Earthwatch Annual Report- 2018 Fielding Season

Monitoring, understanding and managing the impact of large scale mammal re-introductions in Majete Wildlife Reserve, Malawi.

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DISCLAIMER/AUTHORS’ NOTE

The Majete Wildlife Research Programme is an independently run research programme based at the Department of Conservation Ecology & Entomology, Faculty of Agrisciences, Stellenbosch University, South Africa. The research programme is being undertaken in collaboration with African Parks (Pty) ltd. The research programme is partially funded by the Earthwatch Institute.
To all our wonderful volunteers through 2018....

Yet another fantastic season has come to an end.....however, the “Animals of Malawi” fielding season will continue in 2019, wrapping up just before Christmas. We really had a wonderful 2018, from a research point of view. Every day in 2018 brought new sights, sounds and challenges, and as always it was wonderful having all you volunteers on board and being able to share our humble research home with you. You dug deep, worked incredibly hard and in so doing rewarded us with a mountain of scientific data that we are still ploughing through!

Even after all this time in the field we are constantly humbled by the splendour of our surroundings. Nature sure has a way of lending the observer perspective in this regard!

The 2018 field season brought much joy and also sometimes difficult challenges, as is expected when carrying out the work we do in any isolated area. Through all of this, you, the volunteers, were there, helping us maintain a high standard of science and lending us support in countless different ways. For this we say a huge “thank you”.

Some highlights with regards to African Parks, Majete in 2018. Thirteen giraffe joined the wildlife family - a first for Majete and they have settled down very well indeed. The two large male lions (Sapitwa and Chimwala) were translocated to Liwonde National Park and were replaced by three gorgeous females and two handsome young males. All part of the lion management programme conducted by African Parks. And there is rumour of another rhino calf (or two!).

Wesley and Sally have had an excellent year in the field and their projects are progressing well (see their progress reports that follow below). For those of you who fielded in 2017, Anel Olivier who was studying the ecology of black rhino, graduated successfully with an MSc degree in December 2018 and Kayle Geenen is also currently wrapping up her thesis write-up and will graduate mid-2019.

Apart from all the endless hours you spent assisting us in the field, thank you too for your generous donations of batteries for our camera traps and especially for all the school donations. Together we made a few hundred school children smile a little more, never to be forgotten, and they in turn put a smile on our faces.

Remember to keep an eye on our projects Facebook page - for research updates, unusual animal sightings and behavior...and more.

From the bottom of our hearts, we would like to thank you all for joining our project, for being such an intrepid bunch and especially for giving back more than you took...

We hope you will join another of our teams....or tell a friend (or 10!) about the Animals of Malawi expedition.

Many thanks from all of us!

Alison, Sally, Wesley & Fleur
SUMMARY

Provide a brief (3-5 sentences) summary of outcomes for this fielding year.

- African Parks introduced 13 giraffe to Majete Wildlife Reserve - 9 from South Africa and 4 from Nyala Park in Malawi and 5 additional lions were re-introduced, 3 females and 2 young males.
- The research team hosted 8 Earthwatch teams, including 37 volunteers from all over the world.
- 2 master students completed their field work in 2018, one of whom graduated in December 2018: i) Ecology of Black rhino (*Diceros bicornis*) in Majete Wildlife Reserve, by Anel Olivier who graduated, ii) The impact of herbivores on vegetation surrounding artificial waterpoints in Majete Wildlife Reserve, by Kayla Geenen who will graduate in mid-2019.
- PhD candidate, Katharina Von Durckheim (Olfaction in African elephants) will also graduate in 2019.
- 2 new masters projects commenced: i) Demography, spatial use patterns and reaction to a drone of African elephants (*Loxodonta africana*) in Majete Wildlife Reserve, Malawi, by Wesley Hartmann, ii) Species richness and spatial use patterns of medium and large mammals in Majete Wildlife Reserve, Malawi.
- 7 schools were visited during the fielding season.
- A highlight was a visit to Kenya by the PI and a PhD student in September 2018. The team visited Tsavo, Amboseli and Samburu Nationals Parks. The visit was to meet with the Save the Elephants (STE) research team and to get the Majete translocated elephants onto the STE database. See the attached article.

GOALS, OBJECTIVES, AND RESULTS

Objective #1. Assessing and modeling the population dynamics of various re-introduced herbivore species.

Monitoring of populations of the various herbivore species will provide the data necessary for the development of models that can be used to make predictions about the impacts of potential future management interventions, for example, the removal of excess herbivores from Majete for further re-stocking programs elsewhere. This greater project commenced in June 2013 with an initial focus on the population ecology, distribution and diet of impala and waterbuck within the reserve. These two species are so called “aggressive” species as they are very successful, currently rapidly increasing in numbers and thriving in the park. This study was completed by Kate Spies in 2015.

The following is the link to the completed thesis which is available from Stellenbosch University’s library: [http://hdl.handle.net/10019.1/101508](http://hdl.handle.net/10019.1/101508)

A follow-up project under this objective was undertaken by Charli de Vos and involved studying the ecology of zebra in Majete. Charli completed her studies in 2017 and graduated with an MSc in Conservation Ecology.

The following is the link to the completed thesis which is available from Stellenbosch University’s library: [http://hdl.handle.net/10019.1/102624](http://hdl.handle.net/10019.1/102624)

A new MSc project commenced in March 2018, entitled: Species richness and spatial use patterns of medium and large mammals in Majete Wildlife Reserve, Malawi. This project is being undertaken by Sally Reece and is due to be completed by December 2019. Please see the most recent progress report below:
INTRODUCTION

The human population in many African countries is predicted to double in the coming decades, posing a threat to biodiversity due to expanding settlements and land use changes (United Nations 2017). African wildlife finds itself increasingly confined to Protected Areas (PAs) whose connectivity is set to decrease as human populations expand in the already fragmented landscapes (Newmark 2008; Lindsey et al. 2014; Tobler et al. 2015). The ability of PAs to function independently and sustain viable populations of wildlife is therefore becoming increasingly important for biodiversity conservation. The increasing isolation of PAs in the landscape calls for their more intensive management, and an urgent need for understanding the variables driving mammal’s spatial use patterns.

Within each of these PAs, medium and large mammal space use is a function of its unique environmental and anthropogenic characteristics (Rich et al. 2016). This space use by medium to large mammals in turn can highlight areas of ecological importance for sustaining biodiversity (Rich et al. 2016). It is thus important to measure the spatial use of medium and large mammals in PAs, as well as to understand the ecological and anthropogenic drivers of this spatial use. This information can guide conservation strategies, and highlight anthropogenic impacts on biodiversity (Yoccoz et al. 2001; Tobler et al., 2008). Majete Wildlife Reserve in Malawi is an
isolated protected area that lies in a mosaic of rural settlements and agricultural land use, as can be seen in Figure 1. A comprehensive understanding of how all the medium and large mammals use this landscape is unknown, as are the variables that drive their space use patterns.

This study aims to fill the knowledge gap at Majete, and provide data that will assist management to secure the future of the reserve’s medium to large mammal populations in its isolated position in the larger landscape.

A method available to obtain the information is through camera trapping, which is becoming an increasingly popular tool for mammal surveys (Mackenzie & Royle 2005; Tobler et al. 2008; Tobler et al. 2015; Rich et al. 2017b). Using camera trap data, researchers are able to estimate the occupancy, richness and abundance of medium to large mammals. Occupancy as a state variable examines whether a species is present at a site or not, and is highly suitable for studying broad-scale species distribution patterns (Mackenzie & Royle 2005; Tobler et al. 2015). Species richness is frequently used to evaluate the impacts of management interventions or anthropogenic disturbance on biodiversity (Yoccoz et al. 2001; Tobler et al. 2008). This study will use camera traps to generate data on medium and large mammal species presence and absence across the landscape of MWR. These data will then be used to investigate the species richness and space use of the medium and large mammals in relation to ecological and anthropogenic characteristics at MWR.

Figure 1. Land cover of Majete Wildlife Reserve and surrounding landscape (African Parks Majete (Pty) Ltd., 2015)
The research questions for this study are as follows:

- What are the occupancy patterns of the medium and large herbivores and the large carnivores across the landscape of MWR?
- What are the species richness patterns of the medium and large herbivores and the large carnivores across the landscape of MWR at broad and fine scales?
- How do environmental and anthropogenic variables influence the observed occupancy and species richness patterns?
- How does species richness and occupancy of the medium and large herbivores and the large carnivores in MWR vary seasonally?

**METHODS**

The entire reserve was surveyed over one dry season (June - December 2018) and over one wet season, which is currently underway. Cuddeback X-Change™ Color Model 1279 camera traps each with a colour strobe flash are being used. The 700 km² area of MWR was divided into three blocks of 233 km² each and each was surveyed on a 40-day rotational basis. A camera was placed at the centre of each grid cell facing an animal trail and left in place for 40 days. Figure 2 shows the 5 km² grid overlaid over the reserve and the location of each camera point, along with the location of the three rotations. The road network is also indicated. Cameras were set to take three photographs at every trigger event, with a 30 second interval between new trigger events. Rotating cameras to new sites is more effective for measuring species richness and detecting rare species than leaving cameras at fewer sites for longer periods (Mackenzie & Royle 2005; Si et al. 2014).

The following predictor variables can drive medium and large herbivore, as well as large carnivore, distribution and abundance: Vegetation type, vegetation cover, vegetation density, distance from water, distance from reserve boundary, distance from release site of reintroduced species, relative predator abundance, relative prey availability and relative competitor abundance. Vegetation density and cover were measured at each site when deploying cameras with the remaining variables calculated as a desktop study using Quantum GIS analysis tools.

![Figure 2. A map of the reserve indicating the grid overlay with camera placement, the road network and the location of the three 40-day rotation cycles](image-url)
PRELIMINARY RESULTS

As the wet season survey is currently underway, all results refer only to the dry season survey. A full analysis including a modelling process is to be conducted on the data in March 2019, and so the results represent broad outcomes from the dry season survey as they currently stand.

A total of 140 camera trap sampling points were surveyed between June and December 2018. The study accumulated 5457 camera days of the expected 5600 camera days. Of the 140 sampling points, seven did not yield full data sets as they were either disturbed by an elephant or batteries ran flat and SD cards filled due to false triggers. A total of 119454 images were captured and after filtering for dud and repeat images, 45210 images were processed, of which 12201 were independent observations of target species. Thirty six species were recorded of which 23 are target species. Table 1 shows the species captured as well as the number of captures of each and their capture frequencies (average number of captures per 100 trap days).

Table 1. The species captured within the dry season survey, the number of times they were captured by cameras and the capture frequency

<table>
<thead>
<tr>
<th>Genus</th>
<th>Species</th>
<th>Common name</th>
<th>Number of captures</th>
<th>Capture Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orycteropus</td>
<td>afer</td>
<td>Aardvark</td>
<td>86</td>
<td>1.61</td>
</tr>
<tr>
<td>Lepus</td>
<td>victoriae</td>
<td>African savannah hare</td>
<td>14</td>
<td>0.26</td>
</tr>
<tr>
<td>Papio</td>
<td>cynocephalus</td>
<td>Baboon</td>
<td>607</td>
<td>10.97</td>
</tr>
<tr>
<td>Diceros</td>
<td>bicornis</td>
<td>Black rhinoceros</td>
<td>47</td>
<td>0.85</td>
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<tr>
<td>Syncerus</td>
<td>caffer</td>
<td>Buffalo</td>
<td>626</td>
<td>11.33</td>
</tr>
<tr>
<td>Tragelaphus</td>
<td>scriptus</td>
<td>Bushbuck</td>
<td>562</td>
<td>10.31</td>
</tr>
<tr>
<td>Potamochoerus</td>
<td>larvatus</td>
<td>Bushpig</td>
<td>122</td>
<td>2.31</td>
</tr>
<tr>
<td>Caracal</td>
<td>caracal</td>
<td>Caracal</td>
<td>10</td>
<td>0.18</td>
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<tr>
<td>Civettictis</td>
<td>civetta</td>
<td>Civet</td>
<td>70</td>
<td>1.27</td>
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<tr>
<td>Sylvicapra</td>
<td>grimmia</td>
<td>Common duiker</td>
<td>460</td>
<td>8.34</td>
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<tr>
<td>Redunca</td>
<td>arundinum</td>
<td>Common reedbuck</td>
<td>55</td>
<td>1.02</td>
</tr>
<tr>
<td>Tragelaphus</td>
<td>oryx</td>
<td>Eland</td>
<td>192</td>
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</tr>
<tr>
<td>Loxodonta</td>
<td>africana</td>
<td>Elephant</td>
<td>267</td>
<td>4.85</td>
</tr>
<tr>
<td>Alcelaphus</td>
<td>lichtensteinii</td>
<td>Lichtenstein’s hartebeest</td>
<td>160</td>
<td>2.88</td>
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<td>Hippopotamus</td>
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<td>Hippopotamus</td>
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<td>capensis</td>
<td>Honey badger</td>
<td>3</td>
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<td>melampus</td>
<td>Impala</td>
<td>1100</td>
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<td>Klipspringer</td>
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<td>strepsiceros</td>
<td>Kudu</td>
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<td>Genetta</td>
<td>maculata</td>
<td>Large-spotted genet</td>
<td>37</td>
<td>0.69</td>
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<tr>
<td>Species</td>
<td>Common Name</td>
<td>Average captures per 100 trap days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Panthera pardus</td>
<td>Leopard</td>
<td>43</td>
<td></td>
<td></td>
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<tr>
<td>Panthera leo</td>
<td>Lion</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tragelaphus angasii</td>
<td>Nyala</td>
<td>165</td>
<td></td>
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<tr>
<td>Smutsia temminckii</td>
<td>Pangolin</td>
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<td></td>
<td></td>
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<tr>
<td>Hystrix africaeaustralis</td>
<td>Porcupine</td>
<td>140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hippotragus niger</td>
<td>Sable antelope</td>
<td>773</td>
<td></td>
<td></td>
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<tr>
<td>Leptailurus serval</td>
<td>Serval</td>
<td>19</td>
<td></td>
<td></td>
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<tr>
<td>Raphicerus sharpei</td>
<td>Sharpe's grysbok</td>
<td>64</td>
<td></td>
<td></td>
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<tr>
<td>Canis adustus</td>
<td>Side-striped jackal</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Galerella sanguinea</td>
<td>Slender mongoose</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crocuta crocuta</td>
<td>Spotted hyena</td>
<td>83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Otolemur crassicaudatus</td>
<td>Thick-tailed bushbaby</td>
<td>1</td>
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<tr>
<td>Chlorocebus pygerythrus</td>
<td>Vervet monkey</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phacochoerus africanus</td>
<td>Warthog</td>
<td>3508</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kobus ellipsiprymnus</td>
<td>Waterbuck</td>
<td>1268</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equus quagga</td>
<td>Plains zebra</td>
<td>598</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3 shows the capture frequency of the species observed. A mean of 11 species was recorded per station with a range of 0 - 23 species. The number of sightings and capture frequencies per species varied, with number of sightings of individual species ranging between 0 - 3508. Capture frequencies ranged between 0.1 - 64 captures per 100 trap days (mean 6.52).
A naïve occupancy estimate is shown in Figure 4, which illustrates how evenly the animals captured on the cameras are distributed across the reserve. These results show kudu and warthog to be most evenly distributed across Majete, followed by sable antelope, baboon and common duiker. With regards to the carnivores, spotted hyena has the most captures and is distributed more widely across the reserve compared to leopard, followed by lion.

This naïve estimate does not take into account possible imperfect detection at each camera station, i.e. simply because a species was not captured at a site, does not mean it is absent from a site, which the modelling process will account for.

**FURTHER ANALYSES**

Comprehensive analyses to determine species richness and occupancy across the reserve will be conducted in March 2019, with the following methods:

**Species richness at varying scales**

Species richness will be determined for the medium and large herbivores and large carnivores and will be assessed firstly across the entire reserve and secondly based on vegetation type and other fine scales, which will identify biodiversity hotspot areas.
Occupancy

The reasons for herbivore and carnivore distribution will be estimated by comparing the capture frequencies and detection probabilities of each species in relation to environmental and anthropogenic predictor variables. Multi-species occupancy modelling will then be conducted using PRESENCE (Bailey et al. 2007) whereby presence/absence data, the camera station environmental covariates and the survey covariate data- the wet or dry season, will be modelled to produce species-specific site occupancy estimates and create distribution maps for the herbivores and carnivores, in a similar manner as to those seen from another study shown below in Figure 5.

![Figure 5. An example of occupancy maps which were produced for a study in Costa Rica by Ahumada et al. (2013).](image)

The completed thesis will be available in early 2020.

REFERENCES


Objective #2. Implementation of a predator monitoring program to assess the species success and their impact on various prey species.

This project was initially started by African Parks when the first four leopards were introduced in 2011. These leopards were collared with satellite collars and released. An additional two leopards were collared and re-introduced in early 2012 and towards the end of 2012, three adult lions, of which two were satellite collared, were also re-introduced into Majete. GPS data were collected from the animals on a daily basis. However, by mid-2013 all but one remaining collar had stopped working (battery life depleted). In October 2013 a trapping session was conducted and collars were removed from three leopards. These were the individuals that were tagged/collared as sub-adults and had subsequently grown, so this had to be done so as to avoid the collars becoming too tight. We currently have a very large on-going database with all the satellite data and camera trap photographs. Additionally, Willem Briers-Louw commenced with a new predator ecology study in early 2016 which was successfully completed at the end of 2017.

The following is the link to the completed thesis which is available from Stellenbosch University’s library (http://hdl.handle.net/10019.1/102619)

Some of the work was published online at the end 2018 and in hard copy in January 2019. See publications section below and attached PDF.

However, this larger predator study is a long-term research project which will continue focusing on predator/prey associations, home-range overlaps and the interactions between lions, leopards and hyenas, as all these factors change regularly. This is crucial to understand particularly when competing top predators are confined to small to medium sized fenced areas. The current and newly introduced lions were monitored by African Parks staff in 2018. Additionally, Sally Reece’s project mentioned above under Objective #1, is also looking at the occupancy patterns and species richness patterns of the large carnivores across the landscape of Majete Wildlife Reserve and what variables may influence these patterns.
Objective #3. Determining the impact of megaherbivores (elephant, buffalo and rhino) on the habitat.

This project commenced in 2011 with a student from Stellenbosch University studying the “Woody vegetation change and elephant water point use in Majete Wildlife Reserve: implications for water management strategies”. The project was completed at the end of 2013 (cut and paste the following link: http://scholar.sun.ac.za/handle/10019.1/85753). A new project, undertaken by Frances Forrer commenced in 2015, and was completed in December 2016 (cut and paste the following link: http://scholar.sun.ac.za/handle/10019.1/101294)

In 2017 two further megaherbivore projects commenced in Majete.

1. The Ecology of Black rhino (Diceros bicornis minor) in Majete Wildlife Reserve, Malawi. By MSc candidate, Anel Olivier which was completed in 2018 (see the link to abstract/thesis under Objective #5 below).

2. Olfaction and kin recognition in African elephants (Loxodonta africana). By PhD candidate Katharina Von Dürckheim.

   Please see the below PhD proposal and first published paper PDF.

   A pachyderm perfume?

   Olfaction and scent discrimination in African elephants

   PhD candidate: Katharina Von Dürckheim.

1. Problem statement

Scientific research on olfaction and chemical communication in African elephants (Loxodonta africana) is scant. Peer-reviewed research on Asian elephants (Elephas maximus) - a different Genus - is limited to one author (Rasmussen). This research suggests that Asian elephants utilize their olfactory senses during fundamental, life-strategy decisions (Rasmussen & Krishnamurthy, 2000; Rasmussen 1988; Rasmussen, 1995, Rasmussen & Schulte, 1995). Studies demonstrate how exudates such as pheromones and chemical signals in breath, urine, and temporal glands are fundamental to elephant behaviour and communication. Rasmussen further suggests that chemical signals play an important role in the establishment, determination and maintenance of familial and non-related proximate relationships (Rasmussen & Krishnamurthy, 2000). Elephants live in highly complex multi-tiered fission fusion societies. Yet it is unknown whether olfactory signals are closely correlated enough with relatedness to be sensitive cues for phenotype matching and kin selection and discrimination.

This study proposes to test whether elephant body odours signal genetic information that may confer considerable benefits including inbreeding avoidance and altruism. Results will establish to what extent olfaction may play a role in kin recognition and discrimination - a novel contribution to elephant ecology and evolution.

2. Rationale

Most vertebrates recognise close relatives (kin recognition) to avoid mating with them or to identify them as recipients of nepotistic behaviour (kin discrimination). In the scientific literature, social learning and olfactory imprinting are largely credited with kin recognition, whereas discrimination of unfamiliar kin defies explanation via associative learning. Sex-biased dispersal in long-lived species such as elephants cannot prevent encounters with familiar kin. Mechanisms to avoid inbreeding with familiar kin are not fully understood. Much research has
focussed on whether animals, from rodents to primates, utilise olfactory imprinting as a tool to avoid inbreeding with genetic relatives or whether animals use phenotype matching. Phenotype matching has been demonstrated in other vertebrates, and the use of olfactory cues explored (Brown & Eklund, 1994; Manning et al., 1992; Zelano & Edwards, 2002). Research from 35 years of observational and genetic data on African elephants in Amboseli, Kenya, shows that African male elephants not only avoid breeding with natal kin but with paternal kin (Archie et al., 2007), suggesting that males may be using phenotype matching to identify kin.

There is a growing body of evidence that odours signal genetic information that may confer considerable benefits including inbreeding avoidance and nepotism. As well as signalling sex and age, research suggests that differences in odour may signal genetic relatedness and heterozygosity. Individual odour similarities covary with genetic similarity, allowing animals to assess their genetic relatedness to one another by comparing the similarities between their individual odours. Studies on fur seals (Stoffel et al., 2015), lemurs (Boulet et al., 2009) kitiwakes (LeClaire et al 2012), otters (Kean et al, 2017), mice (Heth et al., 2001), Australian sea lions (Pitcher et al, 2015), humans (Wedekind et al., 1995) and hamsters (Heth, Todrank & Johnston, 1999) have demonstrated that the closer the genetic similarity between two individuals, the more similar the qualities of their individual odours. African elephants are an important group of mammals when investigating olfaction and chemical communication in vertebrates: Elephants have reduced eyesight and an increased reliance on a highly developed olfactory system. African elephants have the highest number of olfactory receptor genes of any mammal (Niimura et al, 2014) and display remarkable olfactory acuity (von Durckheim, 2018; Bates, 2007, Rizvanovic, 2013, Arvidsson, 2012, Miller et al., 2015).

3. Methodology

During an elephant translocation in 2017, 120 elephants were swabbed, and buccal, temporal and genital swabs were taken as well as blood for the DNA analysis. The Queller and Goodnight pairwise estimator was used for relatedness. GC-MS at CAF was carried out on all 360 swabs. Using the methods of Boulet et al, 2009, LeCLaire et al, 2012 and Stoffel et al, the covariance between relatedness and odour is being investigated.

The PI has further done the relatedness analysis on 12 domestic elephants. Urine and dung will be collected from the elephants and tested for covariance, as the PI could not access urine and dung during the translocation. The urinary signature will further be investigated for type and strength of signal over a four day period. Lastly, behavioural trials will be conducted with a subset of these elephants. They have already been trained to match human skin scent to sample in what is known as a Matching To Sample protocol, used for training elite canine forensic units (von Durckheim et al, 2018). The PI will build on this training and test the elephants’ ability to match elephant odour samples to target, including urine, dung, temporin and breath. PI will also be joined by an international elephant infrasound expert to record elephant behaviour during trials.

4. Scientific contribution (stand-alone papers)

A novel investigation using Odour Gene Covariance (or chemical fingerprinting) into whether odour cues in temporin, breath, genitalia, urine or dung contain cues for relatedness, and the implications for kin recognition in African elephants.

Novel contributions into the olfactory ability of elephants in phenotype matching as an olfactory mechanism in kin selection and recognition.

Population structure of a translocated population and the implications for management and welfare.

Fission/fusion of ten matriarchs post translocation and fine scale habitat use in a novel environment.
Possible collaboration with MHC and MUP global experts to characterise these section of the elephant genome.
(References upon request)

A new project commenced in 2018 entitled: Demography, spatial use patterns and reaction to a drone of African elephants (*Loxodonta africana*) in Majete Wildlife Reserve, Malawi, by Wesley Hartmann.

Please see the progress report below:

**Demography, spatial use patterns and reaction to a drone of African elephants (*Loxodonta africana*) in Majete Wildlife Reserve, Malawi.**

By MSc candidate Wesley Hartmann

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**Introduction**

Detailed demographic data for wildlife species with high economic- and conservation-value are sparse (Gaillard *et al.* 1998), and often information from multiple populations does not exist, with only a single population providing all current knowledge (Gaillard *et al.* 2000). Ultimately, our understanding of life history strategies across species and ecological systems is lacking, resulting in a limited ability to evaluate demographic responses to both anthropogenic pressures and ecological changes (Stockwell *et al.* 2003; Owen-Smith *et al.* 2005; Wittemyer *et al.* 2013).

The African elephant (*Loxodonta africana*) is one wildlife species which has been better studied, which is no coincident, as the African elephant is a keystone species (Power *et al.* 1996), thus playing a significant role in the diversity of the habitat it occupies (Dublin *et al.* 1990; Pringle 2008; Blake *et al.* 2009; Wittemyer *et al.* 2013). It is therefore no understatement that the state of elephant populations is vital to the health and integrity of the ecosystem in which they exist (Laws 1970). Both conservation and management authorities alike require
comparative data on populations experiencing a wide array of pressures to determine differences in population status and response to human influences (Wittemyer et al. 2013).

A considerable anthropogenic influence experienced by/exerted on wildlife populations is that of translocation events. A major reintroduction event recently occurred in Malawi. A total of 524 elephants (154 elephants from Majete Wildlife Reserve and 370 elephants from Liwonde National Park) were reintroduced to Nkhotakota Wildlife Reserve (NWR). Traditionally, sink populations are often monitored closely and the effects of translocation events on animal welfare studied intensely (Skarpe et al. 2004; Millsbaugh et al. 2006; Willems study; IUCN, 2013). Gregarious species, such as the elephant, in source populations may suffer stress if the removal of key individuals disrupt well defined social hierarchies and relationships (Gobush et al. 2008; Silk et al. 2010; IUCN, 2013). Additionally, source population demographics are rarely studied post-translocation and yet they provide an opportunity to fill the hole of demographic responses to anthropogenic influences.

The removal of 154 has provided an opportunity to reassess the demographics of the elephant populations within Majete Wildlife Reserve. As a species of high conservation concern and extreme life history strategy, with the longest mammalian gestation period (as well as long reproductive life), understanding the demographic status and response to different human pressures and ecological conditions is invaluable for theoretical and practical applications (Wittemyer et al 2013). Simultaneously, an opportunity has been provided to investigate the movements/spatial use patterns of the remnant population.

The development and use of new technologies have greatly aided the wildlife sciences. Examples of such benefits include motion triggered camera traps (O’Connell et al. 2011), aircraft (Fleming and Tracey 2008), remote sensing satellites (Kerr & Ostrovsky 2003), radar (Larkin 2005), thermal cameras (O’Neil et al. 2005), projectile-based animal capturing devices and chemical immobilization agents (Roffe et al. 2005; Schemnitz 2005), and a vast number of electronic animal tracking devices, as well as all of the accompanying software (Thomas et al. 2011). Unmanned aircraft systems (UAS), unmanned aerial vehicles (UAV), remotely piloted aircraft systems or, popularly known as ‘drones’ promise to offer further assistance to conservation efforts and the wildlife sciences. The timely, repeatable, and unobtrusive manner in which drones are able to collect very high-resolution aerial data as well as its ability to access areas that are difficult to observe via foot are enabling drones to find new ways to be utilized in the civil sector. Chabot and Bird (2015) conducted an extensive review of the applications of drones in wildlife management, in which they highlighted optical surveying and observation of animals; uses in autonomous wildlife telemetry tracking; habitat research and monitoring; as well as a review of the broader potential for UAVs. While the capabilities and potential practical uses of drones in the field of wildlife and conservation biology has been investigated thoroughly their effects on the subjects of the studies (i.e. the animals) has been investigated to a much lesser extent.

The following study investigated the current population demographic structure of Majete Wildlife Reserve’s elephant population, one-year post translocation event, in an attempt to better understand how source elephant populations respond to large scale translocation events both demographically and spatially. Additionally, I aim to assess the effects of drones on African elephants. Whilst the African elephant is a species whose demographic data (Kioko et al. 2013; Wittemyer et al. 2013), as well as behavior (Douglas-Hamilton 1972) and ecology, (Douglas-Hamilton 1972; van Aarde et al. 2006) have been studied in great detail, there is a clear need for guidelines as to how to conduct drone research focusing on elephants. The protocols developed in this study can be used to ensure the minimum amount of stress is induced when utilizing drones for elephant related research.
Objective 1: The Demography of the remnant elephant population

The objectives of this chapter include: i) to determine how the size of the elephant population in MWR changed since its last intensive census in 2015, and ii) to determine how the population’s age/size class and sex structure changed since its last intensive census in 2015? (Number of males and females, number of infants, calves, juveniles and adults).

Population Size, Class- and Sex-Ratio

Methods:

The majority of individual elephants needed to be identified in order to determine the current size, age structure and sex ratio of the elephant population found within MWR. Two primary methods were used to sample the MWR elephant population. The first was field observations which comprised of randomized distance sampling and waterhole counts. The second made use of camera traps, which recorded images of individuals and herds, where cameras were placed along the road network in grids, as well as at various watering holes and springs.

a) Individual Identification Techniques

Mark and re-sight methods were used, and upon observation in the field, photographs of the elephants were immediately taken. Individuals were ‘marked’ by recording various characteristics and unique markings. Such details were used to facilitate individual identification.

b) Distance Sampling

Drive transects were conducted along established roads throughout MWR. Upon the initial sighting of an elephant an observation period will commence; the date, time of observation, GPS position of observer, total number of elephants seen, number of males and females and their respective age classes of individuals (infant, calf, juvenile, small-, medium-, and large-adult) were all recorded. A “Quality of Count” index was used to exclude problematic observations whilst still maximizing the data used. Each observation was noted as being “Perfect”, “Good Count”, or “Ball Park”. Such an index is useful in situations where elephant herds are large and/or are heading in a direction which the researcher could not follow.

c) Waterhole Counts

Ten borehole-fed artificial water points are found within MWR. Counts were conducted at four artificial water points in the Sanctuary region (Nsepete, Nakamba, Thawale and the Heritage) and at two artificial water point in the Pende region (Ntumba and Pende 1), with counts conducted from June 2018 to December 2018. Each count lasted a period of 12 hours, starting at 06h00. During such counts, the data collected included: weather conditions (cloud cover, temperature), total number of elephants sighted, time of observation of individual or herd, the sex and ages of each individual and several other behavioral observations (both intraspecific and interspecific interactions).

d) Camera Trapping

Cameras were distributed throughout the reserve. Two reserve-wide surveys were conducted; once over the dry (July-September) and once over the wet (December-February) season. Cuddeback Xchange Professional Colour cameras - 1279 (strobe flash) were used, each having a protective case. Cameras were placed at various water points (both natural and artificial) throughout the reserve.
e) Aerial Census

African Parks, Majete (Pty) Ltd. conducts aerial surveys approximately every two years for the purpose of coarse animal population estimates. The aerial count was conducted in the dry season (Oct/Nov 2018) and each count consisted of a pilot and 1-2 observers. Counts were flown in transects with the calibrated strip width of each transect set at 500m and the flight path oriented in an east to west direction. When an animal was sighted, the data recorded included GPS track log of all transects, game species and number of individuals, and any significant waypoints were also marked using a GPS.

f) Identifying Individual Elephants and Herds

In order to analyze the camera trap images the following assumptions applied: 1) a single image containing elephants (bulls or family herds) was considered a single observation if no other photographs are taken; 2) if individuals were captured on camera in a continuous sequence of photographs in a short period of time (~30 minutes) on the same day, they were assumed to be from the same herd; 3) when family herds were confirmed, the sequence of photographs captured of the herd within 60 minutes was considered a single observation for that particular herd; 4) if a time period of greater than 60 minutes had elapsed between photographs and new individuals were confirmed it will be assumed that they are from a different herd; and 5) small, medium and large adult bulls generally leave their family herds between the ages of 11 and 13 years, and so if an individual bull was captured on a photograph with a family herd, notes were taken but it was assumed that the individual ranges alone.

Preliminary Results:

It is important to note that not every individual has been identified and assigned to the appropriate sex grouping and age class yet. However, it is interesting to note the skewed ratio of adult male-female elephants. This is likely due to the 2017 translocation focused specifically on the removal of only herds (adult females and dependent offspring). With such a skew, future population growth rates could be significantly affected as a result of the lack of viable females.

Table 1. Age and sex structure of the elephant population in MWR in 2018 and early 2019. The sex ratios and the proportion of each age class in the population are also shown. Sex for 30 infants, calves and juveniles was not determined. It should be noted, not all elephants have been sexed and assigned to an age class yet.

<table>
<thead>
<tr>
<th>Age Class</th>
<th>Total</th>
<th>Males</th>
<th>Females</th>
<th>Unknown Sex</th>
<th>Sex Ratio</th>
<th>Age Class Proportion of Population (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant (&lt;1 year)</td>
<td>19</td>
<td>6</td>
<td>5</td>
<td>8</td>
<td>28:27:30 (1:1:1)</td>
<td>10.27</td>
</tr>
<tr>
<td>Calf (1-4.9 years)</td>
<td>30</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td></td>
<td>16.22</td>
</tr>
<tr>
<td>Juvenile (5-9.9 years)</td>
<td>36</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td></td>
<td>19.46</td>
</tr>
<tr>
<td>Small Adult (10-19.9 years)</td>
<td>27</td>
<td>15</td>
<td>12</td>
<td></td>
<td>65:35 (2:1)</td>
<td>14.59</td>
</tr>
<tr>
<td>Medium Adult (20-34.9 years)</td>
<td>45</td>
<td>30</td>
<td>15</td>
<td></td>
<td></td>
<td>24.32</td>
</tr>
<tr>
<td>Large adult (&gt;35 years)</td>
<td>28</td>
<td>20</td>
<td>8</td>
<td></td>
<td></td>
<td>15.14</td>
</tr>
<tr>
<td>Total</td>
<td>185</td>
<td>93</td>
<td>62</td>
<td>30</td>
<td></td>
<td>100.00</td>
</tr>
</tbody>
</table>
Objective 2: Artificial Water Point (AWP) Usage over Time

The objectives in this chapter include: i) determining how the usage of the different AWPs in Majete by elephants have changed over time; ii) determine why certain AWPs are utilized more so than others, and iii) have individual herds, traditionally found in the south of the reserve, moved northward to fill the vacuum created by the translocation.

1. AWP usage Over Time and Individual Herd Use of Certain AWPs

Camera traps will be utilized in order to determine what AWPs areas the remnant elephant herds and bulls are utilizing as well as how certain herds have moved throughout the reserve.

a) Camera trap placement and settings

Camera traps were placed at nine artificial waterholes and two perennial springs. These camera traps have been a part of the long-term ecological monitoring conducted for the management of Majete Wildlife Reserve. Cameras are set to take one photo upon being triggered with a 1-minute buffer period between each capture.

b) General Usage of AWPs and Identifying Individual Elephants and Herds

Images recorded from camera traps set at water points, only included elephants so as to determine which water points were preferred and how family herds and bulls differed in their water point usage. The assumptions mentioned above (Objective 1, f) apply to this section but for clarification, an observation at a water point was defined as the presence of elephants (bulls or herds) at a water point for a period of no shorter than 5 minutes and no longer than an hour. Once the time frame was over, unless proven otherwise, a new observation was started with a new elephant.

Preliminary Results: Analysis has not yet commenced.
Objective 3: Quantifying African elephant reactions to the presence of a drone

The objectives in this chapter include: to determine how an unmanned aerial vehicle should be operated when observing African elephants (What is the optimal height and distance from elephants when observing elephants aerially; what is the ideal approach speed and angle when observing elephants aerially); ii) to determine how different elephant groups (breeding herds vs lone bulls vs bachelor herds) respond to the presence of a drone?, and iii) to determine how the elephant populations of Majete Wildlife Reserve and Liwonde National Park differ in their responses to the presence of a drone?

1. Unmanned Aerial Vehicle (Drone)

The UAV quadcopter named Mavic Pro Platinum (DJI, Shenzhen, China) was used in this study. This specific model was chosen for its compact design (easy to carry out in the field), ability to launch and land in most places (thanks to its quadcopter design) and noise reduction blades (4 dB quieter than the traditional DJI Mavic Pro). The drone is equipped with a GPS and internal measurement unit which both aid in determining the position and height of the drone. The drone is controlled via the use of a remote control (DJI, Shenzen China) and has a maximum range of 7km. More information regarding the drone’s specifications can be found in Table 1.

Data Collection

As elephants range widely and unpredictably, the sampling scheme will be opportunistic in nature. Primarily, data was collected around water points (both artificial and natural), as here is the greatest likelihood of encountering herds of elephants.

When an elephant or herd was spotted, the drone was launched (either from the ground or hand) and flown towards it/them. The DJI flight software displays the appropriate metadata (altitude, distance, speed, etc.) and was captured by screen-recording the playback device (Apple iPhone 7+, Apple Inc., USA). The location of launch and landing was recorded as well as the ambient temperature and strength and direction (up, down or cross) of the wind. Wind strength will be determined by using the Beaufort Scale. Flights were not conducted if the wind speed was greater than a ‘Strong breeze’ (Beaufort number 6, 10.8-13.8 m.s⁻¹), as this exceeds the drone’s wind tolerance capabilities.

The drone was launched at a minimum distance of 100 m, as to ensure as safe enough distance from the elephant(s) should the launch induce an aggressive response. From the launch site, the drone ascended vertically to varying heights (30, 50 and 100 m), and then approached the elephant(s). The speed and angle of approach was varied in the following manner: (speed: 2, 4 and 6 m.s⁻¹; angle: 45° and 90° from the horizon-thus, the 90° trajectory involved flying directly over the elephant(s) before descending). The following results in six different ways to approach an elephant from each height, ultimately resulting in nine flight patterns.

During each flight pattern, the live on-screen video was recorded and analysed post-flight for elephant reactions. At one-minute intervals, the height and distance from the elephant was recorded, as well as the elephant’s dominant behaviour and dominant reaction over the course of that minute. Elephant reactions were defined using the categories developed by Hahn et al. (2016) with the addition of the ‘agitated response’. The five categories are: 1) No reaction; 2) Vigilance response; 3) Agitated Response; 4) Flight response; and 5) Aggressive. Flights will be terminated should the elephants(s) display a flight (4) or an aggressive (5) response as to minimize the stress for the animal(s). Flights were deemed ‘successful’ and thus terminated should the drone be within a 30 m radius of the elephant(s) without eliciting an agitated, flight
or aggressive response. Thirty meters was determined to be close enough as the Mavic Pro’s 2x zoom capability enables high resolution observations from this distance.

**Preliminary Results:**

No statistical tests have been run on the data yet, however, Figure 3 provides us some basic insights into possible trends, or rather, the lack thereof. Currently, it appears that there is no trend in how elephants respond to the presence of a drone, with all types of response (1-4, excluding 5, an aggressive response) being elicited at similar distances. What the figure fails to demonstrate is the number of data points in each response (this will be indicated in the final report), with the vast majority of responses being either No Response (1) or Vigilance Response (2). Further analysis will investigate these data and attempt to determine how best to replicate such a response. Likewise, the negative response data points (those falling under Agitated [3] or Flight [4] response) will be analyzed to determine how not to fly around elephants.
Figure 2. A box and whisker plot displaying the different elephant categories (Bachelor herd, Lone bull, Mixed herd and Breeding herd) and their responses to the presence of a drone at various distances over the Wet and Dry season. Elephant responses were categorized as 1 - no response, 2 - vigilance response, 3 - agitated response, 4 - flight response and 5 - aggressive response. Boxes represent the first and third quantile and the horizontal bar within the box represents the median. The lower and upper whiskers represent the minimum and maximum values respectively. Dots are outlier values.
References


IUCN (web: https://www.iucn.org/content/new-guidelines-conservation-elephant-translocations-published-iucn)


Objective #4. Studying the population dynamics and distribution of spotted hyena.

This study was completed in December 2016, however monitoring of the hyena population continues via camera traps and population data will be updated on an annual basis.

The following is the link to the completed thesis which is available from Stellenbosch University’s library (http://hdl.handle.net/10019.1/98847)
Objective #5. Studying population performance and habitat use of black rhinoceros.

This project is in collaboration with African Parks, Majete and their rhino monitoring scouts. The scouts continuously monitor the black rhino. Throughout 2013 and 2014 monitoring was on a daily basis to achieve between 30 - 35 rhino tracking outings per month. Rhino trackers have a camera to take photographs of each sighting as evidence of which rhino they have seen as far as possible. Sightings are recorded on a daily basis and a sighting of each individual is attempted per week. Majete Wildlife Reserve revamped the rhino monitoring program in 2015 and an additional 2 rhino scouts were added to the team bringing the total to four. In 2015 a number of the sub-adults were ear-notched by the African Parks Majete team and one calf was born in November 2015. In 2016 a fourth year Conservation Ecology student from Stellenbosch University studied rhino activity patterns and drinking behaviour based on over 30 000 camera trap photographs (see the 2016 fielding report for the PDF of the study).

In 2017, a new rhino ecology study was undertaken by MSc candidate, Anel Olivier. This study was completed in 2018 and the candidate successfully graduated. Below is the abstract of the completed thesis only, as the thesis is under an embargo at Stellenbosch University due to the sensitivity of any rhino research.

The ecology of black rhino (*Diceros bicornis minor*) in Majete Wildlife Reserve, Malawi.

By Anel Olivier, Supervisor Dr Alison Leslie

Abstract

The critically endangered African black rhino (*Diceros bicornis*) is under immense pressure from growing anthropological activities, and illicit poaching has significantly contributed to patchy distribution and low population numbers. Apart from frontline protection to save the species, biological management is acknowledged as a priority, through expansion of the black rhino range together with effective monitoring. The black rhino in Majete Wildlife Reserve (MWR) is an example of a successful reintroduction, as part of a larger Malawian metapopulation. Sound applied research is vital for the sustainable management of protected populations. Therefore, this study aimed to gain a better understanding of black rhino ecology to inform conservation and management plans to ensure persistence and growth of the MWR population.

Black rhino feeding ecology is linked to population health and carrying capacity. Building on a pilot study conducted in 2011, this study conducted comprehensive research on black rhino diet composition and browse availability. Backtracking was used to record browse marks and identify food plants to species level along feeding trails. A total of 69 browse species were recorded, with high seasonal selectivity for certain principal and preferred food plants. Browse availability, measured as the plant volume that is accessible to black rhino, was found to vary noticeably among sub-areas and among vegetation types. The percentage of browse available for black rhino utilization was calculated at 9.13% of the entire reserve’s volume below the 2m feeding height.

Information on the ranging behaviour of black rhino provides a better understanding of habitat preferences and their spatial relationships within a reserve. The α-LoCoH 95% home ranges and 50% core ranges of black rhino in MWR were calculated using location data obtained by trackers. Great individual variation in annual and seasonal ranges were found, while mean annual home and core ranges were estimated at 30.36 ± SD14.12 and 7.80 ± SD3.68 km² respectively. The percentage occupation of vegetation types within the home ranges were calculated and revealed clear preference for the woodland below 250m in altitude. Ranging behaviour with regards to surface water sources was analysed with the use of Euclidean distances,
and results showed great individual seasonal variation. It was found that black rhino range at a mean of 2 406 ± SD 1 485 m to the nearest utilized waterpoint and at 5 086 ± SD 4 370 m to the nearest perennial river.

This study filled the knowledge gaps of black rhino feeding ecology in MWR and built on past diet studies by enhancing our broader understanding of browse species selection and preferences. Results showed high individual and seasonal variation in black rhino ranging behaviour and habitat use in MWR, and, by applying standardized home range estimations, this study is also applicable to a broader audience. From the comprehensive ecological information gained by this research, the mean black rhino carrying capacity density of MWR was estimated at 0.17 individuals per km². To conclude, applicable scientifically-backed recommendations were discussed, which will provide vital inputs to future management plans for this small but vital population. Such research may also contribute to metapopulation management resulting in increasing black rhino populations in Africa.
Objective #6 (included as of 2017). Ecological impact of large herbivores on vegetation in Majete Wildlife Reserve.

This is a new overall Majete Wildlife Research Programme objective that commenced in 2017, and will be added to over the years.

Ecological impact of large herbivores on vegetation at selected artificial watering points in Majete Wildlife Reserve

Kayla Adriana Geenen, MSc Conservation Ecology

Progress report for 2018

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Chapter 1: Introduction

Herbivore-vegetation dynamics is a vast and well explored topic within the savanna ecosystem (Makhabu 2005; Redfern et al. 2006; Asner et al. 2009; Buitenwerf et al. 2011; Treydte et al. 2013; Staver and Bond 2014). Herbivores play a role as a major disturbance (top-down effect) as well as a core focus in conservation (Maron and Crone 2006; Riginos and Grace 2008; Fuhlendorf et al. 2009; Schippers et al. 2014). The alteration of herbivore populations in order to keep an ecological balance may be highly contradictory, too many or too few herbivores could cause detrimental effects to ecosystem functioning through changes in vegetation structure and composition. Herbivores including buffalo, elephant, zebra, giraffe and many other ungulates have contributed to structural changes present in the different African landscapes (Skarpe 1990; Mosugelo et al. 2002; De Garine-Wichatitsky et al. 2004; Birkett and Stevens-wood 2005; Riginos and Grace 2008; Hamandawana 2012; Morrison et al. 2016). These structural changes in vegetation are usually exaggerated around a water source due to trampling and overgrazing. Despite
this, there have been few studies focusing on water use by wildlife as well as the relationship between herbivores and vegetation surrounding the artificial water points.

Water is a vital aspect of life and has the ability to drive animal ecology, behaviour and distribution. (Hayward and Hayward 2012). Water is often supplemented for two main reasons in conservation areas. These include the boosting of herbivore population sizes as well as to enhance biodiversity through the increase of habitat heterogeneity. An additional reason for the placement of artificial water points is to enhance wildlife viewing for tourism (Farmer 2010).

The management of water requires an important understanding of the impacts of supplementation on the ecosystem. Herbivores, especially those which are mainly water-dependent, tend to be in close proximity to water. This is exaggerated especially during the dry season when natural surface water is scarce (Owen-Smith 1996; Smit et al. 2007). This congregation around water points results in the trampling and overgrazing of the surrounding vegetation, forming gradients of utilisation. Vegetation within these gradients become scarce and over utilised with an increase in proximity to a water source, forming a piosphere effect. The piosphere theory states that degradation surrounding a waterpoint is determined by the trade-off between water and forage requirements of the animals. The size of this degradation is limited by the distance herbivores travel between drinking events, relating to quality and quantity of the forage surrounding a waterpoint (Smit et al. 2007; Farmer 2010; Šmilauer et al. 2015). Water point impact is understood and visualised by circular piospheres with emphasis on the degradation level around a single waterpoint and the probability of the merging of piospheres. The greatest degradation occurs closest to the water point followed by a zone of change to a point where it tails off and shows its true ecological potential (Graetz and Ludwig 1978).

Seasonal variation is observed as water dependent herbivores tend to congregate around permanent water sources during the dry season, while dispersing into areas away from perennial water sources during the wet season (Thrash and Derry 1999; Thrash 2000; Young et al. 2009). Vegetation surrounding these water sources are therefore relieved of the severe grazing pressure during the wet seasons. The placement of AWP away from perennial water sources allows for further wet season dispersal ranges relative to the dry season concentration areas. Vegetation situated near AWP needs to be relieved of grazing pressure during the wet season for the recovery from dry season grazing and trampling to occur. This requires a region with sufficient food and situated at distance from water, to attract herbivore populations. Regions lacking this recovery period may experience a coalescence in vegetation degradation, causing a short-term increase in herbivore abundance and a drastic decrease during drought periods. Animal populations may therefore fail to regain their former levels during the intervals between (Owen-Smith 1996).

This study therefore aims to explore the damage to vegetation and soil surrounding artificial water points (AWP) within Majete. This will aid in determining the extent of the piosphere effect surrounding AWP’s and how these AWP’s may be better managed to decrease this affect by exploring which waterholes are utilised the most during the various seasons and within the various areas of the reserve.

1. Study area

Majete Wildlife Reserve, covering 70000ha, is situated in the Lower Shire valley region of southern Malawi (Figure. 1). The western region of the reserve consists of the highest terrain as steep undulating hills and river valleys. The eastern section experiences a decrease in altitude and the terrain is relatively flat. There are two perennial rivers transecting the reserve, the Shire River and Mkurumadzi River. I have selected seven AWP for this study based on their position within the reserve, the surrounding vegetation types and altitude. Two of these AWP will be studied independently due to their differing altitudinal gradients. These include Diwa within the Namisempha region and Phwadzi in the south-western section.
Pende 1 and Ntumba will be compared due to their placement in the same vegetation type (savanna). Thawale, Nkamba and Nsepete will be compared as they are all situated within the sanctuary region which is dominated by woodland below 250m (Figure. 1). Expected annual precipitation ranges between 700-1000mm in the western highlands and 680-800mm in the eastern lowlands, with a wet season from November until early April (Malawian Department of Climate Change and Meteorological Services). Majete is primarily woodland dominated and vegetation types fall within the Miombo woodland ecoregion (Wienand 2013).

![Map of Majete Wildlife Reserve](image)

**Figure. 1.** Majete Wildlife Reserve in relation to Malawi; the location of the ten artificial water points (AWPs) and perennial rivers within the reserve.

Over 2550 individual animals from 14 species were reintroduced into Majete via different stages. The 140km² sanctuary area was initially fenced in 2003 for the wildlife reintroduction. The remaining area of the reserve was fenced in 2008. This was followed by the removal of the sanctuary fencing by September 2011, allowing the animals to spread out into the newly opened area of the reserve.

Water management is a controversial issue within African savannah conservation areas. This issue should be managed as such to increase herbivore numbers as well as vegetation or habitat heterogeneity. Artificial water points are perennial water sources for herbivore species, which can change vegetation surrounding these sources through herbivory and trampling. This study has been initiated to better understand the impacts of herbivores on the vegetation surrounding the artificial water points within a given reserve, Majete Wildlife Reserve.
Chapter 2: The Piosphere effect on vegetation surrounding artificial water points (AWP) within Majete Wildlife Reserve

2. Aims and objectives

- To investigate the impact of large herbivores on vegetation surrounding artificial waterholes in Majete Wildlife Reserve, Malawi
  - To determine vegetation change surrounding waterholes using fixed point photography over a five year period
  - To assess the structure of woody and herbaceous vegetation from the edge of the waterhole to 2000m away
  - To establish the ecological index of herbaceous vegetation surrounding the AWP

3. Methods and materials

Three transects starting at the AWP and measuring 2000 m in the direction of N, SW and SE, will be used to determine woody and herbaceous vegetation communities (Thrash et al. 1993). This transect length was chosen as most water dependent species congregate in close proximity to a water source during the dry season, contributing to the piosphere effect. Vegetation structure and composition will be investigated within 20m x 20m plots placed at 0m, 50m, 150m, 300m, 500m, 1000m, 1500m and 2000m away from the waterhole. Previous studies have found a greater rate of change closer to AWPs, therefore intervals within 1km of the Artificial water point will be smaller than those exceeding 1km (Owen-Smith 1996).

Sampling for woody vegetation and percentage herbaceous vegetation cover will take place during the dry season (July to November) as accessibility is made easier. Herbaceous sampling will take place during the wet season (February to April) as this is the flowering period of most herbaceous species, making species identification easier.

The percentage herbaceous basal cover within each plot and transect will be measured by using the Step-point technique (Evans and Love 1957; Owensby 1973). This technique involves recording observations along a walking transect at specified intervals (steps), where a pin is projected at the mark on a boot and into the vegetation. The plant base or ground cover intersected by the point is recorded and referred to as a ‘hit’. In this study I will conduct these steps every 1m within a 10m x 10m plot with a result of 100 points measured. The cover of a species is then calculated using the following equation:

\[
\text{Cover of Spp } A = \left( \frac{\# \text{hits Spp } A}{\text{total \# points}} \right) \times 100
\]

Dominant woody species (trees and shrubs) within the plots will be identified to species level, followed by recording estimated vegetation cover within <2m, 2-3m, 3-5m and >5m height categories.

4. Preliminary results

The density of woody vegetation 2-3m and 3-5m in height seems to increase with distance from water for Diwa, Phwadzi, Pende 1 and Nsepete (Figure 2a, b, d and e). Vegetation >5m is less dense closer to the AWP, except for Thawale and Pende 1. These two water points show that there is low density of vegetation
<5m and a high density of vegetation >5m. Vegetation >5m is almost absent at 2000m from the AWP while vegetation <5m increases dramatically the further we move from the AWP. The general trend at Pende 1 seems to be that vegetation less than three meters increases with an increase in distance from water (Figure 2d).

Trees taller than five meters dominate 0m - 50m from the waterhole and are lowest at 150m from the waterhole. Vegetation smaller than three meters is absent at the edge of the waterhole. No real trend is seen at Kakoma as there is no drastic change in vegetation density as we move further from water; this could be due to the fact that it is a relatively young waterhole and has not yet experienced the vegetation degradation such as the other AWPs (Figure 2a). Nsepete shows almost no vegetation cover at a distance 0m from the AWP. Vegetation density increases to 40% the further we move from the AWP. Vegetation density did not exceed 55% cover, which shows that the habitat is quite open with little dense cover for woody vegetation <5m (Figure 2f).

We can see a slight piosphere effect in half the AWPs (Figure a, e and f) where most of the damage is seen in the sacrificial zone closest to the AWP. As we move further from the AWP, vegetation density seems to increase and become heterogeneous again.
Figure 2. Percentage vegetation cover of the woody vegetation layer at various distances from a) Phwadzi, b) Diwa, c) Kakoma, d) Pende 1, e) Nsepete and f) Thawale waterhole.
Chapter 3: Artificial waterpoint utilisation by herbivores within Majete Wildlife Reserve

5. Aims and objectives

- To investigate the utilisation of artificial waterholes by select herbivores in Majete Wildlife Reserve, Malawi
  - To monitor herbivore visitation patterns at ten artificial water points between 2013 and 2018, using remote imagery and waterhole counts, in Majete Wildlife Reserve
  - To establish herbivore water source utilisation behaviour patterns hourly, daily and seasonally
  - To classify differences between specific species and feeding strategies (grazers, browsers and mixed feeders) in water point use
  - To determine a relative rank of water dependency by comparing water point use with the relative abundance of species in the area

6. Methods and materials

The non-invasive research technique of camera trapping has been used worldwide to determine the abundance of species in specific areas as well as their behaviour in these areas. In this study, camera traps proved to be a useful method of sampling as it increased the sampling area and time while providing continued monitoring of the study area. Cuddeback™ Ambush© and Attack© camera traps were positioned at all ten of the artificial water points between from 1 June 2017 to 15 May 2018. Due to technical issues at some of the waterholes, camera trap active days differed between 204 and 327 days. Cameras were set to take a photograph every minute after an animal had triggered the sensor. Generally, each camera trap was serviced after a 14 to 30-day period which involved changing batteries and SD cards. Once downloaded onto the computer, the photos were sorted into files according to date and location followed by backing up onto an external hard drive. Animals were not necessarily drinking in the photographs taken by the camera traps. Given the risks associated with waterholes and ambush predation, their proximity to the water point suggested that they were or had been seeking water (Crosmary et al 2012).

The relative waterhole use per hour was calculated as the number of observations of individuals divided by the number of camera trapping hours. Running means of raw data were used to plot smoothed water point use functions.

7. Preliminary results

A total of 216 250 observations (a photograph that contained a portion of or an entire study species), from 12 species, were recorded using camera traps at the ten artificial waterholes monitored within MWR during the study period (Table. 1). Of the 216 250 sightings recorded, 28 160 were recorded in the late wet season, 45 820 in the early dry season, 45 820 in the late dry season and 18 548 in the early wet season. Nyala were observed at nine AWPs, Black Rhino and Lichtenstein’s hartebeest were only observed at eight of the ten AWPs. The remaining study species were observed at all ten AWPs. Overall, all ten artificial water points were not visited equally (Chi-square Goodness of Fit Test: \( x^2(df = 9) = 31437, p < 0.001 \)). Likewise, the total number of visitations by all twelve species to artificial water points by season was significantly different (Chi-square Goodness of Fit Test: \( x^2(df = 3) = 53476, p < 0.001 \)).
All species were recorded visiting the various artificial water points during all 24 hourly periods during the entire study period (Figure. 3), except for Black rhino, which did not visit the AWPs between the hours of 09:00 - 09:59 and 11:00 - 11:59 (Figure. 4). Black rhino, bushbuck, eland, hartebeest, impala, kudu, nyala and sable were not observed visiting the various AWPs during all 24 hourly periods within the four seasons.

Majority of the Black rhino observations were recorded at dawn and dusk, peaking at 05:00 - 05:59 (63 observations) 06:00 - 06:59 (75 observations) 17:00 - 17:59 and 19:00 - 19:59 (47 observations, Figure. 4). Bushbuck (1030, 1237 and 1245 observations), Elephant (5559, 5941 and 5417 observations), Waterbuck (3650, 3871 and 3686 observations), Zebra (1648, 1820 and 1580 observations), Hartebeest (275, 210 and 195 observations) and Nyala (830, 1016 and 963 observations) peaked during the 10:00 - 10:59, 11:00 - 11:59 and 12:00 - 12:59 hourly periods respectively (Figure. 4). Impala (3812, 4785 and 4676 observations), Kudu (2150, 2243 and 2164 observations) and Sable (3283, 3115 and 2820 observations) peaked during the 09:00 - 09:59, 10:00 - 10:59 and 11:00 - 11:59 hourly periods respectively (Figure. 4). Buffalo observations were recorded peaking at 17:00 - 17:59 (2595 observations), 18:00 - 18:59 (3207 observations) and 19:00 - 19:59 (3019 observations, Figure. 4). Eland observations were recorded peaking at 07:00 - 07:59 (582 observations), 09:00 - 09:59 (647 observations) and 11:00 - 11:59 (640 observations, Figure. 4).

The time of day buffalo preferred to visit AWPs differed significantly among the four seasons (Chi-square Test of Independence: $X^2_{(df = 69)} = 4216.9$, p-value < 0.001), early dry season showed the strongest correspondence to 16:00 - 16:59 and 17:00 - 17:59, late wet to 22:00 - 22:59, early wet to 19:00 - 19:59 and late dry to 09:00 - 09:59. Elephants preferred to visit AWPs at certain times of day, differing significantly among the four seasons (Chi-square Test of Independence: $X^2_{(df = 69)} = 293.24$, p-value < 0.001), with early dry season showing the strongest correspondence to 22:00 - 22:59, late wet to 03:00 - 03:59, early wet to 08:00 - 08:59 and late dry to 11:00 - 11:59. Waterbuck too differed significantly (Chi-square Test of Independence: $X^2_{(df = 69)} = 3155.6$, p-value < 0.001), early dry season showed the strongest correspondence to 10:00 - 10:59, late wet to 14:00 - 14:59, early wet to 01:00 - 01:59 and late dry to 08:00 - 08:59. Lastly, zebra differed significantly (Chi-square Test of Independence: $X^2_{(df = 69)} = 1142.1$, p-value < 0.001), with early dry season showing the strongest correspondence to 21:00 - 21:59, late wet to 23:00 - 23:59, early wet to 03:00 - 03:59 and late dry to 08:00 - 08:59.

<table>
<thead>
<tr>
<th>Waterhole</th>
<th>Total trapping days</th>
<th>Total trapping Hours</th>
<th>Total observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diwa</td>
<td>204</td>
<td>4896</td>
<td>6103</td>
</tr>
<tr>
<td>Pwadzi</td>
<td>211</td>
<td>5064</td>
<td>2568</td>
</tr>
<tr>
<td>Pende 2</td>
<td>255</td>
<td>6120</td>
<td>29129</td>
</tr>
<tr>
<td>Nakamba</td>
<td>267</td>
<td>6408</td>
<td>21247</td>
</tr>
<tr>
<td>Thawale</td>
<td>276</td>
<td>6624</td>
<td>23885</td>
</tr>
<tr>
<td>Heritage</td>
<td>279</td>
<td>6696</td>
<td>15395</td>
</tr>
<tr>
<td>Pende 1</td>
<td>289</td>
<td>6936</td>
<td>34207</td>
</tr>
<tr>
<td>Nsepete</td>
<td>298</td>
<td>7152</td>
<td>24678</td>
</tr>
<tr>
<td>Kakoma</td>
<td>317</td>
<td>7608</td>
<td>29882</td>
</tr>
<tr>
<td>Nthumba</td>
<td>327</td>
<td>7848</td>
<td>29111</td>
</tr>
</tbody>
</table>
Figure. 3. The frequency of observations for the twelve study species at all of the ten study sites.

Figure. 4. Water use by species observed at ten artificial water points in Majete Wildlife Reserve. Running means of the current hourly period with the hours either side of it were used to smooth the plots. Species have been grouped according to similar observations per sampling hour.
8. Discussion
The four artificial water points in the southern region of Majete (Pende 1, Kakoma, Pende 2 and Nthumba) were visited more than the six remaining water points. This is most likely due to fewer perennial water sources available in the southern region compared to two perennial rivers present in the northern region.

The preferential diurnal use of AWPs by herbivores in Majete may be due to the avoidance of predators as it is well known that predators frequent AWPs, when the ability of herbivores to detect predators is hindered (Ayeni 1975, Hayward and Hayward 2012). Occasional visits by herbivores after dark may be due to heat stress avoidance (Hayward and Hayward 2012) as well as Majete’s low predator density (Briers-Louw 2017).

Waterbuck, elephant, zebra, impala, kudu, nyala and eland all had AWP utilisation peaks between 10:00 and 12:00 which differs somewhat from previous studies (Hayward and Hayward 2012). This may be due to the AWPs running on solar power, which resulted in optimum pumping of water when UV radiation was high, between 10:00 and 14:00. It seems like some herbivores may have adjusted their peak utilisation times in order to visit AWPs when there is water pumping and available. AWP utilisation differed between seasons. During late dry season when natural water sources have been diminished, AWP utilisation is at its highest for all species. This was the opposite for early wet season when natural water sources were replenished, corresponding with previous studies (Ayeni 1975, Cain et al 2011, Valeix et al 2007). Buffalo AWP utilisation peaked at 08:00 - 08:59 and 18:00 - 18:59, differing from the other eleven species. This could be due to the avoidance of heat stress. This research provides information on the importance and benefits of AWPs within Majete Wildlife Reserve, specifically in the southern region, as an important source of water during the dry seasons.

References


Taylor PJC (2011) Vegetation Assessment. In: LAND DEGRADATION ASSESSMENT IN DRYLANDS (LADA) PROJECT.


Objective #7. Implementation of a best practice fire management strategy.

We have not as yet commenced with this study. Majete Wildlife Reserve does have a basic fire management plan and burning takes place annually from early June to mid-August. We will be revising this plan in due course now that the vegetation map has been updated. A potential PhD candidate in 2019 will include fire management as part of a larger study.

Objective #8. Capacity building and implementation of human-wildlife conflict mitigation measures.

A number of studies have been conducted over the past few years with regards to the various local communities’ attitudes towards African Parks and Majete Wildlife Reserve in general. Community benefits provided by African Parks have been through enterprise development and infrastructural projects including: health clinics, school blocks, a maize mill, boreholes, cattle troughs and several capacity building programmes. Additionally, a resource utilization program has been established that uses a permit system that provides bordering communities regulated access into the protected area to harvest allowable natural resources such as thatching grass, bamboo and fire wood. Several hiv/aids committees and home based care groups have been established that engages volunteers from the local communities. African Parks have also established a well-run community based natural resource management (CBNRM) program and have provided training in areas of CBNRM, forestry management techniques, beekeeping, poultry and livestock production, scone baking and banana production. Several training sessions have also been conducted for reserve scouts and extension staff. There are however still many challenges ahead.

In 2015 we started a project specifically to develop a management plan for community-based natural resource harvesting in Majete Wildlife Reserve. The study was undertaken by Master’s student, Claire Gordon and was completed in December 2016. See the 2016 fielding season report for more details.

In 2017 we continued with our school visiting and educational program, visiting eight village schools during the fielding season. Volunteers were given an opportunity to not only share something about Majete Wildlife Reserve and their own countries but also to learn about the life of the children in some of the remote and extremely poor areas surrounding the reserve. School choirs often put on a show and drama productions are performed. These outings are always thoroughly enjoyed by all. Throughout 2017 volunteers once again very generously brought all sorts of school goods with them to donate to various schools in the Shire Valley. Additionally in 2017 we started a new initiative which involved bringing school groups to Majete. This was funded by the research programme and involved fetching the kids by bus, taking them on a game drive in Majete and providing refreshments. In 2018, 7 schools were visited and school goods generously donated by Earthwatch volunteers were distributed. Additionally, volunteers contributed $300 to the fund to bring school kids to Majete. These groups will be hosted in early 2019.
Objective #9. Investigating the potential of payments for ecosystem services and reducing emissions from deforestation and forest degradation (REDD) as a conservation tool (this project is being driven by African Parks, Majete, but was put on hold in 2016, for several reasons.

Majete Wildlife Reserve was assessed for its potential as a REDD project by a consultant group towards the end of 2012. The results from this assessment indicated (estimated) that Majete could sell approximately 100,000 carbon credits per year. It is however, unclear what the future market for REDD will be like - and this is key in assessing the viability of a REDD project at Majete. At the current carbon prices of approximately $2 per ton, it probably would not be worthwhile for African Parks to proceed with the project, but African Parks is currently still in discussions with possible partners with the necessary expertise in the carbon markets to assess the feasibility of the project, and explore the opportunities for possible collaboration. A big challenge is the next step, which is the substantial upfront development costs involved with formally accrediting the carbon credits, and the risk of an unknown future market for these credits. It is unknown at this stage whether African Parks will continue with this objective.

PROJECT IMPACTS

1. Increasing Scientific Knowledge

a) Total citizen science research hours

A total of 37 volunteers were at the project site for a full 10 days (excluding the 2 x travel days). Volunteers contributed an average of 8 hours per person per fielding day = 2960 hours in total for the season.

b) Peer-reviewed publications

A number of publications are in prep/submitted/published:

- Spies, K. and A. Leslie. The diet of impala and waterbuck in Majete Wildlife Reserve using stable isotope analysis.
- Forrer, FA. And A. Leslie. The diet of elephant, Loxodonta africana, in Majete Wildlife reserve, Malawi. (Submitted to African Journal of Wildlife Management)
- Gordon, C. and A. Leslie. Medicinal plants used by traditional healers in Majete Wildlife Reserve, Malawi. (Submitted to Journal of Ethnobiology & Ethnomedicine)
- De Vos, C., A. Leslie and J. Ransom. Time budget behaviour of plains zebra (Equus quagga) in Majete Wildlife Reserve, Malawi (submitted to Applied Animal Behaviour)
c) Non-peer reviewed publications: See the attached article.

d) Presentations:

- Presentations at a WESM (Wildlife and Environmental Society of Malawi) meeting in Blantyre in April by two MSc graduates about their respective projects (Ecology of black rhino in Majete Wildlife Reserve; Ecological impact of large herbivores on vegetation at selected artificial watering points in Majete Wildlife Reserve).

- Presentations to African Parks Management at Majete Wildlife Reserve in March by two MSc graduates on their respective projects preliminary findings (Ecology of black rhino in Majete Wildlife Reserve; Ecological impact of large herbivores on vegetation at selected artificial watering points in Majete Wildlife Reserve).

2. Mentoring

a) Graduate students (as of 2015 only)

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Graduate Degree</th>
<th>Project Title</th>
<th>Anticipated Year of Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kate Spies</td>
<td>MSc Conservation Ecology</td>
<td>Ecology of impala and waterbuck in Majete Wildlife Reserve, Malawi.</td>
<td>Dec 2015</td>
</tr>
<tr>
<td>Francois Retief</td>
<td>MSc Conservation Ecology</td>
<td>The ecology of spotted hyena in Majete Wildlife Reserve, Malawi.</td>
<td>Dec 2015</td>
</tr>
<tr>
<td>Claire N. Gordon</td>
<td>MSc Conservation Ecology</td>
<td>People and protected areas: Natural resource harvesting as an approach to support rural communities surrounding Majete Wildlife Reserve, Southern Malawi: A Case Study</td>
<td>Dec 2016</td>
</tr>
<tr>
<td>Willem Daniel Briers-Louw</td>
<td>MSc Conservation Ecology</td>
<td>Ecology of three apex predators in Majete Wildlife Reserve, Malawi</td>
<td>Dec 2017</td>
</tr>
<tr>
<td>Charli de Vos</td>
<td>MSc Conservation Ecology</td>
<td>Ecology of Boehm’s zebra (<em>Equus quagga</em>) in Majete Wildlife Reserve, Malawi</td>
<td>Dec 2017</td>
</tr>
<tr>
<td>Anel Olivier</td>
<td>MSc Conservation Ecology</td>
<td>Ecology of Black Rhinoceros in Majete Wildlife Reserve, Malawi</td>
<td>Dec 2018</td>
</tr>
<tr>
<td>Kayla Geenen</td>
<td>MSc Conservation Ecology</td>
<td>The impact of herbivores on vegetation surrounding artificial water points within Majete Wildlife Reserve</td>
<td>June 2019</td>
</tr>
<tr>
<td>Name of school, organization, or group</td>
<td>Education level</td>
<td>Participants local or non-local</td>
<td>Details on contributions/ activities</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-----------------</td>
<td>---------------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Vimvi Primary School</td>
<td>10-14 years old</td>
<td>Local</td>
<td>Game to teach about food webs and the importance of Majete.</td>
</tr>
<tr>
<td>Mathithi camp</td>
<td>3-16 years old</td>
<td>Local</td>
<td>Sports day: sack races, tug of war and animal games</td>
</tr>
<tr>
<td>Kakoma village</td>
<td>4-20 years old</td>
<td>Local</td>
<td>Sports day: sack races, tug of war and animal games</td>
</tr>
<tr>
<td>Kachere Primary School</td>
<td>10-14 years old</td>
<td>Local</td>
<td>Lesson &quot;Where am I&quot;. Local village leading to Majete, Malawi, Africa and the Universe.</td>
</tr>
<tr>
<td>Futsa Primary School</td>
<td>10-14 years old</td>
<td>Local</td>
<td>Lesson on birds, specifically owls and vultures to create awareness of their importance, and dispel myths. Played common bird calls.</td>
</tr>
<tr>
<td>Mwembezi Primary School</td>
<td>10-14 years old</td>
<td>Local</td>
<td>Foreign animal talk and animal memory game</td>
</tr>
<tr>
<td>Mavuwa Primary School</td>
<td>10-14 years old</td>
<td>Local</td>
<td>A lesson to compare local animals and similar foreign wildlife</td>
</tr>
</tbody>
</table>

b) Community outreach

Provide details on how you have supported the development of environmental leaders in the community in which you work:
3. Partnerships

List your current active professional partnerships that contribute to your project and indicate the type of support these partners provide:

<table>
<thead>
<tr>
<th>Partner</th>
<th>Support Type(s)¹</th>
<th>Years of Association (e.g. 2006-present)</th>
</tr>
</thead>
<tbody>
<tr>
<td>African Parks (PTY) Ltd</td>
<td>Collaboration &amp; logistics</td>
<td>2013 - present</td>
</tr>
<tr>
<td>Cape Leopard Trust</td>
<td>Collaboration</td>
<td>2013 - present</td>
</tr>
<tr>
<td>Texas A &amp; M University</td>
<td>Academic support/collaboration</td>
<td>2015 - present</td>
</tr>
<tr>
<td>Malawi’s National Commission for Science &amp; Technology</td>
<td>Logistics</td>
<td>2013/4 (initially)</td>
</tr>
<tr>
<td>University of Colorado/Department of Fish &amp; Wildlife, USA. Dr J.I. Ransom</td>
<td>Collaboration / academic support</td>
<td>2016 - present</td>
</tr>
<tr>
<td>Cape Peninsula University of Technology, South Africa.</td>
<td>Collaboration</td>
<td>2018 - present</td>
</tr>
<tr>
<td>Fort Hare University, South Africa.</td>
<td>Collaboration</td>
<td>2018 - present</td>
</tr>
<tr>
<td>University of Stellenbosch. A.J Leslie publication fund.</td>
<td>Funding</td>
<td>2013 - present</td>
</tr>
</tbody>
</table>

¹ Support type options: funding, data, logistics, permits, technical support, collaboration, academic support, cultural support, other (define)

4. Contributions to management plans or policies

List the management plans/policies to which your project contributed this year:

All of the undertaken projects contribute to ecosystem and species management planning in Majete Wildlife Reserve.

<table>
<thead>
<tr>
<th>Plan/Policy Name</th>
<th>Type²</th>
<th>Level of Impact³</th>
<th>New or Existing?</th>
<th>Primary goal of plan/policy⁴</th>
<th>Stage of plan/policy⁵</th>
<th>Description of Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management plan for impala and waterbuck</td>
<td>Management plan</td>
<td>Local</td>
<td>New</td>
<td>Natural resource management</td>
<td>Proposed</td>
<td>Suggested management options</td>
</tr>
<tr>
<td>Elephant management plan</td>
<td>Management plan</td>
<td>Local</td>
<td>New</td>
<td>Species conservation</td>
<td>Proposed</td>
<td>Suggested management options</td>
</tr>
<tr>
<td>Hyena management plan</td>
<td>Management plan</td>
<td>Local</td>
<td>New</td>
<td>Species conservation</td>
<td>Proposed</td>
<td>Suggested management options</td>
</tr>
<tr>
<td>Predator management plan</td>
<td>Management plan</td>
<td>Local, regional</td>
<td>New</td>
<td>Species conservation</td>
<td>Proposed</td>
<td>Suggested management options</td>
</tr>
<tr>
<td>Black rhino management plan</td>
<td>Management plan</td>
<td>Local, regional, national, international</td>
<td>New</td>
<td>Species conservation</td>
<td>Proposed</td>
<td>Suggested management options</td>
</tr>
</tbody>
</table>

² Type options: agenda, convention, development plan, management plan, policy, or other (define)
³ Level of impact options: local, regional, national, international
⁴ Primary goal options: cultural conservation, land conservation, species conservation, natural resource conservation, other
⁵ Stage of plan/policy options: proposed, in progress, adopted, other (define)
5. Conserving natural and sociocultural capital

a) Conservation of taxa

i. List any focal study/species that you did not list in your most recent proposal:

<table>
<thead>
<tr>
<th>Species</th>
<th>IUCN Red List category</th>
<th>Local/regional conservation status</th>
<th>Local/regional conservation status source</th>
<th>Description of contribution</th>
<th>Resulting effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leopard</td>
<td>Vulnerable</td>
<td>Only one viable population (Nyika National Park) other than in Majete.</td>
<td>Dept National Parks &amp; Wildlife (pers. Comm)</td>
<td>“ ”</td>
<td>“ ”</td>
</tr>
<tr>
<td>Hyena</td>
<td>Least threatened</td>
<td>Unknown (assumed low)</td>
<td>“ ”</td>
<td>“ ”</td>
<td></td>
</tr>
<tr>
<td>Sable antelope</td>
<td>Least concern</td>
<td>Rare</td>
<td>Rare. Dept National Parks &amp; Wildlife</td>
<td>“ ”</td>
<td>“ ”</td>
</tr>
<tr>
<td>Black rhino</td>
<td>Critically endangered</td>
<td>Critically endangered</td>
<td>Dept National Parks &amp; Wildlife</td>
<td>“ ”</td>
<td>“ ”</td>
</tr>
<tr>
<td>Elephant</td>
<td>Vulnerable A2a</td>
<td>Unknown</td>
<td>“ ”</td>
<td>“ ”</td>
<td></td>
</tr>
</tbody>
</table>

ii. In the past year, has your project helped conserve or restore populations of species of conservation significance? If so, please describe below:

<table>
<thead>
<tr>
<th>Species</th>
<th>IUCN Red List category</th>
<th>Local/regional conservation status</th>
<th>Local/regional conservation status source</th>
<th>Description of contribution</th>
<th>Resulting effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black rhino</td>
<td>Critically endangered</td>
<td>World</td>
<td>IUCN</td>
<td>Ecology within Majete - management recommendations provided.</td>
<td>To be seen</td>
</tr>
</tbody>
</table>

*b Resulting effect options: decreased competition, improved habitat for species, range increased, population increase, improved population structure, increased breeding success, maintained/enhanced genetic diversity, other

b) Conservation of ecosystems

In the past year, has your project helped conserve or restore habitats? If so, please describe below:

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Habitat significance?</th>
<th>Description of contribution</th>
<th>Resulting effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Miombo Ecoregion (an endangered, species-rich African tropical savanna ecosystem)</td>
<td>All of the below mentioned.</td>
<td>Providing an understanding of ecosystem dynamics</td>
<td>Helping to maintain the extent thereof.</td>
</tr>
</tbody>
</table>

7 Habitat significance options: nursery, breeding ground, feeding site, corridor, migration path, refuge, winter range, summer range, spring range, fall range or other (define)

8 Resulting effect options: extent maintained, condition achieved, restored, expanded, improved connectivity or resilience
c) Ecosystem services

Indicate which ecosystem service categories you are directly studying in your Earthwatch research and provide further details in the box below.

☒ Food and water
☐ Flood and disease control
☒ Spiritual, recreational, and cultural benefits
☒ Nutrient cycling

Details:

All research projects are related to ecosystem management and restoration. The ecological studies are all focusing on spatial ecology, diet and waterhole use.

The sustainable harvesting project certainly has cultural benefits, in particular as the medicinal harvesting of plants may be encouraged.

Indirectly the research programme will contribute to the conservation of endangered remnant east African miombo woodland.


d) Conservation of cultural heritage

Provide details on intangible or tangible cultural heritage components that your project has conserved or restored in the past year:

<table>
<thead>
<tr>
<th>Cultural heritage component*</th>
<th>Description of contribution</th>
<th>Resulting effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional subsistence living</td>
<td>By quantifying the extent of natural resource harvesting within Majete (2016) A future project is planned to determine the available biomass of preferred plant species to be harvested.</td>
<td>Current harvesting seems to be sustainable and can possibly be increased to include the harvesting of medicinal plants. Additionally, the propagation of indigenous species by local communities was discussed in 2017 and could become a reality in 2018/2019.</td>
</tr>
</tbody>
</table>

\* Cultural heritage component options: traditional agriculture, artifacts, building(s), hunting ground or kill site, traditional ecological knowledge and practices, monument(s), oral traditions and history, spiritual site, traditional subsistence living

RESEARCH PLAN UPDATES

Report any changes in your research since your last proposal/annual report. For any ‘yes’ answers, provide details on the change in the ‘Details’ box.

1) Have you added a new research site or has your research site location changed? ☒Yes ☐No
2) Has the protected area status of your research site changed? ☐Yes ☒No
3) Has the conservation status of a species you study changed? ☐Yes ☒No
4) Have there been any changes in project scientists or field crew? ☒Yes ☐No
Details - provide more information for any ‘yes’ answers:

Dr Frans Radloff, a senior lecturer and wildlife ecologist from the Department of Conservation & Marine Science, Cape Peninsula University of Technology (CPUT) and Dr Craig Tambling, a senior lecturer from the Department of Zoology and Entomology, Fort Hare University, joined the Majete Wildlife Research Programme as project supervisors in 2018. Mr Craig Hay, Park Manager is leaving Majete in early 2019 and Mr John Addendorf will take over as Park Manager and new co-PI. One new PhD candidate and an additional research assistant will join the project in 2019.

5) Provide details on any changes to your objectives, volunteer tasks, or methods, include reason for the change:

Two new projects were added in 2018, however they fall within the initial proposed objectives. An additional new PhD project will be added in 2019.

ACKNOWLEDGEMENTS

As always, during any Earthwatch fielding season for a project, there are a number of organisations and people who need to be thanked and the 2018 season was no different. Thanks go to Stellenbosch University and PI Alison Leslie, for creating the opportunity. From African Parks the following people all played a vital role in making sure we could operate. African Parks CEO for Malawi, Patricio Ndadzela. Park Manager, Craig Hay and Field Operations Manager, Gervaz Tamala provided vital support to the project. Beatrice, Bookings Manager for African Parks, assisted with all campsite and recreational day bookings, Felix, SunBird manager for Thawale Lodge for allowing us access to the lodge for the waterhole counts, Mike and Henry at the campsite made sure that our volunteers were always attended to, Chitsanzo is thanked for keeping our research camp neat and tidy and Jackson at the Heritage and Educational Centre who helps out with all sorts of logistics, from vegetable deliveries to sourcing of spares! The community extension team, Carol, Dixie, Steve, Kamiza and Alexander, were invaluable in organising and accompanying volunteers on school and community visits. From Law enforcement, Mr Martin Awazi and Mr Toyolo Moyo and their team of scouts are thanked for always making sure that our volunteers stayed safe in the field. In particular we would like to thank the scouts who helped Sally with her project and who walked 100’s of km’s in the camera trapping project, namely: Jan levi, Morgan Chingala, Jonathan Magalasi, Benito Willie, Symon Dyton, James Chindodo, John Kadauma, Moses Nyirenda, Boston Phiri, Mtachi Makhongwe, Chikumbutso Mathews, Stanley Katopola and Falosi Nyirenda. A special thank you to the fantastic Isaac Millo, mechanic extraordinaire, and his assistants Scotch and Ian, who helped us keep our vehicles running under tough circumstances. A big thank you to, Fleur Visser, a Dutch research assistant, who gave us 7 months of her time in Majete. Last by not least, to all the volunteers of the 2018 expedition season, thank you for providing us the opportunity to conduct our research in Malawi and for making a lasting contribution to conservation in this part of Africa. Without your financial support and additional hands, this research programme would not be possible. Your spirit and enthusiasm in the field was always inspirational and it is through your effort that we were able to collect the data we did in 2018 and hopefully long into the future.

LITERATURE CITED

PLEASE SEE THE INDIVIDUAL REPORTS/THESSES.

ANYTHING ELSE

Our plans for 2019: One new PhD student and a research assistant to Majete in March and May respectively - namely: Wian Nieman and Sophie Pyper.
Katharina von Durckheim and Kayla Geenen to graduate in 2019.
The Liwonde National Park cheetah study by Olivia Sievert will also be completed towards the end of 2019.
And... plenty more so keep an eye on www.african-parks.org