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EXPEDITION REPORT

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ABSTRACT

The Lilongwe Wildlife Trust (LWT) 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 for a second year between 22 September and 18 October 2019 in two two-week long groups comprising twelve citizen scientists per group from Australia, Canada, Germany, the UK and the USA.

Large mammal surveys

Camera trapping surveys were successful and recorded a high species diversity in VMWR (24 species) in 1,670 images. One large carnivore (leopard) and seven mesocarnivores was detected, proving again the success of camera traps at providing data on elusive and nocturnal species. Transect surveys, covering nearly 200 km, recorded 11 different species and a 43% encounter rate. Species of note were roan antelope, which are rarely sighted, and puku, as they are classified by the IUCN Red List as Near Threatened. Hippo surveys of the populations in Lake Kazuni along the southern border of VMWR yielded an average of 125 hippos, which is lower than the previous year. Survey results confirm a high species diversity in VMWR.

Elephants were observed mainly along the shores of Lake Kazuni, with data collected on herd demographics and individual identification. These observations produced numerous second-sighting records and 10 new individual identifications, bringing the total elephant database to more than 200 individuals, which is estimated to be two-thirds of the total VMWR elephant population.

Bat, insect and vegetation monitoring

Bat surveys resulted in 51 bats caught representing 11 species. Two new bat species, *Myotis bocagii* and *Laephotis botswanae* were recorded for VMWR. *Kerivoula lanosa* was also caught for the first time in Malawi for African Bat Conservation. Nine standardised bat surveys were conducted at 7 different sites comprising 6 surveys in floodplain and 3 in woodland. The highest relative bat species richness was recorded in woodland. Of the new bat species records, *Laephotis botswanae* is of particular interest as little is known about its distribution and the few records indicate patchy distribution. This record therefore provides valuable data for the conservation of this species. Over 9,000 insects were captured in 13 different orders. Four new orders were captured not previously recorded in 2018, although in very low numbers, suggesting they likely occur at low densities in VMWR. Although the 2018 and 2019 expedition results are based on relatively low sample sizes, they add to growing records of biodiversity surveys for bats and insects in VMWR and show high diversity in abundance and overall presence of orders. In addition, vegetation surveys completed in conjunction with bat and insect surveys provide baseline ecological data and serve as indicators for any changes to the local environment. Climate change and other anthropogenic impacts in VMWR will first be noticed in changes to the vegetation and insects and bats, which feed on them. As such, the continued monitoring of these species is of upmost importance for the conservation management of VMWR.

Primate behaviour

In March 2019, LWT released a troop of 13 vervet monkeys into Vwaza Marsh Wildlife Reserve. After initial predations and emigrations, the troop observed during this expedition was 6 individuals. Data collected during the expedition contributed to the year-long post-release monitoring and data collection of the release troop. Activity budgets were determined and showed that the troop mimics wild conspecifics in terms of their activity budgets, with the majority of their time spent being Vigilant, followed by Feeding, Travelling, and spending little time Resting. A social network web was created; reflecting observations that the alpha male was the most central figure in the troop and the beta male was the least, often not seen by observers. Both analyses show that the troop is doing well with their new life in the wild.

CHIYAMBI

Ma bungwe a Lilongwe Wildlife Trust ndi Conservation Research Africa ndi ma bungwe oyamba kupanga kafukufuku wokhazikika ku Vwaza Marsh Wildlife Reserve (VMWR). Kafukufuku ameneyu amawona za nyama zosiyanasiyana monga; nyama zomwe zimayamwitsa, njobvu, gulu la anyani, mileme ndi tizilombo ting'ono ting'ono towuluka, ndi cholinga chofuna kudziwa ndi kulondoloza kusinthasintha kwa chilengedwe mu nkhalango ya Vwaza. Kusintha kwa nyengo kukupangitsa kuti malo omwe nyama zimakhala azikumana ndi mavuto, komanso zachilengwe zosiyanasiyana zikukumana ndi mavuto chifukwa cha zichitochito za anthu, monga; kupha nyama za kutchire komanso kudula mitengo mopanda chilolezo. Gulu la akatswiri aza sayansi lotchedwa Biosphere Expeditions linathandizira ntchito ya kafukufukuyi koyamba mu chaka cha 2018. Anthu omwe amagwira ntchitoyi anayigwila kwa masabata anayi kuchokela pa 22 September m'paka pa 18 october mu chaka cha 2019, ndipo anthuwa amakhala m'magulu, ndipo gulu lililose limakhala ndi akatswiri a zasayansi khumi ndi awiri ochokera kumaiko monga; Austria, Canada, China, France, Germany, Malaysia, Switzerland, UK ndi USA.

Kawuniwuni wa Nyama Zikuluzikulu Zomwe Zimayamwitsa

Chiwelengero cha nyama zikuluzikulu zomwe zimayamwitsa chikunka chichepa pa dziko lonse lapansi. Kuchepa kwa chiwelengero cha nyama zoyamwitsa kukhoza kudzetsa mavuto osiyanasiyana ku ubale wa pakati pa nyama ndi zachilengedwe, nyama zinzake, zomera, malo okhala nyama, komaso pa chikhalidwe cha anthu ndi ntchito za chuma. Kalondolondo wa chiwelengero cha nyama zazikulu (zomwe zimayamwitsa) mu mnkhalango ndi kofunikira pa kasamalidwe ka chilengedwe, komaso zimathandiza anthu oyang'anira nkhalangoyo kuti adziwe umoyo, chiwelengero cha nyama, ndikupeza zinthu zomwe zasintha komaso zomwe zimadzetsa kusinthako. Kawuniwuni ogwiritsa ntchito zinthu zojambulira komanso kugawa nkhalango m'magawo magawo zimathandizira kupeza chiwelengerocho. Kafukufuku pogwiritsa ntchito zida zomwe zimajambura ndi zomwe zinathandiza kupeza za chilengedwe zosiyana siyana zomwe zimapezeka mu nkhalango ya Vwaza, ndipo izi zimakwana makumi awiri ndi zinayi (24) kuchokera muzithuzi 1,670 zomwe zinajambulidwa. Njira yotchera zinthu zojambulira inathandizila kupeza nyama zomwe zimayenda usiku komaso nyama zomwe zimavuta kupeza. Inathandizaso kupeza nyama zikuluzikulu ziwiri zomwe zimadya nyama zimnzake zomwe zili mkango ndi kambuku ndi zina zokwaana zisanu ndi ziwiri. Njira yogawa nkhalango m'magawo inagwiritsidwa ntchito pamtunda wokwana pafupifupi 200km, inathandiza kupeza mitundu khumi ndi imodzi ya zachilengedwe zosiyanasiyana mosayembekezeka ndi 43%. Mitundu ya nyama ya zomwe zinaoneka kudzera munjira imeneyi ndi monga mpherembe ndi puku zomwe zili zosowa kuzipeza komaso zili m'gulu la nyama zomwe zili pa chiopsezo chakutha, kuchokera mu ma report a bungwe la (IUCN). Kawuniwuni wa chiwelengero cha Mvuu mu Nyanja ya Kazuni, m'mbali mwa malire a kummwera kwa VMWR anawonetsa kuti nyanjayi ili ndi Mvuu zokwana pafupifupi 125 zomwe zili zochepa kusiyana ndi chaka cha mmbuyo. Zotsatira zonse za kafukufukuyu zinawonetsa kuti ku Vwaza kuli za chilengwe zosiyanasiyana komaso zochuluka. Chiwelengero cha njobvu ku Malawi chili pa chiopsezo kwambiri. Kuchokela mu zaka za 1970, Njobvu za m'dziko la Malawi kuphatikizapo za ku Vwaza Marsh zakhala zikuphedwa chifukwa chofuna nyanga zake. Chiwelengero cha Njobvu zomwe zili mu nkhalango ya Vwaza ndi chachikula koposa mu dera la kumpotoli ndipo njobvuzi sizozungulilidwa ndi mpanda pofuna kupereka mwayi kuti zizitha kuchoka dera limodzi ndi kupita dera loyandikana nalo mmalo otetezedwa. Ndipo kafukufuku wa Njobvuzi wachitika wochepa. Chiwelengero cha njobvu chinawerengedwa kuchokera ku njobvu zomwe zimapezeka m'mbali mwa Nyanja ya Kazuni ndipo zimapezeka m'magulu komaso zina zimapezeka pazokha. Kafukufukuyi anatipatsa zotsatira zabwino komanso tinakwanitsa kuwona Njobvu zina khumi zoyenda zokha, zomwe zinapangitsa kuti m'ndandanda wa chiwelengero chonse cha njobvu ukhale opitilira 200, ndipo izi zikuyimila pafupifupi 2/3 ya chiwelengero cha Njobvu zopezeka mu nkhalango ya Vwaza Marsh Wildlife Reserve.

Zotsatira za kafukufuku ameneyi zimathandizira mu m'ndandanda omwe ulipo wa nyama zikuluzikulu zomwe zimayamwitsa m'nkhalangoyi kumbali ya kuchuluka kwa chiwelengero chake, umoyo ndi mmene zinthu zilili mu nkhalango ya Vwaza Marsh, kuti zithandize ntchito ya kayendetsedwe kabwino ka nkhalangoyi.

Kalondolondo wa Mileme, Tizilombo ndi Zomera

Mileme yokwana 51 inagwidwa popanga kawuniwuni yomwe inali mitundu khumi ndi umodzi yosiyana. Mitundu iwiri yamilemeyi yotchedwa *Myotis bocagii* ndi *Laephotis botswanae* inapezeka ku Vwaza Marsh Wildlife Reserve. Ndipo kwa nthawi yoyamba ku Malawi, mtundu wa mileme yotchedwa *Kerivoula lanosa* inapezeka ndi bungwe la African Bat Conservation. Kawuniwuni wina anachitika mofanana kokwanira kasanu ndi kanayi (9) m'malo asanu ndi awiri (7) osiyana, ndipo kawuniwuni okwanira kasanu ndi kamodzi (6) anachitika mmalo otsika, pomwe kawuniwuni mutatu anachitika ku nkhalango. Zotsatira zinaonetsa kuti m'tundu wa mileme yofanana inapezeka yambiri ku nkhalango. Zolembedwa za mtundu wa mileme ya chilendo yotchedwa *Laephotis botswanae* ndi amene akupereka chidwi chifukwa kufalikira kwawo ndi kochepa ndipo zolembedwa zikuonetsa mbiri pang'ono chabe. Zolembedwazi zikupereka ndondomeko yofunikira kwambiri za mmene mtundu ya milemeyi ingasamalidwe. Tizilombo topitilira 9,000 tinagwidwa mu ma gulu khumi ndi atatu (13) osiyana. Magulu atsopano okwana anayi anagwidwa, ndipo maguluwa sanalembedwe mu chaka cha 2018, ngakhale zikusonyeza kuti akupezeka ochepa kwambiri ku Vwaza Marsh Wildlife Reserve. Ngakhale zotsatira za mu chaka cha 2018 ndi zomwe zinapezeka mu 2019 zikuchokera mu kawuniuni yemwe anachika mu ka dera kochepa chabe, zimaonjezera kuchuluka kwa kawuniwuni wa chilengedwe cha mileme ndi tilombo topezeka ku Vwaza ndipo zimaonetsa kuchuluka kwa magulu awo. Kuonjezera apo, kawuniwuni wa zomera anamalizika pophatikizana ndi kawuniwuni wa mileme ndi tizilombo zomwe zimapereka ndondomeko ya chilengedwe komaso ngati zidziwitso za kusintha kwa chilengedwe mu dera. Kusintha kwa nyengo ndi mavuto ena achilengedwe odza Kamba kazichito- chito za munthu angadziwike mofulumira makamaka ku zomera, mileme ndi tizilombo tomwe timadya zomerazi. Choncho kalondolondo wa mitundi ya zolengedwazi ndiwofunikira kwambiri pothandiza kayendetsedwe ka Vwaza Marsh Wildlife Reserve.

Khalidwe la Magulu a Nyani

Mu dziko la Malawi, chiopsezo chomwe chilipo m'malo omwe nyama zimakhala, zapangitsa kuti mchitidwe wopha nyama za kutchire pofuna kudya ndi kuzisunga kunyumba ngati ziweto kuti ukule. Zimenezi ndi mavuto omwe magulu anyani akukumana nawo makamaka a mtundu wa apusi. Izi zapangitsa kuti Lilongwe Wildlife Centre (LWC), malo okhawo m'dziko la Malawi omwe ntchtio yawo ndikumalanditsa nyama zosiyana siyana ndi kusunga zachilengedwe, kupulumutsa magulu anyani ochuluka omwe ali amasiye komaso ovulala. Cholinga chokhazikitsa malowa ndi kusunga nyama zimenezi ndi cholinga choti ngati kuli kotheka m'tsogolomo adzathe kuzibwezeretsa ku nkhalango komwe zikuyenela kukhala. Mu chaka cha 2012 bungwe la Lilongwe Wildlife Trust linakhazikitsa ndondomeko ya mmene nyama zomwe zasungidwa komanso ndizoyenera kubwezeretsedwa ku nkhalango ingamayendere. M'mwezi wa March mu chaka cha 2019, bungwe la LWT linapititsa gulu la apusi okwana 13 ku nkhalango ya Vwaza Marsh. Zotsatira zomwe zinapezeka mu nthawi ya kafukufukuyi zinathandizira mu m'ndandanda wa pa chaka oyang'anira komanso m'ndandanda obwezeretsa magulu a nyani ku nkhalango komwe akuyenera kukhala. Tsiku ndi tsiku, nyani m'modzi amakhala a kumutsatira kwa mphindi makumi awiri mu nthawi yomwe kumachitika kalondolondo wa nyamazi, izi zinawoneka pogwiritsa ntchito njira yowelengera ya pompopompo komaso yopitilira. Ndondomeko ya ndalama zofunikira pogwiritsa tchitioyi inakozedwa ndipo anawonetsa ndondomeko ya ndalama za gulu lili lonse la anyani potengeranso makhalidwe awo a tsiku ndi tsiku. Tsamba la mchezo pa makina a internet linakozedwa ndipo likuwonetsera zinthu zeni zeni zomwe zinachitika. Njira zonsezi zinasonyeza kut magulu a nyaniwa akukhala mosangalala kunkhalangoko. Zotsatirazi zimathandizira kuti LWT likhale ndi ndondomeko yokhazikika komanso yabwino ya ntchito yobwezeretsa nyama ku tchire.

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1. Expedition Review

Matthias Hammer (editor)
Biosphere Expeditions

1.1. Background

Background information, location conditions and the research area are as per Harwood et al. (2019). The citizen science expedition in Vwaza Marsh Wildlife Reserve (VMWR) in northern Malawi focused on wildlife monitoring of (1) large mammals, through driving and walking line transect surveys and camera trap arrays, (2) the elephant population, through herd observations and identification of individuals, and (3) bat, insect and vegetation monitoring, conducted through standardised bat surveys and light trapping techniques. Citizen scientists also assisted in (4) data collection on primate behaviour as part of an ongoing primate release programme. All data contribute to a long-term dataset and monitoring programme in VMWR and the larger Malawi-Zambia Transfrontier Conservation Area and are shared with local managing groups to empower and influence effective conservation strategies.

1.2. Dates & team

The project ran over a period of one month divided into two 13-day slots, each composed of a team of national and international citizen scientists, professional scientists and an expedition leader. Group dates were as shown in the team list below. Dates were chosen to coincide with the dry season in Malawi and its corresponding ease of access to the reserve and wildlife sightings.

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):

22 September – 4 October 2019: Peter Anderson-Barr (Australia), Kristian Baensch (Germany), Kathleen Byrnes (Australia), Helen Cory (Australia), Steven Crowther (UK), Edward Durell (Germany), Marion Fink-Schneider (Germany), Gary Hogben (UK), Sandra Hogben (UK), Rodney Logan (USA), Winona Selby (Germany).

6 – 18 October 2019: Neil Bowman (UK), Neil Goodall (UK), Matthias Herold (Germany), Charlotte Hull (UK), Thomas Klaus (Germany), Alex Loucks (USA), Carole Mahoney (UK), Brianne Miers (USA), Lora Pope* (Canada), Linda Snodden (UK).

*Blogger producing a feature and an opinion piece

On site field scientists were:

Amanda Harwood – Research Manager, Lilongwe Wildlife Trust
Pilirani Sankhani – Senior Research Assistant, Lilongwe Wildlife Trust (group 2 only)
Leigh-Anne Bullough – Research Assistant, Lilongwe Wildlife Trust
Marta Miguel – Research Assistant, Lilongwe Wildlife Trust (group 1 only)
Karen Shevlin – Lead Research Scientist, Conservation Research Africa
Dominque Greeff – Research Assistant, African Bat Conservation
Brennan PetersonWood – Programmes Manager, Conservation Research Africa (group 2 only)

Ida Vincent, the expedition leader, 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), graduating 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 murder mystery novel.

A medical umbrella, safety and evacuation procedures were in place. There was a bout of sleeping sickness during the second group of the expedition with staff and citizen scientists affected, but now recovered. Persons affected were evacuated in line with safety procedures and the second group was cut short by two days because of the outbreak. An investigation into the causes of the outbreak, as well as research into the tsetse fly and disease prevalence in VMWR, and a review of risk assessment and safety procedures, are ongoing.

1.3. 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.

Figure 1.3a. 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 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. According to WWF-SARPO (2002) there are 26 areas of special biodiversity importance within the country.

The country 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 Northern Region of the country. It covers an area of 1,000 km^2 of mostly flat terrain located in the Central African Plateau on the watershed between Lake Malawi and the eastern lip of the Luangwa rift to the southeast of the Nyika Plateau. The western half of VMWR 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 a part of the Malawi-Zambia Transfrontier Conservation Area (TFCA), encompassing 30,621 km^2. This is a transboundary link to the Luangwa-Zambezi Valley, which connects protected and managed areas in Zambia with VMWR, Nyika and Kasungu National Parks in Malawi (Figure 1.3b).

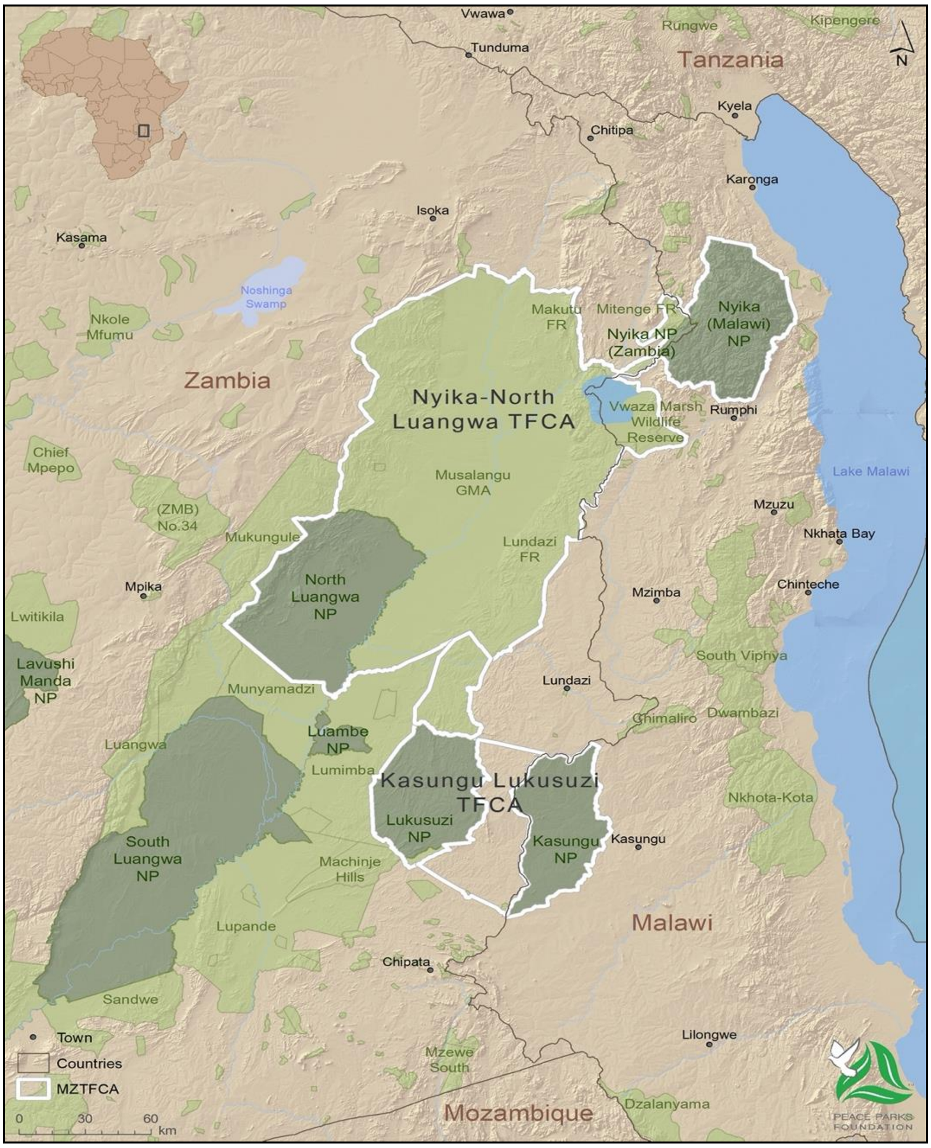

Figure 1.3b Map of the Malawi-Zambia Transfrontier Conservation Area linking wildlife important protected areas and corridors (from Peace Parks 2017).

1.4. Partners

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

LWT was established in 2009 and has grown into one of Malawi's leading conservation NGOs. LWT's mission is to save wildlife, campaign for conservation justice and inspire people to value and protect nature in Malawi. Working in collaboration with local and international partners, the trust responds to urgent conservation challenges and drives long-term social and institutional change. It runs several projects across five programme areas: Wildlife rescue and rehabilitation, wildlife research, environmental education, community conservation and wildlife advocacy and enforcement. LWT has 90 staff working across three offices and several field sites across the country. The government of Malawi has appointed LWT to administer a number of national wildlife management, justice, and advocacy initiatives. They are also a member of the International Union for Conservation of Nature, the Malawi representative for the Species Survival Network, and the Secretariat for the Malawi Parliamentary Conservation Caucus.

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 and several research institutions worldwide.

1.5. 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 DNPW for supporting our programme and assisting with local expertise, logistics and of course assistance from the 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 Amanda Harwood, Karen Shevlin, Pilirani Sankani and Jonny Vaughan for their hard work in making the expedition a reality. We extend our appreciation to our expedition cooks Emmanuel and Fellister Nkhata.

1.6. 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.

1.7. Expedition budget

Each citizen scientist paid a contribution of €2,480 per person per twelve-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	48,245
Expenditure	
Staff Includes local and Biosphere Expeditions staff salaries and travel expenses	9,509
Research Includes equipment and other research expenses	2,401
Transport Includes hire cars, fuel, taxis and other in-country transport	2,450
Expedition base Includes accommodation, food, services & conservancy fees	13,748
Miscellaneous Includes miscellaneous fees & sundries	561
Team recruitment Malawi As estimated % of annual PR costs for Biosphere Expeditions	4,981
Income – Expenditure	**14,595**
Total percentage spent directly on project	**70%**

2. Large Mammal Monitoring

Amanda Harwood
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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 elephants (*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 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 important 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 together 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 decisions.

This research project monitors large mammal populations using camera trapping and transect surveys. These data provide a crucial look at wildlife in VMWR, a critical part of the Malawi-Zambia Transfrontier Conservation Area.

2.2. Methods

2.2.1. Camera trapping surveys

Photographic surveys were conducted with 23 digital camera traps located at stations spaced an average of 1.76 km apart, with one camera per station, along roads throughout VMWR (Figure 2.2.1a). One camera was placed opportunistically aiming at a possible den site during group 1. Forty-six separate sites were covered during the expedition. Group 1 cameras surveyed the southern part of VMWR, while group 2's covered the northern sections. Cameras were deployed for a total of 15 nights for the expedition (group 1: 25 September – 3 October; group 2: 9 – 15 October), with cameras being checked, SD cards changed and data collected twice during group 1 (once after three days and then on the eighth day after setting) (Figure 2.2.1b). Cameras were checked once in group 2 after seven nights. 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 2.2.1c). Only images with animals were used in analysis. Eleven images captured unidentifiable animals, which were discarded for analysis.

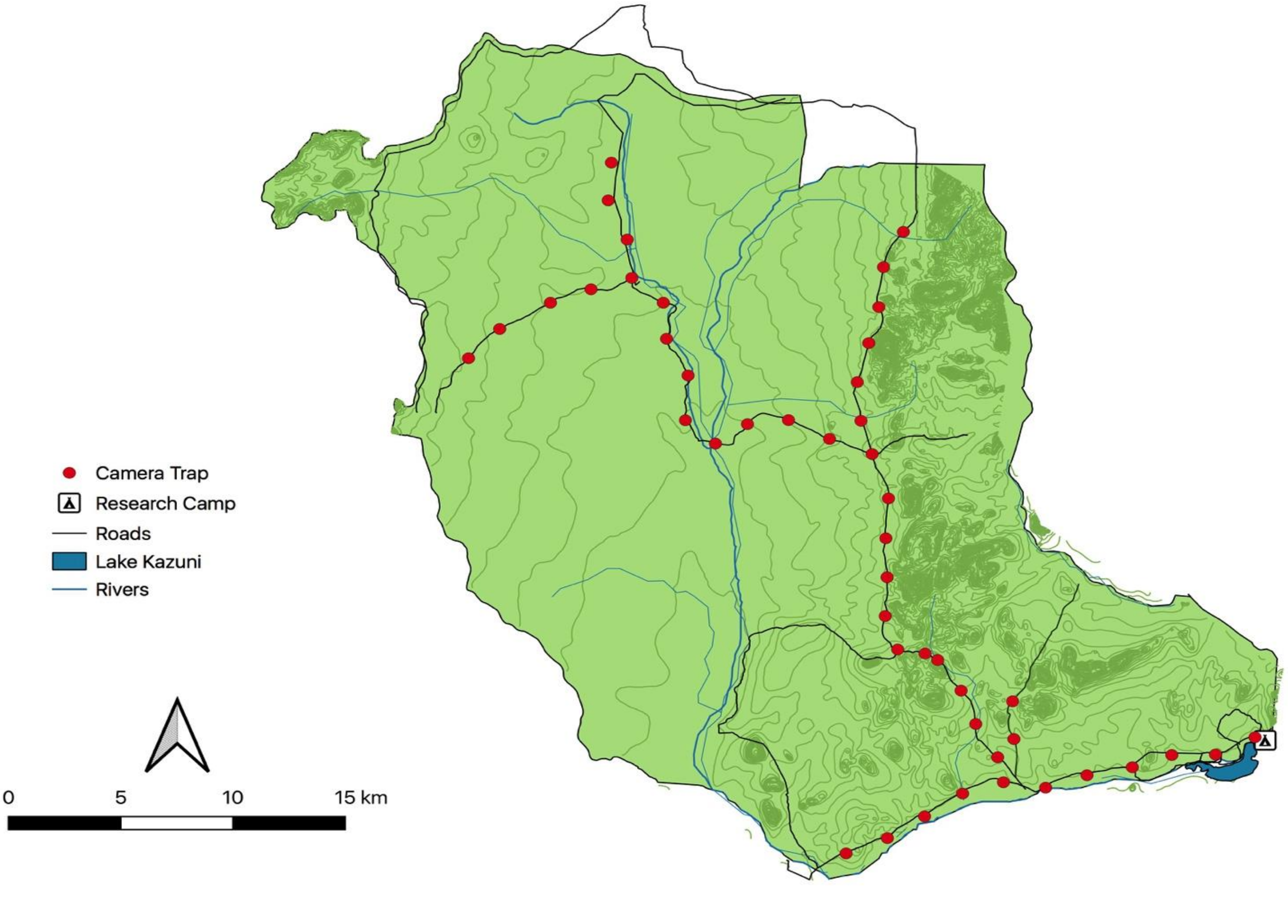


Figure 2.2.1a. Camera trap placement in Vwaza Marsh Wildlife Reserve 2019.

The number of species sighted per station and group are summarised in section 2.3. We calculated the number of capture events (defined as a series of pictures in a time sequence separated by less than five minutes) and the overall capture rate across the expedition (total events/number of camera trap survey nights x 100) for each species recorded. The inter-camera distance was determined using a distance matrix in QGIS. The total sampling area was calculated by using a 2 km spacing grid, creating the same width buffer zone around the camera traps and calculating the area of the polygon in QGIS.

Figure 2.2.1b. Setting a camera trap.

Figure 2.2.1c. Citizen scientists identifying camera trap photos.

2.2.2. Large mammal transect surveys

All roads in VMWR were surveyed for the presence of large mammal species via driven mammal transects (DMTs) (length = 5 km, with a 2 km spacing between transects) (Figure 2.2.2a). Three new driving transects were created during the expedition, on a newly constructed road by DNPW and only accessible in the dry season, bringing the total number of driving transects to 20. Transects were driven at dawn travelling at a maximum of 20-25 km per hour. Walked mammal transects (WMTs) (length = 5 km, n = 10 routes) 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 VMWR (Figure 2.2.2a). 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 coordinates, date, time, habitat, species, number of individuals, group demographics, distance (m) from observer to animal using a range finder, angle of the animal from the transect, and compass angle. Groups of the same species were determined to be different groups if there was a distance of 25 m between them.

We calculated the encounter rate (number of sightings/total km surveyed) and the number of individuals sighted per km surveyed. Each sighting was mapped in QGIS by formula (ActualX=ObserverX+(SIN(RADIANS(Bearing))*Distance), using the distance from observer and the compass angle, producing the GPS coordinates of the sighted individual or group.

Hippos were surveyed using walked 5 km transects along the lakeshore of Lake Kazuni starting from the research camp (Figure 2.2.2b). 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 (if applicable). Hippos were determined to be in a different pod if there was at least 50 metres between individuals.

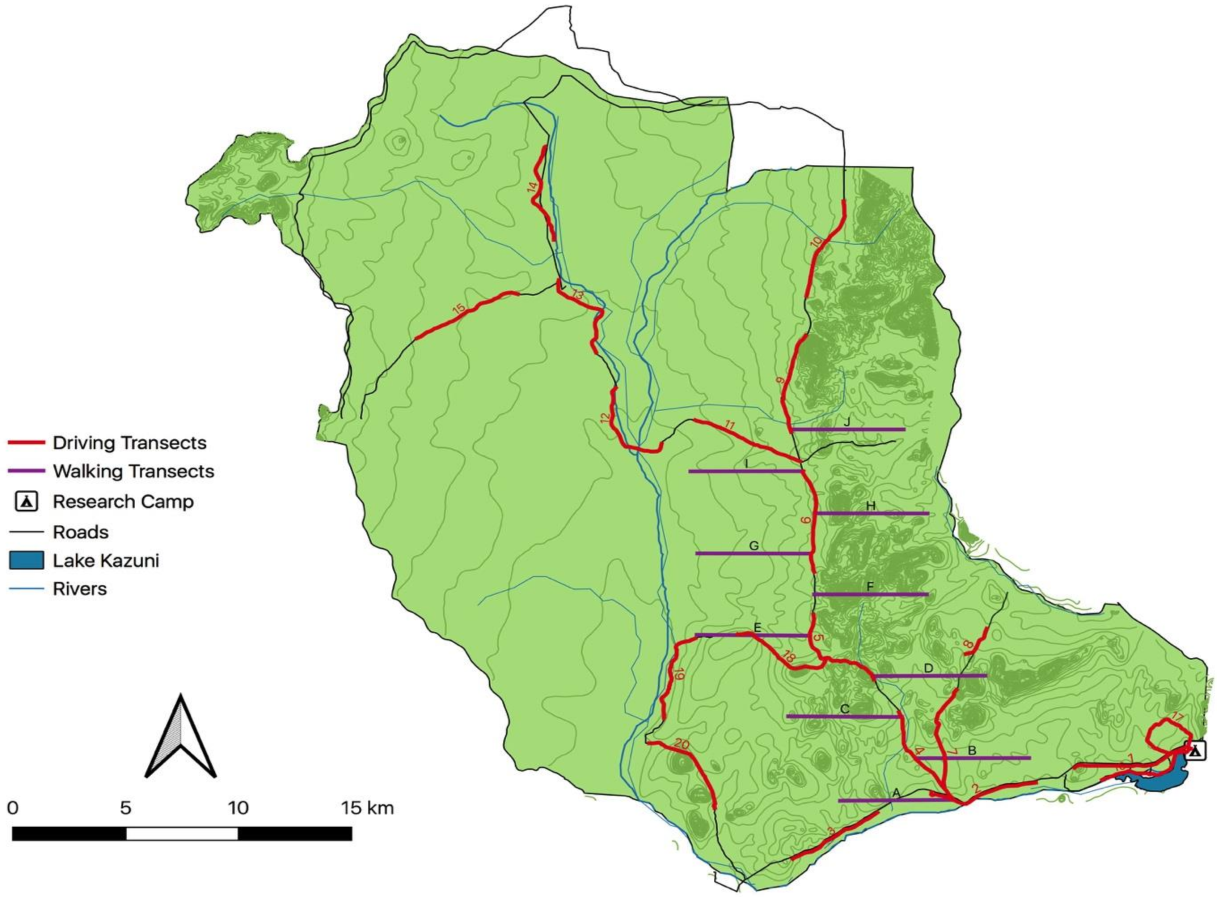


Figure 2.2.2a. Location of 2019 transect surveys in Vwaza Marsh Wildlife Reserve.

Figure 2.2.2b. Collecting data during a hippo transect.

2.3. Results

2.3.1. Camera Trapping Surveys

We conducted two camera trapping sessions, for a total of 15 trapping nights, located on the major roads throughout VMWR. We captured a total of 1,670 images of wildlife, covering a total sampling area of 327 km^2 (Table 2.3.1a). One camera was placed opportunistically near a possible den (species unknown) during group 1.

Table 2.3.1a. Camera trap survey effort across expedition groups.

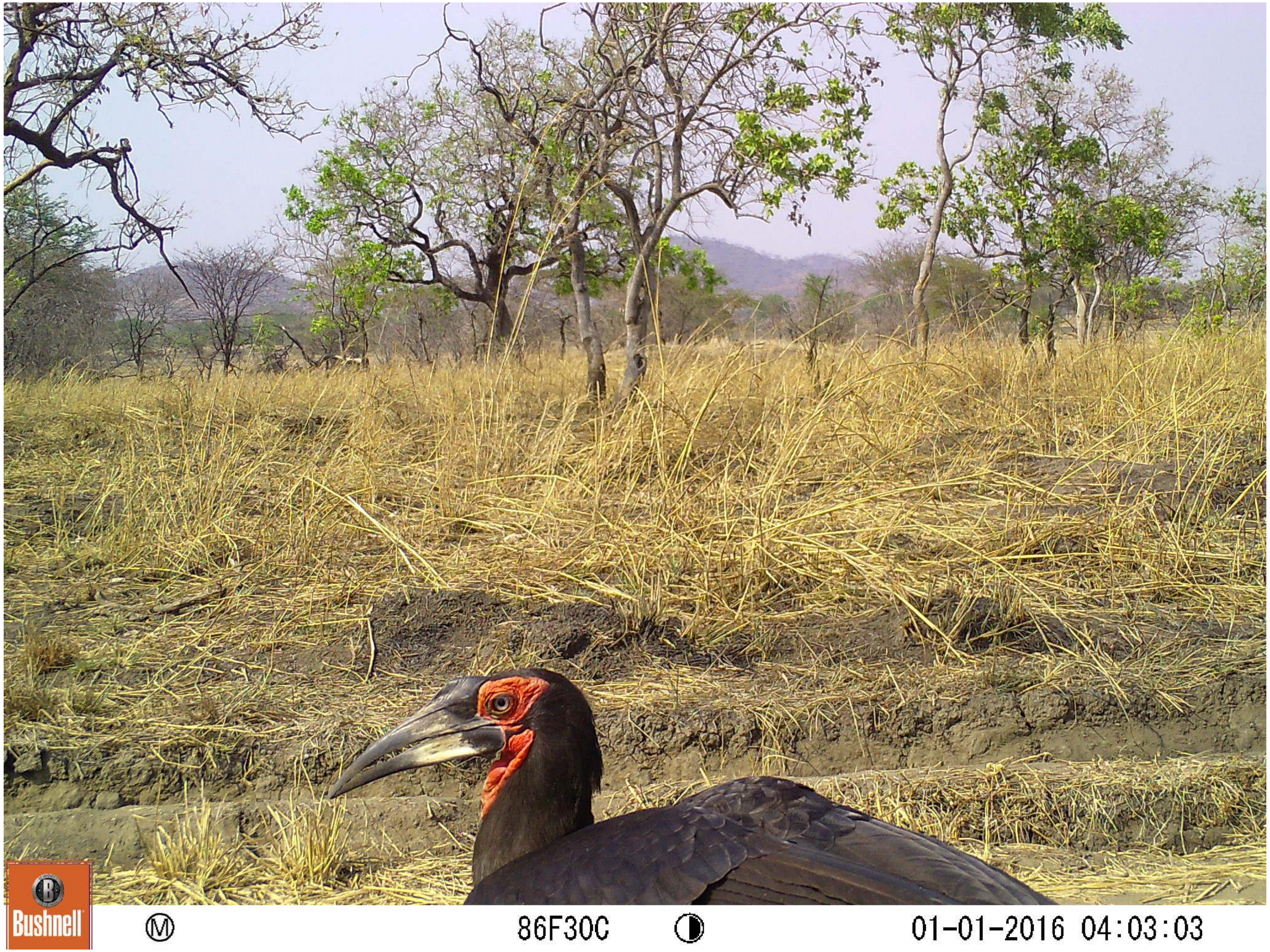
Expedition group	Number of photos	Number of species	Camera traps set	Camera trap nights
1	1,535	21	23	8
2	135	18	23	7
Totals	1,670	24	46	15

A total of 24 different animal species were recorded and identified on the camera traps, comprising 21 mammal and three bird species (Table 2.3.1b). Cameras set during group 1 captured more than 10 times the number of images than the group 2 cameras. Both group's images captured nearly the same number of species, with three species that were only captured in group 2. No images of poachers were captured.

Table 2.3.1b. Species capture record across expeditions. LC = Least Concern, VU = Vulnerable.

Common name	Scientific name	IUCN Red List status	Group 1	Group 2	Total occurrence across groups
	Primates				
Vervet monkey	*Chlorocebus pygerythrus*	LC	✓		1
Yellow baboon	*Papio cynocephalus*	LC	✓	✓	2
	Ungulates				
African elephant	*Loxodonta africana*	VU	✓	✓	2
Bushbuck	*Tragelaphus scriptus*	LC	✓		1
Cape buffalo	*Syncerus caffer*	LC	✓	✓	2
Common duiker	*Sylvicapra grimmia*	LC	✓	✓	2
Greater kudu	*Tragelaphus strepsiceros*	LC	✓	✓	2
Hippopotamus	*Hippopotamus amphibious*	VU	✓		1
Impala	*Aepyceros melampus*	LC	✓	✓	2
Roan antelope	*Hippotragus equinus*	LC		✓	1
Warthog	*Phacochoerus africanus*	LC	✓	✓	2
	Carnivores				
African civet	*Civettictis civetta*	LC	✓	✓	2
Caracal	*Caracal caracal*	LC	✓	✓	2
Honey badger	*Mellivora capensis*	LC		✓	1
Large-spotted genet	*Genetta maculata*	LC	✓	✓	2
Leopard	*Panthera pardus*	VU	✓		1
Serval	*Leptailurus serval*	LC	✓		1
Spotted hyaena	*Crocuta crocuta*	LC	✓	✓	2
Water mongoose	*Atilax paludinosus*	LC	✓	✓	2
	Other mammals				
Four-toed elephant shrew	*Elephantulus rozeti*	LC		✓	1
Porcupine	*Hystrix africaeaustralis*	LC	✓	✓	2
	Birds				
Helmeted guineafowl	*Numida meleagris*	LC		✓	1
Southern ground hornbill	*Bucorvus leadbeateri*	VU	✓		1
Spotted eagle owl	*Bubo africanus*	LC	✓		1

Figure 2.3.1a. Eight examples of interesting camera trap pictures.



Southern ground hornbill *Bucorvus leadbeateri*.

African elephant *Loxodonta Africana*.

Leopard *Panthera pardus*.

Honey badgers *Mellivora capensis*.

Caracal *Caracal caracal*.

Serval *Leptailurus serval*.

Large-spotted genet *Genetta maculata*.

Spotted hyaena *Crocuta crocuta*.

Overall, in comparison to the 2018 expedition (Harwood et al. 2019), twelve fewer species were recorded during the 2019 expedition. Large carnivore target species were recorded with a lower capture rate than the previous year's expedition, with only one capture event of leopard (Figure 2.3.1b). We also did not capture any photos of the VMWR lion, despite receiving reports of hearing a lion a month prior. Both diurnal primate species (vervet monkey and yellow baboon) were captured, but no nocturnal galago species. Of the 24 species recorded, elephants were the most frequently captured (8.12% capture rate), followed by baboon (6.67%), bushbuck (5.51%) and civet (4.64%) (Figure 2.3.1c).

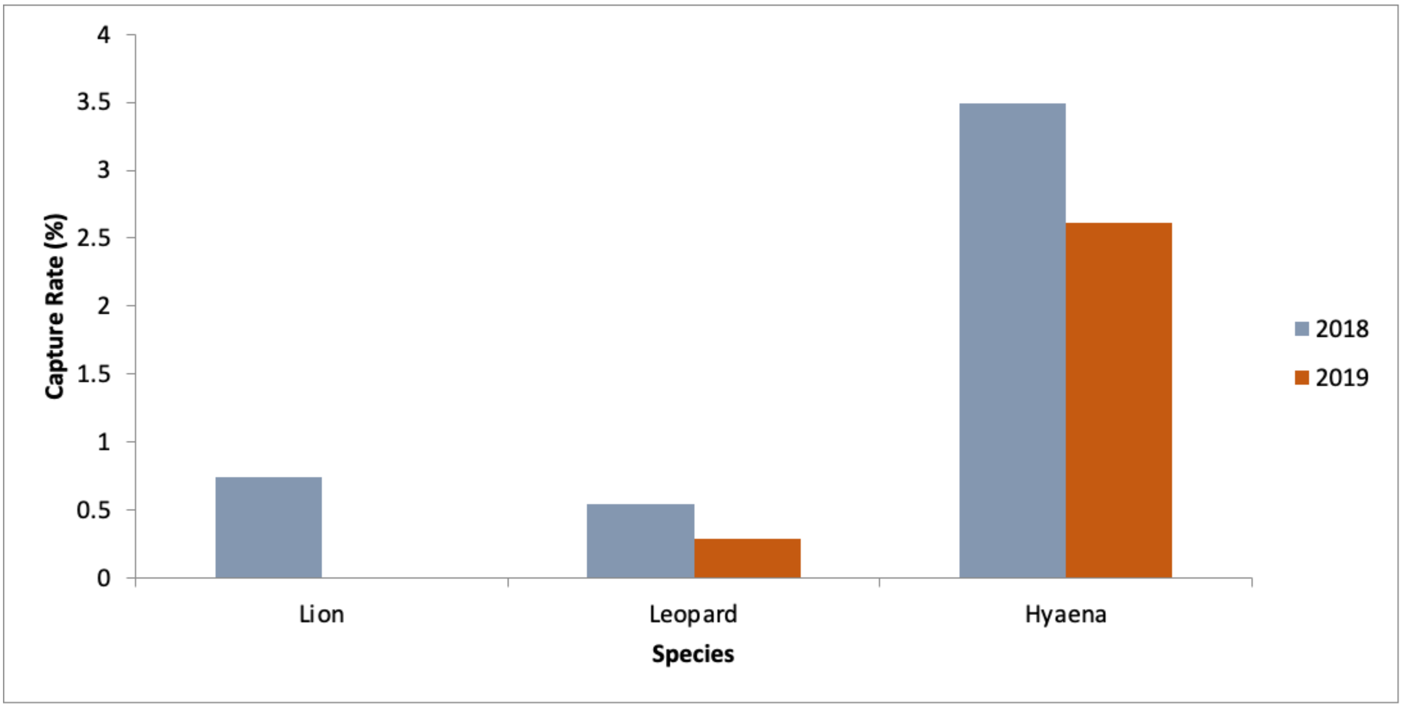


Figure 2.3.1b. Comparative capture rates for large carnivore species compared across two expeditions.

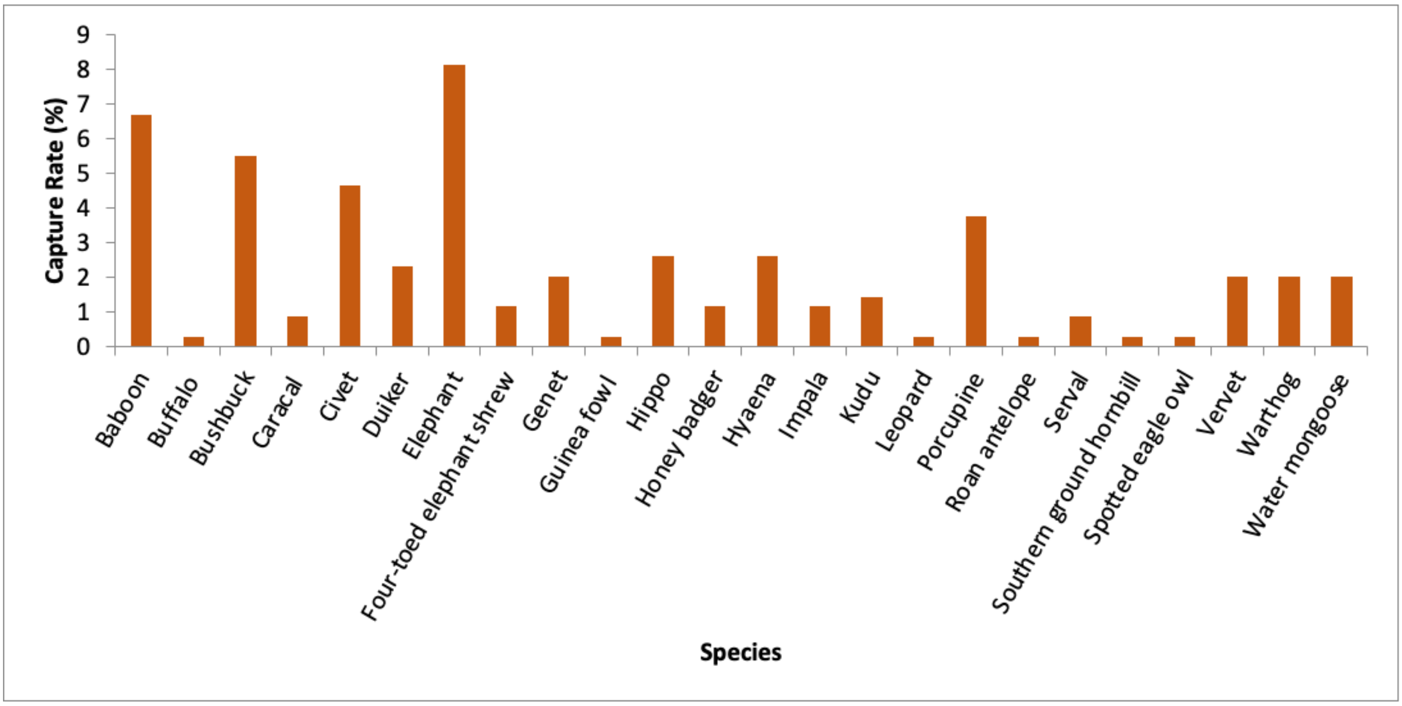


Figure 2.3.1c. Capture rates for all species in 2019.

The cameras in group 1 were 100% successful for captures, whereas only 61% of the cameras were successful in group 2. Elephants were the most widely recorded species across camera stations (30% of stations), followed by bushbuck (26% of stations), and baboon and porcupine (each 24% of stations). All target species (elephants, primates, and large carnivores) were captured at fewer locations than in 2018 (Figure 2.3.1d).

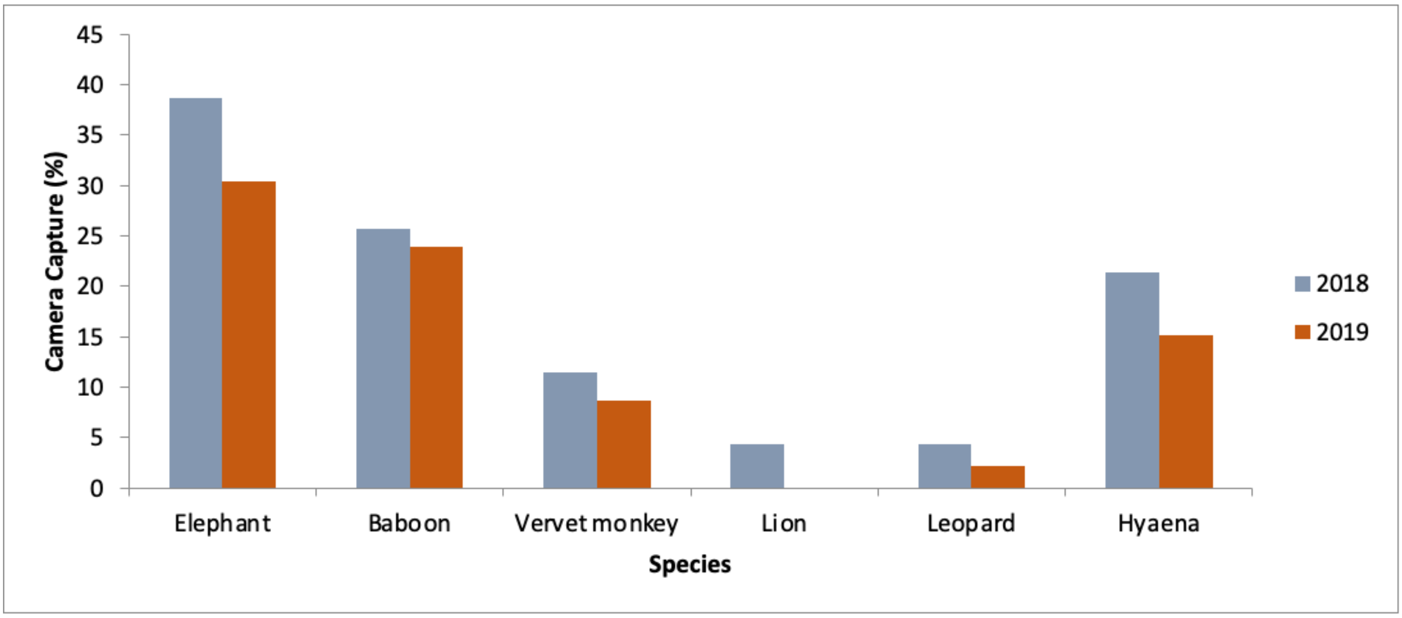


Figure 2.3.1d. Comparative camera trap capture success for target species across two expeditions.

2.3.2. Large mammal transect surveys

We conducted a total of 39 transect surveys across this year's expedition (Table 2.3.2a), covering a total of 195 km, during which we recorded eleven different species. No walking transects were conducted during group 2 of the expedition due to time and staff constraints. We had an average of 2.4 sightings per transect and an overall encounter rate of 0.45 sightings/km (Table 2.3.2b). The majority of mammal sightings were in the southern part of VMWR closest to the permanent water sources that remain present during the dry season (Figure 2.3.2a). The two expedition groups each recorded the same 10 diurnal large mammal species, except for Cape buffalo, which were only recorded during group 1, and elephants, which were only recorded during group 2.

Table 2.3.2a. Large mammal transects survey effort during the 2019 expedition.

Activity	Group 1	Group 2	**Total**
Driven Mammal Transect (DMT)	18	18	**36**
Walked Mammal Transect (WMT)	3	0	**3**
No. sightings on DMTs	40	48	**88**
No. individuals recorded on DMTs	323	195	**518**
No. sightings on WMTs	7	0	**7**
No. individuals recorded on WMTs	30	0	**30**
Total species recorded on DMTs and WMTs	10	10	**11**
Mean no. sightings per transect	2.2	2.7	**2.4**
Total km DMT	90	90	**180**
Total km WMT	15	0	**15**
Total km surveyed	105	90	**195**

Table 2.3.2b. Species survey results and encounter rates.

Species	Sightings	Individuals recorded	Mean individuals per sighting (SD)	Encounter rate (sightings/km)	Individuals per km
Bushbuck	5	5	1.0 (±0)	0.03	0.03
Cape buffalo	1	2	2.0 (±0)	0.01	0.01
Common duiker	3	3	1.0 (±0)	0.02	0.02
Elephant	2	24	12.0 (±4.2)	0.01	0.12
Greater kudu	8	23	2.9 (±0.8)	0.04	0.12
Impala	12	92	7.7 (±7.1)	0.06	0.47
Puku	3	23	7.7 (±2.5)	0.02	0.12
Roan antelope	10	66	6.6 (±5.9)	0.05	0.34
Vervet monkey	9	31	3.4 (±3.2)	0.05	0.16
Warthog	11	40	3.1 (±1.9)	0.06	0.21
Yellow baboon	19	209	11.0 (±31.4)	0.10	1.07

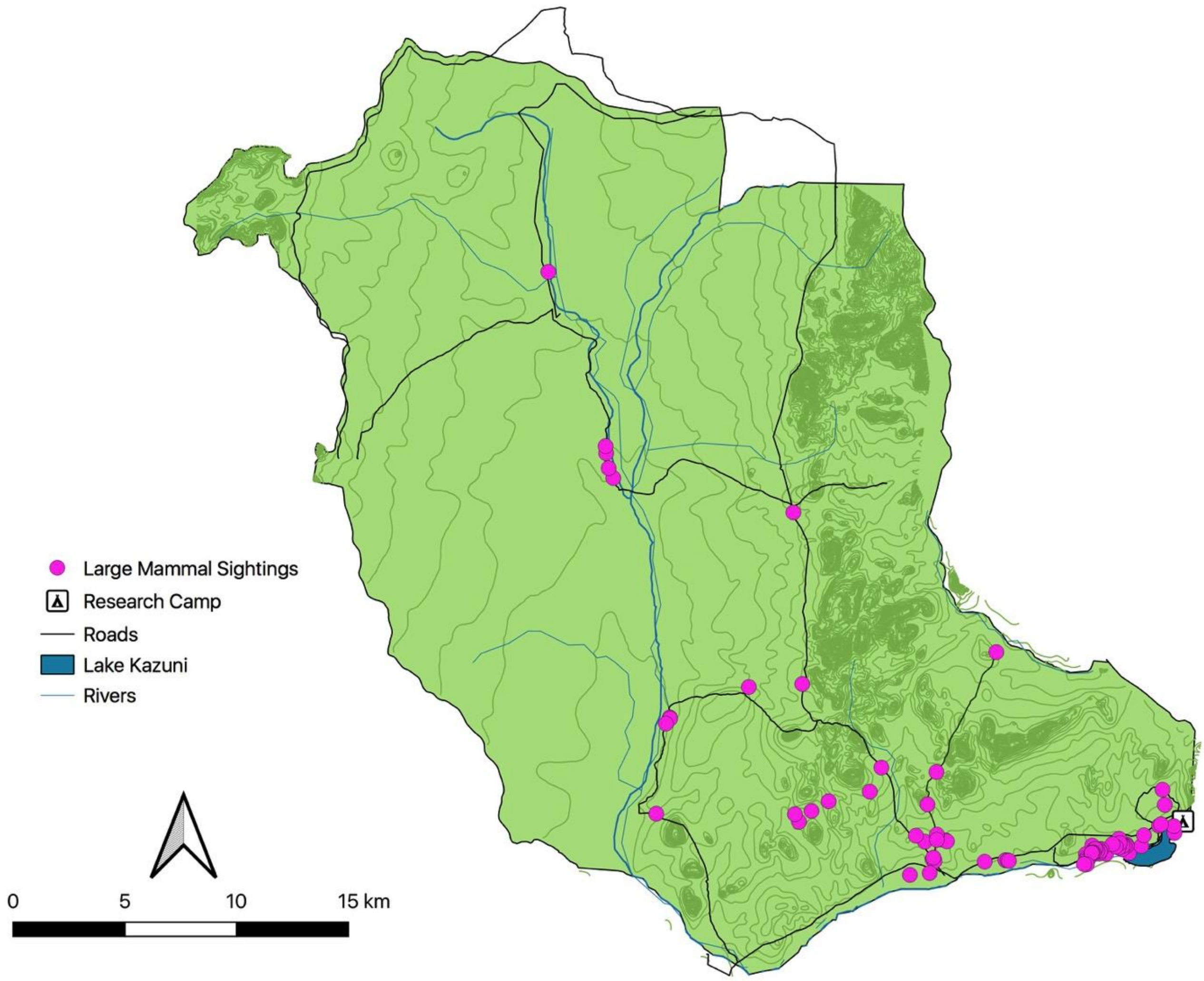


Figure 2.3.2a. Locations of large mammal sightings from transect surveys 2019.

Yellow baboons were the most frequently sighted species on transect surveys (encounter rate = 0.10/km), followed by impala (encounter rate = 0.06/km) and warthog (encounter rate = 0.06/km). These were also the most frequently sighted species during the 2018 expedition survey. Unlike the camera trap survey, which saw an overall smaller capture rate of species between survey years, the encounter rate during the transect survey in 2019 was higher for all species than the 2018 survey results (Figure 2.3.2b), discounting bushpig and hippo, which were only captured in the 2018 survey year.

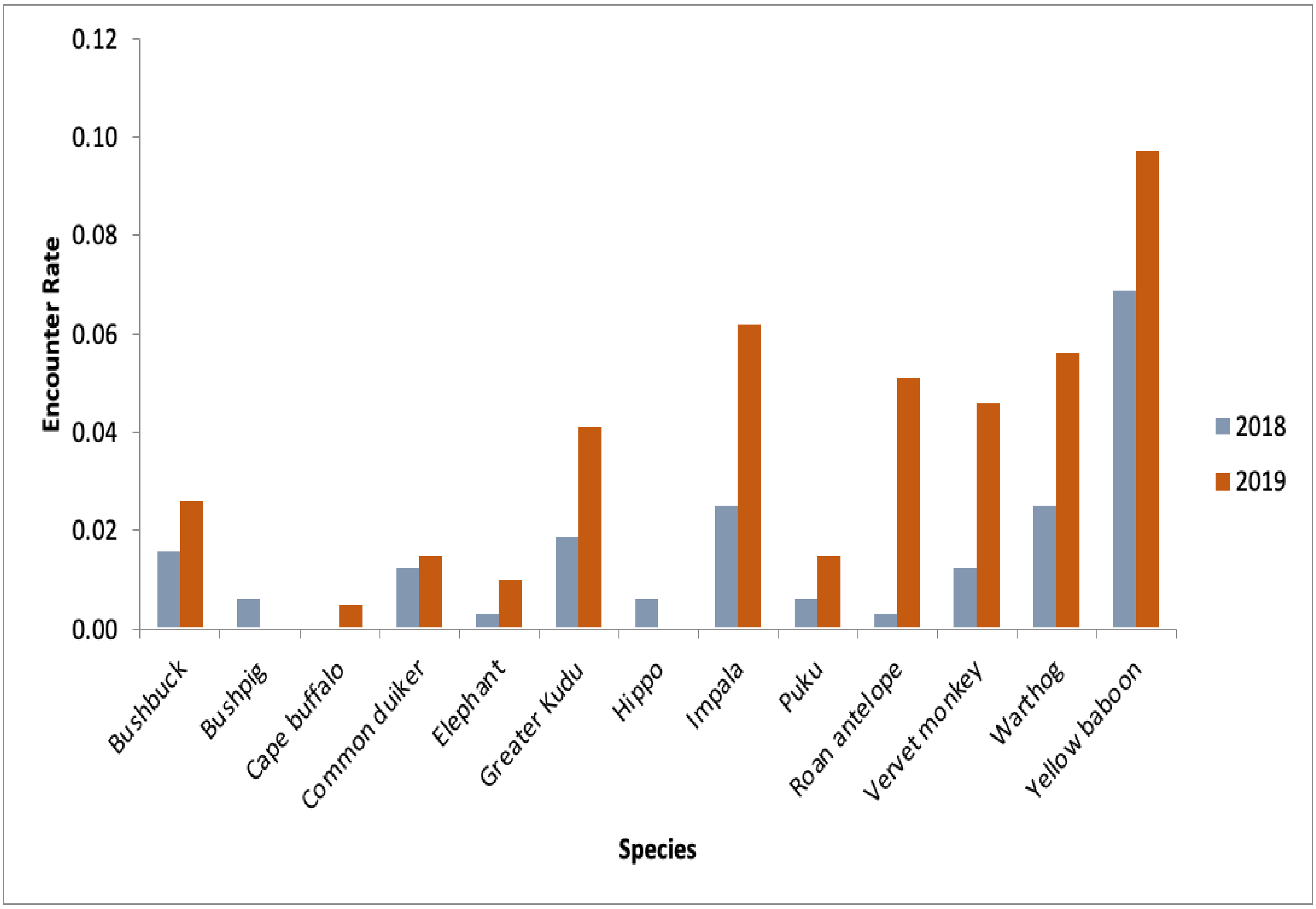


Figure 2.3.2b. Comparative species encounter rates from transect surveys 2018 and 2019.

Hippo surveys

We conducted eleven hippo transects across the two expedition groups. These yielded a mean sighting of 124.80 hippos per transect (Table 2.3.2c). This mean is suggestive of the total number of hippos likely to be in the area during this time of year.

Table 2.3.2c. Hippo transect survey effort and sightings 2019.

Activity	Group 1	Group 2	**Total**
Hippo walking transect	5	6	**11**
No. hippos sighted	542	831	**1373**
Mean no. hippos per transect	108.40	138.50	**124.80**

2.4. Discussion and conclusions

The camera trap survey was successful in capturing a high diversity of species, including a number of nocturnal or elusive species. The number of captures, capture rates and species diversity from this year's survey were lower than 2018. This may be explained by the lower sample size as three groups were conducted in 2018 compared to two in 2019. Almost twice as many images were recorded in 2018 than 2019. The lower capture rates are not necessarily reflective of actual lower species diversity and density; this can only be confirmed by collecting a larger dataset.

We recorded fewer leopard captures than expected, with only one capture event for leopard, although leopards are known to be shy and elusive. The first leopard density estimates in miombo woodlands are currently in press (Davis et al. 2020 *in press*). It is possible that these low capture records are due to high poaching pressure but further surveys across VMWR are needed to provide robust estimates.

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 mesocarnivores, such as civet, genet, and honey badger, compared with large carnivores, such as lion and leopard, might suggest potential mesocarnivore increase caused by a reduction in the large carnivore populations. However, all capture rates for target species were low (<10%), requiring a larger sampling effort in order to draw conclusions.

There were no images caught of lion. The reduced sampling effort this year might account for this, however, the previously recorded lone male lion is likely to be transient and might have moved out of the area. However, research and DNPW staff have recorded indirect evidence, such as tracks, signs and vocalisations of lion in the park quite regularly throughout the year.

We captured over ten times the number of images with expedition group 1 than with group 2. Cameras during group 2 were placed in the northern area of the park, which has fewer permanent water sources during the survey time of year, Malawi's dry season. This forces mammals to congregate in the southern region where the South Rukuru River and Lake Kazuni provide a large permanent water source, potentially explaining the lower concentration of wildlife in the northern reaches of VMWR. Compared to similar placement during the 2018 expedition, we still captured a lower than expected number of images in this region. It is possible that there was less permanent water in 2019, decreasing resource availability in the north. We also had a low camera success rate (61%) in group 2, with only 14 cameras recording wildlife. As all cameras were working properly, we can assume this was due to low animal numbers or changes in activity patterns or movement, rather than camera malfunction.

Camera trap surveys are also able to yield information on the health of wildlife populations. From images we were able to ascertain body condition and physical ailments. This study captured no images of animals with snares, which is a positive indicator that perhaps there are fewer snares in VMWR than in the previous year.

Large mammal transects recorded all of the targeted diurnal species. Of these, baboons were the most frequently encountered, suggesting there is a healthy yellow baboon population in VMWR. Baboons are also arguably the most detectible species as they travel in large groups, are vocal, and have a low flight distance.

Species of note that were sighted during the transect surveys are roan antelope (which are elusive and often occupy woodland habitats) and puku (a shy antelope species that prefer floodplain habitats and classified as Near Threatened by the IUCN). Puku were only sighted on the floodplain transect along Lake Kazuni and the South Rukuru River along the southern edge of VMWR.

The majority of mammal sightings were in the southern part of VMWR closest to the remaining water in the dry season. The southern area is under pressure from human encroachment and identification of these wildlife hotspots helps assist the DNPW in anti-poaching. Animals sighted in the northern part of VMWR were in close proximity to the Central Luwewe River running through the middle of VMWR, which has limited pools of permanent water in the dry season.

Interestingly, while the camera trap survey yielded lower capture rates in 2019 than the 2018 survey, the large mammal survey encounter rates were higher than those in 2018. This could be due to the later time of year the 2019 expedition was conducted, further concentrating the wildlife at the end of the dry season. This year's survey also had over double the sightings per transect than 2018. A larger dataset is needed to make long-term inferences about the population trends of VMWR.

Hippo surveys of the population inhabiting Lake Kazuni in the south of VMWR were successful, yielding an average of 125 hippos per transect. Although this count is lower than the 2018 average (147 hippos), this still presents a healthy population for the area. These data contribute to a long-term dataset from which inferences can be made over a longer period of time.

These results continue to indicate high species diversity in VMWR. Four species recorded by the expedition are classified as Vulnerable and one species as Near Threatened by the IUCN. These species are threatened by the increasing human pressures in VMWR, including snares for bushmeat and targeted hunting for ivory. An aerial survey conducted in 2015 (Macpherson 2015) recorded eland (*Taurotragus oryx*; n=2), sable (*Hippotragus niger*; n=1), reedbuck (*Redunca arundinum*; n=42) and zebra (*Equus quagga*; n=5). These species were not sighted during the expeditions in 2018 or 2019 or indeed by any of the research activities conducted since 2017. This suggests that the larger antelope species make easier targets for poaching and are more sensitive to the anthropogenic habitat pressures of the area. A three-year absence of sightings suggests that these species may have been extirpated from the area since 2015. Historical records of these species (Macpherson 2015, Happold 2014), suggest that VMWR is able to support an even larger diversity of large mammals.

Data collected during this expedition contribute valuable data to our larger dataset to build a long-term monitoring database of large mammal, hippo, and carnivore populations in VMWR. As more research and future expeditions are conducted, we will be able to perform more robust analyses of population trends, including density, occupancy, and population dynamics to inform effective management of large mammals in VMWR.

2.5. Outlook for future expedition work

The expedition continues to be a showcase on how citizen science can make a significant, efficient and effective contribution to conservation data collection in partnership between international citizen science non-profit and national wildlife conservation NGOs. As such, the expeditions should be continued as soon as the coronavirus pandemic is sufficiently under control to allow international citizen scientists to travel to Malawi again. As soon as this is possible, the expedition should:

- Build the dataset during future expeditions to investigate if the preliminary results presented here are representative of long-term population trends. To do this, we should expand the camera trap survey to cover at least three months of the dry season to yield further insight into the large and meso-carnivore populations of VMWR. Transect surveys should also be continued to develop a more robust dataset to determine large mammal density estimates and trends.

- Based on existing and further results from the activities above, conduct occupancy modelling of uniquely identifiable species to calculate density estimates, occupancy patterns, niche partitioning, and habitat characteristics in relation to carnivore population trends.

- Continue to share all data with the DNPW to assist them in making conservation management decisions.

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3. Elephant Monitoring

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Biosphere Expeditions

3.1. Introduction

Best estimates of elephant populations in Malawi 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 decreasing due to human encroachment and deforestation (Blanc et al. 2007). Losing elephant populations in Malawi will lead to a significant gap in the African elephant range. 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), encompassing 30,621 km^2, including VMWR, along with Nyika and Kasungu National Parks in Malawi. 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 (Thouless et al. 2016). This brings elephants into increasing conflict with human populations surrounding the protected areas.

Isolation, encroachment and habitat loss are threatening elephant populations in Malawi (Munthali 1998). Management and conservation are limited by a lack of rigorous research and survey data (Blanc et al. 2007). 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. Accurate data on elephant numbers and distribution are essential for effective conservation management of the species (Blanc et al. 2007). However, precise and accurate estimates of elephant numbers in Malawi are lacking (see 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 VMWR, 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 that remain available in the dry season (May-November), e.g. Lake Kazuni and the South Rukuru River located in the southern part of VMWR. 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.

The aim of the elephant monitoring project is to obtain close population estimates and herd demographics by creating an individual identification database. This database will enable monitoring of long-term trends as well as allow researchers to study behavioural ecology once the database is well established.

Table 3.1a. Elephant population estimates in Malawi (from 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

We followed methods developed by Elephants for Africa (www.elephantsforafrica.org), a Botswana-based NGO. We observed elephant herds both from vehicles in VMWR and from the expedition base camp. Because of the tendency for large numbers of elephants to congregate at the water resource of Lake Kazuni, 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 (Figure 3.2a). To guarantee this, we recorded data only on groups that arrived at the lake after the researchers.

At the start of each observation session, we recorded the date, time, GPS coordinates, and situational data on the datasheet. Focusing on one herd at a time, we recorded herd composition data, including age and sex classes, herd leader and herd size. Sex and age classes were determined by certain developmental and physical characteristics. Often it was difficult to tell one herd from another and if this was the case, we focused solely on individual elephant identification.

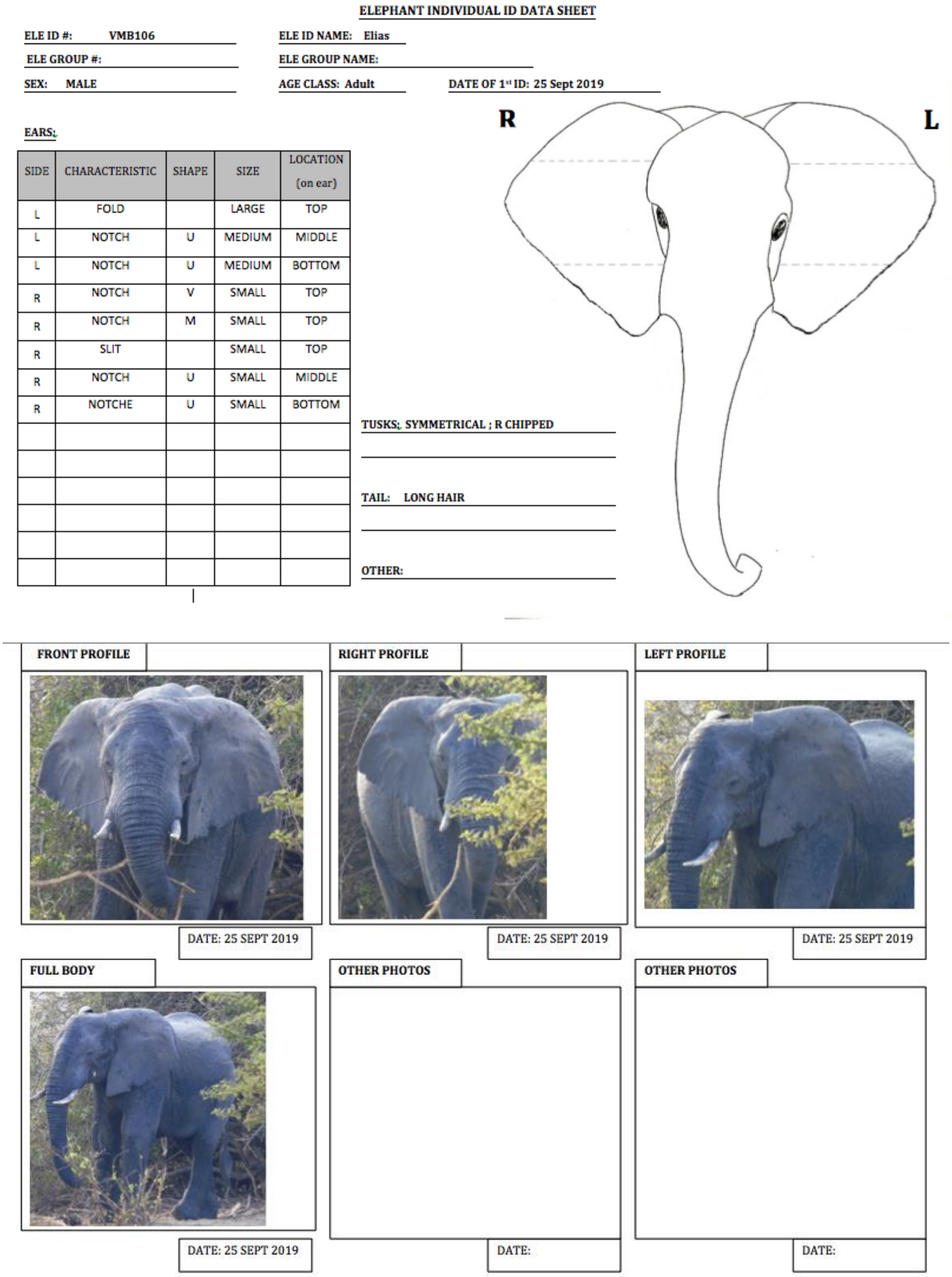
Figure 3.2a. An elephant herd on the Lake Kazuni floodplain, with hippos in the lake in the background. Photo courtesy of Laura Pope.

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. Identifying features were characterized according to a set of standard terminology.

At the end of an observation session, photographs were reviewed to identify each elephant. If an individual had 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.

3.3. Results

We completed 26 herd observations and confirmed 14 second sightings of identified elephants. We identified 10 new individual elephants (see Figure 3.3a for an example), five males and five females.


ELEPHANT INDIVIDUAL ID DATA SHEET

ELE ID #: VMB106
ELE ID NAME: Elias
ELE GROUP #:
ELE GROUP NAME:
SEX: MALE
AGE CLASS: Adult
DATE OF 1st ID: 25 Sept 2019

EARS:

SIDE	CHARACTERISTIC	SHAPE	SIZE	LOCATION (on ear)
L	FOLD		LARGE	TOP
L	NOTCH	U	MEDIUM	MIDDLE
L	NOTCH	U	MEDIUM	BOTTOM
R	NOTCH	V	SMALL	TOP
R	NOTCH	M	SMALL	TOP
R	SLIT		SMALL	TOP
R	NOTCH	U	SMALL	MIDDLE
R	NOTCHE	U	SMALL	BOTTOM

TUSKS: SYMMETRICAL ; R CHIPPED

TAIL: LONG HAIR

OTHER:

Figure 3.3a. Example profile of an adult male elephant, Elias, identified during the expedition.

One new identified elephant was a subadult, while the rest were adults. Four males were identified in a bachelor herd, one male by himself, and five females from two different herds. These new individuals brought the database total to 203 identified individuals. Three of the second-sighted elephants were individuals first identified by the 2018 expedition. Herd observations revealed a mean herd size of 18 individuals each with an average of eight adults. Of the observed herds, 78% had at least one infant, with 61% having more than one infant.

3.4. Discussion and conclusions

Elephants were observed solely around Lake Kazuni and in front of the expedition base camp. During the height of the dry season, elephants need to drink at least once a day and come to Lake Kazuni as the main permanent water source to drink and bathe. Often multiple herds were observed congregating at once on the lakeshore, making herd demographic data difficult to collect. During these times we focused on individual identification. The ten elephants identified during this year's expedition pushed our total database to over 200 individuals. Passing the 200 individuals mark was a goal we were excited to accomplish with Biosphere Expeditions, as we believe the database now comprises the majority of the VMWR elephant population, estimated to be around 300 individuals (pers. comm. Leonard Moyo, DNPW, 2017). An aerial count by Macpherson (2015) reported 203 elephants, but our database, casual observations and DNPW communications suggest that there are now more, however numbers can often be affected by seasonal migratory patterns.

These identifications provide a solid baseline from which we can monitor elephant populations long-term. The number of second-sighted elephants was low due to the time it takes to identify each elephant accurately, a challenge we experienced throughout the expedition. Data will continue to be analysed by the permanent research staff. The high percentage of herds with infants, including the majority having more than one infant, is an encouraging indication for this population, especially given the high rate of elephant poaching in the area. The reproductive success of the elephant population will be monitored and can be an indicator of the success of the DNPW law enforcement efforts in the area. The elephant ID database is also useful in identifying poached animals (of which we identified three in the previous year).

3.5. Outlook for future expedition work

This long-term research project will continue to monitor, identify, and refine our database of individual elephants and the herds of the VMWR elephant population, using continued observations and possibly capture-recapture techniques to monitor densities. Once we have a solid baseline, we will focus further on herd compositions and expand into behavioural interactions. We will also refine our database to present it and provide training to the DNPW so they can continue to work with us on monitoring the VMWR elephant population long-term.

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4. Bat and insect monitoring

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Biosphere Expeditions

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 and associated habitat loss and degradation poses the most serious threat to bat populations. In Africa, these threats are increasing with the annual human population increasing more rapidly than that of any other continent (Hutson et al. 2001). Bats are key indicator species as they are nocturnal, relatively taxonomically stable, perform key ecosystem services and have a rich trophic diversity (Tsang et al. 2016). Bats therefore make effective bio-indicators, capturing the responses of a range of taxa and reflecting components of biological diversity such as species richness (Jones et al. 2009). 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).

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 growing 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. 1982, 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).

The bat and insect surveys conducted during the expedition provide critical data for 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; creating an early warning system to identify any declines or significant negative trends in populations.

Biodiversity monitoring through bat and insect captures during this Biosphere Expedition adds to ABC's ongoing database of ecosystem health monitoring. Surveys completed in Vwaza Marsh Wildlife Reserve (VMWR) represent data for undisturbed, protected areas. ABC's other survey sites include highly disturbed urban areas such as Lilongwe and mono-culture crop lands such as tea estates in Southern Malawi. Other undisturbed survey sites include Kasungu, Nyika and Liwonde National Parks, Kuti Wildlife Reserve and many forest reserves.

Vegetation surveys

Vegetation surveys were conducted in conjunction with bat mist netting and harp trapping surveys. In addition to providing a baseline dataset of tree species present in VMWR, vegetation surveys allow for fine scale analysis of bat micro-habitat preferences and providing quantitative data on the physical environment bats are caught in. Bat species are adapted to forage and navigate in different habitats and acoustic environments. A more densely "cluttered" environment requires a unique form of echolocation to avoid collision with objects and specific wing loading and aspect ratios to allow for slow manoeuvrable flight. As such, specific morphological differences have evolved to suit the favoured environment of each bat species. Comparing tree density with bat species caught in the area can help reinforce species identification and provide insights into the feeding and roosting behaviour and preferences of bats. Long-running baseline vegetation data are also important for measuring the health of the ecosystem as a whole, as plants and trees are often the first victims of invasive species, toxins or changes in global and local climate. Local weather conditions have been monitored with a Davis Instruments Vantage VUE weather monitoring station (model no. 6250UK).

4.2. Methods

Bat surveys

Bats were surveyed at spatially independent survey sites in VMWR using standardised trapping as part of the ABC biodiversity monitoring programme (BMP) at permanent survey sites, or opportunistically at randomly selected sites in each habitat (floodplain and woodland) (Fig 4.2a). The surveys provide insights into the species richness across different survey sites with varying levels of human disturbance and different habitat types as well as general population monitoring. Bats were surveyed for one night per site during each expedition group. Bats were captured at each site using two mist nets and two harp traps set over trails, slow moving water, or openings where bats forage. A distance of at least 2 km separated each site to prevent pseudoreplication. The limited geographical spread of the bat survey sites was due to timing restrictions during the expedition (each survey takes 3.5 hours at each site).

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 size of mist nets (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). The presence of dangerous animals occasionally limited the total trapping time to under 3.5 hours. Additionally, one harp trap (1.8 x 1.8 m) was also used at each site for a total of 50 square metres of net at each survey site. Species richness is then calculated by number of individuals caught per metre of net (which is standard across all surveys) by time (which had slight deviations due to the presence of dangerous animals).

The species of captured individuals were identified using external characteristics and dentition from keys and published information (Happold & Happold 1989, 1997). Individuals were photographed and the following biometrics collected: age (juvenile, adult), sex, reproductive status, forearm length, ear length & width, and weight. Age is 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. Tissue samples for DNA analysis were taken with wing puncture kits to improve our understanding of the taxonomic ranks of the species captured.

Insect surveys

As with the bat surveys, all insect surveys were carried out at the same standardised biodiversity monitoring sites in floodplain or woodland habitat. All surveys were carried out within a range of 8 km of camp. The limited geographical 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 Surveys.

Standardised Biodiversity Monitoring insect surveys

ABC uses a standardised biological diversity monitoring programme (BMP) 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 use these data to measure relative species diversity and abundance of bats between habitats, and across landscapes to predict diversity and abundance of bats and determine spatial and temporal trends in bat populations to inform conservation management.

Insects surveyed as part of the BMP were sampled for the duration of each bat survey. Surveys were conducted at randomly selected sites within the different habitats of VMWR and used one Heath light trap, fixed with a 20W cylinder black light. These surveys were used to estimate order level richness and relative abundance, and relate this to bat species richness and abundance over time.

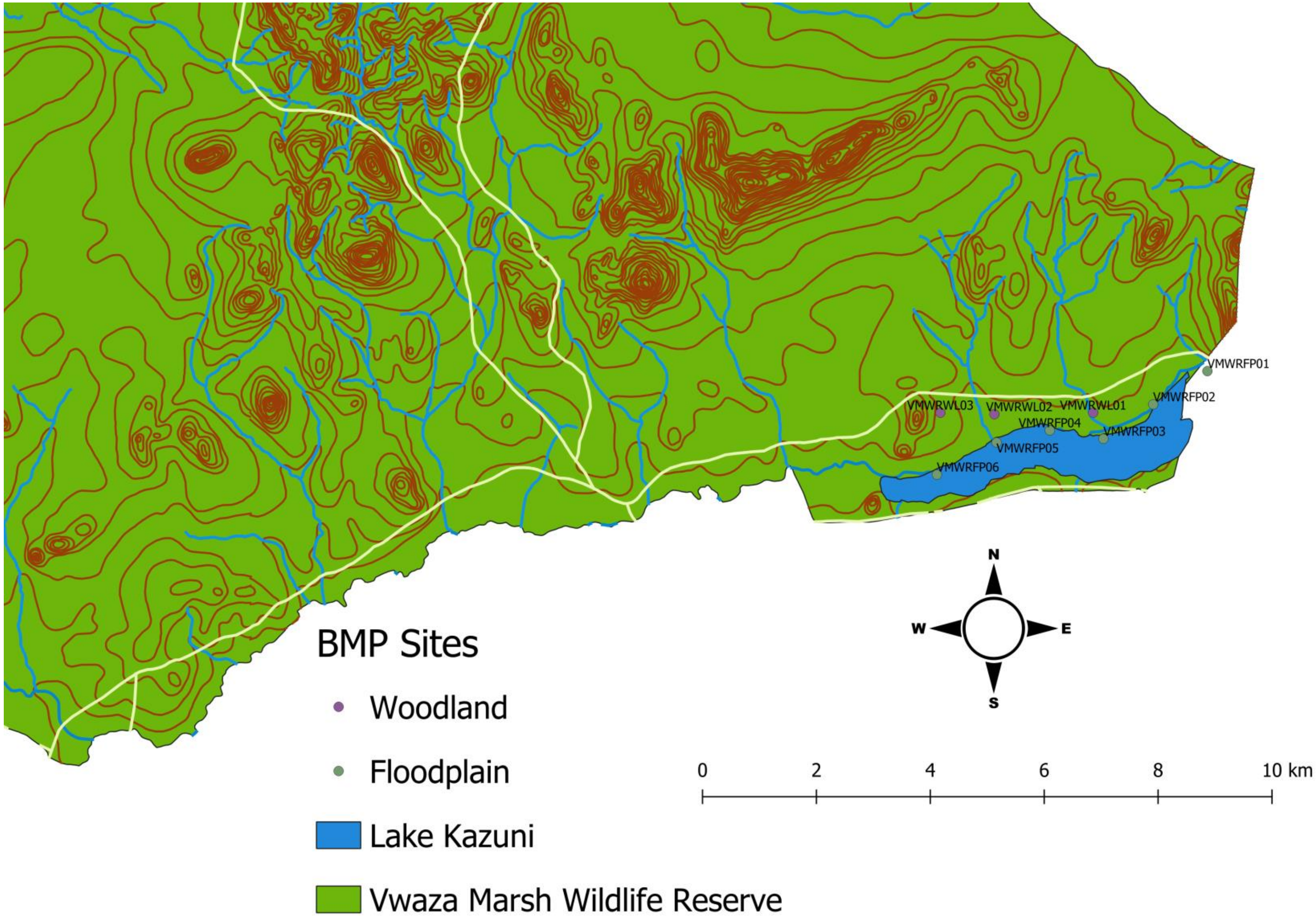

Figure 4.2a. BMP survey sites for bats and insects representing undisturbed survey locations in two different habitats, woodland and floodplain.

Each trap was placed a minimum of 25 metres from all bat traps, out of the line of sight of the bat traps to reduce influence on bat capture rates. Light traps were positioned on game trails, on edge habitat or close to water bodies. Each trap was left active (switched on) for 30 minutes before sunset, and three hours thereafter, according to ABC BMP protocols for surveying bats.

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 VMWR.

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 grams. This was used to give an indication of the insect biomass under 5 mm collected from each survey. All identification was carried out using Sholtz & Holm (1985).

Vegetation surveys

Vegetation surveys were conducted when logistically possible at each bat and insect trapping location. External factors such as time and the presence of dangerous wildlife limited the vegetation surveys. Surveys were conducted within a 20 m x 50 m plot centred on the nets, which was then divided into ten 10 m x 10 m subplots, of which five were randomly selected and sampled for vegetation. The following variables are then recorded: species, tree or sapling, height, diameter at breast height (DBH), canopy length and width, clutter at sample point, basal area, status, foliage height density (FHD), use of herbicides/pesticides/fertilisers.

4.3. Results

Bat surveys

A total of nine bat trapping surveys were completed at seven sites and two habitats (floodplain, n=6 and woodland, n=3), yielding a total of 2714.4 trapping metre survey hours (Table 4.3a).

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

Expedition Group No.	No. opportunistic trapping surveys	Total Trapping Metre Hours (TMH)	Total No. bats caught	No. bats /TMH	No. spp. caught	No. spp. / TMH
1	6	1688.4	34	0.02	9	0.005
2	3	1026	17	0.016	6	0.005
Totals	**9**	**2714.4**	**51**	**0.018**	**11**	**0.004**

Fifty-one bats were captured in total, with an average no. of spp. / TMH of 0.004 and 11 different species.

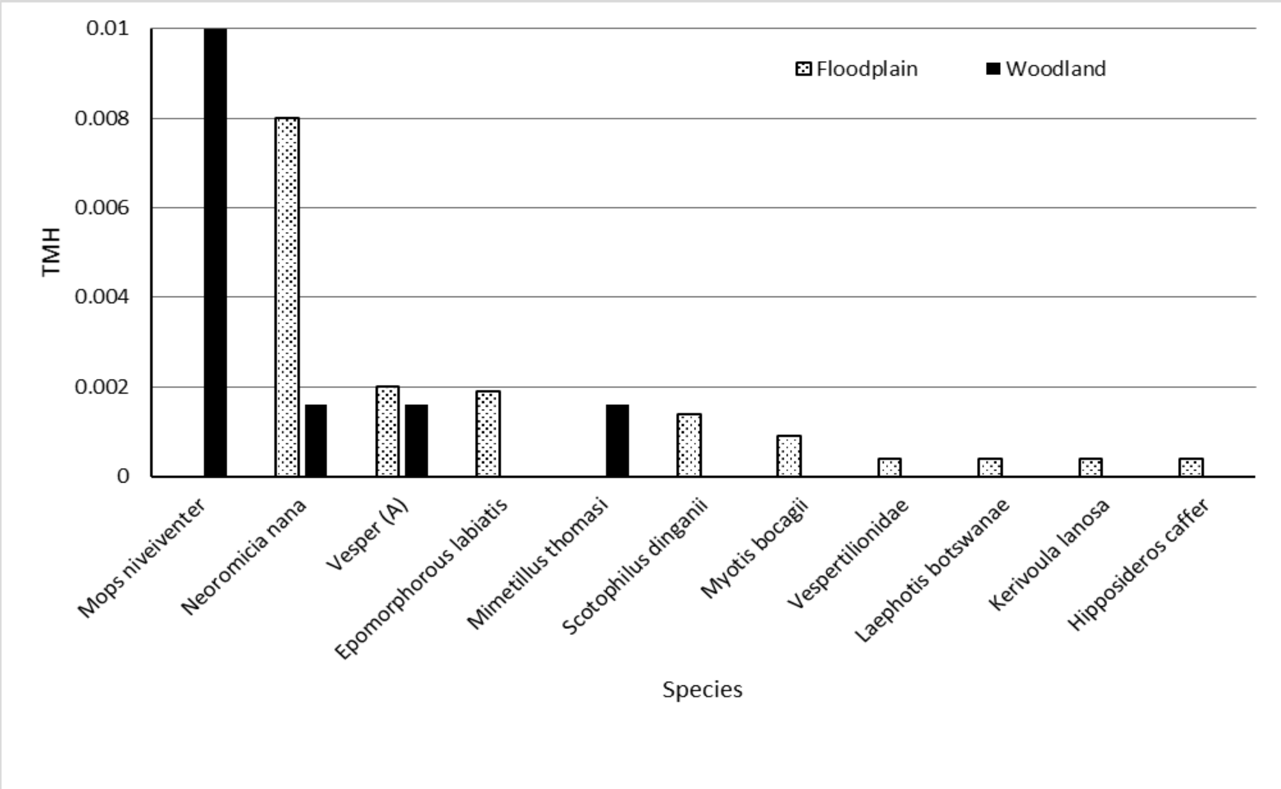

Figure 4.3a. Bat species richness (bats/trapping metre hour (TMH)) per habitat.

Table 4.3b. Bat species caught during the expedition.

Latin name	English name
Mops niveiventer	White-bellied free-tailed bat
Neoromicia nana	Banana Pipistrelle bat
Vespertilionidae species 1*	
Vespertilionidae species 2*	
Epomophorus labiatus	Ethiopian epauletted fruit bat
Mimetillus thomasi	Thamas's flat-headed bat
Scotophilus dinganii	Yellow house bat
Myotis bocagii	Rufous mouse-eared bat
Laephotis botswanae	Botswanan long-eared bat
Kerivoula lanosa	Lesser woolly bat
Hipposideros caffer	Sundevall's roundleaf bat

*Two Vesper species were thought to have been caught based on slight physical differences. This will have to be confirmed via DNA from wing samples

Expedition group 1 recorded nine bat species out of 34 individuals captured. Group 2 recorded six different bat species out of 17 individuals captured. In total eleven bat species were recorded (Figure 4.3b) over the two groups. Overall species richness was dominated by *Neoromicia nana* (37% of total captures), *Mops niveiventer* (15% of total captures) and closely followed by Vespertilionidae species 1 (13% of total captures).

Trapping metre hour (TMH) is defined by the number of bats captured per hour and square metre of netting deployed during the survey including both harp traps and mist nets giving a standardised and quantifiable number of bats species richness. The highest relative bat species richness was recorded in woodland habitat at 0.006 species/TMH, followed by floodplain with an average of 0.004 species/TMH. Although bat abundance between sites was almost identical (woodland habitats 0.0019 bats/TMH, floodplain 0.0018 bats/TMH), floodplain nets captured 39 total bats during 6 surveys while woodland nets caught 12 total bats during 3 surveys. *Mops niveiventer* was only recorded in woodland, and all but one *N. nana* were recorded in floodplain, while all but Vespertilionidae species 1 were captured in floodplain (Figure 4.3a).

Vegetation surveys

Three vegetation surveys were completed with a fourth not completed due to elephants passing through the area.

Table 4.3c. Results of three vegetation surveys.

Activity	Group 1	Group 2	**Total**
Surveys completed	2	1	**3**
Trees measured	8	73	**81**
Tree species identified	5	2	**7**
Tree species	*Acacia spp.* *Acacia karroo* *Lantana camara* *Lantana trifolia,* *Albizia harveyi*	*Friedolesia obovate* *Terminalia sericea*	

Insect surveys

A total of six BMP surveys were conducted with over 15,000 insects processed (Table 4.3d). An insect "soup" of species under 5 mm was weighed in grams as the sheer quantity would have been extremely difficult and time consuming to order and count. An estimated number was then calculated from the weight based on the known weight of insects such as mosquitos and other small flying insects. Group 2 had a large quantity of insect "soup", which brought their total number from 757 individually identified insects up to roughly over 6,000 when including the insect "soup".

Table 4.3d. Insect survey effort per group.

Activity	Group 1	Group 2	**Total**
BMP Survey	3	3	**6**
Insect processing	3	3	**6**
Insects processed	9,000+	6,000+	**15,000+**
No. of orders identified	11	11	**11**

Biodiversity Monitoring Programme

Thirteen orders of insects were represented in the BMP surveys (Table 4.3e). Apart from Diptera, the number of orders and abundances recorded for each order were relatively equal between groups. Only four orders (Coleoptera, Diptera, Hymenoptera and Lepidoptera), were recorded by both groups out of thirteen recorded throughout the expedition.

The most numerous orders for BMP surveys were Diptera (n=8424), Coleoptera (n=657) and Lepidoptera (n=536). The highest abundance recorded was in the Diptera and the lowest abundance was recorded in the Mecoptera and Odonata (n=1 each) orders. Interestingly, a massive drop in captures was recorded for Diptera between groups 1 and 2 (G1=8291, G2=133). All other orders had relatively even capture numbers between both groups.

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

Order	Group 1	Group 2	Total #
Diptera (true flies)	8291	133	8424
Coleoptera (beetles)	294	363	657
Lepidoptera (moths & butterflies)	346	190	536
Hymenoptera (bees, wasps & ants)	63	15	78
Hemiptera (true bugs)		42	42
Neuroptera (antlions & lacewings)	7		7
Heteroptera (true bugs)		6	6
Mantodea (praying mantids)		3	3
Orthoptera (crickets, grasshoppers & katydids)		3	3
Ephemeroptera (mayfly)	2		2
Isoptera (termites)	2		2
Mecoptera (scorpionflies)		1	1
Odonata (dragonflies and damselflies)		1	1
Total number of insects	**9005**	**757**	**9762**

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4.4. Discussion

Bat surveys

Bat surveys were very successful with 51 bats captured representing eleven species. *Neoromicia nana* dominated the species composition despite all but one bat being caught in floodplain habitat, a change from 2018 when most *N. nana* were captured in woodland. This difference in capture location could be related to seasonal changes in insect diversity and abundance across habitat types, potentially influenced by climatic factors on a local scale. These differences highlight the importance of long-term monitoring as over time patterns can be analysed alongside environmental variables such as rain fall, temperature, vegetation density and diversity which might influence local foraging patterns and preferences of bats.

Neoromicia nana, being the most common capture, 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. It will also roost in buildings, caves and crevices. This species may be roosting both in the reserve and in the villages where banana crops are grown and commuting into the park for foraging. Currently the taxonomy of this species is in debate as it was previously listed as *Pipistrellus nanus,* or the banana pipistrelle after its common roost habitat of banana leaves. Recent genetic studies have shown that it is actually more closely related to species in the *Neoromicia* genus. 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. *Neoromicia nana* was also the most frequently captured species during the 2018 expedition. The similarity between 2018 and 2019 surveys is expected and the consistency is encouraging as it shows no drastic ecosystem-wide changes. Since bats act as important indicator species, drastic changes in the local environment from climate, human pollutants or other sources would be reflected in bat survey data.

Captures of *Kerivoula lanosa, Myotis bocagii* and *Laephotis botswanae* are of particular interest and excitement as they represent new species records for Malawi and VMWR for ABC. *Myotis bocagii* and *Laephotis botswanae* are new species records for VMWR while *Kerivoula lanosa* is new for Malawi for the ABC records. This may suggest that these species have a limited distribution in VMWR, however, this can only be confirmed by additional surveys and increased sample size to provide a robust assessment of range and distribution of the species. *Kerivoula lanosa* are typically only found near water, as such its close proximity to Lake Kazuni is unsurprising. They often roost in abandoned bird's nests, particularly those of weavers whose enclosed nests provide protection from predators and the elements. (Monadjem et al. 2017). *Myotis bocagii* are usually found in dry savannah habitat and have a broad yet patchy and isolated known distribution across the African continent (Monadjem & Jacobs 2017). *Laephotis botswanae* is found in dry and moist savannahs and often within the presence of rivers. Little is known on its distribution although it appears to have patchy distribution, which can be a cause for concern as populations become isolated. Little is known about its roost requirements although Ansell & Dowsett (1988) recorded it roosting under the bark of trees in pairs in Malawi.

With further work in VMWR, we hope to find out more about the ecology and roosting requirements of these species to fill knowledge gaps and inform conservation management.

Vegetation surveys

Vegetation survey results show no significant changes from 2018 to 2019, corroborating results of the bat and insect surveys of a stable environment.

Group 2 measured 73 trees during their single survey, while group 1 measured eight. This large difference can be attributed to the habitat type of the survey location. Both surveys of group 1 were conducted on the floodplain surrounding Lake Kazuni, which has limited vegetation due to seasonal flooding. The survey of group 2 was conducted in woodland habitat. Miombo woodland is characterised by dense foliage and thick tree structure, hence the large difference in number of measured trees between each group.

Insect surveys / Biodiversity Monitoring Programme

There was a wide representation of insect orders from the BMP surveys, with thirteen orders recorded, up three from the ten recorded during the 2018 expedition. Four orders were captured in 2019 that were not recorded on the 2018 expedition. Those orders are Ephemeroptera (two captures), Isoptera (two captures), Mecoptera (one capture) and Odonata (one capture), which were the four least captured orders (Table 4.3e). With only six total individuals captured across all four orders, it is likely they were not recorded in 2018 simply because they exist at a low density in VMWR. Diptera, 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 Diptera, Coleoptera and Lepidoptera are three 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 these data with confidence. Similar results were recorded on the 2018 expedition where Diptera, Coleoptera and Lepidoptera were the most numerous recorded groups. Similar to the results from bat surveys, in which the same species was most commonly recorded from both 2018 and 2019 expeditions, the results are expected and again provide an insight into the health of the ecosystem. If major climatic or human caused events had impacted the local environment, insects would be an important indicator species from which to record the changes, furthering highlighting the importance of long-term insect monitoring.

Orders such as Odonata, Mecoptera, Mantodea, Ephemerotera, Isoptera 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 Diptera, Coleoptera and Lepidoptera. Seasonality will also be expected to impact abundance of certain orders. As the expedition took place in September and October at the end of the cold/dry season and moving into the hot/wet season, orders such as Isoptera (termites) would not be expected until after the first rains when they leave their underground burrows in the millions. As such, the low numbers of Isoptera is not unusual, even for an order that is usually commonly found in massive numbers in VMWR.

Although these results are based on a small sample size, they do show quite a variation in abundances and presence of orders overall. As the second year of surveys in conjunction with Biosphere Expeditions, these results continue to build on a growing body of data for VMWR. 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.

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 and follow-up 2019 expeditions, in particular to assess the new and interesting records of *Kerivoula lanosa, Myotis bocagii* and *Laephotis botswanae* bat species. ABC are commencing behavioural ecology research on these rare species to ascertain their habitat and foraging preferences to inform habitat and conservation management.

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 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

Malawi, one of the world's least developed and most densely populated countries, is dealing with extreme poverty, high population growth, and a rapid expansion rate and clearing of land for agriculture. As a result, habitat pressures allow the bushmeat and pet trades to have become a problem for primates, mainly vervet monkeys (*Chlorocebus pygerythrus*) and yellow baboons (*Papio cynocephalus*), as has been seen across primate species in Africa (Munthali and Mkanda 2002). This has led to the Lilongwe Wildlife Centre (LWC), Malawi's only wildlife rescue and rehabilitation facility, taking in hundreds of orphaned and injured primates. LWC's goal is to rehabilitate these animals for the purpose of releasing them back into the wild whenever possible. In 2012, LWT developed a Primate Release Programme (PRP) to ensure that all releases are done to the highest standard. The aim of LWT's PRP is to return groups of rescued and rehabilitated Malawian primates back into protected Malawian habitats where they will eventually be able to settle and sustain without direct human support, to actively improve the welfare of the release stock, enabling them to function normally and live self-sufficiently in their natural environment.

While vervet monkeys in Malawi are listed as Least Concern on the IUCN Red List (Kingdon et al. 2008), the LWT releases are strictly speaking welfare releases. LWT's release programme is one of the first primate release programmes to adopt the IUCN guidelines for primate welfare release (Beck et al. 2007). Since the start of the programme in 2012, LWC has conducted five troop releases, totalling over 100 individuals, of both vervets and yellow baboons, which have all been considered successful. All primates are rehabilitated at LWC in naturally replicated troops and assessed extensively pre-release to ensure their highest success post-release.

The success of a welfare release programme is based on the idea that the welfare of a wild animal in captivity is compromised when compared to that of wild conspecifics (Broom 2011). Therefore, the success of a welfare release should be measured in terms of increased welfare and therefore must determine welfare status pre- and post-release. LWT's PRP works to define these parameters and establish a precedent for scientific research on primate releases. The primary welfare indicators that are recorded are behavioural indicators such as stress, maintaining positive social relationships, expressing activity budgets closely matching those of wild conspecifics (based on previous studies), physical indicators measured by body condition, and life history indicators such as births, deaths, immigrations, and emigrations.

Data collected and information gathered during the release and post-release process will be able to better inform the scientific community, provide feedback on LWC's rehabilitation techniques, as well as inform other rehabilitation centres about primate release methods, which is still a small but growing body of knowledge (Armstrong and Seddon, 2007). Most importantly, data collected post-release will help us understand the changes in welfare for our troops and individuals. Expedition citizen scientists assisted the author in collecting these data.

5.2. Methods

Data collection

In March of 2019, LWT released a troop of 13 vervet monkeys into VMWR. This was the first release in VMWR for LWT (the others were previously in Kasungu National Park). Five adult monkeys were fitted with Very High Frequency (VHF) radio transmitter collars allowing the LWT research team to find and follow the troop every day (Figure 5.2a). Each collar emitted a specific frequency. Individual monkeys were identified by uniquely coloured eartags and physical characteristics. At the time of the expedition, there were six individuals still in the group (Table 5.2a). In the first three months of the release, three adult males emigrated from the troop and four adult females were predated.

Figure 5.2a. Adult male vervet monkey, Mr Poop, wearing a VHF radio collar.

Table 5.2a. Demographic details of the six individuals in the study group.

Name	Code	Sex	Age
Mr Poop	MP	Male	Adult
Kuti	KU	Male	Adult
Dexter	DX	Female	Adult
Thursday	TH	Female	Adult
Ghost	GO	Female	Juvenile
Leilo	LE	Female	Juvenile

During surveys of the troop, one individual was observed at a time for a 20-minute sampling period, using a combination of instantaneous and continuous focal sampling methods (Table 5.2b). All behaviours, determined by the ethogram (Appendix I), were recorded at one-minute intervals as event behaviours. Dominance, stress, and human-directed behaviours were recorded continuously whenever they occurred during the 20-minute focal observation. Social indicator behaviours (e.g. grooming) were recorded as one-zero occurrences continually during the focal sampling period. Each individual in the troop was sampled during each field session.

Table 5.2b. Recorded primate behaviours by recording method.

CODE	BEHAVIOUR	CATEGORY	RECORDING METHOD		
			Instantaneous	Continuous	One-Zero
G-	Grooming (allogrooming)	Social	X		X
G+	Grooming received	Social	X		X
PR-	Presenting to another	Social	X	X	
PR+	Being presented to by another	Social	X	X	
C	Contact	Social	X		
CL	Clinging	Social	X		
N	Nursing	Social	X		
SU	Suckling	Social	X		
PL	Playing	Social	X		X
MA	Mating	Social	X	X	
MO	Mounting	Social	X	X	
FE	Feeding	Feed	X		
FO	Foraging	Feed	X		
L	Locomotion	Other	X		
R	Resting	Other	X		
V	Vigilance	Other	X		
PA	Predator Avoidance	Other	X		
O	Other	Other	X		
OS	Out of Sight	Other	X		
A+	Aggression	Dominance	X	X	
A-	Receive Aggression	Dominance	X	X	
TH+	Threat	Dominance	X	X	
TH-	Receive Threat	Dominance	X	X	
MP+	Making place for focal individual	Dominance	X	X	
MP-	Making place by focal individual	Dominance	X	X	
SC	Scratching	Stress	X	X	
SG	Self-grooming (autogroom)	Stress	X	X	
YA	Yawning	Stress	X	X	
SM	Self-mutilation	Stress	X	X	
PC	Pacing	Stress	X		X
PH	Positive towards humans	Human	X	X	
AH	Agonistic towards humans	Human	X	X	

On the 0, 10 and 20 minutes of the focal period, a proximity scan was conducted. Each visible monkey in the troop was placed into an approximate distance category (<1 m, 1-5 m, 5-10 m, >10 m) from the focal individual, based on the observer's visual estimate. These data can then be used during analysis to create a social network web indicating relationships and cohesiveness.

During each focal period and at every full hour, the GPS coordinates of the troop were recorded. These data contribute to measuring the establishment of a home range. When the troop was first found for each field session, a census of the animals present was taken. If an animal was missing, extra effort was put in to find that animal.

Data analysis

Activity budgets were determined by calculating the percentage of each individual's and the whole troop's time spent performing each recorded behaviour. This percentage was calculated by dividing the total occurrences of each behaviour by the total number of all observed behaviours. These data were taken from the instantaneous focal observations. Detailed behaviours were aggregated into five main categories, Feeding, Locomotion, Resting, Social and Vigilance. These are standard categories across primate research for analysing activity. Feeding comprised of 'foraging (FO)' and 'feeding (FE)'; Social combined 'grooming (G-, G+, SG)', 'presenting (PR-, PR+)', 'playing (PL)', 'mating (MA)', 'mounting (MO)', 'aggression (A-, A+)', 'threatening (TH-, TH+)' and 'making place (MP-, MP+)'.

Social Network Analysis was conducted using the proximity scan data (physical distance) through the program Gephi. Associations were weighted on a scale of 1-4 mirroring the recorded categories of distance between individuals. Distance was categorised as 'undirected' as both the focal individual and the associated individual serve as actors in determining their own physical distance to one another. Multiple data points between the same individuals were aggregated.

5.3. Results

The troop spent most of its time being vigilant (37%), followed by feeding (28%) and travelling (18%) (Figure 5.3a). Resting made up little of their activity at only 0.4%. Activity budgets broken down by sex reflect similar results (Figure 5.3b). Females displayed more of each behaviour than males, except when it came to Feeding, where males spent over 5% more time.

Social Network Analysis indicated that adult male Kuti (KU) was the least central member of the troop and Mr. Poop (MP) was the most (Figure 5.3c). MP and juvenile female Ghost (GO) were in closest proximity to each other most often. As the resulting graph shows, MP was the most central figure in this troop.

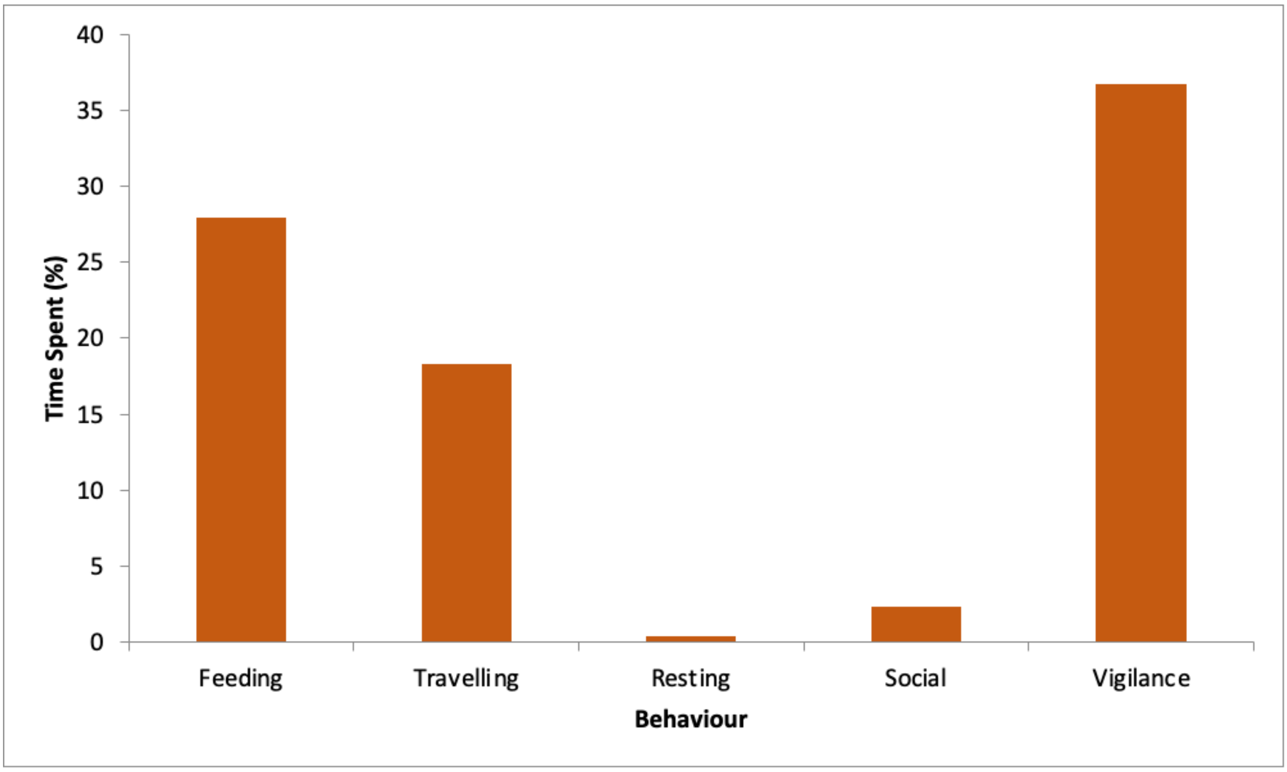

Figure 5.3a. Activity budget of the vervet study troop.

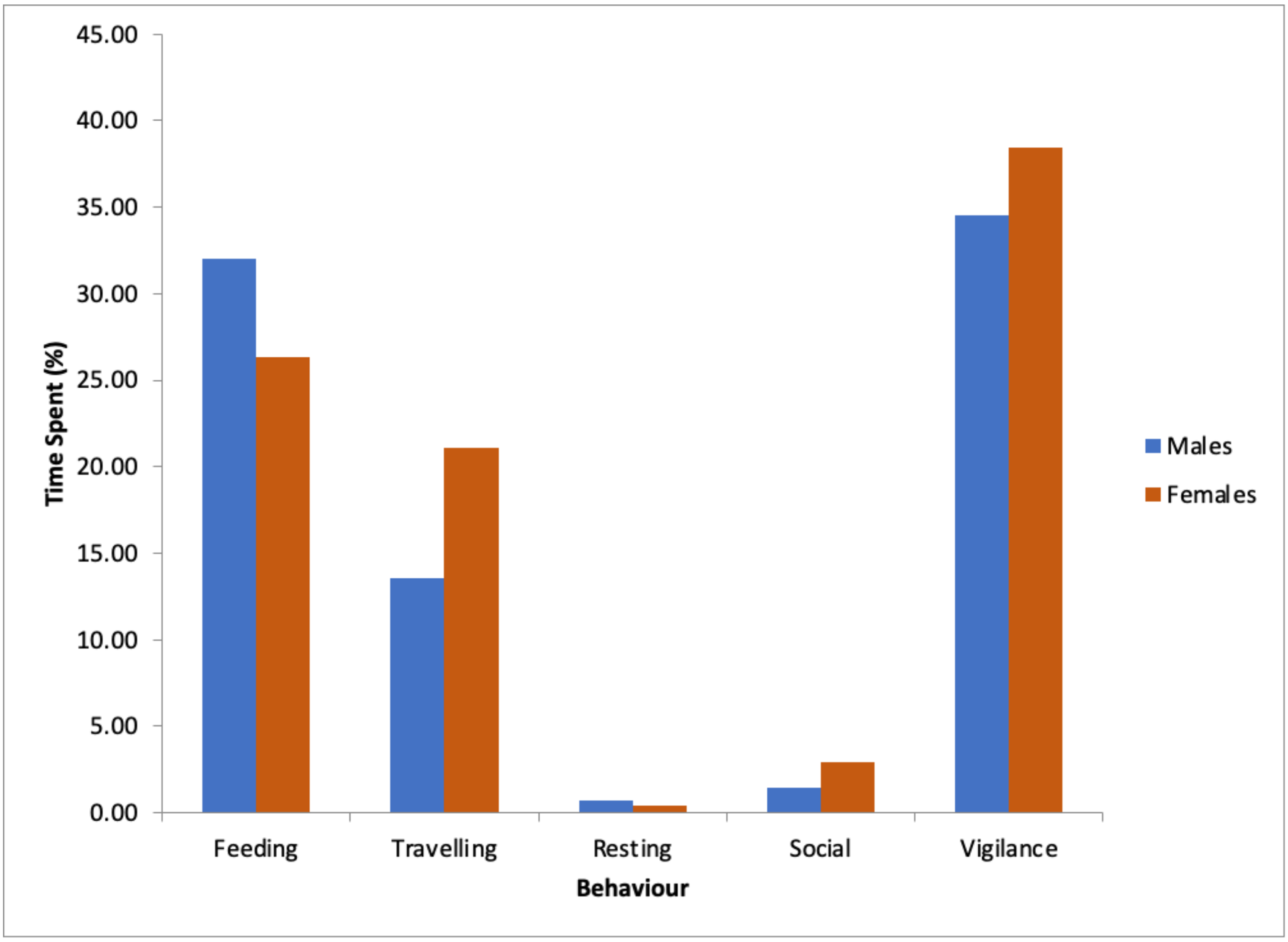

Figure 5.3b. Activity budget broken down by sex.

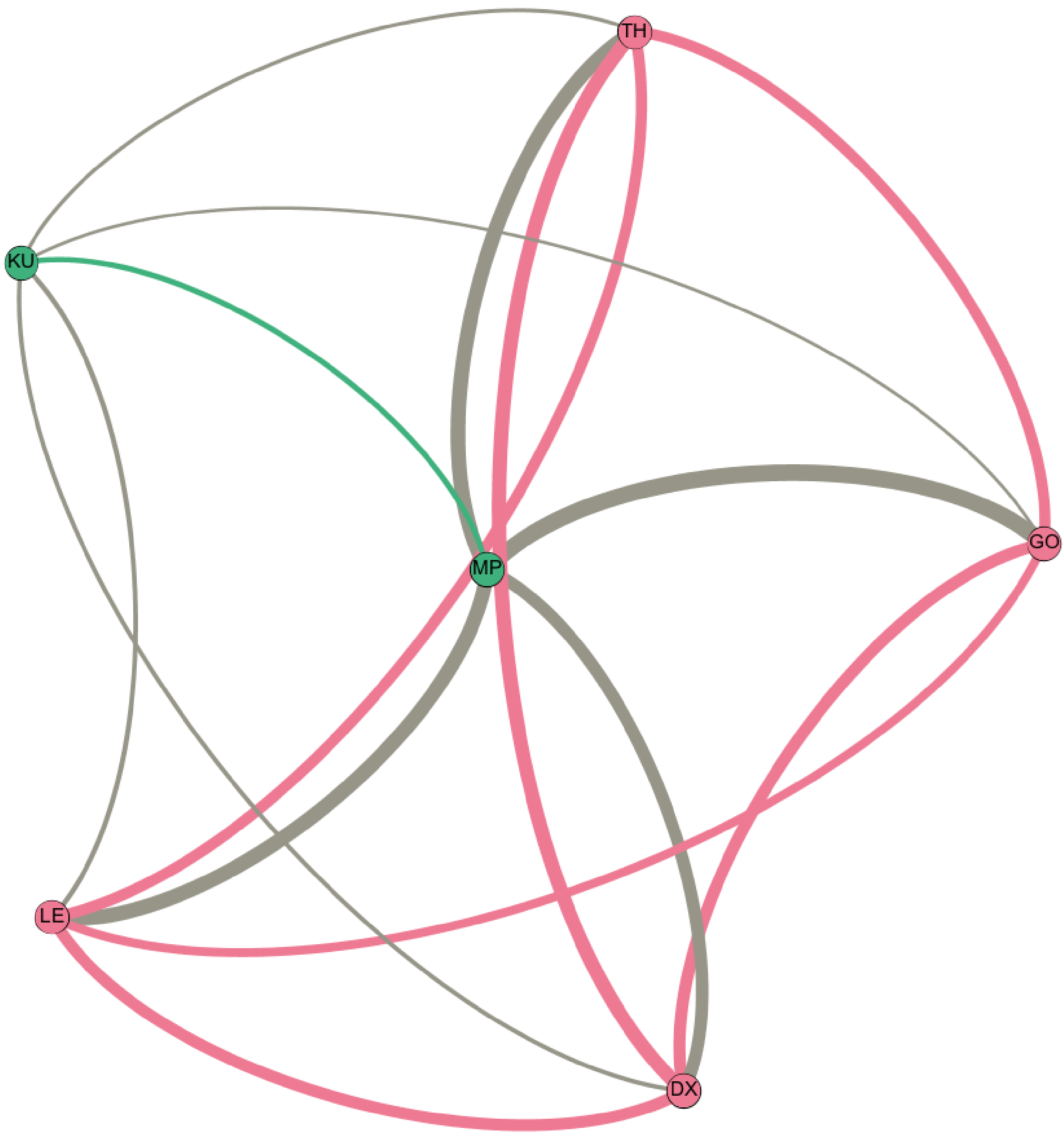

Figure 5.3c. Social Network Analysis of the vervet study troop.
Thicker lines indicate closer physical distance.
Colours differentiate male (green) and female (pink).

5.4. Discussion and conclusions

The activity budget of this troop is consistent with both previous release troops as well as wild studies (Brennan et al. 1985, Isbell and Young 1993). Feeding and travelling together present the majority of behaviours recorded. This is as expected, especially during the dry season as animals need to move farther and forage more to find food. Results for resting were less than expected as this time of year is very hot and most animals rest in the heat of the day. This may be attributed to the fact that we observed this troop mostly in the early morning and late afternoon when the temperatures were lower. Resting and vigilance also go hand in hand as monkeys will often be resting, but also maintain a level of vigilance. Vigilant was the behaviour recorded most, as was expected. This is a good sign for a released troop as they are unused to the changes and threats of a wild and dynamic environment, and thus must remain vigilant more than natural wild troops.

We see that males spent more time foraging/feeding, likely to support their larger weights. Interestingly, females also engaged in more vigilant behaviour, which is usually predominantly in males. It is a good adaptation that the core of the troop is being so vigilant, especially after three early deaths in the troop within one month post-release and with so few adult males, the females must take on this responsibility. The frequent demonstrations of vigilance indicate a positive longevity for this troop.

The social network analysis based on the physical distance kept between individuals corroborate what we would expect based on the dynamics observed of this troop. MP is the most central figure in the troop, which reflects his status as alpha male and leader. Kuti is confirmed to be more on the outskirts of the troop. This is consistent with what we observe in the field, as Kuti is often not even seen by the researchers. He prefers to stay farther away from humans than the other members of the troop do and is often not seen for days, perhaps indicating that he leaves the troop for periods of time. The relationships between the females are stronger than those between the males, meaning that the core of the group is close-knit and remains strong after 6-7 months since being released. MP's close relationship with GO is surprising as adult males are usually not that close to juvenile females. However, GO is the daughter of the alpha female, so it is interesting that her dominance status even as a juvenile and without the presence of her mother, remains high and close to the alpha male.

5.5. Outlook for future expedition work

The data collected during the expedition will be combined with the data LWT researchers have been collecting since the troop was released in March. This larger dataset will be analysed on its own, compared to data collected pre-release, and combined with release data from other years to create a much larger dataset. These cumulative datasets are being analysed and modelled for welfare, activity budgets, social network analysis, dominance relationships, and troop survival. We are currently performing this analysis and preparing the data for peer-reviewed scientific publication. The Lilongwe Wildlife Centre is also currently preparing another vervet troop of 23 individuals for released in early 2021. They are in their pre-release phase where they are being monitored and data are being collected. We plan to continue our primate release research to continue to build our dataset, in order to make robust conclusions about the nature of welfare releases to inform both our own release strategies and those of other wildlife centres.

5.6. Literature cited

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Appendix I: 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 II: Expedition diary, reports and resources

Project updates, reports and publications:
https://www.researchgate.net/project/Malawi-Monitoring-and-protecting-wildlife-of-Vwaza-Marsh-Wildlife-Reserve-through-citizen-science

All expedition reports, including this and previous expedition reports:
https://www.biosphere-expeditions.org/reports

Expedition diary/blog:
https://blog.biosphere-expeditions.org/category/expedition-blogs/malawi-2019/

Pictures, videos, media coverage of the expedition:
https://www.biosphere-expeditions.org/malawi