EXPEDITION REPORT

Expedition dates: 2 September – 19 October 2018

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From elephants to cats to butterflies: Monitoring biodiversity of Vwaza Marsh Wildlife Reserve, Malawi

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in memory of Alex Chalkley

ABSTRACT

The Lilongwe Wildlife Trust and Conservation Research Africa are the first to conduct long-term research projects in Vwaza Marsh Wildlife Reserve (VMWR). These projects focus on large mammals, elephants, primates, bats and insects, and aim to identify and monitor biodiversity and long-term trends in VMWR. Habitats are under increasing pressure from climate change and wildlife populations are at risk from many anthropogenic threats, such as poaching and deforestation. Biosphere Expeditions citizen scientists supported these research projects for the first time in 2018. Field work was conducted between 2 September and 19 October 2018 in three two-week long groups comprising twelve citizen scientists per group from Austria, Canada, China, France, Germany, Malaysia, Switzerland, the UK and USA. The inaugural expedition was a success and a showcase on how citizen science can provide resources and critical data gathering abilities to important wildlife studies. It is the intention of all partners to continue the successful partnership.

Large mammal surveys

Camera trapping was the most successful large mammal survey method, recording the highest species diversity (36 species) and more than 3,300 images. The surveys provided the first ever images of lion in the VMWR, known to be present but previously never recorded on camera. Other rarely seen carnivores were also recorded including serval, caracal and leopard. Large mammal transect (LMT) surveys were less successful than camera trapping surveys in detecting mammal presence and diversity. LMTs yielded twelve species, with baboons being most frequently encountered. Species of note were roan antelope, which are rarely sighted, and puku, as they are classified as Near Threatened (IUCN). Surveys of hippo populations inhabiting Lake Kazuni in the south of the reserve were very successful, yielding an average 147 hippos per transect, which demonstrates a healthy population for the area. Elephants were observed mostly at the lake and river in front of the expedition base camp and along the lakeshore. The expedition augmented the existing identification database by 20%.

Results indicate high large mammal species diversity in VMWR. Five of the species recorded by the expedition are classed as Vulnerable and one species (puku) as Near Threatened by IUCN. Results provide an important baseline for future monitoring of large mammal populations in the VMWR. Future expeditions will be augment these data and conduct more robust analyses of populations, including estimates of population density to facilitate effective management of large mammals in the park.

Bat and insect monitoring

Bat species and abundances were assessed at spatially independent survey sites using standardized biodiversity monitoring surveys, across two habitat types: floodplain and woodland. A total of 17 bat surveys were completed, at 17 sites, resulting in 5,519 trapping meter survey hours. Bat surveys were successful with 62 bats captured representing six species and one species group. *Chaerephon pumilus* dominated the species composition despite only being recorded in woodland. *Neoromicia nana* was the most common species. This runs in accordance with other studies in Africa. as this is generalist species occupying a range of habitat types. Captures of *Pipistrellus rueppellii* are of particular interest as this species has rarely been captured by African Bat Conservation in the previous five years. This may suggest that the species has a limited distribution in VMWR, however, this can only be confirmed by additional surveys and thereby greatly increased sample size.

Insect species diversity and abundances were assessed as part of the standardised biodiversity monitoring surveys at spatially independent sites, alongside bat surveys. They were also assessed opportunistically at random sites using three butterfly traps, ten pitfall traps and one Heath light trap. A total of six standardised biodiversity monitoring surveys, and four opportunistic surveys were conducted. There was a wide representation of insect orders from the biodiversity monitoring surveys, with ten orders recorded. Coleoptera and Lepidoptera contained the highest abundances of individuals. Orders such as Mantodea, Trichoptera and Orthoptera occurred in much smaller abundances in general, and were absent completely from some surveys. Even though a small number of opportunistic insect surveys were conducted over a short period of six weeks, a substantial insect diversity was apparent, with 68 morpho-species recorded, representing nine orders. Lepidoptera, Coleoptera and Hymenoptera were the most diverse. The opportunistic discovery of an Embioptera individual is a significant addition to the insect diversity of VMWR.

Although these results are based on a small sample size, they do show quite a variation in abundances and presence of orders overall. Continued monitoring of insect populations alongside bat populations will allow us to monitor any trends and any effect that these variations may have on the insectivorous bat populations of VMWR, across seasons and habitats.

Primate behaviour

Two baboon troops were observed by the expedition participants with most data collected from one troop that occupied the area around the Department of National Parks and Wildlife staff village. The staff village provides a number of benefits for baboons, including access to nutritious human-foods (e.g. nsima, maize) and increased protection from predators. Data collected provide a baseline for further research and provide a framework for developing future studies on baboons. Future expeditions will include habituation of the baboon troops in VMWR to facilitate research on behavioural ecology and ranging patterns. These data will be used for future genetic work to assess the possible hybridisation zone of yellow and kinda baboon species of the VMWR.

CHIYAMBI

Lilongwe Wildlife Trust komanso Conservation Research Africa kwa nthawi yoyamba m`mbiri ya dziko lino ikhazikitsa ntchito yakafukufuku yomwe ichitike kwa nthawi yayitali kwambiri m`nkhalango yotetezedwa ya Vwaza Marsh Wildlife Reserve (VMWR). Kafukufukuyu akhudza kwambiri nyama zikuluzikulu monga Njobvu, Anyani amitundu yosiyanasiyana, mileme ndi zinthu zina zamoyo zing`ono zing`ono zowuluka, ndicholinga chofuna kudziwa zambiri za moyo wa zachilengedwezi komanso m`mene izo zimadzithandizira kuti zikhale ndi moyo kwa nthawi yaitali. Nkhani yodziwikiratu ndiyakuti malo amene zachilengedwezi zimakhala ali pachiopsezo kamba kakusintha kwa nyengo. Moyo wa nyama komaso zomerazi ulinso pachiopsezo kamba ka kamchitidwe owononga chilengedwe omwe anthu akupanga monga kupha nyama zakuthengo ndi kudula mitengo mwachisawawa. Bungwe la Biosphere Expeditions lidzapeza njira zina zatsopano komaso zosatira zopezaka kuchokera kafukufukuyu zidzagwiritsidwa ntchito ngati poyambira pakawuniwuni wa zachilengedwe m`nkhalango ya VMWR. Zotsatirazi za zomwe zidzapezeke zidzanthandiza kupereka chinthuzithuzi cha kuchulukuka kwa nyama mu nkhalango ya VMWR kwa nthawi yayitali.

Bungwe lalikulu pa dziko lonse lapansi lotchedwa Biosphere Expeditions lomwe limadziwika bwino ndi ntchito yakafukufuku wa zinthu za moyo pogwiritsa ntchito njira za sayansi lidalowa nawo m`gulu la mabungwe ogwira ntchitoyi koyamba m`mbiri ya dziko lino mchaka cha 2008. Ntchito yoyamba yobweretsa zotsatira zakafukufukufuku woyambilira kuchokera m`madera okhudzidwa, idachitika kwa masabata awiri kuyambira pa 2 Sepitembala kufika tsiku la 19 Okutobala chaka cha 2018.Ntchitoyi idagwiridwa ndi akatswiri azasayansi nkhumi ndi awiri wochokera  m`maiko monga: Austria, Canada, China, France, Germany, Malaysia, Switzerland, UK ndi USA. Cholinga chakafukufukuwu chidali chofuna kupeza zotsatira zochuluka zomwe zingathandizire kuti kafufuku otsatira akhale ndi zinthu zonse zofunika.

Zotsatira zochokera ku kafukufuku oyamba zidasonyeza kuti m`nkhalango yotetezedwa ya VMWR muli zinthu zachilengedwe zosiyanasiyana monga nyama. Nyamazi ndi monga mikango komanso nyama zina zomwe zimadya nyama zinzake, ndipo nyamazi zidajambulidwa nthawi yomwe ntchitoyi imagwiridwa. Chiwerengero cha nyama monga njobvu ndi mvuu chidaonetsanso kuti chinali chokwera kuphatikizapo nyama zosiyanasiyana, kusonyeza kuti chilengedwe chidakali bwino ndithu. Kafukufuku oyambilirayo adasonyezanso kufunika kwa mitsinje ikuluikulu polimbikitsa kupezeka kwa zinthu zamoyo zosiyanasiyana mchigawo chakumpoto kwa dziko lino. Ndipo kupitiliza kafukufukuyu kuthandiza kumvetsesa kwa kufunika kwa zachilengedwe komanso kuchuluka kwake m`nkhalango yotetezedwa ya VMWR. Kafukufukuyi athandiziraso kumvetsesa kwa kufunika kwa malo abwino okhala zinthu zamoyo zosiyanasiyana ndi kudalirana pakati pa zamoyozi.

CHIYAMBI

Lilongwe Wildlife Trust kweniso Conservation Research Africa kwa nyengo yakwamba mu mbiri ya chalo chithu cha Malawi yakhazikiska ntchito yakafukufuku iyo ichitikenge kwa nyengo yitali chomene m`thengere lakuvikililika la Vwaza Marsh Wildlife Reserve (VMWR). Kafukufuku uyu wakhwaskenge chomene nyama zikuluzikulu nga zovu, bamunkhwere bakupambanapambana, bakasuska, na vinthu vinyake vyamoyo vidokovidoko ivyo vikuduka m`chanya, nachakulinga chakukhumba kumanya vinandi vakukhwaska moyo wa vyachilengiwa kweniso umo ivyo vikujiwovwilirira kuti vikhale na moyo kwa nyengo yitali. Nkhani yakumanyikirathu njakuti malo awo vyachilengiwa ivi vikukhala ngawemi chala chifukwa cha kusintha kwa nyengo. Nabo umoyo wa nyama zamthengere kweniso makuni nguwemi chala chifukwa cha nkhalo yabanthu abo bakukoma nyama nakudumula makuni mwambula kupwelerera chala. Bungwe la Biosphere Expeditions lilikusanga nthowa zinyake zasono kufumira kuvipambi vyakukafukufuku wakwambilira izo zikoleskekenge ntchito mukafukufuku wasono.Vipambi vya kafukufuku wasono vizamuwovwira chomene pakuona kuti nyama nizinandi uli mu nthengere lakuvikilililka la VMWR kwa nyengo yitali chomene.

Bungwe lakumanyikwa makola pa chalo chonse cha pasi la Biosphere Expeditions ilo likumanyikwa makola na ntchito yakafukufuku wa vinthu vya moyo pakukoleska ntchito nthowa za sayansi likanjira nabo m`gulu la mabungwe awo bakugwira ntchito iyi kakwamba mu mbiri ya chalo chithu cha Malawi mchaka cha 2008. Ntchito yakwamba yakwiziska vipambi vyakafukufukufukufuku wakwambilira kufumira m`mizi yakukhwaskika, ikachitika kwa masabata babiri kuyambira pa 2 Seputembala kufika pa dazi la 19 Okutobala chaka cha 2018.Ntchito iyi ikagwirika na nkhwantha zasayansi zakukwana 12 kufumira m`vyalo nga: Austria, Canada, China, France, Germany, Malaysia, Switzerland, UK na USA.Chakulinga chakafukufuku uyu chikaba chakukhumba kusanga vinthu vinandi ivyo vingawovwira ku kafufuku uyu wapangikenge sono.

Vipambi vyakufumira ku kafukufuku wakwamba vilikuoneska kuti mthengere la kuvikililika la VMWR muli vinthu vyachilengiwa vyakupambanapambana nga nyama. Nyama izo zikasangika ni nga nkhalamu kweniso nyama zinyake izo zikurya nyama zinyake, ndipo nyama izi zikajambulika vithuzi panyengo iyo ntchito iyi ikachitikanga. Chiberengero cha nyama nga zovu na vigwere chikaoneskaso kuti nacho chikaba chakukwera kusazgapo nyama zakupambanapambana, kung`anamula kuti chilengiwa chichali makola. Kafukufuku wakwambirila uyo wakaoneskazaso uwemi wamadambo ghakulughakulu pakupwelerera vinthu vyamoyo vyakupambanapambana mchigaba chakumpoto kwa chalo chino. Ndipo kulutiligza kafukufuku uyu kuwovwilenge kusanga uthenga wakukhumbikira chomene pakupwerelera vwachilengiwa kweniso unandi wake m`thengere lakuvikililika la VMWR. Kafukufuku uyu awabowvirengeso kupulikiska uwemi wakukhala na malo ghawemi ghakusingirako vinthu vyamoyo vwakupambanapambana na umo ivyo vikukalira lumoza.

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Matthias Hammer (editor)
Biosphere Expeditions

1.1. Background

Biosphere Expeditions runs wildlife conservation research expeditions to all corners of the Earth. Our projects are not tours, photographic safaris or excursions, but genuine research expeditions placing ordinary people with no research experience alongside scientists who are at the forefront of conservation work. Our expeditions are open to all and there are no special skills (biological or otherwise) required to join. Our expedition team members are people from all walks of life, of all ages, looking for an adventure with a conscience and a sense of purpose. More information about Biosphere Expeditions and its research expeditions can be found at www.biosphere-expeditions.org.

This project report deals with an expedition to the Vwaza Marsh Wildlife Reserve (VMWR). that ran from 2 September to 19 October 2018 with the aim of increasing data collection and to contribute to long-term datasets through citizen science by working with Lilongwe Wildlife Trust and Conservation Research Africa who are conducting the first long-term research projects in VMWR.

Malawi is recognised as being of international importance in supporting a rich array of endemic species, including some that are restricted to single mountains. However, this rich biodiversity base is seriously threatened by an unsustainable rate of exploitation mainly through deforestation, pollution, invasive species and development. Montane and upland forests are under particular threat, with many areas converted to tea plantations and other agricultural uses. For the most part, the only remaining upland forests are those that have been protected since the 1920s. Conversion to agriculture, firewood collection, wild fires and invasion by alien species are all real threats. Deforestation is a considerable problem too with Malawi losing 2.8% of forests per year.

VMWR, the expedition study site, was proclaimed a Wildlife Reserve in 1977. It is home to the widest variety of large mammals in Malawi (including lion, leopard, elephant, hippopotamus, buffalo, zebra and many other species) and a fascinating range of lowland birdlife of over 300 species of birds. However, currently there is limited capacity and resources for park and wildlife management. In partnership with the Department of National Parks and Wildlife, this project is providing vital information to inform conservation and wildlife management in order to enhance and conserve the park habitats and species.

1.2. Research area

Malawi is a landlocked country in southern Africa, bordered by Zambia to the northwest, Tanzania to the northeast and Mozambique on the east, south and west. The country is separated from Tanzania and Mozambique by Lake Malawi. Malawi encompasses 119,000 km^2, of which 20% is water. Malawi has an estimated population of 17 million with an average population density of 139 people/km^2 and a population growth rate of 2.8% per annum. Its capital city is Lilongwe, which is also Malawi's largest city. The name Malawi comes from the Maravi, an old name of the Nyanja people that inhabit the area. The country is also nicknamed "The Warm Heart of Africa".

Malawi is listed as a World Wide Fund for Nature (WWF) Global 2000 Ecoregion because of its high species richness and endemism. It lies at the heart of three eco-region categories including the central and eastern Miombo Woodlands, Zambezi Flooded Savannahs and Southern Rift Montane Woodlands. Malawi is of international importance due to its rich array of endemic species, including some that are restricted to single mountains. According to [WWF-SARPO (2002)]() there are 26 areas of special biodiversity importance within the country. The ecoregions of Malawi include mountainous rainforest, tropical and subtropical grasslands, savannahs, and shrublands of the miombo woodland, dominated by miombo trees; and the Zambezian and mopane woodlands, characterised by the mopane tree; and also flooded grassland providing grassland and swamp vegetation.

Figure 1.2a. Flag and location of Malawi and study site.

An overview of Biosphere Expeditions' research sites, assembly points, base camp and office locations is at [Google Maps]().

Malawi is home to mammals such as elephants, hippos, big cats, primates and bats; and a great variety of birds including birds of prey, parrots and falcons, waterfowl and large waders, owls and songbirds. Lake Malawi, a World Heritage Site, covers 20% of the land area of Malawi (>29,000 km^2) and has one of the richest lake fish faunas in the world.

Malawi has five national parks, four wildlife reserves, 87 forest reserves and three nature sanctuaries, most of which are listed as Important Bird Areas (IBAs).

VMWR is a wildlife reserve located in the north of the country. It covers an area of 1,000 km^2 of flat terrain located in the Central African Plateau on the watershed between Lake Malawi and the eastern lip of the Luangwa rift to the south east of the Nyika Plateau. The western half of the reserve borders Zambia and comprises plateau Miombo woodland, clay soils dominated by Mopane (*Colophospermum mopane*) woodland and wetland marshes, while the eastern half of the reserve contains Miombo and broad-leaved (*Combretum*) woodlands in the foothills of the Nyika plateau.

VMWR is home to many species of ungulates (impala, reedbuck, kudu, bushbuck and buffalo) and carnivores (spotted hyaena, leopard, side-striped jackal) and has healthy populations of elephants and hippo. Lions are also seen occasionally. Wildlife can move freely between the reserve and the Luangwa valley in Zambia. The south and eastern boundary of the reserve is fenced, with villages right up to the reserve boundaries.

1.3. Dates

The expedition ran over a period of six weeks divided into three twelve-day groups (with a break week in between groups two and three), each composed of a team of international citizen assistants, scientists and an expedition leader. Group dates were:

2 - 14 September **|** 16 - 28 September **||** 7 - 19 October 2018

Expedition participants could join for multiple groups (within the periods specified). Dates were chosen to coincide with the contrasting wet and dry seasons in Malawi.

1.4. Local conditions & support

Expedition base

The expedition base was a rustic, but comfortable field camp with large, twin or double bed safari tents on raised platforms, including linen and furniture. Smaller single tents could be arranged on request for those wanting to stay in single accommodation. The camp had seat toilets and showers, as well as a permanent and comfortable chalet-type structure for eating, meeting, relaxing and watching the elephants that often pass by. There was limited electricity for a few hours a day. There were 240V (UK type G sockets) and USB sockets.

Figure 1.4a. Expedition base: The chalet-type structure.

Figure 1.4b. Expedition base: Safari tent accommodation.

There was also limited mobile phone coverage (provider Airtel). All meals were prepared for the team by the camp chef and special diets were catered for.

Weather

The climate in Malawi exhibits two distinctive seasonal changes from the wet season (November to April) and the dry season (April to October). The expeditions took place during the hot, dry season months with temperatures reaching up to 40°C.

Transport & vehicles

Team members made their own way to the assembly point in Lilongwe. From there onwards and back to Lilongwe all transport was provided for the expedition team. The expedition used a combination of cars from local partners Lilongwe Wildlife Trust and Conservation Research Africa. Surveys were conducted on foot or by vehicle.

Medical support and incidences

The expedition leader was a trained first aider and the expedition carried a comprehensive medical kit. The nearest doctor, public hospital and clinic are in Mzuzu (45 km / 45 minutes). All team members were required to carry adequate travel insurance covering emergency medical evacuation and repatriation. Safety and emergency procedures were in place, but did not have to be invoked as there were no medical accidents or mishaps.

1.5. Expedition scientists

On site field scientists were:

Amanda Harwood – Research Manager, Lilongwe Wildlife Trust
Pilirani Sankhani – Senior Research Assistant, Lilongwe Wildlife Trust
Alex Chalkley – Research Assistant, Lilongwe Wildlife Trust
Joselyn Mormile - Research Assistant, Lilongwe Wildlife Trust
Karen Shevlin – Lead Research Scientist, Conservation Research Africa
Andrew Mcvinish – Research Assistant, Conservation Research Africa
Kelly Rosier – Research Assistant, Conservation Research Africa

Dr Emma Stone, Director of Conservation Research Africa and Senior Lecturer in Conservation Science at the University of the West of England, Honorary Fellow at the University of Bristol and Cardiff University, was the absentee expedition lead scientist.

1.6. Expedition leader

Ida Vincent grew up in Sweden and lived in Australia for ten years before moving to Seattle in the USA. Ida studied Marine Biology at the University of Queensland and Environmental Science at Murdoch University (both in Australia), finishing with BSc and Masters degrees respectively. Ida has worked as a marine scientist and aquatic ecologist in Madagascar, Papua New Guinea, the Philippines, Australia and the Pacific Northwest in the USA. She is also a qualified PADI divemaster, Reef Check trainer, as well as a climbing leader and instructor with the North Cascade Mountains as her backyard. Ida also enjoys photography, painting and writing. She has published both scientific and magazine articles about alpine climbing, as well as a novel.

1.7. Expedition team

The expedition team was recruited by Biosphere Expeditions and consisted of a mixture of ages, nationalities and backgrounds. They were (in alphabetical order and with country of residence):

2 - 14 September: Janet Bellairs (UK), John Haddon (UK), Elizabeth Hayman (UK), Ng Kui Lai (Malaysia), Isabel Pfundstein (Switzerland), Ben Rees (UK), Rebecca Tunstall (UK), Kathrin Weber (Germany), Steve White* (China).

16 - 28 September: Anneliese Allen-Norris (UK), Jodi Dockman (Canada), Susan Gorr (USA), Peter Gorr (USA), Eckart Lindner (Germany), Monique Lindner (Germany), Christine Plocek (Austria), Andrea Rohlf (Germany), Gerhard Schwarz (Austria), Nicole Stinn (Canada), Verena Thuerey (Germany), Stefan Thuerey (Germany).

7 - 19 October: Tom Bartel* (USA), Harald Ernst (Germany), Kathrin Haase* (Germany), Linda Hall (USA), Judyth Hill (USA), Heather Hughes (UK), Bob Hussey (UK), Sanam Iverson (USA), Matthew Kaller (USA), Suesanna Moloy (France), Helena Smith* (UK), Ingeborg Stephan (Germany), Laura Trudel (USA).

*Member of the media.

1.8. Partners

Biosphere Expeditions' two main partners for this expedition were the Lilongwe Wildlife Trust (LWT) and Conservation Research Africa (CRA).

LWT is a leading local non-governmental organisation, established in 2007, committed to protecting the wildlife and habitats of Malawi. LWT runs several projects across five programme areas: Wildlife rescue and rehabilitation, wildlife research, environmental education, community conservation and wildlife advocacy and enforcement. LWT has 72 staff working across three offices and several field sites across the country.

CRA is a science-driven registered charity in England, working in Malawi, whose mission is to conduct applied research to inform wildlife conservation in Africa. CRA works in partnership with the Department of National Parks and Wildlife Malawi (DNPW), LWT, The University of the West of England, the University of Bristol, Cardiff University, Nottingham Trent University, University of Southampton (all UK universities), Bunda University (Malawi) and the University of Pretoria (South Africa). CRA has been working in Malawi since 2013 and is the umbrella organisation for a variety of applied conservation research projects including African Bat Conservation, Carnivore Research Malawi and the Urban Wildlife Project in Lilongwe City. CRA have established four research centres (Vwaza Marsh Wildlife Reserve, Nyika National Park, Kasungu National Park and Lilongwe City) from which they conduct applied research.

1.9. Acknowledgements

We are very grateful to all the expedition citizen scientists, who not only dedicated their spare time to helping but also, through their expedition contributions, funded the research. We would also like to thank our key partners, the Department of National Parks and Wildlife (DNPW) for supporting our programme and assisting with local expertise, logistics and of course assistance from wildlife rangers. We would like to thank Elephants for Africa (EfA) for developing the elephant research protocols. Biosphere Expeditions would also like to thank members of the Friends of Biosphere Expeditions and donors for their sponsorship, as well as Karen Shevlin, Amanda Harwood and Jonny Vaughan for their hard work in making the expedition a reality. We extend our appreciation to our expedition cooks Emmanuel and Kevin Nkhata.

1.10. Further information & enquiries

More background information on Biosphere Expeditions in general and on this expedition in particular including pictures, diary excerpts and a copy of this report can be found on the Biosphere Expeditions website www.biosphere-expeditions.org.

Enquires should be addressed to Biosphere Expeditions at the address given on the website.

1.11. Expedition budget

Each citizen scientist paid a contribution of €2,240 per person per seven-day period towards expedition costs. The contribution covered accommodation and meals, supervision and induction, special research equipment and all transport from and to the team assembly point. It did not cover excess luggage charges, travel insurance, personal expenses such as telephone bills, souvenirs etc., or visa and other travel expenses to and from the assembly point (e.g. international flights). Details on how this contribution was spent are given below.

Income	€
Expedition contributions	81,593
Expenditure	
Expedition setup Includes costs to research, reccee and set up expedition	7,843
Expedition base includes all food & services	21,602
Transport includes hire cars, fuel, taxis in Malawi	4,333
Equipment and hardware includes research materials & gear etc. purchased internationally & locally	6,009
Staff includes local and Biosphere Expeditions staff salaries and travel expenses	15,749
Administration includes miscellaneous fees & sundries	610
Team recruitment Malawi as estimated % of annual PR costs for Biosphere Expeditions	8,676
Income – Expenditure	**16,726**
Total percentage spent directly on project	**80%**

2. Large mammal monitoring

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Lilongwe Wildlife Trust

Emma Stone
Conservation Research Africa

Matthias Hammer (editor)
Biosphere Expeditions

2.1. Introduction

Large mammal populations are declining globally (Ripple et al. 2015). Loss of large mammals can have cascading effects on ecosystems, including other mammal species, vegetation and habitats, as well as socio-economic consequences for humans (Diplock et al. 2018). Wildlife population declines also have considerable impacts on other animal populations (e.g. loss of prey species leads to a decline in carnivores), ecological effects such as a lack of proper seed dispersal, and a decrease in local tourism revenue (Diplock et al. 2018). In addition, little is known on how large mammal declines affect mutualistic species population trends (Galetti et al. 2018, Diplock et al. 2018).

Between 1970 and 2005, large mammal populations across Africa's protected areas have decreased by nearly 60% (Craigie et al. 2010). Poaching for ivory is a particularly grave threat, mainly to the elephant (*Loxodonta africana*) (Maisels et al. 2013), leading to a 75% decline of elephant populations (Wittemyer et al. 2014). Similarly, large carnivore populations are facing threats from rising anthropogenic pressures (Nowell and Jackson, 1996) and are already known to face extirpation (Maisels et al. 2001). In Malawi, these species have already experienced devastating losses over many years (Munthali and Mkanda 2002).

Monitoring populations of large mammals is fundamental for conservation management, allowing park managers to assess the health and resilience of populations, and to identify changes in populations and potential drivers of change. Transect and camera trap surveys work hand in hand to deliver data to assess these.

Camera trapping has rapidly become one of the most popular tools for conservation researchers and wildlife managers to monitor wildlife. Camera traps are automated cameras triggered remotely by movement to capture records of animals. Today, remote cameras are used by researchers around the world, in a range of environments and for a variety of objectives. They have been established as a standard non-invasive surveying method, with the number of published papers utilising them continuing to increase (Rovero et al. 2013). Because the use of remote cameras for wildlife research allows researchers to address questions that traditional survey techniques have been unable or difficult to address, particularly in detection of elusive and nocturnal species, their results provide important information for governing and regulatory bodies that need to make wildlife conservation and management. To date, there are no published studies using camera traps in Malawi (Agha et al. 2018).

This, therefore, is the first study to catalogue total (both diurnal and nocturnal) mammal species presence in Vwaza Marsh Wildlife Reserve.

2.2. Methods

Camera trapping surveys

Photographic surveys were conducted with 24 digital camera traps located at stations spaced an average of 1.73 km apart, with one camera per station, along roads throughout the Reserve. Forty-eight separate sites were covered during the expedition (Figure 2.2b). Cameras were deployed for a total of eight days for each group (group 1: 5-12 September; group 2: 19-26 September; group 3: 10-17 October), with cameras being checked, SD cards changed, and data collected twice during that period (once after three days and then on the eighth day after setting). Images that captured no animals or humans (i.e. just grass or shadows) were deleted. All other images were sorted into folders and catalogued through the program Wild.ID version 0.9.28. Animals (or humans) in each image were manually identified by citizen scientists with assistance from staff.

Figure 2.2a. Setting a camera trap.

The number of species sighted per station and group are summarised below. For species of interest and rare species with enough captures, we calculated the number of capture events (defined as a series of pictures in a time sequence separated by fewer than five minutes), and the overall capture rate across the expeditions (total events/number of camera trap survey nights x 100). The total sampling area was calculated by using the 2 km spacing grid, creating the same width buffer zone around the camera traps and calculating the area of the polygon in QGIS.

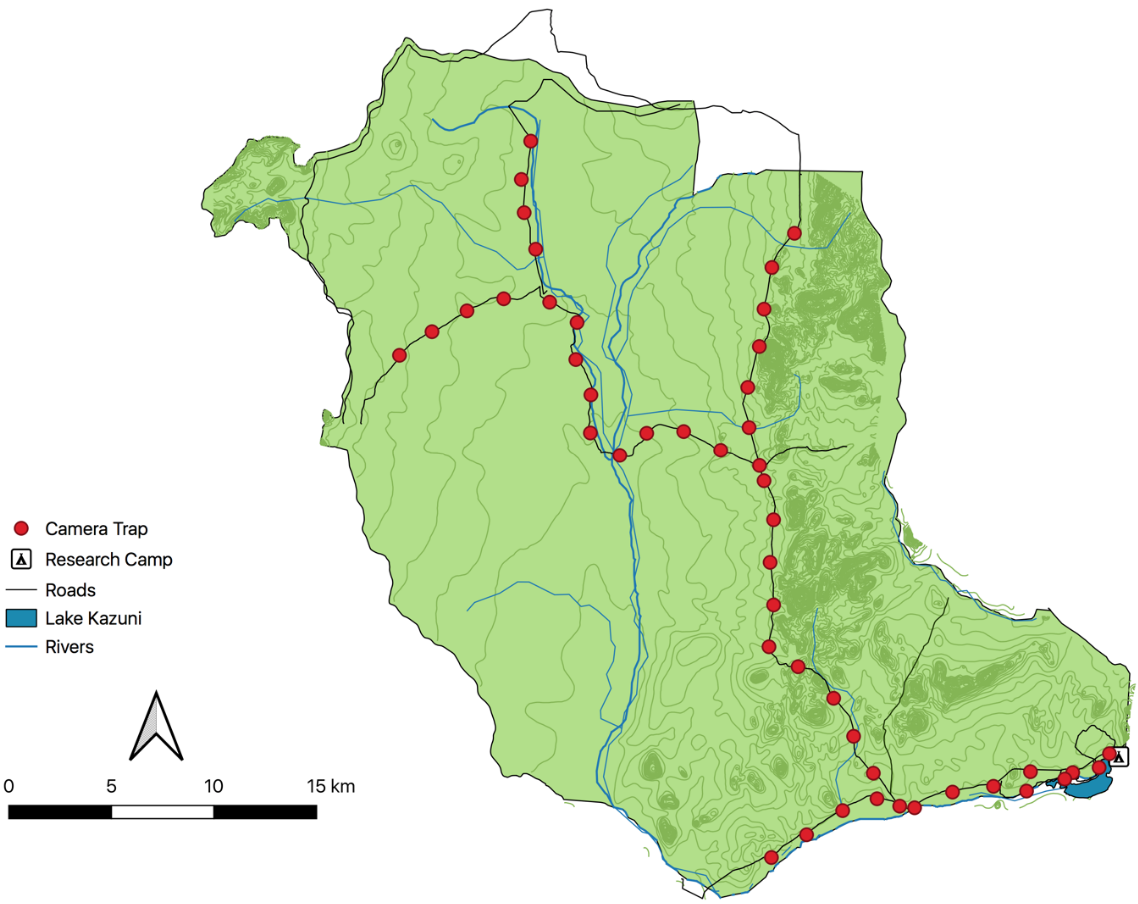

Figure 2.2b. Camera trapping sites of the expedition.

Large mammal transect surveys

All roads in the Reserve were surveyed for the presence of large mammal species by means of driven mammal transects (DMTs) (length = 5 km, with a 2 km spacing). Transects were driven at dawn travelling at a maximum of 20-25 km per hour. Animals were recorded if they were between 90° and 0° from either the left or right side of the transect. Upon sighting animals, the following parameters were recorded: GPS location, date, time, habitat, species, number of individuals, group demographics, distance from animal to transect (m), angle of the animal from the transect, and compass angle (Figure 2.2c).

Walked mammal transects (WMTs) (length of transects = 5 km) were also conducted, by walking in teams of four to six persons commencing at dawn from starting points selected using a stratified sampling design across the park (Figure 2.2f).

Hippos were surveyed using both walked and driven 5 km transects along the lakeshore of Lake Kazuni starting from camp. When hippos were sighted the following parameters were recorded: GPS location, date, time, number of individuals, their perpendicular (90°) distance from observer, and their distance from water (Figure 2.2e). Hippos were determined to be in a different pod if there was at least 50 m between individuals.

Figure 2.2c. Driving transect.

Figure 2.2d. Walking transect.

Figure 2.2e. Hippo transect.

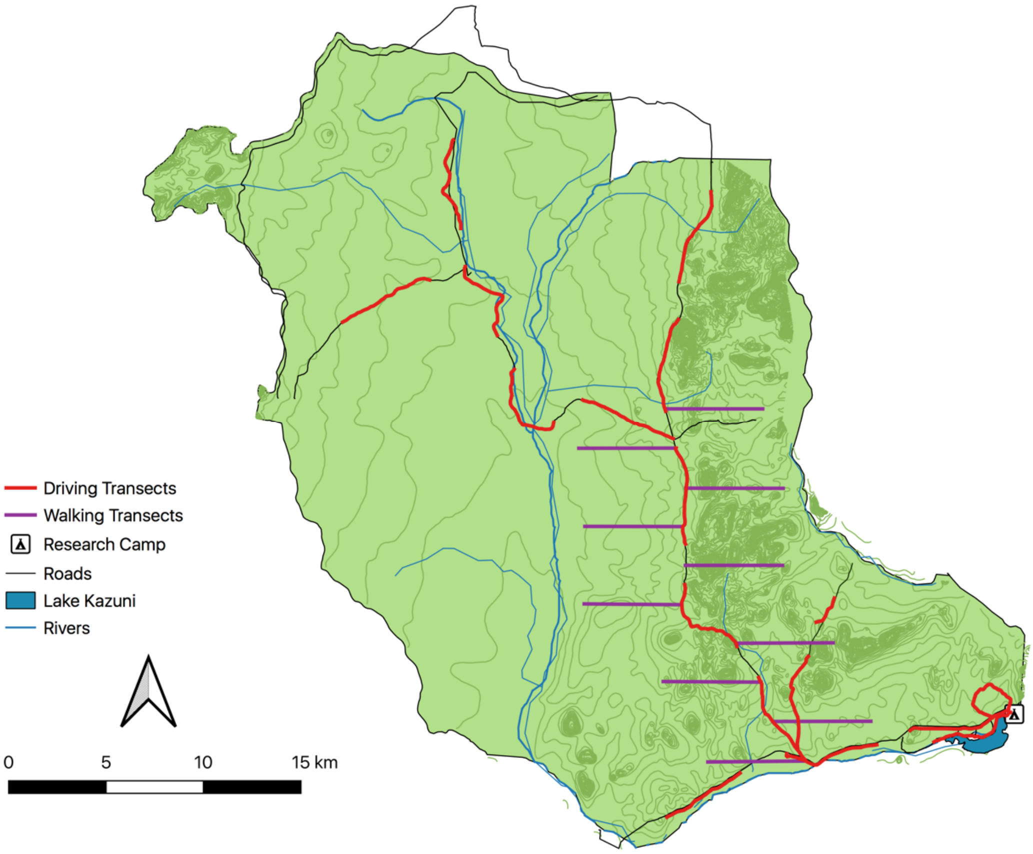

Figure 2.2f. Location of driving and walking transects
(the hippo transect along the northern shore of Lake Kazuni is not shown because it is too short).

2.3. Results

Camera trapping survey

We conducted three trapping sessions (each comprising eight days) located on roads throughout the park (Figure 2.2b Table 2.3a). We collected a total of 3,383 images, covering a total sampling area of 623 km^2.

Table 2.3a. Camera trap survey effort across expedition groups.

Expedition group	Number of photos	Number of species	Camera traps set	Camera trap days
1	1,263	28	22	176
2	835	23	24	188
3	1,285	28	23	180
Totals	**3,383**	**36**	**69**	**544**

A total of 36 species (see Figure 2.3a for examples) were recorded on camera traps, comprising 30 mammal and six bird species (Table 2.3b). The highest number of species were recorded during expedition groups one and three (n = 28 species), followed by expedition group two with 23 species. Of the 3,383 images captured, 13 contained species that were unidentifiable. We also captured 38 images of poachers over five events (capture rate = 1.10%).

Table 2.3b. Species capture record across expeditions. LC = Least Concern; NT = Near Threatened; VU = Vulnerable.

Common name	Scientific name	IUCN Red List status	Group 1	Group 2	Group 3	Total occurrence across groups
		Carnivores				
Lion	*Panthera leo*	VU	y	y		2
Leopard	*Panthera pardus*	VU	y			1
Serval	*Leptailurus serval*	LC	y		y	2
Caracal	*Caracal caracal*	LC		y	y	2
African wildcat	*Felis silvestris*	LC	y		y	2
Spotted hyaena	*Crocuta crocuta*	LC	y	y	y	3
Honey badger	*Mellivora capensis*	LC	y	y	y	3
Civet	*Civettictis civetta*	LC	y	y	y	3
Large-spotted genet	*Genetta maculata*	LC	y	y	y	3
Slender mongoose	*Herpestes sanguineus*	LC		y	y	2
Water mongoose	*Atilax paludinosus*	LC	y		y	2
White-tailed mongoose	*Ichneumia albicauda*	LC	y	y	y	3

Common name	Scientific name	IUCN Red List status	Group 1	Group 2	Group 3	Total occurrence across groups
		Primates				
Vervet monkey	*Chlorocebus pygerythrus*	LC	y	y	y	3
Yellow baboon	*Papio cynocephalus*	LC	y	y	y	3
Greater bushbaby	*Otolemur crassicaudatus*	LC	y		y	2
		Ungulates				
Elephant	*Loxodonta africana*	VU	y	y	y	3
Buffalo	*Syncerus caffer*	LC	y	y	y	3
Greater kudu	*Tragelaphus strepsiceros*	LC	y	y	y	3
Roan antelope	*Hippotragus equinus*	LC		y		1
Impala	*Aepyceros melampus*	LC	y	y	y	3
Puku	*Kobus vardonii*	NT	y			1
Bushbuck	*Tragelaphus scriptus*	LC	y	y	y	3
Warthog	*Phacochoerus africanus*	LC	y	y	y	3
Bushpig	*Potamochoerus larvatus*	LC	y	y		2
Common duiker	*Sylvicapra grimmia*	LC	y	y	y	3
Hippopotamus	*Hippopotamus amphibius*	VU	y		y	2
		Other mammals				
Aardvark	*Orycteropus afer*	LC			y	1
Porcupine	*Hystrix africaeaustralis*	LC	y	y	y	3
Scrubhare	*Lepus saxatilis*	LC	y	y	y	3
Elephant shrew	*Elephantulus rozeti*	LC	y			1
		Birds				
African grey hornbill	*Tockus nasutus*	LC			y	1
Cape turtle dove	*Streptopelia capicola*	LC	y			1
European bee-eater	*Merops apiaster*	LC			y	1
Fiscal flycatcher	*Meleanomis silens*	LC		y		1
Ground hornbill	*Bucorvus leadbeateri*	VU			y	1
Helmeted guineafowl	*Numida meleagris*	LC	y	y	y	3
Totals			**28**	**23**	**28**	**-**

Examples of camera trap pictures (Figure 2.3a):

Lion (*Panthera leo)*

Leopard (*Panthera pardus)*

Aardvark (*Orycteropus afer*)

Caracal (*Caracal caracal*)

Spotted hyaena (*Crocuta crocuta*)

African civet (*Civettictis civetta*)

Large-spotted genet (*Genetta maculate*)

Honey badger (*Mellivora capensis*)

All key target species were recorded including lion, leopard, spotted hyaena and both primate species. Elephant were the most frequently recorded species across camera stations (39% of stations), followed by baboon (26% of stations) and spotted hyaena (21% of stations) (Table 2.3c). The percentage of camera trap stations where captures were successful was 100%.

Table 2.3c. Percentage of camera stations at which each target species was recorded within each expedition group (elephant, leopard, lion, spotted hyaena, yellow baboon, vervet monkey).

Exp. group	Elephant	Spotted hyaena	Lion	Leopard	Baboon	Vervet monkey
1	47.8	8.7	4.3	13.0	17.4	17.4
2	16.7	12.5	8.3	0	12.5	0.0
3	52.2	43.5	0.0	0	47.8	17.4
All groups	**38.6**	**21.4**	**4.3**	**4.3**	**25.7**	**11.4**

Of those species for which capture rates were calculated, genets were the most frequently recorded (capture rate = 8.46%), followed by civet (6.62%) and honey badger (3.86%) (Figure 2.3b).

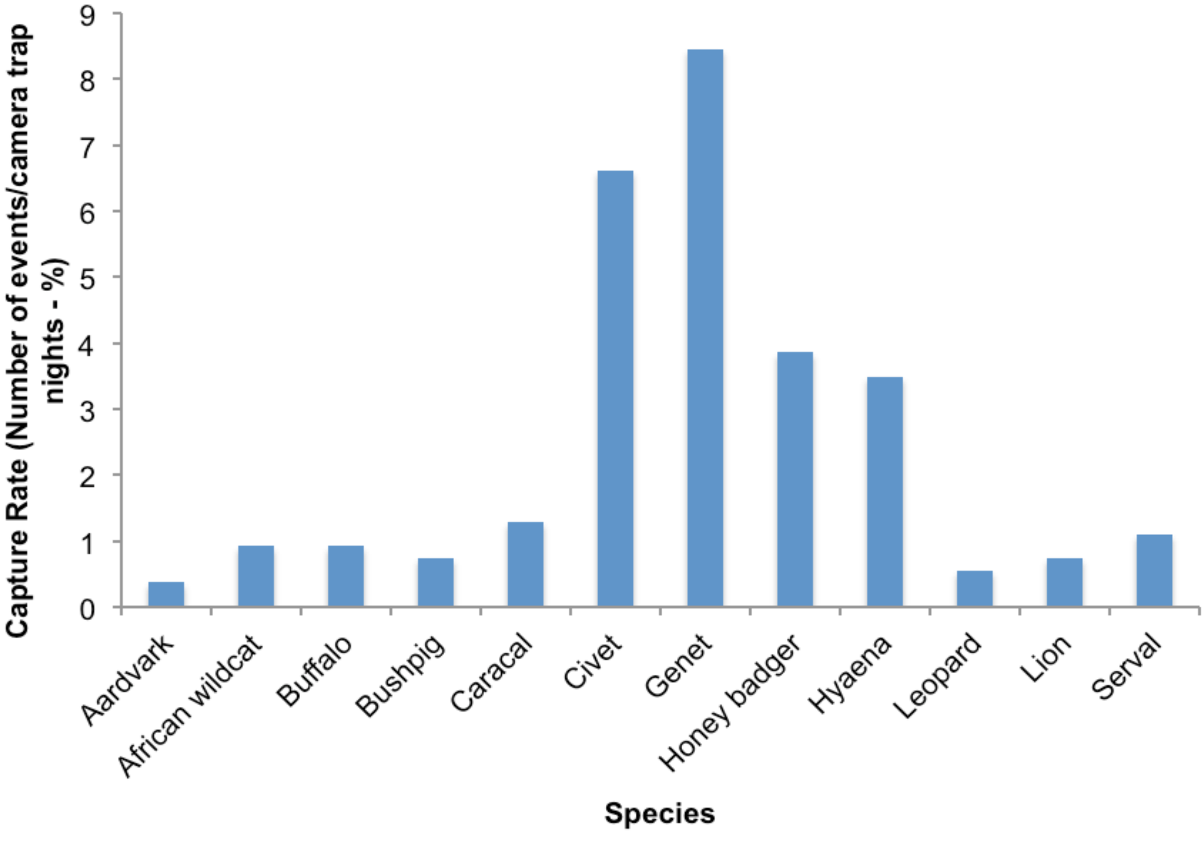

Figure 2.3b. Capture rates for species of interest and rare species during the expedition.

Large mammal transect surveys

We conducted a total of 53 driven and 11 walked transect surveys across all groups (Table 2.3d). We recorded a total of twelve species on transect surveys (mean = 1.1 sightings per transect), and an overall encounter rate of 0.22 sightings/km (Table 2.3e). Encounter rates were similar between driven (0.22 sightings/km) and walked transect surveys (0.24 sightings/km) (Table 2.3e). The majority of mammal sightings were in the southern part of the reserve closest to the permanent water sources which remain present during the dry season (Figure 2.3c).

Table 2.3d. Large mammal transect survey effort during the expedition in Vwaza Marsh Wildlife Reserve.

Activity	Group 1	Group 2	Group 3	**Total**
Driven Mammal Transect (DMT)	11	20	22	**53**
Walked Mammal Transect (WMT)	3	4	4	**11**
No. sightings on DMTs	8	27	22	**57**
No. individuals recorded on DMTs	16	221	127	**364**
No. sightings on WMTs	2	8	3	**13**
No. individuals recorded on WMTs	15	39	17	**71**
Total species recorded on DMTs and WMTs	6	10	8	**12**
Mean No. sightings per transect	0.7	1.5	1.0	**1.1**
Total kms DMT	55	100	110	**265**
Total kms WMT	15	20	20	**55**
Total kms surveyed	**70**	**120**	**130**	**320**

Table 2.3e. Species-specific encounter rates and number of individuals recorded during large mammal transect surveys.

Species	Sightings	Individuals recorded	Mean individuals per sighting (SD)	Encounter rate (sightings / km)	Individuals per km
Baboon	22	236	11.1 (±18.8)	0.069	0.738
Bushbuck	5	5	1.0 (±0)	0.016	0.016
Bushpig	2	8	4.0 (±2.8)	0.006	0.025
Duiker	4	4	1.0 (±0)	0.013	0.013
Elephant	1	2	1.5 (±0.7)	0.003	0.006
Hippo	2	2	1.0 (±0)	0.006	0.006
Impala	8	57	7.1 (±4.5)	0.025	0.178
Kudu	6	20	3.3 (±1.4)	0.019	0.063
Puku	2	19	9.5 (±2.1)	0.006	0.059
Roan antelope	1	14	14.0 (±0)	0.003	0.044
Vervet monkey	4	20	5.0 (±2.9)	0.013	0.063
Warthog	8	18	2.4 (±1.1)	0.025	0.056

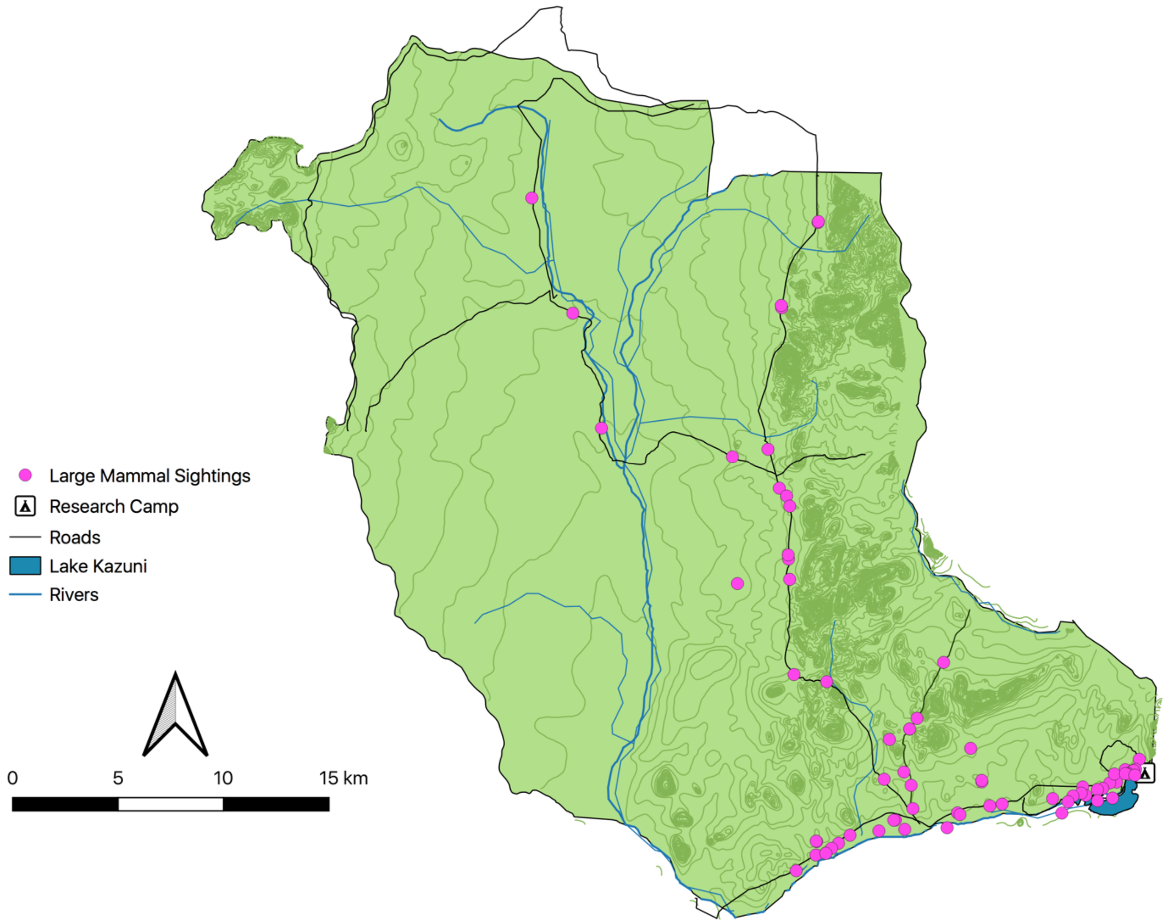

Figure 2.3c. Location of large mammal sightings from transect surveys.

Baboons were the most frequently sighted species on transect surveys (encounter rate = 0.069/km), followed by impala (encounter rate = 0.025/km) and warthog (encounter rate = 0.025/km) (Figure 2.3d).

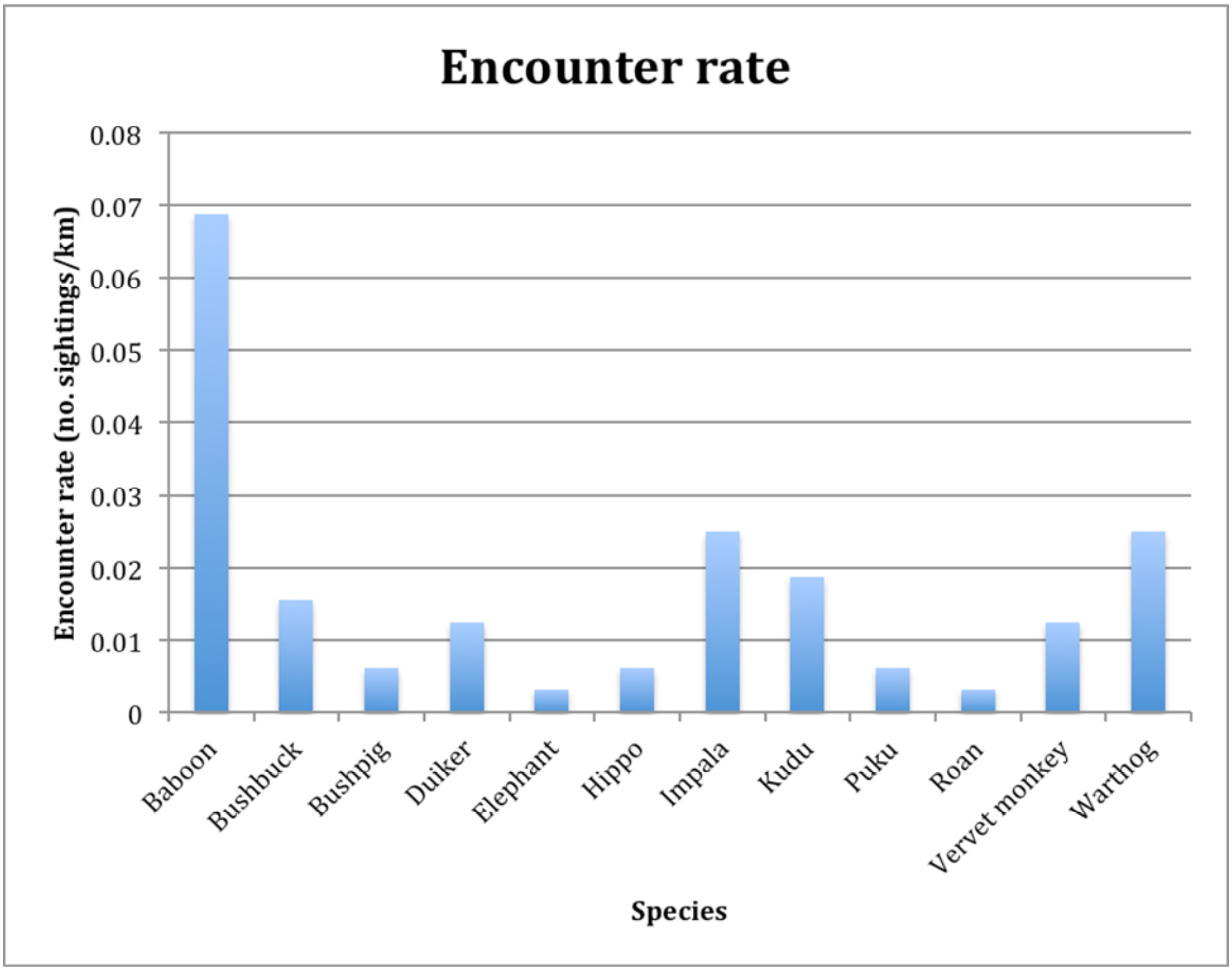

Figure 2.3d. Species-specific encounter rates (sightings/km) from large mammal transect surveys.

Hippo count transects

We conducted 18 hippo transects across the three expedition groups (n = 11 walked and 7 driven) and recorded a mean of 147.6 hippos per transect (Table 2.3f). This mean is suggestive of the total number of hippos likely to be in the area during this time of year.

Table 2.3f. Hippo transect survey effort and sightings across three expedition groups.

Activity	Group 1	Group 2	Group 3	**Total**
Hippo driving transect	2	2	3	**7**
Hippo walking transect	3	3	5	**11**
Total No. hippos from driven transects	300	228	516	**1044**
Total No. hippos on walked transects	368	458	787	**1613**
Mean No. hippos per transect	133.6	137.2	162.9	**147.6**

2.4. Discussion and conclusions

Of all large mammal surveys, camera trapping was the most successful, recording the highest species diversity (36 species) and more than 3,300 images.

Camera trapping surveys provided the first ever images of lion in the Reserve, known to be present, but previously never recorded on camera. There are a few reports of lion sightings, calls, or tracks every year in the Reserve. We recorded the same young male captured across the expedition, and there was no evidence that there was more than one individual. It is typical of young male lions to disperse to new areas looking for females and it may be the case that the lion in the Reserve is a dispersing animal looking for new prides. As Vwaza border connects with Zambian protected areas through the Transfrontier Conservation Management Area, it is likely that this male lion originated from Zambia.

Other rarely seen carnivores were also recorded including serval, caracal and leopard. We recorded fewer leopard captures (only recorded by expedition group 1) than expected (based on casual track and sign observations), though leopard are known to be shy and elusive. There was also an unconfirmed leopard sighting during group 1 in the north of the Reserve. The capture rate for leopard was lower than that for lion. There are no published studies on leopard density or activity in miombo woodlands from which to draw conclusions, but it is likely they are affected by high poaching pressure.

Capture rates for interesting and rare species can be used comparatively between species to give an idea of relative abundance. The higher capture rates for genet and civet compared with large carnivores, such as lion and leopard, might suggest potential mesopredator increase caused by a reduction in the large carnivore population. However, all capture rates for target species were low (< 10%), so a larger sampling effort would be required to draw conclusions and more robust density estimates.

We did not detect side-striped jackal, though they are relatively common in Malawi, both outside and inside protected areas. This may be due to low density, or habitat preferences. Further camera trap surveys are required to assess this.

We captured fewer images and fewer species with expedition group two, most likely because cameras deployed by this group were placed in the far northern sections of the Reserve, where there are fewer permanent water sources in the dry season. Due to this, we would expect a lower concentration of wildlife. Over the course of the expedition, two camera traps were stolen. We therefore lost data that might have been recorded on these.

Camera traps can also be an important tool for anti-poaching efforts (Laurance 2013). During the expedition, we recorded 38 images from five separate events of poacher activity. These images were immediately shared with the Department of National Parks and Wildlife (DNPW) to assist in their law enforcement efforts. Camera trap surveys are also able to yield information on the health of wildlife populations. From images we are able to glean body condition and physical ailments. This study captured images of at least two hyaenas with snares around their necks. Snares are a heavily used poaching method in the Reserve, mostly for subsistence poaching of antelope. However, they often end up injuring or killing other wildlife. We can use these images to monitor the animals' health and also to inform veterinary efforts to remove the snares. As this was the first survey of its kind in the Reserve, these data are crucial for DNPW by providing important data on the presence and health of carnivore populations in the park.

Large mammal transect surveys were less successful than camera trapping surveys in detecting mammal presence and diversity. They yielded twelve species, with baboons being most frequently encountered. Species of note were roan antelope, which are rarely sighted and frequently occupy woodland habitats, and puku, as they are classified as Near Threatened (IUCN). Puku prefer floodplain habitats and are often recorded on the banks of Lake Kazuni and the South Rukuru River in the southern part of the Reserve. The majority of mammal sightings were in the southern part of the Reserve closest to the remaining water in the dry season. The southern area is under pressure from human encroachment and identification of these wildlife hotspots can help aid the DNPW in law enforcement efforts.

Hippo surveys of populations inhabiting Lake Kazuni in the south of the reserve were very successful, yielding an average 147 hippos per transect, which demonstrates a healthy population for the area. Counts were higher during group 3 as this took place during the height of the dry season, when water levels were at their lowest. Therefore, hippos were more concentrated and easily visible.

Our results indicate relatively high species diversity in VMWR. Five of the species recorded by the expedition are classed as Vulnerable and one species (puku) is classed as Near Threatened by IUCN. These particularly at risk species are threatened by the increasing human pressures in the Reserve. Results from the expedition provide an important baseline for future monitoring of large mammal, hippo and carnivore populations in the Reserve. With future expeditions we will be able to augment our data and conduct more robust analyses of populations, including estimates of population density (using distance sampling from transect surveys (Buckland et al. 1993)), occupancy (using presence only modelling with data from camera trapping data), and population dynamics. All of this information is important for effective management of large mammals in the park.

2.5. Outlook for future expedition work

We will build our dataset during future expeditions and combine data across years to conduct occupancy modelling of uniquely identifiable species to calculate density estimates (MacKenzie et al. 2002). In addition, we will conduct vegetation sampling along three 200 m transects radiating from each camera station. Canopy cover, height, % understory, understory height and mean visibility will be recorded at 20 m intervals along each transect. Generalised linear models with binomial errors will be used to investigate the relationship between competing carnivores, habitat and landscape and capture success. A photographic database has been created and those species with diagnostic coat patterns (e.g. leopard and spotted hyaena) are being analysed and identified to individuals to quantify abundance and distribution.

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3. Elephant monitoring

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Biosphere Expeditions

3.1. Introduction

Elephant populations in Malawi are in crisis. Best estimates suggest a 71% decline in elephants between 2002 and 2006 alone (Thouless et al. 2016). Since the 1970s, elephants across Malawi, including Vwaza Marsh Wildlife Reserve (VMWR) have been heavily poached for their ivory. Threats to elephant populations in Malawi differ from most other range states, because Malawi is a small country with a very high population density and therefore human population pressure, few contiguous protected areas (only 9% of the country is protected) (Blanc et al. 2007), and the second highest rate of deforestation in Southern Africa (UNEP 2002). Elephant populations in Malawi are small and isolated, only remaining in protected areas, which are dwindling due to poaching for ivory (Munthali 1998), human encroachment and deforestation (Blanc et al. 2007). Losing elephant populations in Malawi means that a significant gap in the African elephant range will open up. Malawi's elephants are geographically important as they provide a transboundary link to priority populations (as listed by the African Elephant Conservation Fund) in the Luangwa-Zambezi Valley through the Malawi-Zambia Transfrontier Conservation Area (TFCA), which includes VMWR, along with Nyika and Kasungu National Parks, encompassing 30,621 km^2. This TFCA facilitates elephant dispersal, movements, and genetic diversity. Elephants in Malawi are suffering from increasing isolation caused by decreasing connectivity through agricultural expansion and human encroachment. This brings elephants into increasing conflict with human populations surrounding the protected areas.

Elephants in Malawi can be considered Endangered according to the IUCN. Isolation, encroachment and habitat loss are threatening populations in Malawi, and management and conservation is limited by a lack of rigorous research and survey data. Over 50% of elephant population estimates are low quality guesses (Blanc et al. 2007) and surveys are not standardised or rigorous, limiting interpretation of elephant status and trends across Malawi. And yet accurate information on elephant numbers and distribution is essential for effective conservation management of the species (Blanc et al. 2007). However, precise and accurate estimates of elephant numbers in Malawi are lacking (Table 3.1a).

There has been no previous systematic census or monitoring of the elephant populations in VWMR. There are an estimated 300 elephants in the Reserve, with some populations migrating to areas in the TFCA throughout the year. VMWR is unique as large mammals there are heavily dependent on the few water resources, which remain available in the dry season (May-November), e.g. Lake Kazuni and the South Rukuru River located in the southern part of the reserve. These are utilised by elephants throughout the year for drinking, swimming, bathing and to cover themselves with mud and sand. This means that large numbers of elephants congregate at these resources.

Table 3.1a. Elephant population estimates in Malawi (Blanc et al, 2007).

INPUT ZONE	CAUSE OF CHANGE[1]	SURVEY DETAILS[2]			NUMBER OF ELEPHANTS		SOURCE	PFS[3]	AREA (km²)	MAP LOCATION	
		TYPE	RELIAB.	YEAR	ESTIMATE	95% C.L.				LON.	LAT.
Kasungu National Park	**RS´**	AS1	B	2005	58	218	Ferreira et al., 2005	1	2,463	33.1 E	12.9 S
Liwonde National Park	NG	OG3	E	2006	530		African Parks Foundation, 2006b	2	538	35.3 E	14.9 S
Majete Wildlife Reserve	**NP**	IG3	D	2006	70		African Parks Foundation, 2006b	3	140	34.7 E	16.0 S
Nkhota-Kota Wildlife Reserve	DD	AS2	E	1995	1,037	1,511	JICA & Government of Malawi, 1997	1	1,802	34.0 E	12.9 S
Nyika National Park	——	AS1	B	1997	339	239	Gibson, 1997	1	3,134	33.8 E	10.6 S
Phirilongwe Forest Reserve	——	IG3	D	1998	50		S.M. Munthali, pers. comm., 1998	2	640	35.0 E	14.6 S
Thuma Forest Reserve	——	IG3	D	1998	30	20*	S.M. Munthali, pers. comm., 1998	2	370	34.2 E	13.9 S
Vwaza Marsh Wildlife Reserve	NG	IG3	D	2005	270		Ferreira et al., 2005	1	976	33.4 E	11.0 S

* Range of informed guess

[1] Key to Causes of Change: DA: Different Area; DD: Data Degraded; DT: Different Technique; NA: New Analysis; NG: New Guess; NP: New population; PL: Population Lost; RS: Repeat Survey (RS´ denotes a repeat survey that is not statistically comparable for reasons such as different season); ——: No Change

[2] Key to Survey Types: AS: Aerial Sample Count; AT: Aerial Total Count; DC: Dung Count; GD: Genetic Dung Count; GS: Ground Sample Count; GT: Ground Total Count; IG: Informed Guess; IR: Individual Registration; OG: Other Guess. Survey Type is followed by an indicator of survey quality, ranked from 1 to 3 (best to worst). Survey Reliability is keyed A-E (best to worst)

[3] PFS: Priority for Future Surveys, ranked from 1 to 5 (highest to lowest). Based on the precision of estimates and the proportion of national range accounted for by the site in question, PFS is a measure of the importance and urgency for future population surveys. All areas of unassessed range have a priority of 1. See Introduction for details on how the PFS is derived.

3.2. Methods

Elephant herd observations and individual identification (ID)

Methods followed protocols developed by Elephants for Africa (www.elephantsforafrica.org). We observed elephant herds both from vehicles in the Reserve and from the expedition base camp. Because of the tendency for large numbers of elephants to congregate at the water resource of Lake Kazuni (Figure 3.2a), we used this location to conduct many of our research sessions. However, we were careful to record groups that arrive at the lake together and leave together, not short-term interactions brought on by resource availability. To guarantee this, we recorded data only on groups that arrived at the lake after the researchers.

Figure 3.2a. Elephant congregating at Lake Kazuni, within 100 m of the expedition base camp.

At the start of each observation session, we recorded the date, time, GPS coordinates, and situational data on the datasheet (Figure 3.2b). Focusing on one herd at a time, we recorded herd composition data, including age and sex classes, herd leader and herd size. Often it was difficult to tell one herd from another and if this was the case, we focused solely on individual elephant identification.

Once each herd was counted, we focused on the individual identification of each elephant. We used photos of the notches and holes in the ears, tusk and tail characteristics, and other physical markers to identify individual elephants. Photos were taken of both ears, straight on, both tusks, and the full body. Binoculars were also used to identify these characteristics.

Figure 3.2b. Recording elephants from the expedition base camp.

Figure 3.2c. Collecting dung samples.

At the end of the observation session, photographs were reviewed to identify each elephant. If an individual had already been identified previously, we recorded it as a repeat sighting for that individual in our master database. If the elephant was new to the database, an ID descriptive datasheet was drawn with the individual's characteristics, photos were stored and catalogued, a profile page for the elephant was created, and all of the characteristic and sighting information was recorded in the master database.

Elephant dung was collected opportunistically. When a fresh sample was found, we recorded GPS location, total number of boli, time and date collected. Three of the most intact boli from the sample were collected and taken back to the research base. There the diameter of each bolus was measured, with an average taken from which to estimate the elephant's age. All boli were sorted through by hand to extract seeds. The seeds were cleaned and stored for further measurement and species identification.

3.3. Results

We completed 38 herd observations, and confirmed 43 second sightings of identified elephants. Twenty-eight new individual elephants were identified, five of which were females and 23 males, and all of which were adults. These individuals make up nearly 20% of our overall elephant identification database. New individuals (see Figure 3.3a for an example) were identified in six known herds and three males comprising a small bachelor herd that was not previously recorded.

We collected and processed 35 elephant dung samples, with an average diameter of 12.76 cm for each boli, indicating that the majority of dung was from sub-adult elephants. A total of 2,836 individual seeds were collected (mean = 81 seeds per dung sample). There were 38 species of seeds recorded (Table 3.3a), with two species of thorn trees being dominant (76%). We also identified pumpkin seeds, mango pips, and maize cobs. Seventeen percent of seeds were from 30 additional as of yet unidentified species (Figure 3.3b).

Table 3.3a. Seed species identified in elephant dung.

Number of seeds	Percentage occurence in dung samples	Species	Common name
850	30%	*Senegalia polyacantha*	White thorn tree
1304	46%	*Vachellia robusta*	Splendid thorn tree
131	5%	*Grewia bicolor*	White raisin tree
18	1%	*Rauvolfia caffra*	Quinine tree
2	0.1%	*Scherlocarya birea*	Marula tree
55	2%	Human foods (maize, mango, and pumpkin)	
476	17%	Unidentified (30 species)	

ELEPHANT INDIVIDUAL ID DATA SHEET

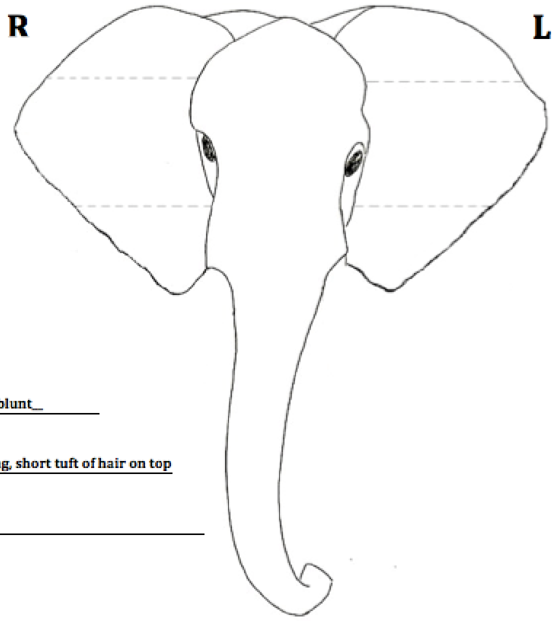
ELE ID #:VMB073 **ELE ID NAME: Snort**

ELE GROUP #: **ELE GROUP NAME:**

SEX: Male **AGE CLASS: SubAdult 14 ______** **DATE OF 1ST ID: 21 Sep 2018__________**

EARS:

SIDE	CHARACTERISTIC	SHAPE	SIZE	LOCATION (on ear)
R	Hole	Round	S	T
R	Notch	U	Small	Middle
R	Notch	Keyhole	S	Middle
R	Tatty			Middle
R	Hole	Round	S	Middle
R	Notch	N	S	Middle
R	Notch	M	S	Bottom
R	Notch	U	S	Bottom
R	Notch	V	S	Bottom
L	Notch	V	S	Middle
L	Notch	N	S	Middle
L	Notch	V	S	Middle



TUSKS: Short and fairly blunt_

TAIL: hair on bottom long, short tuft of hair on top

OTHER:

FRONT PROFILE

DATE:

RIGHT PROFILE

DATE: 21 Sep 2018

LEFT PROFILE

DATE: 21 Sep 2018

FULL BODY

DATE: 21 Sep 2018

OTHER PHOTOS

DATE:

OTHER PHOTOS

DATE:

Figure 3.3a. A male elephant profile identified during the expedition, affectionately named Snort.

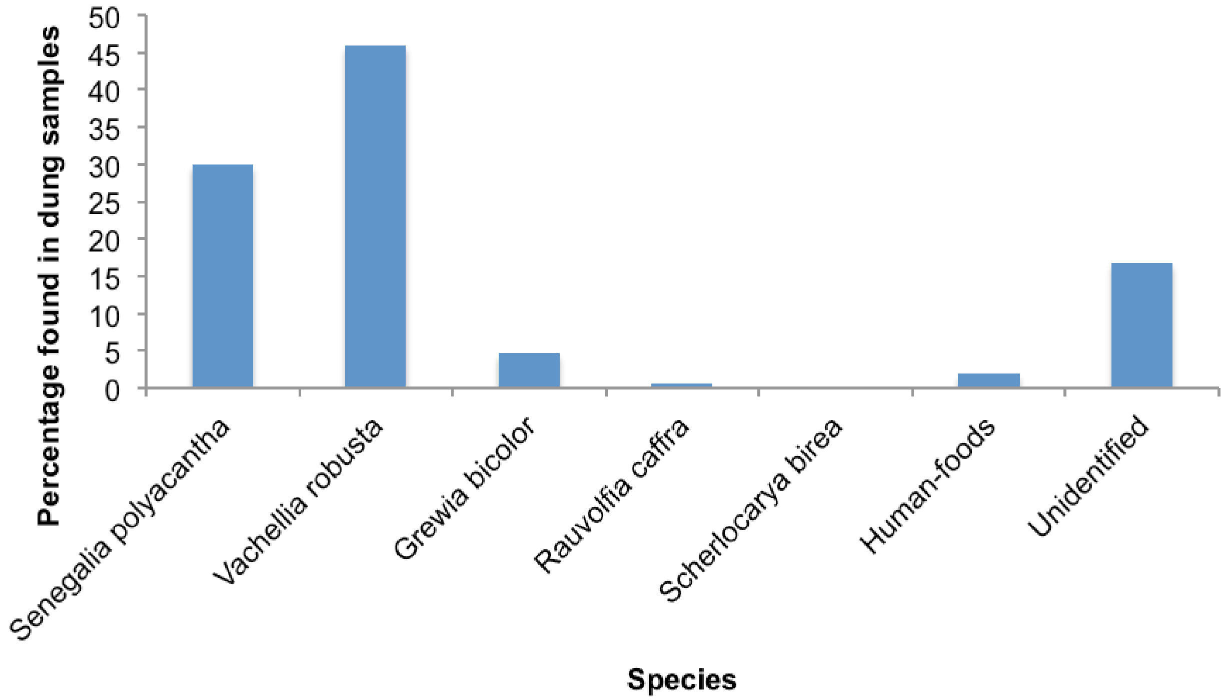


Figure 3.3b. Species variation and occurrence in elephant dung samples.

3.4. Discussion and conclusions

Elephants were observed mostly at the lake and river in front of the expedition base camp and along the lakeshore. A limitation of collecting herd composition data was the large congregation of different herds at the same time in the same place, often with more than 80 elephants together making it difficult to identify individual herds. During those times, we focused on individual identification. We augmented our identification database by 20%, which will allow us to monitor these populations more effectively. These data will be used and updated regularly long-term in order to track any population changes throughout the Reserve. They allow us to be able to track individual elephants' movements and identify individual elephants that are injured or poached. Increased IDs allow us to have a more robust long-term dataset for monitoring these populations.

As expected, the predominant seed species found in elephant dung differed to those found in other seasons of the year. These are our first results from this time of year and will augment our long-term monitoring of temporal changes in elephant diet. Finding human food parts in the dung suggests increasing human-wildlife interactions.

3.5. Outlook for future expedition work

Our elephant identification and population surveys will continue to be conducted long-term in order to monitor population changes. There are still hundreds of unidentified elephants, which will need to be identified during further expeditions to continue to build an accurate and robust profile of the elephants in Vwaza.

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4. Bat and insect monitoring

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4.1. Introduction

Bats

Bats are members of the order Chiroptera, one of the most diverse and widely distributed groups of animals (Nowak *et al*. 1994). Bat populations are declining worldwide (Hutson *et al.* 2001). The rapid increase in human populations, with the related habitat loss and degradation, poses the most serious threat to bat populations. In Africa, these threats are increasing with the annual population increasing more rapidly than that of any other continent (Hutson *et al.* 2001). Bats are key indicator species as they are nocturnal, taxonomically stable, perform key ecosystem services and have a rich trophic diversity (Kunz & Fenton 2005). Bats are the second most species-rich mammalian order in the world (Wilson & Reeder 2005) and represent a significant contribution to global and African biodiversity (Altringham *et al.* 1996, Racey & Entwistle 2003). Bats therefore make effective bio-indicators, capturing the responses of a range of taxa and reflecting components of biological diversity such as species richness and abundance (Jones et al. 2009).

Insects

Insects, a class of animals within the phylum Arthropoda, are the most diverse group of animals on the planet, making up three quarters of all known species (Samways 1993). They have colonised every continent, can live on land, in water, and in air. With approximately 1 million species currently described, estimates of the actual number of insect species on earth vary from 5.5 million to 10 million (Ødegaard 2000, Stork *et al*. 2015). As a result, insects occupy a vast number of ecological niches in almost every habitat on earth. They maintain ecological functions (Bengtsson *et al.* 2000, Srivastava 2006, Zavaleta *et al*. 2010), deliver ecosystem services (the services provided by insects are worth $57 billion to the US economy alone according to Losey & Vaughan (2006)) and are effective, cheap indicators of ecological interactions and ecosystem health (McGeoch 1998, Rainio & Niemelä 2003, Forup *et al.* 2008, Arimoro & Ikomi 2009).

Despite these well-known facts, entomology remains a heavily neglected area of study in Africa, especially for applied conservation research. Africa's protected species and habitats are disappearing at a rate faster than they can recover (Ceballos *et al*. 2015, De Vos *et al.* 2015, WWF 2018). At the same time, the continent's human population is rapidly expanding (United Nations 2011). These issues combined with the importance of insects for maintaining and monitoring protected areas (Foster 1993, Nervo *et al.* 2017; Wills & Landis 2018), sustaining Africa's booming human population (either as a direct source of food (Gahukar 2011), or indirectly as a food producer through pollination or soil turnover (Rodger *et al*. 2004)), leave entomology as a serious gap in conservation research that requires urgent attention. Insects themselves have drastically declined worldwide in recent decades (Alstad *et al.* 1989, Hallmann *et al*. 2017), leading to worldwide concern and alarm amongst scientists as to the fate of all global natural systems that are largely reliant on insects (Potts *et al.* 2010, Rader *et al.* 2016). In contrast to the time and funding needed to survey charismatic large mammals (Oliver & Beattie 1996, Jones & Eggleton 2000), insects can be easily and cheaply surveyed and generate a significant amount of data and information about the surrounding environment for each survey effort,

The bat and insect surveys conducted during the expedition provide critical data towards an ongoing long-term population and biodiversity-monitoring programme by African Bat Conservation (ABC), which aims to: (a) identify temporal changes in bat and insect populations to inform biodiversity management and IUCN action planning, (b) assess and compare species richness and composition between protected (undisturbed) areas and unprotected (disturbed) areas subject to anthropogenic change and (c) identify drivers of population change; thereby creating an early warning system to identify any declines or significant negative trends in populations.

4.2. Methods

Bat surveys

Bats were surveyed at spatially independent survey sites (replicates) in Vwaza Marsh Wildlife Reserve (VMWR) using standardised trapping as part of the biodiversity monitoring programme (BMP) at repeated specified sites, or opportunistically at randomly selected sites in each habitat (floodplain and woodland) (Figure 4.2b). Bats were surveyed for one night per site during each expedition group. Bats were captured at each survey site using two mist nets and two harp traps (Figures 4.2a and c) set over trails, slow moving water, or openings where bats forage. A distance of at least 2 km separated each survey site to prevent pseudoreplication. All surveys were carried out either along the floodplain of Lake Kazuni in the south east of VMWR, or in the Miombo woodland within 5 km of camp. The limited geographic spread of the bat survey sites was due to time restrictions during the expedition (each survey takes 3.5 hours at each site).

Figure 4.2a. Setting a mist net trap.

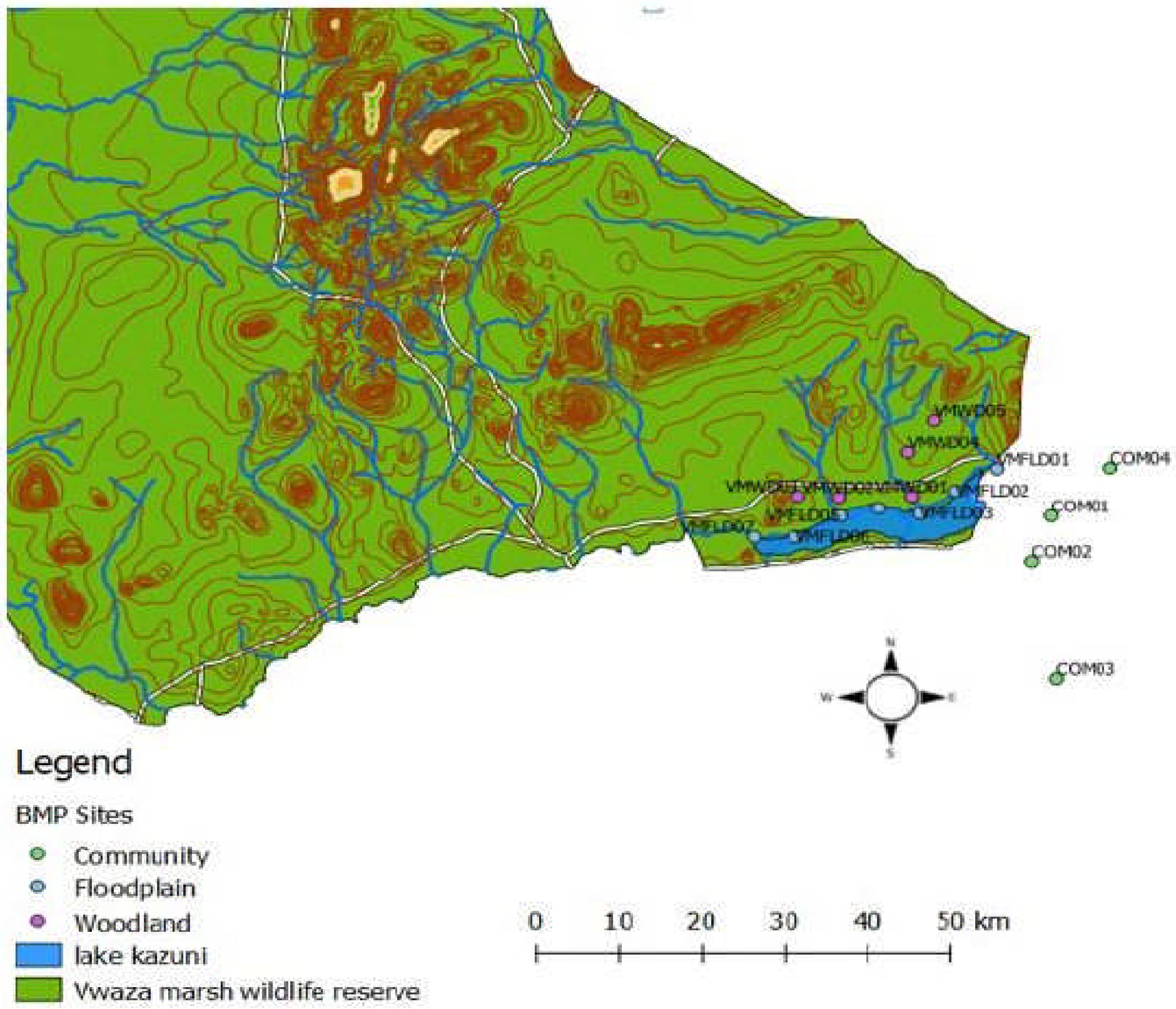

Figure 4.2b. Biodiversity Monitoring Programme (BMP) survey sites.

Figure 4.2c. Checking a harp trap.

Figure 4.2d. Recording external standardised characteristics of a bat for species identification

The size of mist nets (range 2.6 x 12 m and 2.6 x 6 m) were selected to suit the physical characteristics of each site. Traps were opened 30 minutes before sunset and monitored at 10 minute intervals for a period of three and a half hours using a standard trapping procedure described by Kunz & Parsons (2009).

Captured individuals were identified to species level using external characteristics and dentition from keys and published information (Happold & Happold 1989, 1997). Individuals were photographed and the following data collected: age (juvenile, adult), sex, reproductive status, forearm length, ear length & width, and weight (Figure 4.2d). Age was determined by observing the degree of ossification of hand joints. Females were checked for signs of lactation to determine reproductive state. Male reproductive status was determined by assessing the extent of descended testes.

Insect surveys

As with the bat surveys, all insect surveys were carried out at standardised biodiversity monitoring sites in floodplain or woodland habitat. All surveys were carried out within a range of 8 km. The limited geographic spread of the insect surveys was due to the need for time for processing and identification after each survey during the expedition. Insects were surveyed using Standardised Biodiversity Monitoring Insect Surveys and Opportunistic Surveys.

Standardised Biodiversity Monitoring insect surveys

This is a standardised biological diversity monitoring programme used to assess the status, distribution of and threats to bats and biodiversity in Malawi. Surveys are conducted in the different habitat types of VMWR at permanent sites, over different seasons, which are monitored using bat harp-trapping and mist netting, vegetation and insect surveys.

ABC will use these data to measure relative species diversity and abundance of bats between habitats, and how trends in vegetation and insects may affect bat populations. Surveys are repeated each year to build long-term datasets, enabling the monitoring of trends in abundance and diversity over time.

Insects surveyed as part of the Biodiversity Monitoring Programme (BMP) were sampled for the duration of each BMP bat survey. Surveys were conducted at randomly selected sites within the different habitats of VMWR and used one Heath light trap (Figure 4.2e), fixed with a 20W cylinder black light. These surveys were used to gain a representation of the insects present at each BMP site during each survey, in relation to bat species and abundance and vegetation structure, over time.

Each trap was placed a minimum of 25 metres away from all bat traps, and positioned out of the line of sight of the bat traps as much as possible to reduce influence on bat trapping. The light trap was positioned on game trails, on edge habitat or close to water bodies. The trap was left active (bulb on) on site for 30 minutes before sunset, and three hours thereafter, in line with the BMP methodology for surveying bats.

Figure 4.2e. Setting the Heath light trap before sunset.

At the end of each survey, all insects caught were euthanised using cotton wool soaked in ethyl acetate in a jar, which was inserted into the light trap box. The light trap box was then sealed in a plastic bag overnight and processed the following day. All insects in each trap were identified to order level and separated into size classes of 6 mm each ranging from 5 mm to 95 mm. This range is based on the variation in catch from pilot surveys conducted in Vwaza Marsh.

As it is very difficult to examine morphological characteristics accurately with individuals below 5 mm, all catch under 5 mm was compiled and weighed in mm. This was used to give an indication of the insect biomass under 5 mm collected from each survey. As the order Coleoptera (beetles) are typically the most populous group in the light trap, and can be functionally distinct within each habitat/site, they were further identified to family level, and assigned functional groupings. All identification was carried out using Scholtz & Holm (1985).

Opportunistic insect surveys

Insects were also collected independently in the form of opportunistic surveys to build the first records of insect diversity and abundance specifically in VMWR. These surveys were conducted at random sites in different habitats of the reserve using three butterfly traps, ten pitfall traps and one light trap. As insects are so diverse in their distribution and habitat use, the use of multiple trap types targets different groups that occupy different ecological niches, thus providing a more holistic representation of the diversity and distribution of insects in the reserve.

Figure 4.2f. Processing insects.

Each butterfly trap was set in a flowering tree, or in any pockets of greenery, in a shaded area, and baited using rotten banana. All ten pitfall traps were set in transects, with 1 m spacing. Pitfalls were not baited and were left dry (i.e. no killing agent, to prevent damage to any by-catch). The light trap was used opportunistically during opportunistic bat surveys, and generally left out for a period of 2-3 hours just after sunset. Additional factors of height of each butterfly trap from the soil surface, elevation, weather and habitat type were recorded. The pitfall and butterfly traps were typically left out for two days and then collected. The light trap was set during opportunistic bat surveys at night, for a duration of 2-3 hours.

Lepidoptera caught in the butterfly traps were inserted into euthanising jars containing cotton wool balls soaked in ethyl acetate. All pitfall samples were inserted into containers of ethanol. Non target animals such as any reptiles or arachnids caught were carefully removed before the sample was inserted into ethanol. The light trap was collected using the same method as described above for BMP surveys.

All specimens were separated to order level, measured, and then assigned a morpho-species code, i.e. an individual that looks morphologically distinct from another, is given its own morpho-species code. As there are no published taxonomic keys for the identification of insect species in this part of Africa, morpho-species codes still allow for an approximate indication of diversity when no other resources are available. When another specimen of the same morpho-species code is found again at another site in another survey, its own morpho-species code is recorded as occurring again for that site. All specimens were then kept for the establishment of the first physical collection of the insects of VMWR.

4.3. Results

Bat surveys

A total of 17 bat trapping surveys were completed at 17 sites and two habitats (floodplain, n=10 and woodland, n=7), yielding a total of 5,519 trapping meter survey hours (Table 4.3a).

Table 4.3a. Bat survey effort across expedition groups and survey type.

Expedition group	No. opportunistic trapping surveys	No. BMP trapping surveys	Total Trapping/Meter Hours (TMH)	Total No. bats caught	No. bats /TMH	No. spp. caught	No. spp. / TMH
1	3	1	1627.6	8	0.005	3	0.002
2	4	2	1801.2	23	0.013	4	0.002
3	3	3	2090.1	31	0.015	6	0.003
Totals	**10**	**6**	**5518.9**	**62**	**0.011**	**7**	**0.001**

Sixty-two bats were captured in total, with 49 and 13 bats captured during opportunistic and BMP trapping sessions respectively.

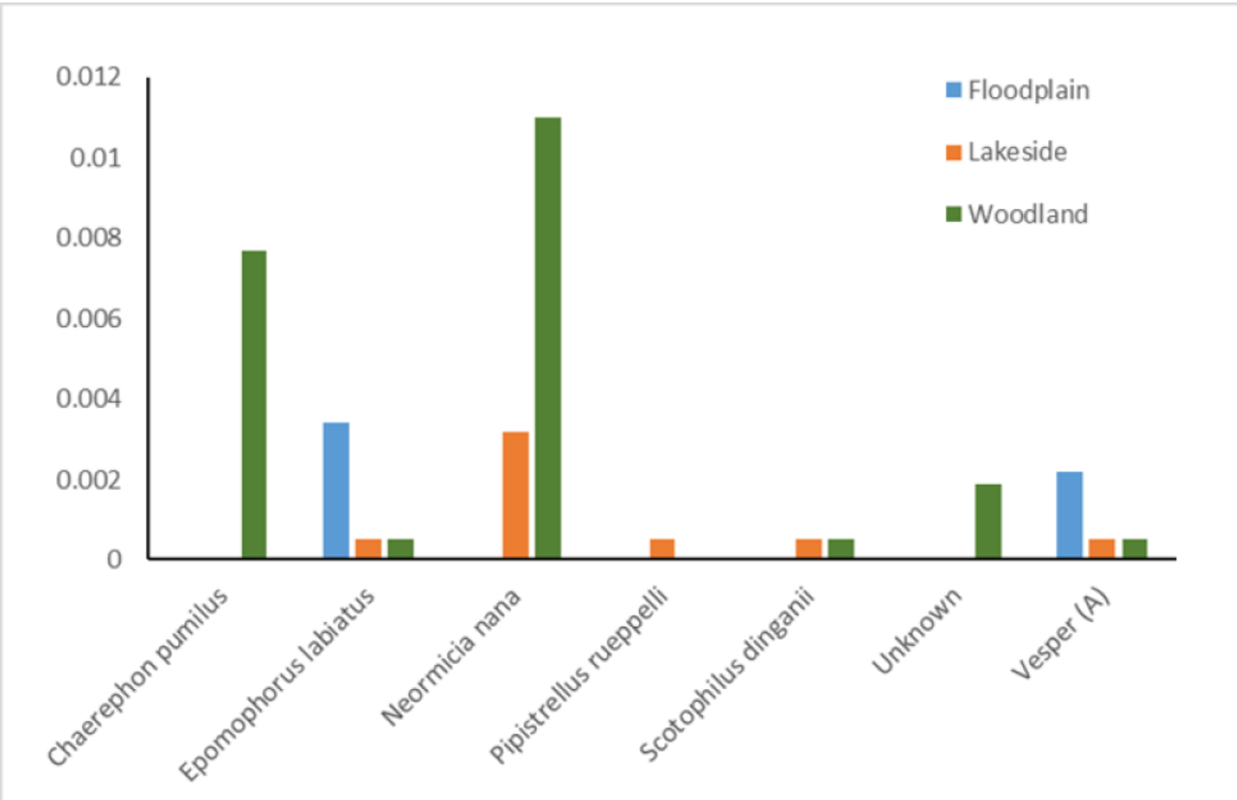

Figure 4.3a. Bat species richness (bats/TMH) per habitat.

Seven bat species were recorded (Figure 4.3a). Expedition group three recorded the highest number of bat species (n = 6) and individuals (n = 31) (Table 4.3a). Overall species richness was dominated by *Neoromicia nana* (48% of total captures), followed by *Chaerephon pumilus* (26% of total captures). The highest relative bat species richness was recorded in floodplain habitat (0.003 species/TMP) followed by woodland and lakeside, each with an average of 0.002 species/TMP.

The highest bat abundance was recorded in woodland habitats (n = 0.007 bats/TMP), followed by floodplain (n = 0.0056 bats/TMP) and lakeside (n = 0.0005 bats/TMP). Only two species (*Epomophorus labiatus* and *Vesper* (A)) were recorded in all three habitats, with numbers of both species highest in floodplain. *C. pumilus* was only recorded in woodland, and the highest numbers of *N. nana* were recorded in woodland (Figure 4.3a).

Insect surveys

A total of six biodiversity monitoring surveys and four opportunistic insect surveys were conducted (Table 4.3b).

Table 4.3b. Insect survey effort per group.

Activity	Group 1	Group 2	Group 3	**Total**
BMP survey	1	2	3	**6**
Opportunistic survey	0	2	2	**4**

Biodiversity Monitoring Programme

Ten orders of insects were represented in the BMP surveys conducted (Table 4.3c). Apart from Trichoptera and Diptera, the number of orders and abundances recorded for each were noticeably lower for group 1. Coleoptera, Diptera, Hemiptera and Lepidoptera were the only orders, out of ten recorded throughout the expedition, to be recorded by every group.

The most numerous orders for BMP surveys were Lepidoptera (n=843), Hymenoptera (n=208) and Coleoptera (n=183). The highest abundance recorded was in the Lepidoptera and the lowest abundance was recorded in the Blattodea (n=8). Interestingly, Hymenoptera, which were quite numerous in surveys conducted by groups 2 and 3, were completely absent for BMPs in group 1.

Opportunistic surveys

In the first opportunistic surveys carried out specifically on the insects of VMWR, we identified 68 morpho-species from nine orders. Nine out of the ten orders recorded for the BMP surveys were also recorded during these surveys (Table 4.3d). Blattodea was the only order not recorded. Lepidoptera, Coleoptera and Hymenoptera were the most diverse, with 19, 17 and 14 morpho-species identified respectively, while Orthoptera (n=1), Diptera (n=3) and Neuroptera (n=2) were the least diverse.

Table 4.3c. Number of individuals from each insect order caught during BMP surveys per expedition group.

Order	Group 1	Group 2	Group 3	**Total #**
Blattodea (termites & cockroaches)	1	7	0	**8**
Coleoptera (beetles)	19	92	72	**183**
Diptera (true flies)	5	1	70	**76**
Hemiptera (true bugs)	3	5	13	**21**
Hymenoptera (bees, wasps & ants)	0	80	128	**208**
Lepidoptera (moths & butterflies)	15	212	616	**843**
Mantodea (praying mantids)	0	7	8	**15**
Neuroptera (antlions & lacewings)	0	2	9	**11**
Orthoptera (crickets, grasshoppers & katydids)	0	10	2	**12**
Trichoptera (caddisflies)	8	7	0	**15**

Table 4.3d. Number of morpho-species identified from Opportunistic Surveys across all expeditions groups.

Order	Group 1	Group 2	Group 3	**Total #**
Coleoptera (beetles)	7	4	6	**17**
Diptera (true flies)	1	2	0	**3**
Hemiptera (true bugs)	1	2	1	**4**
Hymenoptera (bees, wasps & ants)	5	6	3	**14**
Lepidoptera (moths & butterflies)	5	6	8	**19**
Mantodea (praying mantids)	0	2	2	**4**
Neuroptera (antlions & lacewings)	0	0	2	**2**
Orthoptera (crickets, grasshoppers & katydids)	0	1	0	**1**
Trichoptera (caddisflies)	2	0	2	**4**
Total # morpho-species	**21**	**23**	**24**	**68**

An additional order of insects for VMWR was recorded during the expedition. The wide-ranging but rarely seen Embioptera was found and identified during dinner one night in camp by the expedition entomologist (Figure 4.3b). Often confused for termite alates, the Embioptera are the only known group to spin silk from enlarged tarsi on their forelegs to create silk tunnels in cracks of wood or amongst the leaf litter.

Figure 4.3b. Images of single male individual of the order Embioptera.

4.4. Discussion and conclusions

Bat surveys

Bat surveys were very successful with 62 bats captured representing six species and one species group.

Chaerephon pumilus dominated the species composition despite only being recorded in woodland. *C. pumilus* is a generalist species, found across Malawi. This could be because Miombo woodland is the dominant habitat type in the south of VMWR, where the bat surveys were carried out. A higher sampling effort across habitats and seasons will assess the actual distribution of *C. pumilus* in VMWR.

Neoromicia nana was the most common species, which is representative of other studies in Africa, as this species is a generalist, occupying a range of habitat types (Skinner and Chimimba 2005). This species is known for roosting in banana plants, using its sticky thumb pads to stick to the inside of the unfurled banana leaves. This species may be roosting both in the reserve and in the villages and commuting into the park for foraging. Currently the taxonomy of this species is in debate. Our wing punch samples will be used to add to the regional genetic database for this species to improve our understanding of the species group. Global population trends of this species are currently unknown. Data from the expedition will contribute to long-term monitoring being conducted by African Bat Conservation to inform our understanding of population trends in Malawi.

Captures of *Pipistrellus rueppellii* are of particular interest as this species is rarely captured by the African Bat Conservation team. This may suggest that the species has a limited distribution in VMWR, however, this can only be confirmed by additional surveys and thereby greatly increased sample size. We can then ascertain with statistical significance whether or not it has a limited presence. *P. rueppellii* roosts in buildings and rock crevices, though few studies have ever recorded it from roosts, with most captures from mist nets during free flight surveys, as with this record. With further work in VMWR, we hope to find out more about the ecology and roosting requirements of this species to fill knowledge gaps and inform conservation management.

Insect surveys

Biodiversity Monitoring Programme

There was a wide representation of insect orders from the BMP surveys, with ten orders recorded. Coleoptera and Lepidoptera were by far the most numerous orders of those recorded for BMP surveys. This could be sampling bias due to the use of a light trap, which uses black light to attract nocturnal insects, but could also indicate that the Coleoptera and Lepidoptera are two of the main food source insect groups for insectivorous bats at night. However, a much larger sample size and deeper analysis would be required to be able to interpret this data with confidence. The noticeably lower order abundance, and the number of orders represented, in the results from group 1 is probably due to the much lower survey effort for group 1. Two surveys had to be cancelled for safety reasons due to elephants and buffalo passing through the survey site.

Orders such as Mantodea, Trichoptera and Orthoptera occurred in much smaller numbers in general, and were absent completely from some groups. Members of these orders typically tend to be less active at night, and are also not as diverse as the Coleoptera and Lepidoptera. Hymenoptera were completely absent from group 1. This could be due to only one BMP survey being carried out and thus not yielding enough of a survey effort to be able to interpret the data. But it could also be that conditions were still very dry during group 1, and all three groups coincided (on purpose) with the transition from the dry to the wet season. Thus we would expect to see a higher abundance of certain groups, such as the Hymenoptera, as the wet season approaches.

Although these results are based on a small sample size, they do show quite a variation in abundances and presence of orders overall. Continued monitoring of insect populations alongside bat populations will allow us to monitor any trends and any effect that these variations may have on the insectivorous bat populations of Vwaza Marsh, across seasons and habitats.

Opportunistic surveys

Even though only three opportunistic insect surveys were conducted, over a short period of six weeks, a substantial insect diversity was apparent, with 68 morpho-species recorded, representing nine orders. All surveys were carried out in floodplain or seasonally flooded grassland (termed dambo) habitats. These results may be a good indicator of the diversity of insects overall for VMWR, especially as these surveys were conducted during the end of the dry season, typically the harshest time of year for all animals, when water and nutrient levels in the environment are at their lowest. Repeat surveys will assess if this is a true reflection of high insect diversity in VMWR.

Lepidoptera, Coleoptera and Hymenoptera were the most diverse. This could be because they are typically three of the most diverse orders of insects in many habitats worldwide (Gaston 1991). The diversity of all other orders recorded was low with just a few species recorded. This is also representative of the typical lower species diversity in these groups. However, these results are over a small snapshot of time (6 weeks), and only two habitats. Diversity would most likely increase with a larger sampling effort – i.e. higher trap count, over a longer survey period and higher habitat diversity. Notably, four morpho-species of Tricoptera were recorded, which is encouraging as the Tricoptera are a useful indicator group of water quality (Houghton 2006). Depending on the species they can be a useful and accurate indicator of poor or good quality freshwater (Dohet 2002). There is potential for further study in this line of research, especially as VMWR is a wildlife reserve where communities are allowed access to the reserve's resources within 5 km of the reserve boundary and a large lake lies within that 5 km access zone (National Parks and Wildlife Act 2017).

As with the BMP surveys, the sample size for the opportunistic surveys was also small. However, a substantial diversity was gathered from a small sampling effort during the dry season. This is an exciting start to the surveys of insect species of VMWR. Continued sampling will provide a more detailed picture of the diversity and distribution of insects across habitats.

The opportunistic discovery of an Embioptera individual is a significant addition to the insect diversity of VMWR, and illustrates that fascinating discoveries can be made in entomology whether in the bush or sitting down to dinner.

4.5. Outlook for future expedition work

Further surveys of the bat species and populations of VMWR are needed to support the data collected during the inaugural 2018 expedition, in particular to assess the interesting records of *Chaerephon pumilus* and *Pipistrellus rueppellii*. We intend to cover a wider range of habitats for bat surveys and explore areas previously unsurveyed by African Bat Conservation in VMWR.

Similarly with the insect results, we aim to increase survey effort and the diversity of habitats surveyed. The high diversity recorded by the expedition presents exciting potential for species richness relative to bat species abundance and diversity in relations to the habitat diversity of VMWR.

It is our intention to use data collected by Biosphere Expeditions on both of these important indicator groups to assess the health and function of the VMWR ecosystem and function, and inform management practices in partnership with the Malawi Department of National Parks and Wildlife.

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5. Primate behaviour surveys

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5.1. Introduction

Baboons are the most widely distributed and occupy the broadest array of habitats of primates in the family Cercopithecidae (Swedell 2011). The genus *Papio* is divided into six species (chacma baboons, *Papio ursinus*; yellow baboons, *Papio cynocephalus*; olive baboons, *Papio anubis;* Guinea baboons*, Papio papio*; kinda baboons, *Papio kindae;* and Hamadryas baboons, *Papio hamadryas*) based on morphological, ecological, and behavioral characteristics, as well as a parapatric geographic distribution (Zinner et al. 2013). Baboons are sexually dimorphic, with females weighing around 15 kg and males weighing up to 35 kg (Swedell 2011). With the exception of hamadryas (*P. hamadryas*), baboons live in multi-male, multi-female troops of typically 20-80 individuals, but may include up to 150 (Swedell 2011). Troop size varies depending on habitat resource quality and quantity, as well as the level of predation risk (Barrett and Henzi 2008). Males disperse from their natal groups when they reach sexual maturity. Baboons are generalist, opportunistic omnivores, with such varied diets that it is easier to list the foods they do not eat, rather than the ones they do. While they mainly feed on vegetables, fruits, leaves, grasses, roots, and seeds, they also eat insects and the occasional small mammal or bird (Swedell 2011).

Primates are especially responsive to human encroachment, because they are able to adapt and survive in human-modified environments. Increasingly, "direct conflict between humans and non-human primates is fast becoming as serious a concern for some species and populations as habitat loss or the bushmeat trade" (Strum 2010). Primates exemplify an extreme response to human disturbance, which can be considered an indication of greater human impacts on wildlife (Gautier and Biquand 1994). Baboons are especially adept at exploiting human resources and environments, because they are highly adaptable and ecologically flexible (Hoffman and O'Riain 2011). Baboons are also important members of a healthy ecosystem, as they are critical seed dispersers (Johnson et al. 2013).

The aim of this project was to evaluate methods and gather initial data to provide the basis for a future long-term research project for Lilongwe Wildlife Trust.

5.2. Methods

Baboons were located opportunistically from two troops. Behavioural data was collected using instantaneous scan sampling. Scans were conducted every two minutes for a length of two minutes. All visible baboons were scanned from left to right so that each baboon was only observed once. Sex and age classes were recorded for each baboon when determinable, as was the behaviour of each baboon observed, according to the ethogram (Appendix II).

Figure 5.2a. Observing baboons using instantaneous scan sampling.

Scans were completed and data were collected for an opportunistic sample period (i.e. this was not predetermined and observation periods began when we found the baboons and ended either when we could no longer see baboons or when the scheduled activity period ended). Citizen scientists worked in pairs with one observer and one recorder. Activity budgets were calculated as the number of an observed behaviour divided by the total number of observations. Detailed behaviours were condensed into five main categories (Social, Resting, Feeding, Travelling and Vigilance) for analysis and then broken down into age classes.

5.3. Results

We conducted eleven baboon behavioural surveys across the three expedition groups with a total of 251 scan samples and an average of 8.1 behavioural observations recorded per scan sample (Table 5.3a).

Table 5.3a. Baboon survey effort.

	Group 1	Group 2	Group 3	**Total**
Number of scans	28	118	105	**251**
Number of observations	273	892	871	**2,036**
Mean observations per scan	9.8	7.6	8.3	**8.1**

The baboons spent most of their time travelling (36%), followed by socialising (20%) and feeding (19%). They spent the least time resting (15%) and being vigilant (11%) (Figure 5.3a).

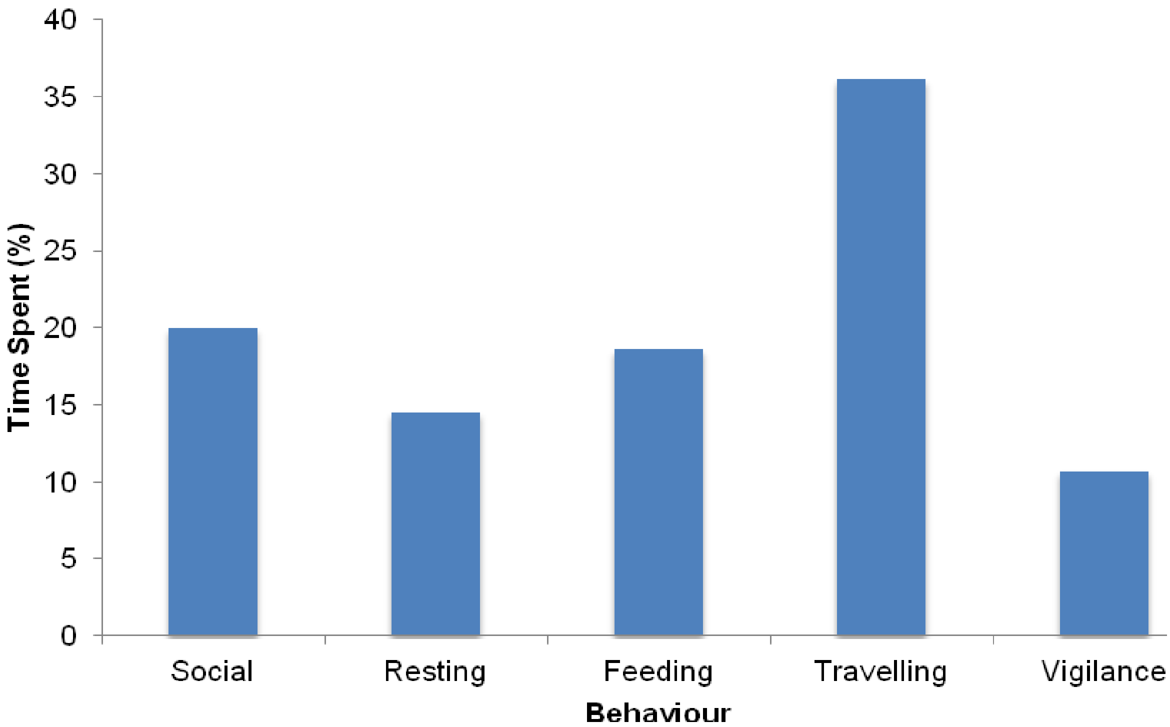

Figure 5.3a. Activity budget across baboon troops.

When broken down by age class, adults and juveniles spent most of their time travelling (16% and 15% respectively) (Figure 5.3b). Sub-adults showed vigilance more than any other behaviours, while infants spent most of their time engaging in social behaviours (5%). Social behaviours were recorded most often for juveniles, while vigilance was dominated by adults.

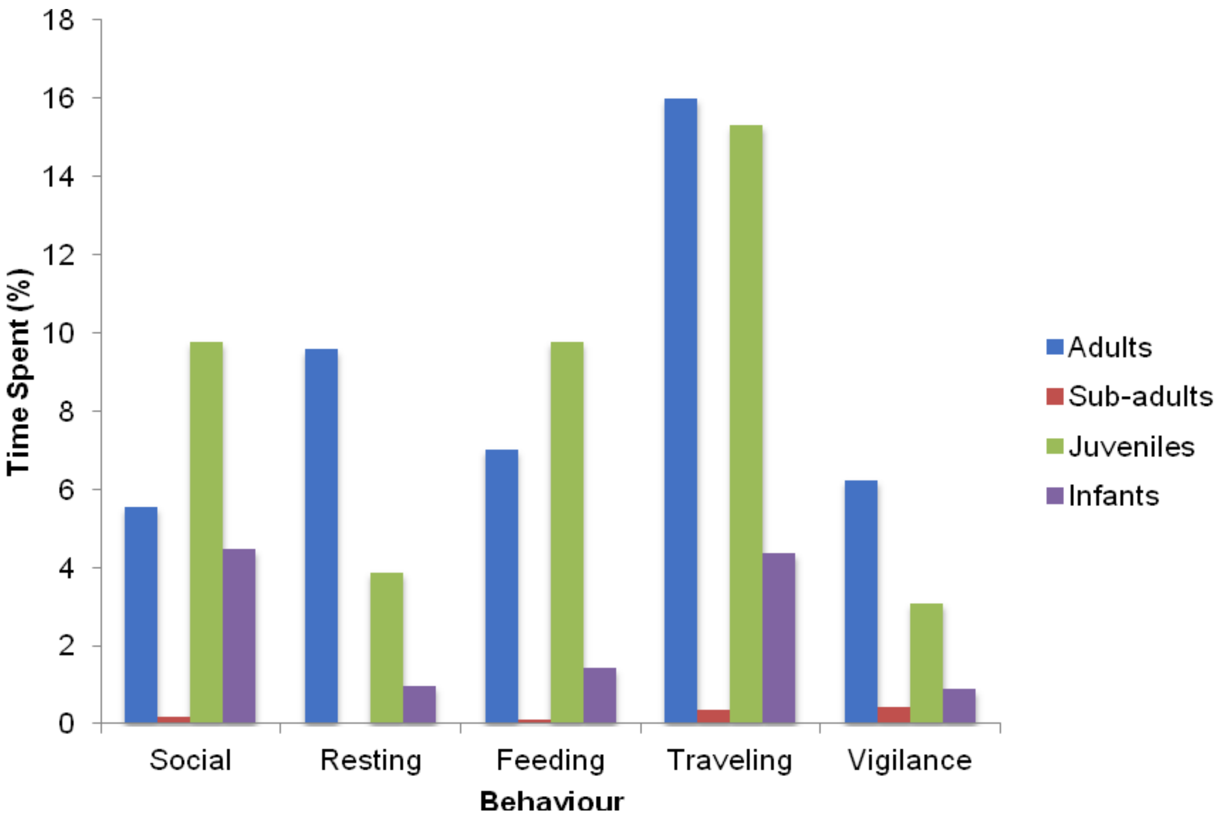

Figure 5.3b. Activity budget by age class.

5.4. Discussion and conclusions

While two baboon troops were observed, most data were collected from one troop that spent most of its time by the staff village. This human-dominated area provides a number of benefits for baboons, including access to rich human-foods (e.g. nsima, maize) and increased protection from predators. These allow primates to spend more time socialising and resting, rather than feeding/foraging and being vigilant (Altmann and Muruthi 1988).

Our data were collected when baboons were both in this human-modified environment and when the baboons were in natural woodland environment. As such, their activity budgets occupy a middle-ground between completely wild troops and troops adapted to living in human-modified areas (Saj et al. 1999). We would expect to see travelling and feeding as the predominant activities, but the high occurrence of resting and socialising, and the low occurrence of vigilance is indicative of the influence of this human-modified environment on these baboons. Through decreased stresses of predator detection and avoidance and increased nutrient intake from rich human-foods, baboons are able to spend more time resting and socialising as their need to forage intensely and remain vigilant lessens (Johnson et al. 2013). Going forward, it would be interesting to compare the troop that spends its time by the staff village to troops that are totally wild feeding in VMWR to investigate the influences the staff and the village have on the troop.

These results are also what you would expect to see in a breakdown by age classes. Juveniles and infants were observed to engage in social activities more than the other age classes, as you would expect young baboons to play and be groomed more. Adults were the predominant class observed being vigilant. This is to be expected as they are the most adapted to the environment and are the ones responsible for protecting the younger troop members.

Results such as the low occurrence of sub-adult behaviour observations can be attributed to the fact that it is often hard to determine the difference between an adult and a sub-adult. These troops are quite big and it is often easier to notice and observe the adults and the juveniles. One limitation of this study was the unavailability of a long training period for observers. It can be quite difficult to determine age and sex classes quickly during scan sampling, especially for juveniles and infants. Data were not examined by sex class as there were too few data recorded by sex. Another possible bias was the time of day observations were conducted. Sampling was designed to avoid the heat of the day, and for ease of finding the troops, which might affect activity budgets recorded.

These data provide us with a baseline to investigate further and provide a framework for developing future studies on these baboon troops. Through this pilot project, we were also able to evaluate and develop the methodology. The first group also conducted individual focal sampling. However, we quickly realised that this method was difficult and not suited to collecting enough data, so the method was not utilised in the second and third groups.

5.5. Outlook for future expedition work

More research and habituation of the baboon troops in Vwaza will be undertaken further to understand their behavioural ecology and ranging patterns. This information will be used for future genetic work on the possible hybridisation zone of yellow and kinda baboon species of the Vwaza area. These data will also contribute to a larger primate census of baboon and vervet troop distribution in the Reserve, which will help inform our CRA's Primate Release Programme.

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Appendix I: Bird list compiled by the expedition

This bird list was compiled during the expedition through opportunist recording and identification by interested citizen scientist birders. It list serves as baseline for future expeditions. Bird names follow the IOC naming convention. Species are arranged by family.

Common name	**Family**	***Scientific_name***
African Hoopoe	Upupidae	*Upupa africana*
African Sacred Ibis	Threskiornithidae	*Threskiornis aethiopicus*
Hadada Ibis	Threskiornithidae	*Bostrychia hagedash*
Glossy Ibis	Threskiornithidae	*Plegadis falcinellus*
African Spoonbill	Threskiornithidae	*Platalea alba*
Greater Blue-eared Starling	Sturnidae	*Lamprotornis chalybaeus*
Miombo Blue-eared Starling	Sturnidae	*Lamprotornis elisabeth*
Violet-backed Starling	Sturnidae	*Cinnyricinclus leucogaster*
Spotted Eagle-Owl	Strigidae	*Bubo africanus*
Pearl-spotted Owlet	Strigidae	*Glaucidium perlatum*
Hamerkop	Scopidae	*Scopus umbretta*
Common Sandpiper	Scolopacidae	*Actitis hypoleucos*
Wood Sandpiper	Scolopacidae	*Tringa glareola*
Common Greenshank	Scolopacidae	*Tringa nebularia*
Common Bulbul	Pycnonotidae	*Pycnonotus barbatus*
Dark-capped Bulbul	Pycnonotidae	*Pycnonotus tricolor*
Meyer's Parrot	Psittacidae	*Poicephalus meyeri*
Chinspot Batis	Platysteiridae	*Batis molitor*
Cardinal Woodpecker	Picidae	*Dendropicos fuscescens*
Green Wood Hoopoe	Phoeniculidae	*Phoeniculus purpureus*
Common Scimitarbill	Phoeniculidae	*Rhinopomastus cyanomelas*
Scaly Francolin	Phasianidae	*Pternistis squamatus*
Red-necked Spurfowl	Phasianidae	*Pternistis afer*
Great White Pelican	Pelecanidae	*Pelecanus onocrotalus*
Northern Grey-headed Sparrow	Passeridae	*Passer griseus*
Yellow-spotted Bush Sparrow	Passeridae	*Gymnoris pyrgita*
Denham's Bustard	Otididae	*Neotis denhami*
Helmeted Guineafowl	Numididae	*Numida meleagris*
Scarlet-chested Sunbird	Nectariniidae	*Chalcomitra senegalensis*
Shelley's Sunbird	Nectariniidae	*Cinnyris shelleyi*
Purple-crested Turaco	Musophagidae	*Tauraco porphyreolophus*
Grey Go-away-bird	Musophagidae	*Corythaixoides concolor*
White-browed Scrub Robin	Muscicapidae	*Cercotrichas leucophrys*
Red-capped Robin-Chat	Muscicapidae	*Cossypha natalensis*
Collared Palm Thrush	Muscicapidae	*Cichladusa arquata*
Miombo Rock Thrush	Muscicapidae	*Monticola angolensis*
Arnot's Chat	Muscicapidae	*Myrmecocichla arnotti*

Common name	Family	*Scientific_name*
African Pied Wagtail	Motacillidae	*Motacilla aguimp*
African Pipit	Motacillidae	*Anthus cinnamomeus*
African Paradise Flycatcher	Monarchidae	*Terpsiphone viridis*
Little Bee-eater	Meropidae	*Merops pusillus*
European Bee-eater	Meropidae	*Merops apiaster*
Brown-crowned Tchagra	Malaconotidae	*Tchagra australis*
Black-backed Puffback	Malaconotidae	*Dryoscopus cubla*
Braun's Bushshrike	Malaconotidae	*Laniarius brauni*
Long-billed Crombec	Macrosphenidae	*Sylvietta rufescens*
Black-collared Barbet	Lybiidae	*Lybius torquatus*
Arrow-marked Babbler	Leiothrichidae	*Turdoides jardineii*
Hartlaub's Babbler	Leiothrichidae	*Turdoides hartlaubii*
Greater Honeyguide	Indicatoridae	*Indicator indicator*
Barn Swallow	Hirundinidae	*Hirundo rustica*
Wire-tailed Swallow	Hirundinidae	*Hirundo smithii*
Collared Pratincole	Glareolidae	*Glareola pratincola*
Yellow-fronted Canary	Fringillidae	*Crithagra mozambica*
Cape Canary	Fringillidae	*Serinus canicollis*
Common Kestrel	Falconidae	*Falco tinnunculus*
Sooty Falcon	Falconidae	*Falco concolor*
Lanner Falcon	Falconidae	*Falco biarmicus*
Blue Waxbill	Estrildidae	*Uraeginthus angolensis*
Bronze Mannikin	Estrildidae	*Lonchura cucullata*
Fork-tailed Drongo	Dicruridae	*Dicrurus adsimilis*
Pied Crow	Corvidae	*Corvus albus*
Racket-tailed Roller	Coraciidae	*Coracias spatulatus*
Lilac-breasted Roller	Coraciidae	*Coracias caudatus*
Broad-billed Roller	Coraciidae	*Eurystomus glaucurus*
Ring-necked Dove	Columbidae	*Streptopelia capicola*
Laughing Dove	Columbidae	*Spilopelia senegalensis*
Emerald-spotted Wood Dove	Columbidae	*Turtur chalcospilos*
Blue-spotted Wood Dove	Columbidae	*Turtur afer*
Tawny-flanked Prinia	Cisticolidae	*Prinia subflava*
Yellow-billed Stork	Ciconiidae	*Mycteria ibis*
African Openbill	Ciconiidae	*Anastomus lamelligerus*
Black Stork	Ciconiidae	*Ciconia nigra*
White Stork	Ciconiidae	*Ciconia ciconia*
Blacksmith Lapwing	Charadriidae	*Vanellus armatus*
Senegal Lapwing	Charadriidae	*Vanellus lugubris*
Black-winged Lapwing	Charadriidae	*Vanellus melanopterus*
Common Ringed Plover	Charadriidae	*Charadrius hiaticula*
Kittlitz's Plover	Charadriidae	*Charadrius pecuarius*
Three-banded Plover	Charadriidae	*Charadrius tricollaris*

Common name	Family	*Scientific_name*
Pennant-winged Nightjar	Caprimulgidae	*Caprimulgus vexillarius*
Water Thick-knee	Burhinidae	*Burhinus vermiculatus*
Yellow-billed Oxpecker	Buphagidae	*Buphagus africanus*
Southern Ground Hornbill	Bucorvidae	*Bucorvus leadbeateri*
African Grey Hornbill	Bucerotidae	*Lophoceros nasutus*
Trumpeter Hornbill	Bucerotidae	*Bycanistes bucinator*
Western Cattle Egret	Ardeidae	*Bubulcus ibis*
Grey Heron	Ardeidae	*Ardea cinerea*
African Palm Swift	Apodidae	*Cypsiurus parvus*
White-faced Whistling Duck	Anatidae	*Dendrocygna viduata*
Spur-winged Goose	Anatidae	*Plectropterus gambensis*
Knob-billed Duck	Anatidae	*Sarkidiornis melanotos*
Egyptian Goose	Anatidae	*Alopochen aegyptiaca*
Yellow-billed Duck	Anatidae	*Anas undulata*
Red-billed Teal	Anatidae	*Anas erythrorhyncha*
Chocolate-backed Kingfisher	Alcedinidae	*Halcyon badia*
Striped Kingfisher	Alcedinidae	*Halcyon chelicuti*
African Harrier-Hawk	Accipitridae	*Polyboroides typus*
Brown Snake Eagle	Accipitridae	*Circaetus cinereus*
Bateleur	Accipitridae	*Terathopius ecaudatus*
Crowned Eagle	Accipitridae	*Stephanoaetus coronatus*
Martial Eagle	Accipitridae	*Polemaetus bellicosus*
Lesser Spotted Eagle	Accipitridae	*Clanga pomarina*
African Hawk-Eagle	Accipitridae	*Aquila spilogaster*
Black Kite	Accipitridae	*Milvus migrans*
Yellow-billed Kite	Accipitridae	*Milvus aegyptius*
Common Buzzard	Accipitridae	*Buteo buteo*

Appendix II: Primate ethogram

	CODE	BEHAVIOUR DESCRIPTION	Cat.
1	G-	Grooming – Taking care of the fur of another individual, by pushing aside its fur and inspecting for foreign objects (dirt/insects). Also includes taking care of another animals' teeth or skin *(record other individual(s)+ record as duration behaviour for continuous)*	Social
2	G+	Getting groomed – The focal animal is groomed (as described above) by another individual *(record other individual(s)+ record as duration behaviour for continuous)*	
3	PR-	Presenting – Presenting itself (either the body or hind quarters) to another primate. Inviting them for social contact, such as grooming or mounting *(record other individual(s))*	
4	PR+	Being presented – Being presented to by another individual *(record other individual(s))*	
5	C	Contact - Individuals touching in a non-aggressive way, such as nosing or cuddling, but not grooming or playing *(record other individual(s))*	
6	CL	Clinging – Clinging to another individual while being carried, specifically for infants	
7	N	Nursing young – Mother breast feeding an infant	
8	SU	Suckling – Feeding from the mother, specifically for infants/juveniles	
9	PL	Playing – All types of interactions between two or more animals using the relaxed open mouth play face (mouth is half or wide open, teeth are covered by lips or at least the upper incisors are showing) Interactions such as touch, pull, push, hit, chase, bite and hug *(record other individual(s)+ record as duration behaviour for continuous))*	
10	MA	Mating – A male mounting a female, or a female is mounted by a male,with actual penetration. Often accompanied by a copulation call *(record other individual)*	
11	MO	Mounting – The focal animal mounts another individual or is mounted by another individual. Either male/female without penetration, male/male or female/female *(record other individual)*	
12	FE	Feeding – The actual act of eating, food is touching the lips or is in the mouth in combination with chewing *(list food type)*	Feed
13	FO	Foraging – Looking for food to eat. Includes turning rocks or other objects upside down and pushing away objects on the floor/sand.	
14	L	Locomotion - Any movement to get from one place to another, such as walking running and jumping. In any direction possible direction on the ground, in the trees or on buildings.	Other
15	R	Resting – Sitting or laying down without any activity, and low levels of awareness of the environment. The eyes may be open or closed, but generally the head is down.	
16	V	Vigilance - Any level of observation or awareness of their environment. This includes sitting in a tree or on the ground, with head up eyes open looking. Not only for extreme vigilance	
17	PA	Predator Avoidance – Any form of predator avoidance behaviour, this includes alarm calls or responding to alarms calls and hiding into the trees *(record details on additional data sheet)*	
18	O	Other – Any other behaviour not defined in the descriptions of the behaviours mentioned *(describe types of 'other' behaviour on data sheet)*	
19	OS	Out of Sight – The focal animal is partly or completely invisible, i.e. when behaviour could be missed because of lack of sight.	
20	A+	Aggression - Physical aggression with a (potentially) damaging action, including biting, slapping, grabbing and hair pulling. Usually occurs with mouth-open and teeth exposed *(record other individual(s)+ record as point behaviour + outcome conflict for continuous)*	Dominance
21	A-	Receive aggression - Receiving physical aggression *(record other individual(s)+ record as point behaviour + outcome conflict for continuous)*	
22	TH+	Threat: Non-physical aggression towards another individual, such as chasing with and open-mouth facial expression and teeth exposed. Often accompanied by vocalisations. Also includes threatening other individuals (with raised eyebrows, mouth is open like an 'o', theeth are covered), head-bobbing (short movements with head and/or shoulders) towards other animals whilst staring, lunging, and display behaviours (shaking trees, bushes or other objects) *(record other individual(s)+ record as point behaviour + outcome conflict for continuous)*	
23	TH-	Receive threat – Receiving threat as described above *(record other individual(s) (record other individual(s)+ record as point behaviour + outcome conflict for continuous)*	
24	MP+	Making place - Another animal moves away when the focal animal approaches (closer than 2m) or after being threatened by the focal animal *(record other individual(s)+ record as point*	

25	**MP-**	Making place - Focal animal moves away when other animal approaches (closer than 2m) or after being threatened by the other animal *(record other individual(s)+ record as point behaviour + outcome conflict for continuous)*	
26	**SC**	Scratching - A single scratch or repetitive movement of scratching the body with hand or feet *(record as point behaviour for continuous)*	**Stress**
27	**SG**	Self-Grooming - The focal animal grooms itself by pushing aside its fur and inspecting for foreign objects (dirt/insects). Includes taking care of its own skin, teeth and fur. *(record as duration behaviour for continuous)*	
28	**YA**	Yawning - The focal animal yawns, opening mouth and showing teeth *(record as point behaviour for continuous)*	
29	**SM**	Self mutilation – The focal animal exposes a (potentially) damaging action to its own body. This includes hair pulling, self-hitting or biting *(record as duration behaviour for continuous)*	
30	**PC**	Pacing and other abnormal behaviour- Moving in a stereotyped pattern, unrelated to stimuli of the immediate environment. Including repetitive walking up and down (score when the animal walks back and forth at least twice), and other motor stereotypies *(record as duration behaviour for continuous)*	
31	**PH**	Positive social (affiliative) behaviour towards humans. This includes coming to the fence to sit/stand next to the observer/other people around, lip-smacking towards people, or trying to reach out for any human contact *(record as point behaviour for continuous)*	**Human**
31	**AH**	Agonistic behaviour towards humans. This includes all threatening behaviours described above *(record as point behaviour for continuous)*	

Food Types and Codes		P – Pods	FR – Fruit	TB – Tree Bark
BU - Buds	E – Eggs	G – Grass	I – Insects	FL - Flowers
YL – Young leaves	ML – Mature leaves	M – Mushrooms	URF – Unripe Fruit	O - Other
RE - Reptile	RO – Roots	S – Seeds	PF - Provisioned Food	UK - Unknown
MK – Milk (infant suckling only)		GUM– Gum		

Position in Canopy	Use a combination of letter and number codes to indicate position and height from ground
TC – Top of Canopy	
MC – Middle of Canopy	1 – less than 5m from ground
LC – Lower Canopy	2 – 5-10 meters from ground
G – on Ground	3 – 10-20 meters from ground
MM – on Manmade structure	4 – more than 20 meters from ground
NS – on elevated Natural Structure, such as tree trunks, and termite or ant hills	

Weather	SU – Sunny	C – Cloudy/Overcast (not rain)
W – Windy	LR – Light Rain	HR – Heavy Rain

Temperature	H - Hot
W – Warm	C - Cold

Appendix III: Expedition diary, reports and supporting material

A multimedia expedition diary is available on https://blog.biosphere-expeditions.org/category/expedition-blogs/malawi-2018/.

All expedition reports, including this and previous expedition reports, are available on www.biosphere-expeditions.org/reports.

More pictures, videos, media coverage of the expedition are available via www.biosphere-expeditions.org/malawi.