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Human impacts on the habitat structure for reptiles in the Uzungwa scarp nature forest reserve (USNFR)

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**HUMAN IMPACTS ON THE HABITAT STRUCTURE FOR REPTILES
IN THE UZUNGWA SCARP NATURE FOREST RESERVE (USNFR)**

John Valentine Lyakurwa

**A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of
Master's in Life Sciences at the Nelson Mandela African Institution of Science and
Technology**

Arusha, Tanzania

April, 2019

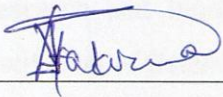
ABSTRACT

While knowledge of African herpetology has increased dramatically in recent years, many areas have not yet been adequately explored. The need for assessing habitat characteristics for reptile species is urgently required due to anthropogenic threats and how to best understand/mitigate such changes. Intensive field work was conducted during the rainy season from December 2017 to April 2018 to assess reptile occurrence mostly in biologically least explored areas of the Uzungwa Scarp Nature Forest Reserve (USNFR) which is part of the Udzungwa Mountain range in the Eastern Arc Mountains (EAM), and adjacent agricultural areas. Bucket pitfall traps, funnel traps, night transects, time constrained and opportunistic searches were used to sample reptiles across four zones; in lowland, submontane and montane forests of the USNFR and in neighboring farmlands. Interviews were used to assess farmers' perceptions on reptiles and provided data to supplement trapping in farmlands. Forty-five reptile species across 14 families were recorded, mostly concentrated in the lowland and submontane forests. Most endemic and threatened species were found in the submontane forest. This study reports nineteen species new to the USNFR, one being new to science. Five and four species represent distribution and elevation range extensions, respectively. Reptile species diversity and abundance differed significantly across the four zones, except between montane and farmland zones and between lowland and submontane zones. Species composition was strongly affected by elevation and land use type with farmland being more discordant from other zones and sites closer to each other being more related in their reptile species composition. Farmers were poorly informed on reptiles, and killing was the major action taken when a snake was encountered by them. This study adds to the importance of the EAM not only in harbouring large numbers of species but also as an important hotspot for endemic and threatened reptiles.

Keywords: Eastern Arc Mountains, farmland, elevation, reptiles

DECLARATION

I, John Valentine Lyakurwa, do hereby declare to the senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is entirely my own original work and that it has neither submitted nor being submitted for degree award in any other institution.



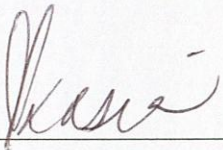
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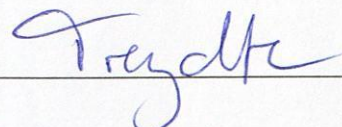


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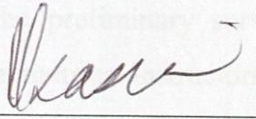
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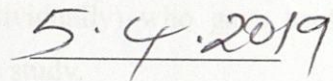
CERTIFICATION

The undersigned certify that they have read and hereby recommend the dissertation entitled "Human Impacts on the Habitat Structure for Reptiles in the Uzungwa Scarp Nature Forest Reserve (USNFR)" as a fulfilment of the requirement for the degree Master of Life Sciences at the Nelson Mandela African Institution of Science and Technology.

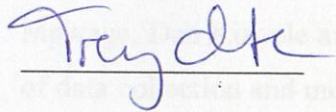


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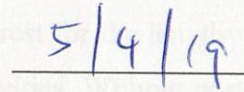


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DEDICATION

This work is dedicated to my mentor, Prof. Kim Monroe Howell, for the training, support and guidance he gave me since infancy stages of my professional carrier as a herpetologist. To him I owe a debt that will be extremely difficult to repay. May God bless him with more strength and energy to enjoy the future works in herpetology from the firm base he established on my carrier.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of Variance
cm	Centimeter
CR	Critically endangered
EAM	Eastern Arc Mountains
EN	Endangered
Farm	Farmland
IUCN	International Union for conservation of Nature
km	Kilometer
Low	Lowland
m	Metre
m.a.s.l	Metres above sea level
mm	Millimeter
Mon	Montane
NM-AIST	Nelson Mandela African Institution of Science and Technology
NT	Near threatened
Sub	Submontane
TFS	Tanzania Forest Service Agency
TH	Threatened
USNFR	Uzungwa Scarp Nature Forest Reserve
WWCT	Whitley Wildlife Conservation Trust
WWF	World Wide Fund for Nature

CHAPTER ONE

INTRODUCTION

1.1 Background

The Eastern Arc Mountains (EAM) are composed of thirteen separate mountain blocks of which 12 are found in Tanzania and one in Kenya (Burgess *et al.*, 2007). These mountains are amongst the most important places for biodiversity conservation as they harbour large number of endemic and threatened species of plants and animals (Shangali *et al.*, 1998; Burgess *et al.*, 2007; URT, 2010; Rovero *et al.*, 2014; Gereau *et al.*, 2016). They hold the highest concentration of endemic species per 100 km² of all biodiversity hotspots (Myers *et al.*, 2000) with more than 30% of the endemic vertebrates being reptiles (Burgess *et al.*, 2007; Rovero *et al.*, 2014). The Udzungwa mountain block is one of the most important of the EAM due to its large size and large number of endemic species (Burgess *et al.*, 2007; Rovero *et al.*, 2014). It has several protected areas one of which is the Uzungwa Scarp Nature Forest reserve (USNFR) (URT, 2010).

About 21.7% and 53.6% of the herpetofauna found in the USNFR are endemic to the Udzungwa Mountain block and EAM respectively (Menegon and Salvidio, 2005). Despite being highly important for conservation, the USNFR is one of the world's most threatened areas of biodiversity importance (Dinesen *et al.*, 2001; Rovero *et al.*, 2012). Most threats arise from anthropogenic activities (Rovero *et al.*, 2010) especially expansion of agricultural activities, fire wood collection, logging and poaching (Zilihona *et al.*, 1998; Rovero *et al.*, 2010). However, this reserve was recently upgraded from “forest reserve” to “nature reserve” category (URT, 2017), calling out for a higher protection status due to its uniqueness in biodiversity. Despite this upgrade, information regarding the USNFR's biodiversity is extremely scanty.

The number of endemic species of reptiles in the USNFR is reported to increase with an increase in altitude and some species are highly restricted in distribution to a certain altitude range (Menegon and Salvidio, 2005). It is possible to use these species as indicators for studying the impact of the ongoing climate change and habitat modification/transformation. Analysis by Meng *et al.* (2016) on threats facing reptiles in Tanzania shows agricultural activities and biological resource use (hunting/trapping, logging and wood harvest) to have affected more species (20% and 19% respectively) than any other threat. While the sensitivity

of reptiles to land use changes has been reported (Santelmann *et al.*, 2006), our knowledge on how these land modifications affect reptiles is still scant (Maritz and Alexander, 2007). Most reptiles have specific habitat requirements (Maritz and Alexander, 2007) and thus it is likely that any modification to their habitat will likely affect their behavior and reproductive potentials. Some of these habitat requirements have been reported *i.e* elevation, woody structure, water availability, canopy cover, temperature and humidity (Maritz and Alexander, 2007; Pike *et al.*, 2011; McDiarmid *et al.*, 2012; Bohm *et al.*, 2016) and most of them are affected by land modification/transformation (Masterson *et al.*, 2009).

Although herpetological studies in the USNFR reserve date back to more than 70 years ago (Loveridge, 1933), new species of reptiles and range extensions have been discovered from this area in the past decade (Menegon and Salvidio, 2002; Salvidio *et al.*, 2004; Menegon and Salvidio, 2005; Lyakurwa, 2017) indicating how little is known about this fragile ecosystem and its inhabiting species and the need for more long-term surveys especially in least explored areas.

Most reptiles are good biological control agents; for example, *Pseudaspis cana* and *Duberria lutrix* are harmless snakes which feed exclusively on mole rats and slugs/ small shelled snails, respectively (Spawls *et al.*, 2004). These species can be important to farmers for prevention of crop losses and for keeping population of some disease vectors down. This study aimed on providing detailed information on reptile habitat structure in the USNFR, utilization of encroached/agricultural areas by endemic and threatened reptile species and human-reptile interactions in villages bordering the reserve.

1.2 Problem statement and justification

The earth has faced an alarming loss of biodiversity in recent years, with extinction rates estimated to be higher than at any other time in the fossil record (Baillie *et al.*, 2004) and mostly associated to anthropogenic activities (Gardner *et al.*, 2007). Reptiles are one conspicuous component of the world's vertebrate fauna that has suffered more than most other groups in terms of population decline (Gibbons *et al.*, 2000). This is mainly due to the reptiles' poikilothermic nature (Rohr and Palmer, 2013), their often narrow range of habitat (Meng *et al.*, 2016) and their partly temperature dependent sex determination (Rödder and Ihlow, 2013). Despite the alarming records on loss of species, little has been done to assess biodiversity patterns and threats among African reptiles (Meng *et al.*, 2016). Tanzania harbors more than 321 reptile species of which about 28% and 13% are endemic and

threatened, respectively (Meng *et al.*, 2016). Most of these endemic and threatened species are found in the EAM.

Despite being one of the biologically diverse areas for reptiles, the EAM have faced a number of threats in recent years with agriculture encroachment, logging activities, firewood collection and climate change being the most important factors (Zilihona *et al.*, 1998; Menegon and Salvidio, 2005; Meng *et al.*, 2016). The mountains have lost over 70% of the forest cover to agriculture (Newmark, 1998; Newmark, 2002; Hall *et al.*, 2009) and currently support a large number of people (Ndangalasi *et al.*, 2007; Platts *et al.*, 2011). Since a number of reptile species have very small distribution ranges and depend on highly-specific habitat requirements (Spawls *et al.*, 2004; Meng *et al.*, 2016; Spawls *et al.*, 2018), they are highly vulnerable to the ongoing anthropogenic activities. Menegon and Salvidio (2005) show effects of elevation in determining distribution patterns of reptiles in the USNFR and reported most endemic species to be restricted to higher elevations, which have faced severe agricultural expansion (Zilihona *et al.*, 1998). Little is known on how this expansion impacts reptile species diversity and distribution. Since many reptiles are known to occur outside the existing protected areas (Meng *et al.*, 2016) it is important to understand how they respond to the ongoing land use transformations and how they utilize different habitats within the agricultural landscapes for proper management and sustainable conservation (Maritz and Alexander, 2007).

Several reports exist on reptiles of the USNFR (*e.g.* Menegon and Salvidio, 2005; Lyakurwa, 2017). However, they investigated species occurrences and neither of them focused on the details of habitat availability and demand. Similarly, these surveys were limited to the southern part of the USNFR and none studied how reptiles utilize the agricultural areas surrounding the reserve. Since these reports examined amphibians and reptiles simultaneously (except Lyakurwa, 2017), the surveys were limited to methods which could capture both species groups at once. One ongoing project in the USNFR on hyper-endemic amphibians has revealed a number of new records (especially the extension of distribution for the hyper-endemics and at least 3 new species of *Nectophryoides* into previously biologically unexplored areas (Tonelli *et al.*, 2017) and has shown the need to conduct detailed surveys for reptiles. This study was focused on providing detailed information on reptile species and their habitat characteristics in the USNFR and surrounding agricultural lands and to investigate farmers' knowledge on reptiles occurring in their farm plots.

1.3 Research objectives

1.3.1 General objective

The main objective of this study was to assess how environmental factors such as elevation, humidity, canopy cover, understory cover, leaf litter depth and temperature impact endemic and threatened reptile species abundance and distribution in the USNFR and surrounding agricultural lands.

1.3.2 Specific objectives

- i. To examine the distribution of reptiles in the USNFR and surrounding agricultural lands.
- ii. To determine species which are sensitive to farmland expansion and, thus, could act as important indicator species for ecosystem health.
- iii. To examine habitat characteristics that determines the abundance and diversity of reptiles both in the USNFR and in bordering agricultural areas.
- iv. To assess the farmers' awareness and perceptions on reptile occurrence in the farms bordering the USNFR.

1.4 Hypotheses

- i. Sites adjacent to each other have greater similarity in reptile species composition than distant sites.
- ii. Sites within the protected area are more similar in reptile species composition compared to sites in agricultural lands.
- iii. Since most of the EAM endemic/ near endemic reptile species are forest dependent and unlikely to survive in absence of the forest, they might serve as good indicators of the ecosystem health especially in monitoring the ongoing encroachment activities.
- iv. Various habitat factors that are associated with the distribution and abundance of most reptiles in the USNFR and surrounding areas can be determined.
- v. Farmers have little awareness on the ecological, economic and cultural importance of reptiles.

1.5 Significance of the study

This study provides data on the status of reptile species in the USNFR and adjacent areas encroached by human activities. An updated list of reptiles in the USNFR is provided with detailed information on utilization of transformed and protected landscapes by reptiles. This information will enable wildlife managers to devise better ways in which reptiles can be conserved inside and outside the protected areas and might be important in land use plans. A manual with coloured photos of reptiles present in the farms is going to be prepared for the farmers by using data obtained by this study. The manual will contain information for each species stating if a species is venomous or not, its habitat and food habit. Promising indicator species for forest changes are given and might prove useful in monitoring the ongoing encroachment activities following more studies. The relationship between habitat factors and reptile species occurrences in the USNFR is highlighted. This is useful not only in assessing the impacts of the anthropogenic activities to reptiles but can be used to assess the restored/regenerated forests as refuge for reptiles. This is the first study to assess the perception and knowledge of farmers bordering the USNFR towards reptiles. This information will assist managers in developing better management protocols that will conserve reptiles even outside the current protected areas.

CHAPTER TWO

LITERATURE REVIEW

Introduced in 1980s, the word “Eastern Arc” describes the arc of forest-capped ancient crystalline mountains of eastern Tanzania and south-east Kenya (URT, 2010). The EAM are among the oldest mountains in East Africa, and harbour many species of plants and animals (Lovett *et al.*, 2004). They consist of thirteen separate mountain blocks together forming an Arc shape which collectively cover an area of about 32 000 km² (Burgess *et al.*, 2007).

For their size, the EAM are biologically the richest area in Africa (Newmark, 2002). They contain larger number of endemic species than any other place in the region (Newmark, 2002). About 32 species of reptiles are endemic to the EAM, the majority being chameleons in the genera *Chamaeleo*, *Rhampholeon* and *Kinyongia* (URT, 2010; Meng *et al.*, 2016). Some species are restricted to only a single mountain block (Burgess *et al.*, 2007). However, many areas of the EAM have not been adequately explored and it is not possible to accurately assess their importance as endemic habitats for reptiles.

At the south-western end of the EAM, lies the Udzungwa Mountain range. These mountains have the largest number of single-block endemic vertebrate species compared to any other mountain block in the EAM (Burgess *et al.*, 2007; Rovero *et al.*, 2014). However, the Udzungwa Mountains are experiencing increasing human pressure and significant declines in local species abundance (Dinesen *et al.*, 2001; Rovero, 2007; Rovero *et al.*, 2010; URT, 2010; Rovero *et al.*, 2012).

Uzungwa Scarp Nature Forest Reserve (USNFR) is one of the largest continuous forests within the Udzungwa mountains with an area of 207 km² and stretches from 300 m to 2068 m a.s.l (Menegon and Salvidio, 2005; URT, 2010). The great altitude range of the USNFR is reflected by its remarkable diversity in vegetation types (Shangali *et al.*, 1998), which possibly accounts for the unique number of strictly endemic species found within it. Rovero *et al.* (2004) estimated the density of the EAM endemics and near endemics in the USNFR to be 30.8 per 100 km², much higher than that for the entire Eastern Arc (4.5 per 100 km²). The USNFR is a hotspot within the EAM hotspot and it is especially important in terms of herpetofauna. It contains about 36 species of amphibians from six families (Menegon and Salvidio, 2005) and 38 species of reptiles from eight families (Lyakurwa, 2017).

Several researchers have surveyed the Eastern Arc Mountains and mentioned the USNFR to be of greater biological importance than other forests in the EAM (Dinesen *et al.*, 2001; Menegon and Salvidio, 2005; URT, 2010; Rovero *et al.*, 2012). Despite of its great importance, the USNFR is not fully protected, and much is expected in the future following its recent upgrade in conservation status. Although few researchers have worked on reptiles in the USNFR the area is known to harbour number of endemic, endangered and vulnerable species (Appendix 1). More surveys are needed in order to assess the status of these species, and to document areas which have not yet been sampled in detail. Since reptiles may be found from below the ground to the tree canopy (Howell, 2002) protecting them through habitat protection will benefit many other species. For example, conserving the undergrowth and leaf litter will not only serve the fossorial and ground dwelling reptiles but will also accommodate other endangered and endemic species like the Grey-faced Sengi *Rhynchocyon udzungwensis* (VU, Udzungwa endemic), *Nectophrynoides viviparous* (VU), *Nectophrynoides wendyae* (CR) and *Nectophrynoides poyntoni* (CR) which prefer moist areas with considerable ground cover.

USNFR is also very important to the livelihoods of local peoples as it supplies most of their basic needs like water for domestic and agricultural use (Newmark, 2002; Rovero *et al.*, 2004). So, protecting the forest will also maintain the water catchments which supply water throughout the year to people living in Kilombero valley part of which is an important conservation area “a ramsar site”.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study site

Data for this study were collected in the Uzungwa Scarp Nature Forest Reserve (USNFR) and surrounding areas. The USNFR covers the south eastern part of the Udzungwa Mountains and lies between 7°39' - 7°51' S, and 35°51' - 36°02' E (Ndangalasi, 2005; Fig. 1). With an altitudinal range of 300-2068 m.a.s.l, it covers a total area of 207 km² (Shangali *et al.*, 1998, URT, 2010). It borders Chita River to the south, the Kidete River to the north and the Ruaha, Iwolo and Lukosi rivers to the west (Ndangalasi, 2005). It stretches between two administrative regions, Morogoro (Kilombero district) and Iringa (Mufindi and Kilolo districts). Annual average rainfall in the study area is unimodal (from November to May) and ranges from 1800 mm to 3000 mm (Shangali *et al.*, 1998; Ndangalasi, 2005). Temperature varies seasonally and along elevation and is estimated to range from 15 °C to 20 °C on the highlands and 19 °C to 27 °C on the lowlands (Ndangalasi, 2005).

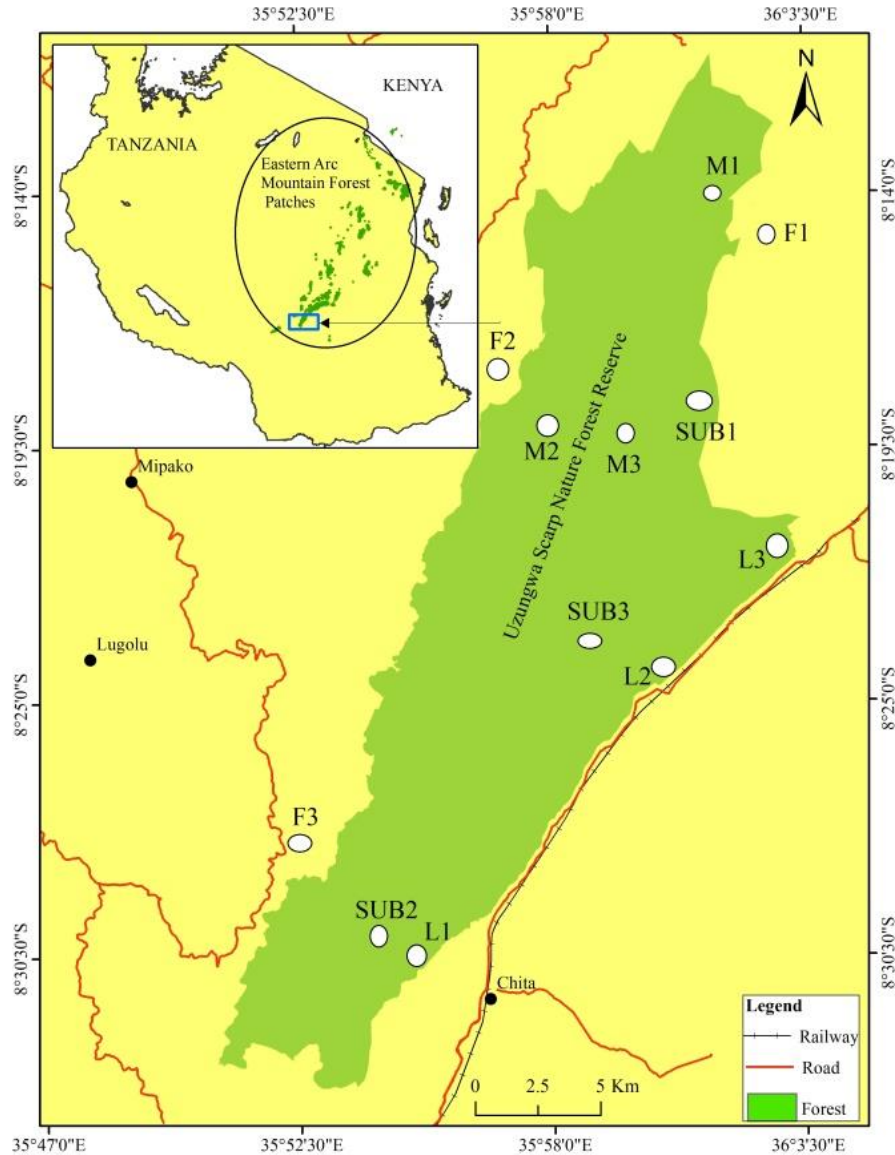


Figure 1: The Uzungwa Scarp Nature Forest Reserve’s location with respect to the Eastern Arc Mountains, Tanzania with the 12 surveyed sites indicated as white circles. F = Farmland, M = Montane, L = Lowland and SUB = Submontane.

The reserve comprises lowland, submontane and montane forests and contains areas of seasonally inundated grasslands and grassland with bushes (Shangali *et al.*, 1998; Zilihona *et al.*, 1998; URT, 2010). Lowland forests are relatively dry and have a low, often broken canopy with woodland species except near streams where riverine forest occurs (Shangali *et al.*, 1998; Menegon and Salvidio, 2005; URT, 2010). Submontane forests are well developed, though they have species often associated with dry forest on the ridges (Shangali *et al.*, 1998). A large area of the scarp is occupied by montane forest which is mostly dominated by shrubs with understory and few trees which are not as tall as in submontane forest (Shangali

et al., 1998). Extensive stands of bamboo occur on the western side especially near Idegenda, Masisiwe and Mbawi villages (Shangali *et al.*, 1998; Menegon and Salvidio, 2005). The USNFR is surrounded by 19 villages most of which occur on the plateau side (Ndangalasi, 2005) and carry out their farming activities close to the reserve.

3.2 Study design and field protocols

Data were collected during day and night for five consecutive months in the wet season from mid-December 2017 to the end of April 2018. Selection of sampling sites was primarily based on elevation, vegetation types (Shangali *et al.*, 1998; Zilihona *et al.*, 1998) and land use type (Fig. 2). Other factors known to influence reptile abundance and distribution were also considered at each site. These factors included the amount of leaf litter, availability of rotten logs, distance from water bodies, termite mounds and rock crevices following Howell (2002) and McDiarmid *et al.* (2012). The study area was divided into four zones; three inside the USNFR, *i.e.* lowland forest (< 700 m.a.s.l), submontane forest (700-1400 m.a.s.l) and montane forest (> 1400 m.a.s.l) following Shangali *et al.* (1998) and Zilihona *et al.* (1998) with some slight modifications. The fourth zone was set in farmlands bordering the USNFR. These farms were located on the plateau side of the USNFR, (elevation > 1400 m.a.s.l, outside the USNFR) and were of interest to this study to verify if the observed pattern of endemism in the reserve would extend beyond the protected area. Each zone consisted of three sites (12 sites in total, see Fig. 1), each with a radius of 1 km, and placed at least 2 km apart. Data collection took place for ten days at each site, making a total of 120 days (90 and 30 days in and outside the USNFR, respectively). Several methods (bucket pitfall traps with drift fences, funnel traps, night transects, time constrained searches and opportunistic searches) were used following Howell (2002) and McDiarmid *et al.* (2012) in order to maximize captures.



Figure 2: Major land use patterns in the USNFR and surrounding areas. “A” represents farmlands bordering the USNFR (note a small portion of the USNFR in the right side of the picture), “B” represents closed forest of the USNFR near Uluti village. Photos were taken in December 2017.

3.2.1 Bucket pitfall traps, funnel traps and a drift fence

Bucket pitfall/funnel traps with a drift fence is an effective method of trapping forest floor species and one among the very few methods suitable for burrowing reptiles (Howell, 2002). The principle involved in this method is that a reptile moving on the forest floor encounter a barrier (drift fence) and rather than crossing the fence, burrow under it, or break through it, takes the route of minimum resistance by moving either right or left following the fence which lead it to a funnel trap or to drop into a pitfall trap. Although this method requires a considerable amount of time and energy to establish, it is very effective in capturing animals that would not otherwise be detected (Howell, 2002).

Eleven 20 litre buckets (black in colour) were sunk into the ground at an interval of 5 metres in a straight line with their rims flush to ground level (Fig. 3A). Several small holes were made at the base of each bucket to allow water to drain from them. A transparent plastic sheet of 0.5 m high was erected along the bucket line crossing the centre of each bucket to form a ‘drift fence’ (Fig. 3A). One double-ended funnel trap was set alternately between each bucket (Fig. 3A and B). This made one bucket pitfall line to consist of a 50 m long drift fence, eleven 20 litre buckets and 10 double-ended funnel traps. Double-ended funnel traps are among the most effective traps for ground dwelling snakes and lizards. Two bucket pitfall lines were established at each site making a total of six bucket pitfall lines (66 buckets, and 60 funnel traps per zone). Trapping was done for eight consecutive nights, in which trap

monitoring was done immediately following sunrise and late afternoon following Stanley *et al.* (1998) and Howell *et al.* (2012). A total of 176 bucket pitfall trap nights and 160 funnel trap nights were established at each site leading to 2112 and 1920 bucket pitfall trap nights and funnel trap nights, respectively, for the entire study.



Figure 3: Part of a bucket pitfall trap line showing, a bucket, drift fence and a funnel trap (A), a closer look of a funnel trap, with the researcher removing a snake from it (B).

3.2.2 Night surveys

Night transects can be used to monitor changes in species diversity, abundance and distribution through time and space (McDiarmid *et al.*, 2012). This is a very effective method for sampling chameleons and nocturnal reptiles such as most geckos and some snakes. A total of four 50 m night transects were established at each site (total of 48 transects for the entire study). Each transect was located and marked with a neon flagging tape at each 10 m in advance during the day for easy searching during the night. Transects were set to cover a range of microhabitats (*sensu* Menegon *et al.*, 2008). Searches involved two people each with a head torch, walking along the transect looking for reptiles from 19:00 hrs to around 22:00 hrs the time which most nocturnal reptiles are active.

3.2.3 Time constrained and opportunistic searching

Since pitfall/funnel traps and night transects alone cannot adequately sample all species of reptiles, these methods were supplemented by time constrained searching (Howell, 2002) and opportunistic encounter methods (McDiarmid *et al.*, 2012). Time constrained searching involved three people searching for reptiles in their possible hiding/basking places *e.g.* in rotting logs, under stones, around termite mounds and along/around water bodies during the

day for two hours at each site (making a total of 72 person-hours of searching for the entire survey period). Animals that were found outside the above systematic sampling procedures together with those found outside the 12 sites but still within the study areas were recorded as opportunistic encounters.

3.2.4 Measuring environmental/habitat variables

All habitat characteristics were recorded at every trapping site and at all points where reptiles were encountered. At the bucket pitfall lines and night transects habitat characteristics were recorded at the beginning, middle and end at randomly selected points within 15 m of a transect/bucket line in both sides of a drift fence/transect (right and left) making six habitat recordings per a pitfall line/transect. At each point variables were measured in four cardinal directions (totaling 648 recordings) and then averaged. Elevation was recorded by a handheld GPS (Garmin GPSmap 64st), canopy cover by spherical crown densiometer (Lemmon, 1957), temperature and humidity by Oregon scientific thermohygro, leaf litter measurements followed Van Sluys *et al.* (2007) and understory vegetation cover was estimated in 1 x 1m plot.

3.2.5 Nomenclature of the study species

Nomenclature and taxonomy of East African reptiles has changed dramatically in recent years, thanks to the advancement of molecular techniques (Freitas *et al.*, 2018; Spawls *et al.*, 2018; Wüster *et al.*, 2018). While the taxonomy of reptiles in East Africa is yet to be settled, this study generally followed nomenclature by Spawls *et al.* (2018) except for *Mochlus sundevallii* which followed Freitas *et al.* (2018). Specimens collected were preserved in 70% ethanol and deposited at the Department of Zoology and Wildlife Conservation of the University of Dar es Salaam (see Appendix 1 for accession numbers).

3.2.6 Interviews

Trapping and direct observations in farmlands were supplemented by data from local people which was obtained through interviews (Fig. 4A & B). Four villages located on the plateau, closest to the USNFR were selected following Ndangalasi (2005). A total of 112 respondents were expected to be interviewed following the sample calculations formula by Cochran (2007). Proportional allocation (Cochran, 2007) was used to locate the sample size in each village, in which individuals were randomly selected. The respondents were asked about the

kind and species of reptiles found in their farms (pictures were used to assist them). Farmer's knowledge on reptiles, farming practices, perceptions on reptiles and incidences of snake bites were also explored.



Figure 4: Interviewing a small holder farmer around the USNFR (A), showing a green snake (*Philothamnus* sp) to a farmer to confirm what they mentioned during interviews.

3.3 Analysis

The findings are presented using both descriptive and inferential statistics. Species similarity among the surveyed sites and zones was computed using Bray-Curtis similarity index (Legendre, 1998; Greenacre and Primicerio, 2013) on which a dendrogram and a matrix table were given. This index works almost the same as other indices (*e.g.* Sørensen), except that it uses quantitative data while others uses presence - absence data only (Greenacre and Primicerio, 2013). Canonical correspondence analysis (Ter-Braak, 1986) was used to relate species to the environmental variables. Generalized linear model was also applied to examine how species were distributed along the elevation gradient (*sensu* Kutt *et al.*, 2011). Linear, exponential, logarithmic and polynomial fits were tested to determine the one which best explains the relationship by examining the percentage deviance or the resultant residual sum of squares (*Sensu* Kutt *et al.*, 2011). Kruskal Wallis test (Kruskal and Wallis, 1952) with Dunn's multiple comparisons as a post hoc was used to compare abundance of species in the four zones. Shannon Wiener diversity index was used for species diversity in which comparisons were made using one way ANOVA with Turkey test as a post hoc. Tolerance level of farmer's towards reptiles was computed following Nahonyo (2006). Other attributes from farmers were computed in percentages and presented in simple bar graphs. Data were analyzed using R software version 3.5.0 and Paleontological Statistics software (PAST)

version 2.17 (Hammer *et al.*, 2001). Comparisons were considered significant when P value was less than 0.05.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Distribution of reptiles in the USNFR and surrounding agricultural lands

A total of 358 individual reptiles were recorded, representing 45 species across 14 families (Appendix 1). Thirty three species were found in the USNFR alone, two in farmland alone, and 10 in both (Fig. 5; Appendix 1). Seven species (*Kinyongia sp.*, *Trioceros deremensis*, *Broadleysaurus major*, *Crotaphopeltis tornieri*, *Dendroaspis angusticeps*, *Gonionotophis nyassae* and *Lycophidion uzungwense*) were singletons (single observations), three (*Urocotyledon wolterstorffi*, *Trioceros tempeli* and *Afrotyphlops nigrocandidus*) were doubletons (double observations) while the rest of the species were observed at least three times throughout the study.

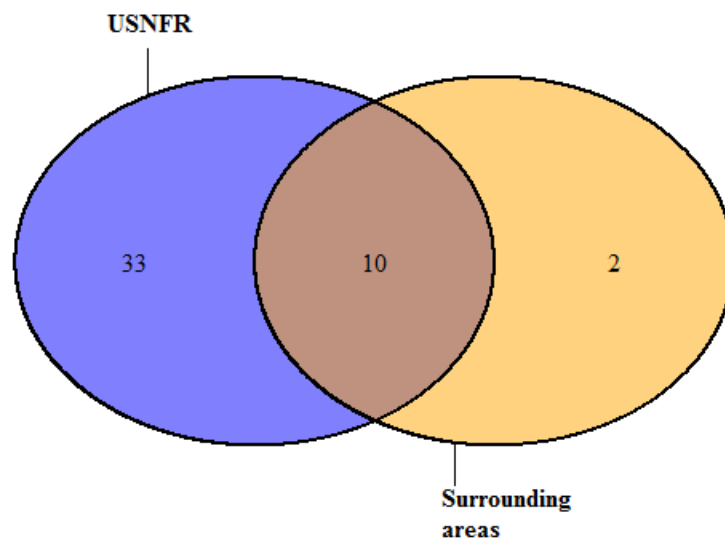


Figure 5: Number of reptile species recorded between December 2017 and April 2018 both inside and outside the USNFR.

Nineteen species were new records for the USNFR, five of them representing range extensions (Appendix 1) from previously known distribution ranges. This raised the number of species that had been reported previously in the USNFR and surrounding areas (Menegon and Salvidio, 2005) to reach 60 species across 16 families (Table 1; Appendix 1).

Table 1: Total number of reptile species, number of endemic and threatened species, per families found in and around the USNFR (Sources: Menegon and Salvidio, 2005; Lyakurwa, 2017, this study). EN = Endangered, NT = Near threatened, VU = Vulnerable according to IUCN classification (IUCN, 2018; Uetz *et al.*, 2018).

Family	Total	Endemic	EN	NT	VU
Agamidae	1	0	0	0	0
Atractaspidae	2	0	0	0	0
Chamaeleonidae	9	7	1	2	0
Colubridae	12	2	1	1	0
Elapidae	2	0	0	0	0
Gekkonidae	8	2	0	0	2
Gerrhosauridae	1	0	0	0	0
Lamprophiidae	3	1	0	0	0
Natricidae	1	0	0	0	0
Psammophiidae	2	0	0	0	0
Pseudoxyrhophiidae	2	0	0	0	1
Pythonidae	1	0	0	0	0
Scincidae	9	2	1	0	1
Typhlopidae	1	1	0	0	1
Varanidae	1	0	0	0	0
Viperidae	5	1	0	0	3

All reptiles reported in preliminary surveys (Lyakurwa, 2017) were also recorded during this study, except for *Bufo procterae*, *Natriciteres variegata*, *Python natalensis* and *Xyelodontophis uluguruensis* (Appendix 1). Nine species previously recorded by Menegon and Salvidio (2005) in the same area were not found during this study (Appendix 1). *Lycophidion uzungwense*, previously found inside the USNFR by Menegon and Salvidio (2005), was only found in a natural forest patch outside the USNFR during this study. These patches (Fig. 6A and B), together with commercial forests and fruit trees in agricultural lands (Fig. 6B), also proved to be important for chameleons, especially *T. tempeli* and *T. werneri* (Fig. 7F) in this study.

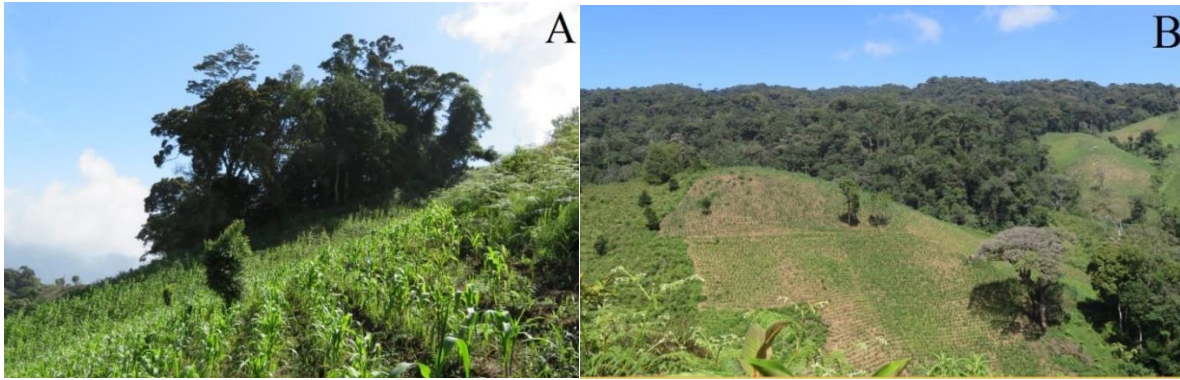


Figure 6: One of the natural forest patches within agricultural lands surrounding the USNFR (A). These forest patches are believed to be remaining fragments from previously larger expanding USNFR. Agricultural activities bordering the Uzungwa Scarp Nature Forest Reserve (USNFR) (B). Photos were taken at Uluti in December 2017.

Kinyongia sp. (Fig. 7E) is believed to be a new species similar to *Kinyongia fischeri* based on morphological grounds. Similarly, *Aparallactus sp* (Fig. 7D) needs further studies as the currently available identification key by Spawls *et al.* (2018) was not sufficient to identify it to species level. The genera *Lygodactylus*, *Cnemaspis* (Fig. 7C) and *Urocotyledon* (Fig. 7A and B) encompass individuals with highly varying morphology and these findings likely represent more than one cryptic species in these genera, hence, require further molecular analyses to clarify their taxonomic identity.



Figure 7: Some of the reptile species recorded in the USNFR between December 2017 to April 2018. Male (A) and Female (B) *Urocotyledon wolterstorffi*, *Cnemaspis* sp (C), *Aparallactus* sp (D), *Kinyongia* sp. (E) and a male *Trioceros weneri* on a commercial plant outside the USNFR (F). The above *Cnemaspis*, *Aparallactus* and *Kinyongia* could not be identified with certain to species level using Spawls *et al.* (2018).

This study also documented that the USNFR harbours about 21% of reptiles that are endemic/near endemic to Tanzania (Appendix 1). About 69% of reptiles endemic/near endemic to EAM are now confirmed to occur in the USNFR (Appendix). A large number of these endemics were chameleons (7 species), representing 29% of all Tanzanian endemic

chameleons. Submontane zone contained the largest number of endemic and threatened species than other zones (Fig. 8).

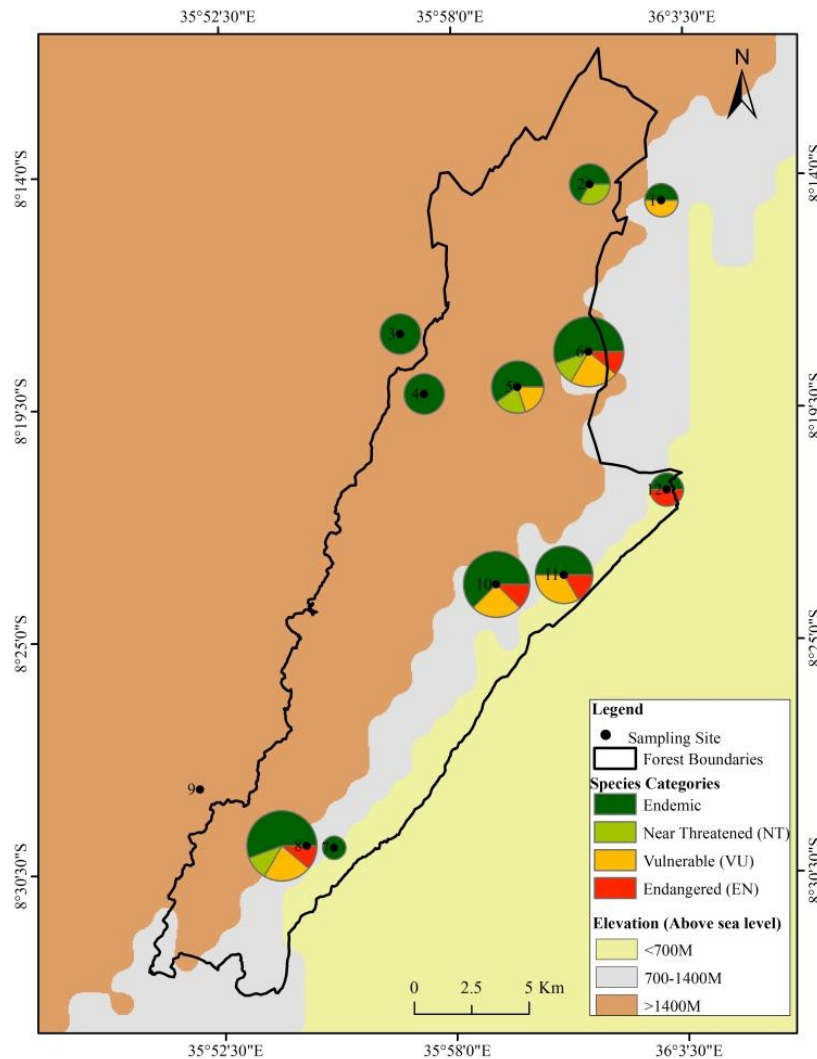


Figure 8: Distribution of endemic (dark green), Vulnerable (yellow), Near Threatened (light green) and Endangered (red) reptile species in the Uzungwa Scarp Nature Forest Reserve and surrounding areas as assessed from Dec 2017 to April 2018. Numbers represent the site ID

Bray-Curtis similarity index showed farmland to be the most discordant zone (Fig. 9 and 10), with lowland and submontane zones being more similar in species composition. Lowland, submontane and montane zones contained more forest dependent species than farmland zone (Appendix 1)

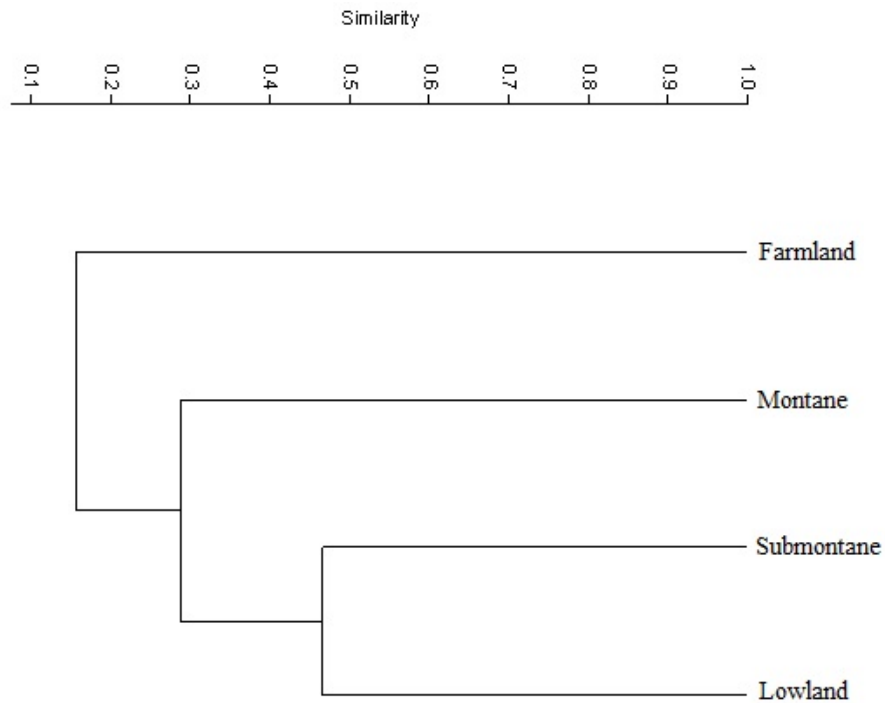


Figure 9: Similarity cluster among the four zones of the Uzungwa Scarp Nature Forest Reserve and adjacent areas based on Bray-Curtis similarity index (Single Average Link) as per the current study.

Sites in the farmland zone (abbreviated as Farm) were very similar in species composition and dissimilar to sites in protected areas *e.g.* the similarity index of Farm1 vs Farm2 = 0.5634, Farm1 vs Farm3 = 0.8400 and Farm2 vs Farm3 = 0.6575 (Fig. 10; Appendix 2). Some farmland sites showed 100% differences in reptile species when compared to sites in protected areas *e.g.* Farm2 vs Sub2 (Sub represents Submontane), Farm2 vs Low2 (Low represents Lowland) and Farm3 vs Low2 (Appendix 3). Also, as expected, sites close to each other were more similar in species composition than distant sites *e.g.* Mon3 vs Sub1 (Mon represents Montane) (Fig. 10; Appendix 2), whereby some distant sites showed completely no similarity *e.g.* Mon2 vs Sub2, Mon1 vs Low2, Mon2 vs Low2 and Mon3 vs Low3 (Appendix 2). Some sites in lowland forest showed great similarity with those of submontane forest *e.g.* Low2 vs Sub2, (Fig. 10; Appendix 2). Similarly, sites in the same elevation zone were more related than when compared with sites in other zones *e.g.* sites Low1 vs Low3, Sub1 vs Sub3, Mon1 vs Mon2 and all sites in farmland zones (Farm1, Farm2, Farm3) (Fig. 10; Appendix 2).

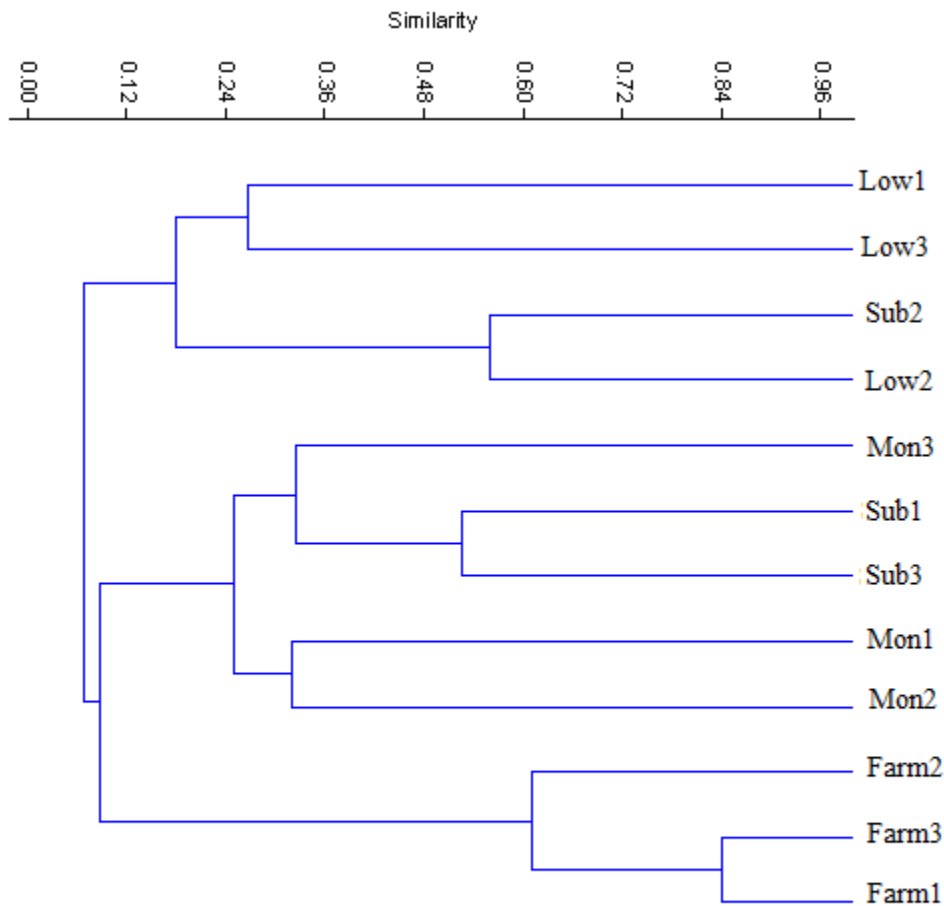


Figure 10: A dendrogram based on Bray-Curtis species similarity index (Single Average Link) for reptiles from the 12 sites surveyed between December 2017 to April 2018 in the Uzungwa Scarp Nature Forest Reserve and surrounding areas. Low = Lowland, Sub = Submontane, Mon = Montane, Fam = Farmland.

4.1.2 Species sensitive to farmland expansion: possible indicator species

The majority of species recorded during this study (33 out of 45) were found only inside the USNFR, while 10 were found both inside the USNFR and adjacent farms. Only two species *i.e.* *Lycophidion uzungwense* and *Broadleysaurus major* were found in farmland zone alone with the latter being found opportunistically in farms adjacent to lowland forest (< 700 m.a.s.l.). When these species were compiled with results from previous records (Menegon and Salvidio, 2005; Lyakurwa, 2017), and classified based on their dependencies to forest

following Burgess *et al.* (2007), nineteen species were classified as mainly forest, forest visitor and strictly forest (Table 2).

Except for *A. nigrocandidus*, all strictly forest dependent endemic/ near endemic species were restricted to the USNFR (Appendix 1). Similarly, all other endemic reptiles were restricted to areas inside the USNFR with exception of *T. tempeli*, *T. weneri* and *L. uzungwense* (Appendix 1). Outside the USNFR, *A. nigrocandidus* was found in a farm plot while *T. tempeli*, *T. weneri* and *L. uzungwense* were only found in natural forest fragments, in fruit trees (the former two) and in commercial forests dominated by *Cupressus* sp (Fig. 7F) and *Pinus* sp.

Maize and bean fields were poor in reptile species, with only *Philothamnus hoplogaster*, *Lygodactylus grotei* and *Trachylepis varia* being the common residents. All the 19 species which were found to be associated with forest habitat are endemic to Tanzania (Except *Philothamnus macrops* which is near endemic), and encompass all threatened species in the USNFR. The use of these species as indicators of ecosystem health, especially changes in forest cover which is likely due to observed logging activities (Fig. 11) and encroachment activities is discussed in Section 4.2.2.



Figure 11: Some of the illegal destructive activities (poacher's camp and timber making) observed in lowland and submontane forests of the USNFR during this study.

Trioceros weneri and *T. tempeli* are among the 19 species classified, but were found both inside the forest, at the forest edge, and outside the USNFR. However, outside the USNFR the two were found only in natural vegetation and on commercial plants close to forest edge (for *T. weneri*) and are unlikely to sustain their populations in absence of woody plants.

Kinyongia cf. oxyrhina, *Rhampholeon moyeri* and *Atheris ceratophora* were found inside the USNFR and at the forest edge and none was found outside the USNFR. *Urocotyledon wolterstorffi* was also found on submontane and lowland forests, close to forest edge (on the lowland side). *Cnemaspis uzungwae* was found almost throughout the USNFR (none outside). These species can serve as good indicators of ecosystem especially changes in forest cover upon further studies (see Section 4.2.2).

Table 2: Eastern Arc Mountain endemic/near endemic species recorded in the USNFR classified based on their forest dependencies following Burgess *et al.* (2007). Sources for species were from Menegon and Salvidio (2005), Lyakurwa (2017) and this study.

Forest dependency	Common name	Scientific name
Forest visitor	Udzungwa viper	<i>Atheris barbouri</i>
	Usambara bush viper	<i>Atheris ceratophora</i>
	Red-snouted wolf snake	<i>Lycophidion uzungwense</i>
	Usambara green snake	<i>Philothamnus macrops</i>
	Usambara three horned chameleon	<i>Trioceros deremensis</i>
	Spiny-flanked chamaleon	<i>Trioceros laterispinis</i>
	Udzungwa double-bearded chameleon	<i>Trioceros tempeli</i>
Mainly forest	Werner's three horned chameleon	<i>Trioceros werneri</i>
Strictly confined to forest		<i>Afrotyphlops nigrocandidus</i>
	Bicoloured blind snake	<i>Bufo procterae</i>
	Uluguru forest snake	<i>Cnemaspis uzungwae</i>
	Udzungwa forest gecko	<i>Crotaphopeltis tornieri</i>
	Tornier's cat snake	<i>Dipsadoboa werneri</i>
	Werner's tree snake	<i>Kinyongia sp. nov</i>
	East Africa Montane chameleon	<i>Kinyongia cf. oxyrhina</i>
	Uluguru one-horned chameleon	<i>Rhampholeon moyeri</i>
	Udzungwa pygmy chameleon	<i>Scelotes uluguruensis</i>
	Uluguru fossorial skink	<i>Urocotyledon wolterstorffi</i>
	Uluguru tail-pad gecko	<i>Xyelodontophis uluguruensis</i>
	Dagger-tooth vine snake	

4.1.3 Habitat characteristics determining reptile abundance and diversity

Most individual reptiles were found on trees (40.3%), understory (25.5%), underground (9.1%), dead logs (6.6%), rocks (3.3%) and in farmlands, few individuals were found on

house walls (0.8%). Among individuals, which were found above the ground (n= 177), 52.0% were found at 50-100 cm height, 32.2% between 100-300 cm height, and 15.8 % were found above 300 cm from the ground.

Lowland and submontane forests contained a similar number of reptile species, which decreased significantly towards montane forest and farmland zones (H= 18.187, P=0.0004; Fig. 12).

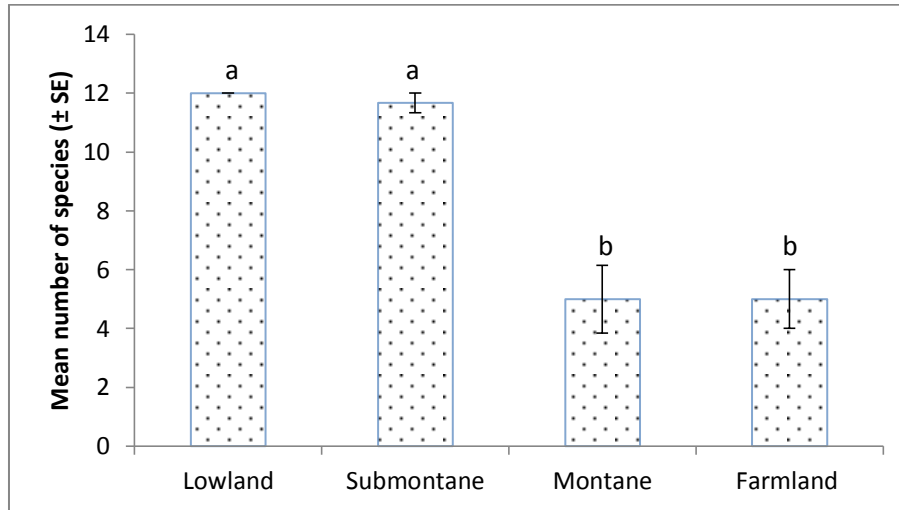


Figure 12: Mean number (\pm SE) of reptile species in four zones in and around the Uzungwa Scarp Forest Nature Reserve. Lowland = < 700 m.a.s.l, submontane = 800-1400 m.a.s.l, montane = > 1400 m.a.s.l and farmlands = farms bordering the Uzungwa Scarp Nature Forest Reserve on the plateau side. Bars with dissimilar letters are significantly different based on Dunn's multiple comparison post hoc test.

Species diversity differed significantly across all zones (F= 9.709, H= 0.0048) except between farmland and montane and between lowland and submontane forests (Fig. 13). Farmland and montane zones were the least diverse in reptile species (Fig. 13). However, species rarefaction curves for the zones did not reach an asymptote (Fig. 14). The mean (\pm SE) number of species for Chao estimator was higher than the observed species in all zones (Table 3).

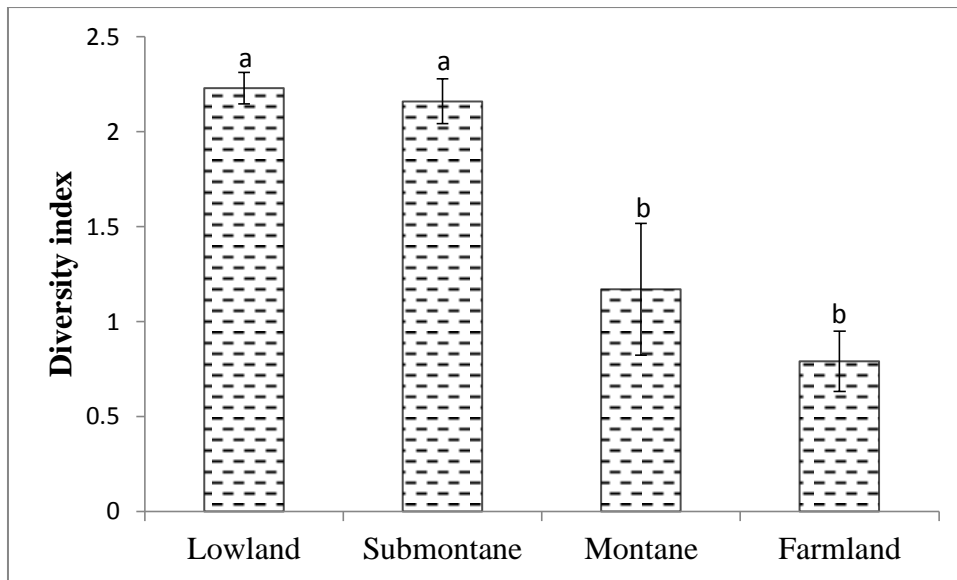


Figure 13: Shannon Wiener diversity index (mean \pm SE) for the four surveyed zones of the USNFR and surrounding areas. Bars with dissimilar letters are significantly different based on Turkey's multiple comparison test.

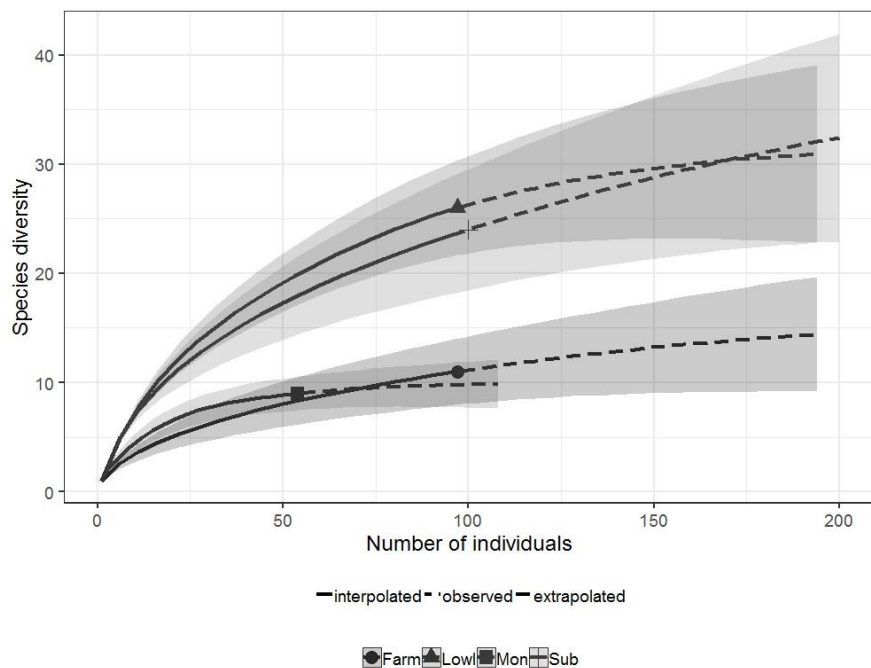


Figure 14: Rarefaction curves for species recorded in the four sampled zones of the USNFR and surrounding areas from December 2017 to April 2018. Farm = Farmland (circle), Low = Lowland (triangle), Mon = Montane (square), Sub = Submontane (plus sign). Shaded region surrounding each line represent 95 % confidence levels.

Table 3: Species richness, diversity and Chao richness estimator (\pm SE) for the four sampled zones

	Lowland	Submontane	Montane	Farmland
Species observed	26	24	9	11
Chao Estimator	32.17 \pm 5.13	43.97 \pm 17.26	9.98 \pm 2.22	17.19 \pm 7.48
Shannon diversity	2.23	2.16	1.17	0.79

Canonical correspondence analysis (CCA) diagram demonstrated temperature, elevation and canopy cover as the most important environmental factors associated with distribution and abundance of most reptile species in the USNFR (Fig. 15). Most species were associated with high temperatures, closed canopy and low elevation (Fig. 15). Sites in farmland were characterized by low temperatures and more open canopy cover and, hence, fewer species were found there (Fig. 15 and 16). Some species were correlated with more open canopy and high elevations (hence, low temperature) *e.g.* *Trioceros tempeli*, *T. weneri*, *Psammophylax variabilis*, *Lycophidion uzungwense* and *Afrotyphlops nigrocandidus* (Fig. 15).

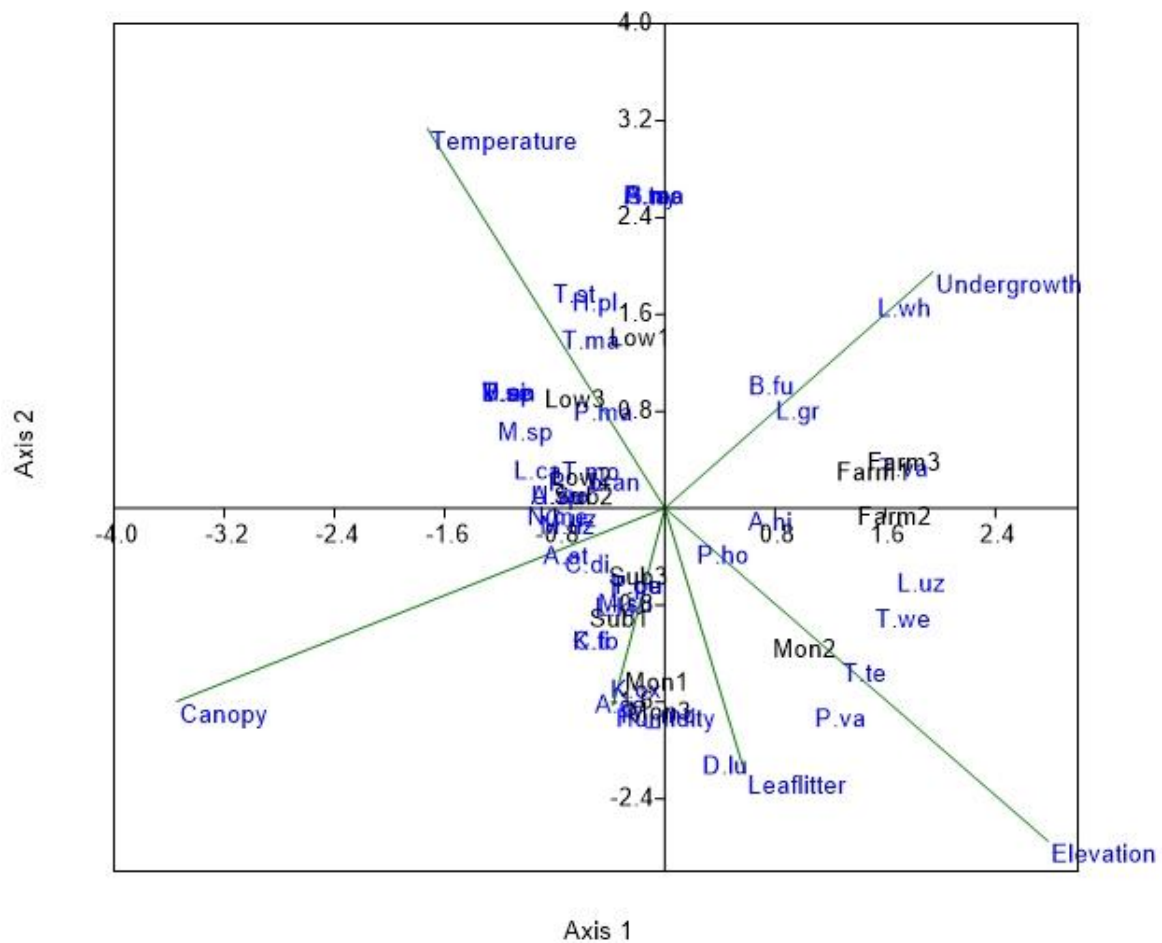


Figure 15: Canonical correspondence analysis diagram showing the influence of environmental factors on distribution and abundance of reptile species in and around the USNFR. Lines represent environmental variables (elevation, undergrowth, temperature, canopy, humidity and leaf litter). Low = lowland, Sub = Submontane, Mon = Montane, Farm = farmland. Species names are abbreviated (First letters of the genus and two first letters of the specific epithet (e.g. T.te for *Trioceros tempeli*). Full names of species are found in Appendix 1.

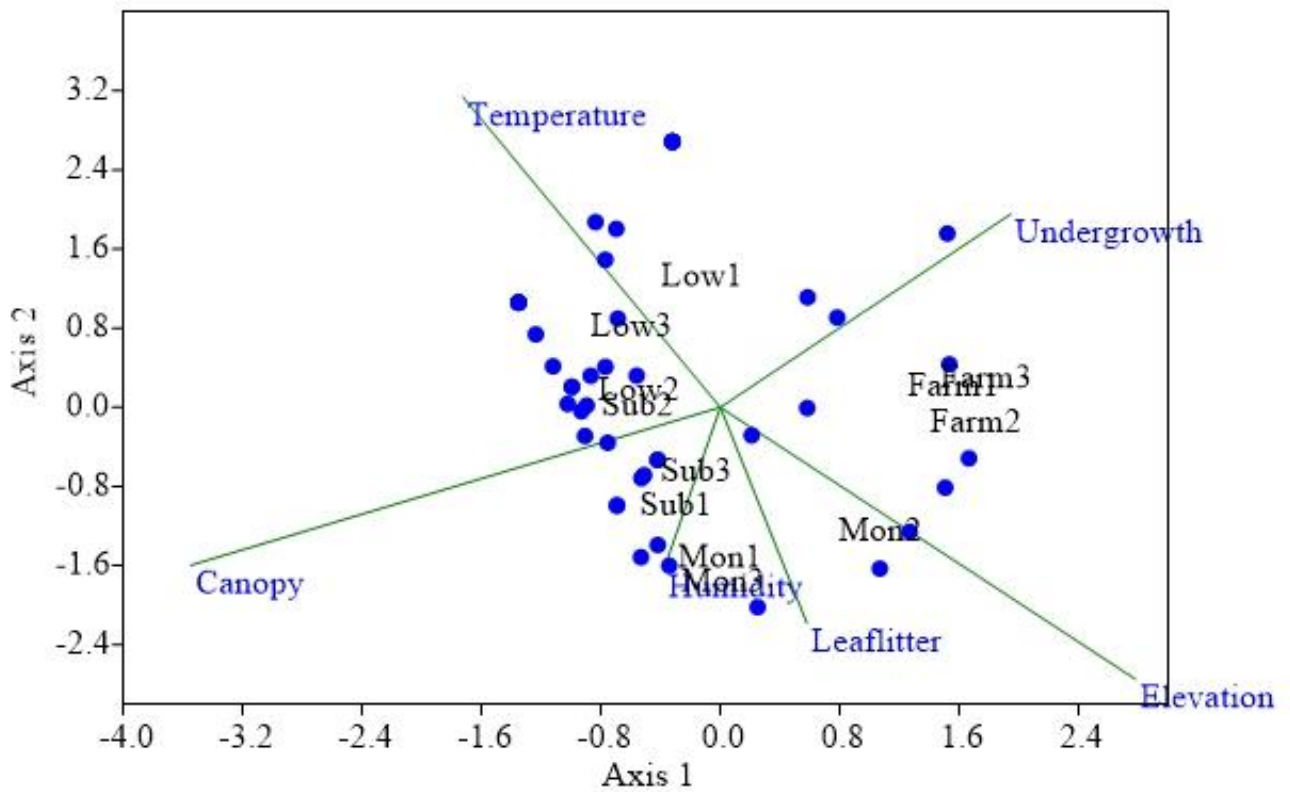


Figure 16: Canonical correspondence analysis diagram showing the influence of environmental factors on the 12 surveyed sites in and around the USNFR with species names replaced with dots. Lines represent environmental variables (elevation, undergrowth, temperature, canopy, humidity and leaf litter), Low = lowland, Sub = Submontane, Mon = Montane, Farm = farmland.

Generalized linear model revealed a decline in species numbers along elevations ($y = 12.561 + 0.0002x - 0.000002x^2$, $R^2 = 0.5728$) (Fig. 15). However, an unusual high number of species were observed in mid elevation (between 1000 and 1500 m.a.s.l) (Fig. 17).

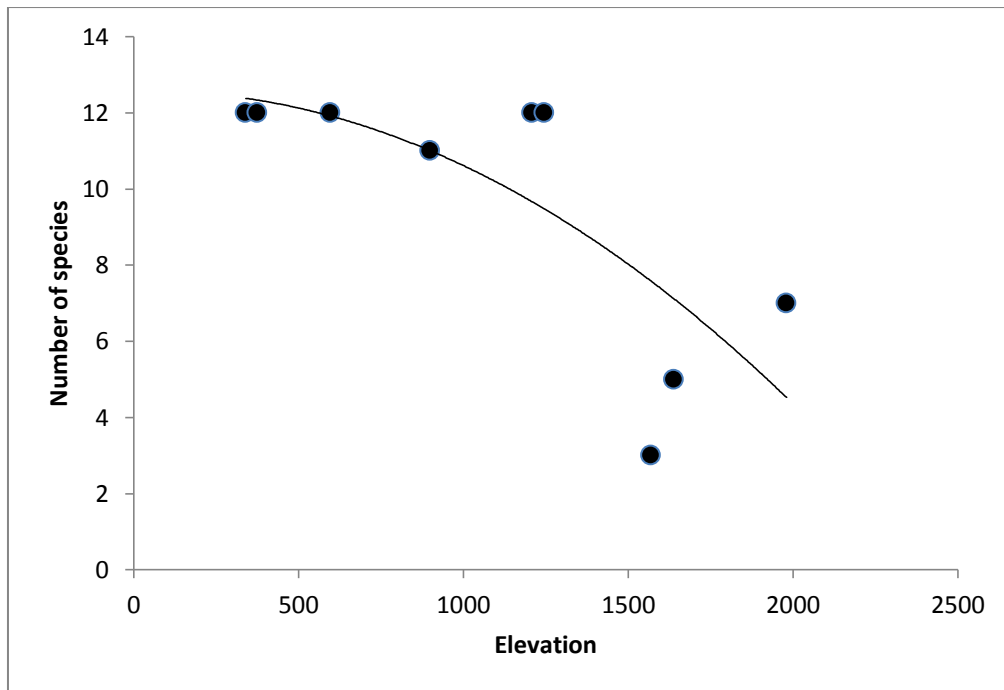


Figure 17: Relationship between species richness and elevation in the USNFR. The relationship with species richness is a negative polynomial distribution $y = 12.561 + 0.0002x - 0.000002x^2$

Most of the elevation ranges for species recorded in this study agrees with Spawls *et al.* (2004) and Spawls *et al.* (2018) except for *Afrotyphlops nigrocandidus*, *Kinyongia cf. oxyrhina*, *Lygodactylus grottei* and *Rhampholeon moyeri*, for which an extension in their elevation range is reported (Table 4).

Table 4: Elevation range expansion (min-max) for reptile species recorded in the USNFR and surrounding areas according to literature (Spawls *et al.*, 2004; Spawls *et al.*, 2018) and during this study. All units are in m.a.s.l..

Species	Literature	This study
<i>Afrotyphlops nigrocandidus</i>	1450 - 1750	1246 - 1447
<i>Kinyongia cf. oxyrhina</i>	1400 - 1900	846 - 1663
<i>Lygodactylus grottei</i>	0 - 1000	360 - 2038
<i>Rhampholeon moyeri</i>	1200 - 1900	1121 - 1953

4.1.4 Farmers' awareness and perceptions on reptile occurrence in farms bordering the USNFR

A total of 71 respondents were interviewed on their perceptions and awareness on reptiles occurring in their farm plots. The plan was to reach 112 respondents but some respondents were not willing to participate due to current boundary conflicts between the USNFR management and villagers surrounding the reserve. These villagers thought that by participating in the study, and by admitting reptile biodiversity in their farms, the USNFR's management could annex their plots as part of the reserve. All respondents were small holder farmers, with their plots close to the USNFR and had been cultivating mostly once per year. All of them practiced mixed farming, with maize and beans being common, 17% of respondents also possessed commercial tree plots and 7% switched to finger millet at the end of the farming season. About 94% of respondents were using fire during farm preparations and 54% used pesticides in their farming practices, most often Thiodan (88%). About 12% of respondents did not know the kind of pesticide they used (they only borrowed from friends/sought advice from extension officers).

All reptiles which were recorded through interviews were confirmed through trapping and direct observations (Fig. 18) except three species (Cobras *Naja* sp, Bush Vipers *Atheris* sp and Puff Adders *Bitis arietans*) (Appendix 1).

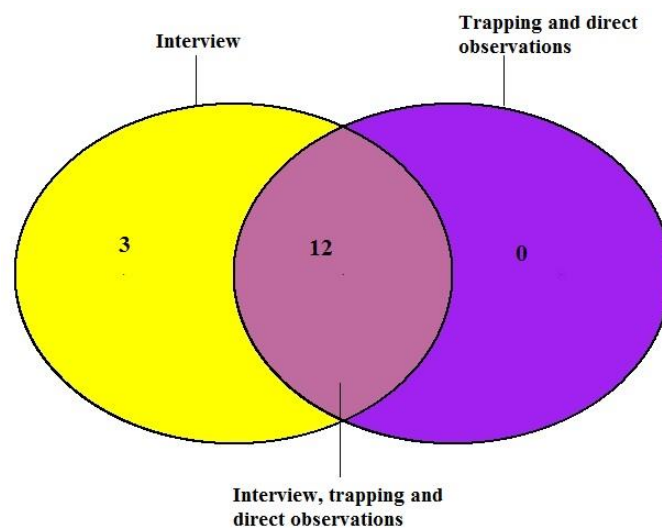


Figure 18: Total number of species reported in farms bordering the USNFR.

Snakes were the most often mentioned (91%) reptile group to occur on farms, followed by lizards (skinks 83%, geckos 73% and chameleons 70%). However, trapping/direct

observation results showed skinks (specifically variable skink *Trachylepis varia*) to be the most common in the farmlands followed by dwarf geckos *Lygodactylus* sp, chameleons, and snakes were the least common (Appendix 3). When asked about the most common species in their farm plots, green snakes, *Philothamnus* sp were mostly mentioned followed by variable skink *Trachylepis varia*, and dwarf geckos *Lygodactylus* sp (Fig. 19).

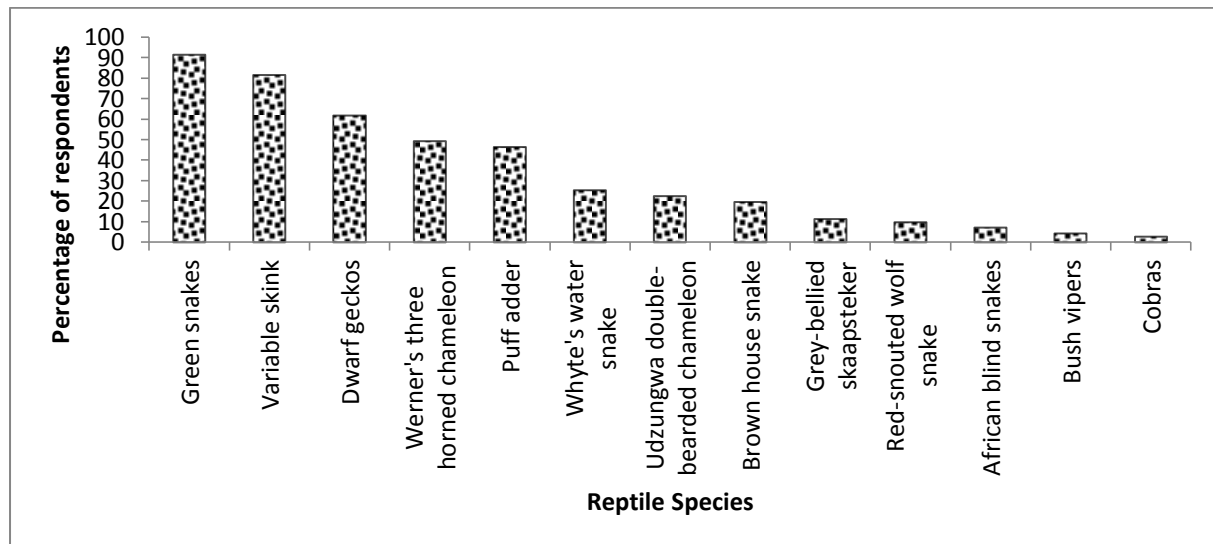


Figure 19: Response of farmers surrounding the USNFR on reptile species common to their farm plots (n =71).

When asked on whether reptiles are important, 96% said no, while the rest were indifferent. Out of the 71 interviewed farmers, (55%) wanted to see no reptiles in their plot, while 42% wanted reptiles in their plots and 3% were indifferent. About 35% were able to tolerate the presence of reptiles, regardless of not seeing their benefits. Most respondents were not aware of most reptile species and reptile related issues (including snake bite and related issues).

All respondents had a generally good knowledge on most reptile groups and considered only snakes as a dangerous group. Only few respondents (0.04%) confused limbless lizards (*Melanoseps* sp) and caecilians (*Scolecophorus* sp) with snakes. When asked about occurrence of snake bites, 74% had heard/experienced snake bite cases in their areas while 26% did not experience it (n=66). The majority feared mostly green snakes *Philothamnus*, brown house snakes *Boadon fuliginosus*, Puff adder *Bitis arietans* and Whyte's water snake *Lycodonomorphus whytii* and they considered them to be the most dangerous (Fig. 20). Surprisingly, most of the reported snakes (Fig. 20) were harmless, with the exception of puff adder *Bitis arietans*, bush vipers *Atheris* and cobras *Naja*.

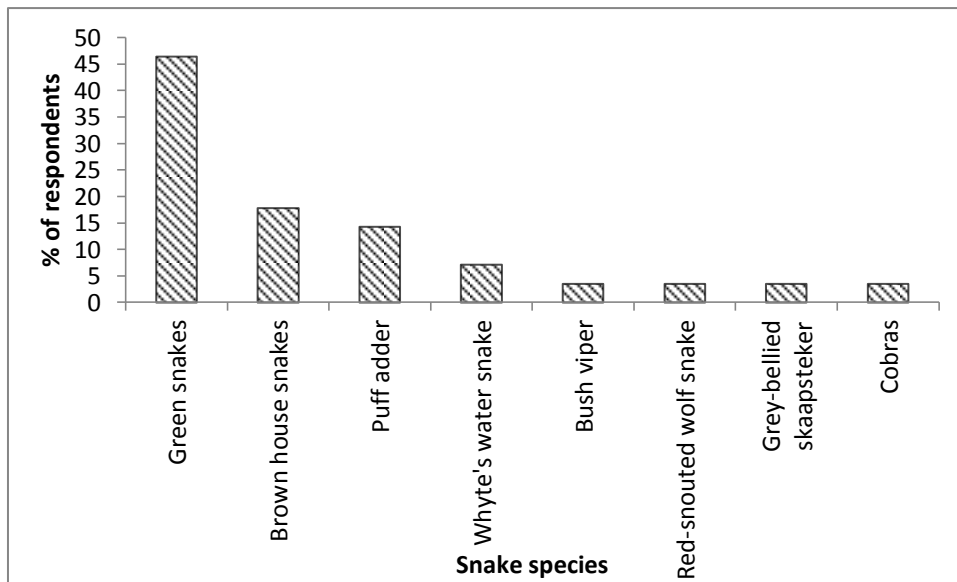


Figure 20: Snake species associated with the most frequent snake bite incidences in areas surrounding the USNFR (n= 28).

The majority of respondents (70%) mentioned killing as the only action to consider when a snake was found on their farm. All showed to have no fear on other reptile groups and they took no action against them although limbless lizards (*Melanoseps sp*) and caecilians (*Scolecophorus sp*) might also be victimized in the name of snakes. About 15% of respondents had no idea what to do when they encountered a snake on their farm while about 5% opted to run or run/kill depending on the situation *e.g.* type and size of snake involved.

4.2 Discussion

4.2.1 Distribution of reptiles in the USNFR and surrounding agricultural lands

This study almost doubled the previously reported number of reptile species for the USNFR, from 33 and 38 species mentioned by Menegon and Salvidio (2005) and Lyakurwa (2017), respectively, to currently 60 species. This pinpoints the Udzungwa mountains as biologically the richest mountain block in the EAM in terms of herpetofauna, harbouring 34 endemic and near endemic reptile species followed by East Usambara (32), Uluguru (29) and Nguru (19) (Burgess *et al.*, 2007), highlighting its previously underestimated diversity (Howell, 1993; Burgess *et al.*, 2007). Thirty three percent of species (3 species out of nine), that have been classified as globally threatened, endemic to Tanzania and climate change-vulnerable by Meng *et al.* (2016), are now confirmed to occur in the USNFR through this study. This

highlights the importance of protecting these mountains and calls out for more long-term surveys in other parts of Udzungwa and EAM.

Although faunal surveys are recognized as one of the most critical steps in assessing forest biodiversity (Stanley *et al.*, 1998), relatively little attention has been given to African herpetology (Spawls *et al.*, 2004; Largen and Spawls, 2010; Meng *et al.*, 2016; Tolley *et al.*, 2016). There are many areas in East Africa which are yet to be scientifically explored (Spawls *et al.*, 2004) and this study shows the need for detailed surveys even in previously visited areas as highlighted by Howell (1993) and Spawls *et al.* (2004). The overall shortage of information adds more risk to the sustainability of African biodiversity (Tolley *et al.*, 2016), particularly the herpetofauna, and potentially could lead to mis-allocated conservation priorities (Pimm *et al.*, 2014), especially in a biodiversity rich country like Tanzania.

Contrary to previous studies, we found that most endemic, near endemic and threatened species were concentrated in the submontane forest of the USNFR. Menegon and Salvidio (2005) and Menegon *et al.* (2008) reported that the number of endemic and near endemic reptile species increases with an increase in elevation. Similarly, Burgess *et al.* (2002) reported more endemic vertebrates in montane forests of the EAM and fewer in lowland, submontane and upper montane forests. It is likely that submontane forests were previously under-sampled, leading to the few records available. Menegon and Salvidio (2005) sampled more montane sites than submontane forest areas. A large number of endemic and threatened species in the submontane forest areas might be due to the intermediate environmental conditions in the mid-elevation zones, which accommodate both high and low elevation specialists (McCain, 2010). However, the same zone has suffered from severe forest loss in recent years (Burgess *et al.*, 2002; Menegon and Salvidio, 2005) and it is not clear on how this has been affecting its reptile inhabitants. The recent upgrading of the conservation status of the reserve is hoped to reduce the destruction activities that have been going on in submontane forests. Finding more reptiles at lowland and submontane forests agrees with Spawls *et al.* (2004), who reported more reptile species at moist areas with low elevation.

Recording almost similar numbers of reptile species in montane forest and farmlands shows the importance of areas surrounding the USNFR in conserving reptiles. These findings are in contrary with Maritz and Alexander (2007) and Masterson *et al.* (2009), who found more reptile species in riparian than in non-riparian and in natural than in modified habitats, respectively. However, farmlands were more discordant from other zones and contained most

of the non-forest specialist species. Getting higher similarity in sites close to each other agrees with Ngalason and Mkonyi (2011) who reported more similarity in amphibian species compositions among close sites in the Uluguru mountains. It is also in agreement with Menegon and Salvidio (2005) who showed more similarity in herpetofauna species composition in sites from same elevation zones. The higher similarity in species composition in farmlands, on same zones and on close sites seems to be a function of altitude and land use. The two have been reported to affect distribution of reptiles (Spawls *et al.*, 2004; Menegon and Salvidio, 2005; Maritz and Alexander, 2007; Masterson *et al.*, 2009; Tolley *et al.*, 2016; Spawls *et al.*, 2018). Since majority of Tanzanian reptiles are specialists of specific microhabitats (Meng *et al.*, 2016) it was expected to find geographically close sites with more similarity in species composition as these sites are more homogeneous than distant sites.

4.2.2 Species sensitive to farmland expansion: possible indicator species

Although invertebrates have mostly served as ecological indicators (Siddig *et al.*, 2016), small terrestrial vertebrates, especially amphibians, reptiles and birds have also shown to be effective (Blaustein and Bancroft, 2007; Gadner *et al.*, 2008; Morrison and Naikatini, 2008; Schneider-Maunoury *et al.*, 2016), particularly due to their sensitivity to the ongoing habitat destructions (Schneider-Maunoury *et al.*, 2016). The knowledge on reptile species is relatively better compared to many invertebrate groups that are highly understudied in Tanzania, which places the former in a better position to be used as state indicators (Bibby, 1999).

Although 19 out of the total 60 species we documented to occur in the USNFR are endemic/near endemic and forest dependent, and therefore might be sensitive to habitat alterations, they need to be assessed in order to get species which can best show the driver-response relationship (Schneider-Maunoury *et al.*, 2016) and thus being used as effective indicators. Most of these species are also globally threatened and supports Bibby (1999) who selected globally threatened bird species as effective environmental indicators. It also agrees with Spawls *et al.* (2018) who showed endemic reptile species to be of conservation concern in East Africa. Most strictly forest dependent endemic/ near endemic species were found inside the USNFR indicating the importance of montane, submontane and lowland forests in harbouring forest dependent reptiles. Recording a larger number of forest dependent endemic/near endemic species in USNFR than in the cultivated surrounding areas agrees with

Burgess *et al.* (2007) who reported that more than 76% of the EAM endemic species as specialists of dense forests.

However, the majority of the 19 species (11 species) were singletons or doubletons or were not recorded during this study, indicating either their rarity or low population sizes and, thus, they might not qualify to be used as effective indicators (Lindenmayer and Likens, 2011; Schneider-Maunoury *et al.*, 2016; Siddig *et al.*, 2016). Only Usambara bush viper *A. ceratophora*, Usambara green snake *P. macrops*, Udzungwa forest gecko *C. uzungwense*, Werner's three horned chameleon *T. weneri*, Udzungwa pygmy Chameleon *R. moyeri* and Uluguru one-horned chameleon *K. cf. oxyrhina* qualify because they are easy to detect, and they allow for quantitative estimates which are crucial in using indicators (Schneider-Maunoury *et al.*, 2016). Selection of these six species also agrees with Hilty and Merenlender (2000) who recommended only species that can be easily detected and monitored. The proposed species can be screened further upon more studies in order to determine high performance indicators which can discriminate different land uses as suggested by Gardner *et al.* (2008). These species will not only play part in monitoring forest loss but also will be useful in evaluating the usefulness of regenerated forests as refuge for threatened species (Gardner *et al.*, 2008).

Most of these species are easy to sample in the field (McDiarmid *et al.*, 2012), and their monitoring demands little in terms of costs of identification compared to invertebrates (Gardner *et al.*, 2008). The proposed species are mostly composed of Chameleons (3 species out of 7) which are far easier to sample than most reptiles (McDiarmid *et al.*, 2012). Chameleons have also been reported to be especially sensitive to human disturbances (Shirk *et al.*, 2014) and make them more favourable candidates for monitoring environmental changes. Therefore, we recommend *A. ceratophora*, *T. weneri*, *R. moyeri*, and *K. cf. oxyrhina* as best candidates to be used as indicators of environmental changes and call for more studies on the selected species as per the criteria suggested by Lindenmayer and Likens (2011).

4.2.3 Habitat characteristics determining reptile abundance and diversity

Although the USNFR is a relatively small reserve when compared to other protected areas in Tanzania, it possesses substantial variation in habitat types, which allows a unique assemblage of amphibians and reptiles (Menegon and Salvidio, 2005). Variation in microhabitats has allowed localization of specialized species in the USNFR, *e.g.* more cool-

adapted species in montane areas (Menegon and Salvidio, 2005). This is supported by data from this study, as some of species were found only in one site or restricted only in one elevation zone.

This study recorded canopy cover, temperature and elevation, as the most important factors associated with abundance and diversity of most reptiles in the USNFR. Except for elevation and understory, other factors (temperature, leaf litter and canopy cover) were relatively low in farmland zones, which might explain why most endemic and threatened reptile species were restricted to areas inside the USNFR since most of these species are forest dependent (Burgess *et al.*, 2007) and thus associated with more closed canopy. Ngalason and Mkonyi (2011) reported agricultural activities to be associated with removal of plant cover, which affects thickness of leaf litter, humidity and canopy cover. However, there is a paucity of information on the relationship between reptile occurrences and habitat characteristics in the EAM making it difficult to do comparisons with this study.

Nevertheless, some studies on the relationships between amphibian assemblage and environmental parameters have been reported from east Africa, and provide a room for comparison as these two groups are known to display similar ecological patterns and are usually sampled using almost similar methodologies. Behangana *et al.* (2009) showed amphibians in the Albertine rift region to be influenced by canopy cover and altitude which supports the findings of this study. The authors show large number of amphibian species to be associated with closed canopy and low elevations, which is also the case for reptiles in the USNFR as per this study. These findings alert us not only on the ongoing illegal logging activities, but also show the importance of mature/primary forests (where canopy is more closed) in conserving reptiles.

Elsewhere, canopy cover has been shown to have negative impacts on herpetofauna. Pringle *et al.* (2003) explained the influence of canopy openness on reptile species distribution as this factor affects the amount of solar radiation reaching the forest floor. The authors went further by showing how the impact of the openness depends on the location of the canopy gape relative to sun position. However, the USNFR terrain is highly variable (with elevation ranging from 300 to 2068 m.a.s.l) and temperature is mostly influenced by elevation and seasonality (Ndangalasi, 2005) with lowland sites being hotter than highland sites. Pike *et al.* (2011) suggested a reduction in open habitat-specialist species in more closed forests.

However, although USNFR is generally classified as closed forest, it possess highly heterogeneous habitats *e.g.* patches of open canopy forests, montane grasslands/open areas, swamps and large portions of continuous closed canopy (Menegon and Salvidio, 2005; Lyakurwa, 2017), which provides refuge for large number of habitat-specialist species. A study by Reisinger *et al.* (2006) shows the distribution of the dwarf chameleon *Bradypodion sp* not to be influenced by canopy cover. Conversely, the two dwarf chameleons recorded in this study (*Rhampholeon moyeri* and *Rieppeleon brevicaudatus*) were associated with closed canopy and were not found in agricultural areas.

Elevation has been reported to affect large number of environmental factors (Lovert, 1996; Körner, 2007; Ngalason and Mkonyi, 2011) and has been known to influence activity pattern of reptiles (Amat *et al.*, 2003). A general decline in herpetofauna along elevations have been reported (Vonesh, 2001; Spawls *et al.*, 2004; Ngalason and Mkonyi, 2011; Spawls *et al.*, 2018) and best explained by temperature (Behangana *et al.*, 2009; McCain, 2010). Altitude is known to exert its impact through affecting temperature and productivity (Rahbek, 1995). While the general decline pattern might sound obvious for reptiles for which their ecology and physiology (as those of other ectotherms) depends on the temperature of the surroundings and so more species to be expected in warm environments, some unique patterns are known. Behangana *et al.* (2009) show mid elevation to be the most important for amphibians in Albertine rift region. A global synthesis of species assemblage along elevations has resulted into four distinct patterns; unimodal mid-elevation peaks, low-elevation plateaus, decreasing diversity and low-elevation plateaus with mid-peaks for reptiles (McCain, 2010). The complete picture of how species are distributed along elevation in the USNFR might rely on subsequent surveys in order to establish a more complete list for the area, which will lead to a better understanding of the species-elevation relationships. With respect to threatened and endemic species of reptiles in the USNFR, mid elevations are the most important, which is contrary to Burgess *et al.* (2002), who reported the same at higher elevations. Some few species (*Afrotyphlops nigrocandidus*, *Lycophidion uzungwense*, *Trioceros weneri* and *Trioceros tempeli*) that were found to be associated with high elevations are known specialists of highlands (Spawls *et al.*, 2004; 2018). While we have shown the importance of elevation, canopy cover and temperature in determining reptile species abundance and diversity, there must, however, be a concern on the impact of the ongoing illegal logging activities on these environmental variables. Information on this report might be important not

only in managing our protected areas but also useful in assessing the potentials of restored areas as refuge for reptiles.

4.2.4 Farmers' awareness and perceptions of reptiles

Farmers around the USNFR had a relatively good knowledge on lizards, despite having received no awareness on reptiles. Generally agamas, chameleons and snakes are mostly poorly known among vertebrates and are perceived negatively by most people (Whiting *et al.*, 2009; Spawls *et al.*, 2018). However, no agamas were recorded in villages involved in this study, and people had a relatively good knowledge on chameleons. This study supports what has been reported by a number of authors (Broadley, 1983; Howell, 1993; Marais, 2004; Spawls *et al.*, 2018) on most people being highly feared and misinformed on snakes despite most of the reptiles being harmless to humans (Spawls *et al.*, 2004; Spawls *et al.*, 2018). Majority of people have been reported to kill snakes erroneously due to lack of knowledge on their biology (Broadley, 1983; Howell, 1993; Spawls *et al.*, 2018) and the same actions were recorded from the respondents in this study.

Despite reptiles being highly important economically (Klemens and Thorbjarnarson, 1995; Thorbjarnarson, 1999; Carpenter *et al.*, 2004; Pernetá, 2009; Wilgen *et al.*, 2010; Robinson *et al.*, 2015), ecologically (Spawls *et al.*, 2004; Wilson and Winne, 2016; Spawls *et al.*, 2018), as food to humans (Klemens and Thorbjarnarson, 1995; Magnino *et al.*, 2009) in both traditional and modern medicine (Grenard, 1994; Pal *et al.*, 2002; Alves *et al.*, 2009), most respondents in this study did not see any importance of having reptiles. This is probably attributed to the little attention given to reptiles by most people (Howell, 1993) or due to the rarity and cryptic nature of most reptiles (Wilson and Winne, 2016), which make them difficult to observe and therefore not appreciated by many people. Contrary to this study, López-del-Toro (2009) reported coffee farmers in Mexico who had attended some environmental awareness courses to be aware on some importance of having reptiles and positively perceived snakes.

Awareness raising campaigns (including field trips) have been recommended in order to improve conservation of reptiles (López-del-Toro, 2009; Yorek, 2009; Ballouard *et al.*, 2012). At the same period when data for this study were being collected, a booming rodent population, which hampered rice cultivation, was reported in Kilombero valley (Libenanga, 2018). This valley borders the study area to the east and the high rodent population might probably be linked to decline in natural enemies such as snakes in cultivated areas. Snakes

have been reported to be especially effective in controlling rodent populations (Spawls *et al.*, 2004). Wilson and Winne (2016) reported snakes to consume more than 200 kg of amphibian prey within 5.4 ha per year, and this might be equated to very large number of small rodents (mice and shrews). Hence, the absence of reptiles on farms might be associated with a higher presence of rodent and insect crop pests. Spawls *et al.* (2004) showed how killing of mole snakes *Pseudaspis cana* in Nakuru golf courses led to the destruction of golf course greens by mole rats, which boomed after removal of their natural enemy. Therefore, farmers in villages surrounding the USNFR should be educated on reptiles especially snakes for better conservation of these vertebrates outside their protected ranges.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study has increased the number of species (total numbers, endemic, and threatened species) that had ever been detected by any previous study in the same region. This now ranks the Udzungwa mountains as the leading mountain block in having more endemic/ near endemic reptile species than any other in the EAM. Reptile species composition in the USNFR and surrounding areas is best explained by elevation and land use. Abundance and diversity of reptile species in the USNFR correlate most strongly with temperature, canopy cover and elevation with submontane forest positive correlated with reptile diversity. Lowland and submontane forests are almost equally important for reptile species. Farmers surrounding the USNFR have a relatively good understanding on lizards and only consider snakes to be dangerous among reptiles. However, their knowledge on snakes is poor, and the majority considers killing as the only action to be taken when a snake is encountered.

5.2. Recommendations

While this study has gathered data on reptiles from more sites and over a prolonged period in the wet season compared to any other study in the Udzungwa mountains, there is still a need for subsequent surveys in the area, both in the dry and wet seasons. Some reptile species are highly secretive, have low population densities and/or are locally distributed (Spawls *et al.*, 2004; Meng *et al.*, 2016), making it possible to miss them when sampling only in one season. Three to five years of consecutive trapping (McDiarmid *et al.*, 2012) across various seasons (Stanley *et al.*, 1998; Howell, 2002) has been recommended in order to increase the probability of recording rare species. Subsequent surveys will also enable documenting species that this study failed to record. This will add to the conservation value of not only the USNFR and Udzungwa mountains but the entire EAM region. This study has shown the importance of re-assessing the herpetofauna of EAM, and adds to the importance of conserving the mountains.

More studies are needed to investigate how farming activities impact reptile assemblages around the USNFR, as these activities (especially small holder farming, logging and wood harvesting) have been reported as common threats to reptiles (Meng *et al.*, 2016; Tolley *et*

al., 2016). Activities like the use of fire in farm preparation and the use of pesticides were observed to be common around the USNFR and it is not clear how they impact the resident reptiles. Elsewhere, fire has been reported to affect reptiles negatively through its impact on vegetation (Masterson *et al.*, 2008). Similarly we recommend more studies on resource availability across elevations both in and outside the USNFR so as to get a clear picture on what affects reptile occurrence in this area. We call for a harmonized land-use planning particularly in the farmlands as the endemic species were found mainly in natural forest patches, fruit trees and commercial tree plantations near the USNFR, which might decline in the future without proper land management. Finally, awareness campaigns on reptiles are highly needed among farmers who surround the USNFR. It is important for the farmers to be aware on the importance of reptiles, the harmless and venomous reptile species found in their farm plots, how to avoid snake bites and basic issues related to first aid to snake bite victims.

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APPENDICES

Appendix 1: Reptile species and their threat category per families recorded in Uzungwa Scarp Nature Forest Reserve and surrounding areas. Note; * = species that were recorded by Menegon and Salvidion 2005 and not found by this study, ^φ = recorded by Menegon and Salvidio but not surely in USNFR (either from general bibliography or from surrounding villages); ‡ = collected by Lyakurwa 2017 and not found by this study. LC = Least concerned, NT = Near threatened, EN = endangered, VU = Vulnerable. Low = Lowland, Sub = Submontane, Mon= Montane, Farm = Farmland

Species	Voucher	Low	Sub	Mon	Farm	Threat category
Agamidae						
<i>Agama mossambica</i> Peters, 1854		x				LC
Chamaeleonidae						
<i>Kinyongia sp. nov</i>	JVL 1709		x			
<i>Kinyongia cf. oxyrhina</i> (Klaver and Böhme, 1988)			x	x		NT
<i>Rhampholeon moyeri</i> Menegon, Salvidio and Tilbury, 2002			x	x		LC
<i>Rieppeleon brevicaudatus</i> (Matschie, 1892)		x	x			LC
<i>Trioceros deremensis</i> (Matschie, 1892)	JVL 1718		x			LC
<i>Trioceros laterispinis</i> (Loveridge, 1932) ^φ						EN
<i>Trioceros tempeli</i> (Tornier, 1899)				x	x	LC
<i>Trioceros wernerii</i> (Tornier, 1899)				x	x	LC
Gekkonidae						
<i>Cnemaspis cf dickersonae</i> (Schmidt, 1919)	JVL 1735, JVL 1733, JVL 1733		x			LC
<i>Cnemaspis uzungwae</i> Perret, 1986	JVL 1712	x	x			VU
<i>Hemidactylus mabouia</i> (Moreau de Jonnès, 1818)	JVL 1724	x				LC
<i>Hemidactylus platycephalus</i> Peters, 1854	JVL 1725	x				LC
<i>Hemidactylus sp</i>	JVL 1723	x				
<i>Lygodactylus capensis</i> (Smith, 1849)		x			x	LC
<i>Lygodactylus cf angularis</i> Günther, 1893	JVL 1701,	x	x		x	LC
<i>Lygodactylus grotei</i> Sternfeld, 1911		x			x	LC

Species	Voucher	Low	Sub	Mon	Farm	Threat category
<i>Urocotyledon wolterstorffi</i> (Tornier, 1900)	JVL 1737, JVL 1722	x	x			VU
Gerrhosauridae						
<i>Broadleysaurus major</i> (Duméril, 1851)	JVL 1727		Opportunistic in lowland farms		x	LC
Scincidae						
<i>Leptosiaphos kilimensis</i> (Stejneger, 1891)	JVL 1707, JVL 1706		x			LC
<i>Melanoseps loveridgei</i> Brygoo and Roux-Estève, 1982 *						LC
	JVL 1710, JVL 1711, JVL 1731, JVL 1732, JVL 1731,					
<i>Melanoseps uzungwensis</i> Loveridge, 1942	JVL 1732	x	x			EN
<i>Mochlus sundevallii</i> (Peters, 1854)	JVL 1715, JVL 1716		x			LC
<i>Mochlus sp</i>	JVL 1719	x				
<i>Scelotes uluguruensis</i> Barbour and Loveridge, 1928 *						VU
<i>Trachylepis maculilabris</i> (Gray, 1845)	JVL 1719	x	x			LC
<i>Trachylepis striata</i> (Peters, 1844)		x				LC
<i>Trachylepis varia</i> (Peters, 1867)			x	x	x	LC
Varanidae						
<i>Varanus niloticus</i> (Linnaeus, 1766)		x				LC
Atractaspidae						
	JVL 1729, JVL 1721	x	x			
<i>Aparallactus sp</i>						
<i>Atractaspis aterrima</i> Günther, 1863	JVL 1708, JVL 1720	x	x			LC
Colubridae						
<i>Boaedon fuliginosus</i> (Boie, 1827)		x		x	x	LC
<i>Crotaphopeltis tornieri</i> (Werner, 1908)			x			LC
<i>Dasypeltis medici</i> Bianconi, 1859 *						LC
<i>Dipsadoboa weneri</i> (Boulenger, 1897) *						NT
<i>Philothamnus hoplogaster</i> (Günther, 1863)	JVL 1703	x	x	x	x	LC
<i>Philothamnus macrops</i> (Boulenger, 1895)		x	x			LC

Species	Voucher	Low	Sub	Mon	Farm	Threat category
<i>Philothamnus punctatus</i> Peters, 1867			x			LC
<i>Philothamnus semivariatus</i> (Smith, 1840) [¶]						LC
<i>Telescopus semiannulatus</i> Smith, 1849		x				LC
<i>Thelotornis kirtlandii</i> (Hallowell, 1844) *						LC
<i>Thelotornis mossambicanus</i> (Bocage, 1895)		x	x			LC
<i>Xyelodontophis uluguruensis</i> Broadley & Wallach, 2002 [‡]						EN
Elapidae						
<i>Dendroaspis angusticeps</i> (Smith, 1849)		x				LC
<i>Naja cf melanoleuca</i> Hallowell, 1857		x	x			LC
Lamprophiidae						
<i>Gonionotophis nyassae</i> (Günther, 1888)	JVL 1724	x				LC
<i>Lycodonomorphus whytii</i> (Boulenger, 1897)	JVL 1713			x	x	LC
<i>Lycophidion uzungwense</i> Loveridge, 1932					x	LC
Natricidae						
<i>Natriciteres variegata</i> (Peters, 1861) [†]						LC
Psammophiidae						
<i>Psammophis tanganicus</i> Loveridge, 1940		x				LC
<i>Psammophylax variabilis</i> Günther, 1893	JVL 1704, JVL 1705			x	x	LC
Pseudoxyrhophiidae						
<i>Bufo procterae</i> (Loveridge, 1922) [†]						VU
<i>Duberria lutrix</i> (Linnaeus, 1758)				x		LC
Pythonidae						
<i>Python natalensis</i> Smith, 1840 [‡]						LC
Typhlopidae						
<i>Afrotyphlops nigrocandidus</i> (Broadley and Wallach, 2000)	JVL 1702		x		x	VU
Viperidae						
<i>Atheris barbouri</i> Loveridge, 1930 [¶]						VU
<i>Atheris ceratophora</i> Werner,			x	x		VU

Species	Voucher	Low	Sub	Mon	Farm	Threat category
1896						
<i>Bitis arietans</i> Merrem, 1820 ^φ						LC
<i>Bitis gabonica</i> Duméril, Bibron and Duméril, 1854 ^φ						VU
<i>Causus defilippii</i> (Jan, 1863) ^φ						LC

Appendix 2: Bray Curtis species similarity index summary for the 12 sites surveyed in Uzungwa Scarp Nature Forest Reserve and surrounding areas from December 2017 to April 2018. Note; 0 represents no similarity (100% dissimilarity) while 1 represents 100% similarity. Note; Low = Lowland, Sub = Submontane, Mon = Montane, Farm = Farmland. Numbers in dark red indicate more strongly related sites (>50%) while those in purple indicate 100% dissimilarity.

	Farm 1	Farm 2	Farm 3	Mon 1	Mon 2	Mon 3	Sub 1	Sub 2	Sub 3	Low 1	Low 2	Low 3
Farm 1	1.0000											
Farm 2	0.5634	1.0000										
Farm 3	0.8400	0.6575	1.0000									
Mon 1	0.0625	0.0364	0.0588	1.0000								
Mon 2	0.1951	0.2813	0.1861	0.3200	1.0000							
Mon 3	0.0377	0.0264	0.0364	0.2703	0.3044	1.0000						
Sub 1	0.0364	0.0513	0.0351	0.2051	0.2083	0.4333	1.0000					
Sub 2	0.0615	0.0000	0.0000	0.0408	0.0000	0.0286	0.2222	1.0000				
Sub 3	0.1200	0.0882	0.0769	0.2353	0.2791	0.2182	0.5263	0.2887	1.0000			
Low 1	0.0377	0.1316	0.0364	0.0541	0.0435	0.0345	0.0333	0.1714	0.1091	1.0000		
Low 2	0.0526	0.0000	0.0000	0.0000	0.0000	0.0000	0.2169	0.5591	0.2308	0.2716	1.0000	
Low 3	0.1000	0.0317	0.0952	0.0833	0.0606	0.0444	0.1277	0.1053	0.0952	0.2667	0.1765	1.0000

Appendix 3: Reptiles that were recorded in farmlands surrounding the USNFR using interviews, direct observations and trapping. * represents species endemic to Eastern Arc Mountains

Common name	Species	% of respondents	Number of individuals caught/seen
Udzungwa double-beared chameleon	<i>Trioceros tempeli</i> *	23	1
Werner's three horned Chameleon	<i>Trioceros weneri</i> *	49	12
Angulate dwarf gecko	<i>Lygodactylus cf. angularis</i>	62	2
Cape dwarf gecko	<i>Lygodactylus capensis</i>	56	4
Grote's dwarf gecko	<i>Lygodactylus grotei</i>	59	5
Variable skink	<i>Trachylepis varia</i>	82	67
Bown house snake	<i>Boaedon fuliginosus</i>	19	2
South-eastern green snake	<i>Philothamnus hoplogaster</i>	90	4
White's water snake	<i>Lycodonomorphus whytii</i>	27	2
Red-snouted wolf snake	<i>Lycophidion uzungwense</i> *	10	1
Grey-bellied skaapsteker	<i>Psammophylax variabilis</i>	11	1
Bicoloured blind snake	<i>Afrotyphlops nigrocandidus</i> *	7	1
Puff adder	<i>Bitis arietans</i>	46	Not recorded
Cobra	<i>Naja sp.</i>	4	Not recorded
Bush viper	<i>Atheris sp.</i>	4	Not recorded

RESEARCH OUTPUTS

Output one: A research paper presentation entitled “Uzungwa Scarp Nature Forest Reserve; a unique hotspot for reptiles in Tanzania. Accepted for publication by *Acta herpetologica*

Output two: Submitted conference abstract entitled “Conserving endemic and threatened reptiles outside the Udzungwa Mountains. Submitted for Tanzania Wildlife Research Institute conference to be conducted on December 2019

Output three: Seminar presentation entitled “Assessing reptile occurrences in the Eastern Arc Mountains and surrounding areas. Presented to Associated Colleges of Midwest (ACM) program at Training Centre for Development Cooperation in Eastern and Southern Africa (TCDC) Arusha on 11th October 2018.

Output four: Seminar presentation entitled “Eastern Arc Mountains; A reptile hotspot. Presented to McGill University Program in Amani nature reserve on 9th – 13th March 2019.

Output five: Poster presentation



John Lyakurwa <johnlyakurwa@gmail.com>

[AH] Editor Decision

5 messages

Marco Sannolo <marco.sannolo@gmail.com>
To: "Mr. John Valentine Lyakurwa" <johnlyakurwa@gmail.com>

Wed, Mar 20, 2019 at 2:46 PM

Dear John

I'm glad to tell you that, after evaluating the new version of the manuscript you uploaded, I have decided to accept it for publication on Acta Herpetologica.

Please send on my email address a high-quality copy (at least 300 dpi) of all figures present in the manuscript, so that we can start to process it for publication.

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Best,
Marco

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John Lyakurwa <johnlyakurwa@gmail.com>
To: Marco Sannolo <marco.sannolo@gmail.com>

Thu, Mar 21, 2019 at 8:44 AM

Dear Marco,
Thank you so much for the good news. Will always consider Acta for my future works despite the delays. I have learnt many things through the review processes and you and Marco Mangiacotti have always been responding to my emails timely and have been very kind. I know the delays were out of your control as you explained earlier.

Will send the photos as you said in your email.
Many thanks,
John
[Quoted text hidden]

To: Marco Sannolo <marco.sannolo@gmail.com>

Dear Marco,
Please, kindly find the attached figures for the MS. Only figure 2 is missing, which is the chat made in excel and i cant save it as a picture from excel and still maintain its quality. I think the one in the MS is still in good quality (any advice on this will be appreciated as well).
With kind regards,

<https://mail.google.com/mail/u/0/?ik=f50c90fc53&view=pt&search=all&permthid=thread-f%3A1628524941582859200&siml=msg-f%3A162852494158...> 1/3

John

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-  Fig. 3B.jpg
-  Fig. 3C.jpg
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-  Fig. 3E.jpg
-  Fig. 3F.jpg
-  Fig. 4.jpg
-  Figure 5.jpg

Marco Sannolo <marco.sannolo@gmail.com>
To: John Lyakurwa <johnlyakurwa@gmail.com>

Tue, Mar 26, 2019 at 9:49 PM

Dear John,

thanks for the picture, but please send me also fig.2 separately with the best quality as possible. Furthermore, please join all pictures "3" in a single one. I am asking you this because during the proofreading the pictures are deleted from the word document and added only in the final layout.

Best,
Marco
[Quoted text hidden]
--

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John Lyakurwa <johnlyakurwa@gmail.com>
To: Marco Sannolo <marco.sannolo@gmail.com>

Tue, Mar 26, 2019 at 11:03 PM

Dear Marco,



Thank you so much for the quick reply and for the clarification. Please, find the attached files (All figures).

-  Fig. 1.jpg
-  Fig. 2.docx
-  Fig. 3.doc

<https://mail.google.com/mail/u/0?ik=f50c90fc53&view=pt&search=all&permthid=thread-f%3A1628524941582859200&simpl=msg-f%3A162852494158...> 2/3

3/31/2019

Gmail - [AH] Editor Decision

-  Fig. 4.jpg
-  Figure 5.jpg

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How Humans Impact the Habitat Structure for Reptiles in the Uzungwa Scarp Nature Forest Reserve (USNFR)

John V. Lyakurwa^{1,2}, Linus K. Munishi¹ and Anna C. Treydte¹

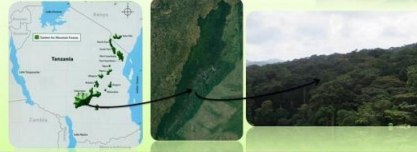
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Introduction

- The Uzungwa Scarp Nature Forest Reserve (USNFR) is one of the largest continuous Forests in the Eastern Arc Mountains and one of the hotspots within the Eastern Afromontane Biodiversity Hotspot [1]
- Largest concentration of endemics (30.8 per 100km²) than that of entire EAM (4.5 per 100km²) [2]
- Endemic species increases with altitude [1]
- Many areas have not been adequately explored

Where?



Why?

- Northern part largely unexplored for reptiles, no studies on environmental factors for species distribution and abundance
- Adjacent areas not explored (does the trend of endemism extends beyond the protected area?)
- Limited methodologies in the past [3]
- Under increasing human pressure
→ Major land transformation to agriculture in the past 60yrs



Objectives

1. To examine the distribution of reptiles in USNFR and surrounding agricultural lands .
2. To examine habitat characteristics that determine the abundance and diversity of reptiles both in USNFR and in bordering agricultural areas
3. To assess the farmers' awareness and perceptions on reptile occurrence in the farms bordering USNFR

How?



- **4 zones:** Lowland (< 700 m.s.l), Submontane (700-1400 m.a.s.l), Montane (>1400m.a.s.l) & Farmland (on the plateau, >1400m.a.s.l)
- **3 sites per zone**
- Night transects, pitfall & funnel traps with drift fences, day searches, opportunistic encounters per each site
- **Environmental variables** → Elevation, canopy cover, leaf litter depth, temperature understory cover and humidity

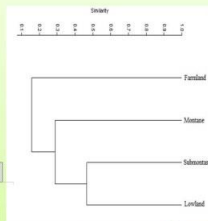
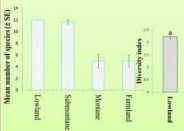
- **Interview with farmers** – four villages closest to USNFR on the plateau
- 71 respondents



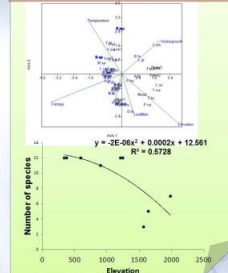
Results and Discussion

Abundance, Diversity and species composition

- 45 species (14 families), 24 new records to USNFR
- 69% endemic to EAM
- 1 new *Kinyongia* species
- 14 distribution range extension

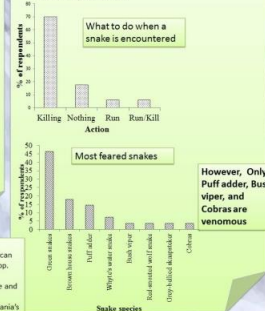


Environmental factors vs species



Interviews

- 96% of respondents- reptiles are not important



Acknowledgements

We are Grateful to Abdallah Chiponda, Elena Tonelli, Michele Menegon, Kim Howell, Magnus Kahise, Michael Mpwaga, Yusuph Tango Renatus Msaabo and the following partners

References

- [1] Menegon, M. and S. Salvadio (2005). Amphibian and reptile diversity in the southern Uzungwa Scarp Forest Reserve, south-eastern Tanzania. African biodiversity: molecules, organisms, ecosystems. In: *Proceedings of the 5th International Symposium on Tropical Biology*, Museum Koenig, Bonn pp. 201-212.
- [2] Rovero, F., Menegon, M. and Struhsaker, T. T. (2004). Biological importance and urgent need for protection of the Uzungwa Scarp Forest Reserve and other forests of the Uzungwa Mountains. A concept paper presented at the Uzungwa Workshop, Morogoro, 15-17th December
- [3] Rovero, F., Mwa, A., Kleghe, A., Nielsen, M. and Jones T. (2010). Uzungwa Scarp Forest Reserve in Crisis. An urgent call to protect one of the Tanzania's most important forests. *Unpublished report for the Forest and Beekeeping Division, Ministry of Natural Resources and Tourism, Dar Es Salaam*