EFFECTS OF LAND USE ON ABUNDANCE, DISTRIBUTION AND DOMESTICATION OF HELMETED GUINEAFOWL IN WESTERN AND EASTERN SERENGETI ECOSYSTEM

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ABSTRACT

The aim of the study was to investigate effects of land use on abundance, distribution and domestication of Helmeted Guinea fowl in western and eastern Serengeti ecosystem. This study addressed three objectives: (1) to determine abundance, density and spatial distribution of the Helmeted Guinea fowl in various vegetation/habitat and land use types; (2) to determine the species site occupancy probability in various habitats and land use types; (3) to assess stocks of Helmeted Guinea fowl under domestication in western and eastern Serengeti ecosystems. Birds were surveyed between November, 2017 and April, 2018 in the land use types of conservation areas, agro-pastoral and pastoralism zones using distance sampling technique. Household surveys were conducted to assess stock size and the socio-economics of the domesticated population of the Helmeted-Guinea fowl in residential areas. Abundance was found to be higher in areas of sparse vegetation in wooded grassland (147 birds) and in conservation areas (central Serengeti) (163 birds) while the densities were higher in bushed grassland (2.058 individuals/km^2) as well as in conservation areas (6.042 individuals/km^2). The study found a significance difference in abundance between various habitat types (Kruskal Wallis: $\alpha = 0.05$, $p = 0.0495$) and among land use types ($p = 0.043$). Site occupancy probability among land uses suggests that pastoral activity (grazing) has low effect on natural habitats and supported higher bird occupancy probability, ψ 0.3238 ± 0.1408 than agro-pastoral (cultivated) zone, which demonstrated least site occupancy probability, ψ 0.3055 ± 0.1125. On the other hand, Helmeted Guinea fowl occupancy probability was most influenced by bushed grassland in areas used by wildlife and livestock in pastoral and Game controlled areas in eastern Serengeti, ψ 0.2874 ± 0.1374 compared to the bushed grassland bordering conservation areas and village lands in western Serengeti, ψ 0.2845 ± 0.1364.

The extent of farming was found to be dominated by free ranging and caging system that hold the potential to support household economy for the keepers through selling farmed birds. This survey discovered that keepers capture birds and collect eggs on cultivated areas, grazing land, and in the protected areas, which increases threat to the species. The effect of land use is more intense in western than eastern Serengeti, therefore, this study recommends an urgent implementation of land use plan as well as directing other conservation and monitoring efforts to the villages surrounding Serengeti ecosystem.

DECLARATION

I, **GRAYSON GODWIN MWAKALEBE** do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been nor being concurrently submitted in any other institution.

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AIC	–	Akaike Information Criterion
ANOVA	–	Analysis of Variance
CI	–	Confidence Interval
CIMU	–	Conservation Information Monitoring Unit
CV	–	Coefficient of Variation
FAO	–	Food and Agriculture Organization
GGR	–	Grumeti Game Reserve
GIS	–	Geographical Information System
GPS	–	Geographic Position System
IGR	–	Ikorongo Game Reserve
KGR	–	Kijereshi Game Reserve
LGCA	–	Loliondo Game Controlled Area
MGR	–	Maswa Game Reserve
NCA	–	Ngorongoro Conservation Area
SENAPA	–	Serengeti National Park
SPSS	–	Statistical Package for Social Science
SUA	–	Sokoine University of Agriculture
SWRC	–	Serengeti Wildlife Research Centre
TAWIRI	–	Tanzania Wildlife Research Institute

WMA	–	Wildlife Management Areas
Ψ or psi	–	Occupancy

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

1.1.1 An overview

Humans around the world have modified over 83% of the earth's land surface through unsustainable utilization of natural land, leading to reduced biological diversity and constrained functioning of ecosystems (Hamilton, 2013). Similarly, in many regions of the world, human-wildlife interactions through different land use types such as hunting/gathering, pastoralism and agro-pastoralism have intensified large areas adjacent to protected ecosystems as a result of human population growth and agricultural activities (FAO, 2015). For example, in Tanzania increased settlements by agro-pastoralists on land adjacent to protected areas has been reported to cause negative impacts on habitats hence reduced environment quality in such areas (Kideghesho *et al*., 2006). Consequently, human-wildlife interaction in Africa is highly reported as one of the main threats to the continued survival of many wildlife species and other biotic communities in space and time (Ladan, 2014).

The Serengeti ecosystem is composed of different forms of land uses which are characterized by village lands and permanent settlements with high human influence near the edge of protected areas boundary (Sinclair, 2008). The wildlife protected areas in the ecosystem fall under three different categories. First, the national park category in which there is Serengeti National Park (central) where there is total protection of wildlife species. Second, the game reserve category, which is comprised of Kijereshi Game Reserve (West), Maswa Game Reserve (South west), and Ikorongo and Grumeti Game Reserves (North west) where human activities including settlements are not allowed except utilization of wildlife under license. Third, the game-controlled category, which is typified by Loliondo Game Controlled Area (North east), an informal multiple land use where settlement, livestock grazing as well as utilization of wildlife under license co-exist.

The Serengeti ecosystem is characterized by savanna habitats of open grassland, woody vegetation and scattered bushes supporting many species of avifauna and their distribution is the function of habitat condition that contribute to availability of food and cover (Condy, 1993, 1994; Nkwabi, 2007). The noted factors such as fire, has affected the breeding performance of ground-living birds, including Helmeted Guinea fowl (*Numida meleagris*) and the habitats they require (Gottschalk, 2002; Nkwabi, 2007; Sinclair *et al.,* 2008). In particular, areas of western and eastern Serengeti ecosystem is covered by a mosaic of habitats i.e. grasslands, mixed *Acacia* woodland, and broadleaved *Terminalia* woodlands, which are influenced by low and higher rainfall patterns thus governing the distribution of major land use such as pastoralism and agriculture (Sinclair *et al*., 2008). As such, the eastern Serengeti is inhabited by pastoral Maasai community with large number of livestock population in the decreasing patches of grazing habitats (Nelson, 2012). On the contrary, the western Serengeti is inhabited by the agro-pastoral community with small-scale cultivation of food and cash crop (Sinclair *et al*., 2008).

1.1.2 Human population growth and influences of land use change

Land-cover changes in the Serengeti ecosystem within a period of 20 years from 1984–2003 have indicated a dense settlements with increase of anthropogenic effects driven by accelerated conversion of natural habitats adjacent to protected areas (Estes *et al.,* 2012). Therefore, increased interactions between humans and wildlife through cultivation in areas bordering protected areas are of conservation concern because the protected ecosystems are affected at the larger landscape scale (Sinclair *et al.,* 2008).

The extent of farming in terms of total cultivated land per hectare in the area of western and eastern Serengeti is noted to vary in size for each household (Estes *et al.,* 2012). Therefore, cultivation near buffer areas and encroachment into protected areas are factors that cause land conversion and ecological effects for the species and habitats. The critical situation noted in other studies by Homewood and Rodgers (1991), McCabe (1997) was that, Maasai community has slowly become more sedentary and adapted to small agricultural practices.

The high number of livestock in pastoral communities has influenced the encroachment and probably contributed to the increased human-wild interactions in many ecosystems of Tanzania (Bonnington *et al.*, 2007). Heavy grazing practices and high concentration of people in the eastern part of the Serengeti ecosystem have caused an intensive transformation of the edge habitat to poor grazing land, which increase competition on smaller land resources available (Kivelia, 2005). Equally, the landscape of western and eastern parts of the ecosystem supports the home ranges of Helmeted Guineafowl that extend outside protected areas. Therefore, increase of agricultural pressure and overgrazing perhaps caused negative effect on habitats and distribution of the Helmeted Guineafowl. The emphasis regarding this study is to recognize effects of land uses possibly affect sustainable conservation effort of the Serengeti ecosystem.

1.1.3 Guineafowl and other game bird communities in savanna ecosystems

There are several species of game birds which also occur in the similar habitat with Helmeted Guineafowl include Grey-breasted spurfowl (*Francolinus rufopictus*), Red-necked spurfowl (*Francolinus afer),* Yellow-necked spurfowl (*Francolinus leucoscepus),* Crested francolins (*Francolinus sephaena),* Hilderbrant's francolins (*Francolinus hildebrandti),* Kori ustard (*Ardeotis kori*), Black-bellied bustard (*Eupodotis melanogaster*) and Ostrich (*Struthio camelus*). The Helmeted Guineafowl is a savanna game bird and its body size is physically described with height ranging from 40 – 72cm (15-28 inches); weight 1.6 – 3.5 Ibs; and the head part with bare skin in blue and red color, and has bony “Helmet” on the crest (Perrins, 2003).

The species occurs mostly across the habitats of open to closed savanna, mixed trees, bushes, and occasionally found near croplands (Sinclair and Ryan, 2003). The species has evolved from ancestral Guineafowl, an Asiatic francolin-like phasianid, to the present taxa, Helmeted Guineafowl, which is believed to migrate through the arid-savanna corridor from Asia to Africa during the Mid-Miocene (Crowe, 1978). Ecologically, this bird is adapted to various climatic conditions and the group size varies according to season and can be concentrated to areas with high availability of food such as seeds, tubers, bulbs, insects and suitable habitat for breeding. In the wild clutch size of 15 to 20 eggs are produced per breeding female and incubation period is ranging from 22 to 28 days (Njifort, 1997).Threats from intense agricultural activities are one of the key factors affecting habitat and the population of Helmeted Guineafowl (Kumssa and Bekele, 2013). Other study by Ebegbulem (2018) reported the species as more resistant to diseases compared to domestic stocks.

1. 2 Statement of the research problem and significance of the study

High pressure caused by intense land use in areas adjacent to protected areas brings long-term negative effects on wildlife protected areas (Hansen and Defries, 2007)**.** Effects of land use on ecosystems have been noted at higher level of intensification of agricultural activities in Sub-Saharan Africa (Lotze – Campen *et al.,* 2010)**.** The extensive level of agricultural fields has caused decline of Helmeted Guinea fowl that is attributed to reduction of cover and suitable nesting areas especially in South Africa (Little, 2000, Ratcliffe and Crowe, 2001).

The Serengeti ecosystem faces many challenges such as large population of livestock with continuous grazing and expansion of agriculture especially along the southwest boundary near the Maswa Game Reserve (Sinclair, 1995; Sinclair *et al.,* 2007). These challenges are largely related to encroachment due to human population growth and increasing resources demand in the protected area buffer zones (Nyahongo *et al.,* 2009, Fyumagwa *et al.,* 2013). This leads to direct impact on biodiversity including decline in avifauna populations due to habitat destruction and land degradation (Mundia and Murayama, 2009; Estes *et al*., 2012; Nyamasyo and Kihima, 2014). Other challenges related to intensive human activities adjacent to wildlife areas have posed threats that caused land-use change around protected areas at different spatial scales (Ogutu *et al*., 2012).

Thus, the persistent agricultural activities in the western and extensive livestock grazing in the eastern areas of the Serengeti might have changed the natural habitat with a resulting effect on the abundance and distribution of the Avifauna (Sinclair *et al.*, 2008). Therefore, Helmeted Guineafowl as species of many savanna ecosystems is facing several threats that are related to human activities and their number is rapidly declining especially in areas where there is intensive cultivation (Hoyo *et al.*,1994; Perrins, 2003; Sinclair and Ryan, 2003).

The landscape connectivity requires a link of suitable habitats to support the wildlife populations in protected areas (Hansen and Defries, 2007). But it is not known how land use and land cover change in the buffer areas of Serengeti ecosystem can indirectly influence Helmeted Guineafowl occupancy. Since little has been done to link the habitat condition and its implication on Helmeted Guineafowl, it is important to understand the status of the species in the ecosystem including the human dominated landscapes through determining the population density, abundance, spatial distribution pattern and site occupancy probability among various land uses and in respect to habitats under different vegetation characteristics. Moreover, there is no information about the domesticated Helmeted

Guineafowl that explains the relationship between existing local farming systems and population attributes and spatial distribution around Serengeti National Park. Therefore, this study covered eastern, western and northern parts of the Serengeti, where a growing human pressure on the ecosystem has negatively impacted the adjacent protected areas through increased disturbances and encroachment (Kivelia, 2005; Kideghesho, 2006; Sinclair *et al*., 2008; Estes *et al.*, 2012). This will help to explain the effects of human activities on the species and their habitats within and outside core wildlife protected areas in the ecosystem.

Moreover, this investigation contributes scientific based management alternatives to reduce the threats Helmeted Guineafowl is facing in agro-pastoral and pastoral zones. This may include reviewing the policies for sustainable conservation of Galliformes of the African savannah.

1.3 Objectives of the Study

1.3.1 Main objective

The main objective of the study was to investigate the effect of land use on abundance, distribution and domestication of Helmeted Guineafowl in the western and eastern Serengeti ecosystem**.**

1.3.2 Specific objectives

Specifically, the study aimed to:

i. Determine abundance, density and spatial distribution of the Helmeted Guineafowl in various vegetation/habitat and land use types.

ii. Determine site occupancy probability in various vegetation/habitat types among land use.

iii. Assess stock of Helmeted Guineafowl under domestication in western and eastern Serengeti ecosystem.

1.4 Research Hypotheses

The study is guided and aimed at testing the following hypothesis:

H_O: The effect of land use types on abundance, distribution and domestication of the Helmeted Guineafowl is more intense in agro-pastoral than pastoral areas.

H_A: The effect of land use types on abundance, distribution and domestication of the Helmeted Guineafowl is less intense in agro-pastoral than pastoral areas.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Impacts of Anthropogenic Activities on the Landscapes of Western and eastern Serengeti ecosystem.

The landscapes of Serengeti ecosystem are surrounded by land use types dominated by village lands, agricultural activities, livestock keeping and expansion of settlements with densely populated areas adjacent to protected areas, and (Fyumagwa *et al.,* 2017). The anthropogenic activities have been contributing to the economy of households through small scale agriculture for cash and food crops and livestock grazing (Sinclair *et al.,* 2007). However increased pressure on available resources particularly in the protected ecosystem and buffer areas caused more impacts on land cover and vegetation characteristics.

The areas near protected areas boundary have been affected by rapid increase of human densities (Fig. 1), which accelerated conversion of land to agriculture and hence change of land cover (Estes *et al.,* 2012). As such, effects of land use from expansion of agricultural activities and extensive livestock grazing in western Serengeti have increased more threats and clearance of habitat cover and continue to open up land and increase invasion of people and anthropogenic activities (Bevanger *et al.,* 2017).

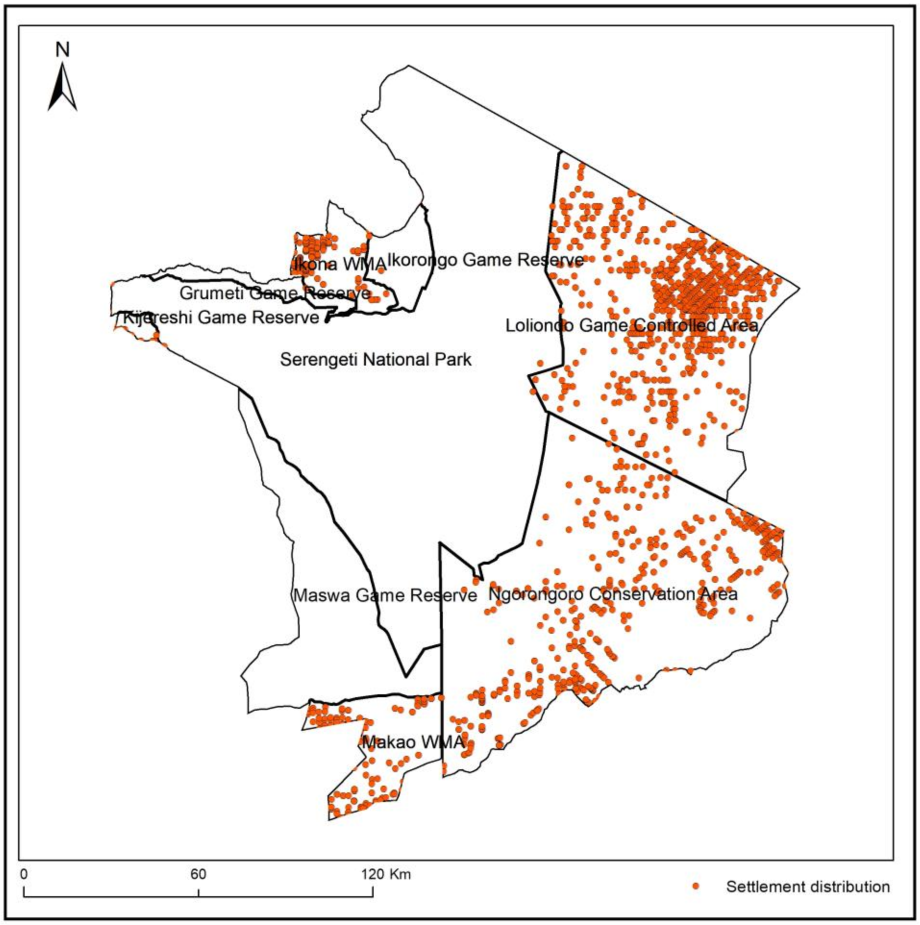

Figure 1: Map of Serengeti ecosystem showing distribution of settlements near protected areas boundary (Data source: TAWIRI-CIMU and GIS mapping by Hamza Kija).

The Serengeti District has consequently been implementing a 10-year land use plan (2016–2026) in four villages namely Nyiberekera, Nyamisingisi, Singisi, and Iharara to minimize cases and solve problems associated with encroachment and help interventions include maintaining land capacity for agricultural activities and livestock grazing (Halmashauri ya Wilaya Serengeti, 2017) as well as conservation of natural ecosystem (Sinclair, 2008) in the overall western Serengeti.

Therefore, investigation of land use effects is associated with understanding the key factors of human increase, which influence land use changes and loss of habitat in western and eastern Serengeti ecosystem. The comparison from investigation helps to define the consequence of agricultural and grazing pressures influencing responses of Helmeted Guineafowl to environmental gradients.

2.2 Effects of anthropogenic activities on abundance of Helmeted Guineafowl across different land use types

Helmeted Guineafowl population (*Numida meleagris galeata*) composition and breeding success are known to vary and to be of moderate performance in protected areas as compared to areas with high human activities (Van Niekerk, 2010). For example, a study by Njifort (1997) in a National Park in Waza Region of North Cameroon where the group size, abundance and distribution patterns varied in vegetation/habitat type, land uses and level of human activity, showed that 58.2% of the birds were found to performed better in *Acacia* dominated habitat. On the other hand, the study by Ratcliffe and Crowe (2001) investigated how agriculture affects populations of Guineafowl (*Numida meleagris)* and the species composition in woodland and grassland biomes in the Midland Kwa Zulu-Natal, South Africa. The study reported a modified landscape to homogeneity cause ecological effects and decline in population of Helmeted Guineafowl. Moreover, Fuller *et al.* (2000) and Gardner *et al*. (2007) assessed diversity of five taxonomic groups of Galliformes to check whether there is decline in number of species along a gradient of increasing human activity, and whether there is dissimilarity in species across landscapes of multiple land use types. The findings indicated that agricultural expansion caused loss of habitat and also affected Francolins and Helmeted Guineafowl population. Further, a study by Ramesh and Downs (2014) suggests that land use types influences site occupancy. For example, farming activities cause positive impact to bird species and attract them to create pest problems and compete seriously with human interest especially when crops are damaged at pre and post germination (Inah *et al.*, 2007).

The findings from analysis of human population data for Greater Serengeti Ecosystem and associated factor of land cover change from the periods of 1984-2003 showed lowest human density (98 people/km^2) close to the park boundary with highest rates of human population growth, 3.5% per year (Estes *et al*., 2012). However, the highest densities (160 people/km^2) and lowest growth rates (2.5% per year) were noted in the areas far from conservation areas (Estes *et al*., 2012). The classified land cover based on land use types exhibited that livestock keeping in the eastern side was an important economic activity than agriculture while in the western side; land cover exhibited increased conversion to agriculture of the land close to the park boundaries (Estes *et al.* (2012). Also based on classified land use types along distance gradient, Estes *et al.* (2012) further demonstrated that the zone 0 - 20 km from protected boundary experienced up to 2.3% annual rate of conversion of land to agriculture per year while those areas with population growth of high human densities showed conversion rate up to 1.0% per year. Therefore, current change rates of land conversion occurred at different patterns from the protected area boundary and it is not known how land use types can have significant impacts on habitat and distribution of Helmeted Guineafowl within unprotected part of the ecosystem.

2.3 Domestication of Helmeted Guineafowl in the residential areas

Farming of the Helmeted Guineafowl in the residential areas is one of the potential socio-economic activities. For example, in Ghana farmed birds comprised of 7.1% of the total poultry population, and 81% of all Guineafowls produced (FAO, 2014; Issaka and Yeboha, 2015). A study on socio-economic attributes of Guineafowl production in two districts in northern Ghana by Issaka and Yeboha (2015) reported to increase benefit through farming activities, and the sale of Guineafowls and eggs that provided considerable income for farmers. Results from the study by Abdul-Rahman and Adu (2017) revealed that Guineafowl production industry has great potential economic benefits to farmers and contribute to the livelihood of the rural farmers.

Similarly, the findings from Ngongolo and Mtoka (2013) reported that community engaged fully in keeping Helmeted Guineafowl mainly for subsistence and commercial purposes as well as for improvement of biological diversity in the inhabited areas. Moreover, Jacob *et al*. (2011) noted that other communities additionally kept Helmeted Guineafowl as farm yard ‘watch dog’; for control of insects and rodents; and as a source of protein and employment. The findings by Odukwe *et al.* (2016) following their evaluation of performance of different stocking density of Guineafowl raised at small scale farming system in the humid tropics indicated that survivability and growth of individuals were important measure in assessing optimum performance of the caged laying Guineafowl. The authors consequently recommended the stocking density of 0.33b/m^2. However, results of a study with high-density cage-layer system by Nahashon *et al*. (2006) reported that space and costs are demand driven key factors towards raising Helmeted Guineafowl at small scale. Therefore, to generate knowledge for conservation implication as basis for understanding the relationships between species and their landscapes, this study determines the relative stock density and how it influences the primary importance of domestication at the landscape scales in the Serengeti ecosystem.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Study Area

3.1.1 Location and boundaries

Serengeti ecosystem lies between $1^0 15'$ and $3^0 30'$S, and between 34^0 and 36^0E and borders with the Maasai Mara National Reserve in Kenya to the North. However, the present study focused on part of Serengeti National Park (from Nyaruswiga hill to western edge of Lake Victoria; Lobo area and the northern corridor, Tabora B and Kleins Gate) and the adjacent landscapes that encompasses Ikorongo, Grumeti and Kijereshi Game Reserves, Ikona Wildlife Management Area in the (western), and Loliondo Game Controlled Area (Fig. 2).

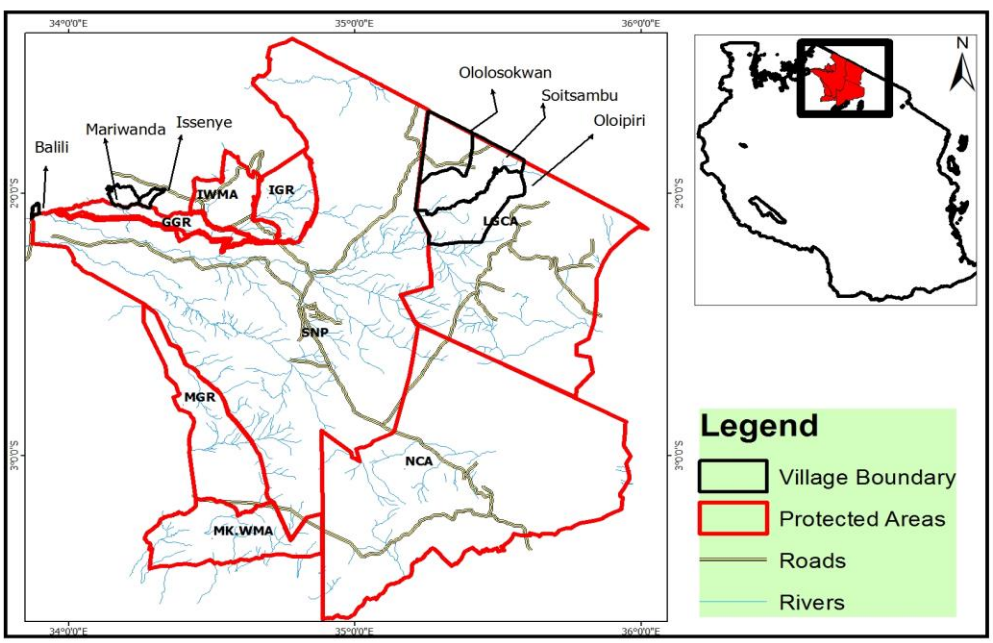

Figure 2: Map of Serengeti ecosystem showing major protected areas (SNP) = Serengeti National park; (GGR) = Grumeti game Reserve; (IGR) = Ikorongo Game Reserve; (LGCA) = Loliondo Game Controlled Area; (IKWMA) = Ikona Wildlife Management Area. The surveyed village of Guinea fowl keepers (Balili, Mariwanda, Issenye) in agro-pastoral zone; and (Ololosokwan, Soitsambu, Oloipiri) in pastoral zone.

3.1.2 Vegetation and soil

Serengeti ecosystem lies south of equator in Acacia savannah woodland, and the vegetation types of the park as described by Herlocker (1974) comprise of major physiognomic types such as wooded grassland, grasslands and woodlands. These form heterogeneous habitats of thorny savanna dominated by woody species such as *Acacia drepanolobium* and *Acacia seyal var fistula* on gray soils; *Acacia tortilis* on slopes of hard pan of gray soils and *Acacia geradii* on thin soils while the *Acacia robusta* is mostly dominant on sandy soil of deep and well drainage soil. Other communities are dominated by *Ostryoderris stuhlmanii, Terminalia sericea* and *Combretum zeyheri* of mostly broad-leaved trees in the north western part of the Serengeti. The scattered shrubs and short grass are alkaline tolerant communities of south eastern plains near Oldvai Gorge.

3.1.3 Land use

The land outside the boundaries of Serengeti National Park consists of a landscape where agriculture and livestock grazing are dominant in the agro-pastoral areas of western Serengeti, and pastoralism dominant in the multiple land use of Loliondo Game Controlled areas in the eastern segment (Fig.3). The human inhabitants are basically the pastoral (the Maasai and Sonjo) and agro-pastoral community in the eastern and western Serengeti, respectively. Therefore, the community in the eastern part is fully dependent on livestock with additional small-scale farming (Sinclair *et al.*, 2008). The changed landscape within the unprotected part of the ecosystem is an indicator of increasing human inhabitants and livestock number, which have reduced the grassland habitat cover (Kivelia, 2005).

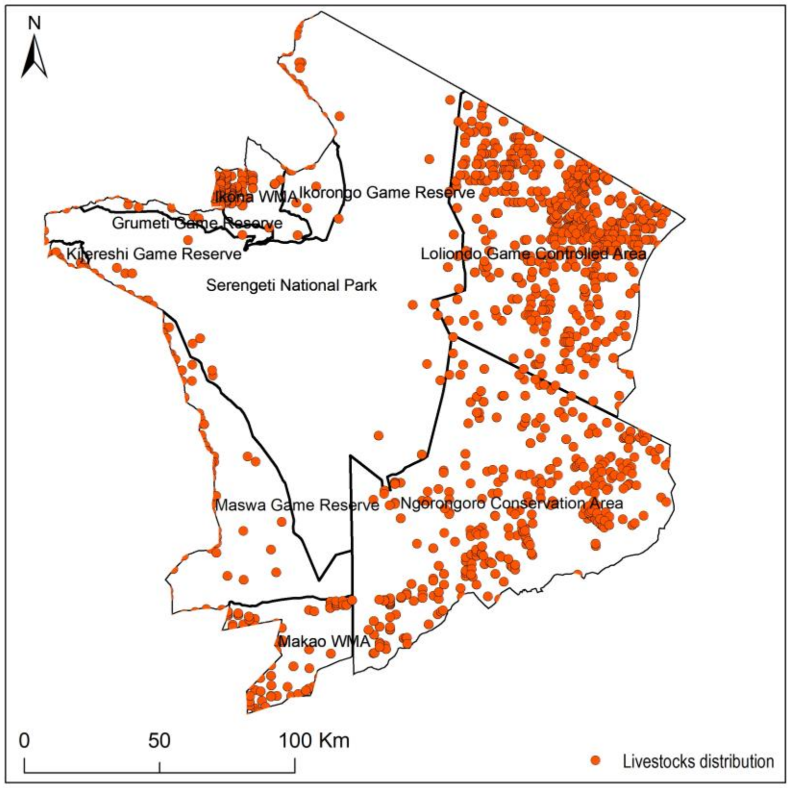

Figure 3: The distribution of livestock population within Serengeti Ecosystem. (Data source: TAWIRI-CIMU and GIS mapping by Hamza Kija)

3.1.4 Climate

The rainfall pattern is bi-modal with dry season from June to October; short rain season in November through February, and long rainy season from March to May (Sinclair, 1979). Rainfall increases from 600 mm/year in the south-east short grassland plains to 1,200 mm/year in the north-west in the landscape area dominated by *Terminalia* woodland and patches of *Acacia* communities. However, the variability can be observed in terms of changes in amount and sometimes through seasonal overlap specifically the slightly shift between days of short rains and log rains (Herlocker, 1974; Sinclair *et al*., 2008).

Temperatures for the mean maximum and mean minimum are 27^0C and 19^0C respectively in the Seronera area, where August to October are the hot months and June to July are cold months

3.2 Study set up

The study area was divided into 3 blocks, each specifying different types of land use and protection status. These were: i) Block A (western block), which consists of agro-pastoral unprotected areas; ii) Block B (central block), which consists of wildlife protected areas; and iii) Block C (eastern block), which consists of pastoral unprotected areas.

The distance sampling technique was used to sample birds, whereby, line transects were allocated randomly in the 3 blocks across the landscapes (Fig. 4). The distribution of transects took consideration of a gradient following change in habitat types. Each line transect was established and marked with a hand-held GPS. The line transects were established using existing roads and divided into sample units of 1 km segments as replicates where observations were carried out. However, fixed interval of 2 km long was established after each 1km Segments, and not included during field observation. Nevertheless, the starting point on each line transect was established randomly whereas the subsequent points were established systematically. GPS coordinates in latitude/longitudes were recorded as reference points at starting and ending position for all 1 km segments. Field observations covered dry season, short rains, and early long rain and were conducted from 7:00 AM to 11:00 AM.

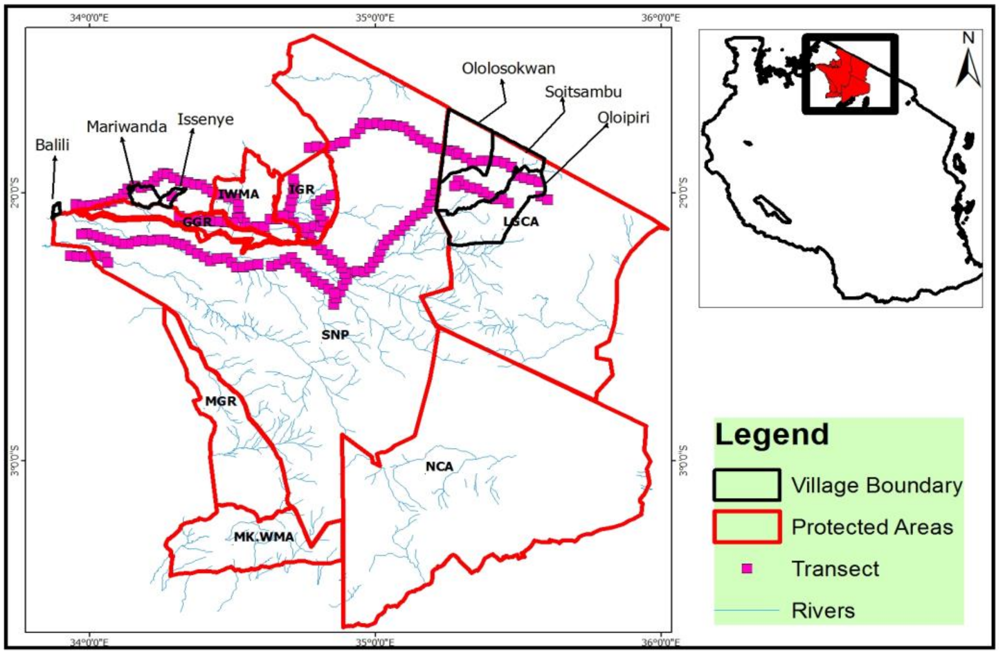

Figure 4: The map of study area showing distribution of transects on existing roads. The roads traverse different land uses in the ecosystem

3.3 Data collection procedures

3.3.1 Abundance and spatial distribution

The distance sampling technique was used to sample the birds. The method was based on the fact that the probability of detecting individuals decrease as the distance from the transect line increases. One advantage of this approach is that sighting of individuals was adjusted according to the visibility and thus allowed a direct comparison of estimated density among vegetation/habitat types (Buckland *et al.*, 2001). Therefore, a series of 1 km long segments (n=197 sample units) were systematically established in the 3 blocks along 15 randomly chosen line transects (covering 670 km) across different vegetation/habitat types on pre-selected roads and used to record any Helmeted Guineafowl detected within a distance from the centre of the road in any habitat type/land use.

A vehicle was driven at a speed of 20–30 km/h, with an observer standing on a pickup to count the birds along both sides of the road. The measured distances followed assumptions required for the successful application of distance sampling theory (Buckland *et al*., 2001). Measurement was recorded from line transects to the centre of each family groups/flock observed. Moreover, the assumption of individual/flock moving between different positions, their distances were only considered when observed at initial points of detection. Therefore when Helmeted Guineafowls were spotted, its sighting distance (r_i) (meters), was then measured with a range finder (LEICA 7 x 42 (BDA CLASS 1 LASER PRODUCT) (Buckland *et al*., 2001). Number of individuals sighted was recorded on data sheets (see appendix 1) together with their habitat/vegetation characteristics and land use. During data collection occasions, transects were alternated and driven on forward and backward basis.

Data for vegetation/habitats was categories based on the visual qualitative physiognomic classification techniques of vegetation following Herlocker (1974). Subsequently, percent cover (percentage of ground surface covered) for tree, shrub and grass communities (Sutherland, 1996) at each sighting point of Helmeted Guineafowl were estimated visually for: (i) woodland (ii) wooded grassland (iii) bush-land (iv) grassland; and (v) bushed grassland. Additionally, estimate of grass height (cm) at each sighting point was recorded randomly. This helped to investigate the role of each vegetation/habitat category in providing suitable habitats for Helmeted Guineafowl. The habitats sampled were compared to different land use types in the study area.

3.3.2 Guineafowl site occupancy and detection probabilities

For occupancy probabilities estimation, presence/absence of Helmeted Guineafowl at each transect were recorded (MacKenzie *et al*., 2006). Other recorded parameters were GPS positions and pastoral or agro-pastoral activities and habitat types.

3.3.3 Stock of Helmeted Guineafowl under domestication

The existing small-scale farming system of Helmeted Guineafowl on the village lands adjacent to protected areas was assessed to understand the status of the stock under domestication in the residential areas. The main focus was to collect information on population size of Helmeted Guineafowl and socio-economic characteristics of local communities engaged in the rearing activities, and if domestication in the village lands contributed to the increasing disturbances on wild population through egg collection and live capture. To that effect, household was used as sampling unit and key source of field data (United Nations Statistics Division, 2005). During sampling, each household or keeper was considered as independent sample unit to represent a targeted study population of agro-pastoralist and pastoral communities.

Purposive selection of 3 villages of pastoral community, and 3 villages of agro-pastoral community (n=6) was carried out along main transects across village lands adjacent to the protected areas. In each village, the register for households (Guineafowl keepers inclusive and marked) was inquired from village leaders so as to draw randomly a desirable sample of Guineafowl keepers i.e.households keeping the bird (n). To determine the required sample size for each village, the formula by Yamane (1967) was used $n = N/1 + N(e)^2$

Where n = is the sample size, N = is the total number of households in a village, e = is the sampling error (0.05 level of significance).

In this case, questionnaire survey method was employed (see appendix 2). The questionnaires were administered to either male or female respondents of age ≥ 18 years per household to assess stocks of Helmeted Guineafowl under domestication in the residential areas. The focus was to compare stock density between keepers in the western and eastern Serengeti, flock structure of farmed individuals among the study villages, and understand the socio-economic status of keepers in western and eastern Serengeti ecosystem. Population density (per site) and economic benefits to keepers such as protein sources and generated household income were assessed. The conducted survey was supported by additional information collected from village offices such as number of households, population and economic activities

3.4 Data Analysis

3.4.1 Abundance, density and spatial distribution

3.4.1.1 Abundance and density

The distance software was used for density estimates (Thomas *et al.,* 2010). The collected variables such as number of observed Helmeted Guineafowls, transect length (km), sighting distances (r_i) (meters), were imported into the Distance Statistical Software version 6.0 (Thomas *et al.*, 2002) in order to estimate density per sq km of the birds in various vegetation/habitats under the existing land use types. Procedures for data analysis in the Distance program involved three phases: i) exploratory data analysis, where cleaning of the collected data and check for any missing variables was performed for the records to be rectified after data entry. Selected portion of data set either observed birds, habitat types, and land use were saved in Tab delimitated text files format; ii) Model selection; where model definitions were run and inspected with the help of histograms, and then truncated by 5% for adjustment in order to fit the detection functions. The following models were used: Half-normal key with cosine adjustment; Hazard-rate key with simple polynomial adjustment; Uniform key with simple polynomial adjustment; and Negative exponential key with Hermite polynomial adjustment (Buckland *et al.*, 2001).

The Akaike Information Criterion (AICc) was used in selecting the best model whereby, a model with the smallest AICc was selected for extracting the density estimate (Buckland *et al.*, 2001). The fit of the models was checked using the Kolmogorov-Smirnov goodness-of-fit test evaluated for *P – value*. The abundance for each vegetation/habitat type, and for the land uses types were drawn as sum of counted individuals from segments for each line transects in the three study blocks. The normality test was employed using Paleontological Statistics (PAST) program version 2.17c (Hammer *et al.*, 2001), and non-normal data were analyzed and subjected to non-parametric test. Therefore Kruskal-Wallis test was performed to infer differences in abundances between habitat types and among land uses types to determine the major factors affecting the Helmeted Guineafowl abundance and their spatial distribution. The significance levels of all tests were assessed at $\alpha = 0.05$.

3.4.1.2 Helmeted Guineafowl spatial distribution in different habitats and land use types

The percentage ground surface covered by tree, shrub, and grass communities and average grass height (cm) were recorded using visual estimate at each location of the individuals birds sighted (Sutherland, 1996)

The GPS coordinates for each sighting were uploaded into GIS software Ver. 9.1 for production of maps that provided insight of the species distribution in the protected area and areas dominated by human activities.

3.4.2 Modelling of site occupancy probability

The PRESENCE software ver. 2.12.17 (MacKenzie *et al.*, 2002, 2003) was used in modeling site occupancy probabilities using single-species, single-season occupancy models with site covariates: land use types, vegetation/habitat types, and human disturbance in buffer areas and near protected areas boundary (Table. 1), to examine their effects on the Helmeted Guineafowl site occupancy probability (MacKenzie *et al.*, 2002, 2003). The analysis involved fitting models to estimate occupancy and to compare the factors affecting the proportion of sites occupied by the species in western, central and eastern Serengeti ecosystem. Counts for each transect were converted to binary data for the occupancy analysis, with “1” as detection and “0” as no detection.

Table 1: **Sites covariates used for modeling analysis to estimate bird occupancy probabilities**

Site covariates	Description
Land use	Areas which are considered as moderate to highly disturbed landscapes mainly due to intense farming and grazing activities.
Land cover	A function of site characteristics such as patch size, and habitat features which affect species presence/absence.
Buffer area + Protected area	Conservation areas + areas adjacent to conservation which are encroached, with subsequent effects on Guineafowl habitat connectivity due to expanded farming, and grazing activities.
Pastoral area + Game controlled area	Areas used by wildlife and livestock and considered as moderate to highly disturbed landscape mainly due to intense grazing activities.
Seasonality	Seasons that might influence occupancy or detection of Helmeted Guineafowl within study sites.

Thus, the following *a priori* models were run to fit the data using the single species single season models to determine the relative importance of covariates which might influence Helmeted Guineafowl site occupancy.

i) ψ (.),p(.), Guineafowl are randomly distributed with assumption that probabilities of occupancy (ψ) and detection (p) is constant and not being affected by site covariates (habitat types, land uses or seasons).

ii) ψ (Land use$_{\text{Agro-pastoral + pastoral activity}}$),p(.), this model assumed that land use (effect of agro-pastoral and pastoral activity) influence site occupancy, while detection probability remains constant.

iii) ψ (Land cover_ $_{\text{habitat types}}$),p(.), this model assumed that land cover (effect of habitat types) influence site occupancy while detection probability remain constant.

iv) ψ ($_{\text{Seasonality_}}$Time),p(.), this model assumed that seasonality (time of sampling) influence site occupancy (in each season such as “ dry, short rain, long rain”) while detection probability remains constant.

The combined site covariates with habitats were used for modeling to assess loss of connectivity due to previous human disturbance and landscape management:

v) ψ (Buffer areas + protected areas_ $_{\text{habitats}}$), p (.) this model assumed that (habitat cover) and connectivity influence site occupancy in buffers and protected areas while detection probability remains constant.

vi) ψ (Pastoral + Game controlled area_ $_{\text{habitats}}$), p (.) this model assumed that (habitat cover) and connectivity influence site occupancy in pastoral and Game controlled area while detection probability remains constant.

The AIC values were used as a measure of support for the best model that has been fit to the data (MacKenzie *et al*., 2002). The relative difference in AIC values between each model and the currently top-ranked model (the one with smallest AIC) and delta AIC were selected as best models. Therefore, all competing models within delta AIC of ≤ 2 were considered (MacKenzie *et al*., 2002).

3.4.3 Comparing stock of Helmeted Guineafowl under domestication

The data collected through questionnaire surveys were coded and then compiled in Microsoft excel, but analysed in the Statistical Package for Social Sciences (SPSS version 16.0). Much focus was directed to descriptive statistics such as mean number of Guineafowl per keeper and per village (Zimi, 2013). The total number of birds for each village was obtained by multiplying the average number of Guineafowl per keeper and number of keepers in a village.

The density of domesticated individuals in the agro-pastoral and pastoral villages was computed by dividing the total Guineafowl for each village per unit area. Consequently, the total numbers of Helmeted Guineafowl per village were subjected to one way ANOVA test at 0.05 *p-values* to infer for any significant difference between land use in pastoral (eastern Serengeti) and agro-pastoral (western Serengeti). Additionally, the total population of Guineafowl under domestication was deduced by summing up the number of Guineafowl in all the studied villages. The flock structure of farmed Guineafowl was calculated in (SPSS 16.0) using descriptive statistic to assess whether there are existing differences in the mean number of flocks for farmed individuals among the study villages. Further analysis focused on socio-economic benefits to keepers such as income generated from selling of birds.

CHAPTER FOUR

4.0 RESULTS

4.1 Abundance, density estimates and distribution

4.1.1 Abundance, and density estimates

The abundance of Helmeted Guineafowl was highest in wooded grassland and least in bushed grassland habitat (Table. 2). Overall, the highest abundance was found under "conservation land use (central Serengeti)" than in the agro-pastoral (western Serengeti) and pastoral (eastern Serengeti) areas of the ecosystem.

Table 2: Abundance of Helmeted Guineafowl per surveyed habitat/vegetation type and land use type

Habitat/vegetation type	Average no. of Helmeted-Guineafowl	Total no. of Helmeted-Guineafowl
Wooded grassland	147.0	441.0
Woodland	52.0	156.0
Bushed grassland	22.0	66.0
Land use /survey zone		
Pastoralism (eastern Serengeti)	51.0	153.0
Conservation (central Serengeti)	163.6	490.8
Agro-pastoral (western Serengeti)	13.3	39.9

Moreover, density of Helmeted Guineafowl varied among habitats, being slightly higher in the bushed grassland compared to wooded grassland and woodland (Table. 3). Also, conservation areas (central Serengeti) had higher density of birds followed by pastoral and agro-pastoral areas.

Table 3: Density estimates of Helmeted Guineafowl per surveyed habitat/vegetation type and land use types as selected from the best models using the smallest Akaike Information Criterion (AIC)

Model	No. par	Delta AIC	AIC	Density/km^2	SE ±
HABITAT					
Woodland					
Half-normal +Cosine	1	0.54	222.55	0.076	0.0312
Uniform + Cosine	0	0.60	222.61	0.100	0.0364
Hazard-rate + Hermite polynomial	**2**	**0.00**	**222.01**	**0.109**	**0.0381**
Negative exponential + Hermite polynomial	1	0.31	222.31	0.082	0.0365
Wooded grassland					
Unifirm + Cosine	**1**	**0.00**	**593.60**	**1.642**	**0.8965**
Half-normal	1	0.05	593.65	1.589	0.8859
Hazard-rate + Hermite polynomial	2	0.02	593.61	1.829	1.0041
Negative exponential + Hermite polynomial	1	0.67	594.27	1.764	1.0328
Bushed grassland					
Uniform + Cosine	1	3.42	289.35	0.788	0.2998
Half-normal + Cosine	2	0.82	286.76	1.471	0.5820
Hazard-rate + Hermite polynomial	2	1.37	287.31	1.542	0.7669
Negative exponential + Hermite polynomial	**1**	**0.00**	**285.94**	**2.058**	**0.8598**
LAND USE/SURVEY ZONE					
Agro-pastoral (western Serengeti)					
Uniform + Hermite polynomial	0	4.40	130.40	0.289	0.0859
Half-normal + Hermite polynomial	1	2.88	128.88	0.551	0.1869
Negative exponential + Hermite polynomial	1	0.00	126.00	0.816	0.3494
Hazard-rate + Cosine	**2**	**0.16**	**125.16**	**0.952**	**0.7305**
Pastoralism (eastern Serengeti)					
Uniform + Hermite polynomial	0	5.24	258.84	0.616	0.1474
Half-normal + Simple polynomial	1	3.72	257.31	1.465	0.6635
Negative exponential + Cosine	**1**	**0.00**	**253.60**	**2.624**	**1.3408**
Conservation areas (Central Serengeti)					
Negative exponential + Cosine	1	0.92	559.81	6.805	3.1054
Uniform + Cosine	**1**	**0.00**	**558.89**	**6.042**	**2.5046**
Half-normal + Simple polynomial	1	0.79	559.67	6.032	2.5347
Hazard-rate + Hermite polynomial	2	1.68	560.57	6.044	2.6543

No. par = number of parameters; SE = standard error; AIC = Akaike information criterion; ΔAIC = Delta Akaike information criterion.

A non-parametric test indicated a significant difference in abundance of Helmeted Guineafowl in the surveyed land uses of pastoralism (eastern Serengeti), conservation (central Serengeti) and agro-pastoral (western Serengeti) (Kruskal Wallis test: $\alpha = 0.05$, $H = 6.316$, $df = 2$, $p < 0.043$). Similar statistical test showed significant difference between habitat types (Kruskal Wallis test: $\alpha = 0.05$, $H = 3.857$, $df = 2$, $p < 0.0495$).

The density of Helmeted Guineafowl (per Sq. km) between land use types showed no significant difference (Kruskal Wallis test: $\alpha = 0.05$, $H = 0.04762$, $df = 2$, $p > 0.8273$). Similarly, density of Helmeted Guineafowl did not show any significant difference between habitats (Kruskal Wallis test: $\alpha = 0.05$, $H = 0.4286$, $df = 2$, $p > 0.5127$).

4.1.2 Helmeted Guineafowl spatial distribution in different habitat and land use types

Helmeted Guineafowls showed higher occurrence in wooded grassland dominated by shrubby vegetation cover compared to bushed grassland and woodland habitat types. As such, sightings in wooded grassland was about three times higher than that of bushed-grassland while the sightings in woodland were about twice higher compared to bushed grassland habitat (Table. 4).

Table 4: The recorded sightings of individuals Helmeted Guineafowl observed in different habitat categories

Habitat category	Frequency	Percent
Wooded grassland	58	53.7
Woodland	33	30.6
Bushed grassland	17	15.7
Total	108	100.0

With regard to land use, more sightings of Helmeted Guineafowl were recorded in the central Serengeti National park and along Nyaruswiga-Ndabaka plains in the western corridor as well as in the northern corridor, particularly lobo area (conservation area) than agro-pastoral (western Serengeti) and pastoral (eastern Serengeti) parts of the ecosystem (Fig. 5).

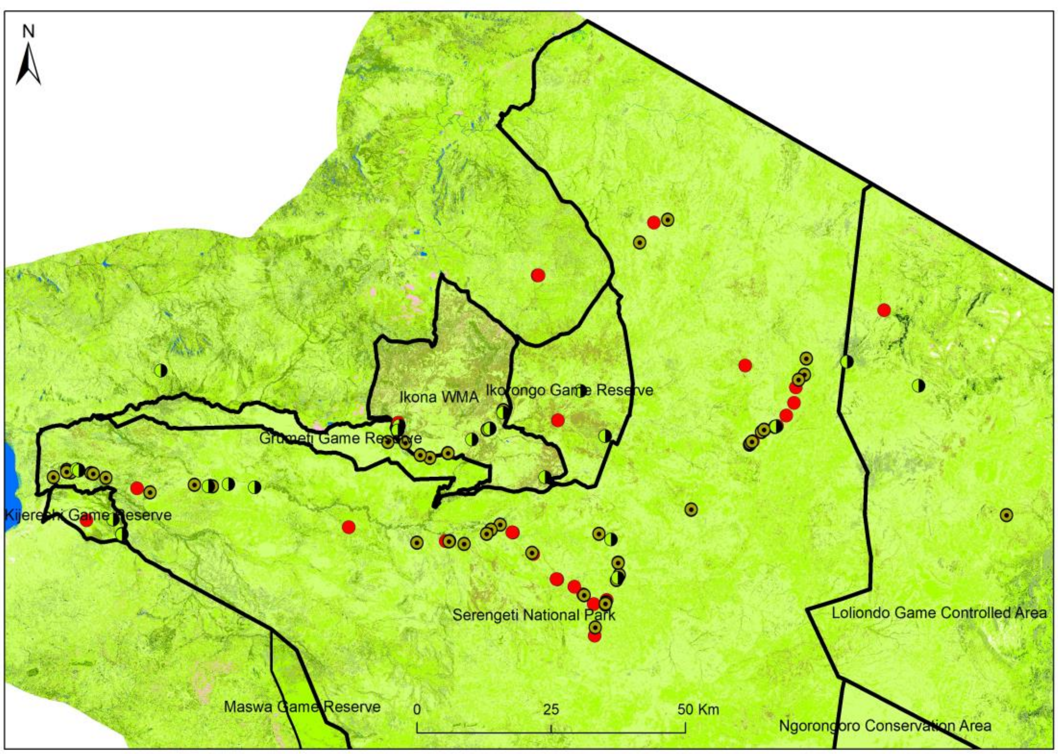

Figure 5: Helmeted Guineafowl Spatial distribution in different habitat types: wooded grassland (brown dots); bushed grassland (half green /black dots); and woodland (red dots).

4.2 Site occupancy probability among land uses

Selection of most parsimonious models was based on AIC values and weights whereby models with Delta AIC of ≤ 2 were considered as best models (Table. 5). Helmeted Guineafowls showed higher occupancy probability on pastoral (grazing) than agro-pastoral (cultivated) land (Table. 5). Moreover, Helmeted Guineafowl occupied nearly all vegetation types except bush-land and grassland. The bushed grassland showed higher occupancy probability in pastoral as well as in game controlled areas in eastern Serengeti, but the occupancy was the least in buffer areas and protected areas in western Serengeti (Table. 5).

Woodland and wooded grassland habitat types influenced higher occupancy probability of Helmeted Guineafowl in pastoral and game-controlled areas in eastern Serengeti, and in conservation areas to areas adjacent village lands in western Serengeti. However, seasonality did not explain differences in site occupancy probability of the Helmeted Guineafowl as the best model was a constant model i.e. ψ(.),p(.) (Table. 5).

Table 5: Site occupancy (*ψ*) and detection (*p*) probabilities of Helmeted Guineafowl in western and eastern Serengeti ecosystem

Covariates/Model	No.Par.	AIC	Δ AIC	AIC weight	-2(log likelihood)	*ψ* ± SE
Land use						
ψ (Agro-pastoral _cultivated),p(.)	**7**	**92.49**	**0.00**	**0.6066**	**78.49**	**0.3055 ± 0.1125**
ψ (Pastoralism_ grazing),p(.)	**7**	**93.42**	**0.93**	**0.3810**	**79.42**	**0.3238 ± 0.1408**
ψ (.),p(.)	2	100.27	7.78	0.0124	96.27	0.5050 ± 0.4607
Land cover						
ψ (.),p(.)	**2**	**674.39**	**0.00**	**0.9997**	**670.39**	**0.5026 ± 0.0687**
ψ (wooded grassland),p(.)	7	690.99	16.60	0.0002	676.99	0.4184 ± 0.0456
ψ (bushed grassland),p(.)	7	696.28	21.89	0.0000	682.28	0.3942 ± 0.0412
ψ (woodland),p(.)	7	696.36	2.00	0.0000	682.39	0.3909 ± 0.0416
Buffer areas + Protected areas (NP+GR)						
ψ (.),p(.)	**2**	**176.94**	**0.00**	**0.3952**	**172.93**	**0.4828 ± 0.2034**
ψ (wooded grassland),p(.)	**7**	**177.36**	**0.42**	**0.3203**	**163.36**	**0.2897 ± 0.0677**
ψ (Bushed grassland),p(.)	**7**	**178.71**	**1.77**	**0.1631**	**164.71**	**0.2762 ± 0.0639**
ψ (woodland),p(.)	7	179.30	2.36	0.1214	165.30	0.2663 ± 0.0612
Pastoral area + Game controlled areas						
ψ (woodland),p(.)	**7**	**41.39**	**0.00**	**0.4584**	**27.39**	**0.2874 ± 0.1374**
ψ (Bushed grassland),p(.)	**8**	**41.79**	**0.49**	**0.3753**	**25.79**	**0.2845 ± 0.1364**
ψ (wooded grassland),p(.)	7	43.88	2.49	0.1320	29.88	0.2537 ± 0.1238
ψ (.), p(.)	2	46.58	5.19	0.0342	42.58	0.3853 ± 0.3246
Seasonality						
ψ (.), p(.)	**2**	**674.39**	**0.00**	**0.9991**	**670.39**	**0.5026 ± 0.0687**
ψ (Long rain season),p(.)	7	688.60	14.21	0.0008	674.60	0.4062 ± 0.0430
ψ (Short rain season),p(.)	7	696.38	21.99	0.0000	682.38	0.3936 ± 0.0414
ψ (Dry season),p(.)	7	696.44	22.05	0.0000	682.44	0.3928 ± 0.0411

No. par = number of parameters; *ψ* = estimated occupancy; SE = standard error; AIC = Akaike information criterion; ΔAIC = Delta Akaike information criterion; NP = National park; GR = Game reserve; *ψ* (.),p(.) = a priori model when site occupancy and detection probability is constant.

Moreover, the best models for the estimated occupancy probability of HelmetedGuineafowl with CI are summarized in (Table. 6).

Table 6: The results of occupancy ψ, standard error SE ±, and the 95% confidence intervals CI were analyzed using covariates land use, land cover, buffer areas and protected areas, pastoral area and game controlled areas.

Covariates	$\boldsymbol{\Psi}$	**SE ±**	**95% CI**	
Land use				
(Agro-pastoral _cultivated land)	0.3055	0.1125	0.1346	0.5543
(Pastoralism_ grazing land)	0.3238	0.1408	0.1195	0.6281
Land cover				
ψ (.),p(.)	0.5026	0.0687	0.3327	0.5094
Buffer areas + Protected areas				
ψ (.),p(.)	0.4828	0.2034	0.1590	0.8217
Wooded grassland	0.2897	0.0677	0.1641	0.4014
Bushed grassland	0.2762	0.0639	0.1694	0.4167
Pastoral area + Game controlled area				
Woodland	0.2874	0.1374	0.0978	0.6003
Bushed grassland	0.2845	0.1364	0.0966	0.5965
Seasonality				
ψ (.), p(.)	0.5026	0.0687	0.3710	0.6339

4.3 Comparison of extent of domestication of Helmeted Guineafowl between pastoral zone (eastern Serengeti) and agro-pastoral zone (western Serengeti)

The mean number of Helmeted Guineafowl per keeper was 12 birds. The estimated number of birds for each village was obtained by multiplying the average number of the Guineafowl per keeper (12 birds) and number of keepers in a village. Therefore, the estimate population of Guineafowl under domestication in all the surveyed villages i.e. 396 birds was obtained by summing up the number of Guineafowls for all the villages (Table. 7).

Table 7: Comparison of Helmeted Guineafowl domestication between agro-pastoral and pastoral areas in Serengeti ecosystem

Land use	Village	No. keepers	Number of Guineafowl for each village
Agro-pastoral	Mariwanda	8	96
	Balili	6	72
	Nyiberekera	15	180
Pastoral	Oloipiri	1	12
	Soitsambu	3	36
	Ololosokwani	0	0
Total		**33**	**396**

The results of statistical F-test have indicated a significant difference in the total number of Helmeted Guineafowl farmed in agro-pastoral zone (western Serengeti) and pastoral zone (eastern Serengeti) ($F=8.446$; $df=1$; $p=0.044$).

For farmed individuals in all the villages there were more adult female and young, than sub-adult and juvenile between agro-pastoral and pastoral (Table. 8). The number of adult males was low compared to the number of adult females kept to support the breeding stock.

Table 8: **Flock structure of farmed Helmeted Guineafowls sampled in the surveyed villages of agro-pastoral and pastoral areas.**

Flock Structure	Sum	Mean	Std. Error Mean
Adult male	77	12.83	5.016
Adult female	119	19.83	9.951
Sub-adult	41	6.83	2.257
Juvenile	59	9.83	4.629
Young	108	18.00	9.455

Moreover, the density of domesticated stocks in villages belonging to agro-pastoral and pastoral areas was 8.190 individuals/ km^2 (Table. 9). However, the stock density was overall higher in Nyiberekera village located within the agro-pastoral landscapes while the villages in the pastoral landscapes registered least level of domestication (Table. 9).

Table 9: Density of domesticated stocks in the surveyed villages of agro-pastoral and pastoral areas

Land use	Village	Number of Guinea fowl for each village	Village area (km^2)	Density of domesticated stocks in each village (number of birds per km^2)
Agro-pastoral	Mariwanda	96	212	0.45
	Balili	72	24	3.00
	Nyiberekera	180	39	4.61
Pastoral	Oloipiri	12	377	0.032
	Soitsambu	36	368	0.098
	Ololosokwani	0	124	0.00
		N=396	**1 144**	**8.190**

Assessment of socio-economic benefits of keeping the Helmeted Guineafowl showed that majority of keepers used the stock primarily as food (source of protein) and for income generation while ornamentation, conservation and other minor motives exhibited least priority (Table. 10).

Table 10: **The purpose of farming that contributed to the keeper’s welfare**

Farming purposes	Frequency	Percent
Food only	7	21.9
Household income only	7	21.9
Food, ornamental and income	9	28.2
Ornamental only	3	9.4
Ornamental and conservation	2	6.2
Traditional values (Sacrifice)	2	6.2
Others	2	6.2
Total	**32**	**100.0**

Selling of farmed Guineafowl and eggs was an important source of the household income to support household livelihood. Results showed that agro-pastoralists in the western Serengeti sold the farmed bird at a frequency seven times higher than pastoralist in eastern Serengeti (Table. 11). The price fetched is TZS 60,000 per farmed adult male, TZS 50,000 for an adult female, and at TZS 25,000 as for sub-adult of both sex.

Table 11: Response of agro-pastoralists and pastoralist communities engaged in the selling of farmed Guineafowl

Community types	Frequency of selling Helmeted Guineafowl	Percent
Agro-pastoral area	28	87.5
Pastoral area	4	12.5
Total	**32**	**100.0**

The keepers sold Helmeted Guineafowl at an average price of TZS 25,000.00. The total income was higher for Nyiberekera (TZS 4,500,000.00) in agro-pastoral area compared to Oloipiri (TZS 300,000.00) in pastoral area (Fig. 6).

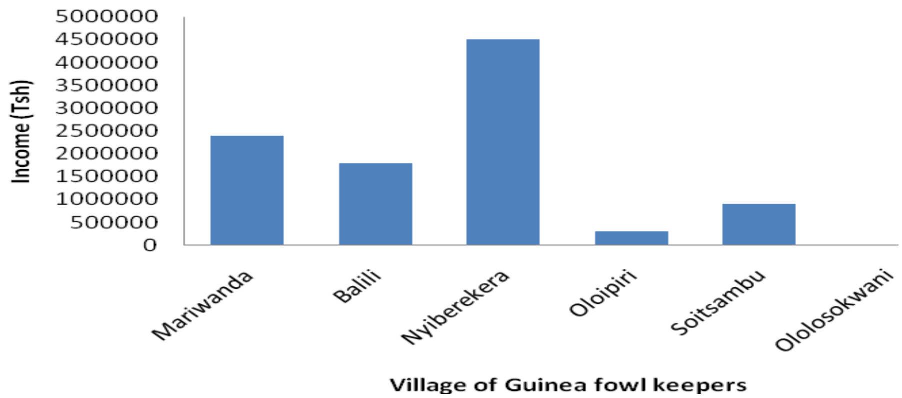

Figure 6: Comparison of income accrued from sales of Helmeted Guineafowl between villages belonging to agro-pastoral and pastoral areas.

The illegal trapping of wild Helmeted Guineafowl in the game reserve was about three times higher compared to the other two wildlife protected area categories in Serengeti National park and game-controlled areas, and overall higher than other land uses with no legal protection status such as grazing lands and farms or croplands. On other hand, egg collection from the nests of wild Helmeted Guineafowl was higher in buffer areas by 29.2% than game reserve (Table. 12).

Table 12: Trapping of wild Helmeted Guineafowl and egg collection in the protected and outside protected areas in western and eastern Serengeti.

Protected areas	**Wild Helmeted Guineafowl trapping (%)**	**Eggs collection (%)**
Game reserve	20.0	24.6
Game controlled area	6.2	6.2
National park	6.2	7.7
Outside protected area		
Buffer area	15.4	29.2
Grazing lands	13.8	7.7
Farms at post harvesting	4.6	1.5
Farms at pre harvesting	3.1	1.5
Farms during cultivation and planting	4.6	4.6

CHAPTER FIVE

5.0 DISCUSSION

5.1 Abundance, density and spatial distribution of Helmeted Guineafowl in various vegetation/habitat and land use types

Analysis of abundance, density and spatial distribution of the Helmeted Guineafowl with vegetation/habitat, and land uses showed that, wooded grassland had higher influence on Helmeted Guineafowl as compared to other vegetation types such as bushed grassland. Other study e.g. by Nsor *et al.* (2018) attributed different levels of influence of habitat types on abundance of Helmeted Guineafowl due to the roles that different habitat types play in nesting, food supply and hiding from predators. Different habitats provide different opportunities for foraging, nesting sites and roosting sites (Girma *et al.,* 2017). In this respect, overall habitat structure and composition of vegetation is the key determinants in bird assemblages and has potential for effectively influencing species habitat preferences (Nsor *et al.,* 2018). Therefore, maintaining habitat heterogeneity requires a link of conservation efforts to reduce effect of human pressure influencing spatial discontinuities or separation of habitat surrounding the ecosystem.

Similarly, the estimated density per sq.km of Helmeted Guineafowl was slightly higher in bushed grassland, followed by wooded grassland and woodland habitat. This was in line with other studies (e.g. Njifort, 1997; Little, 2000; Ratcliffe and Crowe, 2001; Van Niekerk, 2010) have indicated that dense woody vegetation with bush and shrub undergrowth provides better foraging grounds through supporting food resources such as insects. Therefore, this could be the reason behind the support of bushed savannas and woody vegetation to the Helmeted Guineafowl in the Serengeti. Whereas in the study of Njifort, (1997) the anthropogenic factors affect availability of food resources and individuals distribution between habitats.

However, the density estimates in the agro-pastoral (western Serengeti) and pastoral (eastern Serengeti) were lower than that in the conservation area (i.e. central Serengeti). The low density in the western and eastern part of Serengeti was due to intense human activities that led to change in habitat qualities. Therefore, conservation areas in the Serengeti ecosystem are a strong hold of the population of Helmeted Guineafowl compared to adjacent areas that are occupied by humans. However, other studies e.g by Vikery and Arlettaz (2012) reported that land dominated by humans have ecological significance in resources availability and interactions of birds in their preferred habitat.

5.2 Site occupancy probability among land uses

Occupancy models were used to assess the environmental factors on site occupancy of Helmeted Guineafowl in the Serengeti ecosystem. The results showed that pastoral area (grazing land) play important role in supporting bird occupancy than agro-pastoral area (cultivated land). Therefore, grazing activity in pastoral (eastern Serengeti) has low effect on Helmeted Guineafowl habitats compared to agricultural activities in agro-pastoral areas (western Serengeti).

This was in line with Ramesh and Downs (2014) who reported the effect on site occupancy probability of Red-necked spurfowl (*Pternistis afer*) occurs within agricultural landscape in the Drankensberg Middlands, South Africa. Moreover, the wooded grassland played an important role on site occupancy rate than woodland habitat. Similarly, bushed grassland within the pastoral area showed higher occupancy rate in eastern Serengeti. This suggests that pastoral and Game controlled areas in eastern Serengeti, have strong influence on Helmeted Guineafowl site occupancy. Whereas other studies by Little, (2000), Ratcliffe and Crowe (2001), Inah *et al*. (2007), Van Nierkerk, (2010) and McCollum, (2015) reported that bushed habitats with closed vegetation cover are important for providing nesting site for Helmeted Guineafowl.

The least occupancy rate of Helmeted Guinea fowl was noted in buffer area and sites adjacent to conservation areas in western Serengeti. This place face expanded farming and grazing activities which could be reason behind low occupancy rate. Similarly, Cleary (2010) also emphasized this by stating that human disturbances in agro-ecosystems contributes to highly fragmented landscape and separation of habitat, which has negative effect on ground dwelling birds including the Helmeted Guineafowl.

Seasonality failed to explain differences in site occupancy probability of the Helmeted Guineafowl in the Serengeti ecosystem. This corroborated with other findings e.g. by McCollum (2015) who found out that site occupancy rate of Helmeted Guineafowl showed no variation in repeated surveys in dry, short rain and long rain, within Northern Tuli Game Reserve, Botswana (McCollum, 2015). The population of Helmeted Guineafowl was observed to occupy many locations in the study area whereby their distribution in all seasons was related to availability of food resources and habitat suitability. Thus, the present study highlights the importance of wooded grassland and bushed grassland habitat in influencing higher site occupancy probability of Helmeted Guineafowl in the Serengeti ecosystem

5.3 Comparison of extent of domestication of Helmeted Guineafowl between the pastoral zone (eastern Serengeti) and agro-pastoral zone (western Serengeti)

Farming of Helmeted Guineafowl was found to be an important socio-economic activity in communities dominated by agro-pastoral (western Serengeti). Therefore, domestication activities that aimed to raise Helmeted Guineafowl for food and income generation was reported higher in western Serengeti than in eastern Serengeti.

Saina (2005) pointed out that rearing of Guinea fowl under the semi-extensive system has more economical value for smallholder producers. Yakubu *et al.* (2014) also pointed out that the fundamental reason of increase in rearing activity in the Nasarawa State, Nigeria was related for the rural community to access meat and eggs as well as income generation through sales of live fowl and eggs.

Under the current study, purpose of farming Helmeted Guineafowl in residential areas included food and income generation through selling farmed birds that added economic benefits for the keepers. Findings by Abdul-Rahman and Adu (2017) revealed that the industry has huge potential for income generation to support household economy and to meet the social and cultural needs. The current study found out that income generated from sales was higher in Nyiberekera, Balili and Mariwanda villages in western Serengeti than in pastoral communities in Soitsambu, Oloipiri and Ololosokwani villages in eastern Serengeti. This is not surprising as traditionally the pastoral Maasai are fully depending on cattle, sheep and goats in meeting household requirement such as food and income (Nyariki *et al.*, 2009).

The rearing activities of Helmeted Guineafowl was found growing fast in western Serengeti and the respondents were reportedly to mostly visit the game reserves for trapping wild Helmeted Guineafowls. The visitation rate for eggs collection was higher in buffer areas than grazing lands and protected areas. There was also illegal capture and majority of adult males and females Helmeted Guineafowls were captured purposely for supporting the breeding stock, food, and other economic benefit. Both sexes showed similar importance and did not vary significantly among the individuals of Helmeted Guineafowl captured near farms by keepers. This illegal off take might bring negative effect on population of Helmeted Guineafowl as a study Ratcliffe and Crowe (2001) have reported their decline was due to illegal activities such as hunting in the Midlands of KwaZulu-Natal province, South Africa. Moreover, study by Jenkins *et al.* (2017) reported that trapping of birds is a significant source of income in supporting local livelihoods, but when trapping is non-selective can affect occurrences and community structure of other local bird populations.

Therefore, key findings from this household survey showed that farming of Helmeted Guineafowl in agro-pastoral and pastoral communities is mostly dominated and operated at small scale. However, the study observed that to sustain rearing activities the keepers use opportunity to capture and collect eggs of wild population of Helmeted Guineafowl near cultivated areas. Therefore, implications of the study regarding domestication of Helmeted Guineafowl in residential areas, is depending on how wildlife managers, agriculture and livestock extension officers will be equipped with this information in order to control effects on wild Guineafowl population.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The present study has investigated the abundance and occurrences of the Helmeted Guineafowl, and its interactions with its habitat in agricultural and grazing landscape. The findings contribute relevant ecological information for improving management of Helmeted Guineafowl habitat to facilitate landscape connectivity between protected areas or movement of individual species among resources patches in western and eastern Serengeti ecosystem. Further, loss of habitat is critical component in agro-pastoral than pastoral areas. On the other hand, the site occupancy probability among land uses was higher in the bushed grassland in pastoral and game-controlled areas in eastern Serengeti. However, this study emphasizes the importance of trees and shrubs vegetation cover to maintain microhabitats for the Helmeted Guineafowl in the fragmented areas surrounding the Serengeti ecosystem.

Effects from stressors such as grazing and bush clearing for farming were stronger in western part of Serengeti. Changes in vegetation characteristics affected Helmeted Guineafowl occupancy probability in agro-pastoral areas in western Serengeti. Thus, intense anthropogenic activities in agro-pastoral (western zone) and pastoral areas (eastern zone) is an important alert for effective measures to be taken for proper conservation of biodiversity in Serengeti ecosystem.

The farming of Helmeted Guineafowl is of great concern since it increases interaction with wild stock population in pastoral and agro-ecosystem of the Serengeti. The extent of domestication of Helmeted Guineafowl is growing fast, and this activity holds potential to support household economy in villages bordering protected areas. Therefore, this must be given attention to make sure that illegal trapping of wild stock is restricted in villages surrounding the Serengeti ecosystem for sustainable conservation of Helmeted Guineafowl population. This is accepted as challenges for interdisciplinary team to facilitate intervention and discourage intensification practices and illegal off-take of wild stock.

6.2 Recommendations

Finally, this study recommends that:

1. Landscape planning should be effected to reduce large scale human-induced impacts for sustainability of heterogeneous habitats and abundance of Helmeted Guineafowl population and other ground dwelling birds adjacent to Serengeti ecosystem.
2. The district game officers and village administrative authorities of western and eastern Serengeti ecosystems are required to conduct seminars and regular patrol to control illegal trapping and collection of eggs from wild Helmeted Guineafowl.
3. Further research is needed to assess illegal off-take and review of regulations and licenses of farming and selling of Helmeted Guineafowl in local markets surrounding Serengeti ecosystem.

REFERENCES

Abdul-Rahman (II)., and Adu, Y. E. (2017). The role of the rural farmer in Guineafowl (*Numida meleagris)* value chain, a case study of the Tolon district. *Journal of Livestock Research for Rural Development* 29 (4):13.

Bevanger, K., Chande, O., Haule, K., Lejora, I., Mwakipesile, A., and Kaswamila, A. (2017). Northern Serengeti Road Ecology. In: *Outlook for the Northern Serengeti Road Ecology*. (*Edited by Fyumagwa, R. D., Mfunda, I. M., Ntalwila and Roskaft, E.),* Fagbokforlaget Kanalveien 51 .pp. 106 – 123.

Bonnington, C., Weaver, D., and Fanning, E. (2007). Livestock and large wild mammals in the Kilombero, Valley in Southern Tanzania. *African Journal of Ecology* 45: 658 – 663.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., and Thomas, L. (2001). *Introduction to distance sampling estimating abundance of biological populations.* Oxford University Press, Inc; New York, USA. 358 pp.

Cleary, K. A. (2010). Species Richness, Densities, Habitat Relationships, and Conservation of the Avian Community of the High-Altitude Forests of Totonicapan, Guatemala. MSc Thesis, 118 pp.

Condy, M. L. (1993). Bird diversity Components within and between habitats in Australia. Book. In: *Historical and Geographic Perspectives*. *(Edited by Ricklefs, E. and Schluter, D.),*University of Chicago Press, Chicago. pp. 147 – 158.

Condy, M. L. (1994). Mulga bird communities. I. Species composition and predictability across Australia. *Australia Journal of Ecology* 19: 206 – 219.

Crowe, T. M. (1978). Evolution and Ecology of Guineafowl. PhD Thesis, Faculty of Science (Dept. of Zoology) University of Cape Town, 263 pp.

Ebegbulem, V. N. (2018). Prospects and Challenges to Guineafowl (*Numida meleagris*) production in Nigeria. *International Journal of Avian and Wildlife Biology* Mini Review 3: 3.

Estes, A. B., Kuemmerle, T., Kushnir, H., Radeloff, V. C., Herman, H., and Shugart, H. H. (2012). Land-cover change and human population trends in the greater Serengeti ecosystem from 1984–2003. *Biological Conservation* 147: 255 – 263.

FAO. (2014). *Poultry Sector Ghana*. Animal Production and Health Livestock Country Reviews. No. 6. Rome

FAO. (2015). *Sustainable wildlife management and human-wildlife conflict*. 4 CWP fact sheet. 1 - 6 pp.

Fuller, R. A., and Garson, P. J. (Eds.) (2000). *Pheasants. Status Survey and Conservation action Plan* 2000-2004. WPA/BirdLife/SSC Pheasant Group. IUCN, Gland. Switzerland and Cambridge, UK and the World Pheasant Association, Reading, UK . vii + 76pp.

Fyumagwa, R., Gereta, E., Shombe, H., Kideghesho, J. R., Røskaft, E., Keyyu, J., Magige, F., Mfunda, I. M., Mwakatobe, A., Ntalwila, J., Nyahongo, J. W., Runyoro,V., and Kohi, E. M. (2013). Roads as a Threat to the Serengeti Ecosystem. *Conservation Biology* 00 (0): 1 ‑ 4.

Fyumagwa, D. R., Mfunda, I. M., Ntalwila, J., Jackson, C. R., and Roskaft, E. (2017). The Serengeti Ecosystem. In: *Outlook for the Northern Serengeti Road Ecology*. (*Edited by Fyumagwa, R.D., Mfunda, I.M., Ntalwila, J., and Roskaft, E.)*, Fagbokforlaget Kanalveien 51 . pp. 1 – 45.

Gardner, T. A., Caro, T., Fitzherbert, E. B., Banda, T., and Punit, L. (2007). Conservation value of Multiple Areas in East Africa. *Conservation Biology* 21(6): 1516 – 1525.

Girma, Z., Mengesha, G., and Asfaw, T. (2017). Diversity, Relative Abundance and Distribution of Avian Fauna in and Around Wondo Genet Forest, South-central Ethiopia. *Research Journal of Forestry* 11: 1 – 12.

Gottschalk, T. K. (2002). A remote sensing and GIS-based model of avian species habitat and its potential as a part of an environmental monitoring programme, Unpublished Ph.D. Thesis, University of Vechta.

Halmashauri ya Wilaya ya Serengeti (2017). *Mpango wa Matumizi Bora ya Ardhi Kijiji cha Nyamisingisi, kata ya Issenye, Tarafa ya Grumeti, Wilaya Serengeti, Mkoa wa Mara (2016 – 2026).* SENAPA, FZS, GIZ. 1 – 14pp.

Hamilton, C. M,. Martinuzzi, S., Plantinga, A. J., Radeloff, V. C., and Lewis, D. J, et al. (2013). Current and Future Land Use around a Nationwide Protected Area Network. *PLoS ONE* 8(1): e55737. doi:10.1371 /journal. pone.0055737

Hammer, Q., Harper, D. A. T., and Ryan, P. D. (2001). PAST: Paleontological Statistics software package for education and data analysis. *Palaeontologia Electronica* 4 (1): 9.

Hansen, A. J., and Defries, R. (2007). Ecological Mechanisms Linking Protected Areas to Surrounding Lands. *Ecological Applications* 17(4): 974 – 988.

Herlocker, D. (1974). *Woody Vegetation of the Serengeti National Park*. The Caesar Kleberg Research Program in Wildlife Ecology and Department of Range Science, The Texas A and M University System 31 pp.

Hoyo, J. D., Elliot, A., and Sargatal, J. (Eds.) (1994). *Handbook of the birds of the world: New world vultures to Guineafowl*. Barcelona: Lynx Edicions. 95pp.

Homewood, K. M., and Rodger, W. A. (1991). *Maasai land Ecology, Pastoralist Development and Wildlife Conservation in Ngorongoro, Tanzania*. Cambridge University Press, Cambridge, MA, USA. 298pp.

Inah, E. I., Smith, O. F., Onadeko, S. A., and Akinola, O. O. (2007). The effects of bird species on farming activities within Osun grove, Osogbo, Osun State, Nigeria. *Journal of Food, Agriculture and Environment* 5(2): 247 – 250.

Issaka, B.Y., and Yeboha, R. N. (2015). Socio-economic attributes of Guineafowl production in two districts in Northern Ghana. *African Journal of Agricultural Research* 11(14):1209 - 1217.

Jacob, J., Pescatore, T., and Cantor, A. (2011). Keeping Guineafowl Cooperative extension services. University of Kentucky, College of Agriculture. PhD Thesis. University of London, 329 pp.

Jenkins, H. M., Mammides, C., and Kean, A. (2017). Exploring differences in Stakeholders' perceptions of illegal bird trapping in Cyprus. *J. Ethnobiol Ethnomed* 13: 67.

Kideghesho, J. R., Nyahongo, J.W., Shombe N. H., Tarimo, T. C., and Mbije, N. E. (2006). Factors and Ecological Impacts of Wildlife Habitat Destruction in the Serengeti Ecosystem in Northern Tanzania. *AJEAM - RAGEE* 9: 17 - 32.

Kivelia, J. (2005). Cultivation Trends in the Buffer Zones of East African Rangeland Protected Areas. The Case of Ngorongoro and Loliondo in Tanzania. PhD Thesis University of London, 326 pp.

Kumssa, T., and Bekele, A. (2013). Population status, feeding ecology and activity pattern of Helmeted Guineafowl (*Numida meleagris*) in Abijata-Shalla Lakes National Park. *African Journal of Environmental Science and Technology* 7(1): 49 – 55.

Ladan, S. I. (2014). Examining Human Wildlife Conflict in Africa. International Conference on Biological Civil and Environmental Engineering, Dubai (UAE). 1 - 4 pp.

Little. R. M. (2000). Swainson's Spurfowl. Book. In: *Game birds of Southern Africa. (Edited by Little, R. M and Crowe, T.M.),* Struik, Cape Town. pp. 68 –72.

Lotze-Campen, H., Popp, A., Tim, B., Müller, C., Bondeau, A., Rost, S., and Lucht, W. (2010). Scenarios of global bio energy production: The trade-offs between agricultural expansion, intensification and trade. *Journal of Ecological Modelling* 221: 2188 – 2196.

McCabe, J. T. (1997). Risk and uncertainty among the Maasai of the Ngorongoro Conservation Area in Tanzania: a case study in economic change. *Nom. People* 1:55 – 65.

MacCollum, K. R. (2015). Occupancy Analysis and Density Estimation of Kori Bustards (*Ardeotis kori*) and Helmeted Guineafowl (*Numida meleagris*) for Use in Landscape Conservation Planning in the Northern Tuli Game Reserve, Botswana. Dissertations and Theses in Natural Resources. Paper 126. The School of natural Resources, Graduate College at the University of Nebraska. 107 pp.

MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Royle, J. A., and Langtimm, C. A. (2002). Estimating site occupancy rates when detection probabilities are less than one. *Ecology* 83: 2248 - 2255.

MacKenzie, D. I., Nichols, J. D., Hines, J. E., Knutson, M. G., and Franklin, A. B. (2003). Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology* 84:2200 - 2207.

MacKenzie, D. I., Nichols, J. D., Royle, J. A., Pollock, K. H., Bailey, L. L., and Hines, J. E. (Eds.) (2006). *Occupancy Estimation and Modelling*: *Inferring patterns and dynamics of Species Occurrence*. Academic Press, Elsevier 30 Corporate Drive, Suite 400, Burlington, MA 01803, USA. 343 pp.

Mundia, C. N., and Murayama, Y. (2009). Analysis of Land Use/Cover Changes and Animal Population Dynamics in a Wildlife Sanctuary in East

Africa. *Journal of Remote Sensing* 1:952 - 970;doi:10.3390/rs1040952.

Nahashon, S. N., Adefope, N., Amenyenu, A., and Wright, D. (2006). Effect of varying metabolizable energy and crude protein concentrations in diets of pearl gray Guineafowl pullets. 1. Growth performance Poult. *Sci* 85:1847 – 1854.

Nelson, F. (2012). Natural conservationists? Evaluating the impact of pastoralist land use practices on Tanzania's wildlife economy. Research, Policy and Practice. *Journal of Pastoralism* 2:15.

Ngongolo, K. K., and Mtoka, S. (2013). Biodiversity conservation in inhabited area; what can Helmeted Guineafowl *(Numida meleagris:* Numididae*)* domestication offer in socio-economic development and wildlife conservation. *African Journal of Poultry Farming* 1 (1):001 - 007.

Njifort, H. L. (1997). The Biology and Management of Wild Helmeted Guineafowl (*Numida meleagris pallas*) in the Waza Region of North Cameroon. 149 pp.

Njifort, H. L. (1997). The Breeding Performance of Wild Helmeted Guineafowl (*Numida meleagris galeata pallas*) in the Waza national Park, North Cameroon. *Rev. Ecol. (Terre Vie)*, vol. 52: 173 – 186.

Nkwabi, A. K. (2007). Influence of wildfire on the avian community of the Serengeti National Park, Tanzania. MSc. Dissertation. University of Dar es Salaam. 65 pp.

Nyahongo, J. W., Holmern, T., Kaltenborn, B. P., and Røskaft, E. (2009). Spatial and temporal variation in meat and fish consumption among people in the western Serengeti, Tanzania: the importance of migratory herbivores. *Oryx* 43:258 – 266.

Nyamasyo, S. K., and Kihima, B.O. (2014). Changing Land Use Patterns and Their Impacts on Wild Ungulates in Kimana Wetland Ecosystem, Kenya. *International Journal of Biodiversity* 2014:10 Article ID 486727, http://dx.doi.org/10.1155/2014/486727

Nyariki, D. M., Mwang'ombe, A.W., and Thomson, D. M. (2009). Land use Change and Livestock Production Challenges in an Integrated System: The Masai-Mara Ecosystem, Kenya. *J Hum Ecol* 26 (3): 163 - 173.

Nsor, C.A., Acquah, E., Mensah, G., Kusi-Kyei, V., and Boadi, S. (2018). Avian Community Structure as a Function of Season, Habitat Type, and Disturbance, in Mole National Park, Northern Region (Ghana). *International Journal of Ecology 2014:14* Article ID 2045629, https://doi.org/10.1155/2018/2045629

Odukwe, C. N., Ukachukwu, S. N., Amaefule, K. U., and Onunkwo, D. N. (2016). Evaluation of Different Stocking Density on the Performance of Guineafowl Raised in the Humid Tropics. *International Research Journal of Agricultural and Aquatic Science* 3 (1):101 - 103.

Ogutu, J. O., Owen-Smith N., Piepho, H. P,. Kuloba, B., and Edebe, J. (2012). Dynamics of ungulates in relation to climatic and land use changes in an insularized African savanna ecosystem. *Biodiv. Conserv* 21:1033 - 1053.

Perrins, C. (Eds.) (2003). *The Princeton Encyclopedia of Birds*. Princeton University Press, Princeton, N.J., USA. 656pp.

Ramesh, T., and Downs, C. T. (2014). Land use factors determining occurrence of Red-necked Spurfowl (*Pternistis afer*) in the Drakensberg Midlands, Sauth Africa. *Journal of Ornithology* 155 (2):471 – 480.

Ratcliffe, C.S., and Crowe, T.M. (2001). The effects of agriculture and the availability of edge habitat on populations of Helmeted Guineafowl (*Numida meleagris)* and on the diversity and composition of associated bird assemblages in Kwa Zulu-Natal province, South Africa. *Biodiversity and Conservation* 10: 2109 – 2127.

Saina, H. (2005). Guinea fowl *(Numida meleagris)* Production Under small holder Farmer Management in Guruve District, Zimbabwe. MSc Thesis. Department of Animal Science, Faculty of Agriculture, University of Zimbabwe, 99 pp.

Sinclair, A. R. E. (1979). Dynamics of the Serengeti ecosystem: Process and pattern. In: *Serengeti Dynamics of an ecosystem*. *(Edited by A.R.E. Sinclair and M. Norton-Griffiths.)*, Chicago: University of Chicago Press. pp. 1 – 30.

Sinclair, A. R. E. (1995). Serengeti past and present. In: Serengeti II. *(Dynamics, management and conservation of an ecosystem)*. *(Edited by A.R.E. Sinclair and P. Arcese.)*, Chicago: University of Chicago Press. pp. 3 – 30.

Sinclair, I., and Ryan, P. (Eds.) (2003). *Birds of Africa south of the Sahara*. Penguin Random House South Africa; Cape Town, South Africa. 768pp

Sinclair, A. R. E,. Mduma, S. A. R., and Hopcraft, J. G. C. (2007). Long-Term Ecosystem Dynamics in the Serengeti: Lessons for Conservation. *Conservation Biology* 21(3): 580 – 590.

Sinclair, A. R. E. (2008). *Human impacts on ecosystem dynamics*. In: Serengeti III. *(Edited by A. R. E Packer, C., S. Mduma, A. R., and Fryxell, J. M.)*, University of Chicago Press, Chicago. pp. 522.

Sinclair, A. R. E., Grant, H. C. J., Han , O., Mduma, S. A. R., Galvin, K. A., and Sharam, G. J. (2008). Historical and Future Changes to the Serengeti Ecosystem. In: Serengeti III. *Human Impacts on Ecosystem Dynamics. (Edited by Sinclair; A. R. E, Packer, C; Mduma, S. A. R and Fryxell, J. M.)*, University of Chicago Press, Chicago. pp 7 – 18.

Sutherland, W. J. (1996). *Ecological Census Techniques*: *A handbook.* Cambridge University Press 143 pp.

Thomas, L., Buckland, T. S., Burnham, P. K., Anderson, R. D., Laake, J. L., Brochers, D. L., and Strindberg, S. (2002). Distance sampling. In: *Encyclopedia of Environmetrics.* The Global Population Review. United Nations Population Program, NewYork 1: pp 544 – 552.

Thomas, L., Buckland, S. T., Rexstad, E. A., Laake, J. L., Samantha, S., Sharon, L. H., Bishop, Jon R. B., Tiago, A. M., and Burnham, K. P. (2010). Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* 47: 5 – 14.

United Nations Statistics Division. (2005). *Designing Household Survey Samples*: *Practical Guidelines. Social Science Handbook*. Department of Economic and Social Affairs. Series F No. 98. 264pp.

Van Niekerk, J. H. (2010). Social organization of Helmeted Guineafowl (*Numida meleagris*) at the Krugersdorp Game Reserve, South Africa. *Chinese Birds* 1 (1): 22 – 29.

Vikery, J., and Arlettaz, R. (2012). The importance of habitat heterogeneity at multiple scales for birds in European agricultural landscapes. In: *Birds and habitat*: *relationships in changing landscapes*. *(Edited by Fuller, R. J.),* Ecological reviews. Cambridge University press. pp 204.

Yakubu, A., Musa-Azara, I. S., and Haruna, H. S. (2014). Village Guineafowl (*Numida meleagris*) production systems in Nasarawa State, north central Nigeria: flock characteristics, husbandry and productivity. *Livestock Research for Rural Development* 26 (3). Accessed at http://www.lrrd. org/lrrd26/3/yaku26041.htm

Yamane, Taro. (1967). *Statistics, An Introductory Analysis*, 2nd Edition, New York, Harper and Row.

Zimi, A. (2013). Assessment of the potential of agricultural extension delivery on Guineafowl (*Numida Meleagris*) production by small scale farmers in the upper east region of Ghana. MA. University of Ghana, 98 pp.

APPENDICES

Appendix 1: Data Sheet for recording Helmeted Guineafowl/ Habitat types-vegetation characteristics (land cover)/ Land use

C*ensus data sheet No:……Date:……Transect name……Observers:…………*

***Survey Areas**: Part of Serengeti National Park* (SNP)□ / *Grumeti Game Reserve* (GGR)□ / *Ikorongo Game Reserve* (IGR)□ / *Kijereshi Game Reserve* (KGR)□ / *Loliondo Game Controlled area*(LGCA)□ / *Wildlife open* areas (WOA)□ /*Agro-pastoral area*(APA)□ / *Pastoral area* (PA)□

Time	Survey Area	Transect name	Segment code/ (locality ID)	Latitude	Longitude	Common name	Total No.	Adult. Male	Adult. Female	Sub. Adult	Juvenile	Young	Sight. Dist.	Sight. Angle	Season	Habitat/vegetation type	% Cover	% Trees	% Shrubs	% Grass	Domin Veg	Grass height	Cultivated land	Grazing land	Village land
				i) Population characteristics												*ii) Land cover*							*iii) Land use*		

Habitat type: Woodland=Wd, Wooded Grassland=Wg, Bush-land=Bl, Bushed Grassland=Bg, Grassland=Gl

Appendix 2: Baseline questionnaire for assessment of stocks of Helmeted Guinea fowl under domestication in the residential areas located in Serengeti ecosystem

A. RESPONDENT'S GENERAL INFORMATION (Fill the empty cells)

Date:		Education level:	
Age:		Occupation:	
Gender/Sex:		Village Name:	
Tribe:		GPS location:	
District:		Ward:	
Born in the village/Migrant.		Yes: Born □ No: Migrant □	
If migrant since when		Period of stay Years:	
Marital status		Single/Married	

B. DOMESTICATION OF GUINEAFOWL (Tick |√|the appropriate answer(s) in the small box and fill-in the blanks)

1. Place of Guineafowl capture.

i) Protected area □	(National Park………) (Game reserve………) (Game Controlled area………)
ii) Outside protected area □	(Grazing lands……….) (Farms during growing season…………) Farms at pre harvesting…….) (Farms at Post harvesting…….) Buffer areas……..)

2. What is the purpose of capturing the Guineafowls?

i) Is it for Subsistence □	(Meat…………)
ii) Is it for Commercial purposes □	(Selling live Guineafowl……) (Selling eggs…) (Selling feathers……….) If Yes how much does it cost for (1 Adult Male Guineafowl……), (1 Adult Female Guineafowl………), (1 egg……..), (Feathers…………) Where do you sell Guinea fowl/eggs/Feathers……………
iii)Is it for Small scale Guineafowl production □	Family backyard Guineafowl raising project……….) Community Guineafowl raising project……..)
iv) When hired to capture Guinea fowl, do you get paid for that (Yes □/No □)	If Yes how much………………)

What is the purpose of collecting eggs and where?

i) Protected area □	(National Park………) (Game reserve………) (Game Controlled area………)
ii) Outside protected area □	(Grazing lands……….) (Farms during growing season…………) Farms at pre harvesting…….) (Farms at Post harvesting…….) Buffer areas……..)
i) Is it for Domestic use □	(Food …………)

ii) Is it for Traditional use □	(Medicinal value……………)
iii)Is it for small scale Guineafowl production □	Family backyard Guineafowl raising project……….) Community Guineafowl raising project………..)
iv) If you are hired to collect eggs are you being paid to do this (Yes □/No □)	If Yes how much…………………)

4. What is the purpose for collecting feathers?

i) Is it for Domestic use □	(Ornamental value…………)
ii) Is it for Traditional use □	(Medicinal value……………)
iii) If you are hired to collect feathers are you being paid to do this (Yes □/No □)	If Yes how much……………………………)

5. Which season do you capture Guineafowl?

i) Is it in the Breeding season (Yes □/No □)	(If Yes why……………………………)
ii) Is it in the Non breeding season	(If Yes why……………………………)

(Yes □/No □)	
iii) Is it in the Wet season (Yes □/No □)	(If Yes why……………………………)
iii) Is it in the Dry season (Yes □/No □)	(If Yes why……………………………)

6. Which methods are frequently used to capture Guineafowl?

i) Traditional Trap (Yes □/No □)	(If Yes why……………………………)
	Explain type of materials used for making trap…….. (If Yes why…)
	(How does it operates…………… …...)

7. Which age group of Guineafowl is mostly captured near farm areas?

i) Young ……,	ii) Juvenile ……..,	iii) Sub-adult ………..,	iv) Adult…………

8. Do you catch males or females or both males and females?

i) Is it males only (Yes □/No □)	(If Yes why…………………)
ii) Is it females only (Yes □/No □)	(If Yes why……………………)
iii) Is it both males and females only (Yes □/No □)	(If Yes why……………………)

D. FARMING SYSTEM AND RAISING GUINEAFOWLS AS SMALL SCALE BACKYARD PROJECT

11. When did you start this small scale raising backyard Guineafowl project?

i) Is it 3 / 6 / 9/ 12 / months ago (Yes □/No □)	(If Yes why……………………….)
ii) Is it 2 / 4/ 6 / 8 / 10 / years ago (Yes □/No □)	(If Yes why……………………….)
iii) Is it more than 10 years ago (Yes □/No □)	(If Yes why……………………….)

12. How many Guineafowls do you have so far in your project today?

Age	Sex	Total standing stock
1. Adult	Male:	
	Female:	
2. Sub adult	Unidentified (Male/Female):	
3. Juvenile	Unidentified (Male/Female):	
4.Young	Unidentified (Male/Female):	

13. What are the challenges of raising Guineafowl in your project?

i) Is it Diseases (Yes □/No □)	Which type of diseases…………..
ii) Is it Mortality (Yes □/No □)	What is the mortality rate for 6 months….., 12 months………..
iii)Is it theft (Yes □/No □)	What is the loss in terms of total number of individuals…….. Adult male…….Adult female………..Sub adult (unidentified Male and female)………..

14. What is the price for live Guineafowl and eggs produced from your farm?

i)) How much?	Adult male…………, Adult female……….., Sub adult male,…………, Sub adult female…………,
ii) How much?	1 egg ……………,

15. Where do you sell the live Guineafowl and eggs from your farm?

i)) Is it in the village market?	(Yes □/No □)
ii) Is it outside the village market	(Yes □/No □)
ii) Is it here at home?	(Yes □/No □)

THANK YOU FOR YOUR TIME AND ALL RESPONSES