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Galliform Species Composition, Relative Abundance and Ecological Studies of the Helmeted Guineafowl (*Numida meleagris meleagris*) in the Arjo-Didessa River Valley, southwestern Ethiopia

By

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This is to certify that the dissertation presented by Yihenew Aynalem Berhanu, entitled: Galliform Species Composition, Relative Abundance and Ecological Studies of the Helmeted Guineafowl (*Numida meleagris meleagris*) in the Arjo-Didessa River Valley, southwestern Ethiopia, and submitted in Fulfillment of the requirements for the Degree of Doctor of Philosophy in Zoological Sciences (Ecological and Systematic Zoology) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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DEDICATION

This dissertation is dedicated to my late beloved mother, W/ro. Enatalem Mulusew, who suddenly lost her life to save mine, was an unfortunate motherly sacrifice.

May the Almighty God grant eternal peace and rest to her soul.

ABSTRACT

A study was conducted to investigate Galliform species composition, population size, relative abundance and threats, and the feeding and breeding ecology of wild Helmeted Guineafowl (N. meleagris meleagris) in the Arjo-Didessa River Valley, southwestern Ethiopia. Data were collected from January 2018 to December 2020, covering both the dry and wet seasons. The study area was classified into four habitats: farmland, forest, grassland and riverine areas based on vegetation features. Point count methods and line transect surveys were employed in the dense and open habitats, respectively, to study Galliformes. The species composition and relative abundance of Galliformes were estimated by timed species count and encounter rates. The feeding ecology and habitat use of Helmeted Guineafowls were investigated using direct focal flock observation and scan sampling techniques. The breeding ecology of the species was studied by ground surveys and nest monitoring techniques. Egg morphometry parameters were determined using vernier caliper (range: 0–150 mm, accuracy: 0.001 mm) and digital balance (range: 2000 g x 0.1 g). Direct inventories, questionnaire surveys and informal communications were employed to assess public knowledge and threats to Galliformes. Three Galliform bird species namely: Clapperton's Francolin (Pternistis clappertoni), Helmeted Guineafowl (N. m. meleagris) and Stone Partridge (Ptilopachus petrosus) were recorded in the area. Helmeted Guineafowl were abundant (66.83%) while Clapperton's Francolin was common (30.14%) and Stone Partridge was frequent (3.03%). The population size of Galliformes recorded in the study area was 461 *during the dry and* 365 *during the wet season. The population size of Galliformes showed differences across habitats, and it was statistically significant ($F=90.06$, $df=3$, $p<0.05$). Helmeted Guineafowls were omnivorous with diets consisting of mainly insects (52%), and seeds (53%) during the wet and dry seasons, respectively. The active breeding period of Helmeted Guineafowls was from June through September where intensive egg-laying was observed. A total of 17 active nests comprising 207 eggs were located and monitored throughout the study period. Most of the nests were located in grassland (41.18%, n=7), followed by farmland (35.29%, n=6) and forest (23.53%, n=4) habitats. The mean clutch size of the species was 12.18±1.07 (range: 5-19). The eggs were pointed, with a mean egg-shape index value of 60.15±0.81 mm. The mean egg volume was 37.67 mm^3. The breeding performance of Helmeted Guineafowl recorded in the present study was moderate with an overall breeding success of 64.71% (n=17) and egg-hatching rates of 66.67% (n=207). The mean incubation period was 28.50±1.83 days (range: 25-32, n=6). The majority (86.36%, n=286) of residents have an awareness of Guineafowl and Francolin species and perceive the socio-economic attributes of these birds. Galliformes and their habits in the Arjo-Didessa River Valley area are under immense anthropogenic pressure which needs immediate conservation actions. Further research efforts, community-based conservation interventions and threat reduction are, therefore, essential to understand the post-hatching successes. Thorough monitoring of the population trends of Galliformes and protection of their habitats is vital to enhance the breeding success of the species and hence its conservation in the region.*

Keywords: Breeding success, Diet composition, Foraging ecology, Galliform, Habitat use, Helmeted Guineafowl, Population size, Relative abundance, Species composition.

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ABBREVIATIONS USED

CSA	Central Statistics Agency
ENMSA	Ethiopian National Meteorological Service Agency
ESI	Egg Shape Index
EV	Egg Volume
EWCA	Ethiopian Wildlife Conservation Authority
EWNHS	Ethiopian Wildlife and Natural History Society
HBW	Handbook of the Birds of the World
IBA	Important Bird Areas
IUCN	International Union for Conservation of Nature and Natural Resources
LULC	Land-Use Land Cover
m asl	metres above sea level
SPSS	Statistical Package for Social Sciences
USGS	The United States Geological Survey
WPS	World Pheasant Association

1. INTRODUCTION

1.1 Background and justification

Galliformes are a diverse group of heavy-bodied birds commonly referred to as gallinaceous or gamebirds (Keane *et al*., 2005). The group encompasses about 309 recognized species categorized into 70 genera and five families namely the *Phasianidae* (chickens, quails, grouse, peafowls, pheasants, partridges and turkeys), *Numididae* (guineafowls), *Cracidae* (chachalacas, curassows and guans), *Megapodiidae* (brush turkeys, malleefowls, scrubfowls) and *Odontophoridae* (New World quails) (Sibley and Monroe, 1990; Dickinson, 2003; BirdLife International, 2022). Galliformes are mainly terrestrial and sedentary birds. They are gregarious and social groups may range from solitary dwellers to mated pairs and aggregations of large flocks that use dominance hierarchies. Family groups of these birds often join together and establish flocks by the end of the breeding season (Madge *et al*., 2002).

Galliformes are widespread (Payne, 2000; Conroy and Carroll, 2001). They inhabit a wide range of habitats including forests, farmlands, grasslands, bamboo thickets and riparian areas that offer necessary resources including food sources and protective cover (Zhang *et al*., 2015; del Hoyo *et al*., 2020). They are among the most remarkable avian groups and are renowned for their enduring ecological values. They are regarded as useful bioindicators of environmental and habitat quality since they are sensitive to ecological changes and human disturbances (Bhattacharya *et al*., 2009). They play a significant ecological role as seed dispersers, and predators and form prey bases (Santamaria and Franco, 2000; Case *et al*., 2022). They are also perceived for socio-cultural practices, aesthetic values and economic attributes (McGowan, 2002).

Specimens of Galliform species have been captured by naturalists and explorers since the 19th century. They are also stated in ancient literature and artwork. Among Galliformes, different species such as partridges, quails, francolins, guineafowl and turkeys have been widely introduced, domesticated and reared in common farmyard poultry and captive breeding programmes, and usually hunted as gamebirds and used for food due to their prized meat, both for flavour and medicinal values, recreational sports, ornamental collections, plumage and trade (Ash and Gullick, 1989; Fuller and Garson, 2000; Tian *et al*., 2018).

Galliformes are placed in a unique position as a model for scientific study to advance knowledge of avian studies, wildlife research techniques, and threatened species conservation and management strategies owing to their widespread distribution across diverse habitats, ecological attributes and importance to humans, long-standing history of research and management practices and threat status (McGowan and Garson, 2002; McGowan *et al*., 2012; del Hoyo *et al*., 2014). However, they received less research attention and conservation efforts globally.

Despite being diverse and widespread, Galliformes are among the most threatened avian groups (Keane *et al*., 2005; Brickle *et al.*, 2008; McGowan *et al*., 2012). About 26.4% of Galliformes have declined globally, and are on the brink of extinction in the IUCN RedList category (Fuller *et al*., 2000; Tian *et al*., 2018; BirdLife International, 2022). Anthropogenic threats including habitat destruction and loss, excessive hunting, agricultural intensification, livestock encroachment, invasive species, predation, disease and climate change coupled with overexploitation, cultural practices, trade, recreational and sport hunting caused a rapid population decline of Galliformes (McGowan and Garson, 2002; Tian *et al*., 2018; Wang *et al*., 2023). Further, urbanization, mining and infrastructure development also impact the habitats of Galliformes which in turn reduces food availability, shelter and nesting sites exposing them to predation, competition and disturbance (Keane *et al*., 2005; Zhou *et al*., 2014).

Among the different Galliform species, the Helmeted Guineafowl (*Numida meleagris*) is a large (53-58 cm) terrestrial gamebird in the family *Numididae*, order Galliformes (Payne, 1990; Annor *et al*., 2012). It is among the well-known Guineafowl species and the sole member of the genus *Numida.* The species is gregarious and flocks vary in size and composition. It consists of breeding pairs and family groups during the breeding season, and mixed groups during the non-breeding season. The flocks have a complex social structure, with dominant pecking orders. Helmeted Guineafowl use visual and vocal cues to communicate and maintain potential mates.

Helmeted Guineafowl is one of the most widely recognized and predominantly hunted game bird species in Africa, particularly in the sub-Saharan regions (Crowe, 2000; del Hoy*et al*., 2014). In addition, they are raised on a large scale due to their high egg production capacity and tender meat (Crowe, 1978; Ayeni, 1980; Embury, 2001). Between 15 to 20 eggs per clutch per year are recorded in the wild while 40 to 100 eggs per female per year are recorded in improved stocks (Chrappa *et al.*, 1978; Ayeni, 1980; Embury, 2001). Egg production of the species commences at 28-42 weeks in the wild, and 28-32 weeks in captivity (Ayorinde, 1990, 1991), whereas egg-laying may continue for seven or more years. As a result, there is an increased and growing venture into Guineafowl farming as alternative poultry in many African countries. Helmeted Guineafowl is listed as Least Concern (LC) in the IUCN RedList (BirdLife International, 2022). However, studies reported a population decline of the species in parts of its range owing to threats including habitat destruction and loss, persecution, hunting and overexploitation for food consumption (Church and Taylor, 1992; Ratcliffe and Crowe, 2001).

In Ethiopia, Helmeted Guineafowls (*N. meleagris*) are the most abundant and widespread Galliform bird species. It is a resident and a predominantly hunted game bird in the country. Among the six extant Guineafowl species, and nine recognized sub-species of Helmeted Guineafowls, two of them including the *N. m. meleagris* (Linnaeus, 1758) and *N. m. somaliensis* (Neumann, 1899) is confirmed to exist in the country (Urban *et al*., 1986; Ash and Atkins 2009; Redman *et al*. 2009). *Numida m. meleagris* occurs along the western and northern parts of the Great Rift Valley, while *N. m. somaliensis* exists in the northeastern regions and is considered nearly endemic to Ethiopia with offshoots into Somalia (Ash and Atkins, 2009; Redman *et al*., 2009).

Knowledge and up-to-date information about the population status, distribution, habitat use and threats to the species and its native habitats are essential ecological attributes to better understand bird ecology and stem the gap in knowledge about ecology and conservation of species. Understanding the public attitude and perception of local communities towards species could support the development of an effective and sustainable management strategy to mitigate threats and maintain human-wildlife co-existence (Kideghesho *et al*., 2007; Kideghesho, 2008; Dowle and Deane, 2009). It also supports enhancing public knowledge and positively influences their attitude which in turn motivates local communities to engage and create a sense of ownership toward the sustainability of conservation interventions (Kideghesho *et al*., 2007; Reed, 2008; Selebatso *et al*., 2008). Consequently, there is a need to study the population status, trends and habitat use of Galliform birds throughout their ranges in the country. Hence, the present study aims to assess the species composition, abundance, population size, public knowledge and threats to Galliform birds in the Arjo-Didessa River Valley, southwestern Ethiopia, and investigate the feeding ecology and breeding biology of the abundant Galliform bird species, the wild Helmeted Guineafowl (*N. m. meleagris*) in the study area.

1. 2 OBJECTIVES OF THE STUDY

1.2.1 General objective

The present study aims to assess the species composition, abundance, population size and threats to Galliform birds and investigate the feeding and breeding ecology of wild Helmeted Guineafowl (*Numida m. meleagris*, Linnaeus 1758) in the Arjo-Didessa River Valley, southwestern Ethiopia.

1.2.2 Specific objectives

- To assess the species composition of Galliformes
- To assess the relative abundance and flock size of Galliformes
- To examine the diet composition, foraging habitat use and active foraging time of Helmeted Guineafowl.
- To study the breeding biology of Helmeted Guineafowl
- To determine the conservation threats to Galliformes and their habitats in the Arjo-Didessa River Valley area
- To assess public knowledge and attitude towards the conservation significance of Galliform birds in the study area

1.3 STATEMENT OF THE PROBLEM

Galliformes are among the most recognized groups of birds globally. They are diverse and widely distributed. They have been an integral part of the people and are perceived for their ecological, aesthetic values, and socio-cultural and economic attributes. In Ethiopia, Galliformes are among the most widely recognized birds with about 16 species of which three endemic francolin species including the Black-fronted Francolin *(Pternistis atrifrons*), Harwood's Francolin (*Pternistis harwoodi)* and Moorland Francolin (*Scleroptila psilolaema*) exist. These birds are predominantly hunted as gamebirds and valued as a source of food, income, and socio-cultural and medicinal practices practically in rural areas. However, they are among the most threatened groups of birds owing to a wide array of interrelated anthropogenic pressures including habitat destruction and loss, and hunting activities that influence the population of Galliformes at large. Moreover, Galliformes are among the less-studied groups of birds in Ethiopia. They received less research attention and conservation efforts in many parts of the country including the Didessa River Valley. Consequently, there is inadequate quantitative information about the ecology, population status, trends, distribution and behaviours of the species throughout their range in Ethiopia. Hence, there is a pressing need for research and conservation actions to conserve Galliformes and protect their habitats in Ethiopia. Assessment of Galliform population status and conservation threats, therefore, could provide significant ecological information to develop further research and conservation interventions to maintain the species and protect their native habitats in the region.

1.4 SIGNIFICANCES OF THE STUDY

The significance of this study includes:

- Knowledge and ecological information about the abundance, population status estimates, distribution and habitat use of Galliformes. These will have crucial long-term contributions to attain essential insight into the Galliform assemblage, and fill the gap of knowledge about the species.
- Studies on the diet composition, foraging habitat use and active foraging time of Helmeted Guineafowls have crucial contributions to better understanding the feeding ecology and foraging habitat preference of Helmeted Guineafowls.
- Ecological knowledge about the breeding season, survival rates, breeding success estimates, factors influencing nest survival and causes of breeding failure of Helmeted Guineafowl has fundamental contributions to enriching our knowledge of the breeding biology, nesting habitat requirements and reproductive performance of the species.
- Assessment of local communities' attitudes toward Galliformes provides up-to-date information to ascertain conservation gaps and communities' interests and enhance public understanding of the conservation significance of species which in turn has crucial impacts to precisely define actions, and strengthen conservation efforts to develop species conservation and management decisions in the area.

1.5 RESEARCH QUESTIONS

- What type of Galliform bird species exist in the Arjo-Didessa River Valley?
- What are the factors influencing the population status of Galliformes in the area?
- Which Galliform species is abundant in the Arjo-Didessa River Valley?
- What are the food items of Helmeted Guineafowls?
- Which habitats and foraging period is preferred by Helmeted Guineafowl in the area?
- What are the factors that affect the foraging ecology of Helmeted Guineafowls?
- What is the breeding season of Helmeted Guineafowl in the Arjo-Didessa River Valley area?
- Which breeding sites are preferred by Helmeted Guineafowls?
- What are the nesting materials used by Helmeted Guineafowl in the study area?
- What is the clutch size and egg morphometry of Helmeted Guineafowls?
- What are the major factors influencing the breeding success and egg-hatching rates of Helmeted Guineafowls in the study area?
- What are the threats and potential conservation challenges that affect the population of Galliformes and their habitats in the Arjo-Didessa River Valley area?
- What is the attitude of local communities towards the conservation significance of Galliform birds in the study area?

2. LITERATURE REVIEW

2.1 Galliform diversity

Galliformes are diverse and chicken-like birds. They are mainly characterized by medium-to-large bodies, short blunt wings, small heads, short legs, slightly down-curved thick bills, and strong four-toed feet (Gill, 1990). Some species also have distinct, bright, and colourful plumage, and elaborate head and neck ornamentation, including feathers, wattles, and casques. They are widespread and inhabit a wide range of habitats including dense and open forests, grasslands, scrub, and riparian areas (del Hoyo *et al*., 2014; Zhang *et al*., 2015). They are also commonly spotted in barnyards, and a modest commercial market exists in many areas for their meat and eggs.

Galliformes are gregarious and social groups ranging from mated pairs to flocks of various individuals (Madge *et al*., 2002). Each flock is socially complex and may establish dominance hierarchies within their groups with distinct pecking orders retaining their territories. The flock size of Galliformes is dependent on population density. Family groups often aggregate during the non-breeding season (Johnsgard, 1999).

Guineafowls are among the oldest Galliformes and are endemic to Africa (del Hoyo, 2014; Crowe *et al.,* 2006). The first scientifically recognized Guineafowl was believed to have been recognized from the Guinea savanna in West Africa. They are branched off from the core Galliformes between the *Cracidae* and the *Odontophoridae*. It evolved from a francolin-like Asiatic ancestor (Crowe, 1978; Crowe *et al.,* 2006). They are identified by their naked head with bony crowns on top and dark grey feathers with tiny white patches.

Guineafowls are widely distributed across the continent, mainly in Sub-Saharan regions, and inhabit a wide range of habitats including open woodland forest habitats, savanna grasslands, and semi-desert regions (del Hoyo, 2014; Fuller *et al*., 2000). Guineafowls are sexually monomorphic (Madge *et al.*, 2002). Males are usually slightly larger and adults weigh up to 2.5 kg (Aire *et al*., 1979; Nwagu and Alawa, 1995).

Guineafowls are classified into four genera and six extant species that occur in Africa and Arabia (Urban *et al*., 1986) (Table 1):

Table 1. Taxonomy of Guineafowl species.

Subfamily	Image	Genus	Extant species
Agelastinae		*Agelastes* (Bonaparte, 1850)	i. White-breasted Guineafowl (*Agelastes meleagrides*) ii. Black Guineafowl (*Agelastes niger*)
		*Acryllium* (Gray, 1840)	i. Vulturine Guineafowl (*Acryllium vulturinum*)
Numidinae		*Numida* (Linnaeus, 1764)	i. Helmeted Guineafowl (*Numida meleagris*)
		*Guttera* (Wagler, 1832)	i. Plumed Guineafowl (*Guttera plumifera*) ii. Crested Guineafowl (*Guttera pucherani*)

Helmeted Guineafowl (*N. meleagris*) was first described by Linnaeus in 1758 as *Phasianus meleagris*, and later moved to the genus Numida in 1764 (Linnaeus, 1758). The species is easily identified by the upright, conspicuous horny helmet/casque on the top of their naked and brightly coloured plumage on the head and neck, a white featherless face, short and rounded wings, short tail, dull yellow and reddish bony knob, wattle which is often larger on males, and grey-black body plumage spangled with white-spotted dots (Ash and Atkins, 2009; Redman *et al*., 2009). Adults weigh about 1.3 kg and have rounded medium-sized wingspan (150-180 cm).

Helmeted Guineafowls are abundant and widely distributed across different habitats throughout the continent, mainly in sub-Saharan regions. It inhabits a wide range of habitats from arid savannas to moist woodlands (Embury, 2001; Annor *et al*., 2012). The species has large distribution ranges that extend over much of Africa (Fig. 1). Its widespread distribution is partly due to the morphological and physiological adaptation of the species to varying ecological conditions (Chapin, 1932; Crowe, 1978).

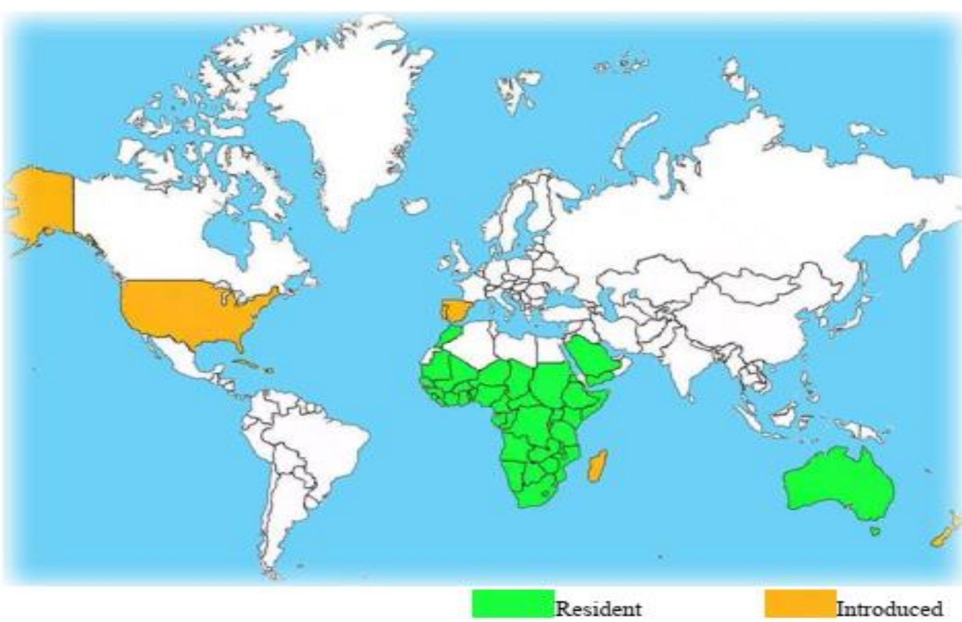

Figure 1. Global distribution ranges of Helmeted Guineafowl.

There are three varieties of Guineafowls including lavender, pearl and white (Nalubama *et al.*, 2014) with nine recognized subspecies (Table 2).

Table 2. Sub-species of Helmeted Guineafowls.

Sub-species	Common name	Distribution	Description
N. m. coronata (Gurney, 1868)	Gurney's Helmeted Guineafowl	Eastern and central South Africa and western Eswatini	Has a large red casque and blue facial skin.
N. m. galeatus (Pallas, 1767)	West African Guineafowl	Western Africa to southern Chad, central Zaire, and northern Angola	Has a small red casque and white facial skin.
N. m. marungensis (Schalow, 1884)	Marungu Helmeted Guineafowl	South Congo Basin to western Angola and Zambia	Has a small red casque and blue facial skin.
N. m. meleagris (Linnaeus, 1758)	Saharan Helmeted Guineafowl	Eastern Chad, Ethiopia, northern Zaire, Senegal, Uganda and northern Kenya	Has a small red casque and white facial skin.
N. m. mitrata (Pallas, 1764)	Tufted Guineafowl	Tanzania, Zambia, Botswana, Somalia, northern South Africa, eastern Eswatini and Mozambique	Has a large black casque and blue facial skin.
N. m. damarensis (Roberts, 1917)	Damara Helmeted Guineafowl	Arid southern Angola, northern Namibia and Botswana north of 26°S	Has a large black casque and white facial skin.

N. m. reichenowi (Grant, 1894)	Reichenow's Helmeted Guineafowl	Kenya and Central Tanzania	Has a small black casque and blue facial skin.
N. m. sabyi (Hartert, 1919)	Moroccan helmeted guineafowl (extinct)	Northwestern Morocco	Had a small red casque and white facial skin.
N. m. somaliensis (Neumann, 1899)	Somali Helmeted Guineafowl	Endemic to Somalia and northeastern Ethiopia	Has a small red casque and white facial skin.

Among these, two sub-species including the *N. m meleagris* (Linnaeus, 1758) and *N. m. somaliensis* (Neumann, 1899), are confirmed to exist in Ethiopia (Urban *et al*., 1986, Redman *et al*., 2009). *N. m. meleagris* occurs in the western and northern parts of the Great Rift Valley, while *N. m. somaliensis* exists in the northeastern regions and is nearly endemic to Ethiopia with offshoots into Somalia (Ash and Atkins, 2009; Redman *et al*., 2009).

In Ethiopia, about 16 species of Galliform birds are categorized under three families, i.e. the *Numididae, Odontophoridae,* and *Phasianidae,* and eight Genera including the *Acryllium, Campocolinus, Coturnix, Numida, Ortygornis, Ptilopachus, Pternistis* and *Scleroptila*. Among these, two of them are Guineafowl species which include the Helmeted Guineafowl (*Numida meleagris),* and Vulturine Guineafowl *(Acryllium vulturinum)* while the remaining are Francolin, Partridge and Quill species (Table 3).

Table 3. Galliform Diversity and Distribution in Ethiopia (Source: Ash and Atkins, 2009; Redman *et al*., 2009; Gedeon *et al*., 2022).

Family	Genus	Species	Subspecies, Status and Distribution
Numididae	*Numida*	Helmeted Guineafowl (*Numida meleagris)*	Two of nine subspecies occur in Ethiopia. a. *N. m. meleagris* (Linnaeus, 1758). Common all-year resident; breeding. Found along the Rift Valley and to the west and north. b. *N. m. somaliensis* (Neumann, 1899). Common all-year resident; breeding. East of Rift Valley. Nearly endemic to Ethiopia, with offshoots into Somalia.
	Acryllium	Vulturine Guineafowl *(Acryllium vulturinum)*	Monotypic. Common all-year resident; breeding. South and southeast (mainly south of 9°N).
Odontophoridae (New World Quails)	*Ptilopachus*	Stone Partridge (*Ptilopachus petrosus)*	*Tetrao petrosus* (*Gmelin,* 1789). Formerly placed in *Phasianidae*. Two of the four subspecies occur in Ethiopia. ● *P. p. petrosus* (Gmelin, 1789). Locally common all-year resident; breeding. Central west and south, patchily distributed. ● *P. p. major* (Neumann, 1908). Uncommon all-year resident; breeding assumed. Few occupied tetrads in the extreme northwest.

Phasianidae	*Ortygornis*	Crested Francolin *(Ortygornis sephaena)*	Two of five subspecies in Ethiopia. ● *O. s. grantii* (Hartlaub, 1866). Resident, and common all year mainly along the Rift Valley and to the east. However, the division line between the two subspecies is unclear (Ash and Atkins, 2009). ● *O. s. spilogaster* (Salvadori, 1888). Common all-year resident; breeding. East and south-east.
	Campocolinus	Coqui Francolin *(Campocolinus coqui)*	One of four subspecies in Ethiopia. *C. c. maharao* (Sclater, 1927). Uncommon all-year resident; breeding. Confined to the central south. Few occupied tetrads.
	Scleroptila	Moorland Francolin (*Scleroptila psilolaema)* *	● *Francolinus psilolaemus* (Gray, 1867). The subspecies *psilolaema* and *elgonensis* are sometimes treated as separate species. One of two subspecies in Ethiopia. ● *S. p. psilolaema* (Gray, 1867). Uncommon all-year resident; breeding. Central Western Highlands (between Blue Nile and Awash) and Arsi/Bale Mountain range (Eastern Highlands). Endemic to Ethiopia.
		Orange River Francolin (*Scleroptila gutturalis)*	● *Perdix gutturalis* (Rüppell, 1835). Located in Halai, Aksum and Temben in Tigray, Ethiopia. Subspecies *archeri* are sometimes included in *lorti*. Three of the six subspecies occur in Ethiopia.

			● *S. g. gutturalis* (Rüppell, 1835). Uncommon all-year resident; breeding assumed. Extreme north (two occupied tetrads). ● *S. g. archeri* (Sclater 1927). Uncommon all-year resident; breeding. Central-south (but collected in Somaliland). ● *S. g. lorti* (Sharpe, 1897). Few occupied tetrads from Bale towards northern Somalia.
	Coturnix	Common Quail *(Coturnix coturnix)*	*Tetrao Coturnix (*Linnaeus, 1758). Two of the five subspecies occur in Ethiopia. ● *C. c. coturnix* (Linnaeus, 1758). Common Palearctic visitor. Records scattered widely throughout Ethiopia, except in the east. ● *C. c. erlangeri* (Zedlitz, 1912). Locally common Afrotropical visitor; breeding. As far north as 10°30´N.
		Harlequin Quail (*Coturnix delegorguei)*	*Tetrao Coturnix* (Linnaeus, 1758). One of three subspecies in Ethiopia. ● *C. d. delegorguei* (Delegorgue, 1847). Generally uncommon all-year resident and Afrotropical visitor (February to August); breeding. Records are scattered widely throughout Ethiopia.

	Pternistis	Chestnut-naped spurfowl *(Pternistis castaneicollis)*	*Francolinus castaneicollis* (Salvadori, 1888). Located in the Lake Chercher, Hararghe, Ethiopia. Formerly divided into different subspecies, as by Ash and Atkins (2009). Monotypic. Common all-year resident; breeding. Mainly western and central Highlands, in the North up to 11°30´. Nearly endemic to Ethiopia, with a small part of the range in Somalia.
		Black-fronted Francolin *(Pternistis atrifrons)* *	*Francolinus atrifrons* (Conover, 1930). Confined in Mega, Boran, Ethiopia. Long treated as a subspecies of *P. castaneicollis*. Monotypic. Uncommon all-year resident; breeding. Confined to a small area in the south (Borana zone), beside one single old record near Moyale in adjacent Kenya. Endemic to Ethiopia.
		Erckel's Francolin (*Pternistis erckelii*)	*Perdix erckelli* (Rüppell, 1835). Monotypic. Common all-year resident; breeding. Located in the Central and northern parts of the Western Highlands. Nearly Endemic to Ethiopia, with a range of parts in Eritrea and Sudan.
		Scaly Francolin (*Pternistis squamatus)*	*Francolinus squamatus* Cassin, 1857. One of three subspecies in Ethiopia. ● *P. s. schuetti* (Cabanis, 1880). Locally common all-year resident; breeding. In the south through the Rift Valley and adjoining areas, and also in the west (south of 10°30´N).

		Clapperton's Francolin (*Pternistis clappertoni*)	*Pternistis clappertoni* (Children and Vigors, 1826). Monotypic. Common all-year resident; breeding. central, western, and north-western Ethiopia.
		Harwood's Francolin (*Pternistis harwoodi)* *	*Pternistis harwoodi* (Blundell and Lovat, 1899). Endemic to Ethiopia. Confined in Aheafeg, Shoa. Monotypic. Locally common all-year resident; breeding. Restricted to a small area in the Western Highlands (valleys of the Blue Nile tributaries).
		Yellow-necked Francolin (*Pternistis leucoscepus)*	*Pternistis leucoscepus* (Gray, 1867). Often treated as monotypic, as by Ash and Atkins 2009. Two subspecies in Ethiopia. ● *P. l. leucoscepus* (Gray, 1867). All-year resident in Northern Ethiopia. ● *P. l. infuscatus* (Cabanis, 1868). Mainly located in the south and east, including Rift Valley. Few occupied tetrads in the extreme west (Gambella area).

**Endemic to Ethiopia.*

The Clapperton's Francolin, also known as Clapperton's Spurfowl (*Pternistis clappertoni*) is a species of bird in the family *Phasianidae*. It is a medium-sized, pale francolin with large patches of red bare skin around the eyes. Heavily marked with black and pale buff on the back, neck, and underparts (del Hoyo *et al*., 2014). Found locally in a variety of savanna habitats and adjacent agricultural areas, often in pairs or small groups. Separated from most other francolins by the red facial skin (Redman *et al*., 2009). It is similar to Harwood's Francolin, but much paler overall, with a mostly black rather than red bill. The call is a rough "kreeya" that is repeated several times. The Stone Partridge (*Ptilopachus petrosus*) is a bird of the New World quail family. This largely brown bird, which commonly holds its tail raised, is found in scrubland and lightly wooded habitats, often near rocks from Kenya and Ethiopia to Gambia (Redman *et al*., 2009; del Hoyo *et al*., 2014).

2.2 Feeding Ecology of Galliformes

The foraging behaviour of birds is an essential ecological attribute that describes the way they exploit resources, interact, and fit and respond to their environment. Foraging guilds show the way species obtain food items and the foraging substrates (Mac Nally, 1994). Ecological studies about food acquisition, diet selection and its composition, foraging strategies, and seasonal shifts of birds are fundamental pursuits to understand the feeding ecology, interactions, ecological functions, and ecosystem services of species (Sutherland, 2004; Sekercioglu, 2012). It also has crucial effects on the survival and reproductive fitness of birds (Davies and Deviche, 2014; Hanspach *et al*., 2015).

Information about the foraging habitat characteristics and foraging habits of the species has an essential role in determining niches. It is associated with crucial life history traits including the breeding and migration of species and hence influences species survival. The foraging behaviour of birds is highly plastic. It is influenced by both intrinsic and extrinsic factors (Lewis *et al*., 2002). Diverse food and feeding strategies, often resolve the use of diverse foraging opportunities in space and time (Gill, 2007). Food limitation is the underlying variation in the life history of birds since seasonal variation in food availability influences the population dynamics and behaviour patterns of avian species (Martin, 1987). Galliformes are omnivores. They feed on a variety of plant and animal matter consisting of seeds, leaves, fruits, shoots, flowers, twigs, tubers, roots, worms, insects and other invertebrates (Johnsgard, 1999; Santamaria and Franco, 2000).

The feeding strategies of Galliformes evolved various morphological and behavioural adaptations to exploit resources optimize their foraging efficiency, and energy intake and reduce predation risk. They have different ways of searching for and accessing food. They often use visual, olfactory and tactile cues to detect, locate and probe for food items. However, structural and behavioural features, habitat types, seasonality, food availability and quality, predation risk, social structure, competition, and human disturbance such as hunting and poaching activities affect the foraging ecology of Galliform birds (Tian *et al*., 2016). As a result, they might deal with shifts in food items across seasons and habitats. For instance, forest-dwelling species such as pheasants and partridges have long tails, strong legs and curved beaks, and claws that enable them to scratch the forest floor for seeds and invertebrates as well as climb and balance on branches in dense vegetation (Hill and Robertson, 1988). Grassland-dwelling species, such as quails and francolins, have short tails that reduce effort and increase running speed. They also have cryptic plumage to camouflage and escape from predators. Some species, such as turkeys, have wattles to manipulate food items. Chachalacas, brush turkeys and pheasants feed communally and benefit from increased vigilance and communication. Helmeted Guineafowls feed mainly on seeds, fruits, tubers, roots, insects, worms, snails, spiders, frogs, lizards, snakes, eggs and small mammals. They often feed in flocks, and sometimes associate with other bird species such as francolins and spurfowls (Hill and Robertson, 1988; Johnsgard, 1999).

2.3 Breeding Biology

Breeding ecology includes a breeding chronology, nesting behaviours, clutch sizes, nest success, and survival rates. Avian reproduction has a series of events including mate formation, courtship, nest site selection, egg-laying, incubation and nestling feeding. Breeding is cyclical and usually seasonal in birds which are essentially allied with favourable environmental conditions (Nussey *et al*., 2005; Parmesan, 2007; Charmantier *et al*., 2008). It varies across species, climatic conditions and geographic locations related to factors including food resource availability, vegetation features and habitat quality and competition (Pigliucci, 2001).

The timing of reproduction is a phenotypically plastic life-history trait. It has crucial effects on the breeding fitness of species, fluctuating environmental conditions, and allows a virtuous overlap between energy requirements and peaks in food accessibility (Nager and van Noordwijk, 1995; Durant *et al*., 2013). Galliformes are sexually dimorphic and exhibit divers mating systems dominantly polygamous (Lack, 1968; Madge *et al.*, 2002). However, species including quail and partridge are monogamous. Galliformes are seasonal breeders whose breeding chronology often relies on local climatic conditions. The large majority of Galliformes are ground-nesting although, some species nest in trees and on cliffs. Galliformes have precocial young (Jones *et al*., 1995; Madge *et al*., 2002).

Galliformes often use acoustic signaling and visual courtship displays such as agonistic interactions, submissive posturing, territoriality and brooding (Stiles and Skutch, 1991; Jones *et al*., 1995). Courtship entails elaborate displays including strutting, tail fluffing, and plumage and behavioural traits like posture movements and sounds as signals to communicate and attract potential mates, territory defence, alarm calling, group formation and individual recognition. Males often display their plumage, vocalizing and aggressive displays like pecking, chasing and fighting to compete for mates and establish and maintain flocking rank which sometimes entails dominant hierarchies with high-ranking males (Johnsgard, 1999; Madge *et al.*, 2002).

2.3.1 Nest site selection

Avian reproduction mainly relies on the selection of appropriate breeding seasons and nesting habitats (Martin, 1995). The habitat use of birds is a hierarchical process where they select specific sites to settle and cover (Hagan and Meehan, 2002). The habitat preference, territory formation, and nest-site selection of birds operate at spatial-temporal scales (Chalfoun and Martin, 2007; Ruth and Skagen, 2017). Nest site selection is a vital component of avian habitat selection (Cody, 1985; Burger, 1985). It influences nesting material selection, predation risks, parasite infection, and nest success in ground-nesting species (Lima, 2009). It also has profound effects on the population status, distribution, survival and breeding performance of species through resource acquisition (Martin *et al.,* 2000; Karakaya and Arikan, 2015; Mansouri *et al*., 2020). However, the nest-site selection of birds is often constrained by various factors including habitat vegetation features, food resource accessibility, parasitism, competition and predation pressure (Martin, 1995; Sosa and de Casenave, 2017).

Climatic factors such as weather conditions, nesting materials, anthropogenic disturbance, breeding experience and landscape effects including habitat loss and fragmentation influence the breeding phenology, nest site selection and breeding performance of birds (Hansell, 2000; Fu *et al*., 2016; Biddle *et al*., 2017; Reidy, 2018). Natural events such as flooding, drought, fire, windstorms, and heavy rains are also among the upsetting factors that determine nest-site selection, breeding success, and population dynamics of species (Hanane, 2015; Ringelman *et al*., 2018). As a result, breeding birds cautiously select suitable breeding seasons and appropriate nesting sites that possibly increase nest concealment to reduce predation risks, minimize breeding failure, and thereby optimize nest survival and ensure better breeding fitness (Hansell, 2000; Mainwaring *et al*., 2014; Jiang *et al*., 2017; Mansouri *et al*., 2020). They also consider the proximity of foraging niches and roosting sites during the selection of nest sites (Morris, 2011; Gibson *et al*., 2016).

The nest site selection of Helmeted Guineafowl is often influenced by breeding habitat features and vegetation structures. The species prefer nesting sites with low vegetation density, height, and cover, but high vegetation diversity and richness that provide essential protective cover to reduce predation risk. The species may reuse the same site to build new nests and also share nest sites with other birds, such as francolins and spurfowls (Little, 2016).

2.3.2 Nest building

Nest-building is a principal phenomenon, and among the most fundamental and widespread behavioural activities in birds (Hansell and Deeming 2002; Deeming and Mainwaring, 2015). It is costly in terms of time and energy (Mainwaring and Hartley, 2013). It encompasses the selection and manipulation of suitable nesting sites and appropriate constituents into a typical structure for incubation and a receptacle for eggs and chicks (Collias and Collias, 1984; Deeming, 2016; Biddle *et al*., 2018).

Nest architecture in birds is species-specific (Hansell, 2000; Biddle *et al*., 2018). They construct nests in a variety of forms which vary in size, structure, composition of contents and functions (Collias and Collias, 1984; Soler*et al*., 1988b; Hansell, 2000; Biddle *et al*., 2018). It is often determined and highly associated with the location and breeding habitat vegetation features, clutch size, body condition, and parental involvement (Walsh *et al*., 2011; Mainwaring *et al*., 2014; Heenan *et al*., 2015).

Nests of birds have been recognized for their multifunctional roles, including incubation and chick-rearing (Biddle *et al*., 2015; Biddle *et al*., 2017), structural support as receptacles for eggs, chicks and breeding parents, insulation and camouflage (Amat *et al*., 2017; Biddle *et al*., 2018). They protect eggs and nestlings against predators, parasites, pathogens, and adverse weather conditions, and hence, have significant effects on the survival and breeding fitness of species (Dubiec *et al*., 2013; Wysocki *et al*., 2015; Soler *et al*., 2017). Nests of birds also have an extended phenotypic value and convey significant information to assess breeding habitats, mate quality and individual fitness, and sexual signalling including mate attraction, pair formation, courtship, competition as well as the evolutionary trends of species (Collias and Collias, 1984; Moreno, 2012; Mainwaring *et al*., 2015; Deeming, 2016).

Birds are selective in using nesting materials. They use a wide variety of nesting constituents, including dry and fresh green plants, animal matter, feathers, and artificial materials (Hansell, 2000; Deeming, 2016; Biddle *et al*., 2018). It often relies on the location of nests, vegetation features, and assemblage of available materials in the surrounding breeding environment (Mainwaring *et al*., 2014). Nesting materials selection and composition have decisive effects on nest quality. It consequently influences predation, nest survival and breeding success of species by enhancing nest concealment (Deeming and Mainwaring, 2015; Mulder *et al*., 2021). Helmeted Guineafowls build nests, which are usually shallow scraps scantily lined with soft grass, dry leaves and feathers. However, no detailed information is available on the nesting ecology and nesting materials of the species across its ranges in the region.

2.3.3 Clutch size and egg morphometry

Clutch size and incubation rhythms are crucial life-history traits in avian reproduction (Perrins and McCleery, 1989; Wiebe and Martin, 2000). It has critical effects on avian reproductive fitness (Winkler and Walters, 1983; Stearns, 1992). The clutch size of birds markedly varies across taxonomic groups and species. It depends on mating parents during the three distinct phases including egg production, incubation and brood-rearing (Møller*et al*., 2014). Clutch size is often constrained by several factors including environmental gradients, weather conditions and breeding season, which depends on food abundance and diet composition. It is also affected by the age, health and body condition, breeding experiences, nest predation and behaviours of breeding parents (Webb *et al*., 2012; Brussee *et al*., 2016).

Nesting habitat features vary in savanna species with larger clutches than other species. The clutch size of birds and its trends are also associated with latitude, as species in the southern have smaller clutches compared to equivalent northern regions (Lack and Moreau, 1965; Ricklefs, 1980; Perrins and McCleery, 1989). The difference in the clutch size also represents variations in the reproductive strategies of species (Martin *et al*., 2000; Christians, 2002). Most members of the order Galliformes are indeterminate layers which makes them exploited for egg production. The clutch size of precocial birds including Galliformes is not predetermined (Erikstad *et al*., 1993; Milonoff, 1993; Milonoff and Paananen, 1993; Møller *et al*., 2014). It is ultimately determined at the egg-laying stage by the ability of the parents to rear young (Beˆty *et al*., 2001). As a result, precocial birds have larger clutches (Winkler and Walters, 1983). However, there is great variation in the clutch size among Galliform species.

Helmeted Guineafowls have a high egg production capacity that produces between 15 and 20 eggs per clutch per year in the wild, and 40 to 100 eggs per female per year in improved stocks (Crowe, 1978; Ayeni, 1980; Embury, 2001). However, the clutch size of the species varies. Age, body condition, breeding experiences and environmental factors including food source availability and predation pressure are the main constraints that influence the clutch size of the species.

The eggs of Galliformes vary in size and shape across families and species. It is often influenced by ontogenetic and environmental features, age, body size, breeding season, breeding experience and clutch size (Christians, 2002). The external (egg weight, egg length, egg width, egg shape index, shell weight and shell thickness), and internal (albumen height, albumen weight, yolk weight) egg morphometry features are crucial egg quality traits of bird's egg. It has critical long-term effects on the breeding success, offspring survival and nestling growth of species (Pinowska *et al*., 2004; Rita *et al*., 2005; Asci and Durmus, 2015). However, factors governing egg size variation are less clear among different birds including Guineafowls (Williams, 1994). Knowledge of the clutch size of birds, therefore, helps to understand the life-history traits and reproductive strategies of species (Conway and Martin, 2000).

2.3.4 Breeding success

Breeding performance is a critical feature of avian reproduction. Nest survival has a substantial effect on the breeding success of species (Martin, 1995). It influences the reproductive outputs and individuals' fitness and has direct consequences on population dynamics (Johnson *et al*., 2007; Cresswell, 2011). Breeding success usually reports the percentage of nest (nest success) and egg (egg success) successful in producing young or offspring that leave the nest. The breeding success of birds is often associated with nutritional, vegetation features, disturbance and predation risk (Lack, 1968; Gilg *et al*., 2006; Smith and Wilson, 2010).

The breeding and the subsequent growth of birds depend on the acquisition of high-protein food (Jones and Ward, 1976; Woodall, 1994). Age, sex ratio, nutrition and predation often influence the breeding performance of birds (Monaghan *et al*., 1992; Greenwood *et al*., 1995; Martin, 1995). Factors including age and breeding experience, body condition, predation pressure and nest defence behaviours of breeding parents also influence the nest survival and breeding success of birds (Beˆty *et al*., 2001; Beckmann and McDonald, 2016; Brussee *et al*., 2016; Burr *et al*., 2017). Climatic factors and environmental features such as weather conditions also influence breeding success in birds (Telleria and Diaz, 1995).

Nest habitat vegetation, nest constancy, proximity to habitat edges, breeding season and human disturbance impact avian breeding performance (Smith and Wilson, 2010; Webb *et al*., 2012; Borgmann and Conway, 2015). Older nests may have greater breeding success rates than nests in the early stages since nest age influences nest survival probabilities related to incubating parents that may leave their nests fewer times and leave fewer cues to predators about nest locations (Dinsmore *et al*., 2002; Zhao *et al*., 2020).

Factors including food availability, habitat quality, predation pressure, weather conditions, predation risk, human disturbance and hunting influence the survival and breeding performance of Helmeted Guineafowl. Galliformes face high predation risk from various predators such as raptors, mammals and reptiles (Jones *et al*., 1995; Johnsgard, 1999). It is also reported that mammals (mongooses, civets, jackals, genets, wildcats, dogs, rodents), raptors including eagles, hawks, falcons, owls, kites, and reptiles such as snakes and monitor lizards are the main predators of Helmeted Guineafowls. However, they have developed numerous anti-predator strategies including camouflage, vigilance and escape to reduce their vulnerability to predators and increase their survival. Estimating the breeding success of precocial birds is often difficult since chicks leave the nest immediately after hatching.

2.4 Conservation Status and Threats to Galliformes

Galliformes are diverse and widespread. However, they are among the most threatened birds due to their essential ecological, socio-cultural and economic attributes (Keane *et al*., 2005; Brickle *et al*., 2008; Ramesh and McGowan, 2009; McGowan *et al*., 2012). According to the IUCN RedList, over 26.4% of species are classified as threatened and on the verge of extinction (BirdLife International, 2022). In comparison to about 13% of all threatened birds, the number is high (McGowan, 2002; Fuller *et al*., 2000; Tian *et al*., 2018; BirdLife International, 2022). Different Galliform species have declined globally (Fuller and Garson, 2000; Tian *et al*., 2018). As a result, around 57 species of Galliform birds are globally threatened and 17 are critically endangered (Fig. 2). The Double-banded Argus (*Argusianus bipunctatus*) and New Zealand Quail (*Coturnix novaezelandiae*) are extinct. Moreover, the Alagoas Curassow (*Mitu mitu*) has been extinct in the wild since 1987 (BirdLife International, 2022). Moreover, about 21 of the 50 species of the *Phasianidae* are on the verge of extinction (McGowan and Garson, 2002; Zhou *et al*., 2014; Tian *et al*., 2018).

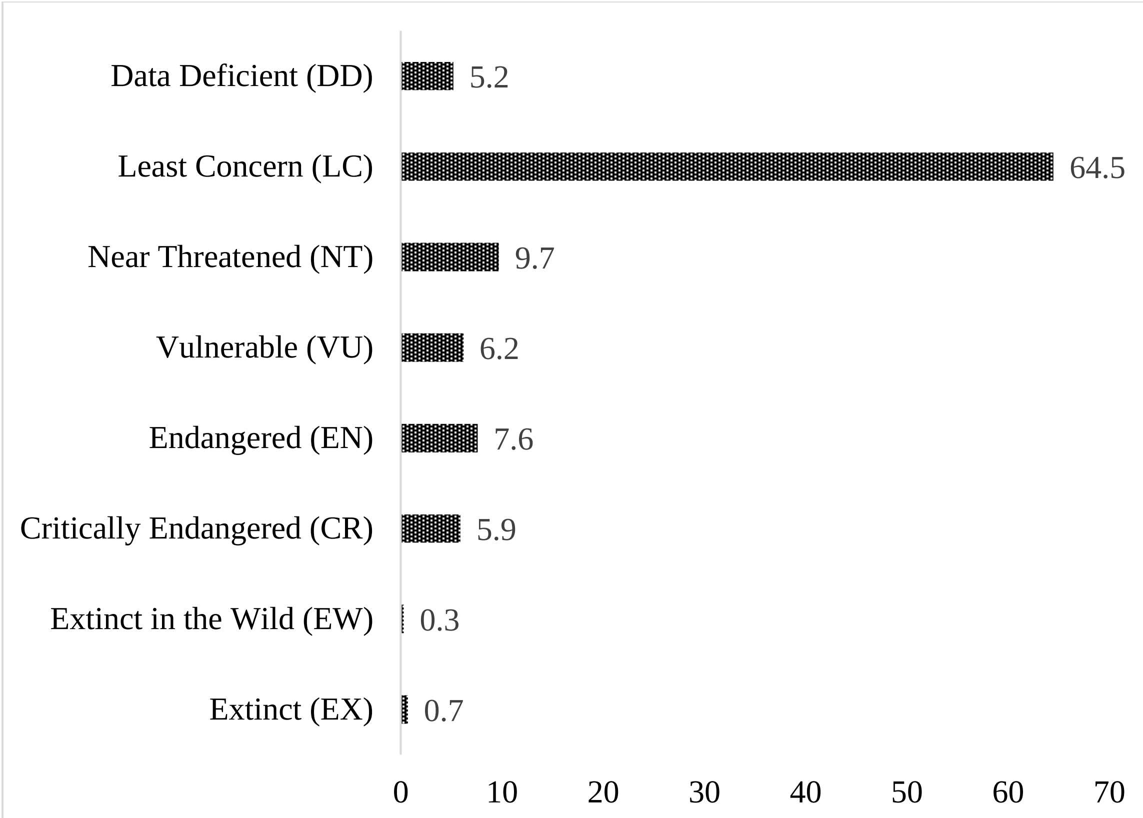

Figure 2. Conservation status of Galliform birds (Source: IUCN, 2018, BirdLife International, 2022).

Galliformes are threatened owing to excessive hunting and overexploitation for food (Fuller and Garson, 2000; Ramesh, 2003; Garson and Zheng, 2006; Tian *et al*., 2018), recreational and sport hunting, plumage, trade and cultural practices (McGowan and Garson, 2002; Ramesh and McGowan, 2009; Ali *et al*., 2015), and habitat destruction and loss (Zhou*et al*., 2014; Tian *et al*., 2018), human disturbance (Storch, 2013). Poaching and overhunting hugely impact habitat-specific and range-restricted Galliformes, leading to population decline and extinction of species. Human population growth, settlement expansion, agricultural intensification, urbanization, logging, livestock encroachment, and depredation by exotic species are the main causes of population decline (Garson and

Zheng, 2006; Zhou *et al*., 2014; Tian *et al*., 2018). Predation, habitat alteration by invasive species and disease also impact the abundance and distribution of Galliformes by altering food resources and breeding seasons (Keane *et al*., 2005; Garson and Zheng, 2006; Khalil *et al*., 2015; Tian *et al*., 2018).

Galliformes play important ecological roles. They perceived socio-cultural and economic interest in humans as domesticated animals or game birds (McGowan *et al*., 1998; Ramesh, 2003). Different species of Galliformes including pheasants and guineafowl have a long history of domestication across the globe. They have been widely reared and persistently hunted mainly for human consumption as sources of food due to their prized meat, distinctive flavour, sources of protein and medicinal values, source of income, recreational hunting, entertainment, trade and cultural practices as well as ornamental collection (Ash, 1978; Ash and Gullick, 1989; Ayorinde, 1991; Viljoen, 2005; Persons *et al*., 2016). Other species such as cracids, are mainly frugivorous and act as keystone species that influence germination and forest community structure. They also have vital ecotourism contributions (Santamaria and Franco, 2000; Peters *et al*., 2016). However, some Galliform species are considered pests and may cause agricultural crop damage (Jones *et al*., 1995). As a result, humans have a significant influence on the Galliformes population and take immediate measures to conserve and manage them sustainably.

Climate change and drought cause a devastating effect on the population of Galliformes. It also significantly impacts the populations of francolins through its effect on habitat destruction. Crops, hunting and trapping, logging and wood harvesting immensely contribute to the population decline of several species (Ayanda and Ayeni, 1980).

Residential and commercial development, energy production and mining, transportation and service corridors, biological resource use, natural system modifications, invasive species and climate change are the main threats to Galliformes (IUCN, 2016). Moreover, they are usually sensitive to habitat destruction, degradation and fragmentation since many Galliformes are mainly ground-feeding and nesting (Garson and Zheng, 2006; Zhou *et al*., 2014).

3. MATERIALS AND METHODS

3.1 Study area

The study was conducted in the Arjo-Didessa River Valley, southwestern Ethiopia. It is located in the Bedelle Zuriya and Jimma-Arjo districts along the East Wollega and Buno Bedelle Administrative Zones of the Oromia Regional State, Ethiopia, at a distance of 395 km from Addis Ababa at 36°39'60.0" E and 8°40'00.0" N (Fig. 3). The river basin is part of the lowland plains of the Sudan-Guinea savannah biome and occupies parts of the western regions of the country. The Didessa River basin encompasses four administrative zones of the Oromia Regional State, including Eastern and Western Wollega, Jimma, Illu Aba Bora, Buno Bedelle, and Kemash from the Benishangul Gumuz Regional State, Ethiopia. Its catchment area is estimated to cover an area of 27,000 km^2 (Muluneh and Mamo, 2014).

The Jima-Arjo district is bordered by Nunu Qumba in the east, Dabo Hana in the west, Leka Dulecha in the north, and Bedelle in the southeast. It covers an estimated area of 741.41 km^2. It is considered highland, except for the Didessa River valley sub-basin. The total population of the district was 86,329, of whom 42,093 were men and 44,236 were women households (CSA, 2007). Bedelle-Zuria district is bounded by the Chora district in the southwest, Dabo Hanna in the north and Gachi District in the east. The district covers an estimated area of 745.0 km^2, and the population size of the district is about 77,687 consisting of 38,654 male, and 39,033 female households (CSA, 2007). The administrative kebeles including Ambelta, Bekelcha Beftu, Chefe Jalela, Haro Tatesa and Kolosere from Bedelle Zuria district, and Bedasa Dedesa, Bedasa Dedesa Sefera Tabia, Gudeya, Luguma Sefera Tabia and Meta from Jimma-Arjo districts were the specific areas encompassed to select participants and assess the public attitude and awareness towards the conservation significance of these birds in the study area. The topography of the study area is characterized as terrain with features consisting of plateau, slope and valley consisting of the Weyna Dega and Kola agroecology. The habitat features of Bedelle Zuria district consist of agricultural farmlands *(*4,719.57 hectares), grazing land (9,848.45 hectares), forest (10,682.7 hectares) and other (724 hectares) land-uses categorized under Dega (16%), Woina-Dega (64%) and Kola (20%) climatic condition. The study site covers an estimated area of 1,486 km^2 with an altitude elevation ranging from 1280 and 2524 m asl.

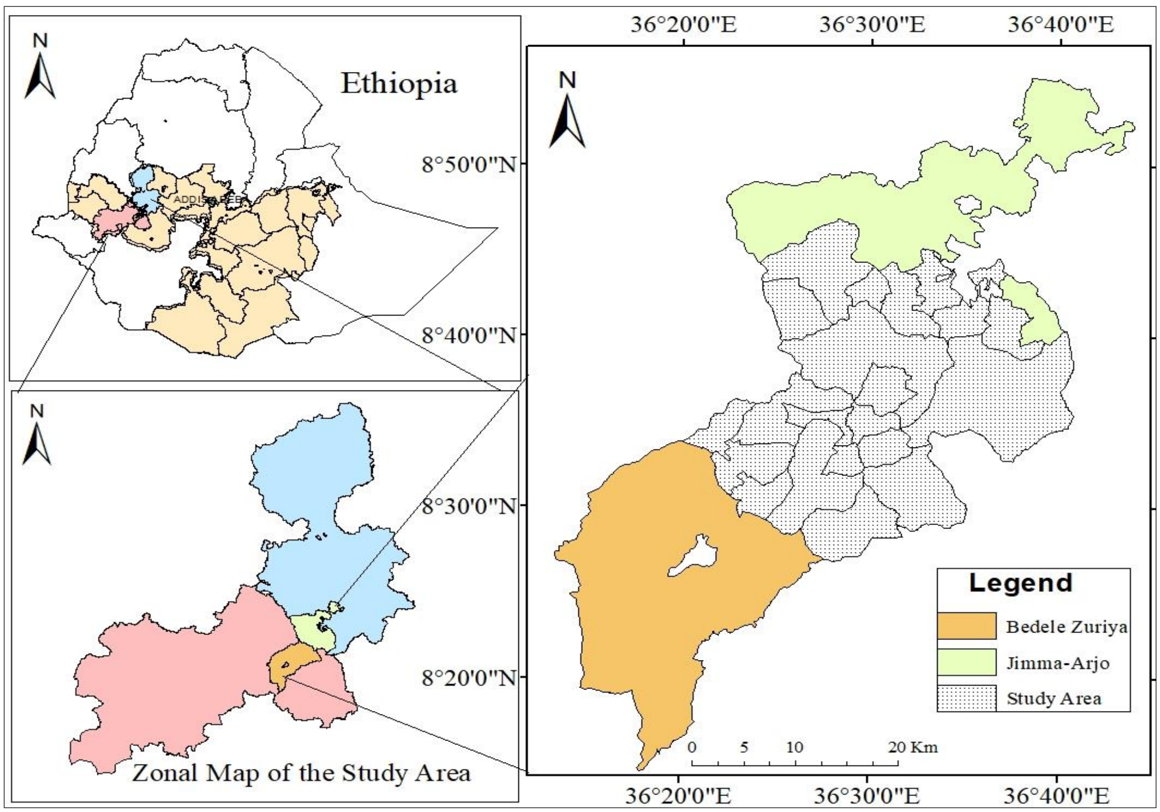

Figure 3. Map of the Arjo-Didessa River Valley area in the southwestern Ethiopia.

The annual maximum and minimum temperature range between 16.8 and 33.5 ˚C (Fig. 4). The area is characterized by a humid tropical climate with a mean annual rainfall of 1,905.07 mm (range: 41.35 – 3,768.80), during which the peak rainy season spans from May to October (Fig. 4).

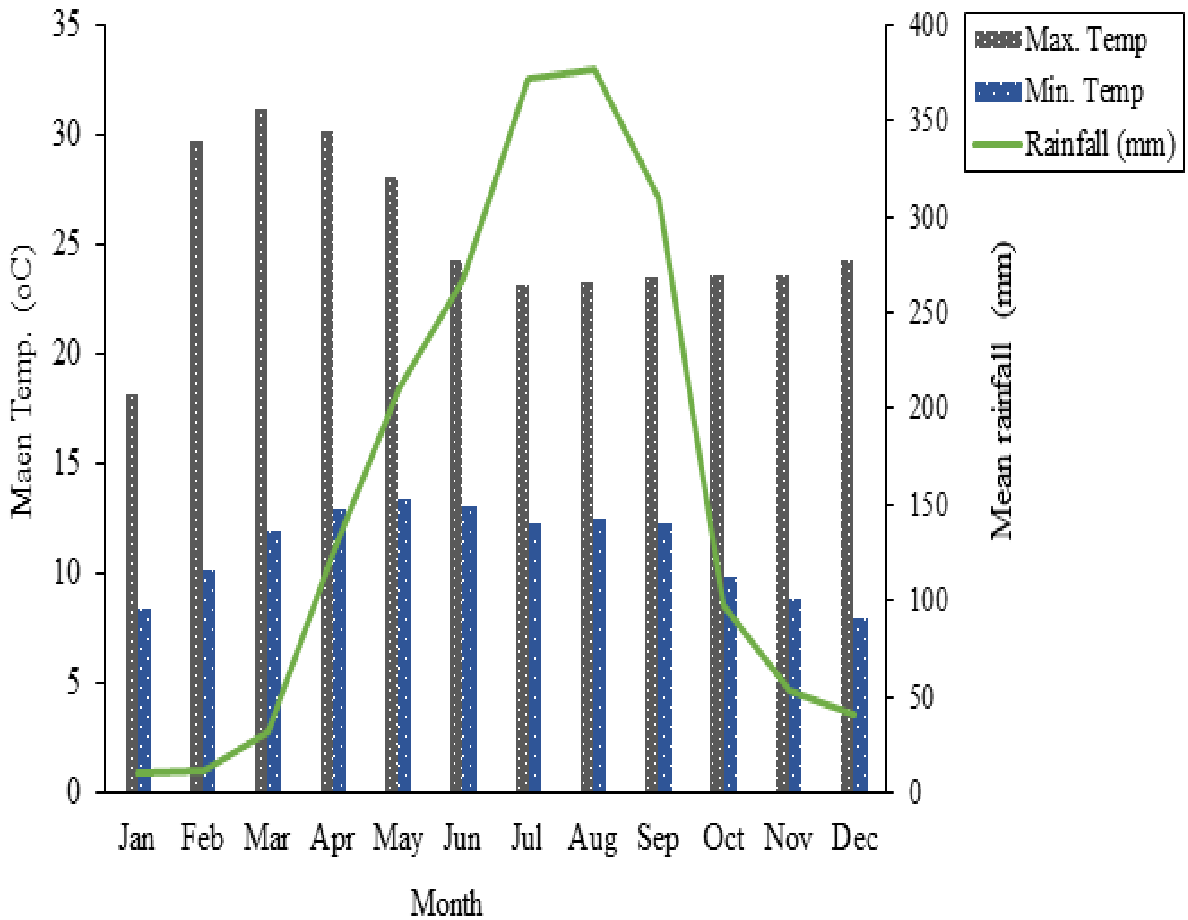

Figure 4. Temperature and rainfall of the Arjo-Didessa River Valley (2011 - 2020).

The habitat features of the study area consisted of woodland forest, savannah grassland, agricultural farmlands, settlement areas, riverine areas, rangelands and fragmented mountains interspersed with high steep-sided gorges and precipices. The land-use of the area comprises croplands (56%), forest (19.6%), shrubland (12.4%), savannah grassland (6%), settlement (5%) and riverine areas (0.2%) (Feyissa, 2009; Chimdessa *et al*., 2018). Agriculture represents the main practice in the area in which more than 88% of the surrounding communities depend on mixed (crop production and livestock rearing) farming systems. Maize, sorghum, coffee and teff are the main cash crops of the area.

The area is rich in biodiversity resources (flora and fauna), and known to support a diversity of wildlife species including mammals, birds, reptiles and amphibians, and other diverse animal species such as buffalo (*Syncerus caffer*), common warthog (*Phacochoerus africanus*), bushpig (*Potamocherus larvatus*) and giant forest hog (*Hylochoerus meinertzhageni*). Bamboo, *Acacia*, *Gravilia robista*, *Cordia africana*, *Croton macrostachyus*, and *Ficus* are the dominant plant species in the area. However, settlement expansion and agricultural intensification in the area increased the continuous conversion of forests and grassland habitats to farmlands.

3.2 Preliminary survey

A preliminary survey was carried out from November to December 2017 to assess the habitat features of the study areas. Indirect evidence such as moulted feathers and calls were used to confirm the presence of Galliform birds in the area (Plate 1). Information about the occurrence of these birds was also solicited through interviews and formal communications with local inhabitants.


Plate 1. Galliformes surveys and species identification, feather of Helmeted Guineafowls (©Yihenew A., 2017).

3.3 Materials

Field materials and equipment including pairs of binoculars (Vortex-Optics Diamondback-8x42), handheld GPS navigator (Garmin eTrex-30), digital camera recorder (Canon Rebel T6), vernier caliper (range: 0–150 mm, and 0.001mm, accuracy), digital Scale (range: 2,000 x 0.1 g), forceps, hand lens, disposable gloves, aerial insect net, insect spread board, insect pins, insect-killing jar, 70% alcohol, stopwatch, bird identification guide books (Ash and Atkins, 2009; Redman *et al*., 2009) were used throughout the study period to aid data field collection, counting and further species identifications. Field data sheets were used throughout the study period to record the necessary ecological data during the fieldwork.

3.4 Data collection

3.4.1 Species composition, abundance and population size of Galliformes

After the occurrence of Galliformes was confirmed, field inventory and data collection were carried out from January 2018 to December 2020, during both the dry (October to April) and wet (June to August) seasons. The study area was classified into four habitat categories: farmland, forest, grassland, and riverine areas based on vegetation features to collect Galliform data from these habitats. A total of 74 point count routes were located and used in the forest habitats. The distance between count stations was between 50 and 250 m radius based on the vegetation features and accessibility of counting stations. Point-count surveys were employed by moving across a pre-determined counting route to standardized data collection following Bibby *et al*. (2000) and Sutherland (2004). About 68 line transects ranging between 2 to 5 km in length were established and employed considering the habitat features of the areas, following Bibby *et al*. (2000) and Sutherland (2004), to estimate the species composition, relative abundance and population size of Galliformes. The distance spacing between the transects was in the range between 125 to

500 m. It was carried out at a walking speed rate of 1.5 km/hr in bushy areas and 2.5 km/hr in open habitats. The sighting distances were set at 50 to 100 m in the dense forest and riverine areas and extended up to 250 m in the open farmland and grassland habitats. Field surveys and data collection were carried out once per month for 14 to 22 days. Four individuals were involved in the fieldwork and data collection activities.

Galliform survey and field data collection were carried out twice a day during the morning from 06:00-10:00 am. and afternoon hours from 14:00-18:00 pm. when most birds were prominently active (Bibby, 2000). A waiting period of three to five minutes before counting was applied to minimize disturbance. A pair of binoculars and a digital camera recorder were used to aid in counting and further identification. For each species of Galliformes encountered, the number of individuals and their habitat features were recorded to determine the species abundance and species composition across habitats. Galliform species identification and taxonomic classifications were executed based on bird guide books including Ash and Atkins (2009), and Redman *et al.* (2009). Morphometric parameters including plumage pattern, body size and shape and calls were used to aid the species identification. The maximum number of individuals per survey was considered as the population size of the species in the particular counting routes to avoid bias in population estimation.

3.4.2 Foraging ecology of Helmeted Guineafowl

The foraging ecology and habitat use of Helmeted Guineafowl was studied by direct observation methods including focal flock observation and scan sampling techniques when birds were actively searching, scratching and picking food items following Morrison *et al*.

(1988) and Sutherland *et al*. (2004). Randomly selected individuals were cautiously observed with the aid of Binoculars for about five to 10 minutes by using a stopwatch and by walking along all the study sites, following Bhatt and Kumar (2001) to investigate the food items, foraging habitat use and active foraging time of the species following Sutherland *et al*. (2004). The distance of observation varies from 10 to 30 m depending on the topography of habitat. Furthermore, the foraging times were categorized into three-time slots, including morning (06:00–10:00 a.m.), mid-day (11:00 a.m.–2:00 p.m.) and afternoon (3:00–7:00 p.m.) hours to determine the active foraging time of the species. To determine the invertebrate food items consumed, a 2 x 2 m radius plot was established in the area where the species was consistently recorded foraging following Gibb and Oseto (2019) (Plate 2).

Plate 2. Invertebrate sample collection in the Arjo-Didessa River Valley (© Ambessaye T., 2019).

3.4.3 Breeding biology of Helmeted Guineafowl

The breeding ecology of Helmeted Guineafowl was studied by using active nest monitoring techniques. Breeding data were collected during the 2018 and 2019 breeding periods of the species. Nest searches were carried out through intensive ground surveys using possible behavioural cues such as following breeding pairs exhibited nesting attempts, carrying nesting materials to the nest sites and alarming calls, following Klett *et al*. (1986), DeSante and Geupel (1987), and Winter *et al*. (2003), and systematic transect plots aided with binoculars. Information about the breeding areas and nest locations was also solicited from public inquiries associated with habitat features of previous breeding sites following Martin (1995).

After nests were located, the sites of active nets were photographed and marked with a handheld GPS navigator. It was also marked with removable reflective tags, placed ~5 m from the nest, and natural markers such as big stones and tall trees to aid relocation during monitoring and egg measurements. Specific numbers were allotted for each active nest for further monitoring, egg measurement activities and to assess the location and breeding habitat types. Breeding habitat vegetation characteristics, nest structure and building materials of each nest were recorded to determine the breeding habitat features and nest-site selection of the species. Nesting materials were recorded immediately after the hatching or predation of eggs by dismantling and tallying the contents of each nests (Appendice 3.3). The contents and proportion of each nesting material were determined by following Tomás *et al*. (2013) and Biddle *et al*. (2018). The types of nesting materials were identified by using Hedberg and Edwards (1989) and Hedberg *et al.* (2003).

The clutch size of the Helmeted Guineafowl was determined by counting the number of eggs located in the active nests of the species. Egg-laying date of active nests found with eggs was defined via back dating assuming one egg is laid per day (Halupka *et al*., 2020).

The external egg morphometric parameters including egg length/mm, and egg breadth/mm were measured by a portable vernier caliper (range: 0–150 mm, and 0.001 mm, accuracy) (Plate 3). And, a digital scale (range: 2000 × 0.1 g) was also used to measure the egg weight of the species with maximum caution to the contents of eggs following Hoyt (1979).

Plate 3. Egg morphometric measurements of Helmeted Guineafowl in the Arjo-Didessa River Valley (©Yihenew Aynalem, 2019).

Active nests monitoring was carried out continuously between 2 to 3 days intervals until egg laying was completed or lost due to various constraints and then monitored every 3 to 5 days until hatching or egg loss due to predation/abandonment following Hazler (2004). Nest checks were made from 5 to 10 m distance with the aid of binoculars and a digital camera recorder by taking maximum caution when approaching them from different directions on consecutive visits to minimize observer-induced interference. Eggs were placed in the same location and direction after recording to minimize potential egg rejection.

Standard protocols following Martin and Geupel (2016) were pursued during nest monitoring and egg measurement activities to minimize and avert probable observer-induced interference and nest predation. For instance, gloves were used consistently throughout the examination and handling of eggs. During the nest monitoring activities, changes in clutch size of nests, nest status, hatching attempts and presence of unhatched eggs along with possible evidence of nest predation and disturbance pressure were assessed and recorded to estimate nest survival and determine the possible causes of breeding failure of the species. Individual eggs from each nest were measured and recorded on separate data sheets to avoid measurement bias (Appendice 3.2).

The egg shape index (ESI) and egg volume (EV) of Helmeted Guineafowl were analyzed using freshly laid eggs according to Hoyt (1979) and Narushin and Romanov (2002), as follows:

$$ESI = B/L*100 \qquad (1)$$

Where,

ESE = Egg Shape Index, L= length of eggs, B = width of eggs.

Egg volume was determined from the egg's length and width measurements following Hoyt (1979), as follows:

$$V = 0.51*LB^2 \qquad (2)$$

Where, V = egg volume,

L = egg length,

B = egg width, and 0.51 = scaling constant which was calculated by Hoyt (1979) where the eggs of most birds have values very close to this average.

The breeding success of Helmeted Guineafowl was estimated as the percentage of successful nests per number of nests located with eggs that produce young and leave the nest, following Mayfield (1975), Johnson (1979) and Streby *et al*. (2014). The egg-hatching success rate of the species was also determined by the percentage proportion of hatched eggs by the number of eggs before hatching in the active nests of the species following Koenig (1982) and Skutch (1985). Six active nests of Helmeted Guineafowl from the 17 nests located were randomly selected to assess the incubation periods of the species. The predation risk and possible causes of breeding failure of the species were assessed and determined through direct inventories of possible clues and signs of predation attempts and evidence such as the presence of damaged eggshell fragments and body part remains surrounding the nesting sites and abandoned nests, following Hazler (2004).

3.4.4 Public Knowledge, Attitude and Threats to Galliformes

Direct inventories, questionnaire-based surveys (Appendice 1), focus group discussions, structured key informant interviews and informal communications were employed to assess public knowledge, attitudes of local communities and possible conservation threats to Galliformes. Study participants were selected from eight adjacent Kebeles, i.e. the smallest administrative unit in Ethiopia, through systematic random and purposive sampling techniques following Yamane (1967) (Equation 3).

$$n = \frac{N}{1 + N(e)^2} = \frac{5,820}{1 + 5,820(0.08)^2} = 152 \qquad (3)$$

Where, n = sample size, N = population size, e = precession level (±8%), at a 95% confidence interval and $p < 0.05$.

In addition, 134 participants were selected using a purposive sampling technique. Hence, a total of 286 participants were involved in the study. Furthermore, the key informant interviewees were selected from the adjacent villages based on their proximity to the escarpment areas through purposive sampling methods targeting community elders, farmer households and agriculture and forest management officers based on management experience, hunting practices and participation in farming activities. Participants who had prior knowledge about these groups of birds were principally included to assess the attitudes of local communities and whether they perceived these birds as negative, positive or neutral thoughts. Informal communications were also conducted to solicit information about Galliformes' hunting and egg collection practices in the area.

3.5 Data analyses

Data analyses were carried out using descriptive statistics in an Excel spreadsheet (version 19) and SPSS software (version 26.0). Data sets were tested for normality using the Shapiro-Wilk test, which is highly recommended due to its higher power in the measure of the value of test normality (Ghasemi and Zahediasl, 2012). Data sets which comprehend the standard normal distribution were subjected to parametric tests. Descriptive statistics were used to determine the population size and threats to Galliformes. The relative abundance of Galliform species was determined by using encounter rates that give crude ordinal scales of abundance following Bibby *et al.* (1998). The encounter rate for each species was calculated by dividing the number of Galliformes recorded by 100 field hours, as follows:

$$\text{Encounter rate} = \frac{\text{Total number of individual birds observed}}{\text{Period of observation in hours}} \times 100 \qquad (4)$$

The encounter rate values were used to categorize each species under five abundance score categories, i.e. <0.1 for rare, 0.1-2.0 uncommon, 2.1-10.0 frequent, 10.1-40.0 common, and > 40 for abundant species following Bibby *et al.* (2000) (Table 4).

Table 4. Encounter rates and ordinal scale of species abundance.

Abundance Category	Abundance score	Ordinal scale
<0.1	1	Rare
0.1–2.0	2	Uncommon
2.1–10.0	3	Frequent
10.1–40.0	4	Common
>40.0	5	Abundant

The breeding success of the species was estimated as the percentage of active nests (nest success) and eggs (egg-hatching rate) in a population that successfully produced hatchlings. Chi-square test and one-way ANOVA were used to determine the association between Galliform population size, diet composition, foraging habitat use and clutch size of Helmeted Guineafowl across spatial-temporal gradients. Independent t-test and one-way ANOVA were employed to infer the associations between Galliform abundance and nest site location of the species across spatiotemporal gradients.

Chi-square test was used to assess the associations between the clutch size of the species and nesting habitats. It was also used to determine the associations between public knowledge, awareness and attitude of respondents towards Galliformes across the gender, age, levels of education and occupational status of participants. While non-normally distributed data sets were analyzed using non-parametric statistical tests.

Pearson Correlation Coefficient (*r*) was used to infer the associations between active foraging time and foraging habitat use of Helmeted Guineafowls across seasons. It was also used to measure the associations between the external egg morphometry features of the species. Nest success estimates were made as a percentage of active nests and eggs (egg hatching success rate) in a population sample that successfully produced young/offspring. Data sets and measurement values were presented as Mean ± SE. Variables tested with a level of difference at $p<0.05$ in a 95% confidence interval were retained as statistically significant. Field data sheets were consistently used to record the necessary ecological information.

4. RESULTS

4.1 Species composition and relative abundance of Galliformes

Galliform birds belonging to three species grouped under three distinct families were: Clapperton's Francolin, *Pternistis clappertoni* (*Phasianidae*), Helmeted Guineafowl, *Numida meleagris* (*Numididae)* (Plate 4), and Stone Partridge, *Ptilopachus petrosus* (*Odontophoridae*) were recorded. Among these species, Helmeted Guineafowl were abundant and Clapperton's Francolins were common while the Stone Partridges were frequent species in the area (Table 5).

Table 5. Species composition and relative abundance of Galliformes in the Arjo-Didessa River Valley (**RA* = relative abundance).

Species	Family	Abundance				
		Dry	Wet	Mean ± SE	*RA (%)	Frequency
Clapperton's Francolin (*Pternistis clappertoni*)	*Phasianidae*	136	113	124.5 ± 11.5	30.14	Common
Helmeted Guineafowl (*Numida meleagris*)	*Numididae*	309	243	276 ± 33	66.83	Abundant
Stone Partridge (*Ptilopachus petrosus*)	*Odontophoridae*	16	9	12.5 ± 3.5	3.03	Frequent
Total		461	365	413 ± 48	100	

Plate 4. Flocks of Helmeted Guineafowls in the Arjo-Didessa River Valley (©Yihenew A., 2020).

4.2 Population size

The total number of Galliform individuals recorded in the Arjo-Didessa River Valley area was 413 ± 48 (Mean ± SE) with a record of 461 individuals during the dry season and 365 individuals during the wet season. However, there was no statistically significant difference in the number of individuals recorded between dry and wet seasons ($\chi^2 = 64.80$, df = 1, $p > 0.05$). Among the three species, the species with the highest population size record was Helmeted Guineafowl, both during the dry and wet seasons, with 309 and 243 individuals, respectively. However, the Stone Partridge population record was the lowest during both the dry (16 individuals) and wet (nine individuals) seasons. The wet and dry season population counts showed statistically significant differences in Clapperton's Francolin ($F = 9.68$, df = 1, $p < 0.05$), and Helmeted Guineafowl ($F = 31.634$, df = 1, $p < 0.05$), but not in Stone Partridge ($p > 0.05$). In the present study, the flock size of Galliformes ranged from one to 22 individuals per flock during the dry season and one to 13 individuals during the wet season. Among the three species, Helmeted Guineafowls recorded the highest flock size during the dry season (22 individuals per flock) and Clapperton's Francolin (13 individuals per flock) during the wet season (Table 6).

Table 6. Group size range of Galliform bird species in the Arjo-Didessa River Valley.

Season	Galliform Species		
	Clapperton's Francolins	Helmeted Guineafowl	Stone partridges
Dry	1.00 –12.00	4.00 – 22.00	1.00 – 6.00
Wet	3.00 – 13.00	1.00 – 7.00	1.00 – 5.00
Combined	1.00 – 13.00	1.00 – 22.00	1.00 – 6.00

The flock size of Helmeted Guineafowl varied across seasons, with the dry season having the highest mean flock size of 13 ± 9 individuals (range: 4.00 - 22.00) and the wet season with the lowest mean flock size of 4.5 ± 3 individuals (range: 1.00 - 7.00). During the dry season, the highest flock size of the species was recorded in April (13.5 ± 8.5; range: 5 - 22). During the wet season, the highest flock size of Helmeted Guineafowls recorded was in July (4 ± 2; range: 2 - 6). Flock size was low in the months from June to September (Fig. 5).

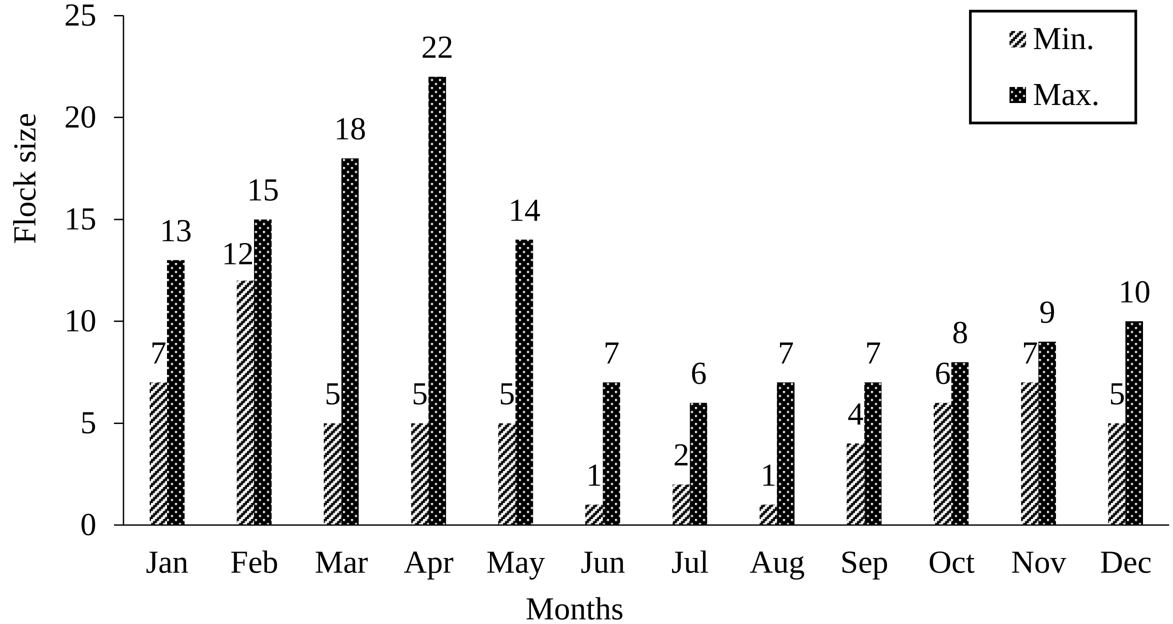

Figure 5. Group size of Helmeted Guineafowl across months in the Arjo-Didessa River Valley.

4.3 Galliform habitat use

All three Galliform species were recorded in the four habitat types in the study area. However, the Stone partridge is only in the forest areas. The population size of the species varied across the spatiotemporal gradients, with the highest mean Galliform abundance recorded in the farmland (141.5 ± 7.5) and the lowest in the riverine (61.5 ± 43.5) habitats (Table 7). There were statistically significant differences in Galliform abundance between the different habitats ($F = 90.06$, df = 3, $p < 0.05$). The study also showed significant differences in habitat use of Galliformes recorded in the farmland habitat both during the dry (134 ± 18) and wet (149 ± 57) seasons, and it was statistically significant ($p < 0.05$). Among the three Galliform species found in the area, Stone Partridge was recorded only in the forest habitat during both dry (16 ± 4) and wet (9 ± 2) seasons, while Clapperton's Francolin and Helmeted Guineafowl were recorded in all four habitats with varying numbers (Table 7).

Table 7. Galliform abundance across habitats and seasons in the Arjo-Didessa River Valley.

Habitats	Season	Galliform Species (Mean ± SE)			Total	*F*	*df*	*p*
		Clapperton's Francolin	Helmeted Guineafowl	Stone partridge				
Farmland	Dry	58 ± 6	76 ± 21		134 ± 18			
	Wet	46 ± 7	103 ± 19		149 ± 57	90.06	3	0.001
Forest	Dry	22 ± 4	93 ± 17	16 ± 4	131 ± 55			
	Wet	40 ± 9	65 ± 7	9 ± 2	114 ± 16			
Grassland	Dry	20 ± 7	71 ± 16		91 ± 51			
	Wet	22 ± 3	62 ± 6		84 ± 40			
Riverine	Dry	36 ± 11	69 ± 19		105 ± 33			
	Wet	5 ± 2	13 ± 2		18.5± 8.5			

4.4 Feeding Ecology of Helmeted Guineafowl

4.4.1 Diet composition

Helmeted Guineafowls are omnivorous and feed on a wide range of animal and plant matters. Their diets consisted of seeds (53%) followed by leaves (36%) and other food items (11%) during the dry season and insects (52%), leaves (26%), worms (14%) and other food items (8%) during the wet season (Fig. 6). There was a difference in the diet composition of the species between the dry and wet seasons, and it was statistically significant ($\chi^2 = 64.79$, df = 1, $p < 0.05$).

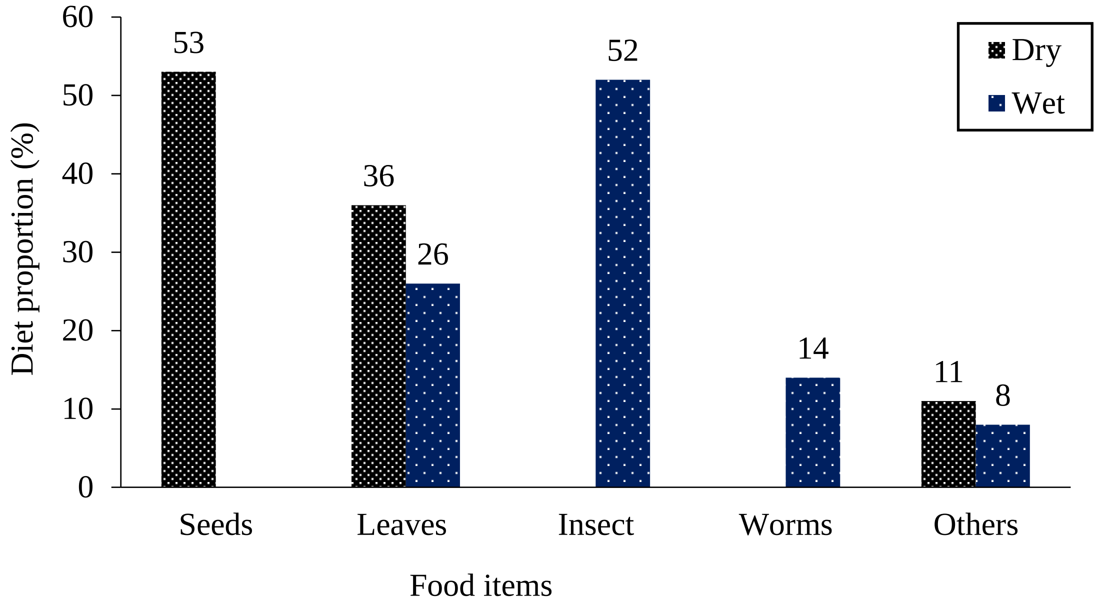

Figure 6. Diet composition of Helmeted Guineafowl in the Arjo-Didessa River Valley.

4.4.2 Habitat use

In the study area, Helmeted Guineafowls were recorded foraging across the four habitat types but they were predominantly observed foraging in the forest habitats during the dry (39.59%, n = 59) and wet (34.33%, n = 46) seasons. The lowest foraging frequency of the species was recorded in the farmland (14.76%, n = 22) during the dry and riverine forest (2.24%, n = 3) habitats during the wet season (Table 8). There was a difference in the foraging habitat use of Helmeted Guineafowls between the dry and wet seasons, and it was statistically significant ($\chi^2 = 32.18$, df = 1, $p < 0.05$).

Table 8. Foraging habitat use of Helmeted Guineafowl in the Arjo-Didessa River Valley.

Season	Foraging frequency across habitats (%)				Sum	χ^2	df	p
	Farmland	Forest	Grassland	Riverine				
Dry	14.76	39.59	24.16	21.48	149	32.18	1	0.001
Wet	32.09	34.33	31.34	2.24	134			
Total	22.97	37.10	27.56	12.37	283			

Helmeted Guineafowls predominantly foraged in the grassland and farmland habitats during the morning hours and forests and farmland habitats during the mid-days. The species spent late afternoon hours in the forest and grassland areas. However, the lowest habitat utilization intensity of the species was recorded in the riverine areas during the morning and late afternoon hours, and in grassland areas during the mid-day hours (Table 9). There was a positive correlation in the habitat use of the species between the active foraging time slots (r = 0.34, df = 4, p > 0.05).

Table 9. Foraging habitat use of Helmeted Guineafowl in different time slots.

Foraging habitats	Frequency of occurrence			Sum	r	df	p
	Morning	Mid-day	Afternoon				
Farmland	24	13	28	65	0.34	4	0.06
Forest	16	41	48	105			
Grassland	33	8	37	78			
Riverine	6	11	18	35			
Total	79	73	131	283			

4.5 Breeding Ecology of Helmeted Guineafowls

4.5.1 Breeding season

The active breeding period of Helmeted Guineafowl in the Arjo-Didessa River Valley was from June through September when intensive egg-laying was observed. A total of 17 active nests consisting of 207 eggs were located throughout the study periods. Among these, six nests (35.29%) with 79 eggs (38.16%) were recorded in 2018, and 11 nests (64.71%) with 128 eggs (61.84%) were monitored during the 2019 breeding season. Peak breeding was recorded during July with seven active nests (41.18%) and 73 eggs (35.27%). August recorded five nests (29.41%) with 72 eggs (34.78%) and the month of September recorded three nests (17.65%) with 44 eggs (21.26%). The lowest number of nests was observed during June when two active nests (11.76%) with 18 eggs (8.69%) were recorded (Table 10). During the 2018 breeding season, two nests of the species had their first clutch in July, three nests during August and one nest in September. During the 2019 breeding season, two nests initiated their first clutch from 2 to 26 June, five nests from 3rd to 24th July, two active nests during August, and two nests initiated their nests from 7th to 25th September. Hence the breeding period of the Helmeted Guineafowls in the Arjo-Didessa River Valley area was from early June to early September.

Table 10. Breeding seasons of Helmeted Guineafowls in Arjo-Didessa River Valley.

Breeding attributes	Breeding years		Breeding period				Total
	2018	2019	June	July	August	September	
Nests Located	6 (35.29%)	11 (64.71%)	2 (11.76%)	7 (41.18%)	5 (29.41%)	3 (17.65%)	17 (100%)
Eggs monitored	79 (38.16%)	128 (61.84%)	18 (8.69%)	73 (35.27%)	72 (34.78%)	44 (21.26%)	207 (100%)

4.5.2 Nest location

Active nests of Helmeted Guineafowls were located in the grassland (41.18%, n=7), farmland (35.29%, n=6), and forest habitats (23.53%, n=4). No nests were located in the riverine areas (Fig. 7). All nests located were on the ground. Nests of Helmeted Guineafowls were located in areas lined with proper vegetation cover with the high possibility of concealing the nests and eggs (Plate 5).

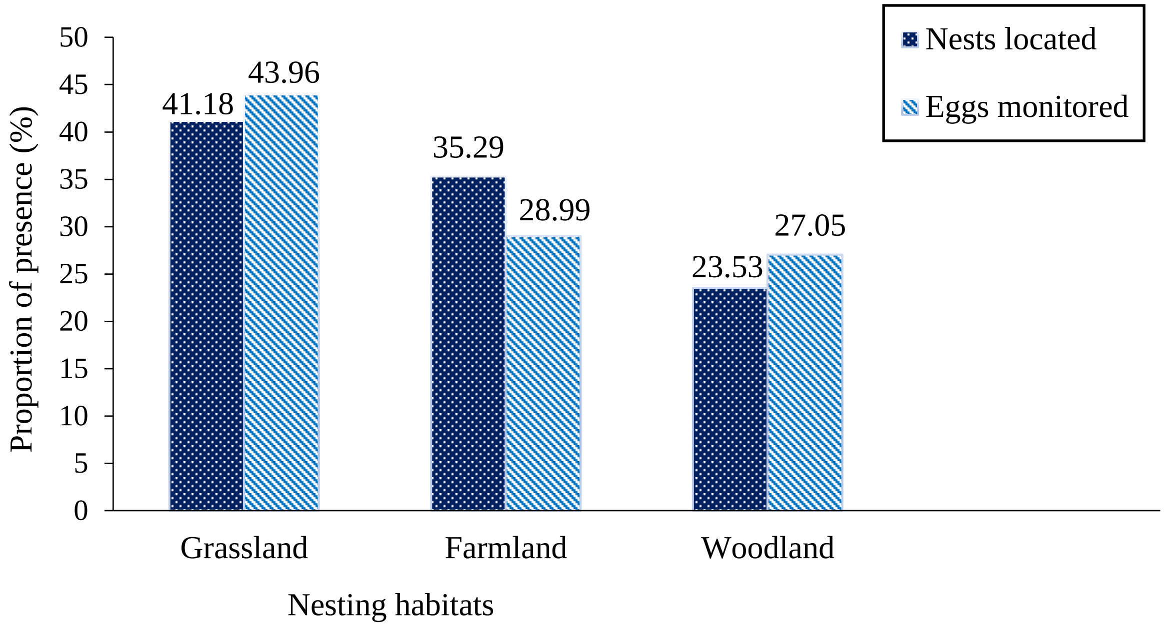

Figure 7. Nest location and breeding habitat characteristics of Helmeted Guineafowls.

Nests of Helmeted Guineafowls were located at different altitudes ranging between 1295 and 1836 m asl (1565.50 ± 270.50 m). The four nests monitored in the forest habitats were at a relatively higher altitude (1,685 ± 109.27 m) than those six nests constructed in the farmland areas (1491.43 ± 144.31 m), and seven nests recorded in the grassland habitats (1427.83 ± 96.31 m) (Table 11).

Table 11. Nest location of Helmeted Guineafowls across different habitats in the Arjo-Didessa River Valley.

Breeding habitats	n	Range of Altitude (m a s l)	Mean Altitude	SE	SD
Farmland	6	1356 – 1796	1491.43	54.54	144.31
Grassland	7	1295 – 1583	1427.83	39.32	96.31
Forest	4	1593 – 1836	1685.00	54.63	109.27
Total	17	1295 – 1836	1514.53	36.99	152.53

Plate 5. Active nests of Helmeted Guineafowl in the Arjo-Didessa River Valley (©Yihenew A., 2019).

4.5.3 Composition of nesting materials

Helmeted Guineafowls build nests with dry grass (45.39%), leaves (27.82%), feathers (11.46%), straws (8.95%), and other nest-building materials (6.38%) such as dry weeds, twigs, and lianas (Fig. 8). *Poaceae* and *Combretaceae* plants were the most commonly used nesting materials by the species.

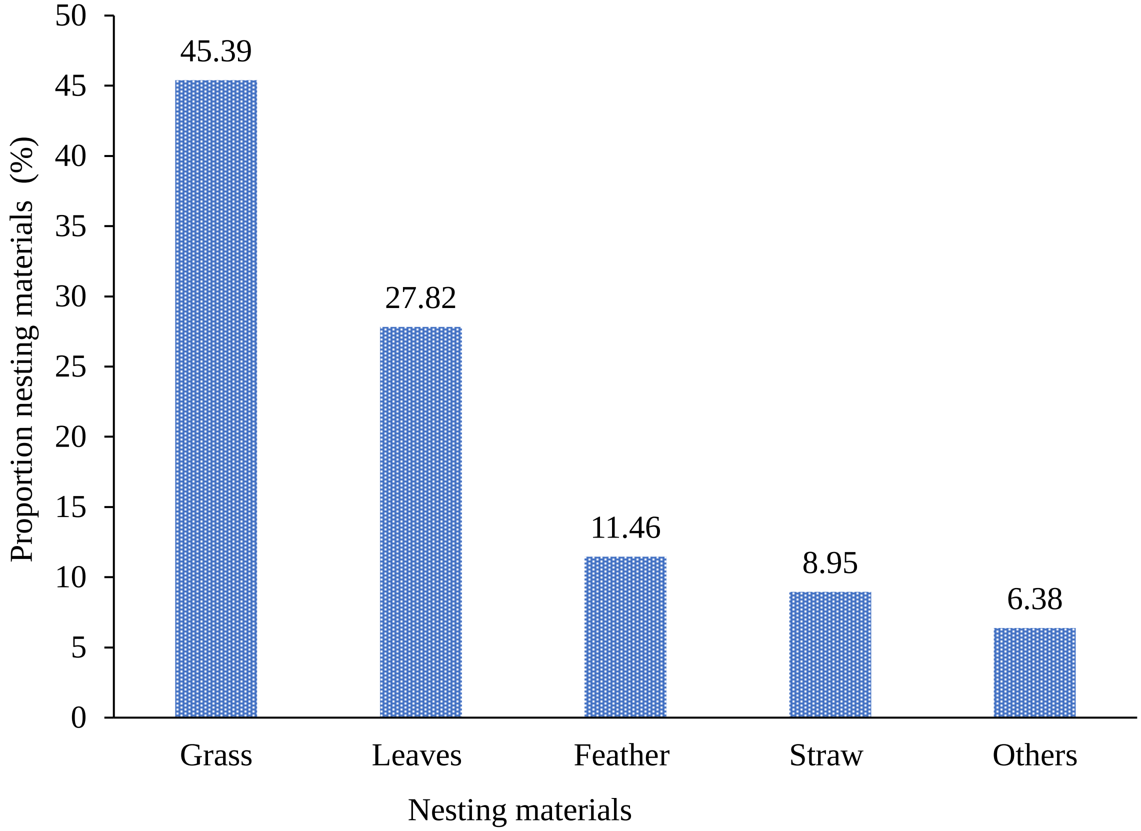

Figure 8. Nest building material composition of Helmeted Guineafowl in the Arjo-Didessa River Valley.

4.5.4 Clutch size

The mean clutch size of Helmeted Guineafowl recorded in the present study was 12.18 ± 1.07 (range: 5–19, n = 207). The clutch size of the species varied across breeding habitats where forests recorded the highest clutch size (14.00 ± 1.41) and farmland areas had the lowest (10.00 ± 4.38). There was a statistically significant difference in clutch size across the breeding months, i.e. July (χ^2 = 7.53, df = 2, p = 0.01), August (χ^2 = 5.98, df = 2, p = 0.04), and September (χ^2 = 10.06, df = 2, p = 0.01). However, it was not statistically significant during June (χ^2 = 2.98, df = 2, p > 0.05) (Table 12).

Table 12. Clutch size of Helmeted Guineafowls across the breeding habitats and seasons in the Arjo-Didessa River Valley area.

Parameters	Variables	n	Range	Mean ± SE	SD	χ^2	df	*P*
	Grassland	91.00	6.00 – 19.00	13.00 ± 1.96	5.19	6.62	2	0.01
Habitats	Farmland	60.00	5.00 – 17.00	10.00 ± 1.78	4.38	5.59	2	0.03
	Forest	56.00	12.00–15.00	14.00 ± 0.71	1.41	19.79	2	0.01
	Sum	207.00	5.00 – 19.00	12.18 ± 0.07	4.40	11.39	2	0.01
	June	18.00	6.00 – 12.00	9.00 ± 3.00	4.24	2.98	3	0.06
Months	July	73.00	5.00 – 15.00	10.43 ± 1.37	3.64	7.53	3	0.01
	August	72.00	6.00 – 19.00	14.40 ± 2.40	5.36	5.98	3	0.04
	September	44.00	12.00–17.00	14.66 ± 1.45	2.52	10.06	3	0.01

3.5.5 Egg morphometry

The mean egg length (cm), egg width (cm), and egg weight (g) of Helmeted Guineafowls in the Arjo-Didessa River Valley were 27.33 ± 0.19 mm, (range: 19.73–33.37, *n* = 207), 16.44 ± 0.11 mm (range: 12.29 – 20.18, *n* = 207) and 43.42 ± 0.34 g, (range: 28.36 – 48.71, *n* = 207), respectively (Table 13). The eggs were white creamy and sharp shaped with a mean Egg Shape Index of 60.15± 0.83 mm. Its mean egg volume was 37.67mm^3. The mean difference in external egg morphometric parameters between the 2018 and 2019 breeding seasons was egg length: 27.91 ± 0.33 and 26.96 ± 0.24, egg width:17.08 ± 0.20 and 16.05 ± 0.11, and egg weight: 43.81 ± 0.36 and 43.42 ± 0.34. The egg shape index (ESI) of the species was 61.19 cm during the 2018 and 59.53 cm in the 2019 during the breeding seasons. While its egg volume was 41.52 mm^3, and 35.42 mm^3 during the 2018 and 2019 breeding seasons, respectively.

Table 13. Egg morphometric measurements of Helmeted Guineafowls in the Arjo-Didessa River Valley area (*****ESI: egg shape index; EV: egg volume).

Breeding season	Morphometric parameters	Sum	Range	Mean±SE	ESI* (cm)	EV* (mm^3)
2018	Egg length (mm)	2205.19	22.79 – 33.37	27.91 ± 0.33	61.19	41.52
	Egg width (mm)	1332.23	14.02 – 20.18	17.08 ± 0.20		
	Egg weight (g)	3461.38	36.80 – 48.10	43.81 ± 0.36		
2019	Egg length (mm)	3424.03	19.73 – 32.17	26.96 ± 0.24	59.53	35.42
	Egg width (mm)	2038.44	12.29 – 18.59	16.05 ± 0.11		
	Egg weight (g)	5482.81	28.36 –48.71	43.17 ± 0.51		
Total	Egg length (mm)	5629.22	19.73 – 33.37	27.33 ± 0.19	60.15	37.67
	Egg width (mm)	3370.67	12.29 – 20.18	16.44± 0.11		
	Egg weight (g)	8944.19	28.36 – 48.71	43.42 ± 0.34		

There was a positive association and moderate correlation between egg length and egg width (r = 0.69, n = 207), and between egg length and egg weight of the species (r = 0.62, n = 207), and it was not statistically significant (p > 0.05). Similarly, its clutch size was negatively correlated with egg length (t =138.72, df = 206, r = -0.04, p = 0.08, n = 207) and egg width (t = 153.28, df = 206, r = -0.12, p = 0.06, n=207). However, there was a positive correlation but weak association between the egg weight and clutch size of the species (t = 126.80, df = 206, r = 0.04, p = 0.08, n = 206). There was no statistically significant difference between the external egg morphometric parameters and clutch size (p > 0.05) (Table 14).

Table 14. External egg morphometry analyses of Helmeted Guineafowls in the Arjo-Didessa River Valley area.

Parameters	*t*	df	Pearson correlations (*r*)				*p*
			Egg length	Egg width	Egg weight	Clutch size	
Egg length (mm)	138.72	206	-	0.69	0.62	-0.04	0.08
Egg width (mm)	153.28	206	0.69	-	0.04	-0.12	0.06
Egg weight (g)	126.80	206	0.62	0.04	-	0.04	0.08

4.5.6 Breeding success

A total of six active nests consisting of 79 eggs, and 11 nests encompassing 128 eggs of Helmeted Guineafowls were monitored during the 2018 and 2019 breeding seasons, respectively. During the 2018 breeding season, four nests (66.66%) consisting of 55 (69.62%) eggs were successfully hatched. Seven (63.64%) nests with 83 (60.14%) eggs were successfully hatched during the 2019 breeding season of the species. Hence, the overall breeding success of the observed nests was 64.71% (n = 11) while the egg-hatching rate of the species was 66.67% (n=138) (Table 15). The mean incubation period of Helmeted Guineafowls in the Arjo-Didessa River Valley was 28.50±1.83 days (range: 25 –32). However, among the 17 nests and 207 eggs of the species monitored throughout the breeding seasons, six nests (35.29%) and 69 eggs (33.33%) failed to hatch due to constraints including human disturbance, abandonment, predation, and illegal egg collection activities.

Table 15. Breeding performances of Helmeted Guineafowls in the Arjo-Didessa River Valley.

Breeding season	Nests located	Successfully hatched nests	Breeding success (%)	Eggs monitored	Successfully hatched eggs (%)	Egg hatching success rate
2018	6	4	66.66%	79	55	69.62%
2019	11	7	63.64%	128	83	64.84%
Total	17	11	64.71%	207	138	66.67%

The breeding success of Helmeted Guineafowls varied between nesting habitats. The highest breeding (100%, n=4) and hatching success (100%, n=56) were recorded in the forest habitats. The lowest breeding (50%) and egg-hatching success rates (36.67%) were recorded in farmland habitats (Table 16). There was a statistically significant difference in the breeding success of the species between the nesting habitats ($\chi^2 = 2.93$, df = 2, $p < 0.05$).

Table 16. Breeding success of Helmeted Guineafowl across nesting habitats.

Breeding habitats	Nests located	Successfully hatched nests (%)	Number of eggs monitored	Egg hatching success rate (%)	Number of failed eggs (%)
Grasslands	7	4 (57.14%)	91	65.93 (n=60)	31 (34.07)
Farmlands	6	3 (50.00%)	60	36.67 (n=22)	38 (63.33)
Forest	4	4 (100%)	56	100.00 (n=56)	-

Among the six unsuccessful nests and 69 eggs of Helmeted Guineafowls, three nests (50.00%) with 31 eggs (44.93%) failed due to abandonment and illegal egg collection activities. However, two nests (33.33%) comprising 29 eggs (42.03%) failed as a result of predation pressure including raptors, mammals and reptiles. One active nest (16.67%) of the species containing nine eggs (13.04%) was unsuccessful in hatching due to unidentified causes (Fig. 9).

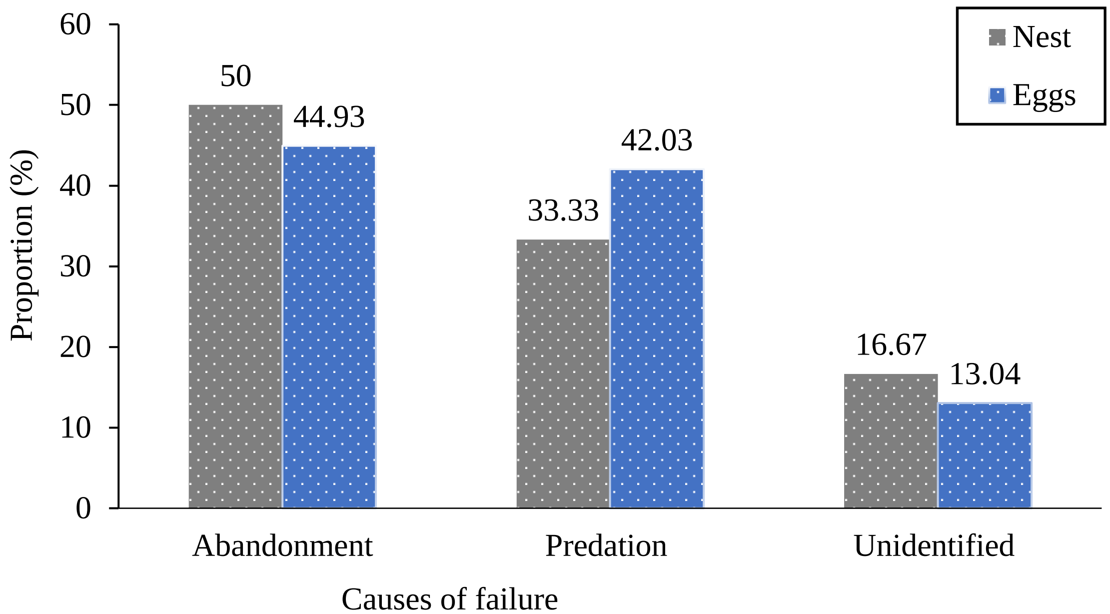

Figure 9. Causes of breeding failure of Helmeted Guineafowl in the Arjo-Didessa River Valley.

4.6 Public Knowledge and Threats

4.6.1 Threats to Galliformes

The present study described habitat destruction and loss (32.18%), agricultural intensification (19.93%), deforestation and overgrazing (14.34%), illegal hunting and eggs collection (11.18%), fire (11.88%) and firewood collection (6.29%) as the main threats affecting Galliformes and their habitats in the study area. The application of agrochemicals such as weed killers and insecticides was also affecting these birds in the area (Fig. 10). Deliberate fire and burning of farmland areas and adjacent forest patches were also commonly practised by farmers and landowners supposed to confiscate leftover straws, weed dumps and pests, which affect essential resources such as foraging niches and resting sites which in turn possibly alter the habitat use and distribution of species in the area since fires have potential effects on the biological, ecological and environmental features.

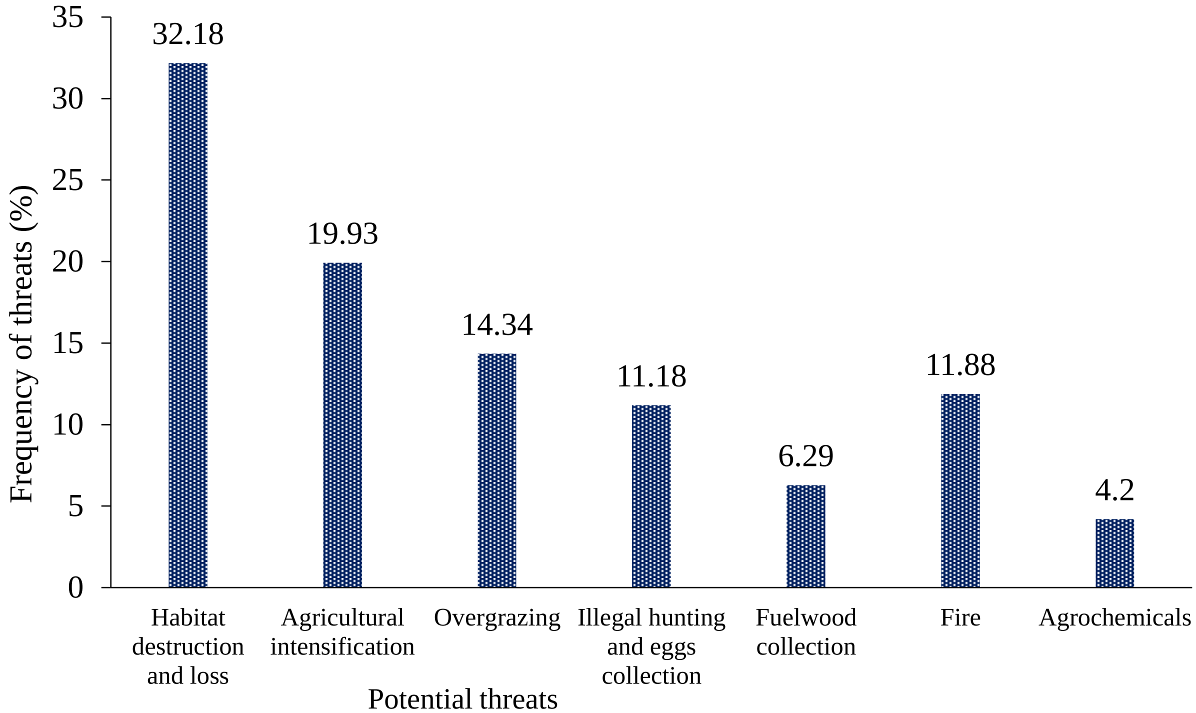

Figure 10. Conservation threats to Galliformes and their habitats in the Arjo-Didessa River Valley.

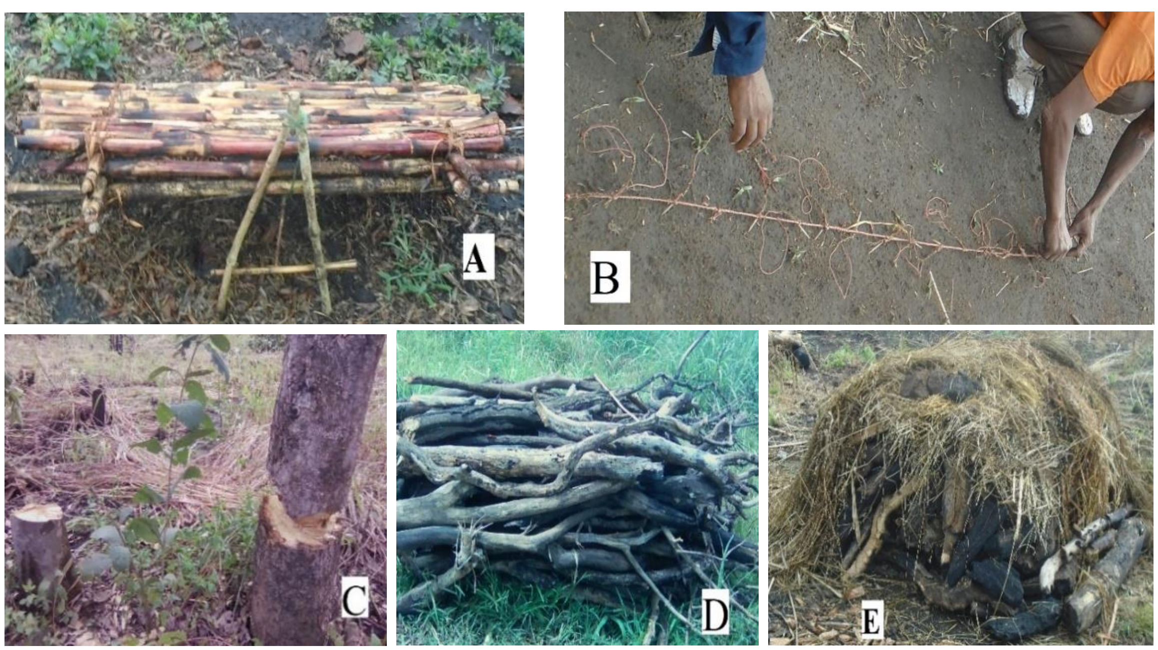

Plate 6. Major conservation threats to Galliformes and their habitats in the Arjo-DIdessa River Valley (A&B = hunting practices through trapping and snaring; C = habitats destruction through deforestation; D = fuelwood collection, E = charcoal production) (©Yihenew A., 2020).

4.6.2 Public knowledge and attitude towards Galliformes

A total of 286, consisting of 174 (60.84%) male and 112 (39.16%) female respondents have participated in the present study. The age category of the respondents was between ≤ 18 (4.50%), 18-30 (31.10%), 31-45 (40.90%), and ≥ 45 years (23.40%). The educational status of the participants was illiterate (49.30%), elementary (16.10%), high school (21.00%), and college diploma and above (13.60%) (Table 17). Accordingly, the occupational status of participants includes farmers, unemployed, government employees, and others including private owners accounting for about 40.90%, 24.50, 21.30%, and 13.30%, respectively.

Table 17. Socio-demographic characteristics of the studied participants.

Parameters	Variables	Frequency	Percentage (%)
Gender (n = 286)	Male	174	60.84
	Female	112	39.16
	Total	286	100.0
Age (n = 286)	≤18	13	4.54
	18-30	89	31.12
	31-45	117	40.91
	≥45	67	23.43
	Total	286	100
Levels of education (n = 286)	Illiterate	141	49.30
	Elementary grade	46	16.08
	High school grade	60	21.98
	College diploma and above	39	13.64
	Total	286	100

Occupational status (n = 286)	Farmers	117	40.91
	Unemployed	70	24.47
	Government employee	61	21.33
	Other	38	13.29
	Total	286	100.0

The majority (86.36%, n=286) of the participants in the study area have prior background knowledge and awareness about Galliform birds, particularly the Guineafowl and Francolin species. They usually encountered these birds in an expected flock size ranging from 6 to 10 (36.84%, n=91), less than five (25.51%, n=63), 11-15 (23.08%, n=57) and ≥16 (14.57%, n=36) individuals. Local communities perceived these birds due to their socio-economic attributes as an important source of food, meat and egg consumption (55.06%, n=87), sales as a source of income (28.48%, n=45), and other purposes (16.45%, n=26) including enjoyment, foster rearing practices, medicine and related traditional values (Table 18). There was a statistically significant difference in public knowledge and awareness of respondents across the age (χ^2 = 10.45, df = 3, p <0.05) and levels of education (χ^2 = 13.08, df = 3, p <0.05) of participants. While gender and occupational status of respondents have no significant effect on the knowledge and awareness of the participants (p > 0.05) (Table 18).

Table 18. Public knowledge and awareness of respondents towards Galliformes.

Parameters	Variables	Frequency	Percentage (%)
Knowledge and awareness of Galliformes (n = 286)	Yes	247	86.36
	No	39	13.64
	Total	286	100

Frequency of Galliformes occurrence (n = 247)	Usually	64	25.91
	Often	102	41.30
	Sometimes	48	19.43
	Rarely	33	13.36
	Total	247	100
Expected flock size of species encountered (n = 247)	1-5	63	25.51
	6-10	91	36.84
	11-15	57	23.08
	≥16	36	14.57
	Total	247	100
Attitude of local communities towards Galliformes (n = 247)	Positive	178	72.07
	Negative	46	18.62
	Neutral	23	9.31
	Total	247	100
Galliform hunting and/or eggs collection experiences (n = 247)	Yes	158	63.97
	No	89	36.03
	Total	247	100
Reasons for hunting Galliformes (n = 158)	Source of food	87	55.06
	Source of income	45	28.48
	Others	26	16.46
	Total	158	100

In the study area, about 72.06% (n = 178) of the respondents had positive attitudes towards Galliformes. However, about 18.62% (n = 46) of the participants had negative attitudes which were mainly allied with their perceptions as pests causing possible crop damage and loss they pose to farmyards through collecting seeds of crops mainly during the sowing seasons as well as causing possible destruction to the grains, leaves and fruits of irrigation crops such as the *Allium*, *Pipper* and *Solanum* species. Whereas, about 9.31% (n = 23) of the participants had neutral thoughts about the conservation significance of these birds (Table 19). There was a statistically significant difference in the attitude towards Galliformes across the age ($\chi^2 = 14.49$, df = 3, $p < 0.05$) and occupational status ($\chi^2 = 10.20$, df = 3, $p < 0.05$) of respondents. However, there were no significant differences in public attitude across the gender and levels of education ($p > 0.05$). Though local communities have prior knowledge and exposure to Galliformes, illegal hunting and egg collection activities are commonly practised in the study area and potentially affect the populations of these birds. Among the study participants, 63.97% (n = 158) of respondents have such experiences in hunting and egg collection activities. Hunters commonly use traps and leg-hold snares set near the foraging and roosting sites.

Table 19. Attitude of local communities towards Galliformes in Arjo-Didessa River Valley.

		Public attitude						
Parameters	Variables	Positive	Negative	Neutral	Sum	χ^2	df	*p*
	Male	108	27	16	151			
Gender	Female	70	19	7	96	10.82	1	0.06
	Total	178	46	23	247			

Age	<18	6	2	0	8	14.49	3	0.02
	18-30	46	19	12	77			
	31-45	81	15	3	99			
	>45	45	10	8	63			
	Total	178	46	23	247			
Levels of education	Illiterate	97	23	12	132	13.08	3	0.08
	Elementary grade	26	7	4	37			
	High school grade	34	7	5	46			
	College diploma and above	21	9	2	32			
	Total	178	46	23	247			
Occupational status	Farmer	77	19	6	102	10.20	3	0.001
	Gov. employee	34	13	4	51			
	Unemployed	40	8	11	59			
	Other	27	6	2	35			
	Total	178	46	23	247			

Accordingly, farmers who perceived Galliformes as pests predominantly employed guarding (67.39%, n=31), trapping and snaring (17.39, n=8), scarecrow (10.87, n=5), and other techniques (4.35, n=2) as a main crop raid measure to protect the possible damage by these birds (Fig. 11).

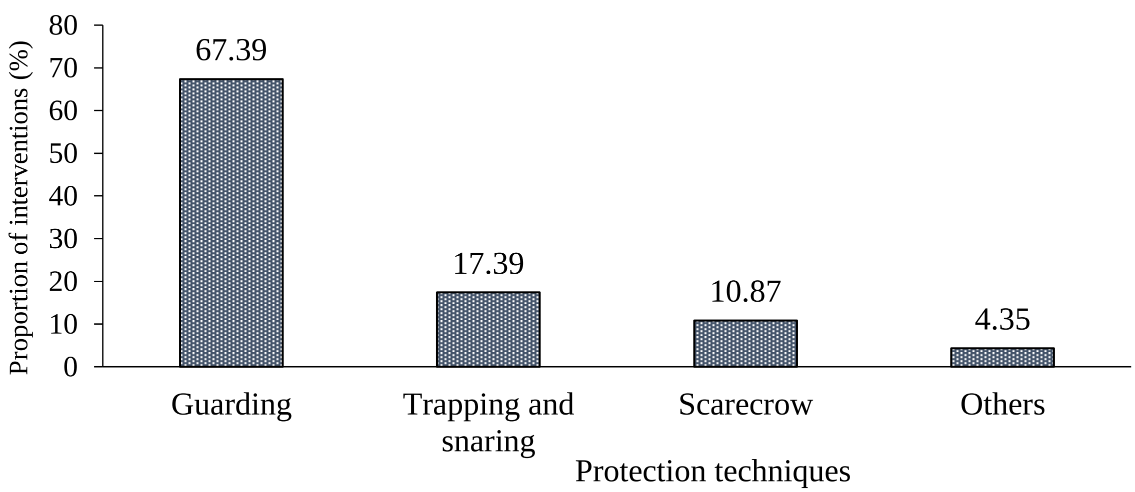

Figure 11. Major crop raid protection techniques in the Arjo-Didessa River Valley area.

5. DISCUSSION

Arjo-Didessa River Valley is an important potential area for the three species of Galliform birds namely, the Clapperton's Francolin (*P. clappertoni*), Helmeted Guineafowl (*N. meleagris*), and Stone Partridge (*P. petrosus*). These species have significant populations inhabiting diverse habitat types to fulfil their ecological requirements. However, the study showed significant differences in Galliform assemblage and populations across spatiotemporal gradients in which the maximum and minimum number of the species were recorded in the farmland and riverine habitats, respectively. The difference in the population size of Galliformes between habitats during the dry and wet seasons may be attributed to the seasonal variations in habitat vegetation features and anthropogenic disturbance pressure related to the intensive agricultural land-use practices in the area that impacts the accessibility of food sources and protective cover to Galliformes (Rands, 1988; Moreau *et al*., 2022).

Helmeted Guineafowls were the abundant Galliform birds recorded in the Arjo-Didessa River Valley area with a mean population size of 276±33 individuals. The population size of the species in the study area was higher than the findings by Kumssa and Bekele (2013) who reported a mean population size of 216.5±5.43 individuals in the Abijata-Shalla Lakes National Park. However, it was lower than the results by Tamrat and Subramanian (2013), who reported a population density range between 7.14±1.96, and 2.02±0.51 in Gonder Woreda, Ethiopia. The difference in the population size of the species between study sites may be attributed to the variations in environmental conditions and habitat features that often impact the resource availability and hence determine the abundance, population size and distribution of species (Waterhouse *et al*., 2002).

In the Arjo-Didessa River Valley, Galliformes were recorded across the four habitat types throughout the study periods. The Helmeted Guineafowl were widely distributed in the forest habitats during the dry and farmland areas during the wet seasons. While the Caperton's Francolins were commonly distributed in the agricultural farmland areas and riverine habitats during the dry and wet seasons, respectively. However, Stone Partridges were entirely restricted to the forest patches throughout the study period. Its consistent occurrence in forest areas may be ascribed to the accessibility of the necessary resources to meet the ecological requirements of the species. It is also reported that Stone Partridges prefer woodland forests and rocky hillside areas with bushes and *Hyparrhenia* grass at an elevation of 620-1400 m asl (BirdLife International, 2022). A strong association of the species with open forests and farmland habitats was also stated by Codjia *et al*. (2021). The variation in the occurrence of the species between habitats across seasons may be attributed to the differences in anthropogenic pressure, habitat size and vegetation features which provide more niches and essential resources including food sources, protective cover, resting areas, roosting areas, and breeding sites. However, a study by Ratcliffe and Crowe (2001) reported a thriving population status, abundance and distribution ranges of Helmeted Guineafowls in modified landscapes. It is also described that forest-restricted birds are less tolerant to habitat modification and hence have smaller distribution ranges (Westphal *et al*., 2003).

The maximum flock size of Galliformes in the study area was recorded during the dry season which may be related to the fact that the dispersed breeding pairs might join other flocks during the dry non-breeding season. Additionally, several flocks of the species often aggregate together and form larger groups during the dry non-breeding seasons where a high anthropogenic disturbance related to agricultural land preparation practices involves deliberate fire that potentially affects the availability of suitable foraging and resting sites. A study by Kumssa and Bekele (2013) also reported a comparable flock size of Helmeted Guineafowls which was in the ranges between one and 21 individuals per flock. The flock size of Helmeted Guineafowls depends on population density and breeding status (Maclean, 1993; Van Niekerk, 2010).

The findings of the present study showed Helmeted Guineafowls were omnivorous with diets consisting of a variety of animal and plant matter. During the dry seasons, the species frequently feed on the seeds and leaves of grasses, grains and tubers while insects including termites (*Isoptera*), butterflies (*Lepidoptera*), ants (*Hymenoptera*) and grasshoppers (*Orthoptera*) were the main food sources of the species during the wet seasons. The difference in the diet composition of the species between seasons may be related to the variations in local climatic conditions such as temperature and rainfall patterns that essentially affect the availability and accessibility of food sources especially invertebrates and consequently insect prey abundance associated with the onset of rainy seasons, combined with the need of providing protein-rich food to the chicks. Similarly, the omnivorous mode of feeding and a high proportion of arthropod diets, mainly insects were also reported in previous studies (Mentis *et al*., 1975; Crowe *et al*., 1986; Little *et al*., 1995; Mwansat *et al*., 2015).

The present study recorded a lower proportion of insects (52%) during the wet, and seed (53%) diets during the dry seasons compared to the study by Kumssa and Bekele (2013), who reported about 71.6% of insects, and 75.2% of nodes and seeds of grasses as the main food sources of the species during the wet and dry seasons, respectively, in the Abijata-

Shalla Lakes National Park. A greater proportion of arthropod diets including insects such as beetles exceeding 80% of the food of the species was also reported during the wet seasons in South Africa (Mentis *et al*., 1975; Little *et al.*, 1995). The differences in diet composition of the species between the study areas may be due to the differences in environmental conditions since seasonality in rainfall patterns, temperature variation and habitats affect the accessibility of food resources and vegetation cover (Cody, 1981). It may also be attributed to the variation in habitat features, disturbance pressure and the application of agrochemicals which may affect insect food abundance in the present study area compared to the Abijata-Shalla Lakes National Park which is a protected area. Habitat features, rainfall frequency and agrochemicals such as pesticides possibly impact the availability, abundance and diet composition of birds, and hence influence the population status and distribution of species including Galliformes (Ahmad *et al*., 2019; Moreau *et al*., 2022).

Helmeted Guineafowls were predominantly observed in the upland forest habitats during the dry and farmland areas during the wet seasons in the ArjoDidessa River Valley. The species used these areas as the main foraging sites throughout the study periods. The use and consistent existence of the species in these habitats may be attributed to the accessibility of basic resources such as food sources, subsequent protective cover and resting and nesting sites since forest patches and edge habitats have heterogeneous vegetation leading to vital effects on the population size and habitat uses of birds (Rotenberry and Wiens, 1998; Van Niekerk, 2013; Zhao *et al*., 2020; Ovat *et al.*, 2022). Furthermore, the species were recorded intensively foraging in the grassland, forest and farmland habitats during the morning, mid-day and afternoon hours, respectively, which might be related to the availability of necessary conditions such as food resources, and accessibility of vegetation features supporting them to hide and reduce exposures from anthropogenic disturbances since the habitat choice and foraging strategies of birds are correlated with food source availability (Zhao *et al.*, 2020). Studies also reported that Helmeted Guineafowls preferred fragmented agricultural areas and adjacent savannah grassland habitats to access vital resources and were also attracted by weeds during the wet seasons (Grafton, 1969; Crowe *et al.*, 1986; Van Niekerk (2013). The dispersion of essential resources across habitats often determines the daily and seasonal movements of Helmeted Guineafowls (Prinsloo *et al*., 2008).

The breeding period of Helmeted Guineafowls in the Arjo-Didessa River Valley area was during the wet seasons between early June to late September which may be aligned with the local climatic and environmental conditions including rainfall patterns through their effects on the accessibility of resources such as food sources, nesting materials and proper cover. Other studies also state the breeding period of wild Helmeted Guineafowls occurs during the rainy seasons in Nigeria (Aire *et al.*, 1979; Ayeni, 1980). A comparable breeding period of the species from August to September during the peak rainy season was also reported by Njiforti (1997) in Cameroon. It is reported that the breeding biology of Helmeted Guineafowls is initiated and closely allied with non-photic cues such as rainfall frequency, temperature and accessibility and abundance of high-protein-rich insect food sources during the rainy season (Mentis *et al*., 1975; Crowe, 1978; Crowe and Siegfried, 1978; Ayeni, 1980; Njiforti, 1997). Food abundance influences the timing of breeding in birds (Newton, 1998). Studies also stated that eggs of the species with low fertility could also be laid during wet off-season periods (Ayorinde *et al*., 1989).

In the present study, Helmeted Guineafowls were ground-nesting. Nests of the species were located in grassland, farmland and forest habitats with an altitude range between 1295 and 1836 m asl. The sites where active nests of the species were located had tall grass scantly lined with adequate shrub vegetation cover to optimize nest concealment. Breeding in these habitats is possibly associated with the accessibility of essential conditions such as protective cover, nesting materials and the acquisition of necessary resources to maintain optimum nest temperature and sustain breeding fitness. However, Njiforti (1997) reported nests of Helmeted Guineafowls (*Numida m. g.*) under scrubs (76%) compared to isolated grass tufts (8%) and open areas (7%) which might be due to variations in ecological and environmental features of the breeding areas. It is reported that the species avoids nesting in dense vegetation, riverine habitats, and settlement areas (Little, 2016).

The nest site selection of species often relies on resource availability, habitat features, competition, breeding experience, and nest predation risk (Martin, 1995; Cancellieri and Murphy, 2014; Fu *et al*., 2016). The nesting constituents of the species in the study areas consisted of grasses, leaves, feathers, straws, dry weeds and lianas since nest-building material composition is significantly associated with the vegetation features of surrounding breeding habitats (Biddle *et al*., 2018; Briggs *et al*., 2019).

The mean clutch size of Helmeted Guineafowl in the Arjo-Didessa River Valley area was 12.18 ± 1.07 which was higher than the findings by Njiforti (1997) who reported a mean clutch size of 7.4 ± 3.1, 9.4 ± 4.3, and 10.2 ± 5.0 (range: 1-20) between the 1992, 1993 and 1994 breeding seasons of the species, respectively, in Cameroon. In the present study, the species laid a comparably good number of eggs per nest. However, this result is comparably lower than those reported by Ayeni (1980) who recorded a clutch of 15 to 20 eggs in Nigeria. A similar study by Clancey (1967), and McLachlan and Liversidge (1972) also reported a clutch size of *N. meieagris* in the ranges between 6 and 19 eggs in Southern Africa. The variation in the clutch size of the species between studies might be due to the differences in environmental conditions and resources supporting the breeding physiology of the species. Studies also stated the clutch size and breeding fitness of Helmeted Guineafowls are highly influenced by food resource accessibility, temperature and rainfall frequency (Crowe, 1978; Crowe and Siegfried, 1978).

The eggs of the Helmeted Guineafowls observed in the present study were pointed-shape with an ESI value of 60.15 ± 0.83 mm. The highest egg length, egg width and egg weight recorded in this study were 33.37 mm, 20.18 mm, and 48.71 gm, respectively. A higher external egg morphometric value, i.e., egg length (47.00 mm), egg width (36.10 mm), and ESI (76.80 mm) of Helmeted Guineafowls were reported by Zeleke *et al*. (2020) under an intensive management system. However, the present study recorded a higher mean egg weight value (43.42 g) than reported by Zeleke *et al*. (2020) with values of 35.90 g. Egg size and weight are important egg quality parameters of the egg shape index which have vital effects on fertility and hatchability rates (Amat *et al*., 2001; Aciand Durmus, 2015). However, it is mostly determined by food abundance and composition, laying season, egg composition, body weight and anatomical structure (Summers and Leeson, 1983; Nol *et al*., 1997; King'ori, 2012).

The breeding success of Helmeted Guineafowl recorded in the present study was 64.71% which was lower than the study by Njiforti (1997) who reported a breeding success of greater than 90% in Cameroon. However, the findings of the present study presented a higher breeding performance of the species than reported by Ayeni (1980) who noted a 28% breeding success in Nigeria. Such differences in the breeding performance of the species between breeding areas may be due to differences in predation and anthropogenic disturbance pressure. It is also stated that climatic and environmental conditions such as vegetation and rainfall patterns significantly influence the breeding success of Helmeted Guineafowl through their effect on food source availability (Mentis *et al*. 1975; Crowe, 1978; Crowe and Siegfried, 1978; Njiforti, 1997).

Egg-hatching rate of the species recorded in the present study was 66.67% which was higher than reported by Ayeni (1980) who noted a hatching success rate of 34% in Nigeria. The variations may be due to the differences in environmental features that support egg hatching, nest disturbance and predation risk. Studies also reported the significant effects of rainfall on the breeding activities of the species in Uganda (Fergin, 1964). Mentis *et al.* (1975) also reported a low guineafowl population and poor breeding success of the species as a result of low rainfall in South Africa. A similar study by Mentis *et al.* (1975) also reported the negative effects of low rainfall on the limited availability of high-protein insect food and associated effects on the poor breeding success of the species.

The breeding performance of Helmeted Guineafowl in the study area varied across nesting habitats which were higher (100%) in forest habitats than in grassland and farmland areas. This may be ascribed to the differences in vegetation features where forests provide high nest concealment. Furthermore, farmland and grassland areas in the Arjo-Didessa area have high anthropogenic pressure related to farming activities and overgrazing which results in cattle trampling and higher predation risks than forest habitats. A study by Martin (1995) and Kragten *et al*. (2008) reported inter-specific variations in the breeding success of ground-nesting birds between nesting habitats, where higher nest loss, clutch destruction rates and lower breeding success were documented in grassland and farmland areas due to farming operation activities. Insufficient reproductive success, clutch destruction and subsequent population decline of ground-nesting farmland birds due to farming operations were also stated by Kragten *et al*. (2008). It is reported that the breeding success and nest survival rates of birds are influenced by nesting habitat features, food abundance, nest age, disturbance, and predation pressure (Webb *et al*., 2012; Sandercock *et al*., 2015; Brussee *et al*., 2016). Environmental conditions and landscape effects such as habitat loss and fragmentation, nesting habitat quality and disturbance also potentially influence the nest survival and breeding success of species (Winter *et al*., 2003). Studies also stated elevated nest predation rates and nest loss in fragmented landscapes, small remnants, habitat boundaries and edges (Robinson *et al*., 1995; Herkert *et al*., 2003; Batary and Baldi, 2004).

In the present study area, anthropogenic disturbances that led to abandonment and predation were the main causes of breeding failure of Helmeted Guineafowls. These findings were in line with the results by Njiforti (1997) who reported nest abandonment

(39.0%), predation by Monitor lizards and snakes (24.4%), flooding (19.5%) and cattle trampling (17.1%) as the main causes for the breeding failure of the species in Cameroon. Studies also reported ground-nesting birds including Galliformes are more susceptible to avian and mammalian predators, and sensitive to changes in land-use practices such as cultivation and grazing intensity (Collias and Collias, 1984; Guerrero *et al*., 2012). Nest predation exerts a substantial effect and significantly influences the habitat selection, breeding success, community structure and species coexistence of birds, mainly in ground-nesting Galliformes, waterfowls and shorebirds (Martin, 1993; Caro, 2005; Ibáñez-Álamo *et al*., 2015). The mean incubation period of Helmeted Guineafowl in the study area was 28.5 ± 1.83 days, which was in agreement with the findings by Ayeni (1980) who reported 27 days in Nigeria.

The findings of the present study described habitat destruction and loss, agricultural intensification, deforestation, overgrazing, deliberate fire, and fuelwood collection as the main threats to Galliform birds and their habitats. This might be due to the ever-increasing land needs and agricultural expansion which significantly impact the natural ecosystems of the area at large. The application of agrochemicals such as weed killers and pesticides and illegal hunting and egg collection activities were also commonly practised which affect Galliform birds in the study area. Land-use practices and agrochemicals remove arthropods and weeds which are essential food sources of the species and their nestling during the breeding season, and hence influence the egg-laying, chick survival, and breeding performance of Helmeted Guineafowls, resulting in species population decline (Malan and Benn, 1999). A study by Mateo *et al*. (2022) also stated that the habitat and dietary preferences of Galliformes such as the Red-legged Partridge (*Alectoris rufa*) which practice granivorous feeding habits and their preferences in cropland areas exposed to several contaminants that make them vulnerable to agrochemicals such as insecticides and fungicides. A study by Gizachew (2021) reported farmland expansion (29.7%), charcoal production, and firewood collection (21.6%) as the main threats to the Arjo-Diga Forest ecosystem. Habitat alteration, deforestation, agriculture, logging and disturbance are the primary causes of habitat fragmentation and population decline of birds (Storch, 2013; Lalthanzara *et al.*, 2014). Similarly, overgrazing, urbanization, settlement and agricultural expansion, habitat fragmentation and resource extraction were defined as the major threats to birds and their habitats in the Cheleleka Wetland (Gibru and Temesgen, 2020).

In agreement with the findings of the present study, deforestation and clearance of trees and thorn scrub for cultivation, fuelwood collection, mining, hunting and egg collection for food and source of income were reported as the main threats to the survival of Harwood's Francolin (*P. harwoodi*) and Erckel's Francolin (*P. erckelii*) in the Central Highlands of Ethiopia (Robertson *et al*., 1997; Abrha *et al*., 2017). Studies also described habitat destruction and degradation, deforestation, loss of foraging and nesting areas, overgrazing, human disturbance and settlement expansion, agricultural intensification due to the increased farming and grazing land demands, firewood collection, overexploitation, hunting and predation activities as the main threats affecting the populations of Helmeted Guineafowl and their habitats in the Abijata Shala National Park, Ethiopia (Kumssa and Bekele, 2014). Overhunting and habitat degradation due to agricultural expansion and habitat conversion are also reported as the major threats causing the population decline of Clapperton's Francolin (del Hoyo *et al*., 2014).

In the study area, deliberate fire and consistent burning of farmland areas and adjacent forest patches were commonly practised and possibly resulted in habitat destruction and impacted vital resources like foraging niches and resting sites since fire has a substantial impact on the physical, biological, ecological, and environmental features, which in turn influences the population status, habitat use, and distribution of the species (Jaiswal *et al*., 2002). The accessibility of resources supporting the ecological needs of birds, such as food sources, protective cover, roosting sites, competition, breeding sites, nesting materials, and predation pressure, is frequently influenced by environmental features, such as microclimate, habitat size and quality, and vegetation structure which in turn determines the abundance, species composition, habitat use and distribution patterns of the species (Rotenberry and Wiens, 1998; Lee and Rotenberry, 2005; Pandey *et al*., 2020).

Studies also reported that anthropogenic intrusions including agricultural intensification, settlement expansion, and investment activities impact the habitat vegetation structure and ecological traits through its effect on habitat destruction and fragmentation that influence the availability of essential resources like food and protective cover, and hence potentially determine the abundance, distribution, habitat use as well as movement of species (Soldatini *et al*., 2010; Ntongani and Andrew, 2013; Ferger *et al*., 2014; Elsen *et al*., 2017). Population growth and settlement expansion, livestock encroachment, land clearing, logging and urbanization, climate change, fire, agrochemicals, habitat alteration by invasive species and disease were reported as the main causes of the population decline of Galliformes globally (Keane *et al*., 2005; Garson and Zheng, 2006; Storch, 2013). Anthropogenic disturbance related to agricultural intensification also results in the destruction and loss of habitat, which in turn has profound effects on landscape modifications that deprive essential resources including the foraging, roosting and nesting sites of birds aggravating the decline of birds. Excessive hunting and overexploitation for food (Fuller and Garson, 2000; McGowan and Garson, 2002; Tian *et al*., 2018), habitat destruction and loss (Zhou *et al*., 2014), human disturbance (Storch, 2013), depredation (Garson and Zheng, 2006), and recreational sport, trade and cultural practices immensely threaten Galliformes population globally (Keane *et al*., 2005). A study by Ayanda and Ayeni (1980) also described habitat destruction, loss and fragmentation, illegal hunting, egg collection, human disturbance, and predation as the main causes of guineafowl population decimation.

A survey of people's knowledge and attitude towards Galliformes showed that the majority (86.36%) of the participants in the study area have prior background knowledge and awareness about Guineafowls and Francolins. They perceived these birds as important due to their economic and socio-cultural attributes such as sources of food, income, enjoyment, foster rearing and medicinal values and related traditional practices, which are in line with the findings reported in Ghana (Issaka and Yeboah, 2016). Illegal hunting and egg collection activities are commonly practised in the study area and potentially affect the Galliform population. This is aggravated by snaring and trapping practices used to catch these birds, which can make them susceptible to predation risk during capture. It is also reported that Galliformes have been extensively hunted primarily for subsistence, sport and trade. Hunters commonly catch these birds through setting leg snaring and live trapping techniques. A study by Khalil *et al*. (2015) also reported gun shooting, and trapping through trained dogs and nets as the main hunting techniques for grey francolins in Pakistan.

In the study area, about 72.06% of people surveyed have a positive attitude towards Galliformes considering their socioeconomic attributes. However, it is less than the findings by Lentijo and Hostetler (2013) who reported a 96% public attitude toward farmland birds in Colombia. The difference in public attitude towards these birds might be attributed to the difference in exposure and conservation efforts between the study areas. The knowledge and awareness of respondents about Galliformes were primarily determined by their age and levels of education. However, there were no significant differences in public knowledge related to gender and occupational status. In contrast to the findings of the present study, Hummel *et al*. (2015) reported that girls have a greater interest than boys, which might be linked to differences in experiences and exposure to these birds and conservation efforts. Those who perceived Galliformes as pests were more likely to have negative attitudes towards these birds. Respondents' age and their levels of education have significant effects on public knowledge and awareness. But gender and occupation status does not impact public awareness towards Galliform birds in the area. Furthermore, it is age and occupational status but not gender and levels of education that influence the public attitude about the conservation significance of these birds in the study area.

Crop-raiding techniques including guarding through stoning and sound production, snaring and trapping scarecrows, and related measures were predominantly employed by local farmers to protect against possible crop damage and disturbance by these birds in the area, which was in agreement with the findings reported by Tracey *et al*. (2007). Similarly, guarding, chasing, fencing, scarecrow, fencing, and smoking techniques were also reported by Kebede *et al*. (2016) in southern Ethiopia.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The Arjo-Didessa River Valley area supported a significant population of three Galliform bird species including the Clapperton's Francolin (*P. clappertoni*), Helmeted Guineafowl (*N. meleagris*) and Stone Partridge (*P. petrosus*). However, the species and their habitats in the area are under immense anthropogenic pressure and need further research and conservation intervention to protect their native habitats and preserve these birds. The population size, foraging activity and habitat uses of Galliformes in the area are potentially influenced by the seasonal differences in environmental conditions, resource availability and anthropogenic pressure. It also resulted shifts in the diet composition of Helmeted Guineafowls across spatiotemporal gradients. The breeding ecology of Helmeted Guineafowls in the Arjo-Didessa River Valley area is aligned with the local climatic and environmental conditions that significantly impact the availability of food sources, protective cover, and nesting materials. The breeding success of the species was constrained by various factors including anthropogenic disturbance, abandonment, predation and illegal egg-collection activities. The consistent practices of burning farmlands and their adjacent habitats predominantly affect the foraging niches and resting sites of Galliformes, which in turn alters the habitat use and population size of Galliform in the area. Furthermore, the application of agrochemicals and illegal hunting are among the common practices that pose a threat to Galliformes and their habitats. The promising public understanding and positive attitude of local communities towards the conservation significance of Galliformes with support from the government can play a significant role in the conservation and maintaining a stable population of Galliform birds and their native habitat in the region.

6.2 Recommendations

Galliformes and their habitats in the Arjo-Didessa River Valley area are under immense anthropogenic pressure owing to a wide array of interrelated threats that urge immediate conservation intervention. Hence, the following interventions are essential to safeguard the species and protect their habitats.

- Further research efforts and conservation interventions are crucial to understand the post-hatching successes and consistently monitor the population trends of Galliform birds in the region.
- Maintaining the foraging and breeding sites could enhance the breeding performance and hence support the conservation of the species in the region.
- The possible impacts of agrochemicals such as insecticide utilization practices on arthropod population density and their probable effects on the distribution patterns, habitat uses and breeding phenology of Galliformes should be studied.
- A community-based conservation intervention including community education and outreach is indispensable and should be strengthened to raise awareness and enhance public understanding of the conservation significance of Galliformes, sustainably maintain the ecosystems and promote human-Galliform co-existence.
- Engagement of stakeholders and collaboration are exceedingly vital and need to be strengthened to mitigate threats in a way to maintain the population of these birds and sustainably protect their ecosystem in the region.

- Furthermore, conservation actions, habitat protection and management strategies should comprise increased legislation and law enforcement to control illegal hunting and logging activities.

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APPENDICES

APPENDICES 1. Questionnaire survey to assess the conservation threats, public knowledge and attitude towards Galliform birds.

General directions:

Dear respondent, the value of this research paper highly relies upon the truthfulness of your response. So, your sincere cooperation in attempting each question is highly important and you are kindly requested to fill each item properly.

- No need to write your name.
- Try to read each question carefully before going to answer.
- Indicate your answer by marking “□” or by writing in the space provided.
- Do not forget to return.

Thank you in advance for your cooperation!

1. Socio-Demographic Status of Respondents

i. Gender: □ Male □ Female

ii. Age: □below 18 □ between 18 and 30 □between 31 and 45 □ above 45

iii. Occupational status: □Farmer □Student □Government Employee □Others

iv. Level of Education: □ Illiterate □Elementary □High School

□College □University Graduate

2. Do you know Galliform birds □Yes □ No

If yes, which species________________________________.

3. How often do you see Galliformes? □Always □Sometimes □Only during farming seasons.

4. What is the expected flock size of Galliformes you watched?

□ between 2 and 5 □ between 6 and 10 □ between 11 and 15 □ More than 15

6. Do you think that Galliformes are pests to farmlands? □Yes □ No

If yes, in what season do you experience them? □ sowing season □ harvesting season □ other

7. What type of seeds do these birds prefer in farmlands: □sorghum □millet □maize □rice □other ____.

8. Have you ever hunted Galliformes/collected their eggs? □Yes □ No

If yes, which techniques did you use to catch them ____.

9. For what purpose did you hunt these birds? □For food □For sale □For recreation □Others if any ____.

10. What factors affect the population of Galliformes and their habitats?

□ Habitat destruction □ Overgrazing □ Fire □ Hunting□Egg collection

□Investment expansion□ Agricultural activities □Agrochemicals

□Others ____.

APPENDICES – 2

Field data sheet used to study the feeding ecology of Helmeted Guineafowl (*Numida meleagris*).

Date of data collection	Field station/site	Habitat type	Survey year	Season	Weather condition	Time of observation	Food item	Foraging habit	Foraging interaction	Remark

APPENDICES – 3

Field data sheet used to study the breeding biology of Helmeted Guineafowl (*Numida meleagris*)

3.1 Breeding habitat characteristics and nest status

Nest No	Nest site location	Nest habitat characteristics	Nest building materials	Nest status	Causes of breeding failure	Remark
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
16						
17						
18						
19						

3.2 Eggs morphometric measurements

Nest No: ______________________

Egg No	Egg length/mm	Egg width/mm	Egg weight/gm	Remark
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				

3.3 Nest building materials

Nest No.	Nest building materials					
	Grass	Leaves	Feather	Straw	Others	Remark
1						
2						
3						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

PLATES

Plate 7. Nesting habitat features of Helmeted Guineafowl in Arjo-Didessa River Valley area (©Yihenew A., 2019).

Plate 8. Egg morphometric measurements of Helmeted Guineafowl (A = Egg weight/g, B = Egg width/mm and C = Egg height/mm) (©Yihenew A., 2019).

Plate 9. Features of successfully hatched nests of Helmeted Guineafowl in the Arjo-Didessa River Valley (©Yihenew A., 2020).

Plate 10. Causes of breeding failure of Helmeted Guineafowl (A = nest predation, B = egg collection) (©Yihenew, 2019.

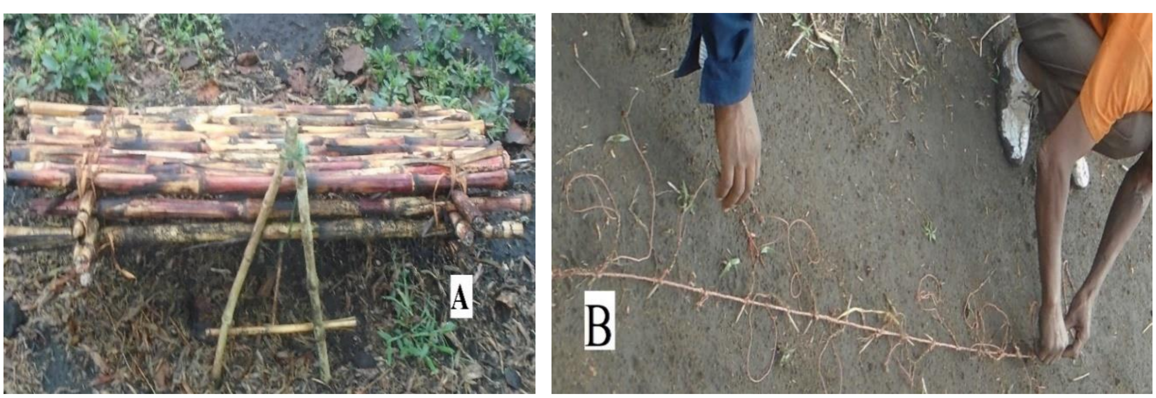

Plate 11. Galliform hunting practices in the Arjo-Didessa River Vall area (A = live trapping, B = snaring) (©Yihenew A., 2020).