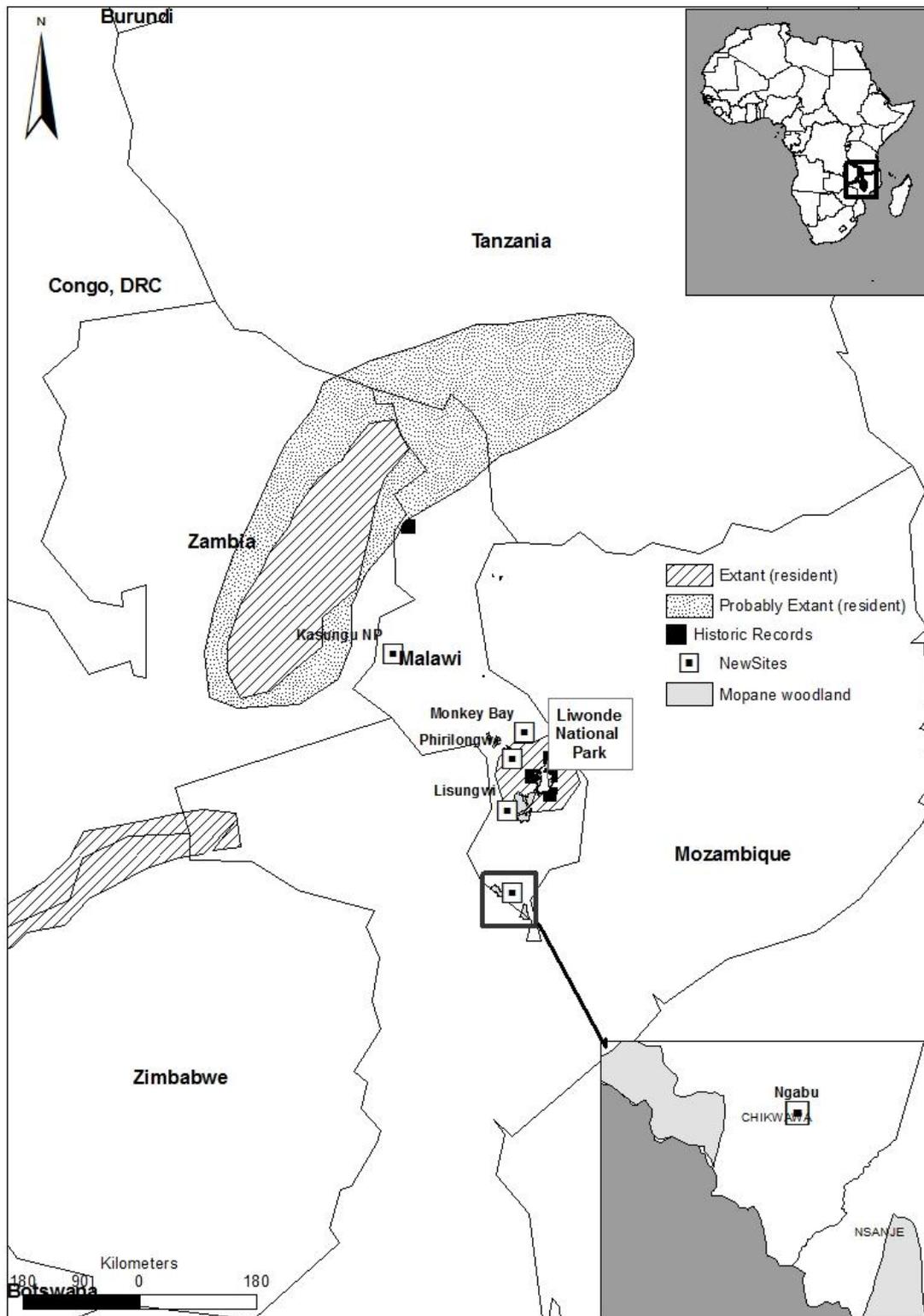


Figure 1: Distribution of Lilian's Lovebirds in Malawi including historical sites (Dowsett-Lemaire & Dowsett 2006), new sites recorded in this study and the current IUCN distribution maps (IUCN 2012).

savannah, *Combretum* savannah-woodland, *C. mopane* woodland, termitaria communities (thickets) and dry forest (Hall-Martin 1969). The dominant vegetation is Mopane woodland covering approximately 70 % of its area (Dudley 1994). We used vegetation descriptions described by the Zoological Frankfurt Society LNP vegetation management map (Msikuwanga pers. comm.). The map divides LNP's main vegetation communities into nine classes (Table 1).

Table 1: Percentage of observations and mean flock size of Lilian's Lovebirds recorded in different vegetation types in Liwonde National Park, Malawi.

Vegetation Type	Sightings (n)	%	Mean flock size (± SE)
Mopane	168	57.7	10.8 ± 0.1
Grass with tree cover	53	18.2	17.4 ± 0.5
Tall grass, tree savanna	24	8.3	17.8 ± 1.1
*Agriculture fields	17	5.8	12.5 ± 1.4
Mixed savannah woodland	10	3.4	8.8 ± 0.6
Riverine thicket	8	2.8	22.4 ± 2.6
Seasonally wet grassland	6	2.1	25.2 ± 6.2
*Water	3	1.0	5.0 ± 1.7
Escarpment mixed woodland	1	0.3	11
Marsh	1	0.3	12
Dry deciduous forest/thicket	0	n/a	n/a

*Not part of LNP vegetation

Distribution of Lilian's Lovebird in Malawi

Historical distributions of Lilian's Lovebird were obtained from the Birds of Malawi Atlas (Dowsett-Lemaire and Dowsett 2006). Data from across Malawi were collected from June 2010 to December 2013. Information leaflets, which included Lilian's Lovebird sighting record sheets, were distributed to scout camps in protected areas, national tourism guides, tour operators and other interested birders to report and record any Lilian's Lovebird sighting throughout Malawi. Site visits to all reported areas were conducted between October 2010 and December 2013.

Distribution of Lilian's Lovebirds in LNP

LNP Management uses an existing map of 25 transects (2 km apart) across the park for an annual mammal census. Thirteen transects were selected from the existing transect map (Fig. 2). Each transect was walked at a constant speed (approx. 2 km h⁻¹) east to west twice a year in 2010 and 2012; once immediately after the rainy season (April – May) and once in the dry season months of September – October (the term dry season refers to the period from August to November, this is the time of the year when the park receives little to no rain). Transect walks were conducted from 05h00 to 11h00 and all Lilian's Lovebird sightings were recorded. Drive transects were conducted during the same season and timings on three of the LNP's main roads (Chinguni – Mvuu, Mvuu – Masanje, Mvuu – Mvera). The car was driven at relatively constant speed of approximately 15 km h⁻¹.

An additional three transects, running continuously from north to south on the western bank of the Shire River were also walked. The data collected in the western bank were used to investigate Lilian's Lovebird presence in the small area of LNP west of the Shire River

(Fig. 2). Opportunistic sightings were recorded during roost searches conducted on foot in LNP. These were also conducted in agriculture fields and village settlements outside the park.

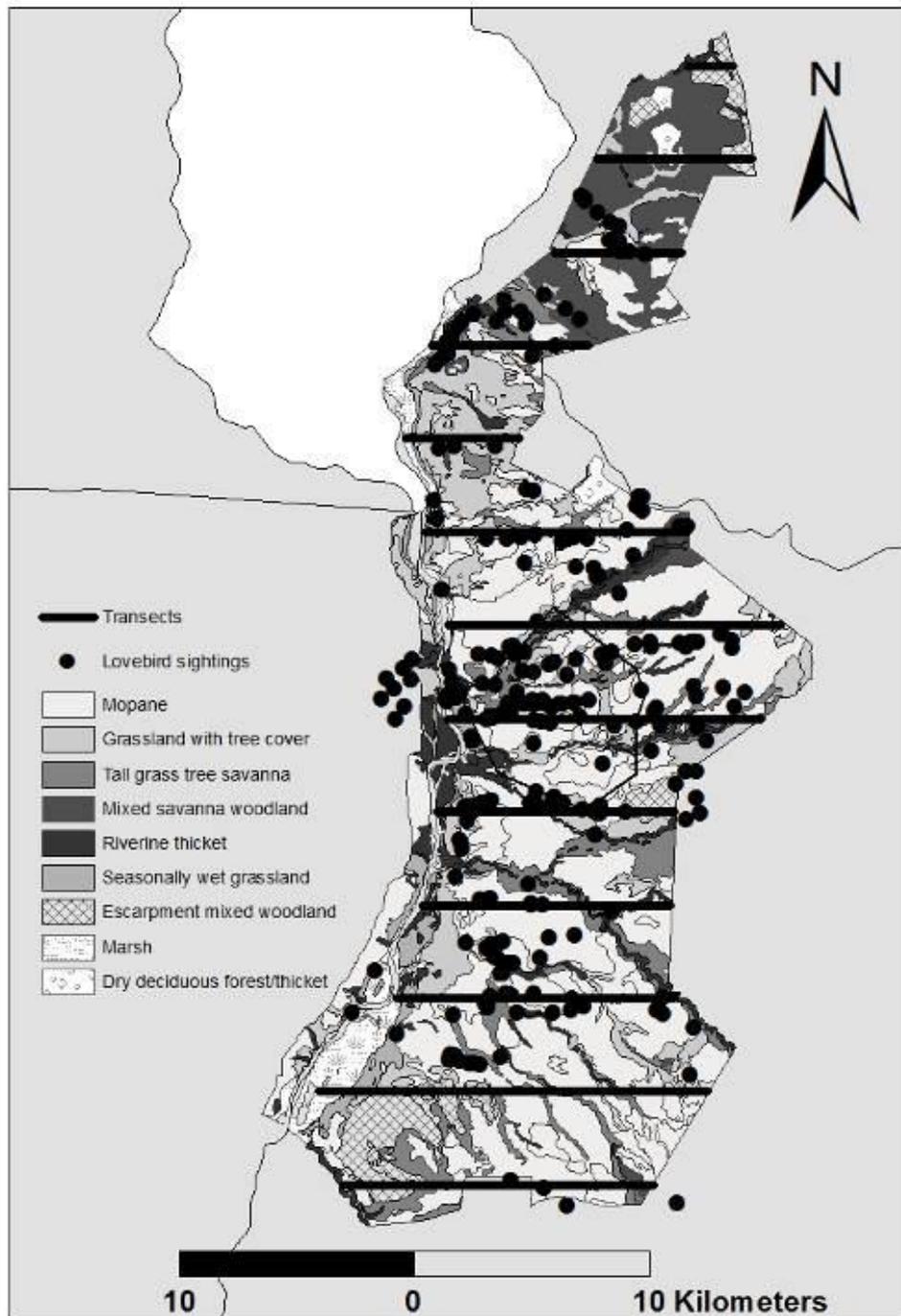


Figure 2: Lilian's Lovebird sightings in Liwonde National Park, Malawi, during the current study.

All geographic locations where the lovebirds were sighted were identified with a Geographic Positioning System (GPS) and the flock size was recorded (Warburton and Perrin 2005a, Mwangomo et al. 2007). Ivlev's electivity index (Ivlev 1961) was used to evaluate habitat association. The index ranges from -1 to $+1$; negative values suggest avoidance while positive values suggest preference and 0 suggests a neutral response (Manly et al. 1993). Mann-Whitney U and Kolmogorov-Smirnov tests were applied using STATISTICA 7 (StatSoft Inc. Tulsa, USA) to test the differences between mean flock sizes in different habitats and in different seasons. Data from drive transects, the western bank and opportunistic sightings were excluded from vegetation association analysis due to bias in search effort.

ArcGIS 10.1 (ESRI 2012) was used to delineate a flat 50 m wide buffer around each of the 13 transects. This buffer was used to 'clip' the LNP vegetation layer; thereafter proportions of each habitat in the 'clipped' sections were calculated. The total area of all the habitat types covered by transects was calculated using ArcGIS 10.1 software. A spatial association was made between the parks vegetation map and all points recorded in LNP and within a 5 km buffer area outside the park. Existing maps of LNP features (i.e. vegetation) were obtained from the Department of National Parks and Wildlife and the Frankfurt Zoological Society. Shape files for the current global Lilian's Lovebird distribution were down-loaded from the IUCN website. These were used as a reference point for all other recorded points (IUCN 2012)

Results

Distribution of Lilian's Lovebird in Malawi

Five new atlas records for Lilian's Lovebirds in Malawi were received from the nationwide survey (Table 2). Three sites were within 40 - 60 km of LNP, Lisungwi, Phirilongwe and Monkey Bay/ Cape MacLear. These were within the immediate edge of the IUCN proposed range for the species in Malawi (Fig. 1). During the site visit, community members stated that Lilian's Lovebirds were often seen in June and July. The reported observation was made on communal land along a river with irrigation agriculture along the river banks (Mzumara, pers. obs.), inferring land use change had occurred. Mopane woodlands were not observed in the area. However, a few isolated Mopane shrubs were present. The presence of agricultural fields and the river provided potential food and water sources accessible to Lilian's Lovebirds, thus making it a suitable foraging area.

The Phirilongwe Forest Reserve is a protected area managed by the Forestry Department. The reserve has small patches of Mopane woodland within its boundary. Lilian's Lovebirds were not recorded in the area during the site visits in October 2010 and May 2013. Local communities observed Lilian's Lovebirds around the area from May to July. Two independent reports were received for sightings in the Monkey Bay/Cape MacLear area. One sighting was in June 2011 while the other was undated. No lovebirds were seen during the June 2012 site visit, however about 20 Lilian's Lovebirds were seen in March 2014 feeding in a Baobab tree (*Adansonia digitata*). The area is on communal land along the road from Monkey Bay to Cape MacLear. One of the key features in the area was the large Baobab trees whose flower petals the lovebirds fed on.

Table 2: Five new atlas records reported in Malawi.

Area Name	Distance from LNP (km)	No. of individuals seen	Date of sighting	Date of site visit
Lisungwi	55.8	20	July 2011	Oct 2012, May 2014
Phirilongwe	43.6	> 50	June 2010	Oct 2010, May 2013
Monkey Bay/ Cape MacLear	55.3	50	Undated, June 2011, March 2014,	June 2012, Dec 2013
Kasungu National Park	± 280	± 20	Jun2 2010	Nov 2013
Ngabu	± 160	±10	undated	Nov 2013

Kasungu National Park (KNP), in Malawi's central region, is approximately 280 km north of LNP. The reported point is relatively close (66 km) to the Lilian's Lovebird population in the Luangwa Valley, Zambia (Fig. 1). KNP is about 200 km from the historical Mbalachanda Lilian's Lovebird record in northern Malawi. Ngabu, on the other hand, is located in the lower-Shire Valley in southern Malawi, approximately 160 km south of LNP. This area is close to the Malawi-Mozambique border but over 400 km from the known Lilian's Lovebird population in Mozambique. However, when mapped against the map of Mopane distribution in Malawi, the Ngabu record is close to two small patches (each approximately 180 km²) of Mopane woodland in southern Malawi (Fig. 1). Visits to the site,

however, revealed that the small Mopane woodlands visible on the map are part of a large cattle farm. The majority of the Mopane woodland on the farm comprised young trees with diameters at breast height < 10cm. Most of the Mopane vegetation was either coppicing stems or Mopane shrubs. Nevertheless, within the nearby area, there are a few private farms and residential areas that have large Mopane trees comparable with those in LNP.

Distribution of Lilian's Lovebird in LNP

Lilian's Lovebirds were recorded at 303 points within and around LNP (Fig. 2). Thirty-nine per cent (n = 117) of the points recorded were from the east-west transect walks. Lilian's Lovebirds were distributed throughout the park including the small section of the park on the western bank of the Shire River. All observations of Lilian's Lovebirds in the northern section of LNP were made during transect walks carried out in the months of September to November. No lovebirds were recorded in the same areas during wet season transect walks between April and May. Targeted searches in June and July also confirmed that the lovebirds were not present in the area. The inaccessibility of this area during the months of January to April prevented us from checking the presence or absence of the lovebirds during these months.

Approximately 10 % (29) of all the records were outside the LNP boundary. The majority of these records (79 %) were in villages west of LNP where Lilian's Lovebirds were observed feeding, including agricultural fields, and along small rivers and streams. Twelve observation records were from agricultural fields > 10 km outside the LNP boundary, including the Kalembo area where it was assumed the lovebirds no longer occur.

Most of the points recorded (58 %, n = 168) were made in Mopane woodland (Table 2). However, 76 % of the observations on east-west transects were made in Mopane woodland. The Ivlev's electivity index obtained for Mopane woodland and 'Grassland with tree cover' was positive indicating preference (Fig. 3). However, a much stronger preference was seen for seasonally-wet-grassland (Fig. 3). The mean flock size in Mopane woodlands was significantly smaller than that of other vegetation types; flocks in Mopane woodland (mean = 10.8 ± 0.12 , n = 168) compared well with other vegetation types, (mean = 17.40 ± 0.50 , n = 123) (Kolmogorov-Smirnov test, $p < 0.0007$). The largest flocks were recorded in two vegetation types, seasonally-wet-grassland and riverine thicket (Table 2). Flock sizes of the lovebirds were significantly larger in LNP in the dry season than in the wet season (Mann-U test, $p < 0.004$).

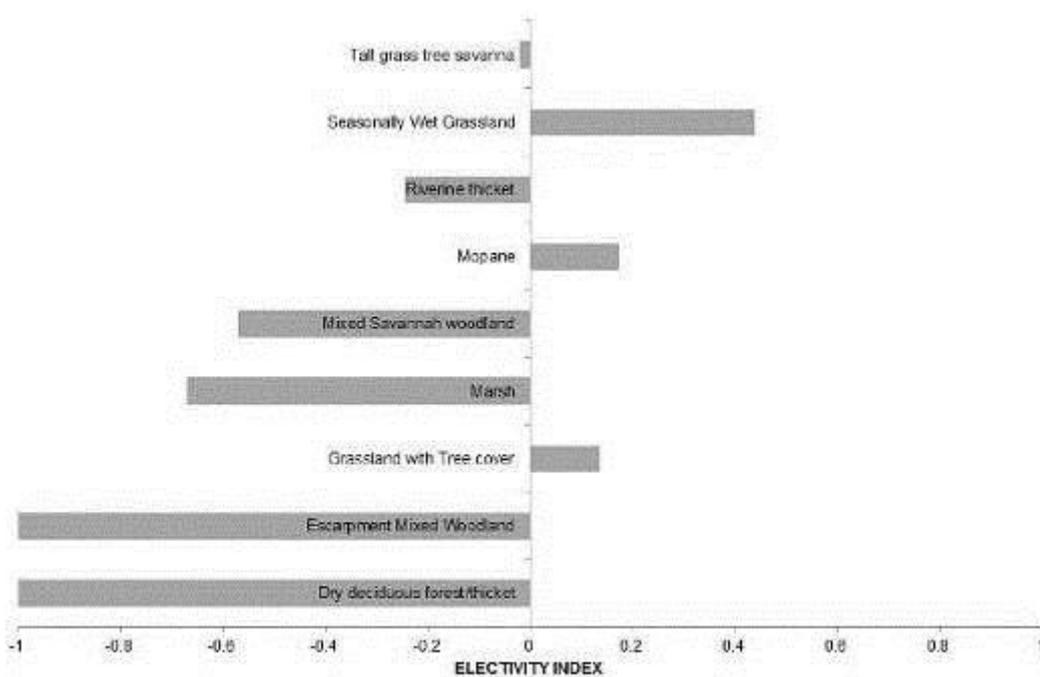


Figure 3: Ivlev's electivity index for Lilian's Lovebird vegetation association in Liwonde National Park, Malawi.

Discussion

The distribution of Lilian's Lovebird in Malawi remains largely within the range described by Dowsett-Lemaire and Dowsett (2006). Their stronghold is a resident and breeding population in LNP. However, three new atlas records have been recorded close to this range: all are seasonal and non-resident. We confirmed that Lilian's Lovebirds still occur in the Kalembo area, as part of the LNP population, where it was thought they may no longer occur (Dowsett-Lemaire & Dowsett 2006). The lovebirds feed in the area but return to LNP to roost. The lovebirds were recorded in agricultural land with a number of *Vachellia* sp. (Acacia) trees but no Mopane woodland. Lilian's Lovebirds feed on Acacia seeds and agricultural crops (Mzumara in prep.).

The KNP and Ngabu sightings of the Lilian's Lovebird represent new distribution areas that are outside the previously known range. Seasonal movements are the most likely explanation for these sightings. These seasonal visitors possibly originate from the eastern limit of the Luangwa Valley Lilian Lovebird population in Zambia. This was also suspected for the single old Mbalachanda record (Dowsett-Lemaire and Dowsett 2006). The sighting record from KNP is evidence that the distribution from Zambia extends further east than shown in the current IUCN maps (IUCN 2012).

The Ngabu sighting is likely of a vagrant flock originating from the Mozambique population. This population may also extend further east than is currently recorded. Further investigation into the status of the Lilian Lovebird populations, the current Mopane distribution and the possibility of seasonal movements in Mozambique is needed. This is particularly urgent as the tobacco industry may increase in this area. Mopane wood is

preferred for tobacco processing (Chikuni 1996). Therefore this habitat is greatly under threat in the area.

The 2004 land use and land cover map for Malawi indicates that Mopane woodland extends further south than LNP. The sightings of Lilian's Lovebirds in the Lisungwi area were within this range. However, extensive Mopane woodland was not observed in this area when visited. This confirms that Mopane woodland has been heavily deforested outside of protected areas in Malawi (Chikuni 1996). This may have caused the current concentration of Lilian's Lovebirds in LNP, as it is the only protected area in Malawi with an extensive Mopane woodland. Historically, the lovebird population may have extended into the Lisungwi area. However, information from the community members and our observation indicates the lovebirds are only seasonal visitors and not resident at Lisungwi.

Phirilongwe Forest Reserve is about 44 km from the northern section of LNP. Lilian's Lovebirds were not recorded in the northern section of the park from April to July. The reported sighting in Phirilongwe was in June 2010 and communities in the area also stated the lovebirds are seen in June and July. Therefore it is possible that the Lilian's Lovebird sub-population in the northern section of LNP moves out of the park to Phirilongwe (and possibly to Monkey Bay/Cape MacLear) during the months of April to July. This study shows that the lovebirds do not visit the exact same places in the following year. This explains why we did not observe the species in the areas during our follow-up visits. Furthermore lovebirds were reportedly seen in the same areas earlier than the suggested June/July period (March 2014).

Our study did not investigate the possible reasons why the Lilian's Lovebirds choose to move from the LNP northern section from April to July. In other months they are most common along the banks of Lake Malombe. Rice farms are the dominant land use type

immediately beyond the park boundary. The rice matures and is harvested from April to June. Lovebirds were observed feeding in rice fields outside the western boundary of LNP. Therefore it was expected that the lovebirds would also feed in the rice fields around the northern section of the park, however this was not the case. The heavy flooding that the area experiences in the rainy season may be plausible explanation. We suggest that the lovebirds leave this area earlier than May, possibly at the time when it receives the highest rainfalls causing it to be flooded. This would explain the sighting in Monkey Bay in March 2014. It is clear that seasonal movements are very important to Lilian's lovebirds.

The majority of Lilian's Lovebirds records were small flocks in Mopane woodlands. This is not surprising as Mopane is the dominant vegetation in LNP. The largest flocks however were in seasonally wet grasslands and riverine thickets. Ivlev's electivity index indicated that seasonally-wet-grassland was the habitat type that the lovebirds spent most of their time in. This is interesting considering that Lilian's Lovebirds are viewed as a 'true Mopane woodland specialist'. Often we observed the lovebirds resting and feeding in these two vegetation types. Our data set was only collected in and around LNP so our results may be indicative of the LNP population only. It is recommended that Lilian's Lovebirds sub-populations in other countries launch similar studies for comparison.

Knowledge of a species' distribution at a fine scale is essential for local conservation efforts and provides valued inputs into global scale conservation assessment (Ferrier et al. 2004). We have shown that Lilian's Lovebirds use a range of habitats. Their association with seasonally wet grasslands is much stronger than with Mopane woodlands. There is a need for further investigation into the seasonal movements of Lilian's Lovebirds within Malawi and from Mozambique and Zambia. These movements are an important part of the lovebird's ecology, and thus are necessary in understanding their conservation needs. Conservation

efforts for the Lilian's Lovebirds should also target seasonally wet grasslands and riverine thicket habitats that are used during the year. Since agricultural fields are a frequented habitat, local communities need to be involved in the lovebird conservation process.

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**CHAPTER 3: Population estimates of the Lilian's Lovebird in Liwonde National Park,
Malawi**

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Summary

Monitoring abundance of threatened species important for conservation planning. Lilian's Lovebird *Agapornis lilianae* is a near-threatened small parrot found in Mopane *Colophospermum mopane* woodland. Its population has not been investigated in any part of its range. We investigated the abundance and density of the Lilian's Lovebird in Liwonde National Park (LNP), Malawi. Both distance sampling (line and point transects) methods and total counts (waterhole and flyway counts) were applied. The point count method gave very low numbers of observation and was discontinued after the first year. Line transects conducted during the wet season had the highest density estimates of 17 ± 4.8 lovebirds km^{-2} of Mopane woodland. However, number of observations per transect in each year were low. Waterhole counts had the lowest density estimates (10 ± 3.5 lovebirds). Flyway counts had the intermediate estimate (13 ± 3.0 lovebirds). The total population of Lilian's Lovebirds in LNP is therefore estimated to be about 4000 individuals. The use of line transect counts at the end of the rainy season is recommended for continued monitoring of Lilian's Lovebirds abundance in LNP.

Keywords: abundance; population estimate, Malawi, lovebird

Introduction

Parrots are often gregarious, flying great distances between nesting, roosting and feeding areas making it difficult to estimate their population densities (Forshaw 1989, Casagrande and Beissinger 1997, Pomeroy and Dranzoa 1997, Marsden 1999, Downs 2005). They are also one of the world's most threatened bird families due to widespread habitat destruction and capture for the illegal pet trade (Collar and Juniper 1992, Owens and Bennett 2000, Snyder *et al.* 2000). *In situ* conservation for threatened species requires knowledge of their population density and trend to determine their status and assist in monitoring population (Casagrande and Beissinger 1997). At the local scale, population trends determine conservation action and allocation of available resources (Buckland *et al.* 2008). Furthermore, population estimates form a main basis for global conservation policy, including the IUCN Red List (IUCN 2013).

Ideally, all threatened species require a population estimate, with low bias and high precision (Buckland *et al.* 2008). However, very little is known about the population status of parrots in the wild (Juniper and Parr 1998), particularly those that are globally recognised as highly threatened (Collar 1997, Snyder *et al.* 2000, Brooks *et al.* 2008). Parrots of Africa and its islands are amongst some of the most traded species in the world, however few have had recent population estimates (Snyder *et al.* 2000, Wirminghaus *et al.* 2000, 2001, Amuno *et al.* 2007, Perrin 2012, Martin *et al.* 2014). The method used in estimating abundance of a particular species *inter alia* determines the accuracy of the estimate. Line transects are often preferred to point transects as they are less susceptible to bias (Casagrande and Beissinger 1997). However, Marsden 1999, states that point counts perform better than line transects for parrots in most situations. Nevertheless most ornithologists agree that the most suitable

method depends upon the species and habitat it occupies (Casagrande and Beissinger 1997, Marsden 1999, Buckland *et al.* 2008).

There are 24 parrot species in Africa and its islands belonging to five *genera*, *Psittacus*, *Psittacula* (2), *Poicephalus* (11), *Coracopsis* (2) and *Agapornis* (9), (Forshaw 1989, Perrin 2012, IUCN 2013). The genus *Agapornis*, commonly known as lovebirds, is endemic to Africa and Madagascar (Forshaw 1989, Perrin 2012, Martin *et al.* 2014). The nine species have allopatric distributions; eight species on mainland Africa and one species on Madagascar (Forshaw 1989, Perrin 2012). Three of the lovebird species on mainland Africa are on the IUCN red list; Lilian's Lovebird *Agapornis lilianae* (near-threatened), Fischer's Lovebird *A. fischeri* (near-threatened) and the Black-cheeked Lovebird *A. nigrigens* (*vulnerable*). Lilian's Lovebirds occur in Malawi, Zambia, Mozambique, Tanzania and Zimbabwe (Hockey *et al.* 2005, Dowsett-Lemaire and Dowsett 2006, Perrin 2012) and its population is estimated to be < 20 000 birds (IUCN 2013).

A few published studies have looked at abundance estimates of large parrots on mainland Africa; the Cape Parrot *Poicephalus robustus* (Wirminghaus *et al.* 2000, Wirminghaus *et al.* 2001, Downs 2005) and the African Grey Parrot *Psittacus erithacus* (Amuno *et al.* 2007). In these studies total counts were used to estimate abundance. Distance sampling was used to estimate abundance of the Seychelles Black Parrot *Coracopsis nigra barklyi* (Walford 2008). The Black-cheeked Lovebird in Zambia is the only lovebird species to have had its abundance investigated (Dodman 1995, Dodman *et al.* 2000). Total counts at known water sources at the peak of the dry season, where the Black-cheeked Lovebirds congregate in the mornings and evening (Warburton 2005), were used to estimate densities per square kilometre of Mopane woodland (Dodman 1995, Dodman *et al.* 2000). Its

population was estimated to be about 10 000 individuals (Dodman *et al.* 2000). It is the closest relative to the Lilian's Lovebird (Moreau 1948, Forshaw 1989, Dodman *et al.* 2000, Warburton 2003).

We estimated the abundance of Lilian's Lovebird in Liwonde National Park (LNP), Malawi, using both total counts and distance sampling. We assessed the shortfalls of each of the methods and recommend a suitable method that can be used for this species in other parts of its range. We expected that waterhole counts would produce the most accurate results.

Methods

Study Site

LNP is situated in southern Malawi between 14°36' to 15°03'S and 35°15' to 35°26'E (Manongi 2004). It covers an area of 548 km² and ranges in altitude from 474 to 921 m a.s.l. Mopane *Colophospermum mopane* Woodland is the dominant vegetation covering 266.07 km². LNP is bounded in the west by the Shire River and Lake Malombe and in the east by hills and ridges of the Chinguni escarpment. The topography is gently sloping, upward from the Shire River, and is broken by two isolated groups of hills (Dudley 1994, Harrison *et al.* 2008). The park has an annual rainfall of 600-1000mm (Dudley 1994). During the rainy season water is available throughout the park in rivers, streams and natural depressions. Temperatures are cooler from May to July with isolated showers (Mzumara pers. obs.). From August to early-November the park is very hot and dry with temperatures ranging from 35°C to 43°C (Dudley 1994). The Shire River is the main water source for the parks diverse fauna during the dry season (Harrison *et al.* 2007). The central section of the park has three artificial waterholes that supply water to the 'fenced' Rhino Sanctuary (Dudley 1994). Data were collected in 2010, 2012 and 2013.

Method selection

Lilian's and Black-cheeked Lovebirds congregate at water sources in the morning and evenings (Forshaw 1989, Warburton 2005, Dowsett-Lemaire and Dowsett 2006, Mzumara pers. obs.), thus total counts at waterholes were adopted. During the dry season, the Lovebirds have routine flyways (east to west) over the Shire River. Therefore we also conducted total counts at flyways (Amuno *et al.* 2007). Total counts (waterholes and flyways) were also selected because they require few resources. Roost counts were not considered due to the difficulty of locating all roosting sites in the park.

Whilst distance sampling methods (points and line transects) have proved inappropriate for some African parrot species (Wirminghaus *et al.* 2000, Downs 2005), they have been recommended as a suitable method for estimating abundance and densities for parrot species (Casagrande and Beissinger 1997, Marsden 1999, Buckland *et al.* 2008). Distance sampling methods have not been used on any lovebird species. We selected to use both point and transect methods in this study. The assumptions for distance sampling are clearly known and documented (Buckland *et al.* 2008).

Distance Sampling

Point counts – LNP has 25 predetermined transects of different length which park management staff use for mammal counts. We used the same transects for easy access and to increase the possibility of continued monitoring of Lilian's Lovebirds by park management. Counting points were set along transects, the first point was 500 m from the park boundary and the remainder were all spaced at 500 m apart (Lambert 1993). At each point the observer

stopped for 5 min and recorded any Lilian's Lovebird sighted around the point noting flock size and activity for each observation. At the end of the five min we estimated the distance of the sighted lovebirds (Casagrande and Beissinger 1997).

Transect counts – Thirteen transects were selected from the existing LNP transects. Transects length ranged from was 1.8 to 12.6 km. We walked each transect once each year for three years 2010, 2012, 2013 just after the rainy season (May-July). Transect walks were conducted at a consistent pace from 05h00 to 11h00. At each point where Lilian's Lovebirds were encountered, the number of birds, time and the perpendicular distance from the transect were recorded (Casagrande and Beissinger 1997, Warburton 2003, Mwangomo *et al.* 2007). A tape measure was used to measure distances less than 50 m whilst laser finder was used to measure distance to measure distances greater than 50 m.

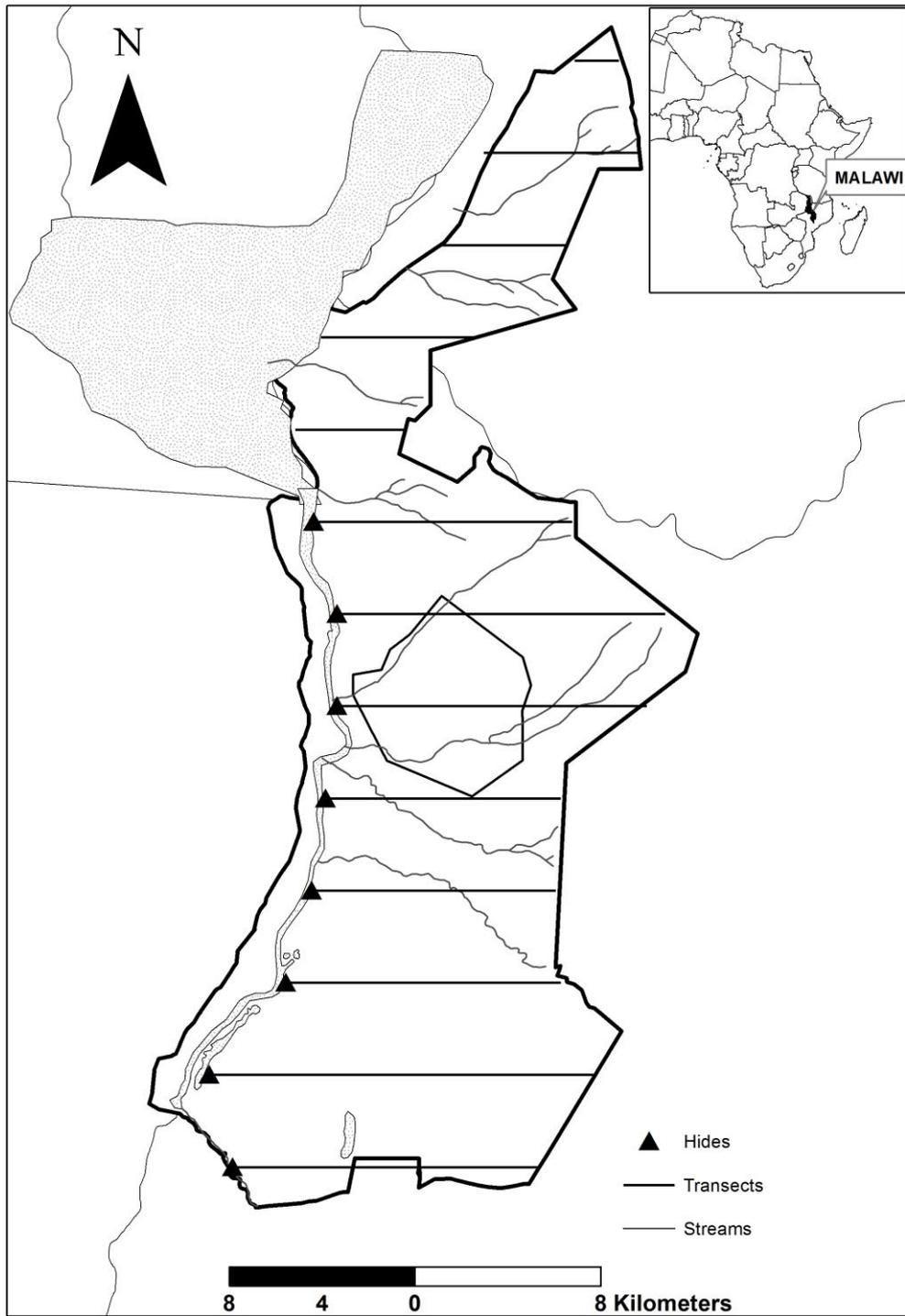


Figure 1: Map of Liwonde National Park (LNP) showing the transects and some of the hides used during this study in the years 2010, 2012 and 2013.

Total Counts

Waterhole counts – We monitored three artificial waterholes in the Rhino Sanctuary in Sept, Oct and Nov of 2010 and 2012 (Fig. 1). These were the only waterholes with water in the sanctuary at this time of the years. Full day counts were conducted simultaneously at the three waterholes from just before sunrise to sunset (04h30 to 18h00). Counts were done during four hour shifts. For Lilian’s Lovebirds that came to drink, the time, flock size and their behaviour were recorded (Warburton and Perrin 2005). The behaviours recorded lovebirds drinking at the waterhole, flocks in flight, or perched in trees. We anticipated that if a flock did not drink, the chances were high that it may return to the waterhole later or go on to drink at another waterhole. Only records of birds that were recorded as ‘drinking’ at the waterhole were used for the abundance estimates to reduce the chances of double counting.

Flyway counts – Lilian’s Lovebird flyways occurred along the western edge of the park bordering the Shire River (Nsikuwanga pers. comm., Mzumara pers. obs.). A systematic search was carried out using the lovebird distribution map (Mzumara *et. al.* 2014). A 32 km transect from the southernmost record of Lilian’s Lovebird distribution to the furthest northerly record, immediately south of Lake Malombe. Sixteen ‘hides’, 2 km apart, were placed along this transect. The ‘hides’ were points with no permanent structures where an individual stood and counted all lovebirds flying from the park to areas across the Shire River (east to west) from 05h00 to 11h00. For each observation, the time, flock size and the direction of flight were recorded (Amuno *et al.* 2007).

Analyses

Transects - Observations from repeated transect walks were pooled and the effort was calculated as transect length multiplied by the number of times it was walked (Buckland *et al.* 2008). Data were analysed using Distance 6 Release 2 software (Thomas *et al.* 2010). A selection of models using the different functions in DISTANCE were ran (Buckland *et al.* 1993). The half-normal function was used to generate density estimates. The most suitable model was selected based on the Akaike's Information Criterion (AIC) values.

Waterholes - Counts from the morning peak were excluded from the analysis. We assumed that 1) Lilian's Lovebirds that drank in the morning probably came back to drink at the same waterhole in the evening; 2) lovebirds coming from outside of the Rhino Sanctuary area also drank at a sanctuary waterhole in the morning. Therefore we only used counts from the evening peak of 16h00 to 18h00 for abundance estimates. We anticipated that the lovebirds recorded drinking at pools at this time represented a significant proportion of lovebirds that roosted in the Rhino Sanctuary (Dodman *et al.* 2000).

The area of Mopane woodland in the Rhino Sanctuary was derived from the LNP vegetation layer in ArcGIS 10.1 (ESRI). Only Mopane woodland was included in the analysis as this is the only vegetation type where the lovebirds roost and breed in LNP. The total number of lovebirds observed at each waterhole was summed to derive the total number for each count. The mean total of the five counts was then divided by the total area of Mopane in the Rhino Sanctuary to estimate density of Lilian Lovebirds in the Rhino Sanctuary. Only flights from east to west were included in the flyways abundance estimates to avoid double counting. Counts were conducted from 05h00 to 08h00, on three consecutive days during the

dry season (Oct) when the most lovebirds were observed to fly across the Shire River in the morning for foraging (Mzumara pers. obs.).

Data from flyways was analysed as follows (Amuno *et al.* 2007):

$$NF_x = D_s / D_f$$

Where NF_x = the number of flyways possible along the Shire River

D_s = the distance between the two most extreme flyways bordering a forest section

D_f = the mean distance between flyways (Distance between ends / number of hides)

Abundance at a fly way was estimated as the mean of all the records from different count days for that flyway.

Results

Population size estimates from distance sampling

Two hundred and forty point counts were carried out during one season of the survey. Only three Lilian's Lovebird observations were made during the point counts. Point counts took considerable time to complete and often times the Lilian's Lovebirds were seen whilst moving from point to point. Therefore this sampling method was discontinued after the first field session in preference for the line transects method.

Total distance of the line transects was 366.6 km and 102 observations of Lilian's Lovebirds were recorded over the three years. The number of observations per transect in each year ranged from 0 to 11, with an average of eight records per transect. Three transects (T1, T23, T25) had no observation of Lilian's Lovebird in the three years. The central

transect, T13, had the highest number of records whilst T21 had the lowest. The distance detection function derived from the raw data showed no bias resulting from movement prior to detection (Fig. 2, Buckland *et al.* 1993). The mean flock size for the pooled data was 9 ± 1.1 Lilian Lovebirds. The mean flock size did not differ significantly across years, (Kruskal-Wallis test: H_2 , $n = 102$, $p > 0.05$) or across transects (Kruskal-Wallis test: H_2 , $n = 102$, $p = 1.000$). Density estimates from the pooled data were 17 ± 4.8 birds km^{-2} of Mopane woodland (Table 1). Population size of Lilian's Lovebirds in LNP was estimated to be 4576 individuals.

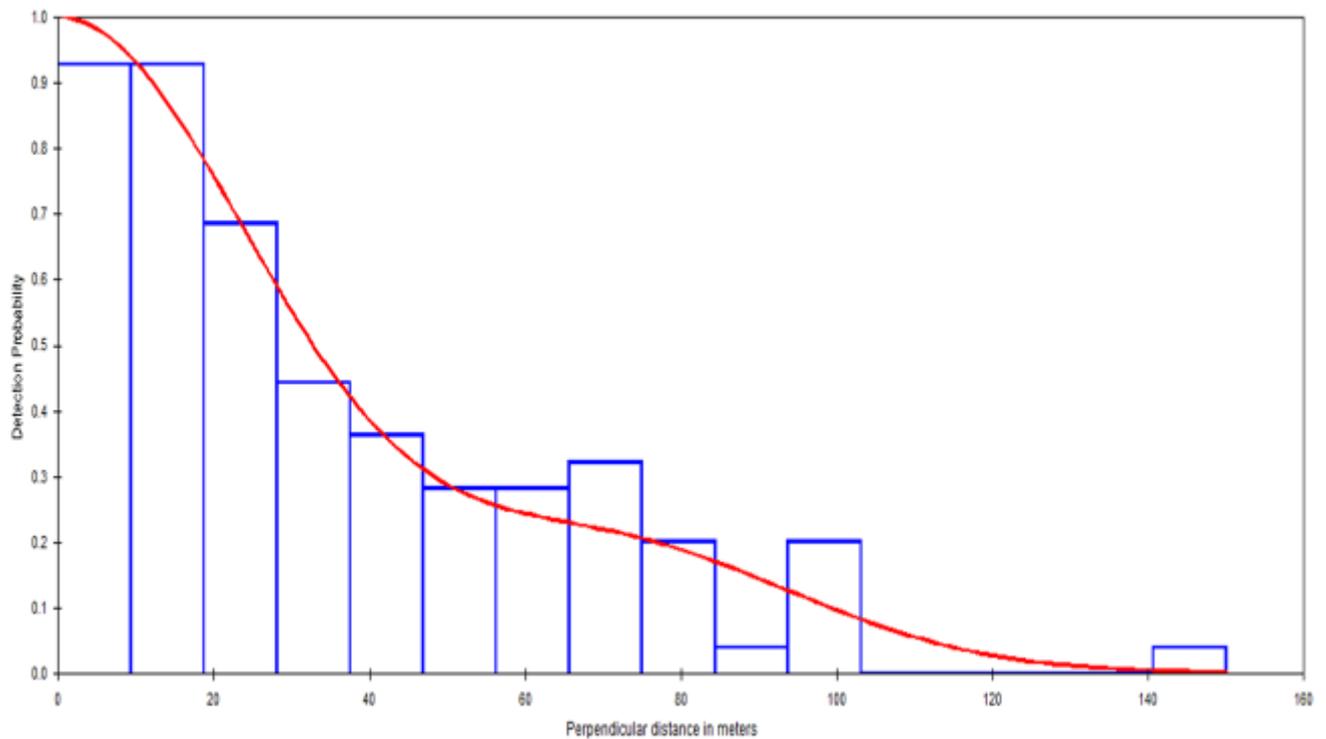


Figure 2: Distance detection function indicating detection probability in relation to distance from observer of the raw data.

Population estimates from total counts

Rhino Sanctuary waterhole counts – Fifteen waterhole counts of Lilian's Lovebirds were carried out (5 counts/waterhole). One hundred and eighty four observations/records were made at the three waterholes (Table 1). The total number of observations recorded on each of the count days varied greatly. Waterholes 1 and 4 had at least one 'nil' count (Fig. 3). The lowest daily sum was 71 lovebirds and the highest was 297 for observations at all three waterholes. Waterhole No. 3 (WH3) had the highest number of Lilian's Lovebirds observed. Totals counts ranged from 71 to 169 individuals. The mean number of lovebirds recorded (\pm SE) at waterholes in the Rhino Sanctuary for the duration of the study was 159 ± 39.7 individuals. Mean flock sizes at the different waterholes differed significantly (Kruskal-Wallis test: $H = 2$, $N = 184$, $p = 0.0016$). The area of Mopane woodland in the Sanctuary was calculated to be 28.8 km^2 . Using the largest number of birds recorded in a day (297) in the rhino sanctuary, estimated density was $10.3 \text{ birds km}^{-2}$ of Mopane woodland in the sanctuary. This translated to an estimated population size of 2743 individuals for LNP. (NB: We used the largest number instead of the mean as our assumption was that all birds that drink from 16h00 to 18h00 were resident in the Sanctuary).

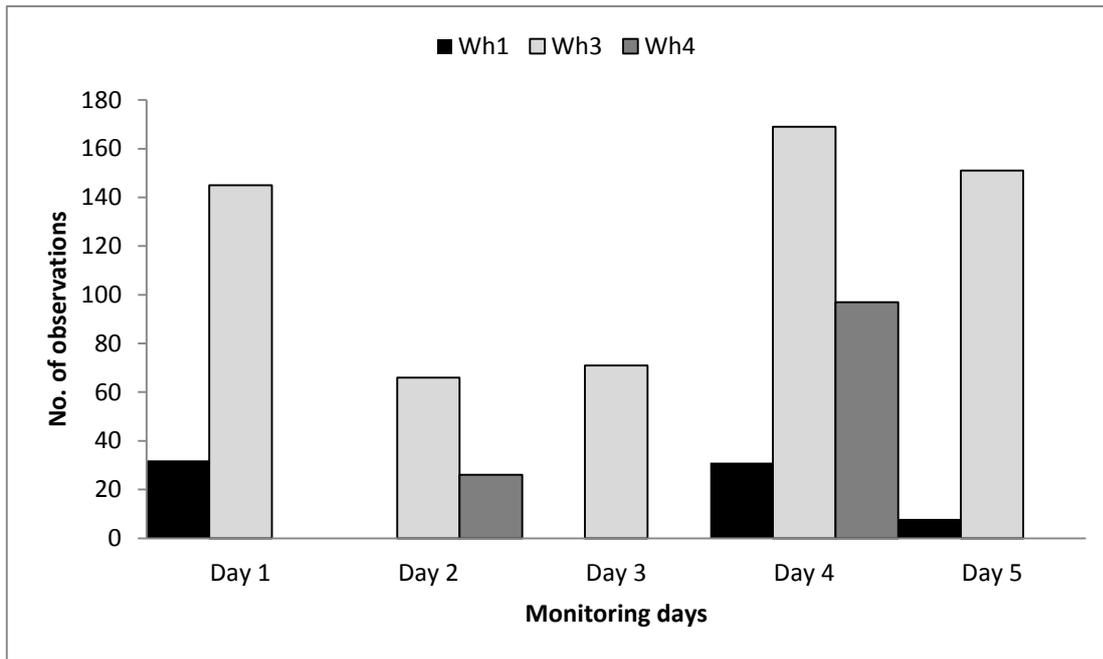


Figure 3: Number of Lilian’s Lovebirds observed at three waterholes in the Rhino Sanctuary in LNP during the current study. (Wh = waterhole).

Flyway counts – Lilian’s Lovebirds were recorded flying over seven of the 16 hides on the western bank of the Shire River. Three were in the southern part of the park and four in the central section of the park. The mean distance between these flyways was 3.6 km. Three flyways were opportunistic findings, one (called J n B) was found in the central section of the park near the tourist lodge Mvuu. The other two flyways (Masanje and Mpwapwata) were in the northern part of the park and differed from the rest as lovebirds did not fly east to west in the mornings.

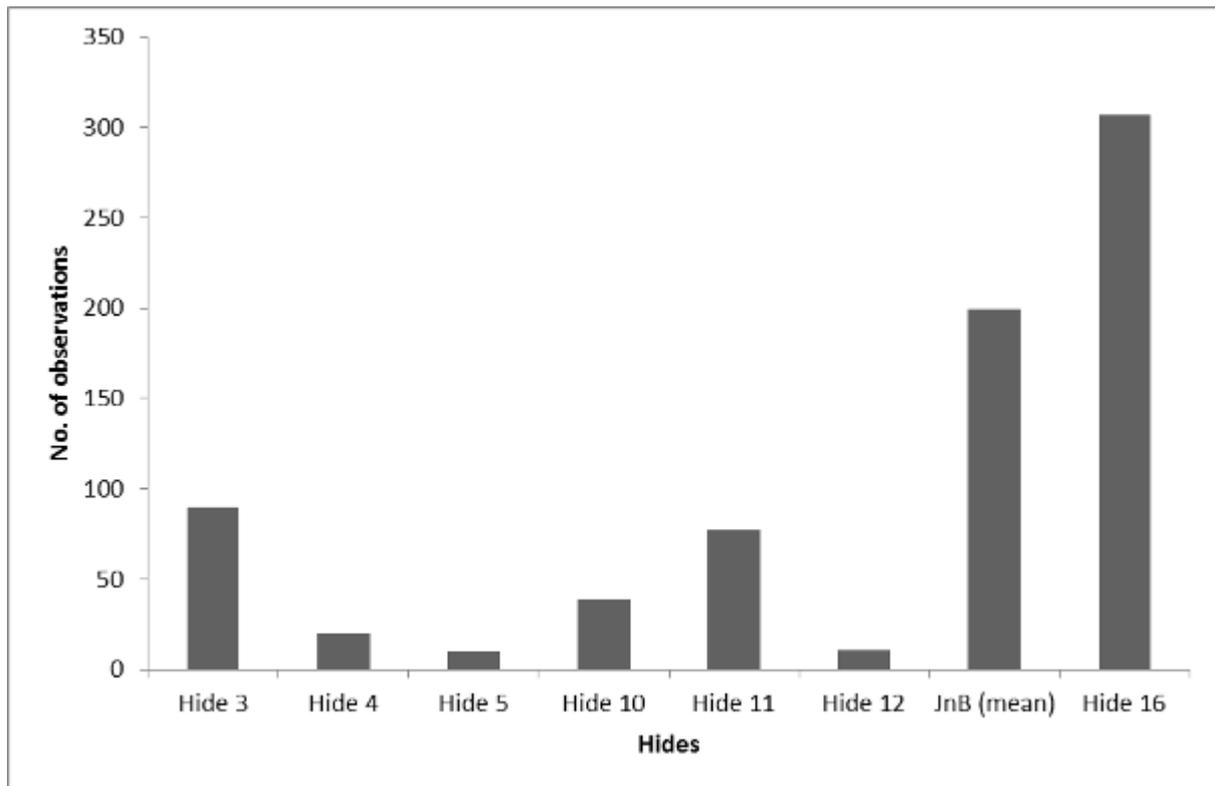


Figure 4: Number of Lilian’s Lovebirds recorded at hides during simultaneous counts in LNP.

Lovebird abundance at flyways in the dry season was estimated using only the counts from flyways with east to west flights (across the Shire River boundary). However, using the estimate for mean distance between flyways we estimated ten possible flyways in the parks eastern border. The mean number of Lilian’s Lovebirds counted at flyways was 199 ± 114.1 lovebirds, this translated to an estimated population size of 3582 individuals for 18 flyways (See Amuno *et al.* 2007)

Table 1: Density and population estimates of Lilian's Lovebird in Liwonde National Park, Malawi, using various techniques

Method	No. of observations	Mean flock size \pm SE	Estimated LNP population
Transect	102	9.0 \pm 1.1	4576
Waterhole	184	10.8 \pm 2.1	2743
Flyways	130	7.6 \pm 3.2	3582

Discussion

Lilian's Lovebird population estimates for Liwonde National Park

The estimated population size of Lilian's Lovebird in LNP was between 2743 – 4576 individuals. This wide variation is expected due to the different approaches used. The most recent published estimate of population of the lovebirds in LNP was >1000 (Dowsett-Lemaire *et al.* 2001). Considering the inadequacies that exist in each of the methods used, we suggest the lovebird population is closer to the line transect estimate, thus between 4000-4500 individuals. Line transects were conducted just after the rainy season when both food and water are widely distributed in LNP (Mzumara in prep, Chapter 4). Therefore the lovebirds are also widespread favouring better accuracy.

The highest density estimate of Lilian's Lovebirds obtained was 17.2 birds km⁻² of Mopane woodland. Since during the wet season water is available throughout the park, we would expect the density of lovebirds would remain largely similar in the Mopane woodland.

Due to the low number of records obtained in the northern and southern areas it was not possible to analyse these data separately for each part of the park using DISTANCE. Increasing the number of transects and effort in these two areas of the park is necessary for continued monitoring so that abundance estimates can be calculated separately.

Density estimates of Black-cheeked Lovebirds in Zambia using waterhole counts ranged from 0.2 - 10.2 birds km⁻² (Dodman *et al.* 2000). These are comparable with the density estimates from the waterhole counts of Lilian's Lovebirds in the Rhino Sanctuary (2.5 – 10.3 birds km⁻²). In this study however, the estimates from the waterhole counts were considered an underestimate of the actual densities. Anecdotal observations made during the course of this study, showed that Lilian's Lovebirds were cautious drinkers, avoiding waterholes when disturbed by large mammals. A similar observation was made for the Black-cheeked Lovebird (Warburton and Perrin, 2005). This resulted in very low observations of Lilian's Lovebirds at waterholes whenever there was a herd of elephant or buffalo for a prolonged period (Fig. 4). In such cases, we expected the lovebirds would drink at any of the other two waterholes within the Sanctuary. This would result in higher numbers recorded at the other two waterholes.

However, this was not observed in this study (Fig. 4), suggesting the lovebirds drank elsewhere inside or outside the Sanctuary. Our initial assumption that all lovebirds roosting in the sanctuary would drink at the three available sources from 16h00 to 18h00 did not appear to hold. Therefore population estimates from this method are most likely inaccurate. Lilian's Lovebirds and their relatives the Black-cheeked Lovebird are known to take advantage of any available water source (Warburton 2005, Mzumara in prep, Chapter 8). They have been observed drinking at even the smallest water sources (< 50 cm wide) in other areas of the

park and in agricultural fields outside the park (Mzumara pers. obs.). This makes estimates from waterhole counts difficult.

Estimates of abundance of Lilian's Lovebirds using flyway counts were also lower than those obtained from the line transects. The number of flyways on the eastern boundary of the park was not ground-truthed so it is not possible to determine the accuracy of these estimates.

Recommended methods for monitoring Lilian's Lovebird population trends in Liwonde National Park

Our results agree with the results of other African parrot studies which have found distance sampling using point counts inappropriate for parrot abundance estimates (Downs 2005, Amuno *et al.* 2007). Very few observations were recorded during point counts although the amount of effort expended is considerable (Buckland *et al.* 2008). The use of line transect just after the rainy season was a much more successful method for estimating abundance of Lilian's Lovebirds. Although the number of observation per transect was also low, repeated counts allowed for data to be pooled before analysis. Overtime it would be possible to analyse data from the south, central and northern sections separately in order to obtain reliable densities of Lilian's Lovebirds for each area.

Total counts of Lilian's Lovebirds at fly ways and at artificial waterholes in the Rhino Sanctuary are good methods for monitoring abundance only when it is possible to cover all available waterholes or flyways. Unlike the transect counts, these need to be done in the dry season to obtain the best results. Counts at flyways and waterholes need to be done for at

least three consecutive days to account for the variations caused by mammal disturbance at waterholes. Simultaneous counts for flyways and waterhole are recommended.

Conclusions

The estimated population size of Lilian's Lovebirds in LNP represents approximately 20 % of the global population. However, this may be an underestimate as LNP is a relatively small area of their range, and detailed studies of their numbers in other parts of their range are required. Continued monitoring is required using the existing line transects. We recommend this to be done immediately after the rainy season to obtain accurate results. Flyway counts and waterhole counts should be used for abundance estimates in the dry season. There is, however, a need to systematically investigate all possible flyway and available waterholes within the park during the dry season.

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CHAPTER 4: Feeding ecology of Lilian's lovebird *Agapornis lilianae* in Liwonde National Park, Malawi

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Abstract: Habitat loss threatens food availability of parrots worldwide. The Lilian's lovebird *Agapornis lilianae* is a small parrot resident in mopane *Colophospermum mopane* woodlands. We investigated the diet and foraging behaviour of Lilian's lovebird in Liwonde National Park (LNP), Malawi. Observations were made in different vegetation types. The nutritional composition of preferred foods were assessed. Lilian's lovebirds fed on 30 different plant species in six vegetation types. In the wet season most lovebirds (23 % of observations) foraged in dambo areas, whilst in the dry season they mainly foraged in grasslands with tree cover (18 %). In mopane woodland feeding flock sizes differed significantly between the wet (mean = 19.8 ± 1.0 lovebirds) and dry season (mean = 33.6 ± 2.3 lovebirds). Grass seeds were their main food source from December to June. Grass seeds had a high protein and energy content. The Lilian's Lovebirds foraging habitat is protected within LNP, however, early season burning in areas outside the park needs to be monitored, to ensure that it does not occur before the months of May/June.

Key words: Feeding ecology, diet, foraging, Lilian's lovebird, conservation

Introduction

Animals need food in order to survive and reproduce (Pyke *et al.* 1997), and feeding ecology influences reproductive success (White 1993, Allen & Hume 1997, Arnot & Perrin 1999, White 2012, Peron & Grosset 2014). It is important to understand the diet and foraging behaviour of a species in order to forecast possible nutritional threats and to help develop species management plans (Sutherland *et al.* 2004, Berg *et al.* 2007, Gilardi & Toft 2012).

Habitat loss is a threat to biodiversity (Owens & Bennett 2000, Brooks *et al.* 2002, Clarke & By 2013). Its impact on resource availability puts ecologically specialized species at a great risk of extinction (Owens & Bennett 2000). A combination of habitat loss and capture for the illegal pet trade are the main threats to parrot populations worldwide (Snyder 2000). Approximately 36 % of parrots (family *Psittacidae*) are threatened with extinction (Pain *et al.* 2006).

The feeding ecology and diet of several wild Neotropical parrots have been described (Renton 2006, Berg *et al.* 2007, Matuzak *et al.* 2008). In Africa, ten parrot taxa have had their diet and foraging behaviour investigated. They include the grey-headed parrot *Poicephalus fuscicollis suahelicus* (Fynn 1991, Symes & Perrin 2003), African grey parrot *Psittacus erithacus* (Chapman *et al.* 1993), Rüppell's parrot *Poicephalus rueppellii* (Selman *et al.* 2000), Cape parrot *Poicephalus robustus* (Wirminghaus *et al.* 2002), brown-headed parrot *P. cryptoxanthus* (Taylor & Perrin 2006), Seychelles black parrot *Coracopsis nigra barklyi* (Walford 2008) and Meyer's parrot *P. meyeri* (Boyes & Perrin 2009). Only three of the small-sized parrots, genus *Agapornis* have received feeding ecological studies; the black-cheeked lovebird *A. nigrigenis* (Warburton & Perrin 2005), the rosy-faced lovebird *A.*

roseicollis (Ndithia & Perrin 2006) and the Fischer's lovebird *A. fischeri* (Mwangomo *et al.* 2008).

The Lilian's lovebird *A. lilianae* is a low altitude species closely associated with river valleys and mopane *Colophospermum mopane* woodlands (Moreau 1948, Forshaw 1989, Warburton 2005, Perrin 2012). Its closest neighbour and relative is the black-cheeked lovebird in Zambia (Dowsett *et al.* 2008). The black-cheeked lovebird largely forages on the ground, feeding mainly on seeds (Warburton & Perrin 2005). They showed no diet specialization and demonstrate some adaptation to human disturbed habitat (Warburton & Perrin 2005). The rosy-faced lovebird in Namibia is similar in its feeding behaviour and diet, and water availability defined the habits in which they forage (Ndithia & Perrin 2006).

Fourteen plant species are documented as a food source for Lilian's lovebird (Table 1). We investigated the feeding biology of the Lilian's lovebird in Liwonde National Park (LNP), Malawi. We determined the diet composition, food preference and foraging behaviour of the Lilian's lovebirds. We expected Lilian's lovebirds would feed on the plants listed in Table 1 which occur in LNP. We also expected that Lilian's lovebirds would not show any specialization for a particular food source but generally feed on available, seeds, fruits, flowers and other items available as observed in other lovebirds (Warburton & Perrin 2005, Ndithia & Perrin 2006).

Table 1: Published records of plant species eaten by Lilian's Lovebirds in the wild.

Species	Family name	Part eaten	Reference
Trees			
<i>Ficus bussei</i>	Moraceae	Fruit pulp	Maasdorp (1995)
<i>Faidherbia albida</i> *	Mimosaceae	Flower	Benson <i>et al.</i> (1971)
<i>Syzigium cordatum</i>	Myrtaceae	Flower bud	Button (1953)
<i>Erythrophloeum africana</i>	Caesalpiniaceae	Flower	Benson <i>et al.</i> (1970)
<i>Vitex duamiana</i>	Verbenaceae	Flower	Benson <i>et al.</i> (1970)
<i>Cordyla africana</i>	Caesalpiniaceae	Flower	Benson <i>et al.</i> (1970), Warburton (2005)
<i>Euphorbia candelabrum</i> *	Euphorbiaceae	Flower	Dowsett-Lemaire & Dowsett 2006
Creepers			
<i>Combretum paniculatum</i>	Combretaceae	Fruit	Warburton (2005)
Grass			
<i>Oryza perennis</i>	Poaceae	Seeds	Fothergill (1984),
<i>Hyparrhenia</i> sp.	Poaceae	Seeds	Perrin (2012)
Agriculture			
<i>Eleusine coracana</i> *	Poaceae	Seeds	Dowsett-Lemaire and Dowsett (2006)
<i>Helianthus annuus</i> *	Asteraceae		Dowsett-Lemaire and Dowsett (2006)
<i>Sorghum bicolor</i> *	Poaceae	Seeds	Dowsett-Lemaire and Dowsett (2006)

*Species also recorded in this study

Methods

Study Area

Malawi is a landlocked country stretching from latitude 9°S to 15°S (McSweeney *et al.* 2007). Lake Malawi runs north to south covering approximately a third of the country's length (Harrison *et al.* 2008). The Shire River is located at the southern end of Lake Malawi. LNP lies along the Shire River which passes through the park approximately 1 km from the western boundary (Manongi 2004). LNP is located between 14°36' to 15°03'S and 35°15' to 35°26'E and covers an area of 548 km², its altitude ranges from 474 to 921 m a.s.l. (Manongi 2004). The parks slope is described as gently rising from the Shire River towards the eastern boundary (Fig. 1).

Mopane woodland is the dominant vegetation (70 %) in LNP and covers an area of approximately 262 km² (Dudley 1994). The park has a wire fence along part of its boundary; there is no buffer zone between the park and surrounding villages (Thomson 1998). The most common land use in areas immediately bordering the park is agriculture (Mzumara pers. obs.). However there are some wetland/grassland areas bordering the park that are not used for agriculture. LNP has a very distinctive wet and dry season. In this study we use the term 'wet season' to define the months when rainfall is received and those when the park still has a large amount of open water in natural waterholes (i.e. December to July). The term 'dry season' defines the period from August to November when the park is generally dry.

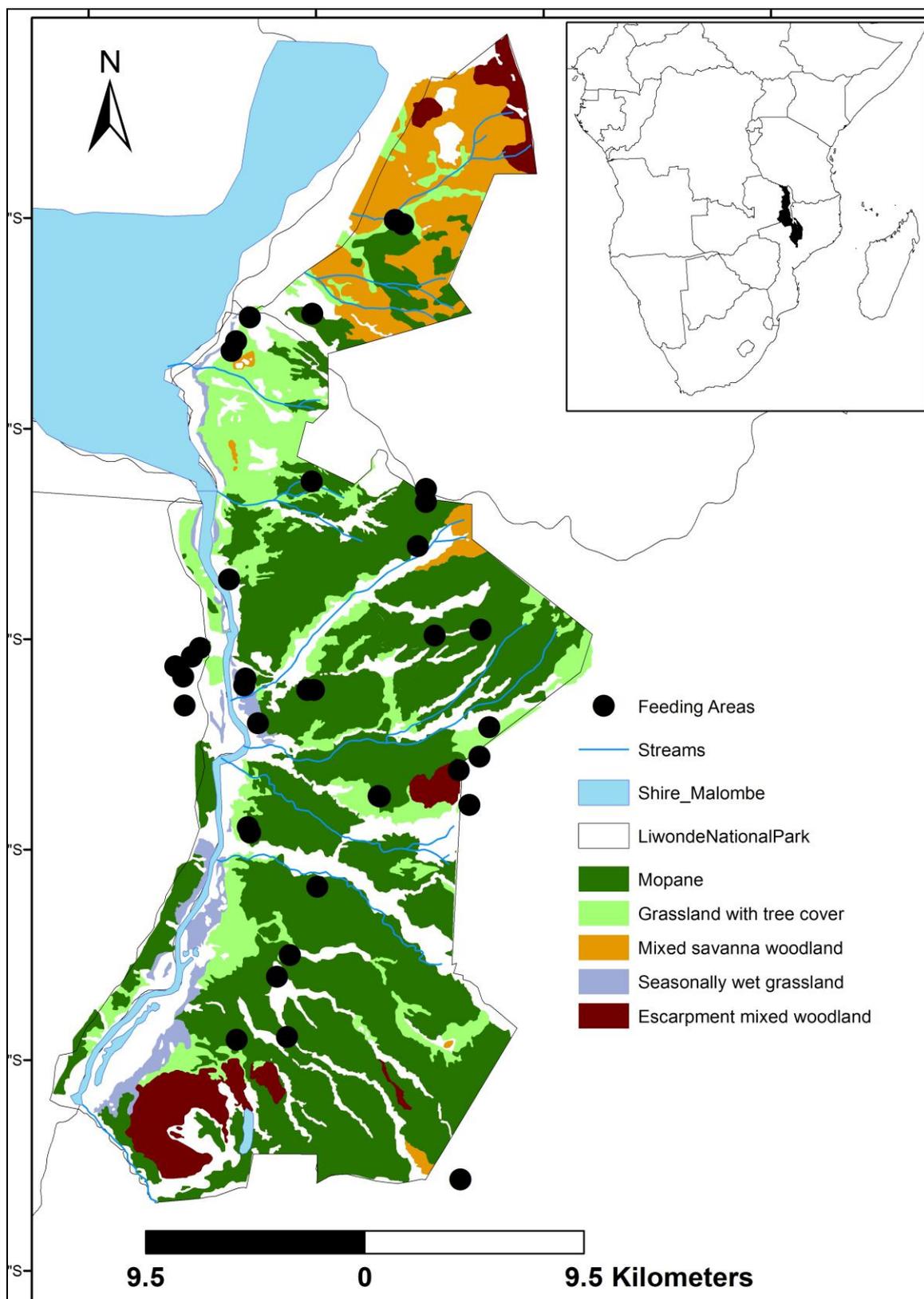


Figure 1: Liwonde National Park (LNP), Malawi, location and feeding locations of Lilian's lovebirds observed in and around the park.

Data collection

We observed the feeding and foraging activities of Lilian's lovebirds in March –November 2010, February – November 2012, and January – July 2013 in LNP. Observations were recorded during transect walks conducted on 13 predetermined transects (total = 80.4km) from 05h00 to 11h00. Opportunistic observations were recorded in all habitats of lovebirds seen feeding when on foot or using a vehicle. Feeding areas and observations outside the park were reported by scout camp guards and local communities near LNP. A pair of binoculars (Lynx 8 X 42) and a telescope (Kowa 10X) were used. For each lovebird feeding observation, date, the time and flock size were recorded. The part of the plant being eaten was recorded and a branch/stem/seed/fruit collected for identification (Berg *et al.* 2007). Plant identification was undertaken by the National Herbarium and Botanical Gardens of Malawi. Notes were taken of lovebird behaviours when feeding. Food 'preference' was determined by frequency of use of a particular food type in a particular season. (Note that preference usually implies use in relation to availability). Selected food samples were collected for nutritional composition analysis on a dry matter basis (Ndithia & Perrin 2006).

Two known Lilian's lovebird flyways near foraging areas were monitored in different months of the year, and the number and size of flocks flying past was recorded. Flyway counts were monitored from a stationary point. One observer counted birds flying out of the park from 05h00 to 08h00. Other species of birds found foraging with the lovebirds were recorded. Feeding areas recorded within the LNP were mapped onto the park's vegetation map in ArcGIS 10.1 (ESRI 2012). A spatial link was used to correlate each point to a particular vegetation type. Feeding areas outside of the park were mapped onto the Malawi vegetation type map. Vegetation shape files were provided by the Department of National Parks and Wildlife, Frankfurt Zoological Society, and the Forestry Research Institute of

Malawi. Statistical analysis was conducted using STATISTICA 7 (Statsoft Inc. Tulsa, OK.).

Results

Lilian's lovebirds were observed feeding in six habitat types during the wet season and four in the dry season (Fig. 2). During the wet season, the lovebirds fed in 'dambo' areas on communal land outside of the LNP eastern boundary. The area is not cultivated alluding to the possibility that it is not suitable for agriculture. Lilian's lovebirds fed on a variety of grass seeds available in this habitat which had several patches of standing water. All of the grass species in Table 3 were present in this habitat. During the dry season, however, no lovebirds were recorded feeding in these areas (Fig. 2). Most observations (18%) of Lilian's lovebirds feeding in the dry season were in the 'grass with tree cover' habitat (Fig. 2) inside LNP. The escarpment-mixed woodland habitat had only one observation during the entire study period.

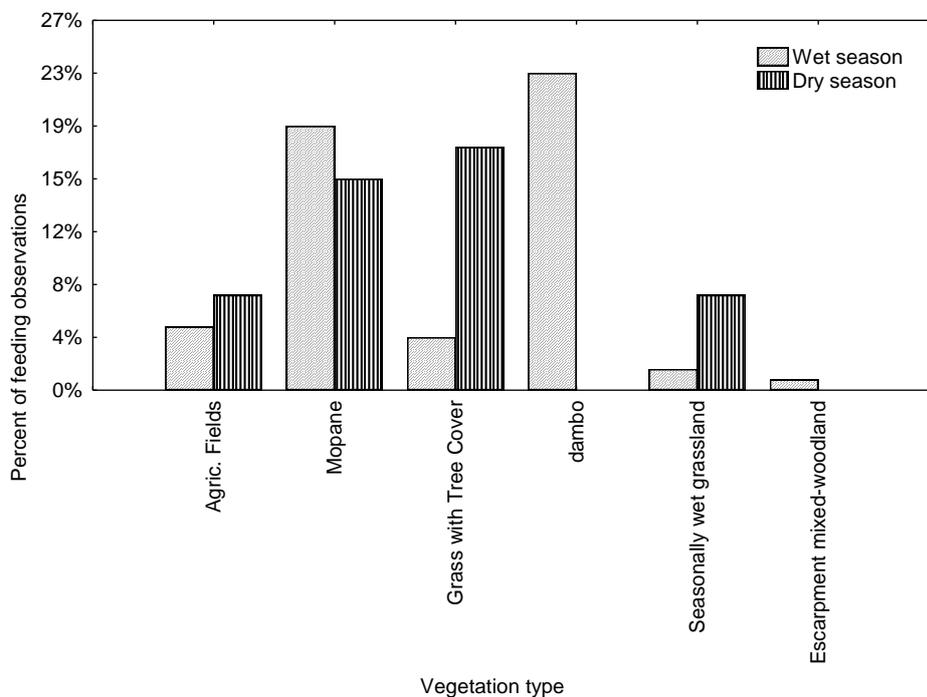


Figure 2: Percentage distribution of Lilian's lovebird feeding observations in different vegetation types during the wet and dry season in LNP.

Lilian's lovebird mean flock size differed significantly between habitats (Fig. 3, Kruskal Wallis, $H = 25.94$, $p < 0.05$). The largest flocks were observed in 'seasonally wet grasslands' (mean = 36.2 ± 2.6 lovebirds) and in 'grass with tree cover' (mean = 34.8 ± 1.0 lovebirds). The mean flock size of lovebirds feeding in the Mopane woodland also differed significantly between the wet and dry seasons (Fig. 3, Mann-Whitney U-test, $p < 0.05$). The lovebirds were observed in smaller feeding flocks during the wet season (wet season mean = 19.3 ± 1.0 birds, dry season mean = 33.6 ± 2.3 lovebirds). Sixty-two percent of all Lilian's lovebirds feeding observations were made between 05h00 and 09h00. The mean flock size during these times was 25.5 ± 6.3 lovebirds.

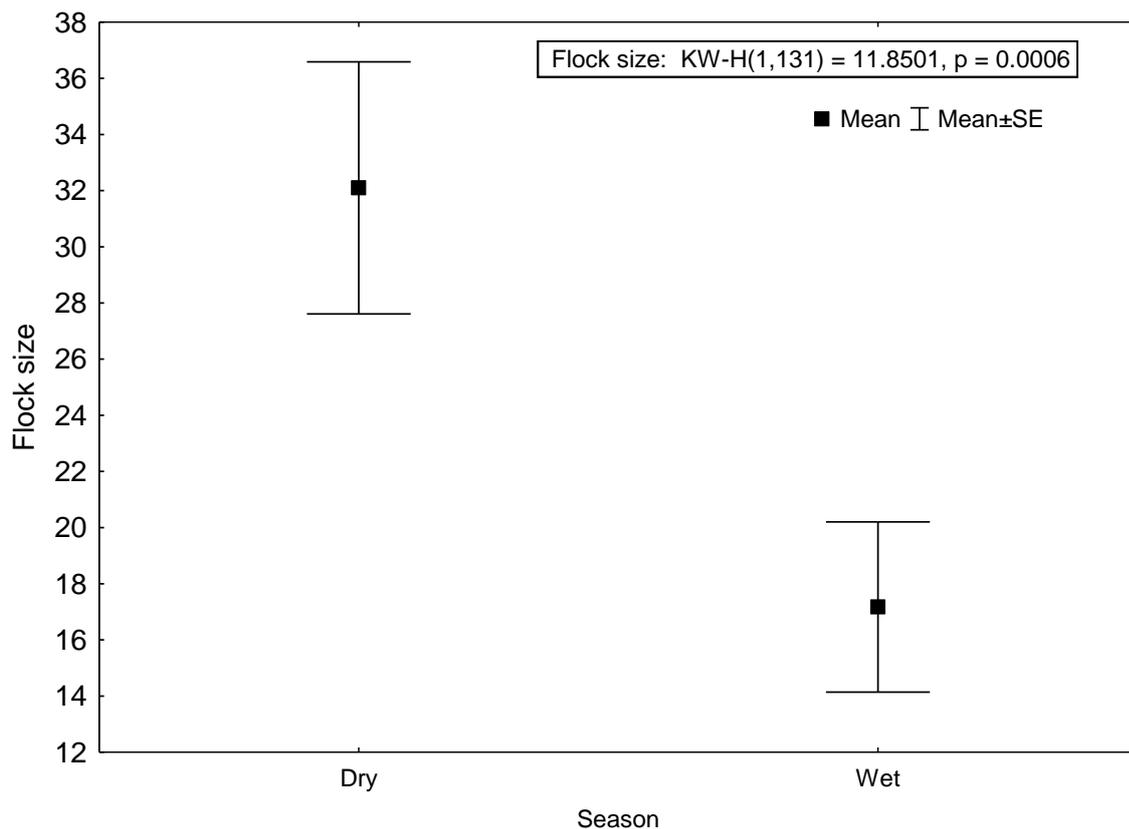


Figure 3: Mean flock sizes of Lilian's lovebirds feeding in mopane woodland in the wet and dry seasons.

Feeding behaviour and food types

Lilian's lovebirds fed on 30 different plant species from ten families (Table 1). Twenty-five of the plant species had not been reported in the diet previously. Grass seeds (family *Poaceae*) formed the major part of their diet during the wet season. Whilst, in the dry season, the diet diversified to include leaf buds, leaves, flowers, fruits and seeds of different tree species (Table 3). The majority of feeding observations were above the ground (94 %, n = 131). Geophagy was not observed directly, however it was suspected, especially when the lovebirds fed on the herb *Portulaca hereroensis* which grows flat on sandy soils.

Lilian's lovebirds exploited several available food sources in a foraging habitat. For example, in the 'dambo' areas outside LNP, an individual would move and feed on one or two different grass species available during a single feeding observation. The grasses *Sorghum arundinaceum* and *Rottaborea exaltata* were the most frequently used (31 %, Fig. 4) food items in the wet season. The size of the grass plant determined how the Lilian's lovebirds fed from it. For the large grasses (height ≥ 2.5 m, e.g. *S. arundinaceum*) the lovebirds perched on the grass, close to the 'head' of the seeds to feed. However, for the medium sized grasses (height ≤ 1 m, e.g. *Panicum maximum*) lovebirds perched lower to the ground and bent the grass seed head downwards to strip the seeds off using the bill. When feeding on *Sporobolus iocladius*, a very short grass (height = 0.15 m), the lovebirds stood on the ground and pulled the grass seed heads down to strip the seeds.

1 **Table 2:** Plant species eaten by Lilian's lovebirds in LNP during this study.

Scientific Name	Family	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grass Species													
<i>Sorghum arundinaceum</i>	Poaceae	s	s	s	s	s	-	-	-	-	-	-	-
<i>Panicum maximum</i>	Poaceae	s	s	s	s	s	-	-	-	-	-	-	-
<i>Sporobolus ioclodus</i>	Poaceae	s	s	s	s	s	-	-	-	-	-	-	-
<i>Panicum phragmitoides</i>	Poaceae	s	s	s	s	s	-	-	-	-	-	-	-
<i>Rottboellia exaltata</i>	Poaceae	-	s	s	s	-	-	-	-	-	-	-	-
<i>Echinochloa pyramydus</i>	Poaceae			s	s								
Herbs													
<i>Portulaca hereroensis</i>	Portulacaceae	s	s	s	s	s	-	-	-	-	-	-	-
Tree species													
<i>Tamarindus indica</i>	Fabaceae	-	-	-	-	-	u	u	-	-	-	-	-
<i>Ficus sur</i>	Moraceae	-	-	-	-	-	-	-	-	-	u	u	-

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Scientific Name	Family	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<i>Colophospermum mopane</i>	Caesalpiniaceae	l	l	-	-	l	-	-	-	-	-	b	l
<i>Vachellia xanthophloea</i>	Fabaceae	-	-	-	-	-	-	-	-	b	s	s	-
<i>Capparis temantosa</i>	Capparaceae	-	-	-	-	-	l	l	l	u	u	-	-
<i>Euphorbia candelabrum</i>	Euphorbiaceae	-	-	-	-	-	-	fl	fl	-	-	-	-
<i>Acacia</i> sp.	Fabaceae	-	-	-	-	-	-	-	-	b	s	s	-
<i>Vachellia tortilis</i>	Fabaceae	-	-	-	fl, b	-	-	-	-	-	-	-	-
<i>Ficus bussei</i>	Moraceae	-	-	-	-	-	u	u	-	-	-	-	-
<i>Senegalia nigrescens</i>	Fabaceae	-	-	-	-	-	-	-	-	b	u	-	-
<i>Thilachium africanum</i>	Capparaceae	-	-	-	-	-	l	l	-	-	-	-	-
<i>Azima tetracantha</i>	Salvadoraceae	-	-	-	-	-	l	l	-	-	-	-	-
<i>Faidherbia albida</i>	Fabaceae	-	-	-	-	-	-	-	-	b	f	-	-
<i>Ficus</i> sp.	Moraceae	-	-	-	-	-	-	-	-	f	f	-	-

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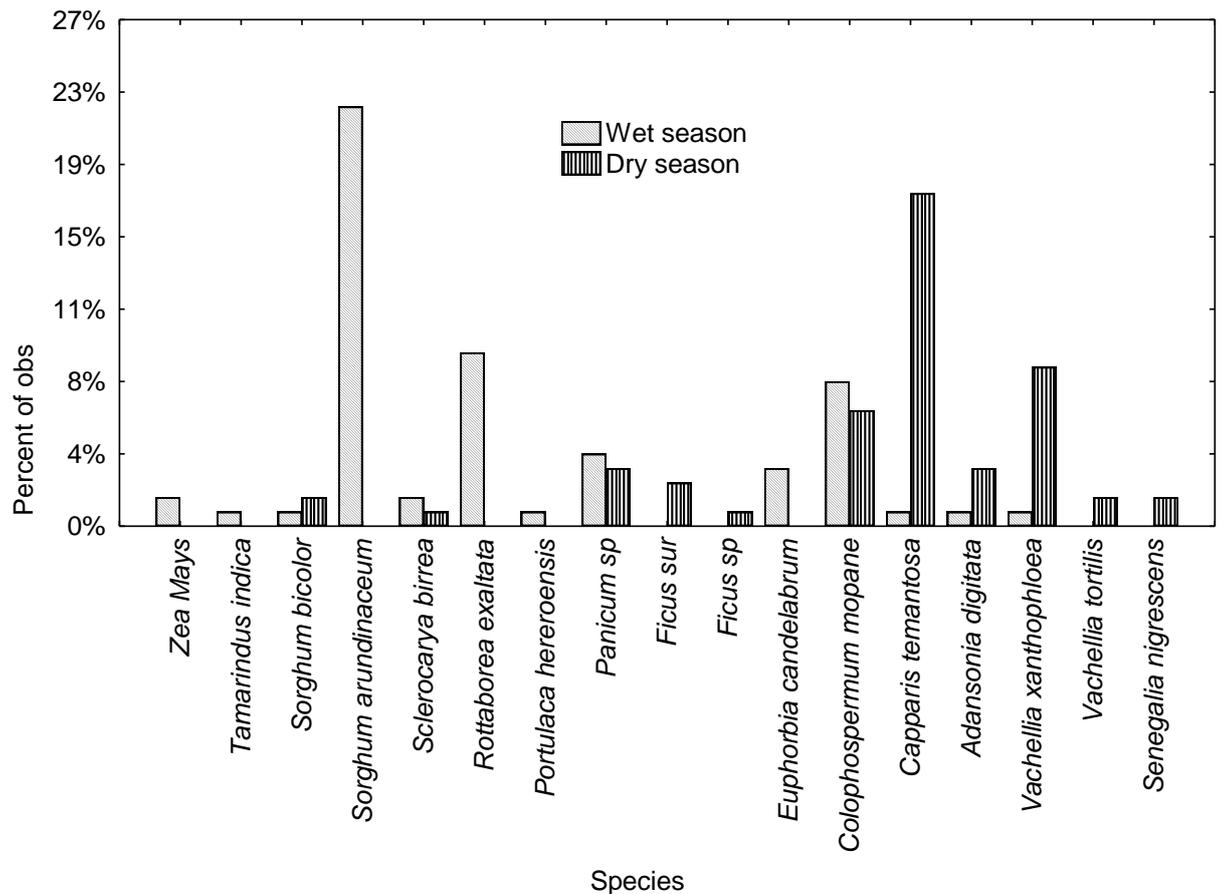
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Scientific Name	Family	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<i>Adansonia digitata</i>	Malvaceae	-	-	-	-	-	-	-	-	-	fl, u	fl, u	-
<i>Mangifera indica</i>	Anacardiaceae	-	-	-	-	-	-	-	-	-	-	f	f
<i>Ziziphus mauritiana</i>	Rhamnaceae	-	-	-	-	-	u	f	-	-	-	-	-
<i>Sclerocarya birrea</i>	Anacardiaceae	-											
Agriculture crops													
<i>Zea mays</i>	Poaceae	-	-	s	s	-	-	-	-	-	-	-	-
<i>Sorghum</i> sp.	Poaceae	-	-	s	s	s	-	-	-	-	-	-	-
	Poaceae	-	-	s	s	s	-	-	-	-	-	-	-
<i>Panicum</i> sp.	Poaceae	-	-	-	-	s	s	-	-	-	-	-	-

8 Abbreviations: s = seeds, f = fruit, u = unripe fruit, fl = flower, b = bud, l = leaf

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13 **Figure 4:** Number of observations of use of different food items by Lilian's lovebirds with
14 season.

15 In the dry season, most Lilian's lovebirds (43 %) fed on seeds from the pods of
16 *Vachellia xanthophloea* and the fruits of *Capparis tomentosa*. These two species occurred
17 together in the 'grass with tree cover habitat'. The lovebirds removed the seeds from the *V.*
18 *xanthophloea* pods by hooking the pod with their foot and then used their bill to open the pod
19 and remove the seeds from inside. All observations were of the lovebirds feeding on green
20 pods. It took 40 ± 2.01 s ($n = 67$) for successful removal of the acacia seed from the pod. In
21 most observations (81 %) the pod was not detached from the tree. The leaves and thorn buds
22 of *V. xanthophloea* were also eaten when the tree had no fruits. Lovebirds were observed

23 'licking' the bark of *V. xanthophloea*. On investigation the tree bark had small ants moving
24 up and down, but no gum was observed on the tree. Lovebirds fed on the seeds of other
25 acacia species including *V. tortilis* and *V. nigrescens*, which occurred in agricultural areas
26 outside the park. Lilian's lovebirds fed on the unripe fruits of *C. tomentosa*. The thin outer
27 covering of the fruit was removed, by manoeuvring with the bill, and the remaining whole
28 fruit was eaten. The lovebirds were also observed eating the leaves of *C. tomentosa* in
29 June/July.

30 In the northern part of LNP an area of woodland had a large number of fig trees, *Ficus*
31 *sur*. The lovebirds were observed feeding on the unripe fruits of these trees in each year of
32 the study. Only one or two of the trees were in fruit during each year's visit. In agricultural
33 fields around the park, the lovebirds fed on a variety of unripe fruits including the exotic
34 mango *Mangifera indica*, and indigenous *Vachellia tortilis*, *V. nigrigens* and *Ziziphus*
35 *mucronata*. The lovebirds also occasionally fed on agricultural crops including rice, millet,
36 sorghum and maize.

37 Lilian's lovebirds feeding areas were within 0.01 – 5.60 km (mean 2.0 ± 0.25 km) to
38 water sources (waterholes/streams/rivers). The dambo site had small pools of water during
39 the rainy season, and was less than 500 m from Masanje River which runs into the Shire
40 River. The other sites were all along the banks of the Shire River and Lake Malombe. The
41 'fig site' in the north had a small depression with water and a seasonal stream within a 100 m
42 of the foraging area.

43

44 **Nutritional composition of selected food items**

45 The energy content of the three grass species preferred by Lilian’s lovebirds ranged between
 46 16.8 – 17.6 MJ/kg (Table 3). The herb *P. hereroensis* had a lower energy content but its fat
 47 content was the highest of all the foods that were tested. The grass *P. maximum* had the
 48 highest protein content (14g/100g) of the wet season foods. Anecdotal notes taken during the
 49 study showed that this grass species was common around the breeding sites. Fruits of *C.*
 50 *tomentosa* were available in the dry season and had a much higher crude protein content.

51

52 **Table 3:** Nutritional composition of preferred foods of Lilian’s Lovebirds.

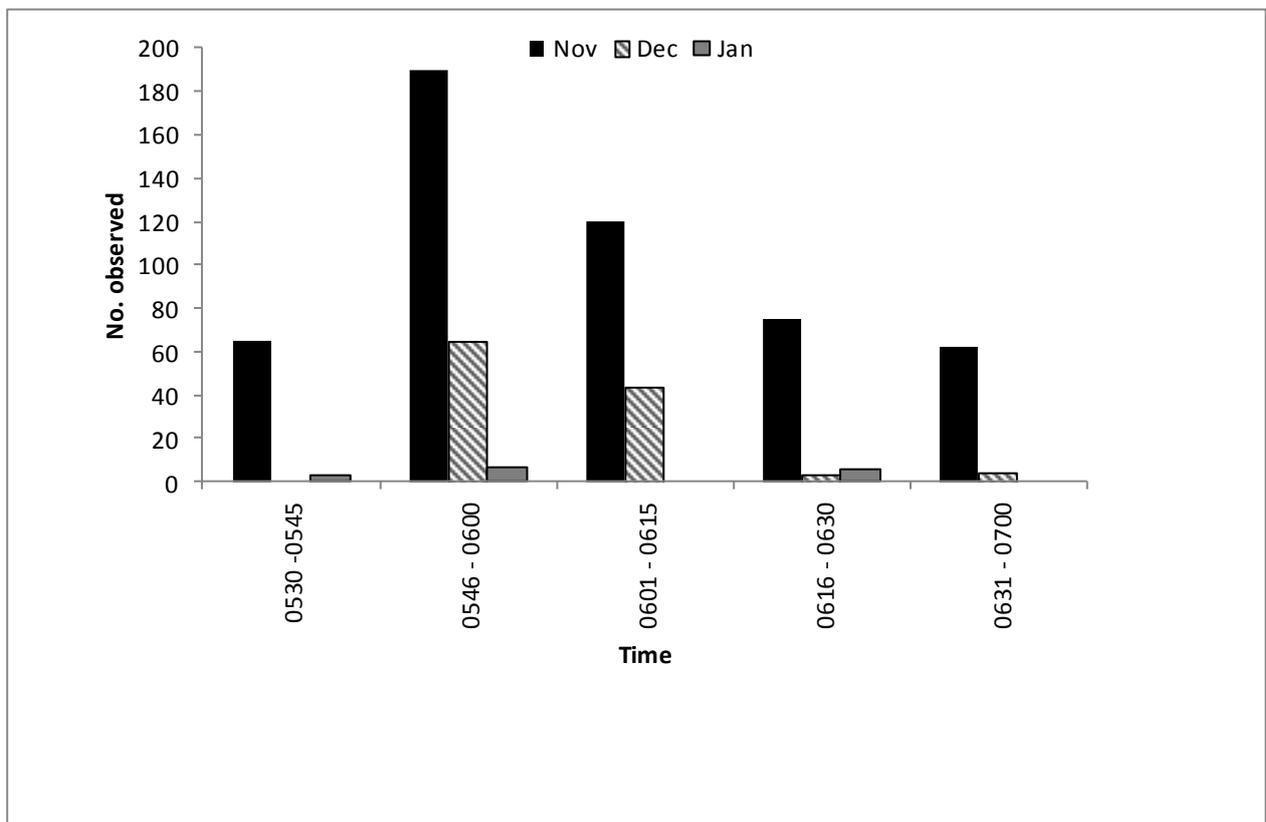
Plant Species	Part eaten	CP (g/100g)*	C Fat (g/100g)	GE (MJ/kg)	Ca mg/g
<i>Panicum phragmatoides</i>	Grass seed	11.3	2.2	17.6	
<i>Panicum maximum</i>	Grass seed	14.0	2.5	17.1	
<i>Sorghum arundinaceum</i>	Grass seed	10.4	1.8	17.6	
<i>Portulaca hereroensis</i>	Herb	12.9	4.4	16.8	
<i>Ficus sur</i>	Unripe fruit	5.3	0.6		83.2
<i>Capparis tomantosa</i>	Unripe fruit	22.4	2.5		213.4
<i>Rottaborea exaltata</i>	Grass seed	3.6	1.7		4.24
Mature <i>Mopane</i> leaves	Mature leaves	3.8	1.7		103.4

53

54

55 **Spatial movements in relation to food availability**

56 Lilian’s lovebirds were observed flying across the Shire River to forage there. The total
57 number of birds that flew across the river decreased from November to January (Fig. 4). The
58 area across the Shire River where the lovebirds went had a high density of *A. xanthophloea*
59 trees (pers. obs.). There was a decline in the number of lovebirds flying across the Shire
60 River from November to January (Fig. 4). Alternatively, flights of lovebirds moving outside
61 the park increased on the eastern border towards the dambo habitat.



62
63

64 **Figure 4:** Seasonal changes in Lilian’s lovebird flocks flying out of the park to foraging areas
65 around Liwonde National Park, Malawi.

66

67

Discussion

68 Lilian's lovebirds in LNP had a seasonally diverse diet similar to those of the rosy-faced and
69 black-cheeked lovebirds (Warburton & Perrin 2005, Ndithia & Perrin 2006). The lack of
70 dietary specialisation is common to several other parrot species (Galetti 1993, Selman *et al.*
71 2002, Symes & Perrin 2003, Taylor & Perrin 2006, Vaughan *et al.* 2006). It is suggested that
72 a diverse diet allows the black-cheeked lovebird in Zambia to explore different food sources
73 within the same area, thus contributing to their localised distribution (Warburton & Perrin
74 2005). This is partially true for the Lilian's lovebird. The general feeding behaviour of
75 Lilian's lovebirds allows them to exploit a variety of food sources in their range. However,
76 their distribution is not as localised as that of the black-cheeked lovebird. Reports of Lilian's
77 lovebird seasonal sightings in areas 40 – 60 km from LNP suggest that they may disperse
78 long distances during certain periods (Mzumara *et al.* 2014).

79 The diet of the Lilian's lovebird comprised of seeds predominantly. In the wet season
80 the seeds were sourced almost exclusively from grass species, whilst in the dry season seeds
81 were obtained from tree species. The preference for seeds is expected as consuming seeds
82 increases foraging efficiency because they have a high energy content (Hulme & Benkman
83 2002). Consequently, we expected the lovebirds to continue to feed on grass seeds in the dry
84 season. This would have required the lovebirds to feed more on the ground as the grass seeds
85 would have dried and dropped to the ground. However, this was not the case, the lovebirds
86 sourced seeds from trees and explored other sources of food including fruits, flowers and
87 possibly insects. This suggests that Lilian's lovebirds prefer arboreal feeding at this time,
88 preferring seeds that are still attached to a plant that are still moist but not dry. The rosy-faced
89 lovebird and the black-cheeked lovebirds feed mainly on the ground (Warburton & Perrin

90 2005, Ndithia & Perrin 2006). Consumption of unripe seed/fruit is suggested to help in
91 avoiding competition (Wirringhaus *et al.* 2002, Boyes 2008).

92 Plant species eaten by Lilian's lovebirds were all from indigenous species with the
93 exception of mangoes and agricultural crops found outside LNP. The food sources were not
94 available year round and thus Lilian's lovebirds switched diets with changing seasons. Only
95 two of the indigenous tree species previously reported as a food item of the Lilian's lovebirds
96 were recorded in this study, *Faidherbia albida* and *Euphorbia candelabrum*. Evidence of
97 infrequent use of some species was recorded; for example *Tamarindus indica* which had only
98 one observation through the study period. This suggests the lovebirds have some food items
99 that they only feed on occasionally, possibly in the case of shortage of a preferred food item.

100 Lilian's lovebird and the black-cheeked lovebird are both mopane woodland
101 specialists but do not show specialization for a particular food type limited to these
102 woodlands. However, both species eat various parts of the mopane tree. Black-cheeked
103 lovebirds eat the leaves, leaf stem, lichen and insects on mopane trees (Warburton & Perrin
104 2005). We observed Lilian's lovebirds feeding in mopane trees in both the wet and dry
105 seasons. In the dry season, mainly in October and November, the lovebirds fed on mopane
106 leaf buds that were just emerging. The young mopane leaves emerge independently of rain
107 and have a high crude protein content of 13.33 ± 0.21 g/100g (Styles & Skinner 1997).
108 Protein is an important nutrient for parrots when in moult and in preparation for breeding
109 (Arnot & Perrin 1999, Koutsos *et al.* 2001, Peron & Grosset 2014). Moult was observed in
110 over 50% of lovebirds mist-netted in October in LNP (Mzumara in prep., chapter 9).
111 Therefore the young leaves provide the proteins for moulting and possibly for the onset of
112 breeding.

113 The nutritional quality of semi-deciduous mopane leaves is known to decrease with
114 age (Schroeder 1986, Styles & Skinner 1997). Lilian's lovebirds however, continued to feed
115 on mopane leaves through their maturity. Breeding pairs of the lovebirds brought twigs with
116 mature mopane leaves to the young birds in the nest (Mzumara in prep., chapter 6). Nest
117 inspection confirmed that the leaves were eaten as they had evident nips taken from them. In
118 addition, recently-fledged chicks were seen in small groups around the nest sites feeding on
119 mopane leaves. Although the crude protein and energy content of the mopane leaves
120 decreases with maturity, the amounts of energy remains higher (18.5 – 20.2 MJ/kg) than
121 those in the grass seed samples (16.8 – 17.6 MJ/kg) (Styles & Skinner 1997, this study). No
122 observations were made of Lilian's lovebirds feeding on mopane seeds.

123 Lilian's lovebirds foraged on grass seeds that occurred in the ground layer vegetation
124 of the mopane woodlands. *Panicum maximum* and *P. phragmatoides* were both found on the
125 ground but not in the same densities as in other vegetation types (Mzumara, pers. obs.). The
126 lovebirds probably found it more efficient to move out of mopane woodland into areas such
127 as the dambo habitat where there were high densities of the same grass seeds to feed on. As
128 the wet season coincided with the lovebird's breeding season, we expected the lovebirds to
129 spend less energy foraging, thus one site with an abundant supply of food was an efficient
130 choice. The two grass species not found in the mopane woodlands were the ones that the
131 Lilian's lovebirds were seen feeding on most often, *S. arundinaceum* and *R. exaltata*. The
132 seeds of the two species matured at different times with some overlap, *S. arundinaceum*
133 (January – March) and *R. exaltata* (April – May). As expected, *S. arundunaceum* had a high
134 crude protein and energy content and was consumed at the peak of the breeding season.
135 Furthermore, these two grass species are large plants allowing the lovebirds to feed above the
136 ground. They may aid vigilance, making them more aware of predators.

160 specialist, limited food supply. Most of the feeding areas of Lilian's lovebirds were within
161 the park and in areas unsuitable for agriculture, so there is little threat from habitat loss.

162

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169

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CHAPTER 5: Roosting behaviour and characteristics of cavities used by Lilian's

Lovebird *Agapornis lilianae* in Liwonde National Park, Malawi

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Abstract

Lilian's Lovebird *Agapornis lilianae* is a secondary cavity user adapted to Mopane *Colophospermum mopane* woodlands. We investigated its roost characteristics and roosting behaviour in Liwonde National Park (LNP), Malawi. We quantified tree and roost site variables for roost and non-roost trees. Sixty-six roosts were found. Lovebirds' roosts were located in large tall Mopane trees with a mean diameter at breast height (dbh) of 57.4 ± 1.64 m, a mean height of 16.5 ± 0.42 m, and with a mean cavity height of 10.0 ± 0.05 m. Non-roost areas had significantly smaller trees (mean dbh = 39.4 ± 1.72 m) and were located significantly closer together. Human disturbance was low in both areas, however, evidence of Elephant *Loxodonta africana* browsing was high with large areas of stunted Mopane woodland recorded in non-roost areas. We recommend that the current LNP vegetation map be updated to highlight areas of stunted Mopane woodland unsuitable for Lilian's Lovebird roosts. The impact of elephant browsing on large Mopane trees should be assessed to understand its impact on the availability of suitable cavities for lovebirds and other tree cavity reliant vertebrate species.

Keywords: Roosting, Lilian's Lovebird, *Agapornis lilianae*, cavity, Mopane, conservation

Introduction

Woodland and forest habitats benefit ecologically from bird communities that use cavities (Sekercioglu 2006; Cockle et al. 2011). Primary cavity users, for example, are ecological engineers that excavate their own cavities but also indirectly provide cavities for other cavity-using species (Jones et al. 1994; Joseph 2008). Secondary cavity users, on the other hand, perform ecological functions such as seed dispersal, which ensures continuation of the plant regeneration process (Holbrook & Loiselle 2009; Cockle et al. 2010). It is therefore necessary to determine the requirements of cavity users to ensure and the continuation of their ecological roles (Cockle et al. 2010). This is particularly true for secondary cavity users as they do not excavate their own cavities. Therefore, their continued existence and abundance is determined largely by the availability of cavities (Marsden & Pilgrim 2003). An understanding of the characteristics and types of cavities used by secondary cavity users is crucial in planning for their conservation.

Additional to excavated cavities, tree cavities can also be created by other processes such as fire, wind, fungal decay and insects (Gibbons & Lindenmayer 2002). The dominance of a cavity formation process in a habitat differs significantly on a global scale (Cockle et al. 2011). In North America, 77 % of cavities used by secondary cavity users are excavated by other species whilst in Australia and New Zealand 100 % of the secondary cavities used are formed by other processes (Cockle et al. 2011), possibly because of an absence of excavating species. There are few published studies of cavity using communities and the types of cavities most commonly used in Africa (Cockle et al. 2011). However, there are data on the

type of cavities preferred by secondary cavity users. The cavities preferred are often in mature old trees (Summers 2007; Cockle et al. 2011; Villard et al. 2014).

Parrots are well-researched secondary cavity users and one of the most threatened bird families (Collar 1997; Owens & Bennett 2000; Snyder et al. 2000). The destruction of nest trees in parrot habitat can cause a serious threat to breeding (Collar 1997). Habitat loss is also a major threat to parrot diversity worldwide (Collar & Stuart 1985; Forshaw 1989; Collar 1997; Pimm 2000; Snyder 2000; Hanski et al. 2005; Pires & Clarke 2011; Perrin 2012). Currently, Africa has very high deforestation rates (FAO 2010; Green et al. 2013). Some of the highly impacted habitats is tropical dry woodland which covers most of southern, eastern and central Africa (Campbell 1996; Grainger 1999).

Lovebirds (genus *Agapornis*) are the smallest of parrot species endemic to Africa and its islands (Moreau 1948; Forshaw 1989; Collar 1997; Perrin 2012). Savannah woodlands have been cleared for agriculture and firewood (Chikuni 1996; Abbot 1999) but some of these woodlands remain in protected areas (PA's) (Chikuni 1996; Bruner et al. 2001). African Elephants *Loxodonta africana* resident in these areas are important agents of vegetation change and may be a major threat to woodlands habitats (Cumming et al. 1997; Mapaure & Campbell 2002) since PA's with high densities of elephants show a decline in the proportion of large trees (Treydte et al. 2007).

Mopane *Colophospermum mopane* woodlands are characterized by the dominance of Mopane trees (Mapaure 1994; Abbot & Homewood 1999; Grainger 1999; Poicelot & Gaidet 2010). Mopane woodlands are an important habitat for cavity dwelling species, including reptiles and small mammals as well as birds, due to the large abundance of naturally occurring cavities (Warburton & Perrin 2005). Lilian's Lovebird *Agapornis lilianae* is a

true Mopane specialist (Harrison et al. 1997) since it roosts, breeds and feeds in Mopane woodlands (Fothergill 1984; Forshaw 1989; Dowsett-Lemaire & Dowsett 2006; Perrin 2012). Liwonde National Park (LNP) is home to the largest breeding population of Lilian's Lovebirds in Malawi (Mzumara in prep., Chapter 6). The park has a large African Elephant population whose browsing impact on its vegetation is clearly visible throughout the park (Mzumara pers. obs.). A number of studies in African woodlands have shown that elephants can negatively impact biodiversity and specifically cavity nesting birds (Joseph 2008; Parker et al. 2009).

Our aim was to investigate the characteristics of trees used by Lilian's Lovebirds as roosts in LNP and their behaviour at roosting sites. We expected that tree diameter at breast height, tree height and cavity height would differ significantly between roost trees and non-roost trees. We predicted that the roost characteristics would match those of the Black-cheeked Lovebird *A. nigrigenis* (Warburton & Perrin 2005) as the two species are closely related and Mopane woodland habitats specialists. We also documented the presence and absence of African Elephant browsing in the areas immediately adjacent to the roost and non-roost trees for conservation purposes as there was a concern that they were negatively impacting availability of trees used for roosting.

Methods

Malawi is bordered by Mozambique, Zambia and Tanzania. It has a network of 45 government-owned PAs, nine of which are national parks. LNP, in Malawi's southern region, is located between 14°36' to 15°03'S and 35°15' to 35°26'E (Manongi 2004). LNP is

bordered by three districts Machinga, Balaka and Mangochi and covers an area of 548 km². It ranges in altitude from 474 to 921 m a.s.l. (Dudley 1991).

The Shire River, the only outlet of Lake Malawi, flows 35 km along the western boundary of LNP (Fig. 1). The park's topography is gently sloping towards the Shire River (Harrison et al. 2008). Mopane woodlands are the dominant vegetation in LNP covering about 60 – 70 % of the park's total area (Dudley 1991; Bhima & Dudley 1996). We used the LNP vegetation map produced by the Frankfurt Zoological Society that divides LNP vegetation into nine main classes. The Mopane woodland vegetation type is further classified into four groups based on the average tree cover/ tree density in the area (Fig. 1). The four types are 1) Mopane clump savannah, 2) Mopane woodland with tree cover < 10 %, 3) Mopane woodland with 10 – 50 % tree cover and 4) Mopane woodland with tree cover >50 %. We were unable to source the detailed description of each of these vegetation types from the LNP. In this study the southern section of the LNP (Chinguni) refers to the area south of the Mwalasi stream. The central part (Mvuu) is the area between Mwalasi stream and Likuzi stream. This is the area which houses the Rhino Sanctuary. North of the Likuzi stream is referred to as northern section of the park.

Data were collected between January 2012 and June 2013. Lilian's Lovebirds roosts were located by following lovebirds during late afternoon when they returned from foraging areas (Warburton & Perrin 2005). At the roost site, Lilian's Lovebirds observations were made using binoculars (Lynx 8 x 42, Gauteng, South Africa). When the lovebirds were observed entering a tree cavity, the time of entry and the number of individuals that entered the cavity were recorded. Before sunrise the following morning, the roost was observed again and the time the lovebirds left the cavity was recorded. A tree cavity was confirmed as a roost site only when lovebirds were seen leaving the roost the following morning. The position of

the tree was then recorded using a Geographic Positioning System (GPS) (Etrex 10 Garmin, Olathe KA). The geographical locations were mapped onto the LNP vegetation layer in ArcGIS 10.1 (ESRI, Redlands CA) to obtain habitat type for each roost.

Using a 20 m x 20 m quadrat around each Lilian's Lovebird roost with the roost tree at its centre, the number of trees (diameter at breast height (dbh) > 10cm) in the quadrat were counted and their dbh measured. For the roost tree, we also recorded species, height of cavity from the ground, height of tree (m) using a clinometer, the orientation of the cavity, origin of the cavity (natural crack in the trunk or resulting from a broken branch or woodpecker / barbet cavity) and distance to White-browed Sparrow-weaver *Plocepasser mahali* nests. Where possible, we measured the diameter of the branch where the cavity was located, and the length and width of cavity entrance. The distances to the nearest tree and roosts were recorded.

After mapping the roost areas on the LNP vegetation map, we identified areas within the same vegetation type where roosts had not been recorded. We then obtained the coordinate points for four areas (Air Strip, Kombe, Namandanje and Mwalasi) and conducted roost watches in the morning and evening for 3 consecutive days. When trees were confirmed to have no lovebird roosts we randomly selected trees to be measured (using random numbers for points along transects). Again a 20 m X 20 m quadrat around each non- roost tree was used and the same measurements as those taken for roost trees were recorded.

To understand vegetation composition of the ground layer, 20 roost trees were randomly selected in the south and central parts of the park. A 20 m X 20 m quadrat was created around each roost site during the rainy season. Plant species (grass, shrubs and trees) present in the under-storey were recorded. To understand the level of browsing and human

activity that occurred in the roost areas, we recorded the presence or absence of evidence of human disturbance and elephant browsing in each quadrat. Five passive infrared digital camera traps (LTI Acorn, 6210MC, China) were installed at known roosts, to record lovebird entry and exit times from October 2012 to May 2013. They also recorded lovebird night-time activity.

Data pertaining to roost orientation and time of roost entry and exit, were analysed using Oriana Software (Kovac 2011). All other statistics and analyses were done using STATISTICA (ver. 7, Statsoft, Tulsa OK).

Results

Roost location

Two main roosting areas of Lilian's Lovebirds were identified in LNP, one in the southern part of the park (Chinguni, Appendix 1) and the other in the central part of the park at the Rhino Sanctuary. Sixty-six roost cavities were recorded (south: $n = 27$, central: $n = 38$, north: $n = 1$). All roost cavities were located in Mopane trees. Roost trees in the south and central parts of LNP were located in 'Mopane woodlands with 10-50 % tree cover. The one roost recorded in the northern part of the park was in 'Mopane clump savannah' vegetation type (Fig. 1). Roost areas were used throughout the year and in subsequent years; however the cavities were not used consistently every night except during the breeding season. The mean orientation for roost cavities in the 'Chinguni' area was east while those in the 'Sanctuary' usually faced west (Table 1). The overall mean orientation was east; with a mean vector 88.2° (Fig. 2).

Roost versus non-roost tree characteristics

Lilian's Lovebirds roosted in relatively tall Mopane trees with mean dbh (\pm SE) of 57.4 ± 1.6 m and a mean height of 16.5 ± 0.4 m. There was a significant difference between the dbh of roost and non-roost trees ($P < 0.001$, t-test). The mean dbh for non-roost trees was much smaller, 39.39 ± 1.72 m. The mean dbh of all Mopane trees within a quadrat in non-roost areas was 30.80 ± 1.20 m. The heights of roost and non-roost trees were not significantly different. The mean height of the roost cavity was 9.98 ± 0.05 m. The majority of non-roost trees (77.5 %, $n = 31$) had no cavities. For the few that had cavities, the height of cavities did not differ significantly between the roost and non-roost trees.

Cavities were formed from either natural cracks (50 %) in the main trunk or branch of the tree while others were at a point where a branch had broken off (48 %). None of the occupied cavities were created by primary cavity users (i.e. excavated by woodpeckers or barbets). We recorded only one excavated cavity in a non-roost tree. The roost entry dimensions varied widely from roost to roost. The widest was 6 x 16 cm whilst the smallest was 3.2 x 4.2 cm (length and width respectively). The majority (80 %) of the cavities had only one entrance to the roost. Distance of roost to White-browed Sparrow-weaver nests was not significantly different between roost and non-roost areas (Mann-Whitney U, $p = 0.491$).

Internal cavity inspection

For most Lilian's Lovebird roost cavities (57 of 60, 95 %) it was impossible to measure their exact depth as the bottom of the cavity could not be reached (> 1 m). Investigation of seven roosts revealed the presence of dry Mopane leaves, twigs and old bird droppings inside. The

mean depth of these was 56.9 ± 5.4 cm. In one roost a small insectivorous bat was found roosting during the day whilst in another a green mamba *Dendroaspis angusticeps* was found. Follow up observation showed that the lovebirds did not return to the roost where the green mamba was found, however they did continue to use the nest where the bat was found roosting.

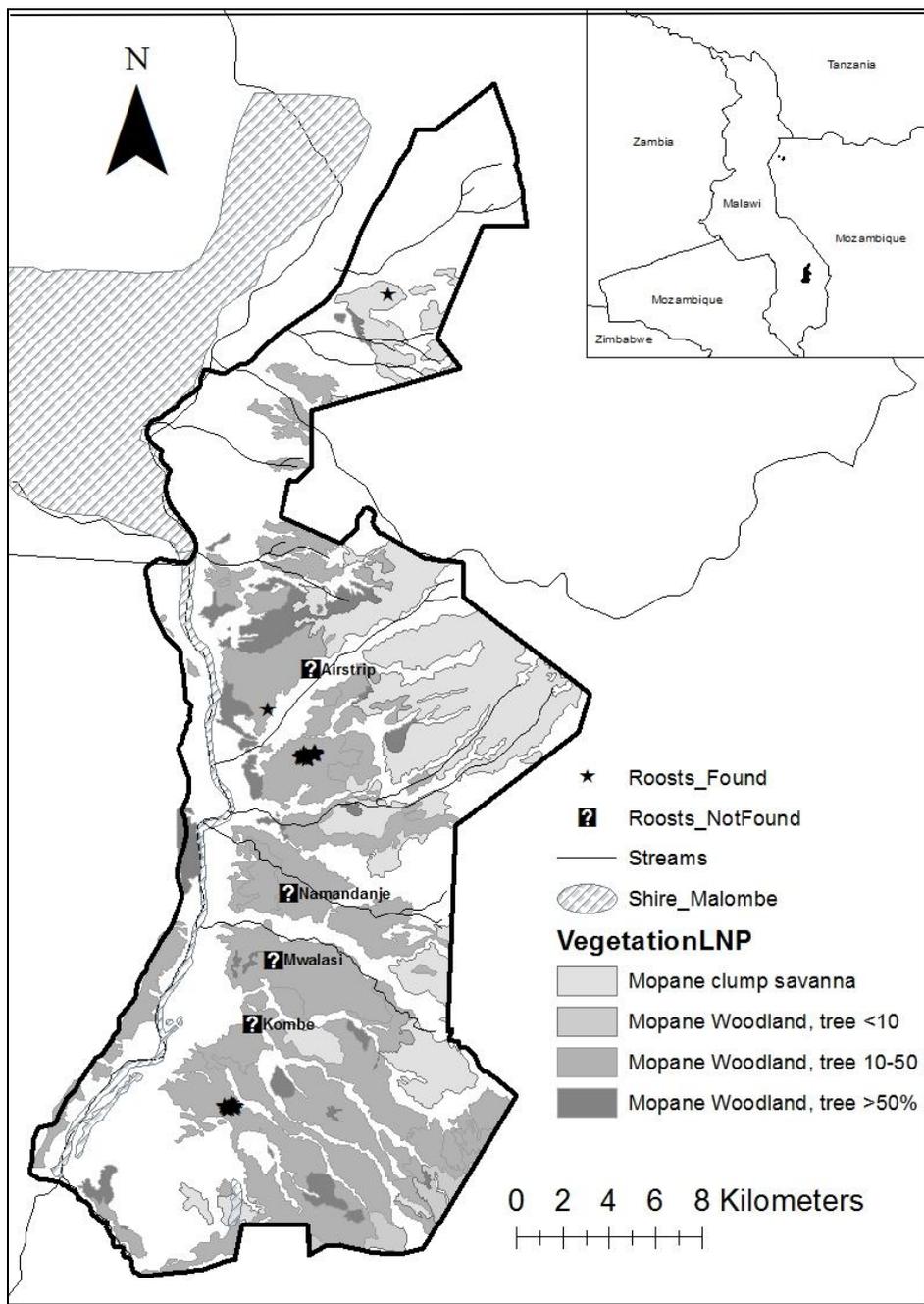


Figure 1. Location of Lilian's Lovebirds roosts in Liwonde National Park, Malawi.

Table 1. Summary of roost and non-roost tree characteristics measured for Lilian’s Lovebirds in Liwonde National Park, Malawi.

	Roost trees					Non-roost trees				
	N	Mean	Min	Max	SE	N	Mean	Min	Max	SE
Cavity height (m)	66	9.98	5.35	21.75	0.38	7	10.87	4.80	17.80	1.922
Tree height (m)	66	16.52	10.10	23.75	0.42	40	19.46	12.80	26.30	0.63
DBH (cm)	66	57.44	20.36	93.83	1.64	40	39.39	25.00	77.98	1.72
Nearest roost (m)	53	27.06	1.60	97.00	0.35	n/a	n/a	n/a	n/a	n/a
Nearest White-browed Sparrow-weaver <i>Plocepasser mahali</i> nest (m)	62	28.68	0.00	65.00	1.93	29	28.45	1.00	112.00	4.42
Cavity depth (cm)	7	56.9	3.0	90.2	5.4	n/a	n/a	n/a	n/a	n/a
No. trees in 20 x 20 m	40	3.85	0.00	10.00	0.40	40	5.9	1.0	15.0	0.6
Branch diameter (cm)	14	24.8	19.1	31.5	0.3	n/a	n/a	n/a	n/a	n/a
Average DBH of trees in quadrat (cm)	6	53.5	40.8	64.5	4.1	37	30.8	18.1	49.0	1.2
Nearest tree (m)	30	8.24	1.20	17.69	0.78	40	4.80	0.15	18.00	0.53

Table 2. Common plants in ground layer vegetation around the roost tree (20 m x 20 m) of Lilian's Lovebirds in Liwonde National Park, Malawi. (Occurrence = % plots where present).

Species name	Plant type	Occurrence (n = 22)
<i>Colophospermum mopane</i>	Tree	100
<i>Spermacoce pusilla</i>	Herb	82
<i>Panicum schinzii</i>	Grass	73
<i>Siphonochilus kirkii</i>	Herb	73
<i>Stylochiton natalense</i>	Herb	73
<i>Crinum macowannii</i>	Herb	64
<i>Digitaria gazensis</i>	Grass	64
<i>Senna obtusifolia</i>	Shrub	64
<i>Grewia bicolor</i>	Shrub	55
<i>Aspilia kotschyi</i>	Herb	55
<i>Floscopa glomerata</i>	Herb	55
<i>Urochloa mosambicensis</i>	Grass	55
<i>Jatropha acrophylla</i>	Shrub	55

Vegetation around roost and non-roost trees

Larger trees (dbh > 10 cm) around the Lilian's Lovebird roost areas were generally sparsely distributed. The mean number of trees around the roost tree was 4.08 ± 0.45 (Table 1). This was significantly different from the mean number of trees in the non-roost quadrats (Mann-Whitney U, $P < 0.003$, Appendix 2). The mean distance to the nearest tree was larger 8.24 ± 0.78 m than around the non-roost trees, 4.80 ± 0.53 m (Mann-Whitney U, $P < 0.001$). Around the roost trees the mean distance to the nearest tree was larger 8.24 ± 0.78 m than around the non-roost trees, 4.80 ± 0.53 m. The majority (85 %) of trees around the roost were Mopane trees; however Baobab *Adansonia digitata* and *Combretum* species were also recorded.

The ground layer vegetation at all Lilian's Lovebird roosts in the south and central LNP areas was < 1 m in height; herb, grass and shrub species were all represented. The one roost in the north of LNP was an exception as its understorey was completely covered by a large grass species, over 1.5 m in height. Two hundred and ten plant species were recorded in the quadrats surveyed. The species composition of herbs, shrubs and grasses differed from plot to plot. Each quadrat had an average 37 different plant species. There were 14 plant species that occurred in 55 – 100 % of plots measured (Table 2). Grass species that form part of the Lilian's Lovebird diet (*Sporobolus panicoides*, *Panicum maximum*, Mzumara in prep., chapter 4) were recorded in 50 % of the plots.

Evidence of African Elephant browsing was observed in 14 of the 22 quadrats (67 %) around roost trees whilst human disturbance was observed in one (5 %). In non-roost areas, elephant browsing was evident in all the sample quadrats except for the ten in the airstrip areas (75 %). We observed that the extent of elephant browsing was very different between roost and non-roost areas, but also within the non-roost areas. Around the roost trees,

evidence of browsing occurred mainly in Baobab or large Mopane trees that were debarked or completely taken down / uprooted by elephants. However, in non-roost areas, the most visually evident aspect of browsing was large areas of ‘stunted’ shrub like Mopane trees. This habitat type results from repeated browsing by elephants and thus is usually approximately 2 m in height. This stunted Mopane vegetation was common at the Namandanje and Kombe and Mwalasi sampling areas. The air strip area however had tall Mopane trees that were very closely spaced with no signs of browsing.

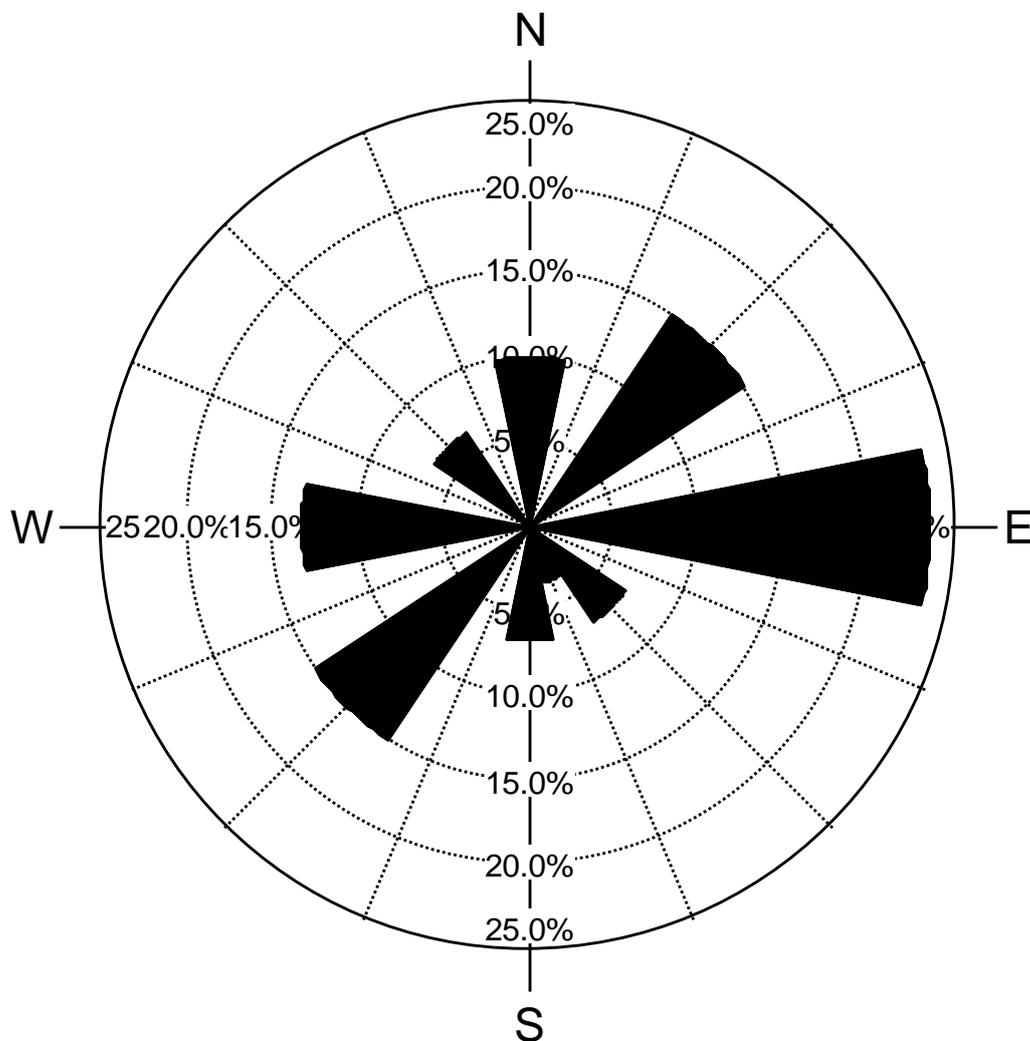


Figure 2. Orientation of roost cavities used by Lilian’s Lovebird in Liwonde National Park.

Roosting behaviour and flock size

The Lilian's Lovebirds emerged from the roost cavities just before sunrise. One individual or two perched at the cavity entrance silently for some time observing its surroundings. Then a contact call was heard at the point where the lovebird flew out of the cavity to the top of a nearby tree. Other occupants of the cavity then followed, each making the contact call as they made their exit. Lovebirds in other roosts in the surrounding areas also exited in the same way and flew to the same tree. A minimum of 10-20 individuals congregated at the top of a large tree before they dispersed as a flock to the feeding and drinking areas.

The number of Lilian's Lovebirds seen exiting or entering a cavity ranged from 1-5 individuals. The mean number of lovebirds in a roost was 2 ± 0.1 . In the evenings, lovebirds arrived in large flocks of up to 50 individuals and settled at the top of the trees in the roost areas. The flocks then broke off into smaller groups and flew towards their roost areas. Flocks of 2-6 individuals investigated several cavities before they broke off into even smaller groups and entered the roost chosen for that night.

Images obtained from the camera traps showed that there was very little activity at the roost during the night. A few images of bats flying past the roosts were captured in < 1 % of the photographs. Occasionally the cameras captured lovebirds 'peeping' out of the roost holes at very late hours (i.e. 19h51, 22h17 and 01h23). These isolated incidents represented <1 % of the footage captured.

Discussion

Mopane trees were the exclusive source of roost cavities for Lilian's Lovebirds in LNP. The cavities used were not excavated by primary cavity users but were formed through natural processes. This agrees with this lovebird's preference for this woodland type. The trees selected for roosting were old, large tall trees as has been recorded for other African parrot species (Warburton & Perrin 2005; Boyes & Perrin 2009). This preference of large trees indicates that not all Mopane habitats in LNP are suitable as lovebird roosts. Therefore the removal of large 'old growth' trees from this habitat may affect the ecology of the lovebirds particularly if elephant impact on this vegetation is not managed (Treydet et al. 2007; Summers 2007; Villard et al. 2014). The measurements of trees in non-roost areas showed that although the tree heights were similar, the dbh was less. The trees in non-roost areas were also very closely spaced. Stunted Mopane trees were also a common and visible aspect of non-roost areas. Elephant browsing and damage may be adversely affecting the natural production of potential nesting cavities for Lilian's Lovebirds and other vertebrate cavity users.

Lilian's Lovebirds appear to select cavities in areas of Mopane with 10-50 % tree cover over Mopane with < 10 % tree cover and Mopane woodland with >50 % tree cover. Large areas exist in LNP with this preferred Mopane vegetation class. However, when considering the specifics of the trees (i.e. dbh, height and spacing measurements) that Lilian's Lovebirds use as roosts, this may be misleading. This is because areas under the same vegetation classification have significantly different vegetation structure with regards to the requirements of their roosts.

Characteristics of the ground layer vegetation also played a role in the location of Lilian's Lovebirds' roosts. The two areas with the most roosts had a diverse ground layer

with herb, grasses and shrubs. Some of the grasses were edible to the lovebirds and the short height of the plants made the soil visible. The dense nature of the grasses common in the Mopane clump savannah vegetation does not allow easy access to water in the woodland. These areas also lacked the diverse plant species in the other two areas. This may explain why only one roost was recorded in the north of LNP.

Lilian's Lovebirds roosts were in cavities in taller trees and higher from the ground than reported for the Black-cheeked Lovebird (Warburton & Perrin 2005). The cavities used by Lilian's Lovebirds were much deeper. Roost selection can be influenced by competition, predation, ectoparasitism and microclimate (Koertner & Geiser 1999; Kerth et al. 2001). These factors likely differ for each cavity-nesting species in its habitat, such as between the two lovebird species.

The pre- and post-roosting behaviour of Lilian's Lovebirds were also very similar to the Black-cheeked Lovebird in Zambia (Warburton & Perrin 2005). Lilian's Lovebirds showed the same pattern of social roosting that has been observed in other African parrots (Taylor & Perrin 2004; Warburton & Perrin 2005; Boyes & Perrin 2009). Lilian's Lovebirds roosted in loose clusters with a relatively moderate distance between adjacent trees. There were at least four Mopane trees around each roost showing the roosts were more widely dispersed than the trees. Lilian's Lovebirds contact called when entering or leaving roosts, aiding flock formation; and later, separation into smaller groups. Observations in Zimbabwe recorded up to 25 individuals of Lilian's Lovebird roosting in one cavity (Fothergill 1984) whereas the largest observed number of individuals sharing a roost in this study was five.

Human disturbance was minimal in roosting areas although elephant damage was common. The extent of damage to trees in non-roost areas was very obvious and may deter roosting. Large Mopane trees were among those elephants brought down. The density of

elephants in LNP may be a future cause of concern for Lilian's Lovebirds conservation, owing to the destruction of roost trees. Elephants are negatively impacting African woodlands in terms of biodiversity and specifically cavity nesting birds (Joseph 2008; Parker et al. 2009). Since niche loss occurs when habitat is lost (Owens & Bennett 2000), ecologically specialized species, such as the Lilian's Lovebirds, can easily be lost from areas.

Conclusions and recommendations

Lilian's Lovebirds in LNP were reliant on Mopane trees for roosting and large, tall trees with deep cavities were most preferred for roosting. The maintenance of the mature Mopane woodlands with 10-50 % tree cover is important for the conservation of Lilian's Lovebird in LNP. We recommend that a vegetation map with specific focus on the lovebird's requirements be created. It should highlight the areas that have stunted Mopane unsuitable for Lilian's Lovebirds roosting. The park management should quantify the impact elephants are having on Mopane woodlands in LNP. Although humans may not be a major threat to this habitat, elephants have the potential to impact on the availability of cavities and thus influence the abundance and persistence of Lilian's Lovebirds in LNP.

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Appendix 1: Park ranger, Mabvuto Kulinji looking up at one of the Lilian's Lovebird roosts at Chinguni roost site, Liwonde National Park.



Appendix 2: Non-roost site of the Lilian's Lovebird in Liwonde National Park.



CHAPTER 6: Breeding biology of Lilian's Lovebird *Agapornis lilianae* in Liwonde National Park, Malawi

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Abstract

We investigated the breeding biology of Lilian's Lovebird *Agapornis lilianae* in Liwonde National Park, Malawi. We collected data through direct observations and infrared camera traps during three breeding seasons. The breeding season ran from February to May. Lilian's Lovebirds nested mainly in south-east facing deep cavities (≥ 1 m) located in large Mopane *Colosphermum mopane* trees (mean dbh = 57.57 ± 2.35 m). Nests were located in loose clusters in the areas where they roosted (mean distance to nearest nest = 24.24 m). Nest fidelity was observed in two nests sites. Clutch size ranged from 3 – 6 eggs, (mean 5.0 ± 0.22). We recorded 49 % hatching success and 69 % fledging success. Breeding success was low mainly due to the loss of eggs to predation.

Key words: Breeding, conservation, Lilian's Lovebird, reproductive success, predation

Introduction

The lack of information on the ecology of African parrot populations in the wild is a major constraint to their conservation (Snyder 2000, Perrin 2012). Ecological studies are key to ensuring effective conservation and management plans for parrot populations worldwide (Podulka *et al.* 2004). There are still many parrot species whose breeding biology is not fully known (Robinet and Salas 1999; Sanchez-Martinez and Renton 2009). Parrots exhibit niche specialization which puts them at a high risk of extinction (Collar *et al.* 1994; Owens and Bennett 2000). Many parrot species are secondary cavity nesters which is a limiting resource (Cockle *et al.* 2011). For effective conservation planning knowledge of the breeding biology of threatened species is essential (Podulka *et al.* 2004; Sutherland *et al.* 2004).

Africa and its islands support 24 parrot species of which approximately 50 % have had a full ecological study (Perrin 2012). The last 14 years has seen several detailed studies of the breeding biology of Africa's parrots (Wilkinson and Birkhead 1995; Warburton 2003; Symes and Perrin 2004; Taylor and Perrin 2004; Ekstrom *et al.* 2007; Perrin 2012). However, studies are biased towards medium- and large-sized parrots of the genera *Poicephalus*, *Psittacula* and *Coracopsis*. The genus *Agapornis* comprises the smallest parrots endemic to Africa. Only two published studies exist on the breeding biology of *Agapornis* species in the wild; the Black-cheeked Lovebird *A. nigrigens* in Zambia (Warburton and Perrin 2005) and the Rosy-faced Lovebird in Namibia *A. roseicollis* (Ndithia and Perrin 2007).

Lilian's Lovebird *A. lilianae* is a near-threatened small parrot with isolated populations in Zambia, Zimbabwe, Malawi, Mozambique and Tanzania (Warburton 2005). Its closest relative is the Black-cheeked Lovebird (Dowsett *et al.* 2008). Lilian's Lovebirds face various threats

including habitat loss, poisoning and capture for the pet trade. Some aspects of its breeding biology were studied previously (del Hoyo *et al.* 1997; Fry *et al.* 2000; Dowsett-Lemaire and Dowsett 2006; Dowsett *et al.* 2008). However, there has not been a detailed study of it in the wild. In Malawi, a breeding and resident population of Lilian's Lovebirds occurs in Liwonde National Park (LNP) (Dowsett-Lemaire and Dowsett 2006; Mzumara *et al.* 2014).

We investigated the breeding biology of the Lilian's Lovebird in LNP. We expected that its breeding biology would be similar to that of the Black-cheeked Lovebird due to their close phylogeny and habitat requirements. We predicted the lovebirds would nest in the tree cavities in which they roost as does the Black-cheeked Lovebird (Warburton and Perrin 2005). We also expected Lilian's Lovebird breeding biology in the wild would be different from that in captivity; in that the birds would not double clutch owing to a short period of optimal conditions for breeding in summer.

Methods

Study Area

Malawi is a relatively small country (approx. 118 000 km²) located at the southern end of the Great Rift Valley (Young and Young 1978). A third of the country is taken up by Lake Malawi, the third largest lake in Africa (Young and Young 1978). Lake Malawi's sole outlet is the Shire River which flows south into the Zambezi in Mozambique. Liwonde National Park (LNP) lies on the eastern bank of the Shire River between 14°36' to 15°03'S and 35°15' to 35°26'E (Manongi

2004; Harrison *et al.* 2008). The river covers a length of about 35 km through LNP, approximately 1 km from the park's western boundary (Fig. 1).

LNP's topology is gently sloping towards the Shire River (Harrison *et al.* 2008). Mopane woodland is the dominant (70%) vegetation type in the park (Dudley 1994). The Shire River is the main source of water for all wildlife in the park during the dry season when the park is very dry. The park has three distinct sections (Fig. 1), the southern part (Chinguni), the central area (Mvuu) and the northern part (Mpwapwata). The central section of LNP differs significantly from the rest of the park as it is home to LNP's fenced Rhino Sanctuary. The sanctuary has artificial water sources that provide an alternative source of water in the dry season.

Data Collection

Anecdotal notes suggest the period from January to March as Lilian's Lovebirds breeding season (Fry *et al.* 2000; Forshaw 2010). The Black-cheeked Lovebird breeds from February to May (Warburton and Perrin 2005). In view of this, data were collected from November to May in three years (2010/11, 2012/13 and 2013/14). As we anticipated the lovebirds would nest in the same areas that they used for roosting in the non-breeding season, these areas were searched for possible nest sites in each field season.

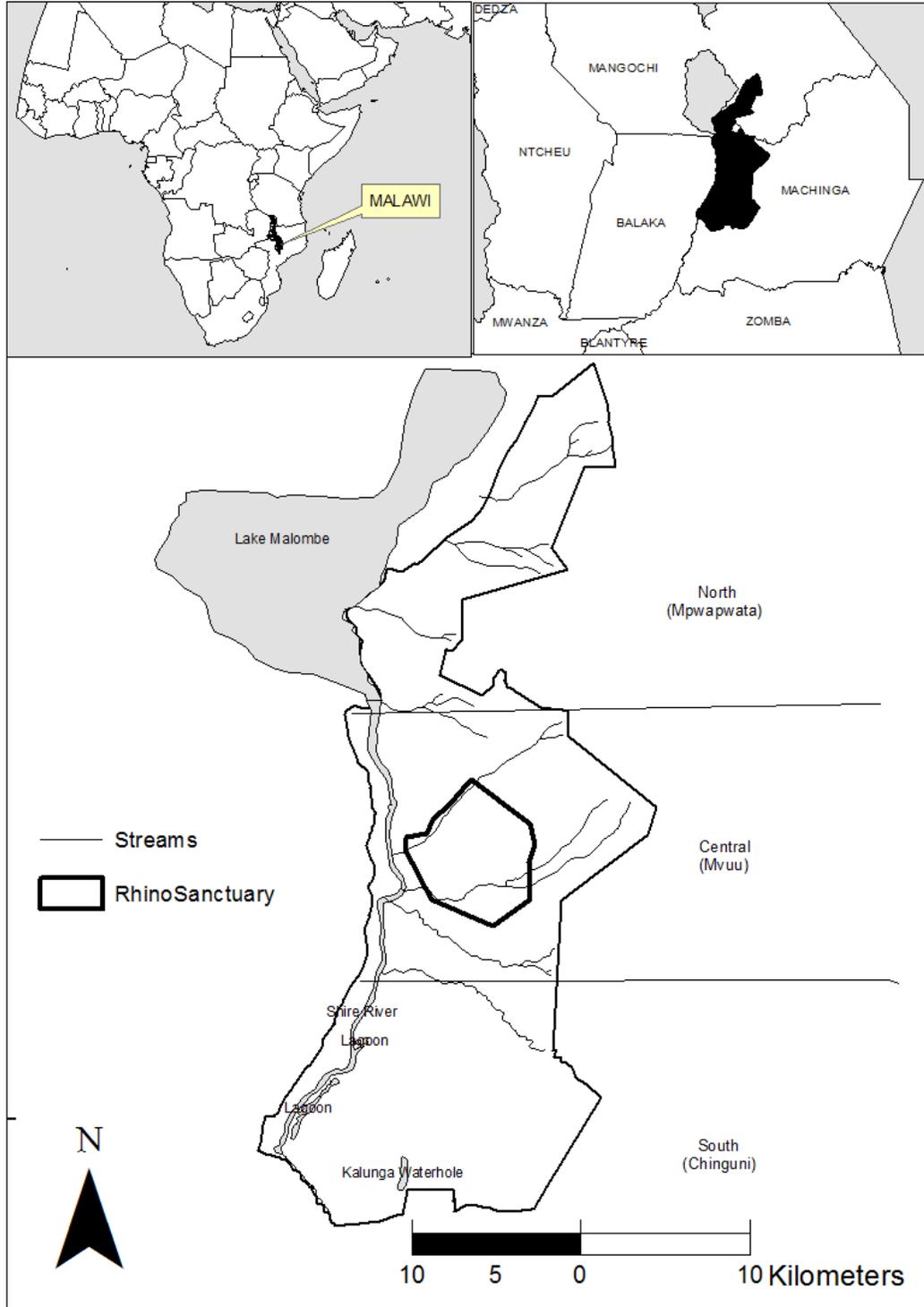


Figure 1: Sites investigated for Lilian’s Lovebird’s nest cavities in Liwonde National Park, Malawi.

At the onset of the breeding season we recorded the behaviour of Lilian's Lovebirds during pre-roosting hours. We noted individuals performing courting behaviours with males head-bobbing and feeding females (Dilger 1960). Potential nest sites were located by following such pairs and recording the cavity they used for roosting that night. Nests were also located by following individuals carrying nest materials to tree cavities. The position of the tree was recorded using an Etrex 10 Garmin Global Positioning System (GPS). An endoscope (Explorer Premium Digital Endscope,) was then used to check the cavity contents on the next day.

Once a Lilian's Lovebird's cavity contained eggs or a nest, we measured and recorded the characteristics of the nesting tree. These included tree and cavity heights (m) using a clinometer, diameter at breast height (dbh in cm) using a dbh meter, the diameter of the branch on which the cavity was located (cm) using a tape measure, cavity depth (m) where possible and cavity orientation using a compass. We also recorded the origin of the cavity, whether it was an excavated cavity, originating from a broken branch, or a natural crack and crevice. Whether the cavity was in a dead or live branch, or on the main trunk of the tree, was recorded. The distance to the nearest tree and the nearest nest site was recorded. A 20m x 20m quadrat was established around the nest tree and the number of trees within the quadrat was counted.

During the 2010-11 breeding season, we collected data on active Lilian's Lovebird's nests using direct observations by individuals in 4 h shifts (Warburton and Perrin 2005). However, during the 2012-13 and 2013-4 breeding periods activities at the nests were obtained using infrared digital cameras (LtI Acorn, 6210MC, China) installed facing the entrance to the nest cavities. Six camera traps were installed, three at Chinguni and three in the Rhino Sanctuary, in each of the other two seasons.

Camera traps were placed facing the cavity entrance of nest cavities where eggs had been observed. The cameras were active for 24 h, they did not take pictures continually and only took pictures when triggered by movement. The cameras took one photo every 10 s whenever movement was detected at the cavity entrance. We inspected nests every seven to 10 days when we exchanged the SD card in the cameras. Each image had a time, date and temperature stamp. An endoscope was used to monitor the contents of the nest every seven days.

Rainfall data were collected from the LNP Chinguni offices. Agriculture fields neighboring the park were visited during the breeding season to monitor lovebird activity in the fields. Lilian's Lovebirds are considered an agricultural pest and there was a concern of them being trapped in the field as a crop protection measure.

Data Analyses

Images obtained from the cameras were scanned for any event (where an event was defined as a picture that had something other than the nest hole itself in view). Events were grouped as either 'lovebird' ('mate feeding' was also specifically labelled) or 'other'. The 'other' images were assessed for the presence of other species, including competitors (species that are secondary cavity nesters) or predators (species known to prey on eggs). All statistical analyses were carried out using STATISTICA 7 (Statsoft, Tulsa, OK).

Results

Nest locations

Eighty four Lilian's Lovebirds nests were identified through observations of birds carrying nest materials. Most of these nests (75 %) were in parts of trees where it was impossible to confirm the cavity contents. Cavities were inaccessible either due to the branch being dead or too small and unsafe to climb. In some cases cavity contents could not be observed with the inspection endoscope camera as the cavity was deeper than 1 m.

We confirmed contents of 21 Lilian's Lovebirds' nesting cavities. All nest cavities were located in Mopane trees in areas where the lovebirds roosted in the non-breeding season. However, the lovebirds did not build their nests in the same cavity used for roosting prior to the breeding season. In all cavities monitored using trail cameras, we noted that the lovebirds returned to the same cavity during November through December. However, in January, when the lovebirds began nest building the cavities were vacated and new cavities were occupied. Vacated cavities were occupied within one week by Grey-headed Sparrows *Passer diffusus* for breeding (n = 5).

Nest characteristics

Lilian's Lovebirds' nest cavities were in trees with dbh ranging from 38 cm to 76 cm (mean = 57.6 ± 2.35 cm, Table 1). Tree height ranged from 11 to 23 m whilst the nest cavities were at a mean height of 10.5 ± 0.63 m from ground level. In each area, nest sites were in loose clusters of trees with the mean distance to the nearest nest site being 24.3 ± 3.18 m. However, the density of

trees in the nesting areas was higher than elsewhere with a mean of 4 trees in a 20 m X 20 m quadrat. The distance to the nearest tree was closer than that of the nearest nest site (8.24 ± 0.93 m).

Table 1: Characteristics of nest trees of Lilian’s Lovebirds in Liwonde National Park.

	Valid N	Mean	Minimum	Maximum	SE
Height cavity (m)	21	10.46	5.35	16.00	0.64
Tree height (m)	21	17.54	11.10	23.50	0.72
dbh (cm)	21	57.6	38.2	76.7	2.4
Branch diameter (cm)	4	24.8	20.4	28.7	2.0
Nearest nest (m)	17	24.34	7.00	55.00	3.18
Nearest tree (m)	13	8.24	3.00	13.40	0.93
Number of cavities	18	2.2	0.0	5.0	0.4
Trees in 20x20 m	11	4.4	0.0	10.0	0.9

Most Lilian's Lovebirds' nests had a predominantly south-east or easterly orientation (Fig. 2, 57 %). No cavity excavated by other species was used for nesting. All cavities recorded originated from either a natural crack or a broken branch. Most nest cavities (80 %) were located in a branch of a tree rather than in the main trunk. In most cases the cavity was close to a 'fork' in a branch or the trunk. Cavities in both live and dead tree branches were used for nesting but most of the nests (85 %) were in live branches. The majority of nest cavities had one entrance hole. However, in a few cases the nest cavities had a hole at the bottom of the nest as well as at the top. In these cases the lovebirds piled twigs to cover the bottom hole and built their nest on top of the piled twigs.

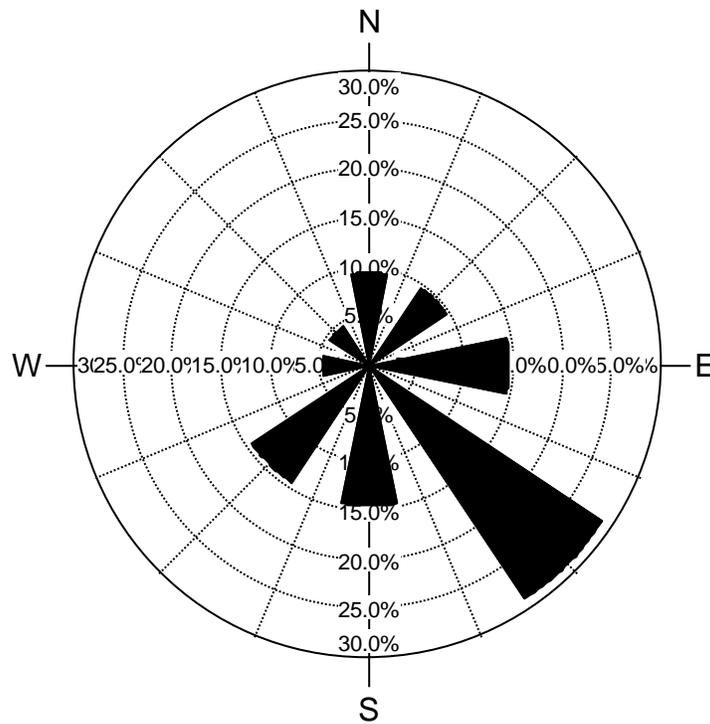


Figure 2: Nest cavity orientation of Lilian's Lovebirds in Liwonde National Park, Malawi.

Courtship

Courtship behavior of Lilian's Lovebirds was observed earliest on 5 November (2010) and the latest on 15 December (2013). The most commonly seen behavior (81 %, n = 103) was mate feeding during pre-roosting hours.

Nests and nest building

Individual Lilian's Lovebirds carrying nest material were observed from January to February (Fig. 3). Materials used to build the nest were mainly twigs and grasses (Appendix 1). These materials were carried in their beak. Lovebirds continued to carry nesting materials throughout the nesting period and after the eggs hatched. The majority of observations 59 % (n = 123) were of lovebirds carrying Mopane petioles or twigs with one or two pairs of leaves at the end. The lovebirds built their nests at the bottom of the cavity against the inside wall of the cavity rather than in the centre. We recorded two incidents where the same tree had Lilian's Lovebirds nests above and a Grey-headed Sparrow nest in another cavity below.

	Nov				Dec				Jan				Feb				Mar				Apr				May			
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Courtship	■	■	■	■	■	■	■	■																				
Nest building									■	■	■	■	■	■	■	■												
Egg laying													■	■	■	■												
Incubation																	■	■	■	■								
Hatching																	■	■	■	■								
Chicks peeping out of cavity																					■	■	■	■				
Fledging																									■	■	■	■
Post Fledging																												
Parks early burning																												
Grass seed availability									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Sorghum seeding																					■	■	■	■				

Figure 3: Time line showing breeding season of Lilian’s Lovebirds in Liwonde National Park, Malawi. (Time periods are in weeks).

Breeding season and success

Lilian’s Lovebirds egg-laying began in mid-February, chicks hatched from mid- to the end of March and by the end of April all chicks had fledged. No evidence of double clutching was observed. We recorded one incident where a pair re-nested after a nest failure; however the second clutch was also unsuccessful. The Tree Squirrel *Paraxerus cepapi* was the only other species seen entering this cavity. We monitored the contents of 20 lovebird nests during the three breeding seasons. In all cases it was not possible to remove the eggs or nestlings from the nest cavities to take measurements. Clutch size ranged from 3 to 6 eggs and mean clutch size was 5.1 ± 0.22 eggs (Table 2). The incubation period ranged from 23 to 25 days. One hundred and one eggs were monitored over the three breeding seasons. Hatching success was 49 % whilst fledging success was 69 % (Table 2). Chicks fledged at 40 to 45 days. The nest was dismantled

after chicks fledged. However, images did not show the parents carrying out the nesting material. However, both chicks and parents continued to use the nest cavity for a minimum of 10 days after fledging.

Table 2: Summary of breeding success of monitored Lilian's Lovebird nests in LNP.

	2010/2011	2012/2013	2013/2014	Summary
Number of nests	4	7	9	20
Total number of eggs	19	32	50	101
Hatching success (%)	79	63	28	49
Chicks fledged (%)	60	75	71	69
Total No. of eggs laid in all periods				101
Mean clutch size \pm SE				5.0 \pm 0.22
Hatching success (%)				49
Fledging success (%)				69

Chick development

Lilian's Lovebirds eggs hatched asynchronously, we observed eggs hatching on different days and chicks were of different sizes. Chicks remained without any feathers for the first seven days and were seen huddled together in the cavity. When feathers developed on the wings, the chicks were seen to move from the main nest, settling on the edges but still close together. The chicks were responsive to the light of the endoscope but not defensive. The conspicuous red beak was the first facial feature to be seen as the chicks grew, followed by the white eye ring. Chicks started to 'peep' out of the nest after about 35 days after hatching. At this stage the chicks were seen to move away from the light when the endoscope was inserted into the nest cavity. Chicks had the lighter peach face than the adults and often peeped out when adults were away. When adults arrived at the nest cavity, chicks called in a light pitched tone.

Nest re-use

We recorded five incidents of Lilian's Lovebirds nest re-use. The lovebirds were not marked therefore it was not possible to know whether the same pair re-used the cavity in the following season. In two of the cases the nests were successful in both season but in one case the nest was preyed upon on in the second season. This nest was later taken over by a pair of Grey-headed Sparrows in the same season, and they bred successfully. There were three incidents where Grey-headed Sparrow pairs took over a Lilian's Lovebird nest and bred successfully during the study. All three incidents were in the Sanctuary area of LNP. No such incidents were recorded in the Chinguni area.

Activity pattern at nest entry

As anticipated, the Lilian's Lovebirds' activity pattern at the nest cavity differed significantly between the breeding and the non-breeding season. In the non-breeding season, Lovebirds exited the roosts just before sunrise and only returned back in the late evening (Fig. 4). There were very few incidents (2 %) when the Lovebirds returned to the roost in the afternoon. However, during the breeding season there was increased activity at the nest cavity. Lovebirds were seen inside or by the nest cavity throughout the day. The highest numbers of observations were between 14h00 and 15h59 hours (Fig. 4).

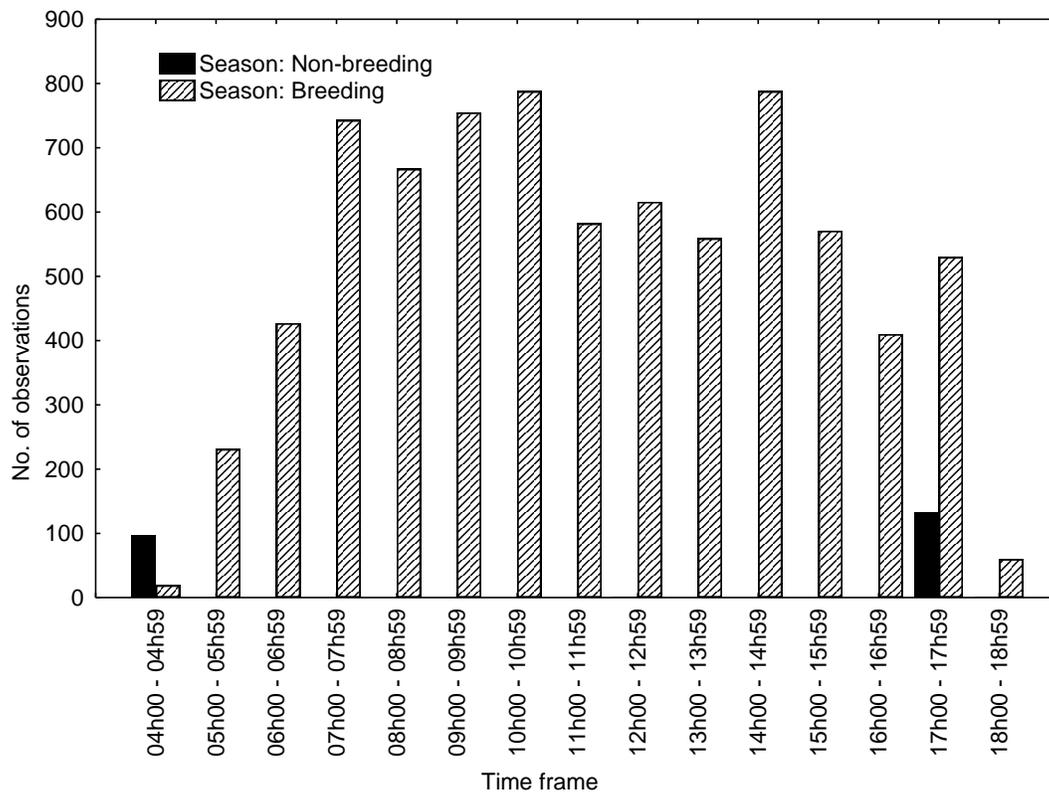


Figure 4: Activity patterns of Lilian's Lovebirds at nest cavities in the breeding and non-breeding seasons in Liwonde National Park, Malawi.

Rainfall and temperature during the breeding season

Maximum and minimum rainfall differed between years (Table 3). The largest values were recorded in 2013 and 2014 (120 and 130 mm respectively). The first rains arrived in October when monthly rainfall was lowest. Most rainfall was recorded in the months of January and February and the last rains were recorded in May.

Table 3: Summary of annual and monthly rainfall (mm) for Liwonde National Park, Malawi.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Annual Total Rainfall
2010	0	28.1	191.7	55.3	313.1	78.9	63	0	744.7
2012	17	2	154.3	252	104.8	248.4	27.8	0	806.3
2013	19	0	281.7	264.2	393.3	75.3	12.6	10.8	1056.9
2014	-	-	-	269.6	260.1	82.5	111	2.5	725.7

Note- No data for Oct, Nov & Dec 2014

Predators and other species at the nests

Approximately 2 % (n = 146) of all observations on Lilian's Lovebird nest cavities were of different species. Fourteen other species were recorded at the nest cavity (Table 4, Fig. 6); the Tree Squirrel *Paraxerus cepapi* was the most commonly recorded species. The number of times this squirrel was recorded at nests differed significantly between the Rhino Sanctuary and those at Chinguni (Fig. 6). For the Chinguni area, the most frequently seen species at the nest cavity

was the Africa Harrier Hawk *Polyboroides typus* (85 %, Fig. 6). In all cases it was unsuccessful at preying on the nest. Whilst the Tree Squirrel was observed from the egg-laying period till just after the chicks fledged, the Harrier Hawk was only recorded after chicks had hatched and were mobile within the nest.

Egg predation of Lilian's Lovebirds was recorded for the Green Mamba *Dendroaspis angusticeps* (n = 1, eggs only, Chinguni area) and the White-throated Monitor Lizard *Varanus albigularis albigularis*, (n = 2, Rhino Sanctuary,). The Green Mamba was not recorded on camera footage but was found in a nest during inspection. We recorded one predation incident on a young lovebird chick (less than 1 week). Eggs from one nest were taken by an un-identified rodent. There were two egg predation incidents where the Tree Squirrel was the only potential predator photographed entering and exiting the cavity.

Table 4: Other species observed entering or exiting Lilian's Lovebirds nest cavities in Liwonde National Park, Malawi

Species	Sanctuary	Chinguni
Reptiles		
White-throated Monitor Lizard <i>Varanus albigularis</i>	8	0
Green Mamba <i>Dendroaspis angusticeps</i>	0	1
Lizard sp.	2	1
Tree Squirrel <i>Paraxerus cepapi</i>	70	14
Birds		
Gymnogene <i>Polyboroides typus</i>	3	29
Long-tailed Glossy Starling <i>Lamprotornis caudatus</i>	5	0
Crested Barbet <i>Trachyphonus vaillantii</i>	1	0
Red-billed Wood-Hoopoe <i>Phoeniculus purpureus</i>	1	0
Common Scimitarbill <i>Rhinopomastus cyanomelas</i>	4	6
Grey-headed Sparrow <i>Passer diffusus</i>	15	3
African Hoopoe <i>Upupa epops</i>	1	0
Brown Snake Eagle <i>Circaetus cinereus</i>	0	1
White-browed Sparrow Weaver <i>Plocepasser mahali</i>	0	1
Mammals		
Bush Baby <i>Galago</i> sp.	6	0
Large Spotted Genet <i>Genetta tigrina</i>	12	0
Unidentified Rodent	6	0

Discussion

The start of the breeding season in the Black-cheeked Lovebird was likely triggered by rainfall (Warburton and Perrin 2005). In LNP, courtship behaviour of Lilian's Lovebirds was observed in different months but always after the first rains. Nest building started after the park has received enough rain to allow the grasses to grow and the trees to have flushed leaves. This ensures that materials necessary for nest building are available as observed for the Black-cheeked Lovebird (Warburton and Perrin 2005). We observed that the lovebirds used grass and fresh mopane twigs for nest building. These are only available after the first rains.

Nest cavity characteristics

Lilian's Lovebirds nested exclusively in Mopane tree cavities. The majority of nest cavities were inaccessible either by positioning or by depth. This most probably ensures nest security from predators. The majority of the accessible cavities were in live branches. Secondary cavity nesters in temperate regions are known to prefer cavities in trees that have some level of decay (Martin *et al.* 2004). However this may be because most cavities in these regions are excavated by primary cavity users (Cockle *et al.* 2011). Cavities in mopane trees form naturally in live trees explaining why most of the cavities used were in live trees.

Lilian's Lovebirds nest trees were located in a loosely clumped structure with only one lovebird nest per tree. This reflects the lovebird's social nature as observed for the Black-cheeked Lovebird (Warburton and Perrin 2005). Lilian's Lovebirds show preference for south and east facing cavities. Secondary cavity nesters show orientation preference when orientation

is related to temperature (Ardia *et al.* 2006). South and east facing cavities are warmer in other parts of the world which may be beneficial to nestlings (Ardia 2005; Dawson *et al.* 2005; Burton 2006). This could also be true for the lovebirds. Lilian's Lovebirds did not use the same cavities used in the non-breeding for nesting. Roost site orientations in the non-breeding season are more easterly oriented, with very few facing south (Mzumara in prep., chapter 5). Future work is needed to investigate if temperature is among the factors that influence the need to change cavities.

Nest fidelity

Lilian's Lovebirds not only used the same trees and sites in successive breeding seasons, they also re-use cavities. Loss of eggs to predation did not deter the lovebirds from re-using the nest cavities. This may suggest that availability of suitable nest cavities is limited. Parrots are known to have high nest site fidelity (Snyder *et al.* 1987; Waltman and Beissinger 1992; Berkunsky and Reboresda 2009). The Black-cheeked Lovebird in Zambia was suspected to re-use the same cavities in successive breeding seasons, although this was not confirmed (Warburton and Perrin 2005).

Competitors and predators

The interactions observed between the Grey-headed Sparrows and the Lilian's Lovebirds support the possibility of limitation in the availability of suitable nest cavities. Cavities vacated by the lovebirds just before the breeding season were later occupied by Grey-headed Sparrows. This

suggests that there is asynchronous breeding between lovebirds and sparrows. The sparrows also took over nests where lovebird breeding was unsuccessful due to predation and they nested in cavities in the same tree as the Lovebirds. This suggests that the requirements for a suitable cavity for breeding are similar for the two species which may lead to competition. The extent of this interaction requires further investigation. No other bird species were recorded occupying previous lovebird cavities.

However, Tree Squirrels did occupy cavities previously used by Lilian's Lovebirds. The Tree Squirrel was also the most common visitor to lovebird nest cavities in the sanctuary. Tree Squirrels are mainly vegetarian but also take insects and small vertebrates (Viljoen 1975). They breed in tree cavities. In South Africa their breeding season is between October and January, with the most young being born in November (Viljoen 1977). Although the breeding season may be different for Malawi, it is likely that there is some competition for suitable nesting/resting cavities between the two species. In the United Kingdom, Grey Squirrels *Sciurus carolinensis* compete with birds at supplementary feeding stations (Bonnington *et al.* 2014). Red squirrels *Tamiasciurus hudsonicus* are important bird nest predators in conifer forests (Willson *et al.* 2003). We suggest that the Tree Squirrel may be an important egg predator for Lilian's Lovebird. However, since it has been shown that snakes such as the Green Mamba are able to enter the nest without triggering the camera, it is not possible to confirm this importance. Further study studies are required to investigate this.

There is a clear distinction between the numbers and diversity of predators and competitors in the central and southern parts of LNP. Lilian's Lovebirds breeding in the Rhino Sanctuary face a large diversity of predators and competitors. A study on small mammals in LNP

reported densities of up to 17/ha, increasing in the wet season due to young requirements, and in unburnt areas (Happold and Happold 1990). We suggest the management of the Sanctuary as an enclosure with artificial waterholes and the lack of early burning impacts the density of fauna in it with more than the rest of the park. All three nests monitored in the sanctuary in 2014 were unsuccessful due to predation by a Monitor Lizard, Tree Squirrel and an unidentified rodent suggesting relatively higher predation rates here.

Activity pattern

During the breeding season Lilian's Lovebirds were active at the nest throughout the day. Activity at the nest was highest when the park was hottest. The lovebirds feed mainly on grass seeds found within the Mopane woodlands during the breeding season. These areas are closer to their nest sites thus they probably return to the nest cavity to avoid the extreme heat of the day. This differs from the lovebirds activity pattern in the non-breeding season when they prefer to rest in the same areas where they feed. These feeding areas are often grasslands with tree cover of *Acacia* sp., *Ficus* sp. or *Adansonia digitata* (Mzumara in prep. Chapter 4).

This study raises important questions requiring further study to better understand the breeding biology of Lilian's Lovebirds in the wild. We suggest the Lilian's Lovebirds face high predation pressure in the wild which significantly and negatively impacts on breeding success. The suggested high competition with other secondary cavity nesters is evidence of limitation in availability of suitable nest cavities. Further studies should investigate the roles of predation and competition in Lilian's Lovebird's breeding success.

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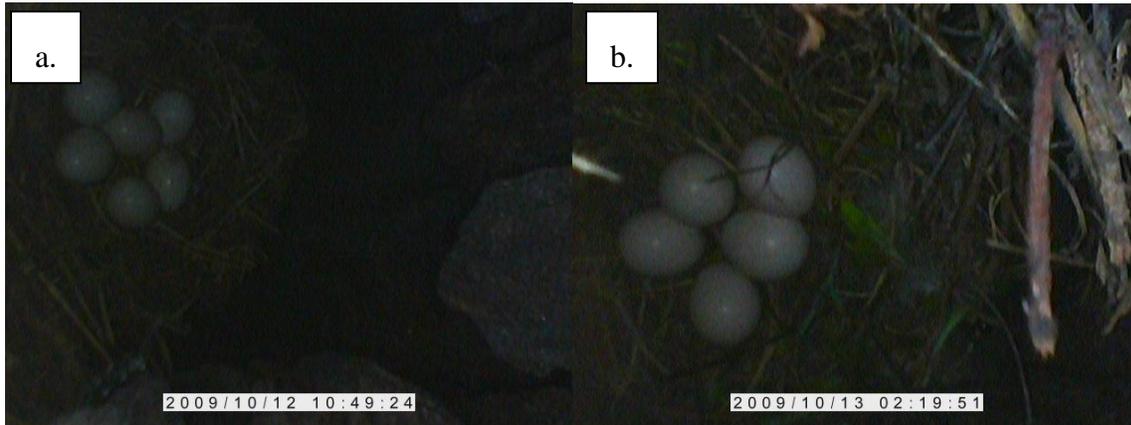
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Appendix 1: Photographs of breeding observations where a. and b. show Lilian's Lovebirds eggs in nest inside cavity with nests built against the inside tree trunk and not centrally placed, and c. showing one egg just hatched (shell still in nest). (NB: Dates on photos are wrong due to an error in the inspection-camera's setting).



CHAPTER 7: The drinking habits of the Lilian's Lovebird and incidents of poisoning at waterholes

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Abstract

Use of poison to kill wildlife is a threat to biodiversity. Lilian's lovebirds *Agapornis lilianae* are among the fatalities at poisoned waterholes in Liwonde National Park, Malawi. Their population in LNP represents about 20% of the global population. We investigated the drinking habits of Lilian's lovebird, availability of natural waterholes and occurrence of poisoning incidents in LNP. Results showed Lilian's lovebirds congregate at waterholes in the dry season with flocks ranging from 1 to 100 individuals. Significantly larger flocks were seen in the dry than the wet season. Poisoning incidents/year ranged from 1 to 8 and were highest in the dry season. Lilian's lovebirds were killed at a mean of four poisoning incidents each year between 2000 and 2012. Number of lovebirds found dead at a poisoned pool ranged from 5 to 50 individuals. There is a need for increased efforts in preventing this lethal activity in LNP.

Key words: Lilian's lovebird, *Agapornis lilianae*, conservation, poisoning, Liwonde National Park, Malawi

Introduction

Protected areas (PAs) safeguard biodiversity (Bruner *et al.*, 2001; Locke & Dearden, 2005) although the extent of their effectiveness is debated (Chape *et al.*, 2005; Hayes, 2006). Most national policies consider PAs an efficient method of *in situ* biodiversity conservation (Bruner *et al.*, 2001; Balmford *et al.*, 2002; Chape *et al.*, 2005; Hayes, 2006). Sub-Saharan Africa has over 1100 national parks and reserves (WCMC, 2004) and many of these face threats from expanding human populations, economic development, globalisation and national governance (Lambin *et al.*, 2001; Newmark, 2008; Brink & Eva, 2009; Rudel, 2013). Controlling illegal hunting remains a challenge for most African PAs (Bruner *et al.*, 2001; Struhsaker, 2005; Lindsey *et al.*, 2013). Recently use of poison to kill wildlife has become a threat to wildlife inside and outside protected areas (Ogada, 2014). The poisons used are cheap and easy to use on damage-causing animals and for poaching (Kissui, 2008; Ogada, 2014).

Malawi is a landlocked country in southern Africa. Habitat loss outside most of its PAs has caused their isolation (Newmark, 2008), producing ‘green islands’ in an agricultural and human dominated matrix. Liwonde National Park (LNP) is located in Malawi’s south. It is classified as a high value and high pressure PA (EU, 2010), and the only location with a resident, breeding population of the Lilian’s lovebird *Agapornis lilianae*, a near-threatened small parrot, endemic to the Zambezian biome (Perrin, 2012).

Parrots worldwide are threatened by habitat loss and illegal capture for the pet trade (Forshaw, 1989; Collar, 1997; Snyder *et al.*, 2000; Pires & Clarke, 2001; Perrin, 2012). In LNP, Lilian’s lovebirds also face threat from illegal hunters poisoning waterholes to catch small

mammals and medium-sized birds for food (Nsikuwanga 2011, pers. comm.). Its impact on the lovebird population in LNP was unknown until recently. Black-cheeked lovebirds *A. nigrigenis* in Zambia also face threats from poisoned waterholes (Warburton, 2003) however this is generally at water sources outside of PAs.

Lilian's lovebirds are mopane *Colosphermum mopane* woodland specialists closely associated with the distribution of rivers (Forshaw, 1989; Warburton, 2005; Perrin, 2012). They form large flocks around water sources (Forshaw, 1989; Dowsett-Lemaire & Dowsett, 2006), as observed in Fischer's lovebird *A. fischeri*, yellow-collared lovebird *A. personatus*, black-cheeked lovebird and rosy-faced lovebird *A. roseicollis* (Forshaw, 1989; Fry *et al.*, 1998; Warburton & Perrin, 2005; Perrin, 2012). Lilian's lovebirds' diet is largely grass seeds (Forshaw, 1989; Fry *et al.*, 1998). They are highly dependent on free standing water (Fisher *et al.*, 1972; del Hoyo *et al.*, 1997; Warburton, 2003) so poisoning of water sources poses a direct threat to their viability.

We investigated the drinking habits of Lilian's lovebirds in LNP, the availability of natural water sources, frequency of poisoning events and its possible impact on population numbers. We predicted that drinking habits of Lilian's lovebirds would be similar to those of the black-cheeked lovebird. We also expected that poisoning incidents would be highest during the dry season (May - Oct) and lowest during the rainy season (Nov - April).

Methods

Study area

LNP (14°36'E to 15°03'S and 35°15' to 35°26'E; 548 km²) ranges from 474 to 921 m a.s.l. (Manongi, 2004). It has distinct rainy (Nov – April) and dry seasons (May – Oct). Average annual rainfall range is 401 - 999 mm (Dudley, 1994). LNP has a 'hard' partially fenced boundary with no buffer zone (Thomson, 1998). In unfenced areas boundaries are well known and marked using fire breaks. Land use bordering LNP is mainly agriculture. Mopane woodland is the dominant vegetation covering approximately 70 % of its area (Hall-Martin, 1969; Dudley, 1994).

Lilian's lovebird drinking habits

We studied drinking by Lilian's lovebirds in the wet and dry seasons of 2010, 2012 and 2013. Drinking places were identified by LNP scouts and opportunistic searches. Three main waterholes in central LNP were monitored for lovebird drinking behaviour. We conducted full day counts for three days at each waterhole at the peak of the dry season and in the wet season. Observations were made using a pair of binoculars (Lynx 8 X 42) and a telescope (Kowa 10X). We recorded when lovebirds drank at the waterhole, and flock size. Flock sizes were compared for three periods of day; morning (05h00 – 09h59); mid-morning to afternoon (10h00 – 14h59) and evening (15h00 – 18h00)

Waterhole availability and distribution after the rainy season

We surveyed 24 transects for the presence of natural waterholes in LNP from May to July, and in October 2012. Transects used were those predetermined by the park management for mammal counts. Transects were 2 km apart and covered the entire park. We recorded geographic locations of all natural waterholes encountered using a global positioning system (GPS, Etrex 10, Garmin, Olathe, Kansas). Each waterhole was described as ‘wet’ (containing water) or ‘dry’ (not containing water). Locations were mapped using ARCGIS 10.1 (ESRI 2012, Redlands, USA).

Locations of waterhole poisoning

Monthly LNP patrol reports were obtained from LNP’s law enforcement department. All reports from all camps in LNP (2000 – 2012) were examined for records of poisoned waterholes. Date, map co-ordinates and camp were recorded for each poisoning incident. ArcGIS 10.1 was used to map all of the poisoning localities and to correlate them spatially with LNP’s vegetation, streams and natural waterholes. We noted that the actual numbers of lovebirds found dead at a poisoned waterhole was not recorded so we administered a simple questionnaire to LNP scouts to estimate poisoning incidents and numbers of birds found dead at poisoned pools. The numbers of lovebirds killed each year could not be estimated because of the possibility of one incident being reported by several scouts. Consequently only data extracted from the scout reports (2000 – 2012) were used when calculating poisoning incidents on a monthly basis.

Estimating proportions of populations at risk with poisoning

Geo-referenced poisoning incidents were inserted as point features on the LNP map. There are no spatial dispersal data available specific to Lilian's lovebirds. However, rosy-faced lovebirds are known to move distances between 1 to 4.5 km (Ndithia & Perrin, 2007). We therefore assumed 4 km as the possible distance Lilian's lovebirds would fly to drink. A 4 km buffer was created in ArcGIS 10.1 for each of the reported poisoning spots. Where buffers intersected, one buffer was created encompassing the intersecting points.

Areas of mopane woodland in buffer zones were calculated as Lilian's lovebirds only roost and breed in mopane trees (Mzumara in prep., Mzumara *et al.*, 2014). Thus their abundance is largely determined by the availability of this vegetation type. The probability of a waterhole causing death of Lilian's lovebirds, and the average number of lovebirds poisoned at a waterhole, were used to estimate the number of lovebirds at risk of poisoning per year. The current population of Lilian's lovebirds in LNP approximates 4000 individuals or 17 lovebirds km⁻² (Mzumara in prep.). Statistical analyses were conducted using STATISTICA (ver. 7; Statsoft, Tulsa, OK).

Study limitations

We were unable to test the probability of finding all poisoned lovebirds at waterholes. Scavengers and experience of observers affect the number of dead birds found (Schutgens *et al.*, 2014). We were also unable to determine the time taken for lovebirds to be killed following exposure to pesticide. We assumed that the impact of poison was immediate (Ogada, 2014).

Results

Lilian's lovebird drinking habits

Lilian's lovebirds drank from different water sources in LNP. These varied from dambos (grassy wetland areas) along the Shire River, big artificial waterholes in the Rhino Sanctuary and small natural waterholes in mopane and mixed woodland habitats. During the wet season, lovebirds drank from the natural waterholes in the mopane woodlands and at small pools on the roads and in grassland areas. No lovebirds were observed drinking from the Shire River channel. In northern LNP, Lilian's lovebirds drank from mud pans and dambos on the banks of Lake Malombe. Lilian's lovebirds drank from water whose quality varied from clear to muddy/ algae infested (Mzumara, pers. obs.).

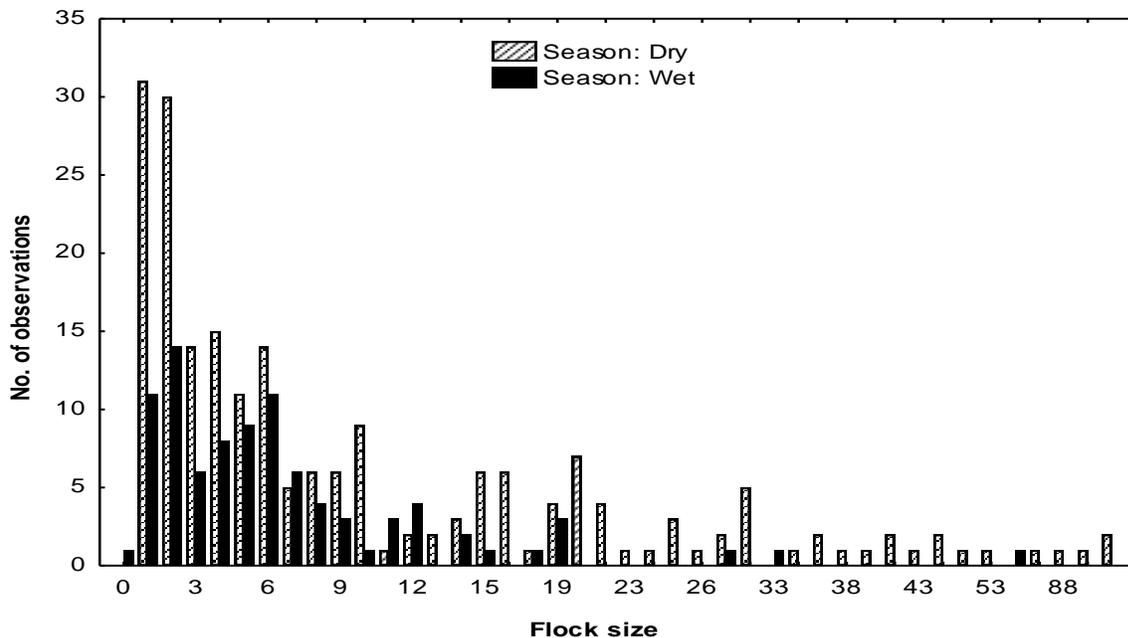


Fig. 1 Number of observations of Lilian's lovebirds flock sizes observed drinking in the wet and dry season at waterholes in Liwonde National Park, Malawi.

The number of observations of Lilian’s lovebird drinking at the three monitored waterholes differed significantly between the wet (n = 91) and dry seasons (n = 208) (Mann-Whitney U test, $P < 0.05$). No lovebirds were recorded at the three main waterholes in the wet season (January – April). Lilian’s lovebirds began visiting these waterholes in the Rhino Sanctuary from May of each year. Flock sizes at waterholes ranged from 1 to 30 individuals (Fig. 1). The most frequently seen flock size was 1 or 2 individuals (28 %). Significantly larger flocks (mean \pm SE) were seen in the dry season (12 ± 0.1 individuals) compared with the wet season (7 ± 0.1 individuals, Kolmogorov-Smirnov Test, $P < 0.025$).

Table 1: Birds observed drinking with Lilian’s lovebirds at waterholes in Liwonde National Park, Malawi.

English Name	Scientific name
Southern grey-headed sparrow	<i>Passer diffusus</i>
Meves’s starling	<i>Lamprotornis mevesii</i>
Cape turtle dove	<i>Streptopelia capicola</i>
Greater blue-eared starling	<i>Lamprotornis chalybaeus</i>
Red-eyed dove	<i>Streptopelia semitorquata</i>
Yellow-fronted canary	<i>Serinus mozambicus</i>
Grey-headed parrots	<i>Poicephalus fuscicollis</i>
Wattled starlings	<i>Creatophora cinerea</i>
Red-billed oxpeckers	<i>Buphagus erythrorhynchus</i>
White-browed sparrow-weavers	<i>Plocepasser mahali</i>
Laughing doves	<i>Spilopelia senegalensis</i>

In the dry season, the number of Lilian's lovebirds drinking in the mornings, afternoons and evenings differed significantly (Kruskal-Wallis test: $P = 0.0195$). More flocks of lovebirds were seen in the mornings between 06h00 – 09h00 and in the evenings between 15h00–18h00. Flock size ranged from one to 100+ individuals. Mean flock size was significantly different in the three periods of the day (Fig. 2, Kruskal-Wallis test, $P < 0.01$). The largest lovebird flocks were seen during the evening hours (17h00 – 17h59) (mean = 43 ± 2.0 lovebirds) and early morning (mean = 20 ± 0.7 lovebirds). At midday very few observations were made of lovebirds drinking.

Lilian's lovebirds avoided drinking at waterholes when there were large mammals present; other species recorded drinking at a waterhole with the lovebirds were all birds (Table 1). The Grey-headed sparrow and the white-browed sparrow-weavers were the species most commonly seen drinking with the lovebirds (>50 %) When there were mammals drinking at a waterhole the lovebirds were seen flying over.

Distribution and availability of natural waterholes

One hundred and seventy five waterholes were recorded along transects in LNP (Fig. 3); most (65 %) were in mopane woodland. The number of 'wet' naturally-occurring waterholes encountered during transect walks decreased by 95 % from May (n = 65) to October (n = 3).

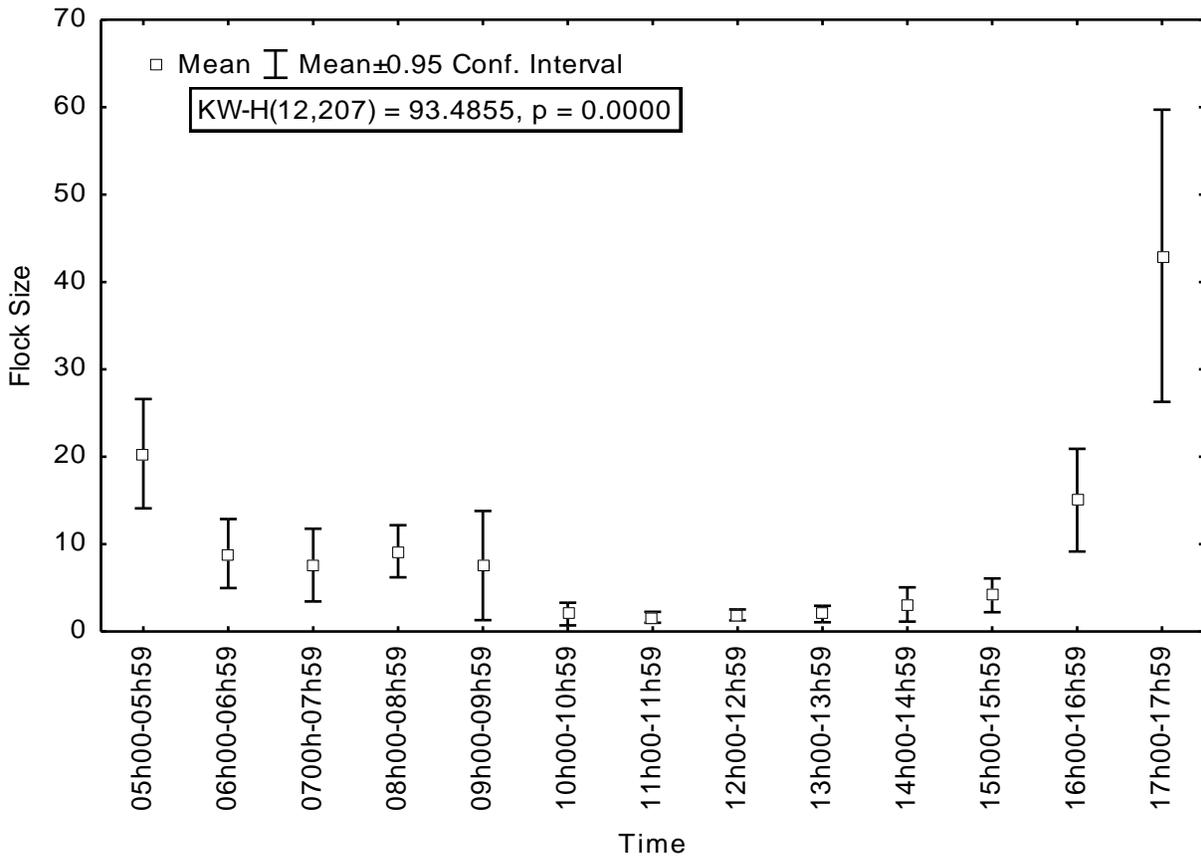


Fig. 2 Variability of mean flock sizes of Lilian’s lovebirds at different times of day at waterholes in Liwonde National Park, Malawi.

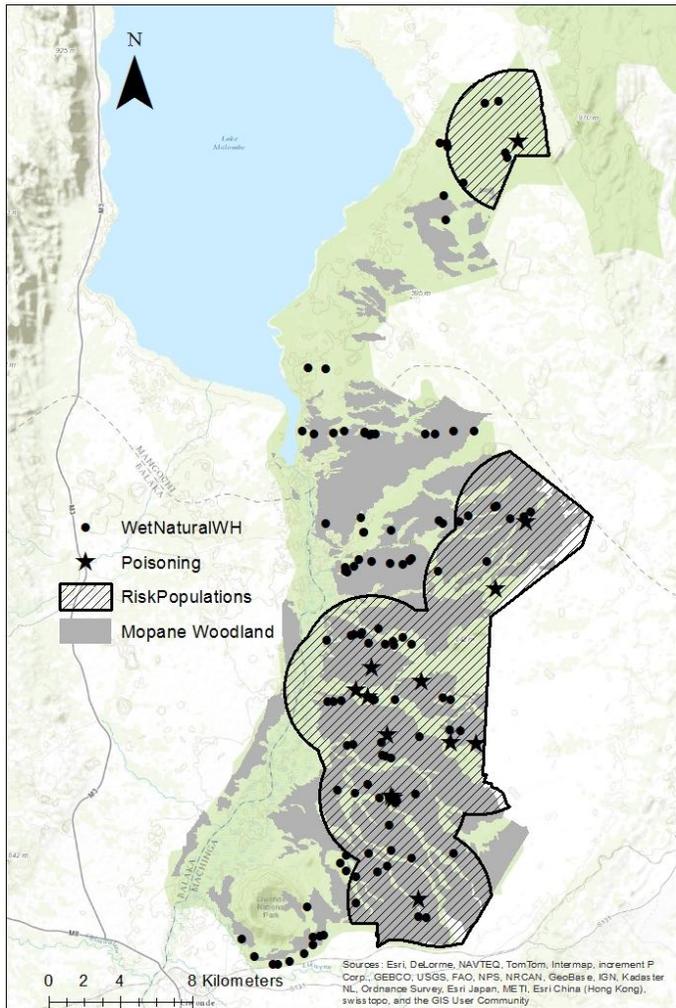


Fig. 3 Spatial distribution of poisoning incidents at waterholes reported between 2005 - 2012 in Liwonde National Park, Malawi. (Circles are the 1 km buffer areas).

Occurrence of poisoning incidents

Thirty-one poisoning incidents were reported in LNP between 2000 and 2012. The number recorded differed significantly between the north, central and southern parts of LNP (Kruskal-

Wallis, $P > 0.001$). Most poisoning incidents (81 %, 25) were from the south of LNP, between Ntulira and Nafiulu Camps (Fig. 3). This area had four places with repeated poisoning incidents over several years; they were Namandanje Dam, Nachibwira Dam, Mwalasi and Bilira waterholes.

All poisoning incidents were inside the LNP boundaries. No poisoning incidents were found in the scout reports from 2000 to 2004. Waterhole poisoning in LNP was reported in all months of the year except for January, March and December between 2005 and 2012. Poisoning occurred mainly from the month of May to October (84%, 26). The highest numbers of poisoning incidents at waterholes were in October, September and May (Fig. 5). The year 2008 had the highest poisoning incidents reported ($n = 9$). This was also the only year with reports of poisoning in February and April (Fig. 5). As predicted, poisoning incidents had a negative relationship with the LNP average monthly rainfall (Fig. 5).

Only 13 poisoning locations from the patrol reports were geo-referenced. Most of these were waterholes in mopane woodland ($n = 9$), two in riverine thicket, one in tall grass-tree savannah and one in mixed savannah woodland. Isolated waterholes were the main target for poisoning ($n = 12$) rather than water present along streams ($n = 1$). The sum of all the vegetation areas covered by the 4 km buffers was 250.7 km², of which the total mopane woodland area was 152.2 km². Assuming the current density estimate of 17 Lilian's lovebirds km⁻² of mopane woodland (Mzumara in prep., chapter 3) this area hosts approximately 2587 individuals. As the mean number of poisoning incidents/year is 4, we can assume 50% of these individuals (1294 lovebirds) are at risk of encountering a poisoned water hole each year (particularly during the wet season when lovebirds do not drink too far away from their roost/breeding sites). This

represents 32% of LNP current lovebird population. The proportion of lovebirds at risk will be greater in the dry season as these waterholes cater for lovebirds from a much larger area.

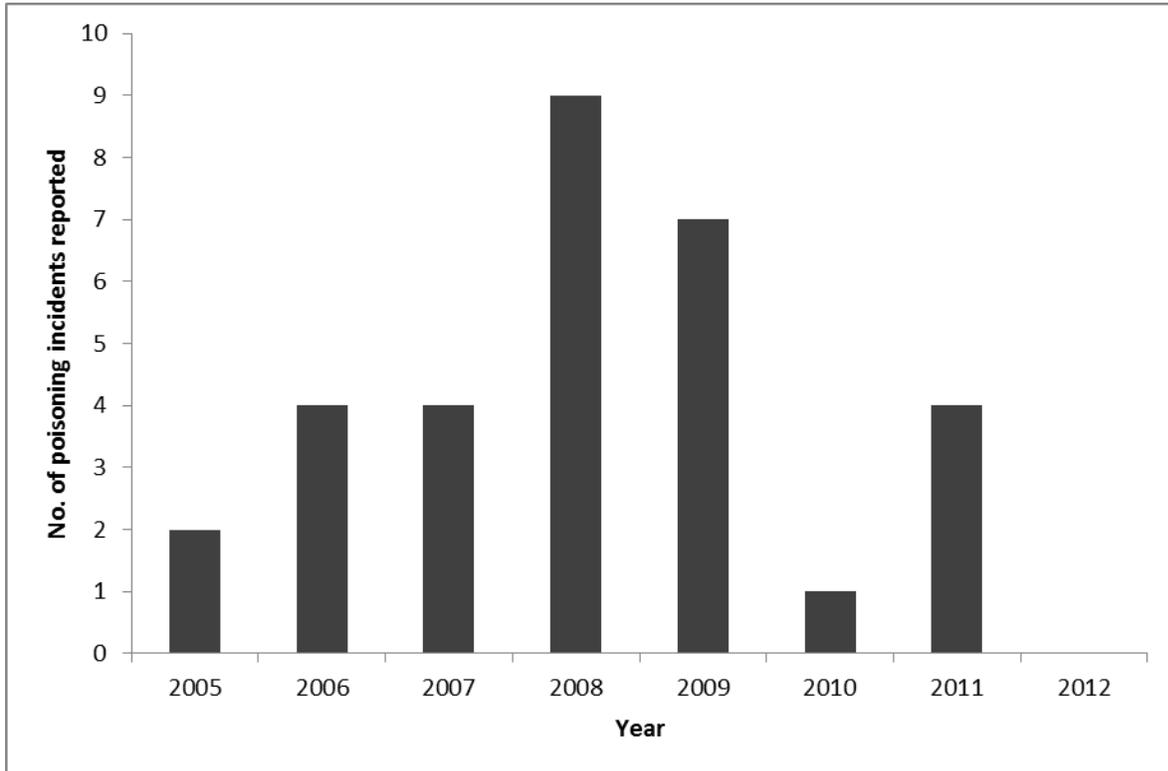


Fig. 4 Total number of reported poisoning incidents extracted from scout reports in Liwonde National Park, Malawi between 2005 and 2012.

Forty five (of a possible 69) questionnaires were completed by scouts and staff at LNP. Most (69 %, n = 31) had encountered waterhole poisoning in LNP. The mean number of poisoning incidents per year (2004 – 2013) where Lilian’s lovebirds were found dead was 4 (Appendix 1). Lilian’s lovebirds found dead at a pool varied from 5 to 50 individuals with a

mean of 17 ± 0.32 lovebirds. One respondent caught a poacher with 500 dead lovebirds confirmed by a photograph in a law enforcement report (Labuschagne, 2002). However, the report did not state whether all the 500 birds were from one waterhole or several.

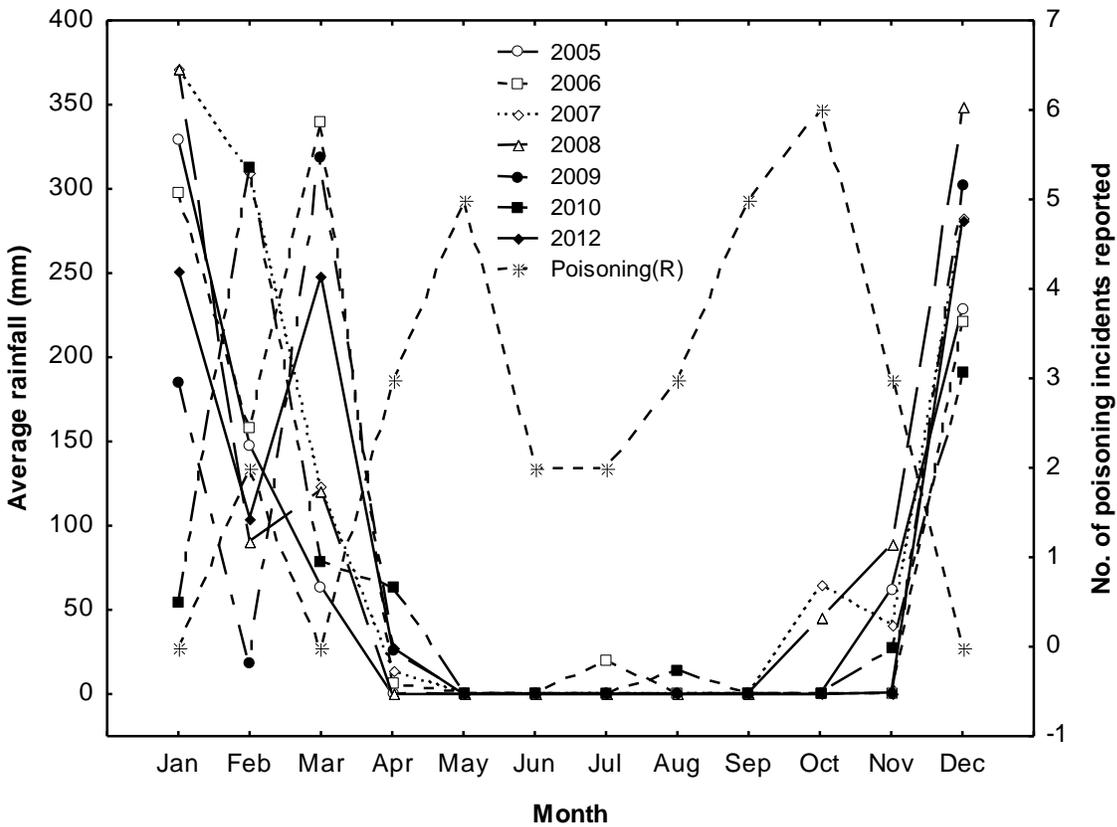


Fig. 5 The inverse relationship between average rainfall in Liwonde National Park, Malawi and the number of poisoning incidents at waterholes reported by park staff.

The most commonly reported poison in the reports of poisoning at waterholes was Temik[®] (Aldicarb), a widely used carbamate pesticide for rats (*Rattus* sp.) in crops and homes. However, scouts also reported the use of natural poisons made from *Euphorbia* sp. and *Triphosia*

sp. tree species (i.e. resulting in dead animals or plants). Usually, when Temik[®] is used evidence, of the poison used is found adjacent to the water source (e.g. the paper packaging is discarded).

Discussion

Lilian's lovebirds drank from diverse water sources but showed no preference for running water. They drank in the early morning and late afternoon similar to the black-cheeked lovebird in Zambia (Warburton & Perrin, 2005). However, the mean flock sizes at waterholes in LNP for the Lilian's lovebird during these peak times of the day differed to those for the black-cheeked lovebird. While larger flocks of black-cheeked lovebirds were seen during the early morning at drinking sites, larger flocks of Lilian's lovebirds were seen drinking in the late afternoon.

The absence of Lilian's lovebirds at monitored waterholes in LNP from January to May confirmed their use of alternative water sources in LNP during the wet season. The lovebirds used a diverse range of accessible waterholes on roads, by river banks, along streams or isolated ones in mopane woodlands. They avoided waterholes when large mammals were present. Black-cheeked lovebirds also avoid waterholes with human or livestock disturbance (Warburton & Perrin, 2005).

Naturally-occurring 'wet' waterholes in LNP reduced from May to October. Consequently Lilian's lovebirds congregated at the few available waterholes during the dry season. Lovebird congregations, especially pre- and post- roosting at waterholes makes them vulnerable to waterhole poisoning in LNP. We did not investigate the times when illegal hunters were most active in LNP, but they likely follow the activities of their target species. Lilian's

lovebirds preferred to use mostly standing water sources, and this further increases their threat from poisoning of waterholes.

Lilian's lovebirds also face risk from poisoning events recorded in the wet season when the lovebirds drink in smaller flocks because they spend more time in LNP feeding on grasses (Mzumara in prep). The amount of rainfall that LNP receives affects the availability of natural waterholes in the park. In 2008 poisoning was reported in February at a time LNP is generally still flooded making it difficult for poachers to trap mammals. However, LNP scouts explained that dry spells within the rainy season allow the park to be dry enough for illegal hunters to use poison at waterholes. We were unable to explore this possibility further. Climate change and its impacts on precipitation may increase poisoning incidents and consequently the effect on Lilian's lovebird LNP population. Current climate models suggest a mean rainfall ranging from a 2 % decrease and 5 % increase in areas around LNP (McSweeney *et al.*, 2007). An increase in rainfall will increase available waterholes thus decreasing poisoning incidents.

As the majority of poisoning incidents in LNP were at natural waterholes along transects, the transects provide a tool for improved monitoring. We recommend regular monitoring for poisoning events. Four areas repeatedly poisoned each year need increased patrols to apprehend the poachers. Use of camera traps to cover unmanned periods at high risk should be explored.

Use of poison for poaching is a threat to biodiversity in PAs. Poisoning incidents in LNP pose a risk to 32% of Lilian's lovebirds and other wildlife. During the wet season, the lovebird's widespread distribution and wide use of water sources exacerbates this problem as waterholes are difficult to monitor. Capture of black-cheeked lovebirds for the pet trade is a threat in Zambia (Warburton, 2003), Zimbabwe (Couto, 1996) and Mozambique (Parker, 2005). In Malawi there

are currently no records of Lilian's lovebirds being captured for the pet trade. Therefore the current main threat might be poisoning of waterholes in LNP.

One in eight bird species in the world is threatened with extinction (BirdLife, 2013). Recently 25 Africa bird species have been up-listed to higher categories of threat in the IUCN Red List (BirdLife, 2013). Human induced-threats are one of the main reasons for this. The LNP Lilian's lovebird population represents about 20 % of the estimated global population (IUCN, 2014). Consequently increased law enforcement patrols to prevent poisoning incidents and so conserve this population are required.

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Appendix 1: Summary of incidents of waterhole poisoning involving Lilian's Lovebirds between 2004 - 2013 in Liwonde National Park, Malawi (questionnaire responses).

Year	Place	Month	No. of Lilian's lovebirds found dead	Other species found
2004		Nov	10	vervet monkeys <i>Chlorocebus pygerythrus</i>
		Aug	8	bushbuck <i>Tragelaphus scriptus</i>
		Oct	6	weavers <i>Ploceus sp.</i>
		Sept	5	mourning doves <i>Streptopelia decipiens</i>
2005		Aug	20	waterbuck <i>Kobus ellipsiprymnus</i>
		Sept	18	greater kudu <i>Tragelaphus strepsiceros</i>
		Oct	15	weavers <i>Ploceus sp.</i>
		Nov	12	
		Nov	5	common duikers <i>Sylvicapra grimmia</i>
2006	Namandanje Dam	Oct	40	sable <i>Hippotragus niger</i> , impala <i>Aepyceros melampus</i> , weavers <i>Ploceus sp.</i> , other birds
		Sept	22	sable <i>Hippotragus niger</i>
			21	
		Nov	17	baboon <i>Papio cynocephalus</i>
		Oct	12	vervet monkeys <i>Chlorocebus pygerythrus</i>
		Aug	5	bushbuck <i>Tragelaphus scriptus</i>
2007		Aug-Dec	25	baboon <i>Papio cynocephalus</i>
2008	Lower Mwalasi	Aug-Nov	15	baboon <i>Papio cynocephalus</i>
		Sept	7	
2009	Lower Mwalasi	Aug	20	warthog <i>Phacochoerus africanus</i>

	Dam seven	Nov	10	
		Aug- Nov	9	greater kudu <i>Tragelaphus strepsiceros</i>
2010	Middle Namandanje	Nov	21	
	Upper Bilila hole	Aug	10	birds, vervet monkeys <i>Chlorocebus pygerythrus</i>
		Aug- Nov	6	weavers <i>Ploceus sp</i>
2011	Ntulira	June	50	buffalo <i>Syncerus caffer</i>
	Namandanje Dam	Oct	30	hippo <i>Hippopotamus amphibius</i> , weavers <i>Ploceus sp.</i> , dove <i>Columbidae</i>
	lower Namandanje	July	16	
		Aug- Nov	5	southern ground-hornbills <i>Bucorvus leadbeateri</i>
2012	Nachimbwila	Sept	8	No dead animals, waterhole found having just recently been poisoned
2013	Namisangu	July	50	
	Mtemankhalamba	May	20	reedbuck <i>Redunca arundinum</i>

CHAPTER 8: Prevalence of Beak and Feather Disease Virus in Lilian's Lovebirds

Agapornis lilianae in Malawi

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Summary

Avian diseases are considered to be one of the key threats to bird conservation. Psittacine beak and feather disease (PBFD) is the most significant infectious disease in psittacines. It is caused by the beak and feather disease virus (BFDV) and currently has no cure. PBFD threatens the survival of wild populations of endangered parrots in Africa. The occurrence of BFDV was investigated in wild populations of the near-threatened Lilian's lovebird *Agapornis lilianae*, a small parrot found in southern-eastern Africa. In addition, evidence of blood parasites presence was also investigated to determine their general health. All samples (n = 48) tested negative for BFDV. Blood parasites were observed in 13 of the 48 samples (27 %). Investigation of virus occurrence in other known populations of the species is recommended to assess the conservation risk faced.

Keywords: Avian disease, Lilian's lovebird, Psittacine beak and feather disease, avian blood parasites

Introduction

Infectious diseases can cause rapid population declines that may lead to species extinctions (Harvell *et al.* 2002; Smith *et al.* 2006). Avian diseases including avian malaria and avian influenza have been well studied mainly due to the implications that these diseases have for humans (Patz *et al.* 2002; Scheuerlein & Ricklefs 2004). However, there is generally limited information about the occurrence of other known avian diseases and parasites in wild populations (Merino *et al.* 2000).

The psittacine beak and feather disease (PBFD) is the most significant infectious disease in psittacine birds (Alley 2002; Raidal *et al.* 1993a). It is a viral disease that was first discovered in Australian cockatoo family *Cacatuidae* in 1975 (Pass & Perry 1984). The disease is caused by the beak and feather disease virus (BFDV) which belongs to the circovirus family (Pass & Perry 1984). Physical manifestation of the disease includes juvenile mortality, deformations of beak and feathers, and generally results in death from secondary infections (Todd 2004, Kondiah *et al.* 2005). Currently the disease has no cure, but some vaccines have been investigated (Raidal *et al.* 1993b)

In southern Africa, BFDV has been found in both wild and captive birds and is a cause for concern (Albertyn *et al.* 2004; Heath *et al.* 2004; Kondiah *et al.* 2005; Stewart *et al.* 2007). Two threatened species, the Cape parrot *Poicephalus robustus* and the black-cheeked lovebird *Agapornis nigrigenis* are both affected by the disease (Warburton & Perrin 2002, Heath *et al.*

2004). Lilian's lovebird *A. lilianae* is the closest relative to the black-cheeked lovebird (Perrin 2012). Captive populations of Lilian's lovebirds are recorded to be affected by Pbfd and suffer 100 % mortality (Kock 1990; Kock *et al.* 1993). Consequently we investigated the possible existence of the BFDV in wild populations of Lilian's lovebirds in Liwonde National Park (LNP), Malawi. We also concurrently assessed the occurrence of blood parasites in Lilian's lovebirds.

Methods

Study Area

Malawi is a landlocked country in south-east Africa (Fig. 1). LNP is located in Malawi's southern region between 14°36' to 15°03'S and 35°15' to 35°26'E (Manongi 2004). The park covers an area of 548 km² and ranges in altitude from 474 to 921 m a.s.l. LNP is the only protected area with a resident population of Lilian's lovebirds in the country.

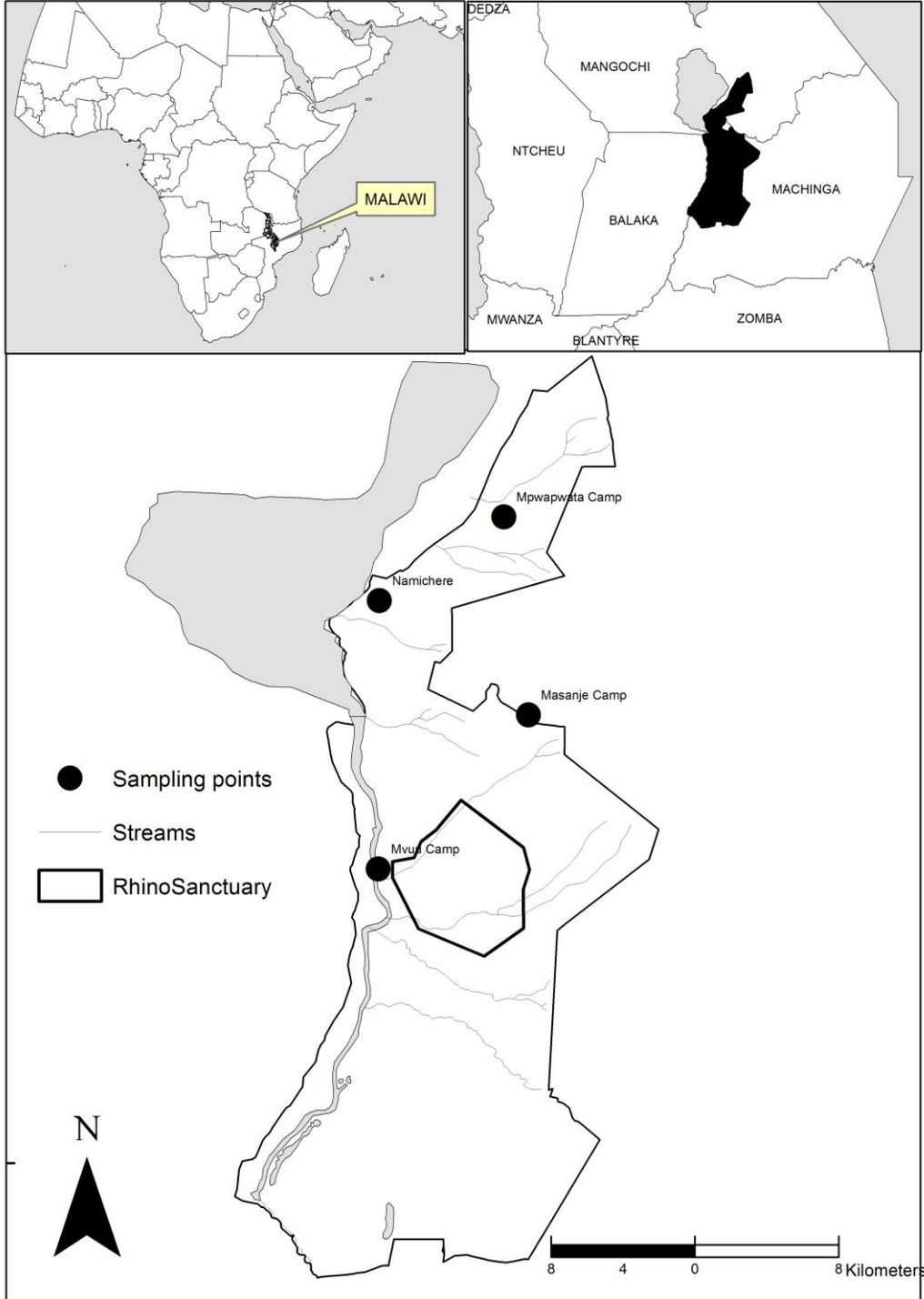


Figure 1: Liwonde National Park, Malawi where the study was undertaken.

Sample collection

Field work was undertaken at three sites in LNP; Mvuu Camp (Nov 2011), Masanje Camp (May 2012) and Mpwapwata Camp and Namichere (Oct 2012). We set mist nets up in areas known to be used by Lilian's lovebirds for drinking and feeding. The nets were erected in each of these areas from 05h00 to 10h00. All lovebirds captured ($n = 55$) were also ringed. We swabbed the ulnar vein of the lovebirds with alcohol then pricked it with a sterile needle and collected a drop of blood on a strip of FTA paper (Albertyn *et al.* 2004). The strip was immediately stored in an airtight Eppendorf plastic tube. Samples were sent to Molecular Diagnostic Services (Durban, South Africa) laboratory for PBFVDV testing using the polymerase chain reaction PCR test. In addition we collected a drop of blood using a capillary tube and used to immediately create a blood smear on a sterile glass slide. We held a swab over the puncture position briefly to stop bleeding. Birds were then released. Slides with dry blood smears (one per individual) were observed under a compound microscope OLYMPUS BX40 using 1000x magnification for any presence of parasites, then photographed. Presence data were then expressed as a percentage of individuals with any blood parasites present of the total individuals examined. Where possible, blood parasites were identified to genus level. Observations of any physical deformities on parrots seen during the study were also checked for and noted.

Results

Blood samples (filter paper and blood smears) were obtained from 48 Lilian's lovebirds. All samples tested negative for the PBFVD. Other parrot species observed during the ringing sessions

included grey-headed parrots *P. fuscicollis suahelicus* (4 individuals) and brown-headed parrots *Poicephalus cryptoxanthus* (8 individuals). None of these individuals or those observed during the full study (not specifically counted) showed any physical signs of PBF. D.

Blood parasites were observed in 13 of the 48 samples (27 %). These were observed outside and inside the erythrocytes (Fig. 2). *Plasmodium* sp. was identified in 3 of the 13 samples. The others were unidentified due to unclear staining.

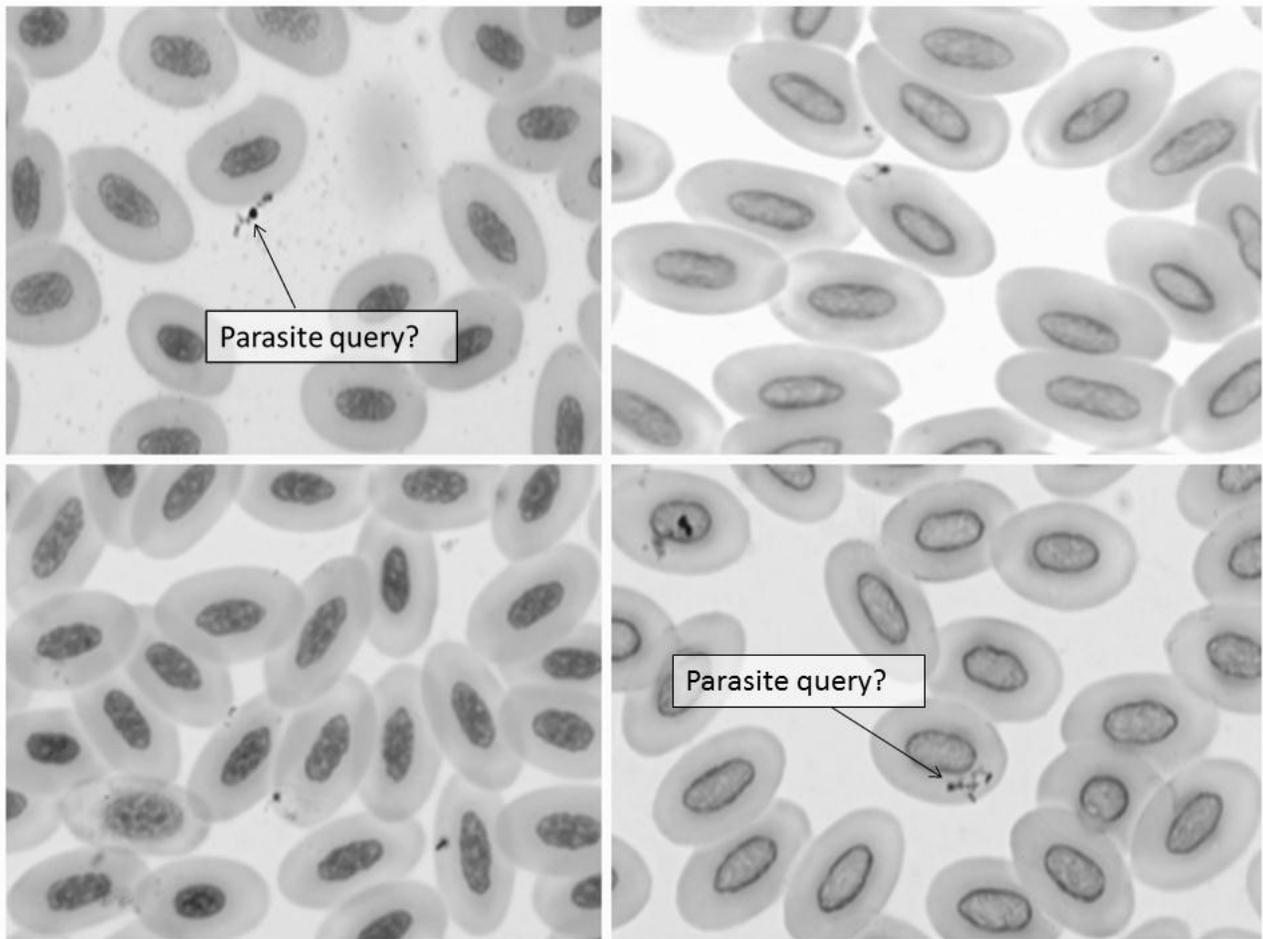


Figure 2: Parasites observed in blood smears from Lilian’s lovebirds from Liwonde National Park, Malawi.

Discussion

African and Australian psittacines are highly susceptible to BFDV (Kondiah *et al.* 2005). This explains the 100 % fatality in captive Lilian's lovebirds from PBFV observed in nearby Zimbabwe (Kock *et al.* 1993). Our results suggest that wild populations of Lilian's lovebirds in LNP do not carry the BFDV. These results confirm observations made in the field where no lovebirds were observed with any symptoms/signs suggestive of PBFV. If the virus is present in the population, the prevalence is extremely low. The absence/low prevalence of the disease in the LNP population is encouraging for the conservation of the species, since the virus occurs in other African parrots (Warburton 2003; Heath *et al.* 2004).

The black-cheeked lovebird is the closest relative to the Lilian's lovebird and BFDV has been detected in its population (Warburton 2003; Heath *et al.* 2004). The prevalence of the disease in this population is not known. We recommend that a study be conducted on the Lilian's lovebirds that occupy the same area as the black-cheeked lovebird in Zambia. It would be beneficial to know the prevalence of BFDV in the other population for their conservation.

During this study no physical evidence / symptoms of PBFV were observed in the brown-headed and grey-headed parrots in LNP. Grey-headed parrots tested for PBFV in north-east South Africa also tested negative (Symes & Perrin 2004). Studies in Europe have shown a high prevalence of the BFDV can occur in captive parrots that appear healthy (Rahaus & Wolff 2003; Bert *et al.* 2005). Therefore it is important to test for the presence of the BFDV in these parrots in LNP to assess possible future threats. We recommend the monitoring of wild and captive

populations in efforts to understand BFDV epidemiology, and to effectively address threats the virus poses to parrot populations (Heath *et al.* 2004).

Despite not having BFDV, almost a third of Lilian's lovebirds had blood parasites. This included the avian malaria parasite *Plasmodium sp.* present in the LNP Lilian Lovebird population. There is a need for further investigation to identify the parasites to species level. We recommend that further studies should be carried out to specifically investigate the haematozoan found in the lovebird species. It has been suggested that the prevalence of blood parasites in birds reflects a balance between exposure and resistance to infection (van Riper *et al.* 1994). Therefore studies may assist in understanding more of the epidemiology of the parasite and help to detect possible threats.

There are 24 parrot species in Africa and its islands (Perrin 2012). The existence of BFDV has been investigated in less than 25 % of these species. There are still very few studies on any avian diseases in wild birds. Disease is a key threat to conservation (Altizer *et al.* 2001). It is impacted by several external factors such as climate change. Therefore there is an urgent need for more studies in disease ecology. This is particularly important for species at high risk of extinction such as parrots.

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fellowship, International Foundation for Science, African Bird Club, BirdLife International, Lovebird societies (Belgium & USA), National Research Foundation (SA) and some interested individuals.

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CHAPTER 9: Notes from ringing Lilian's Lovebird *Agapornis lilianae* in Liwonde National Park, Malawi

Tiwonge I. Mzumara

Summary

As part of a larger study on the ecology of Lilian's Lovebird *Agapornis lilianae*, 55 individuals were mist-netted and ringed in Liwonde National Park, Malawi. Measurements showed that females were significantly larger than males. Birds ringed in October showed- the beginning of primary moult.

The Southern Africa bird Ringing Unit's database has > 2 million records of c.1,400 species (SAFRING 2013). However, there are no ringing data for Lilian's Lovebird *Agapornis lilianae*, which occurs in Zambia, Zimbabwe, Mozambique, Tanzania, and Malawi (Warburton 2005).

This note presents the morphometric, moult and observation data collected from Lilian's Lovebirds ringed in Liwonde National Park, Malawi. This was done as part of a larger study investigating the ecology and conservation biology of the Lilian's Lovebird in Malawi.

Methods

Study Area

Liwonde National Park is located in Machinga District in southern Malawi, between 14°36'–15°03'S and 35°15'–35°26'E (Fig. 1; Manongi 2004). It covers an area of 548 km² at 474–921 m above sea level (Dowsett-Lemaire & Dowsett 2006). The main vegetation is Mopane woodland with some miombo woodland, seasonally wet grassland, wetlands, riverine thickets, and forest. It is the only site in Malawi with a resident population of Lilian's Lovebird.

Mist-netting sites

Field work was carried out in November 2011, May 2012, October 2012 and October 2013. Preliminary observations made in 2010 and 2011 guided the choice of areas to conduct mist-netting. Five areas were selected (Fig. 1) and in each area one or two 40 m mist-net lines were set up.

Namandanje – A seasonally wet grassland area, dominated by *Acacia* sp. trees. The mist net line was placed along depressions where rain water had collected.

Sanctuary – Two net lines were set up, one in the on the eastern edge of an artificial waterhole and the other in a grassy patch of mopane woodland away from the waterhole.

Masanje – Nets were set up in a dambo area dominated by the grass *Sorghum bicolor*. Open water areas were found within the tall grass and the net line was placed along the water's edge.

Mpwapwata – Two mist net lines were set up in this area. One was around a small water hole along a stream and the other was in an area with fig trees *Ficus* sp.

Namichere – An area close to Lake Malombe dominated by *Vachellia xanthophloea*. *Capparis tomentosa* was a common shrub in the area. The mist net line was set in between these bushes.

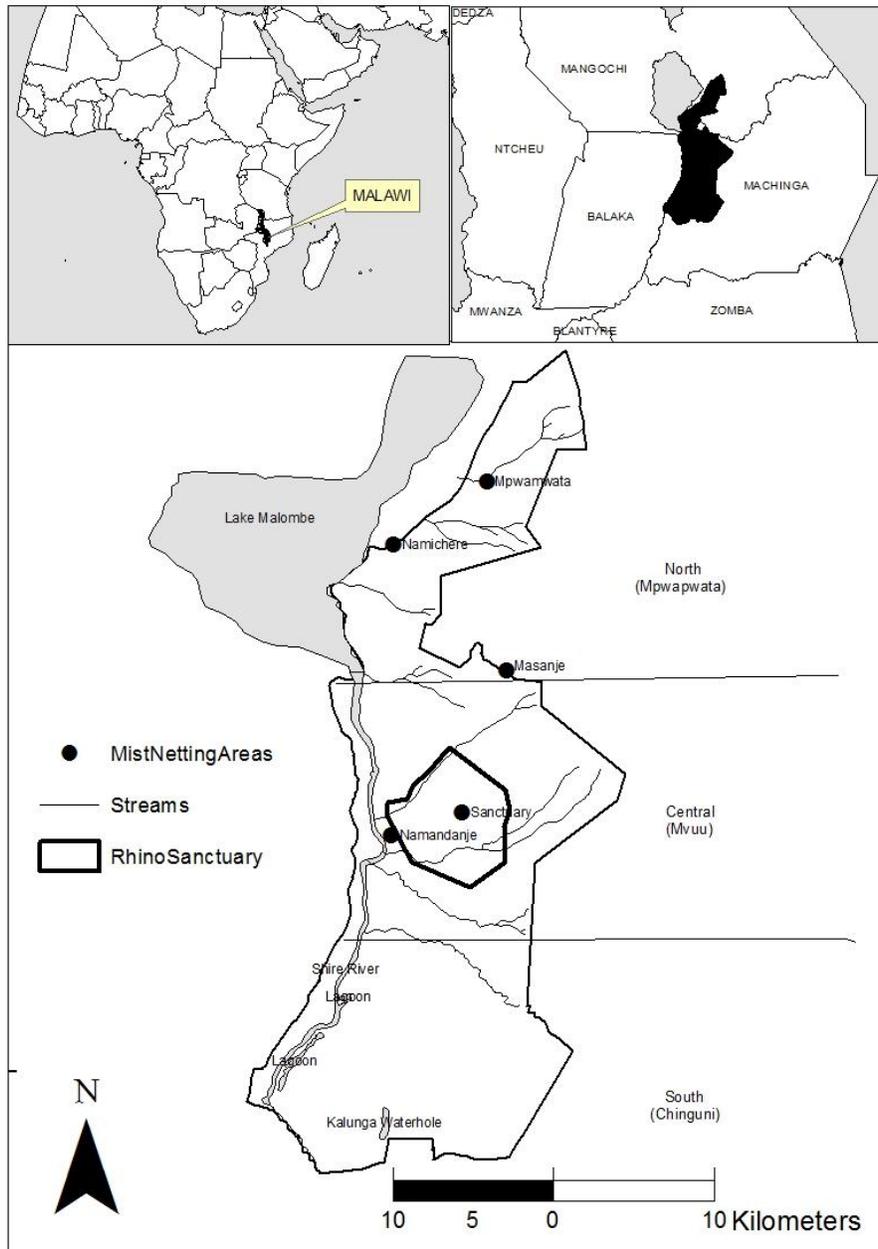


Figure 1. Location of Liwonde National Park, Malawi

Data Collection

All mist-netted lovebirds were ringed with custom-made 4.5 mm rings from L & T bird farm, Westville, South Africa. This was done because the SAFRING rings were too wide for the lovebird's short tarsus. For each individual the measurements taken were body mass (g), and wing, head, tail, and culmen lengths (mm) (Safring Manual, 2000). An electronic scale was used to measure mass (grams \pm 0.1). A small drop of blood was collected for DNA sexing, to be analysed at the Molecular Diagnostic Services Laboratories, Westville, South Africa.

Results

Fifty-five Lilian's Lovebirds were ringed in four of the five sites (Table 1). Mist-netting was most successful near water, except in the sanctuary where all attempts were unsuccessful. Blood samples for sexing were collected from 48 individuals. DNA sexing showed that there were 22 females and 27 males. The mass, wing, and head measurements of female Lilian's Lovebirds were significantly larger than those of males (t-test, $p < 0.001$; Table 2).

Table 1. Number of Lilian's Lovebirds *Agapornis lilianae* caught in Liwonde National Park, Malawi.

Site	Month/Year	N	Male	Female
Namandanje	Nov 2011	16	8	8
Masanje	May 2012	6	5	1
Mpwapwata	Oct 2012	18	8	10
Namichere	Oct 2012	8	5	3

Table 2. Morphometric measurements of Lilian’s Lovebirds *Agapornis lilianae* caught in Liwonde National Park, Malawi. (SE = standard error of mean).

Sex	Value	Mass				
		(g)	Wing (mm)	Head	Culmen	Tail
Male	Minimum	30	90	27.3	9.1	39
	Maximum	42	98	30.5	11.6	45
	Mean	38	93.4	29.4	10.4	42.6
	SE*	0.5	0.4	0.2	0.1	1.0
	N	26	26	23	17	5
Female	Minimum	30	90	28.1	9.2	37
	Maximum	45	98	31.4	13.5	
	Mean	41	95.5	30.2	10.5	
	SE	0.7	0.4	0.2	0.3	
	N	22	22	22	14	1

Primary moult was observed in 10 individuals, one in May 2012 and 9 in October 2012. All individuals were at the beginning of moulting with only the 6th primary showing growth stages one to four.

Attempts to mist-net Lilian’s Lovebirds at the same sites in October 2013 were unsuccessful. The lovebirds were not present in the same numbers as they had been in the previous years and very few were heard calling as they flew over.

Table 3. Moulting scores of Lilian's Lovebirds *Agapornis lilianae* in Liwonde National Park, Malawi.

Ring	Sex	Date	Site	Moult*
MW7	m	23 May 12	Masanje	0000020000
MW13	m	2 Oct 12	Mpwapwata	0000020000
MW11	m	2 Oct 12	Mpwapwata	0000040000
MW17	f	3 Oct 12	Mpwapwata	0000020000
MW19	m	3 Oct 12	Mpwapwata	0000020000
MW24	m	3 Oct 12	Mpwapwata	0000010000
MW29	m	4 Oct 12	Namichere	0000030000
MW31	m	4 Oct 12	Namichere	0000030000
MW34	f	4 Oct 12	Namichere	0000030000
MW30	m	4 Oct 12	Namichere	0000020000

* Grading was done for primary feathers. The scoring numbers reflect the following stages of growth: 5 = new feather fully grown, 4 = new feather 2/3 to fully developed, 3 = new feather between 1/3 and 2/3 grown, 2 = feather emerging from sheath to 1/3 grown, 1 = feather missing or new feather in pin, 0 = old feather remaining).

Discussion

Female Lilian's Lovebirds were significantly larger than males. This differs from previous records suggesting that males are larger than females (Forshaw 1989). These old records of Lilian's Lovebird morphometrics were often taken from museum skins and this may explain the difference.

These results are the first records of moulting in Lilian's Lovebird although moult has been recorded in hybrid lovebirds in Kenya (Thompson 1990). Thompson (1990) indicated a moult pattern in primary feathers of lovebirds similar to other parrots (primaries renewed from the centre outwards beginning at the 6th primary), as was found in this study. The species' breeding season in Liwonde National Park is from November to April depending on the commencement of rains (Mzumara *et al.* in prep.). The one bird caught in May that had a primary moult may indicate that Lilian's Lovebirds start moulting as soon as the breeding season is complete or may be evidence of suspended moult. There is need for more ringing efforts in the months after breeding to investigate this. Nevertheless, September / October are the likely months when moulting commences.

The best places to mist-net the species was at its drinking sites. This was also the case for Black-cheeked Lovebird *Agapornis nigrigens* in Zambia (Warburton 2001). Small water holes where a mist-net can cover a large part of the water were the most productive sites (especially in October when elsewhere in the park it was mostly dry). Sadly, this fact also means that capturing birds in months just after the breeding season to understand the moulting patterns will remain a challenge.

The lovebird's unpredictable movements presented a challenge in selecting sites to mist net. Sites that were frequented daily in 2011 and 2012 had no lovebirds at the same time of year in 2013. The only site where this disappearance could be explained was Mpwapwata, where the small water hole along the stream was dry and the nearby fig trees were not fruiting. However, at each of the other four sites conditions appeared to be similar to previous years.

Most lovebirds were caught in the early morning at all sites, except at Namandanje, where they were only caught in the evening. This site is close to the Rhino Sanctuary which has large artificial waterholes. It is likely that in the mornings the lovebirds drunk at the Sanctuary water holes and then flew to the feeding sites west of the Shire River. When returning from the feeding areas the Namandanje site is possibly the closest water hole and they stopped to drink before continuing to roost. At Namichere, at least 100 individuals were observed feeding and flying about but only eight were caught. Their behaviour indicated that they were able to detect the mist-nets. When some were netted, the remaining lovebirds perched in nearby bushes and occasionally flew over the nets. None of the lovebirds were observed perching on the guide line ropes as recorded in Zambia (Warburton 2001). However, they stayed around the nets and continued to call to the caught birds until these were released. The latter called back to their flocks whilst in the bird bags. They screeched a little when they were removed from the bags but quickly became silent. On several occasions a bird in the hand responded to calls from birds in bags or perched nearby.

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Chapter 10: Conclusion

Introduction

The primary goal of parrot conservation should be the maintenance of viable populations within their natural range (Snyder et al. 2000). This is only possible when there is a fundamental understanding of the species ecology and its natural history (Brussard 1991, Snyder et al. 2000, Doak & Mills 1994). Therefore studies such as this one are particularly important and contribute valuable information to the species conservation biology. Acquiring such information as presented here is often challenging because parrots are difficult to follow and observe, inhabit remote areas and their nest cavities are in tree cavities that are difficult to reach (Snyder et al. 2000).

Species-specific studies are particularly important in Africa where the eight species of parrots have allopatric ranges across different habitat types (Fry 1998, Forshaw 1989, Snyder et al. 2000, Perrin 2012, Martin et al. 2014). A number of recent studies have shown that the threats that these parrots face also vary greatly. Whilst the capture for illegal trade is most significant in species such as the African Grey Parrot *Psittacus erithacus* and the Cape Parrot *Poicephalus robustus*, many including the latter are also threatened by Pscittascine Beak and Feather Disease (Wirminghaus et al. 1999, Downs & Warburton 2002, Perrin 2012, Martin et al. 2014).

There has been more published research in Africa on the larger parrots than the lovebirds (Warburton 2003). However, it is well known that many lovebird populations have undergone many years of capture for the pet trade and it is believed to still occur (Warburton 2003, Parker

2005, Perrin 2012, Martin et al. 2014). It is therefore important for key threats to all lovebird species to be researched and addressed.

Discussion

Lilian's Lovebird *Agapornis lilianae* is a near-threatened small parrot with a resident population in Liwonde National Park (LNP). Aspects of its ecology and conservation biology were investigated and results are presented in this thesis. LNP has an estimated Lilian's Lovebird population of 4000 individuals (Mzumara et al. 2014, chapter 3). This study confirms that the Lilian's Lovebirds and the Black-cheeked Lovebird *A. nigrigenis* in Zambia which are closely related, have similarities in behaviour (Warburton 2003). Lilian's Lovebirds are a Mopane *Colospermum mopane* woodland specialist. They breed and roost exclusively in cavities that form naturally in Mopane trees (chapters 5 and 6). The understory of Mopane woodlands possesses the majority of the grass seeds that the lovebirds feed on during the breeding season (chapter 4). However, not all Mopane woodland types are suitable for use by the Lilian's Lovebirds. They choose to roost and breed in cavities of large tall Mopane trees that are widely spaced (chapter 6). They avoid dense and shrub Mopane woodlands.

During the non-breeding, dry season, Lilian's Lovebirds spend most of their time in other habitat types including grassland with tree cover and in seasonally wet grasslands (chapters 2 and 3). Their diet is varied and reflective of the different habitats they use any time (chapter 4). They feed on a diverse range of foods including flowers, fruits pulp, *Acacia* sp. seeds and herbs, many of which that do not occur in Mopane woodlands. During the dry season, most natural

waterholes dry out in LNP. Lovebirds thus often chose to feed in areas that were in close proximity to water (chapter 4).

In the wild, Lilian's Lovebirds have a low breeding success rate as has been observed in other parrots (chapter 6). Most of their eggs are lost before they hatch due to predation (chapter 6). It was not possible to investigate further the impact of this low breeding success in this study however it is recommended for further study. Ecological studies, such as this, are important in planning for conservation of a species (Podulka et al. 2004). Results of this study indicate three key threats to the lovebirds in LNP. These are, poisoning at waterholes, habitat loss and predation (chapters 6 and 8).

There is only one similarity between threats to this species and its close relative the Black-cheeked Lovebird. The key threats to the latter include absence of dry season surface water supplies, disturbance by people and livestock at potential and actual lovebird drinking sites preventing lovebird's from drinking, decrease in man-maintained sources of surface water, local hunting of lovebirds as a food source and persecution as a crop pest, disease, principally PBFDV, potential resumption of illegal trade in live birds, potential reduction in food availability, in particular, sorghum and millet, habitat destruction for firewood and timber collection, destruction of riverine woodland and poisoning of water pools by local people as a fishing strategy (BirdLife 2013).

Parrots are amongst the world's most threatened birds and are at a high risk of extinction because of their ecological specialisation (Collar et al. 1994; Owens & Bennett 2000; Snyder et al. 2000; Perrin 2012). The first status survey and action plan for the conservation of the world's parrots was produced in 2000 (Snyder et al. 2000). A key recommendation for the African

parrots was the need for more studies of wild populations. Prior to this study, the Lilian's Lovebird was among the 50 % of the world's threatened species without a single publication dedicated to them (Brooks et al. 2008).

The maintenance of viable wild populations is the overriding goal of all parrot conservation (Snyder et al. 2000). Below is a summary of the key threats to Lilian's Lovebirds in LNP as derived from this study and recommendations for further research. Appendix 1 provides for each threat recommended actions for management of LNP. This has been done in an effort to make the science that has been generated through this ecological study available for the management of this park and the conservation of this species.

Key threats

Threat 1: Waterhole poisoning in the National park

At present this is the biggest potential threat to the Lilian's Lovebird population in LNP. There are 4 to 8 poisoning incidents in the park each year with a mean of 17 birds killed per waterhole and up to 200 at risk of being killed (Mzumara et al. 2015, chapter 7). Historic records of up to 500 birds killed in a year are available (Labuschagne 2002).

Threat 2: Habitat loss

Mopane woodland is a key habitat for Lilian's Lovebird in LNP (chapters 2 - 7). They roost and breed exclusively in large Mopane trees. The persistence of fauna that rely on tree cavities is one

of the indicators of a forest that is ecologically sustainable (Abbott 1998). A similar approach should be considered when managing national parks with large fauna such as Elephants *Loxodonta africana* that are capable of causing extensive change to the vegetation structure. Elephants are changing the availability of nesting cavities in LNP and this impact all cavity nesting species (chapter 6).

Threat 3: Predation

Lilian's Lovebirds breeding in the Rhino Sanctuary area of LNP face high egg predation risk (chapter 6). This may be due to the different management regime that the sanctuary has compared with the rest of the park. The presence of artificial waterholes and the lack of early burning practices in the sanctuary may affect the relatively high diversity of predators which may lead to the higher egg predation.

Aspects of Lilian's Lovebird biology requiring further study

1. Spatial ecology – there was evidence of seasonal movement but also cross border movements
2. Competition – a study to investigate the community of secondary cavity users in LNP and their interactions (Particularly looking at the Rhino Sanctuary, compared with other parts of the park)
3. Artificial nest cavities – a study that would assess if availability of suitable nest cavities is a limitation.

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Appendix 1: Proposed Action Plan for the Lilian's Lovebirds in Liwonde National Park, Malawi.

Introduction

The science of conservation assessment must lead to actions that conserve nature (Whitten et al. 2001). From its conception, conservation science aimed to influence conservation management and provide a scientific basis for conservation action (Milner-Gulland et al. 2010). However, there are still very few incidents where direct links exist between the scientists and the managers (Sutherland et al. 2004). The flow of information between the two is rather slow with scientist publishing in peer-reviewed journals in formats that are not friendly to managers (Pullin et al. 2004). In return, managers prefer to act on lessons from their vast experience in the field (Pullin et al. 2004; Sutherland et al. 2004). Sadly, protected areas are often times the only refuge for many threatened and endangered species and thus stand to benefit from evidence based science communicated directly to managers (Pullin et al. 2004; Sutherland et al. 2004, Knight et al. 2008).

Lilian's Lovebirds are Mopane *Colospermum mopane* woodland specialist with a global range scattered through Zimbabwe, Zambia, Mozambique, Malawi and Tanzania (Warburton 2005). Their global population is estimated to be around 20 000 individuals and declining (IUCN 2014). Historical trends of Lilian's Lovebird population across its range are not well known or documented, however it is expected their numbers have declined considerably. The flooding of the Cabora Bassa Dam in Mozambique, destroyed a large part of their habitat (Parker 2005).

Records of confiscation of over 3000 illegally caught Lilian's Lovebirds in Zimbabwe in the early 90's indicates that illegal trade may have also impacted the population (Couto 1990). An investigation into the ecology of the Lilian's lovebird in the wild was conducted between 2010 – 2014 (Mzumara 2014). The study determined the status of the species in Malawi and aspects of its ecology. The study was undertaken in Liwonde National Park which is the only site with a resident and breeding population of Lilian's Lovebirds in Malawi (Mzumara et al. 2014).

Table 1: Lilian’s Lovebird proposed conservation plan to Department of National Park and Wildlife, Malawi.

THREAT	DESCRIPTION	PROPOSED ACTION
<i>Waterhole poisoning in the National Park</i>	Current biggest threat. Happening now throughout LNP. Up to 500 birds killed in a year.	<ol style="list-style-type: none"> 1. Increased Patrols and law enforcement. Identified ‘poisoning hotspots’ to be intensively patrolled. 2. The use of camera traps at these known sites should be explored.
<i>Habitat loss</i>	Happening now. May impact cavity availability. Elephants are capable of extensive change to vegetation structure.	<ol style="list-style-type: none"> 1. Elephant population management – exclusion experiments & translocations to be considered. 2. LNP vegetation map to be updated highlighting suitable & unsuitable Mopane woodland 3. Long term research to investigate impact of Elephants on Mopane
<i>Predation</i>	Suggested threat happening now affecting sanctuary area resulting in high egg predation risk.	<ol style="list-style-type: none"> 1. An assessment of predator abundance and their impact the lovebird population. 2. Restrictions on nest cavities to prevent some predators should be explored

Additional Appendices

Appendix i: Scout Questionnaire given in Liwonde National Park to assess poisoning incidences (Chapter 7).

Name:

Current Camp:

No. of yrs in LNP:

How many long patrols do you do a year:

How many SHORT patrols do you do a year:

Have you ever encountered a poisoned waterhole:

If No. Do not proceed. Submit questionnaire

If yes:

WHEN & WHERE (give date, month or year)	What species did you find dead at the pool?	How many Lilian's Lovebirds at the pool (If none put zero)

In your period at LNP how many times have you found lovebirds dead at a pool?

In a year, how many times do you find lovebirds dead at a pool?

Appendix ii: Selection of fieldwork photographs during the Lilian's Lovebird study in Liwonde National Park.



Picture 1: Lilian's Lovebird chick peeping out of the nest cavity in LNP.



Picture 2: Inspection camera used to check Lilian's Lovebird nest contents (Chapter 6).



Picture 3: Lilian's Lovebird adult – Tree Squirrel interaction at a nest was in the LNP Sanctuary and had 3 chicks at this time (Date formatt – MM/DD/YYYY; Chapter 6).



Picture 4: Adult Lilian's Lovebird carrying nesting material into the cavity (Chapter 6).