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DISTANCE FROM THE TOURIST TRAIL AND DAYLIGHT CONDITION AFFECT THE ABUNDANCE OF MWANZA FLAT-HEADED ROCK AGAMA (*AGAMA MWANZAE*) IN SAANANE NATIONAL PARK, TANZANIA

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ABSTRACT

For newly established protected areas, it is important to document the abundance, structure and distribution of the species within the landscape. Here we assessed the variation in total abundance as well as female, male and juvenile abundance of Mwanza flat-headed rock agama (*Agama mwanzae*) in Saanane National Park, Tanzania, in relation to daylight condition (sunny and non-sunny) and proximity to humans. Twenty-three points of 50-meter radius were randomly placed and thoroughly searched for *A. mwanzae*. Of 364 individual Mwanza flat-headed rock agamas recorded, 85% were adults and 15% were juveniles. Among adults, 45% were males and 55% were females. Daylight condition was observed to affect total abundance and the abundance of females, males and juveniles of *A. mwanzae,* with higher abundance being in sunny periods as compared to non-sunny periods. Distance from the tourist trail was the best predictor for total abundance and the abundance of females and juveniles but not males, with abundance decreasing moving away from the tourist trail. Therefore, we suggest these factors be considered when surveying agamas elsewhere.

Keywords: daylight period; disturbance; human influence; tourist trail; landscape ecology; sunny period

INTRODUCTION

Tanzania is recognized worldwide as a mega diversity nation, and a vital country for African biodiversity conservation (Shemweta & Kideghesho, 2000; Razzetti & Msuya, 2002). Reptiles are no exception to Tanzania's biodiverse portfolio. Razzetti and Msuya (2002) reported more than 275 reptile species, with the majority being endemic to Tanzania and reported on the IUCN Red List of Threatened Species. One well-known East African endemic species is Mwanza flat-headed rock agama *Agama mwanzae* Loveridge, 1923 (figure 1).

Figure 1. Mwanza flat-headed rock agama Agama mwanzae*. Phtotgraph by D.M. Gunda.*

According to the IUCN Red List of Threatened Species, *Agama mwanzae* is listed as a species of Least Concern (LC) found in Tanzania, Kenya, Rwanda, and Burundi in savanna and grassland landscapes (Menegon *et al.*, 2014). This listing is due to its wide distribution and ability to tolerate anthropogenic environmental factors (Menegon *et al.*, 2014), and resilience to extreme hot and dry temperatures of up to 38°C (it will nevertheless hide in shaded areas waiting for cooler temperatures (Mcheto, 2010)). Although *A. mwanzae* can tolerate different environmental conditions, and major threats have not been recorded by IUCN, the species still faces conservation challenges. In particular, it is impacted by the international pet trade (Menegon *et al.*, 2014). The Tanzanian government has established an annual export quota of 2000 agamas (Menegon *et al.,* 2014), but has not pointed out how many individuals of each of the different species of agama present in the country can be exported (Menegon *et al.,* 2014). Therefore, studies on agama species are essential as they will help in revising this export quota by including the current agamid taxonomy (Menegon *et al.,* 2014). Furthermore, *A. mwanzae* population has existed in protected areas such as the Masai Mara Game Reserve, Serengeti and Arusha National Park (Razzetti and Msuya 2002, Spawls et al. 2002). But in order for conservation areas to gauge how well they are doing, it is necessary to collect baseline data on abundance, population structure and species distribution. Presently, there is no documentation of *A. mwanzae* abundance, age structure or distribution inside or outside of protected areas (Menegon *et al.,* 2014). This information is important in assessing population status of the species, which is essential for accurately assigning an IUCN threat status and setting an export quota.

Though the presence of and preliminary behaviour and morphology data on *A. mwanzae* in Kissesa, Mwanza region, on the southern shores of Lake Victoria was documented by Yarnell &

Jones (2001), more surveys and field studies on the reptile species of the area (including *A. mwanzae*) are necessary for effective conservation. Thus, our study was designed to provide baseline data and to assess the factors that may affect the abundance and distribution of the Mwanza flat-headed rock agama in Saanane National Park. To the best of our knowledge, this is the first study on *A. mwanzae* to be conducted in Saanane National Park. We targeted this park as it is located in an urban area, making it helpful in understanding the influence of human activities and disturbances to the species.

MATERIALS AND METHODS

Description of the study area

Saanane National Park is Tanzania's only national park located in a dense urban area, located two kilometres southwest of the Mwanza City Centre at 2° 30'S and 32°E (TANAPA, 2012). It was gazetted as a National Park in 2013. It is the smallest national park in East Africa (TANAPA, 2012) and covers an area of 2.18 km^2. The Park is located on the most southern part of the Lake Victoria Gulf, and comprises three islets: Saanane (largest), Chankende Kubwa and Chankende Ndogo (smallest) (TANAPA, 2012; figure 2). Our study was conducted on Saanane Island because of higher levels of biodiversity, ease of accessibility and the occurrence of tourist activities, as compared to the other two islets.

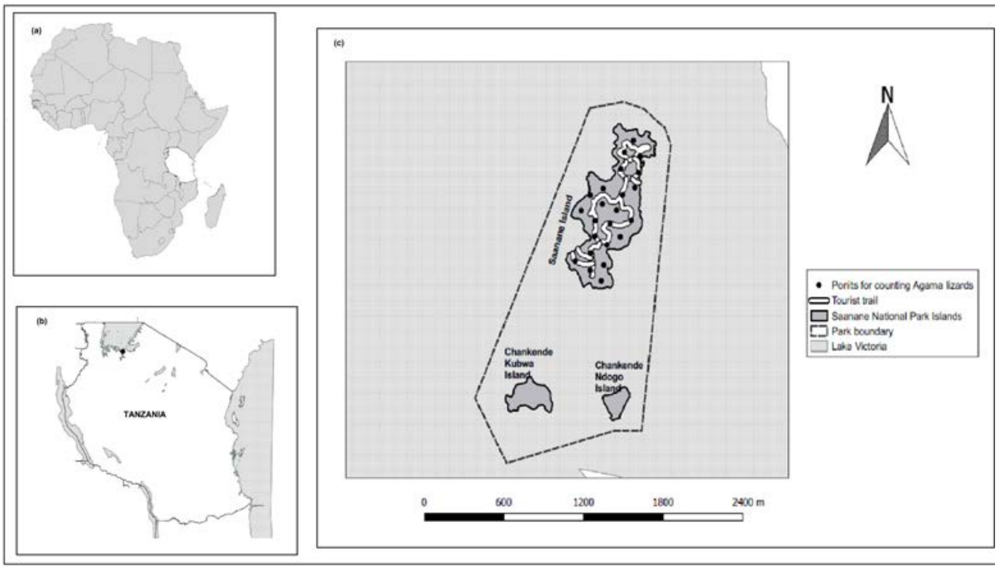

Figure 2. Maps showing location of the study site: (a) Africa showing the location of Tanzania; (b) Tanzania showing the location of Saanane National Park; (c) Saanane National Park with the location of 23 randomly selected study plots marked as black dots.

Data collection

We collected data between 14 November 2017 and 23 January 2018. Twenty-three points along the tourist trail were randomly chosen and their geographic coordinates were marked using a Global Positioning System (GPS) Garmin Etrex 20 (figure 2c). Around each point, a

50-meter radius plot was thoroughly searched for the presence of *A. mwanzae*. To minimize double count, the plot was divided in quarters with each quarter thoroughly searched by one person for utmost 15 minutes by starting from the centre of the point. Therefore, each plot was thoroughly searched by four people simultaneously. Searches were conducted during daylight hours because *A. mwanzae* is diurnal and bask in the sun during mid-day to elevate their body temperature (Blomberg & Shine, 2006; Mcheto, 2010; Menegon *et al.,* 2014). We recorded GPS location, date, time and daylight condition (sunny or non-sunny) before comencing each search. Within each plot, the number of *A. mwanzae* individuals were recorded along with the sex and age group (juvenile or adult) of each agama. The age and sex of adult *A. mwanzae* were determined based on physical and sexual dimorphism features. The physical and sexual dimorphism features used for age and sex determination were as follows: adult male agamas are larger in size than females and possess bright reddish-pink heads, necks and trunks, while their limbs and tail are blue (Yarnell & Jones 2001). These colours are more prominent during the day, but in the darker hours, the males change colour to a dark shade of brown (Mcheto 2010). Adult female and juvenile *A. mwanzae* have a cryptic olive to dark purple/grey/dull brown colour, with most of them possessing a pale dorsal streak (Yarnell & Jones 2001; Mcheto 2010). To determine the proximity of human presence, the distance was measured from each of the 23 points to the nearest tourist trail. Other features of human presence, such as campsite, picnic site, ranger post and bar, were also recorded. A point was classified to be of high human influence if it had both tourist trail and other human features (campsite, picnic site, ranger post and bar), while the points with only a tourist trail or other human feature were classified to be of low human influence.

Data analysis

The sum of individuals in all plots was used to calculate the abundance of the species on the Saanane Island following Nichols *et al.* (2009). Data were entered into a Microsoft Excel spreadsheet in comma delimited format (Comma-Separated Values or CSV) and analysed in R 3.4.2 (R Development Core Team, 2017). Generalized linear mixed model (GLMM) with the package lme4 (Bates *et al.,* 2015) and the function glmer were used to allow for detection of subgroup interactions, while accounting for the clustered structure of a dataset, when random effects are present. We run four GLMMs with different response variables which were total abundance, abundance of males, abundance of females and abundance of juveniles. In all models the fixed explanatory variables were daylight condition, human presence and distance from the tourist trail while sampling locations were treated as the random effect. Since the response variables were count data, we fitted the GLMMs with Poisson distribution and all models were checked for overdispersion. After that, we selected the top-ranked model basing on Akaike's Information Criterion corrected for small samples (AICc) after running all combinations of the global model by using dredge function of MuMIn package (Barton, 2018).

RESULTS

In total, 364 *A. mwanzae* individuals were counted within a 50-m radius at 23 designated points in Saanane National Park. Of them, 308 (or 85%) were adults and 56 were juveniles. There were 139 males (45%) and 169 (55%) females (table 1). The number of *A. mwanzae* varied between sampling localities, with the lowest number counted being two in point 10 and the highest being 51 in point 20 (mean $\pm$ SD of 15.8 $\pm$ 11.6).

Table 1. The abundance of Mwanza flat-headed Agama recorded in 23 points in Saanane National Park.

Point	Male	Female	Juvenile	Daylight condition	Human influence	Distance from tourist trails (m)
1	12	6	2	Non-sunny	High	37
2	22	9	2	Sunny	High	10
3	8	11	4	Sunny	Low	41
4	13	19	1	Sunny	Low	60
5	5	6	1	Sunny	Low	46
20	3	8	0	Non-sunny	High	44
6	4	3	0	Non-sunny	High	8
7	10	16	4	Sunny	High	28
8	9	9	0	Sunny	Low	39
9	3	3	0	Non-sunny	Low	23
10	0	2	0	Non-sunny	Low	9
11	4	3	7	Non-sunny	Low	1
12	1	2	5	Non-sunny	Low	0.5
13	5	5	5	Non-sunny	High	4
15	3	6	2	Non-sunny	High	8
17	4	3	1	Non-sunny	High	18
18	4	5	1	Non-sunny	High	1
19	1	2	2	Non-sunny	High	9
21	5	4	3	Sunny	High	72
22	9	33	9	Sunny	High	2
23	4	3	3	Sunny	High	75
24	5	9	4	Sunny	High	80
25	5	2	0	Non-sunny	High	82

Distance from tourist trail and daylight condition were the best variables in predicting the total abundance, female abundance and juvenile abundance, of *A. mwanzae* in Saanane National Park (table 2a, b and d). Abundance of male *A. mwanzae* was best predicted by daylight condition only (table 2b). The top ranked models showed that an increase in the distance from the tourist trail negatively affects the total abundance, female abundance, and juvenile abundance of *A. mwanzae* in Saanane National Park (table 3 a, b and d). Furthermore, we observed that daylight condition had an effect on total abundance and abundance of; females, males and juveniles of *A. mwanzae*, with abundance being higher in sunny than non-sunny periods (table 3). The odds ratios indicated that the total abundance and the abundance of females and juveniles were at least three times higher in sunny periods than in non-sunny periods (table 3 a, b and d). However, abundance of male *A. mwanzae*, was 1.297 higher in sunny than in non-sunny periods (table 3c). On the other hand, human influence was not found to be the best predictor of *A. mwanzae* total abundance nor the abundance of females, males and juveniles when included in the model (table 2).

Table 2: Model selection for the four generalized linear mixed models with different response variables. (a) total abundance of A. mwanzae*, (b) abundance of females, (c) abundance of males and (d) abundance of juveniles.*

Variables	df	AICc	ΔAICc	weight
a) Total abundance				
Distance from the tourist trail + Daylight condition	4	157.837	0.000	0.44752
Daylight condition	3	158.987	1.150	0.25177
Distance from the tourist trail + Daylight condition + Human influence	5	159.434	1.597	0.20141
Human influence + Daylight condition	4	160.882	3.045	0.09765
Null	2	170.039	12.202	0.00100
Human influence	3	172.513	14.676	0.00029
Distance from the tourist trail	3	172.577	14.740	0.00028
Distance from the tourist trail + Human influence	4	175.361	17.524	0.00007
b) Female abundance				
Distance from the tourist trail + Daylight condition	4	128.047	0.000	0.42428
Daylight condition	3	128.449	0.402	0.34701
Distance from the tourist trail + Daylight condition + Human influence	5	130.592	2.545	0.11887
Human influence + Daylight condition	4	130.822	2.775	0.10593
Null	2	138.381	10.334	0.00242
Distance from the tourist trail	3	140.933	12.886	0.00068
Human influence	3	141.010	12.963	0.00065
Distance from the tourist trail + Human influence	4	143.859	15.812	0.00016
c) Male abundance				
Daylight condition	3	123.870	0.000	0.53588
Human influence + Daylight condition	4	125.578	1.708	0.22812
Distance from the tourist trail + Daylight condition	4	126.405	2.535	0.15085
Distance from the tourist trail + Daylight condition + Human influence	5	128.338	4.468	0.05739
Null	2	130.967	7.098	0.01541
Distance from the tourist trail	3	132.859	8.989	0.00599
Human influence	3	133.306	9.436	0.00479
Distance from the tourist trail + Human influence	4	135.511	11.641	0.00159
d) Juvenile abundance				
Distance from the tourist trail + Daylight condition	4	99.683	0.000	0.29558
Null	2	100.066	0.384	0.24400
Daylight condition	3	100.990	1.307	0.15377
Distance from the tourist trail	3	101.776	2.093	0.10379
Human influence	3	102.550	2.867	0.07049
Distance from the tourist trail + Daylight condition + Human influence	5	102.653	2.971	0.06692

Variables	df	AICc	ΔAICc	weight
Human influence + Daylight condition	4	103.768	4.085	0.03834
Distance from the tourist trail + Human influence	4	104.460	4.777	0.02712

Table 3: Regression coefficient estimates Parameter and variables estimates with their 95% confidence intervals (CI) for the best models where response variable was (a) total abundance of A. mwanzae*, (b) abundance of females, (c) abundance of males and (d) abundance of juveniles.*

	Estimate	Std. Error	Lower CI	Upper CI	z	p-value	Odds ratio
(a) Total abundance							
Intercept	2.352	0.151	2.026	2.645	15.536	<0.001	
Distance from tourist trail	-0.009	0.004	-0.016	0.000	-2.182	0.029	0.992
Daylight condition (Sunny vs Non-sunny)	1.111	0.209	0.679	1.542	5.321	<0.001	3.037
(b) Female abundance							
Intercept	1.461	0.203	1.026	1.848	7.183	<0.001	
Distance from tourist trail	-0.010	0.005	-0.020	0.001	-1.930	0.054	0.990
Daylight condition (Sunny vs Non-sunny)	1.313	0.273	0.750	1.865	4.810	<0.001	3.717
(c) Male abundance							
(Intercept)	1.226	0.196	0.802	1.592	6.267	<0.001	
Daylight condition (Sunny vs Non-sunny)	0.878	0.260	0.359	1.424	3.380	0.001	1.297
(d) Juvenile abundance							
Intercept	0.710	0.318	-0.046	1.263	2.234	0.025	
Distance from tourist trail	-0.018	0.008	-0.036	-0.001	-2.124	0.034	0.982
Daylight condition (Sunny vs Non-sunny)	1.026	0.455	0.143	2.087	2.254	0.024	2.790

DISCUSSION

Documenting species population size, structure and distribution of species of interest within the landscape is essential for newly established protected areas. This allows for better conservation planning and management, and provides baseline data for monitoring, evaluation and decision-making. This study is the first step toward building a foundational dataset for *A. mwanzae* in Saanane National Park.

In this study, we recorded 364 individual Mwanza flat-headed rock agamas in an area that covers 2.15 km^2 located two km southwest of Mwanza City Centre. Of the 364 individuals, 85% of them were identified as adults, which may either imply that fecundity is low in this population, if juveniles are truly missing, or that juveniles are not present in the types of landscapes or are not visually accessible in these daylight surveys. It has been reported that agama juveniles have a higher risk of predation than their larger conspecifics, hide in rock crevices when new stimuli are detected, and rarely share the same retreats with adults (Yarnell & Jones, 2001). During the study, the juveniles may have been hiding from observers in response to the new activity, artificially reducing their perceived abundance. Another reason that could account for finding fewer juveniles may be male cannibalism, as some adult male agamas feed on juveniles (A. Eustace, pers. obs., 2015), which would reduce their numbers. Thus, *A. mwanzae* juveniles may often be hiding as a defence mechanism to avoid potential predators and male cannibalism, which lowers their survival rate, as compared to adult agamas (Nowchild, 2016).

Effect of daylight period on agamas

Agama mwanzae are poikilothermic and bask in the sun to regulate their body temperature. Our models revealed that the abundance of *A. mwanzae* is higher during the sunny periods compared to non-sunny periods (table 3), which would be consistent with their behaviour of basking in sun and hiding in holes or rock crevices during non-sunny periods (Böhme *et al.,* 2005; Blomberg & Shine, 2006). Therefore, sunny periods provide the best opportunity to determine population size, structure and distribution, rather than during non-sunny days when they are seeking shelter.

Tourist trail and *A. mwanzae* abundance

Our results revealed that distance from the tourist trail is the important variable in predicting the abundance of *A. mwanzae* in Saanane National Park (table 2) with increase in distance from the tourist trail, leading to a decrease in the total abundance and the abundance of females and juveniles of *A. mwanzae* in the study area (table 3 a, b and d). This suggests that the *A. mwanzae* in Saanane National Park has been acclimatized to the presence of tourists. However, more data is needed with regard to actual foot traffic along the tourist trail. The behaviour of lizards being acclimatized to tourist presence was also observed in *Teius oculatus* (D'Orbigny & Bibron, 1837) and *T. teyou* (Daudin, 1802) by Cacciali *et al.* (2016) in Laguna Blanca, Paraguay. Apart from lizards, butterflies have been also observed inhabitng tourist trails whereby more than 522 species of butterflies were recorded along tourist trails in Northeast Portugal (Gonzalez *et al.,* 2017). Thus, tourist trails have been reported to harbour diverse species, even though they might have a higher degree of human disturbance.

Human presence and agamas

Humans and their associated activities, including habitat degradation and poaching, have been reported to have negative impact on wild animal populations (Carter *et al.,* 2012; Mbise *et al.,* 2017). Our results revealed that human influence is not the best predictor of the abundance of *A. mwanzae* in the study area. This could indicate that the presence of humans does not influence the abundance of *A. mwanzae* in Saanane National Park. This means that the species can tolerate the presence of humans in the study area. Areas with higher human influence in Saanane National Park were picnic sites, campsites, ranger posts and shops. These areas may have been tolerated by *A. mwanzae* because of food availability and low predation levels. Houses and roofing made of corrugated iron sheets serve as an attraction for *A. mwanzae* as they provide shelter and opportunities for basking in the sun (Yarnel & Jones, 2001; Spawls *et al.,* 2002; Menegon *et al.,* 2014). The presence of ranger houses, shops and campsite washrooms in the surveyed area that were roofed with corrugated iron sheets could be providing shelter and basking sites for *A. mwanzae*. Therefore, further studies are needed to ascertain to what extent and for what purposes human presence can influence the presence of reptiles and other animals.

Study limitations and recommendations

This study represents preliminary ecological and population information about the *A. mwanzae* in Saanane National Park. Due to limited resources, consecutive monitoring for the species in different seasons and estimating population size and determining sex structure could not be conducted. Future studies on *A. mwanzae* in Saanane National Park should include a population monitoring program for the species and implementation of different sampling techniques to obtain robust estimates of population size and structure.

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