College of Natural Sciences

School of Graduated studies

Department of Biology

The Diversity, Runway cross pattern and the Potential Hazards of Mammals on Aviation activities; the case of Aba Jifar Airport, Jimma, Ethiopia

By: - Munewer Kedir

Advisors; -

Main advisor: - Tadesse Habtamu (PhD)

Co advisor: - Galaye Geberemichel (PhD Candidate)

A Thesis Submitted to Department of Biology, Collage of Natural Sciences, Jimma University, In Partial Fulfillment of the requirement for the Degree of Master of Science in Biology (Ecological and Systematic Zoology)

May, 2021

Jimma, Ethiopia

JIMMA UNIVERSITY,

COLLEGE OF NATURAL SCIENCES,

DEPARTMENT OF BIOLOGY

The Diversity, Runway cross pattern and the Potential hazards of Mammals on Aviation activities; the case of Aba Jifar Airport, Jimma, Ethiopia

By: - Munewer Kedir

Advisors; -

Main advisor: - Tadesse Habtamu (PhD)

Co advisor: - Galaye Geberemichel (PhD Candidate)

A Thesis Submitted to Department of Biology, Collage of Natural Sciences, Jimma University, In Partial Fulfillment of the requirement for the Degree of Master of Science in Biology (Ecological and Systematic Zoology)

May, 2021

Jimma, Ethiopia

Declaration

I, the under signed, declare that this thesis is purely my work and all sources of materials used for this thesis have been properly acknowledged. I declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Name: Munewer Kedir

Signature_______________

Name of institution: Jimma University

Date of submission ________________

Thesis has been submitted for examination with my approval as University advisor.

Name	Signature	Date
1. Tadesse Habtamu (PhD)	_______________	_______________
2. Galaye Geberemichel (PhD Candidate)	_______________	_______________

Approved by the examining board

Name	**Signature**
Chairman, Head Department	
Gadisa Natea (MSc)	________________
Research advisors	
Tadesse Habtamu (PhD)	________________
Galaye Geberemichel (PhD Candidate)	________________
Examiners	
External Examiner	
__________________________	________________
Internal Examiner	
Tsegaye Gadisa (PhD)	_________________

Acknowledgements

First and foremost, I would like to thank, the Almighty Allah who made it possible, and gave me the health, strength, patience and support for completion of the study.

I would like to express my deepest gratitude and appreciation to my advisor Dr. Tadesse Habtamu for his constant guidance, invaluable inspiration, brotherly approach, encouragement, unreserved supports and constructive comments throughout my thesis from the beginning up to the end time. He is also highly appreciated for provision of field equipment's. My deepest gratitude also goes to my co-advisor Ms. Galaye Geberemichel for her unreserved and consistent guidance and encouragement from proposal writing to the end of this thesis work. Her critical comments, immediate response and valuable suggestions are greatly acknowledged.

I would also like to express my special appreciation to Dr. Tsegaye Gadisa for his valuable suggestions during the proposal design and research work as well as providing me field equipment's needed for data collection. I would like to extend my appreciation to Jimma Aba Jifar Airport workers for their kind cooperation. I would like to thank Bekelu Wuletaw, the airport officers and Shifera Talta, the airport security officers, who offered me permission and unreserved support during field survey.

I am highly thankful to my family (Brothers and Sisters) for their moral and financial support as well as constant encouragement during my study. Finally, I am also highly indebted to my friends who were directly or indirectly involved to add their efforts, encouragement and moral support for the accomplishment of this study.

Table of contents

Contents Page

List of tables **Page**

List of figure **Page**

Acronyms

AJAC	Aba Jifar Airport Compound
ECAA	Ethiopian Civil Aviation Authority
EL	Ear Length
EMA	Ethiopian Meteorological Agency
FAA	Federal Aviation Administration
HB	Head-Body Length
HF	Hind Foot Length
ICAO	International Civil Aviation Organization
IUCN	International Union for Conservation of Nature
LC	Least Concern
TL	Tail Length
WHMC	Wildlife Hazard Management Committee WHMP
Wildlife	Hazard Management Plan

Abstract

Studies on the diversity and abundance of airport mammals help to evaluate their potential impacts to aviation industries. This study was aimed to record diversity, relative abundance and runway cross pattern of mammalian species in Aba Jifar airport compound, Jimma, Ethiopia. The study was conducted between February and August, 2020 and covers two seasons. To survey and record mammalian species, the 420 ha area of airport compound was conveniently divided in to three blocks (Block I, II and III). To record small mammal diversity, in each block about 30 to 40 mixed live and snap traps were randomly set at about 10 m interval between traps. Line transect method was employed to record medium and large mammalian diversity. Five transects, two for each grassland blocks (I & III) and one for block II (runway) were established along the east-west direction of the airport compound. Each transect has 4 km length and about 200 m space between each. Data for nocturnal mammals and night time runway crossing patterns of mammals sensor camera traps were used. Indirect methods such as dropping, pug mark, scat, and calls were also used to record the presence and absence of mammals. Total count procedure was used to record the dominant species (Bohor reedbucks). A total of 20 species of mammals were recorded, of which five were small mammals. Some of the recorded small mammals were Lophuromys flavopunctatus, Mus musculus and Rattus rattus, while reedbuck, hyena, bush pig, jackal and civet were medium and large sized. The highest species diversity of small mammals was recorded during the dry season (H'= 1.56), while the least was during the wet season (H'= 1.54). Lophuromys flavopunctatus was the most abundant species with 43(30.5%) individual, while the least was Rattus rattus 18(12.77%) individual during both seasons. Regarding medium and large sized mammals, the highest species diversity was obtained during the dry season (H' =1.44), while wet season was the least with (H= 1.42). Bohor reedbuck was the most abundant species with 251 (60.77%) average number of individuals, followed by spotted hyena 134(16.22%) and Bush hyrax was the least 2 (0.24%) in both seasons. Reedbuck and hyena frequently crossed runway and seem potential hazardous species for the aviation activities. Translocating, at least, part of the reedbucks to reduce runway cross and to lower carnivores visit, is recommended to enhance safe aviation activity and to reduce the risk and safeguard the endemic reedbuck sub-species.

Key words: Aba Jifar Airport, Diversity, Relative Abundance, Mammals, Runway cross.

Introduction

1.1 Background

Ethiopia has a large land area with varied topography that produced a wide range of climate and provided diverse ecosystems ranging from humid forest and extensive wetlands to deserts. As a result, it is one of the biodiversity rich countries in Africa (Yalden *et al.,* 1996). The diversity and distribution of plant, animal, settlement and the types of agriculture varied with altitude. Temperature, rainfall and vegetation play major roles in determining the distribution of flora and fauna including that of endemic mammals (Yalden and Largen, 1992). Ethiopia is among the few African countries with high mammal species diversity. Over 320 species of mammals (40% small mammals) are recorded from Ethiopia of which 55 are endemic (Lavrenchenko and Afework, 2017).

Mammals are the most important components of biodiversity all over the world. They are important for the proper functioning of ecosystems. They serve as plant pollinators, in seed dispersal, nutrient recycling and balancing populations through predator-prey interaction (Ojeda *et al*., 2000). However, they faced with a number of challenges across its range. Habitat loss, overhunting, developmental activities, urbanization and human encroachment are among the reason for threatening the survival of mammals (Vaughan *et al.,* 2000). Beside their ecological and economical values, mammals sometimes negatively interact with humans, such as becoming major crop pest, domestic animal raiders, becoming reservoir for deadly zoonotic diseases (e.g. rabies) and cause human fatalities. In addition, those inhabiting airport compounds may become potential hazards for aviation industries. This is because they collide with aircrafts and cause severe accident when they inhibit in or around airport compounds.

Wildlife strikes have occurred ever since the beginning of aviation activities and it is still major concerns of aviation industries worldwide. Globally, aircraft incidences due to wildlife strikes are under reported, since 1988; wildlife strikes have killed over 282 people globally and destroyed over 263 aircraft (Dolbeer and Begier 2019). Wildlife collision costs the industry over 2 Billion USD annually (ICAO, 2009). Birds make up 97% of the reported hazards. Though the hazardous share is low, the resulting damage from mammalian strike can be serious (Wendy *et al.,* 2000).

In Ethiopia aviation industry built reputed history in providing service, however, incidences of wildlife strike are not uncommon. For instance, in 1988, bird strike caused a loss of 35 people in Bahir-Dar (Lewis, 1995). Apart from posing a serious danger to air transport and passengers, wildlife strikes increases airline operational costs. Records of the Ethiopian Civil Aviation Authority (ECAA) indicate that Ethiopian Airlines lost average over 2.5 million dollars each year to repair equipment damaged due to wildlife strike (Elizabeth *et al*., 1996). Airport compounds and their surrounding areas are unique and often have productive habitats and provide niches (food, water, cover) and secured sites for breeding/nesting for different wildlife taxa including mammals, birds, reptiles and others. Reptiles, small and medium sized mammals in airport compound are potential attractants for carnivores and raptors that are hazardous for aviation activities. Birds and mammals are among the most attracted airport wildlife species (Wendy *et al.*, 2000; Tadesse *et al.*, 2012).

Studies on the diversity and abundance of mammalian fauna and recording their rhythmic runway crossing activities in airports help to predict their potential impacts on aviation activities. For the unique habitats in airports and the surrounding areas, it created conducive condition to host diversities of wildlife species and in some cases, become the last refuge for some rare species (such as large ungulates). As the number of mammalian species and their population increase in these areas, their potential hazardous on the aviation safety equally increases. Studies on wildlife composition in airport compound are minimal (e.g. Bird by Elizabeth, 1996; Tsegireda, 2011; Aschalew *et al*., 2017) and mammals (e.g. Tadesse *et al.*, 2012). However, wildlife faunal records (such as mammals and bird) and assessments regarding their potential aircraft strike hazards are overlooked.

Aba Jifar Airport (AJA) in Jimma was established in 1964 and is one of the oldest airports in Ethiopia. Like most other airports, Aba Jifar airport created good habitat for different wildlife species including the endemic sub-species of Bohor reedbuck (*Redunca redunca*). This airport is probably the unique of its kind in hosting large population of this ungulate out of protected area (Tadesse *et al.*, 2012). Following its recent expansion (2015), total area of the compound doubled and well fenced, which in turn provided conducive area for the growth of wildlife population there in. Currently, not only reedbuck, the populations of other mammalian species that are particularly hazardous to aircrafts are increasing in the area, but their species composition and expected potential impacts on aviation activities are not yet assessed. Therefore, the aim of this study was to record species diversity, abundance and daily runway cross pattern of mammalian fauna that can be potential risks on aviation activities in AJA, Jimma zone western Ethiopia.

1.2 Statement of the problem

Wildlife strikes are common occurrences across the World and become issues of national and global concern in recent years. Globally, mammalian aircraft strike problems are a serious safety issue and causes loss of human life and cost airline industry (Cleary and Dolbeer, 2005). Information about the risks posed to aircraft by certain wildlife species has increased in recent years. The poorly reported statistics show that aircraft collisions with mammals and other wildlife are serious economic and public safety problems worldwide (Cleary *et al.*, 2010). Many wildlife species such as otters, deer, coyotes, jackals, squirrels, dogs, foxes, mongooses and reedbucks are among frequently reported to cause aircraft strike (Hesse *et al.*, 2009; Tadesse *et al.*, 2012). The present study area, AJA compound; provides suitable habitat for wildlife animals dominantly reedbuck and many other nocturnal mammals. It was reported that reedbucks regularly cross runways throughout the day, but most in three peaks (Tadesse *et al.*, 2012). However, at that time the airport was not expanded and traditional guarding system were used to prevent reedbucks from crossing runway.

Aba Jifar Airport expansion project doubled the area of the compound and the service upgraded to host international flight for 24 hrs. As aviation service increased the usual management interventions to reduce hazardous may not be effective to prevent wildlife aircraft risks. In addition, the areal expansion, associated with standard fencing and better security is expected to raise the size of the resident population of Bohor reedbuck and other mammalian species native to the area. However, current status of these mammals is not known to predict their hazardous potential. Such ecological survey of the mammalian fauna in this study area helps to investigate mammalian status and alert airport management to design effective control measures. Currently, AJAC host large population of reedbuck and many more mammals with high aviation risks. Like any other airports, incidences of aircraft wildlife strikes are occasionally observed. For instance, one incidence was recorded in Feb, 2020 that end by scarification of the animal, but with no harm on passengers and aircraft, hence urges the need for assessment of mammalian fauna of the area to provide a baseline data and help to identify mammalian species considered hazardous on the aviation safety. Therefore, the present study was aimed at recording mammalian species diversity, abundance, runway cross activity and predict mammalian problem to aviation service at Aba Jifar airport compound, Zima zone, western Ethiopia.

1.3 Objectives of the study

1 .3.1 General objective

The general objective of this study was to record mammalian species diversity, relative abundance, runway cross patterns and evaluate potential impacts they may posed on aviation activities at Aba Jifar Airport, Jimma, Ethiopia.

1.3.2 Specific objectives

The specific objectives of this study were: -

- To assess the diversity of resident and transient mammalian species in Aba Jifar airport compound (AJAC).
- To estimate the relative abundance of each mammalian species in the AJAC for two seasons.
- To examine daily runway cross patterns of major mammalian species in AJAC.
- To correlate runway cross patterns of mammalian species with the major airport activities and predict potential impacts on healthy aviation services and recommend plausible management alternatives in the AJAC.

1.4 Significance of the study

Recording mammalian species diversity and abundance at Aba Jifar airport compound will greatly aid in the formulation of a wildlife hazard management strategies. The study also helps the airport management to evaluate level of vulnerability to mammalian incidents, prioritize, hazardous species for management and implement or improve management techniques. The recommendations made at least may assist airport management to develop and implement effective wildlife management plan to reduce the risk of mammalian strike problem.

.

2. Literature review

2.1 Mammalian diversity

Mammals are among the most widely distributed organisms in the world. They are the most varied and adaptable animals, which survive in the broadest range of habitats from oceans to the poles and from deserts to forests (Afework and Lavrenchenko, 2017). Mammals inhabit every terrestrial biome, from deserts through tropical rainforests to polar icecaps. They can success fully colonize diverse habitat types due to diversity in size and morphological, physiological, and behavioral adaptation (Flym *et al.*, 2005). Mammals range in size from the very small to the largest animals known to have existed. The smallest mammals are those shrews and bats (weight less than 2 kg) to the largest mammal's blue whale which, weigh over 160 tones. The largest terrestrial mammal is the African elephant which can be 3.2 m tall at the shoulder and weight 5.5 tons (Mugatha, 2002).

Today more than 5416 species of mammals, of which 2277 (42%) rodents (Rodentia), 1116 (20.6%) bats (Chiroptera) and 428 (7.9%) shrews and allies (Soricomorpha) comprise the largest species (Wilson and Reeder, 2005). Ethiopia possess unique ecosystems from most of tropical countries, so it has high level of biodiversity and endemism due to wide geographical variation resulted in diverse climate, vegetation, soil, topography and drainage patterns (Yalden, 1983). The species of mammals are estimated to be around 320 species, of this, small mammals constituted 40%; while 60% are medium and large sized mammals (Lavrenchenko and Afework, 2017).

Mammals are the most important components of biodiversity all over the world. Small mammal play important role in natural communities, and provide the main supply of living food for many of the predatory mammals, birds and reptiles. As small mammals influence ecosystems in many ways, dynamics of their diversity is a good indicator of habitat disturbances caused by anthropogenic loads and global climate changes (Lavrenchenko and Afework, 2017). They have diverse ecological, economic, social, medical, cultural, educational, and research values (Tadesse and Afework, 2008).

Medium and large sized mammals are very important for the proper functioning of ecosystems. They are responsible for plant pollination, seed dispersal, nutrient recycling and balancing populations through predator-prey interaction (Ojeda *et al*., 2000). However, the populations of mammals have been declining throughout the world, due to loss of habitat, expansions of agriculture overexploitation, loss of genetic diversity, developmental activities, endangerment and extinction (Vaughan *et al.,* 2000).

2.2 The nature of airports

Airports are complex systems, providing infrastructure and services for the operations of aircraft and handling of passengers and cargo. This requires adequate airfield, including a runway, aircraft parking apron, and terminal facilities for passengers, cargo, general aviation, and aircraft maintenance as well as supporting fixtures for access circulation/car parking, utilities, and other facilities. Airports have developed in response to the overall traffic growth, providing infrastructure and services to their airline customers. Within this airport system, the typical role of an airport operator is to provide and maintain all necessary infrastructure as well as essential services (Ashford *et al.,* 2013).

In addition to giving services for aerial transport operations, airports are productive and secured area that provides feeding/breeding sites for different group of wildlife species. The natural environment and other human activities inside and near the vicinity of airports attract a wide range of wildlife, due to availability of food, water and cover (Gleizer *et al*., 2005). Airports are mostly established in plain areas that are free from other developmental activities and relatively far from cities. Airport environment is mostly unaltered habitats that are dominated by grasslands and wetlands which provide food, water and better protection for wildlife. This attracts wildlife, mostly birds and mammals are among the most attracted airport wildlife species (Wendy *et al.*, 2000; Tadesse *et al.,* 2012). Wildlife populations at airports are considered as hazardous to the aviation industry, because they collide with aircrafts and cause severs accidents. The main goal of wildlife hazard management plan is to minimize wildlife populations on and around an airport that pose a threat to aviation safety. To ensure the safety of airport, wildlife in and around the vicinity of the airports should be managed effectively (Dolbeer *et al.,* 2015).

2.3 Jimma Aba Jifar Airport

Jimma Airport is one of the oldest airports in the Ethiopian aviation history, established in 1964 and with 1234 average flights annually transporting over 22,000 passengers. Recently, however, the airport has been given an upgrading priority to an international standard with all facilities to host international flights. The upgrading program incorporates the expansion of the compound that doubles the previous area (Tadesse *et al.,* 2012). The Ethiopian Airport Enterprise built a new airport in the ancient town of Jimma. The new airport lies on 4665.76 sq.m. plot adjacent to the old Jimma Airport. The new airport runway has four km long and width 60 m. The passenger terminal is a one store building that has restaurants, shops, bank workshop compartment, offices and it can serve 220 passengers and also the apron can accommodate four aircraft at a time.

The airport meets international standards that enable people to transport their products and raw materials to the national and international market. The airport was handle Jimma to; Addis, Hawasa, Gambela, Assosa and Arbaminch flights. As Jimma is a historical town the new airport is believed to play a significance role in boosting the local tourism industry. The Abba Jifar palaces and Awetu Park are some of the tourist attraction sites. Jimma is also known for high coffee production. Jimma Aba Jifar airport is established at the extended wetland plain and flooded grassland far from the city towards the south. This wilderness area remained the last stronghold for most grassland plain that can support a variety of wildlife species dominantly Bohor reedbucks. The change in the land use pattern of the surrounding areas (swampy grassland with eucalyptus plantation) further attracted wildlife to the airport compound. This condition, sooner or later, inevitably posed threat to the growing aviation activities (Tadesse *et al.,* 2012).

2.4 Aircraft-wildlife strikes

Collisions between animals and aircraft are known as wildlife strikes and it is a major concern of aviation industries worldwide. Wildlife-aircraft strikes are a serious and growing problem worldwide. It is becoming a serious safety issue and causes extensive life-threatening damage in the industry. The first powered flight by the Wright Brothers occurred in 1903, and the wildlife strike problem began shortly thereafter. On 7 September 1905, the first reported bird strike occurred, as recorded by Oliver Wright in his diary, when his aircraft hit a bird (a red-winged blackbird). The first reported mammal strike occurred in 1909 at the start of Louis Bleriot's historic first flight across the English Channel from Les Baraques, France, occurred when a farm dog ran into the propeller (Cleary and Dolbeer, 2005). The number of strikes is continually increasing, and evidences revealed that wildlife-aircraft strikes have been an issue since the earliest days of manned flight. Wildlife strikes relatively increasing as aviation service become increased. For instance, between 1990 and 2011 alone, over 115,000 wildlife strikes were reported. Most wildlife strikes occur in the airport environment, when the aircraft is ≤500 ft. (152 m) above ground and also when the aircraft is on the ground during landing or takeoff (MacKinnon, 2004).

Aircraft collisions with birds, mammals and other wildlife strikes continue to be a serious aviation safety issue. Strikes involving mammals, poses significant damage, since their sizes are greater than those of birds. Even small mammals inflict their share of damage; during takeoff and landing, often resulting in damaging runway excursions. Wildlife strike become a serious problem in areas where airports are situated in places with different ecological set ups, such as grasslands, built up areas, farmlands, wetlands, water bodies and waste disposal site (Cleary and Dolbeer, 2005). Land use patterns of the airports and the surrounding areas are among the major reason for attracting wildlife to airport. For example, areas with tall grasslands can provide resting sites for deer. Tall grassland areas also provide cover for small mammals, which attract hazardous wildlife predators including raptors and coyotes (DeVault *et al.,* 2017).

Wildlife-strike data indicates that a number of mammal species have been struck by aircraft in North America. Some, such as deer and Coyote, are directly involved in collisions with aircraft. Nearly 70 percent of all reported mammal strikes in North America involve deer, making this animal the greatest mammal hazard. More than 40 deer strikes are reported annually in North America many resulting in significant aircraft damage. Of the two North American species of deer-Mule Deer and White-tailed Deer, involved in mammal strikes, the White-tailed Deer is the greater hazard due in part to its wider distribution. Coyotes are second only to deer as the most hazardous mammal at North American airports (MacKinnon, 2004).

Small mammals are not a direct threat to aviation; however, they also attract avian predators and large carnivorous mammals. Small mammal populations fluctuate significantly depending on the time of year, quality of habitat, and predator populations. Small mammals require thick vegetation to provide protection from predators (DeVault *et al.,* 2017). Maintaining shorter grass can decrease the amount of small mammals that inhabit the airport. A noticeable increase in avian predators and carnivores can be an indication that small mammal populations are increasing. Grass height in airport habitats can often influence the amount of bird activity. Vegetation provides both a food source and cover for many bird and mammalian species (Cleary and Dickey, 2010). Short grasses may attract geese, gulls and flocks of blackbirds to an area, while longer grasses may produce more seeds attractive to other birds and potentially small mammals. Grass heights can affect the overall attractiveness of the airfield to wildlife and prey species such as insects and small mammals. The FAA recommends that grass heights within the perimeter fence be maintained between 6-12 inches to reduce the overall attraction (Cleary and Dickey, 2010).

2.5 Mammalian behavior that can create aviation hazards

Collectively, mammals show a diverse and complex array of behaviors' that vary with the time of day season, environmental conditions and species.

a. Periods of activity

The majority of mammals are nocturnal; they are active at night. The presence of tracks and droppings are often the only clues that mammals inhabit an area. Identifying these clues and determining which mammals occupy an airport environment is critical in reducing potential hazards, since more than 60 percent of reported mammal strikes occur at night. Some mammals; including rabbits, hares and deer are most active during the early morning and evening periods. They spend mid-day and night at rest. Other mammal species such as squirrels and large herbivores are active only during the day (MacKinnon, 2004).

b. Feeding

Approximately 80 percent of mammal species are herbivorous, living on leaves, shoots, roots, twigs, buds and seeds. Many mammals are attracted to airport environments by grass fields and by trees and shrubs often found growing at airfield perimeters. Most herbivores feed on specific types of vegetation, so eliminating or controlling these food sources can be a primary management method. For example, deer activity can be reduced through removal of shrubs and early succession-forest habitat that provide browse. Similarly, grass-management programs that control broad-leaf cover and seed production can reduce small mammal populations (MacKinnon, 2004). Carnivores are the second most common group of mammals living in airport environments, and are attracted by the presence of small mammals. The presence of Coyotes and foxes indicates healthy populations of small mammals including voles, mice, rabbits and hares. The management of prey populations is often the best means of reducing predator numbers (DeVault *al.*, 2017).

According to MacKinnon (2004), mammalian behaviour that is hazardous to aviation can be grouped as; behaviour that creates direct and indirect threats to aviation, and behaviour that creates other aviation hazards in the airport environment. Mammalian behaviour that creates direct and indirect aviation hazards are, movement and social behavior; while gnawing and burrowing are behaviour that creates other aviation hazards in the airport environment.

2.5. 1 Mammalian behaviour that creates direct and indirect aviation hazards

a. Movements

Mammals do not roam randomly; their daily activities occur within well-defined home ranges and territories. There is great variation in the size of these home ranges, which are key in determining local-population densities. The home-range size is correlated to species size; larger mammals are more mobile and require greater food resources, so they occupy more territory. Home-range movements vary by species. Many carnivorous species move constantly throughout their home range in search of prey. Other species make local movements between different habitats within their home range, responding to local and seasonal changes in abundance of specific food types, or specific breeding habitat requirements. During breeding season, the search for a mate may extend a male's typical home range. Many small rodent species are amazingly static animals, moving less than a few hundred yards in the course of their daily activities. A number of mammals, particularly larger ungulate species such as deer, undertake seasonal migrations. Knowledge of these movements helps wildlife-management personnel reduce the hazards of larger mammals (MacKinnon 2004)

b. Social behavior

Mammals exhibit complex social behaviour in all aspects of their lives. Knowledge on behaviour of mammals provides valuable information for airport wildlife-management personnel specifically in relation to the way individual mammals associate. Some live in small loose groups; others form well-structured herds and packs, or live in highly organized colonies. The majority of North American rodents live solitary lives within their territories. In contrast, a few species of rodents-marmots, ground squirrels and prairie dogs are colonial and live communally in large numbers. Colonial rodents often live in dens and burrows, which members of the colony build and defend collectively. The large, undisturbed grass fields of airports are attractive to such colonies. Ungulates, such as deer, Elk and Caribou, live in groups and herds varying from three to several hundred animals. The White-tailed Deer and Mule Deer are the most common herding species in most parts of North America (MacKinnon, 2004; Biondi *et al.*, 2011)

2.5.2 Mammalian behaviour that creates other aviation hazards

a. Gnawing

Rodents are distinguished by two pairs of specialized, chisel-like incisors used to gnaw and clip vegetation, twigs, bark and seeds. The need to chew leads many rodents to gnaw instinctively on such hard materials as wood, plastic and even soft metals, and often poses a threat to airfield lighting cables, fixtures and to interiors of buildings and aircraft. They can also cause problems at airports by gnawing on cables and wires, and by nesting and storing food in buildings, maintenance equipment and parked aircraft. For airports, which support large populations of small mammals, damage costs caused by gnawing can be significant.

b. Burrowing

Digging and burrowing behavior common to many mammal species is a cause for concern in airport environments. Some mammals, such as Coyotes, foxes and wolves, dig and occupy dens solely for the purpose of rearing young. Groundhog, ground-squirrel and prairie-dog burrows provide nesting sites, shelter for sleeping and protection from predators. These mammals indirectly involved in aviation hazards by attracting larger predatory birds and mammals to airport environments Burrowing activity threatens grass-management programs at airports, interfering with cutting blades and the wheels of cutting machinery. Burrowing can also cause the collapse of runway and taxiway shoulders (MacKinnon, 2004)

2.6 Wildlife Strike Management

Wildlife management involves manipulating an animal's behavior or its habitat in order to achieve a specific goal with regards to an animal's behavior, population, or geographic distribution. At aerodromes, the goal of wildlife management is to change the behavior of animals so that they do not occupy critical safety zones where aircraft operate. The key to managing wildlife at airport is to understand the animals' basic requirements and how their behavior can lead to an aviation safety hazard (Dolbeer *et al.,* 2015). The first step of managing wildlife hazard is to assess the level of risk that each species of animal presents to aircraft operations at the aerodrome. This risk assessment is important to identify the species found in and around the airport; it involves assessing the likelihood of each species striking an aircraft and the probability and extent of damage that may result. The Risk assessment should also identify the biological factors that cause different wildlife species to present a risk to aviation safety. Identification of these factors will greatly aid in the formulation of wildlife hazard management plan (DeVault *et al.,* 2017).

Frequency of mammalian incidents and mammalian species involved in incidents vary by airport type. White-tailed deer were the most commonly observed around airport of North America (Biondi *et al.,* 2011). Therefore, airports may be vulnerable to different mammalian species, making a distinct management regimen necessary for each airport. Adequate management techniques are needed to reduce mammalian risk to aircraft and provide a standardized process for airports to evaluate their vulnerability to mammalian incidents, prioritize hazardous species for management and implement or improve management techniques (Dolbeer *et al.,* 2000).

The Ethiopian Airports Enterprise has planned to implement an integrated wildlife management plan at all airports. Management approaches will include habitat management to reduce the overall attraction of the airport and its surrounds. This usually involves providing training and equipment to airside operations staff to disperse or remove wildlife hazards. Engagement with stakeholders is also a critical element to ensure a truly integrated program. In order to deliver its quality services in a safe reliable and sustainable manner a comprehensive development and management of the airport physical environment and its environs is equally important as fulfillment of other facilities which have already been put in place. This could enhance or promote safety which enables the airport to comply acceptable standards (DeVault *et al.,* 2017).

3. Materials and Methods

3.1 Description of the study area

This study was conducted in Aba Jifar Airport Compound (AJAC), which is located at 2.5 km southwest of Jimma town, capital of the zone. The new airport lies on about 4.7 km^2 area, including the old Jimma airport and geographically located at 7°39’30” to7° 40’30” N, 36°40’ 30” to 36°50’ 0”E and altitude of 1703 m (Fig.1). The extensive wetland formed by over flow of the perennial Kitto River flowing along the northern side of the airport provides permanent moisture to the study area. The area is dominated by few species of grasses, including *Stipa keniensi*, *Hyparrhenia rufa, Sporobolus pyramidalis* and *Eulalia polyneura*. The small hills surrounding the drainage ditches are covered by dense shrubby thickets formed by few plant species like *Dwarf Rhusglutinosa, Psidium guajava, Rubus steudneri, Vernonia auriculifera, Maesalanceolata, Carissa edulis, Calpurnia aurea, Pterolobium stellatum, Achyranthes aspera, Lantana trifolia, Maesa lanceolata and Solanum incanum* with other tall grasses, serve as den for a variety of mammals dominantly, Bohor reedbuck (Tadesse *et al.*, 2012).

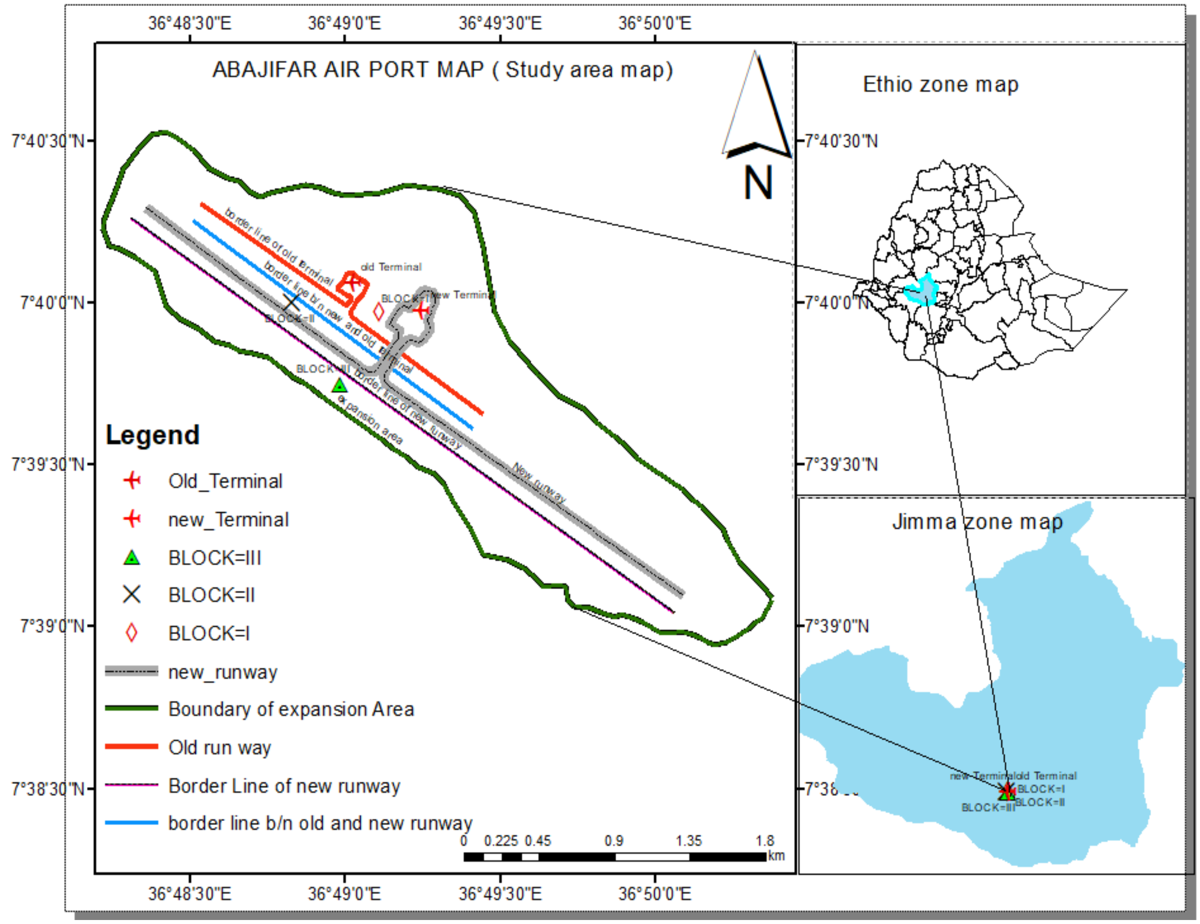

Figure 1: Map of study area

3.1.2 Climate of the study area

Five years data for temperature and rain fall was collected from Ethiopian Meteorological Agency, West Oromia, Jimma Sub-branch (EMA, 2020). The rainfall of the area is one long rain season between, May to September and dry season December to February. The annual rainfall ranges from 1429 to 1935 mm, with the highest peak rainfall in August (with mean monthly rainfall of 1221.5mm) (Figure 2).

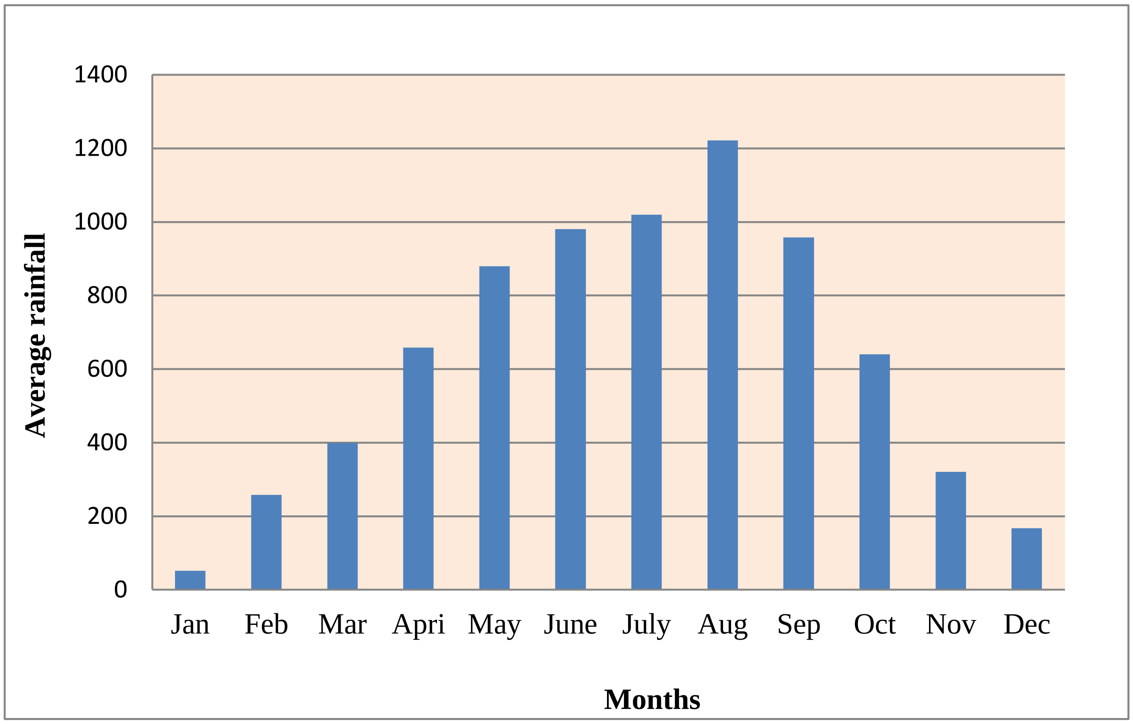

Figure 2: The mean monthly rainfall of the study area (2016 -2020) (EMA, 2020)

The maximum monthly temperature is 30.2°C recorded in February, while the minimum monthly temperature is 7.53°C, recorded in December. The mean daily temperature of the study area is 19.3°C (EMA, 2020) (Fig. 3).

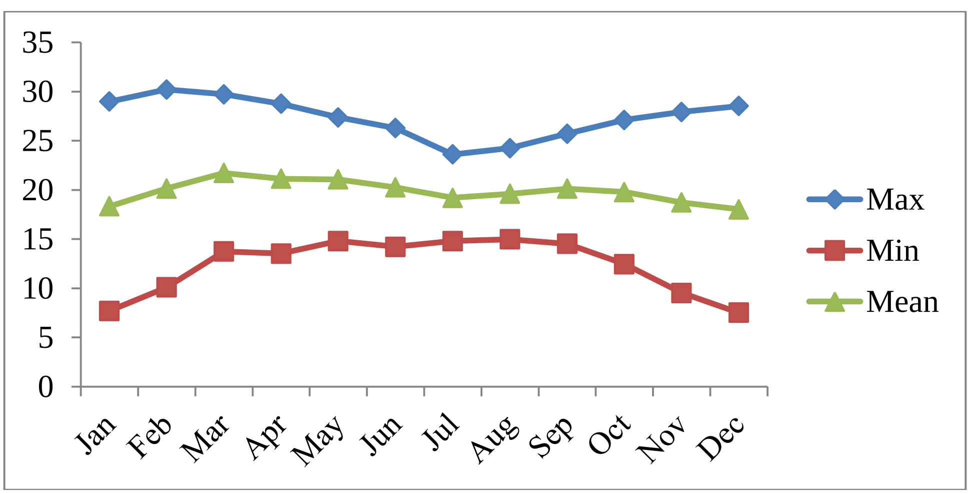

Figure 3: Mean monthly minimum and maximum temperature of the study area (EMA, 2020)

3.2 Materials

During this study, material such as sensor camera, Binoculars (7x50mm), Geographic Positioning System (GPS), mixed live and snap traps, bait (peanut butter and barley flour), Meter rope, Ruler, Pesola spring balance, note books and field guides book to African mammals Kingdon (1997), Solomon (2008), Afework and Yalden (2014) were used for data collection.

3.3 Methods

3.3.1 Preliminary Survey

Preliminary survey was conducted late October, 2019. During this survey actual size of the study area was confirmed, habitat types were described, the whole area was classified in to small blocks based on distinct features such as runway, west, east, north and south sides of the runway. To survey and record mammalian species, the area of Aba Jifar airport was conveniently divided in to three blocks (Block I, II and III). Block I was the area from the main gate-way, which covers north of the old runway including left and right side of the terminal area. The area between the old and the new runway was assigned block II and the area between the new runway and the southern border fence area was assigned block III (Fig. 1).

3.3.2 The study design

During this research mixed live (sherman and snap) trapping procedure with standard equipment were used for small mammalian record. Line transects survey, sensor camera trapping techniques and indirect methods were used to record medium and large sized mammals. Diurnal runway cross was recorded from fixed observation points and nocturnal runway cross were recorded by using sensor camera and indirect evidence. Data for dry season was collected from February to April, 2020 and between Junes to August, 2020 for the wet season.

3.4 Data collection

3.4. 1 Live trapping procedure for small mammals

Live and snap trapping procedures were used to gather information on the diversity and relative abundance of small mammals' (rodents and insectivores). Four 100 m by 100 m blocks were randomly placed on both sides of the runway (the northern and the southern grasslands). In the selected blocks, about, 28 to 30 mixed traps (Sherman and snap traps) were randomly set at about 10 m interval between traps. Small mammals were trapped for both dry and wet seasons, from February to April for the dry and between Junes to August, 2020 for the wet season. Same number of trap was placed along the edge of runway (both sides) to sample small mammals frequenting or favoring marginal areas. Traps were baited with peanut butter mixed with corn or roasted barley flour. Traps were set at late afternoon between 17:30 and 18:30 pm and checked the next morning between 06:00 and 07:00am for nocturnal catches. Trapped animals were removed and traps were cleaned and used for diurnal small mammals. Traps for diurnal small mammals were set between 07:00 and 09:00 am in the morning, checked between 17:00 & 18:00 pm late afternoon for diurnal catches (Tadesse *et al.*, 2013). Same way each block was trapped for three days per seasons.

Standard body measurements, head-body length (HB), tail length (TL), ear length (EL), hind foot length (HF) were recorded. Body weights of trapped animals were measured using Pesola spring balance and animals were sexed using criteria of Afework (1996). Reproductive condition of the female (closed or perforated vagina site of teats) and the male (the position testes either scrotal or abdominal) was assessed (Afework, 1996). Few of the trapped specimens were sacrificed to take standard body measurement and pictures of representative animals were taken before skinning (Tadesse *et al.*, 2019). Species was identified using morphological characters in Kingdon (1997), Afework and Yalden (2014).

3.4.2 Survey of diurnal mammals

Sampling method was used to record mammalian species and to estimate their number. Using the well-defined land marks such as the grassland and the runway areas (north and south of the runway) three mammalian recording blocks was established. A total of five transects, two for each grassland and one for the runway were established along the west-east direction of the airport compound. The length of each transect was about 4 km and each transect was spaced by 200 m. Survey on all transect were conducted at the same time to minimize double observation and counting. At least two surveyors were used for each transect and the diversity record and counting was commenced between 05:30- 07:00 am (early morning) and between 17:30-18:30 pm (late afternoon). The observers recorded all necessary data, such as number of animals seen, transect number, the time of the day and took the pictures of observed mammals. Animals were observed with naked eyes or by using binoculars (7x50 mm). Species was identified on site and using mammalian features in Kingdon (1997), Solomon (2008) and Afework &Yalden (2014).

Total count procedure was used to record the dominant species Bohor reedbucks. Sex and age categories of reedbuck were distinguished on the basis of their body size, presence or absence of horn, size of horn and pelage colour (Estes, 1991; Afework *et al.,* 2010 and Tadesse *et al.,* 2012).

3.4.3 Sensor camera trapping for nocturnal mammals

Data regarding species diversity, abundance and runway crossing patterns of nocturnal, cryptic and transient mammals (those only visiting the airport during the night) were recorded using sensor camera traps. About 10 sensor camera (Bushnell Trophy Cam XLT 2011, Model #S.119537C/11947C/119576C, Overland Park, Kansas 66214) were used to record data. Cameras were equipped with highly sensitive infrared motion detector. Appropriate sites (based on the abundance of wildlife tracks, burrows, broken fences, grazing areas and edge of runway) were searched to place the cameras. Each camera was fixed on appropriate tree tracks (poles), 50 cm off the ground and spaced about 200 m from each other's. Cameras were placed and each season was trapped at least for a month (i.e. 300 trap nights). Cameras were programmed to capture motion at night, record videos for 30s with 1s interval between successive capture (Tadesse *et al.,* 2019).

3.3.4 Movement pattern (Runway count)

Out of the survey seasons, all the cameras were set along the margin of the runways (with 200 m interval) to record the rate and specific time mammals crossed runway during the night. The cameras were placed at least for a month (15 days for each season). For diurnal runway cross, two observers were seated on appropriate site (venture) along the runway with 1 km apart from each other and count mammals crossing the runway 300 m left and right sides. Diurnal runway count was carried out between 05: 30 am in the morning and 19:00 pm, early evening. Runway cross was recorded for a day in a week and two month in each season (when there was no flight). Indirect evidences, such as dropping, pug mark, scat, were regularly observed on the runway to record the mammalian species frequenting the runway.

3.5 Data Analysis

Species diversity of mammals was calculated using the Shannon-Wiener Diversity Index (H') by using the following formula (Shannon and Wiener, 1949): $H' = -\Sigma [\{ni/N\} \times \ln[\{ni/N\}]$

Where ni= number of individuals of each species (the i^{th}species),

N = total number of individuals for the site and ln = the natural log of the number,

Species evenness was calculated by using Begon *et al*. (1996) procedure, **J =H'/Hmax**

Where H' =Shannon-Wiener diversity index, Hmax = ln(S) and S is the number of species.

The relative abundance of mammalian fauna was calculated by dividing the number of individuals recorded for a species by the total number of individuals of all species.

$$\text{Relative Abundance} = \frac{\text{Number of individual}}{\text{Total number of species}} \times 100.$$

Trap success of small mammals was calculated to express the total number of animal trapped per total trap-nights according to Ofori *et al.* (2013). Thus, %**Ts = Nc x 100/Tn,**

Where; *Ts* = trap-success, *Nc*= total number of captures, *Tn*= total number of trap-nights.

Chi-square *($\times^2$)* was used to compare the overall significant difference in relative abundance, trap success and diversity of mammalian species between two seasons. Chi –square analysis was made in SPSS software (SPSS, Version 20). Mammalian species was grouped as common if the probability to see it was 100% every time during each survey or indirect evidences recorded once a day, uncommon if probability to see it is more than 50% or indirect evidences recorded once a weak and rare if probability to see it is less than 50% or only single recorded for the indirect evidences during each survey season (Hillman, 1993; Dereje *et al.*, 2015).

After retrieving all the camera traps, all the photographs were carefully observed and animals were identified up to species level. Each photo was rated as an independent event, if the time between consecutive photographs of the same subject was more than 30 minutes following the principle described by O'Brien *et al.* (2003). Relative Abundance Index (RAI, O'Brien *et al.*, 2003) was computed as the following:

$$\text{RAI} = \frac{A}{N} \times 100$$

Where; A is the total number of detections of a species by all cameras and

N is the total number of days the camera trap was seated in the field

From the capture rate, mammalian abundance was determined (number of species detected by all cameras per number of days the cameras trap was installed). From captured videos, the image of animals with time and date of event was examined. Time stamps on camera trap were used to describe runway cross pattern of the species. The average number of runway cross for the respective number of days for each month gives the mean runway cross.

4. RESULTS

4.1 Species diversity of small mammals

A total of 141 individuals of small mammals from five species (all from Muridae, Rodentia) were recorded from Aba Jifar airport in two season traps. The recorded species were Yellow spotted brush-furred rat (*Lophuromys flavopunctatus*), Multimammate mice (*Mastomys natalensis*), House rat (*Mus musculus)*, Black or Ship rat (*Rattus rattus*) and Ethiopian white footed rat (*Stenocephalemys albipes*). Among the total recorded species of small mammals, 79(56.02%) individuals were recorded during the dry season, while 62(43.98%) individuals were recorded during the wet season (Table 1). The number of individuals captured during the dry season was higher than the wet season, however, the seasonal variation in capture rate was not statistically significant (x^2=2.696, df = 1, P>0.05).

Lophuromys flavopunctatus was the most trapped species from all study sites, while the least was *Rattus rattus*, during both seasons. All five species were recorded during both seasons and seasonal variation in species composition was not observed. With about 43 (30.5%) individuals contribution, *L. flavopunctatus* was the most abundant rodent during this study, and with 31(21.98%) individuals, *M. musculus* follows. However, *R. rattus* was the least 18(12.77%) individuals, during both seasons (Table 1).

Table 1: The small mammal species and individual recorded during two seasons

No.	**Species**	**Dry**	**Wet**	**Both**	**RA (100%)**
1	*Lophuromys flavopunctatus*	24	19	43	30.50%
2	*Mastomys natalensis*	16	11	27	19.15%
3	*Mus musculus*	17	14	31	21.98%
4	*Rattus rattus*	10	8	18	12.77%
5	*Stenocephalemys albipes*	12	10	22	15.60%
	Total No. of individual	**79**	**62**	**141**	100%
	Total No. of species/ seasons	**5**	**5**	**5**	

Table 2 summarizes diversity index and evenness for small mammals between seasons. Accordingly, the highest species diversity was recorded during the dry season with (H'= 1.6), while the wet seasons was the least (H' = 1.54). Individuals small mammal was more even during dry season (J = 1.00) and least (J = 0.96) during the wet season (Table 2).

Table 2: Species diversity (H') and distribution of small mammals in the study area

Seasons	Number of Species	Number of Individuals	Diversity Index (H')	H 'max (lnS)	Evenness (J)
Dry	5	79	1.6	1.6	1.00
Wet	5	62	1.54	1.6	0.96

Of the 672 trap nights, during both seasons, the overall trap success was 20.98%, but this varies among the seasons. From seasonal comparison, the highest trap success was recorded in the dry seasons 79 individuals (23.5%) and the least trap success was during the wet seasons 62 individuals (18.45%)(Table 3). The seasonal variation in trap success was insignificant (P>0.05).

Table 3: Trap success during the dry and wet seasons

Seasons	Trap nights	Total catch	Trap success (%)	Mean trap success (%)
Dry	336	79	23.5	20.98%
Wet	336	62	18.45	
	672	**141**	**20.98%**	

4. 2 Diversity of medium and large sized mammal's

4.2.1 Species richness

The two seasons survey in this area yielded a total of 826 individual medium and large sized mammals distributed in 15 species, eleven families and six orders. Of which four species with 30 individuals were medium sized and eleven species with 796 individuals were large sized mammals for both seasons (appendex.2). Abyssinian hare (*Lepus habissinicus*), White tailed mongoose *(Icheumia albicauda,* Domestic cat (*Felis catus*) and Crested porcupine (*Hystrix cristata*) were medium sized while the remaining were large sized mammals. Relatively, more number (429) of individuals was recorded during the wet season, while 397 individuals were recorded during dry seasons. Except for Crested porcupine (that was recorded indirectly by its spine and excluded from data analysis), all the species were either directly observed (26.67%) or camera trapped 66.67% (Table 4).

The order Carni00vora was the most diversified order constituting five families and eight species, followed by Artiodactyla two families and three species. The order Hyracoidea, Perissodactyl, Lagomorpha and Rodentia were represented by single species each. Family Suidae, Canidae, Felidae and Viverridae were the most diversified families containing two species each, while Bovidae, Procaviidae, Equidae, Hyaenidae, Hyrpestidae, Hystricidae were represented by one species each (Table 4).

Table 4: List of medium and large sized mammalian species identified and recorded from Aba Jifar Airport. (Ct= Camera trap, Pm= Pug mark, Do= Direct observation, Dr= Dropping).

Order	**Family**	**Scientific Name**	**Common Name**	**Identification Methods**
Artiodactyla	Bovidae	*Redunca redunca*	Bohor Reedbuck	Do
	Suidae	*Phacochoerus africanus*	Common warthog	Ct
		Potamochoerus larvatus	Bush pig	Ct
Carnivora	Viverridae	*Genette genetta*	Common genet	Do
		Civetticitis civetta	African civets	Ct
	Canidae	*Canis aures*	Common jackal	Ct
		Canis lupus familiaris	Domestic dog	Do
	Hyaenidae	*Crocuta Crocuta*	Spotted hyena	Ct, Do, Pm,
	Herpestidae	*Icheumia albicauda*	White Tailed Mongoose	Ct
	Felidae	*Felis serval*	Serval cat	Ct
		Felis catus	Domestic cat	Ct, Do
Perissodactyl	Equidae	*Equus ferus caballus*	Horse	Ct, Do
Hyracoidea	Procaviidae	*Hetro hyrax brucei*	Bush hyrax	Do
Lagomorpha	Leporidae	*Lepus habissinicus*	Abyssinian hare	Ct
Rodentia	Hystricidae	*Hystrix cristata*	Crested porcupine	Spine

During the study period, 397 and 429 individuals of medium and large sized mammals were recorded in dry and wet seasons, respectively. The overall abundance of medium and large sized mammals recorded during the present study varied between seasons. However, the variation was not statistically significant (x^2=1.110, df = 2, P>0.05).

Seasonal variation in species composition of medium and large sized mammals was not observed. All the 15 species of medium and large sized mammals recorded in the study area occurred in both seasons. The highest species diversity was recorded during the dry seasons (H' = 1.44), while the least was during the wet seasons (H' = 1.42). Medium and large sizes mammals were more even in dry season (J= 0.53), and wet season was relatively the least (J=0.52) (Table 5).

Table 5**:** Diversity indices (H`) and evenness (J) of medium and large sized mammals.

Seasons	Number of Species	Number of Individuals	Diversity Index (H')	H 'max (lnS)	Evenness (J)
Dry	15	397	1.44	2.71	0.53
Wet	15	429	1.42	2.71	0.52

4.2.2 Relative abundance of mammals

From total individual of medium and large sized mammals recorded, Bohor reedbuck (*Redunca redunca)* was the most abundant species contributing 242(60.96%) and 260 (60.6%) individuals during the dry and wet season, respectively. The second most abundant was Spotted hyena (*C. crocuta*) contributing 134(16.22%) individuals, followed by African civet (*C. civetta*) 48 (5.8%) individuals. However, the least abundant mammalian species were domestic cat (*F.catus)* and Bush hyrax *(H. hyrax brucei*) with 4 (0.48%) and 2 (0.24%), individuals respectively, during both seasons (Appendex.1).

4.2.3 Occurrences of mammals

Among the total recorded species of medium and large sized mammals, 7(46.67%) species were common, 5(33.33%) species were uncommon and 3(20%) species were rare (Table 6).

Table 6: Occurrence of medium and large sized mammals in the study area

No	Common	Uncommon	Rare
1	Bohor reedbuck	Warthog	Serval cat
2	Spotted hyena	White T. Mongoose	Bush hyrax
3	African civet	Common genet	Crested porcupine
4	Common jackal	Abyssinian hare	
5	Bush pig	Domestic cat	
6	Domestic dog		
7	Domestic Horse		
Total	7	5	3
Occurrence (%)	46.67%	33.33%	20%

4.2.4 Sex and age categories of Bohor reedbuck between two seasons

Among 502 total count of Bohor reedbuck, female contributed about 127(52.48%) and 132 (50.77%) individuals, while male accounted 115 (47.52%) and 128 (49.2%) individuals, during the dry and wet seasons, respectively (Table 7). The mean average population of Bohor reedbuck was 251 individuals for both seasons and relatively the population was female-biased (average, 130 individuals), however the difference was not significant (x^2= 0.147, df = 1, P>0.05). Adult population of Bohor reedbuck was higher than sub-adult and juvenile by constituting 145 (59.9%) and 149 (57.3%) individuals, during the dry and wet seasons, respectively. For combined seasons, a mean of 75 (29.9%) individuals, adult female was the most abundant and with a mean of 72 (28.7%) individuals, adult male follows, while juvenile male was the least with a mean of 10 (4%) individuals (Table 7). The overall age categories of Bohor reedbucks between two season was not statistically significant (x^2= 0.618, df = 2, P>0.05).

Table 7: Sex and age categories of Bohor reedbuck in two seasons

	Age and sex categories						
Season	AF	AM	SAF	SAM	JF	JM	Total
Dry	76	69	40	38	11	8	242
Wet	74	75	45	41	13	12	260
Mean	75	72	42.5	39.5	12	10	251
Percent	29.9	28.7	16.9	15.7	4.8	4.0	100%

AF=Adult Female, AM=Adult Male, SAF= Sub-adult Female, SAM= Sub-adult Male, JF=Juvenile Female, JM= Juvenile Male

4.2.5 Runway cross patterns of some mammals

Among the recorded mammals, Bohor reedbuck regularly crosses runway at a different time of the day, mostly in three peaks. The highest peak was recorded in early morning between 05:30 and 08:30 am (51 average individuals), mid-day, from 11:00 to 12:00 (28 average individuals) and evening between 18:00 and 19:00 pm. (59 average individuals). However, it declined to a minimum level (6 &5 average individuals), during late afternoon between 13:00–14:00 and 14:00 to 15:00 pm, respectively. Relatively less number of individual was crossed runway between 12:30 to 15:00 pm and 13:00-16:00 pm, during the dry and wet season, respectively (Figure 4). They cross runway in every direction, when they move between their nesting site to grazing and watering sites. In the morning, more number of reedbucks were observed grazing around northern and eastern area, but in the afternoon they move to southern by crossing the runway. In the afternoon, majority of them were counted from southern (watering site), mostly during the dry season. During the study period, there were strikes of aircrafts with reedbuck. Except for the death of reedbuck, the incidence caused no harm to the passengers and the aircraft. The overall runway crosses activity of Bohor reedbucks showed rhythmic in the different time of the day and seasons. However, there was no significant seasonal variations in their runway cross patterns between wet and dry season.

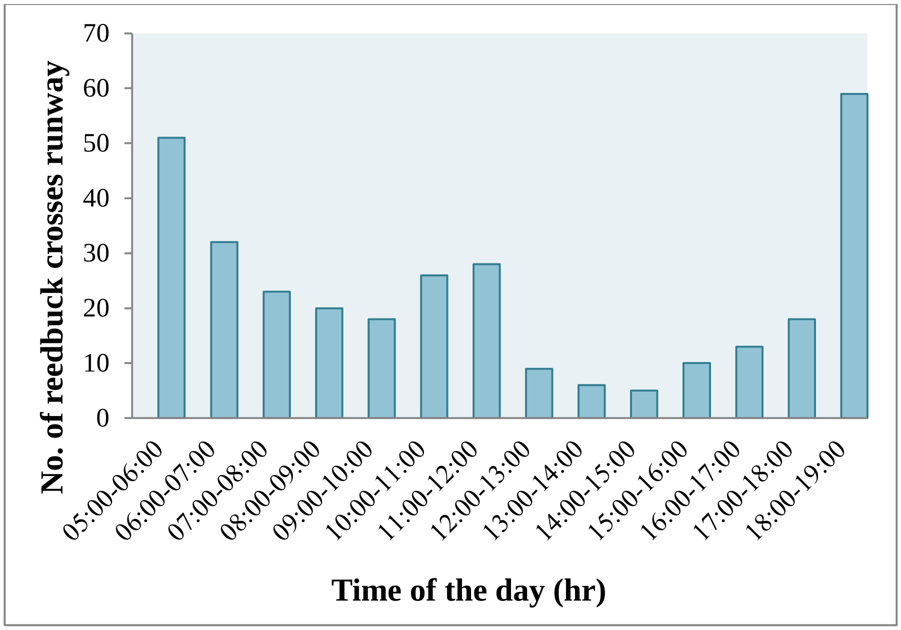

Figure 4: Daily runway crosses of Bohor reedbucks at AJAC

During this study other nocturnal mammals, including spotted hyena, White Tailed mongoose, African civets, Serval cat, Abyssinian hare, Jackal and Warthog were observed crossing runway and encountering the reedbuck. Few nocturnal mammals were dormant and show some sort of rhythmic trend in the night time runway cross data. Peak runway crosses were recorded for hyena, during the evening (between 19:00 and 20:30 pm) and early morning (04:30 and 05:30 am) (Image in Appendix 3).

Even though other mammalian species includes White Tailed mongoose, African civets, Serval cat, Stark's hare, Common jackal and Warthog were involved runway cross, but with very less frequency, compared to the diurnal Bohor reedbuck and nocturnal spotted hyena. More number of Common warthog was observed between 21:00 to 22:30 pm. During the wet season, a number of white tailed mongooses and jackal were observed on the runway between 20:30 and 21:30 pm. (Appendix 3). They were observed capturing insects flying, termites and small mammals on the runway.

5. DISCUSSION

During this study, five species of small mammals from family Muridae and order Rodentia were recorded from Aba Jifar airport in two trapping seasons. Of the five recorded small mammalian species *L. flavopunctatus and S. albipes* were endemic species of Ethiopian, mostly distributed around Ethiopian highland (NABU, 2016). Diversity of small mammalian species at Aba Jifar Airport is comparable with reported fauna from related habitats across the country and elsewhere. For instance; four species of small mammals (3 from unmowed plots and one species from mowed plots) were recorded at Aminu Kano International Airport in Nigeria (Dukiya *et al.*, 2013). The species of rodent recorded from the present study were high related to the areal extent, but relatively low compared to the studies of Jason *et al.*(2011) who recorded 11 species of small mammals from the Indianapolis International airport conservation lands. Early far study by Tadesse and Afework (2013) reported twelve species of rodent from Jiren Mountain, Jimma area nearest to this area. The large, undisturbed grassland of the airports are attractive for small mammals that are serving as food and protection from predators.

Small mammals and reptiles may not constitute direct threat to aircrafts. Small mammal indirectly involve in collisions with aircraft, by attracting predators, such as foxes, mongoose, jackal and raptures, which may be directly involved in collisions. Carnivores are the second most common group of mammals living in airport environments, and are attracted by the presence of small mammals. For instance; the presence of Coyotes and foxes indicates healthy populations of small mammals voles, mice, rabbits and hares (MacKinnon, 2004). Large carnivores can pose significant hazards when they roam onto active runways. In some instances small animals have been known to disrupt flight operations. They can cause a number of problems at airport, interfering with grass-management programs, chewing and damaging electrical cables, undermining runways and taxiways, and attracting both bird and mammal predators. For Aba Jifar airport, which support large populations of small mammals, damage costs caused by this species can be significant.

Variation in the species composition and abundance of rodents among the two seasons was not significant. From the total number of individual recorded, 79 (56.02%) and 62 (43.98%) individuals species of small mammals were recorded during dry and the wet seasons, respectively.

This might be due to homogeneous vegetation with few species of grasses, and flooding of the area during the wet season, thereby reducing the suitability for the survival of the small mammals. The relatively low number of small mammals during the wet seasons might be attributed to the flooding of the study area. Habitat complexity, food and cover availability are key factors influencing the overall distribution of small mammals (Avenant and Cavallini, 2008). Dawit and Afework (2008) stated that habitat type, availability of food and cover might influence the distribution of rodents.

During the present study, *L. flavopunctatus* was the most abundant species contributing 43 (30.5%) individual of the total catch during both seasons. This abundance might be due to its diverse feeding habits, the ability to adapt and tolerate harsh condition of this species. Similar results were reported by Tadesse and Afework (2013) from Jiren Mountain, Jimma area, which is nearest to the present study area. It is also most widely distributed and abundant over most habitats of Ethiopia (Yalden and Largen, 1992). *L. flavopunctatus* is the most success full species, because it can be occupying the niche that is not usually suitable for others, seems to create a reduced competition and coexisting condition with other rodent species in all habitats (Clausnitzer, 2003).

L. flavopunctatus was the most trapped species, while the least was *R. rattus*, during both seasons. This may be due to absence of farming activities in the study area and also impact of grazing; that make less suitable for R. rattus. This species was mostly recorded around houses area, cafeteria and police camp. Low population of *R. rattus* was also recorded by Mulatu Osie *et al.* (2010**)** who suggested that, the species preferred only cereal field. Fekdu *et al.* (2015) also reported that, livestock grazing produce severe effects on dynamics of grassland plants as well as on the abundance of small mammal population, which could force them to migrate to more suitable habitats.

S. albipes is a widespread species in forest habitats on both sides of the Rift Valley in altitudinal ranges between 800 and 3300 m a.s.l (Yalden &Largen, 1992). It also occurs outside of Ethiopia in neighboring Eritrea high lands (NABU, 2016). This species mostly inhibits upland forests and scrub land and rough grassland and at an altitude range of between 800 and 3300 m (Afework and Lavrenchenko, 2017). Across the country, this species has been recorded from various parts of

Ethiopia particularly southwestern area. For instance, Tadesse and Afework (2013) reported from Jiren Mountain, Jimma, NABU (2016) from Kafa Biosphere Reserve and Tadesse *et al.* (2019) from Belete-Gera Forest, Jimma, southwestern, Ethiopia.

Of the 672 trap nights, during both seasons, the overall trap success was 20.98%, but this varies among seasons. From seasonal comparison, the highest trap success was recorded in the dry 79 (23.5%), while the least were during the wet season 62 individuals (18.45%). The reason for this might be the availability of suitable habitat that serves as cover and food during the dry. This area directly results in flooding during the wet season, thereby reducing ground cover and less suitable for small mammals. Trap success is influenced by factors such as food availability and rainfall, which have direct influence on vegetation, and quality and quantity of food affecting the reproductive pattern and shelter of rodents (Datiko and Bekele, 2012).

Small mammal communities are an important component of the ecosystems. They are also a major attractant for raptors at airports. A noticeable increase in avian predators and carnivores can be an indication that small mammal populations are increasing (DeVault *et al.,* 2017). Understanding ecosystems within and around airports can help to determine the causes and possible mitigation measures for collisions between aircraft and wildlife. Maintaining shorter grass can reduce small mammal populations that attract birds and bigger animals (Hauptfleisch *et al.*, 2013). The airport authorities should monitor small mammals, because they are attractants for others.

Regarding the medium and large mammalian species, a total of 15 species recorded from the study area. Since little information has been published on survey of mammalian at airports, it was difficult to compare the finding of the present study with others. The result of the present study was high related to the areal extent, which is higher than some studies from protected area of the country. For instance, Gebrecherkos and Tilaye (2012) recorded 14 species from Yayu forest in Southwest Ethiopia. The diversity of medium and large sized mammals of the present study in such small area is a good indicator of resourcefulness of the area for herbivores that attracts more carnivores. The existences of the most suitable grassland habitat, relatively low level of disturbance of the habitat and high security may contribute for this diversity and abundance of medium and large-sized mammalian species in this area.

Concerning species composition in two seasons, all 15 species recorded in the present study area occurred in both seasons. During wet season, relatively more number of individual (429) was recorded, while the least 397 were recorded during dry season. The ground cover is also important attractant, because mammals are dependent on food sources and protection. The study area has relatively minimal security problems like poaching, burning of fire as compared to the other area.

Variation in the relative abundance of mammalian species in the present study area was observed. Accordingly, Bohor reedbuck (*Redunca redunca)* was the most abundant species of mammals in the study area contributing 251 (60.77%) in average individuals, during both seasons. The grassland surrounding the airport is capable of supporting high populations of mammals dominantly reedbucks. Aba Jifar airport is a favorable habitat for reedbucks, because it provides food, water and shelter. In addition to this, it is secured areas, gets less interference and the limited human activity inside and outside of airport makes the area more favorable for Bohor reedbucks. Bohor reedbuck prefers grassland, wetland plains and avoids thick forest, since they are poorly adapted to jump, run and escape danger (Estes, 1991; Kingdon, 1997). Tadesse *et al.* (2012) reported that, the land use patterns of the surrounding area and better security of the airport may be a main reason for the concentration of Bohor reedbucks in confined swampy grassland habitat of the Jimma Airport Compound.

In this study, in average over 251 individual reedbucks were recorded from the AJAC, which is higher than the protected area of the country. Studies show that, more than 220 individual reedbucks were reported from the same area and outsides (Tadesse *et al.*, 2012). But for the increment of area often expansion and high protection, the number of expected to increase beyond this. The observed minimal growth might be due to the high predation and hunting risk from other carnivore, mostly hyena. This also indicate, they are attractants for other carnivore that may pose further threats to endemics reedbuck sub-species and also hazardous to the aviation services.

The sex categories of Bohor reedbucks in present study area were relatively female-biased. For both seasons, in average female accounted 130 (51.7%) and while male 121 (48.4%). Regarding age structure of reedbuck, adult population was higher than sub-adult and juvenile. The previous studies of Afework *et al.* (2010) from Bale Mountains National Park and Tadesse *et al.* (2012)

from Jimma airport Compound reported that, the age structure of Bohor reedbucks was biased toward the adult. This may not good for the population dynamic of reedbuck in the future.

Spotted hyena (*C. carcuta)* was the second most abundant in the study area. During the study period, the indirect evidence, such as pug mark, dropping, bone scat observed several times, and at night sound was detected and also the video were captured by camera trap. The study area provides suitable habitat for the survival of hyena, including food, water, cover that attract this species. Hyena is attracted to this area by the removal of food leftovers and other wastes disposal which can be used as food source for this animal. The presence of this species in the study area was highly expected, besides the vegetation cover of the surrounding area, high population of Bohor reedbuck and the waste disposal activities, the presence of church and religious burial ground near to the study area may be the major attractant features of hyena. The spotted hyena frequently crossed runway with peaks in the evening and early morning, they move from their dense to the airport compound and to the town as well as return to its nest.

African civet (*C. civetta*) was recorded several times and it is the third most abundant in this area. It also captured by camera trap many times. In addition, indirect sign such as, pug mark; scent marked musk and civet latrines were observed during survey period. The possible reason for this species might be due to the presence of food, food leftovers, water and stability of the area from disturbances. Civet is well known by the resident community of the study area as well as in the Ethiopia for its musk secretion, which is used for perfume production. Historically, traditional farmers in Ethiopia maintain this animal in captivity and harvest musk for traditional and commercial purposes (Tadesse and Afework, 2014). In this study, African civet observed in the airport throughout the study period, but mostly they do not stay around the runway and relatively they are not hazardous to aviation activities.

Mammalian species play important role in environment; however they are also hazardous on aviation activities, because they collide with aircraft. A wildlife collision commonly causes damage to aviation industry around the world and resulted in economic as well as human life losses. Even though less number of terrestrial mammals involved in strikes, mammal incidents cause more damage to aircraft than other wildlife incidents. For instance; terrestrial mammals represent only 2.3% of wildlife incidents, but 59 % of these incidents caused damage to aircraft.

Birds accounted for 97 % of wildlife incidents; however, 87 % of bird incidents do not cause damage to aircraft (Dolbeer *et al.*, 2012). A total of 209 strike incidents were reported in Nigeria between 2005 and 2010 and the airline lost about N15 billion annually due to wildlife strikes (Usman *et al.*, 2012). Even though, various mammalian species have been involved in the strikes, their damaged posed by mammals was not reported separately.

The Airport compound is favorable for mammalian species; it provides nesting, feeding, breeding and resting sites. The main reason for the presence of such large number of mammals in this area might be duo to the availability of sufficient food and shelter. However, they can cause threats to aircraft operation. Food leftovers generated from staff cafeterias are one of the major wildlife attractants, such as pig, civet, jackal, mongoose and hyena. In addition to the vegetation covers of the airport, the surrounding swamp wetland and tree plantation also serve as an ideal safe place for them. The occurrence of large number of mammals in such limited area, especially those herbivores that can attract large carnivores are not good for health aviation activity.

In this study, Carnivora and Artiodactyla were the most abundant and their abundance may contribute to high risk of strikes and their vulnerability, since larger mammals pose a greater risk. Most of the medium and large mammals found in the present study area were crossing the runway. Of the 1,164 terrestrial mammal strikes in the USA, large herbivores, medium carnivores, and medium herbivores/omnivores comprised 55%, 26%, and 18%, respectively (Dolbeer *et al*., 2005). Dolbeer *et al.*(2000) found that, relatively larger body mass of species within Artiodactyla and Carnivora involved in incidents makes damage to aircraft, effect on flight, increases in aircraft out of service time, higher direct damage costs, and injuries more likely during an incident.

Among the recorded mammals from the study area, Bohor reedbuck frequently cross runway, when it moves between feeding, watering and bedding site. They cross runway in every direction at different time of the day, but the highest peak runway cross was early morning; mid-day and evening. In the morning time, they move from roosting site to grazing site and *vice versa* during the night. In mid-day during both seasons, relatively runway cross activity was low and majority of them were at resting. A resting peak for Bohor reedbucks was observed around the mid-day during both seasons (Afework *et al.*, 2010; Tadesse *et al.*, 2012). In early evening particularly between

18:00 and 19:00 hr. (when it gets dark), more number of reedbuck move to or stay around terminal area and resident of security (police comp) to avoid other predators. Runway cross activity of reedbuck is prominent early in the morning and late afternoon. This time of the day determine the significance runway cross activity of reedbucks to implement control measures.

During the study period, there were strikes of aircrafts with reedbuck. Except for the death of reedbuck, the incidence caused no harm to the passengers and the aircraft. Although wildlife collisions are not known to have caused any fatalities in the study area, they can cause significant damage on aviation industries. This information is important to note that there is high risk of aircraft strikes associated with high population of reedbucks in the study area. Wildlife other than reedbuck in the study area could also pose strikes. Inadequate fencing that allows wild animals to the aviation industry is still the main problem for aviation industry. The civil aviation authority worried on the potential hazards may be posed by wildlife live in the Aba Jifar airport compound.

There are 14 flights per week (2 flights per day). The flight schedule is morning between 10:40 and 11:35 am and afternoon between 15:00 to 15:55 pm, arrival and departure time, respectively. The identified three peaks help airport management to give special attention for control measures, based on the recorded three peaks and flight schedule. Such types of information provide a scientific basis for airport management to develop effective management plan in order to mitigate wildlife strike. The airport hires/assigned more than 30 personnel to stand either side of the runways to protect reedbucks, before aircraft landing and during takeoff. Aba-Jifar airport is the unique that harbors high population of Bohor reedbucks, so the use of traditional guarding styles my not effective to prevent aircraft accident. Dolbeer (2009) suggested that wildlife that suddenly moves on a runway or a surrounding area will collide with incoming or departing aircrafts and can possibly result in death, delay, injuries, material damage and economic loss.

During the night, they come to lighting area, security tower and human resident area that may reduce the influence of predators, because spotted hyena, Mongoose, African civets, Serval cat, Abyssinian hare, Jackal and Warthog encountering it. High number of hyena recorded and indirect evidence such as; bones scat, dropping, pug mark was observed on the runway or adjacent to it. This indicates they involves runway crossing that may pose strikes to aircrafts. The resident reedbucks of the study area became habituated to the loud noises of plane and human activities. Tadesse *et al.* (2012) indicated that, in response to predation avoidance, over 85% of the reedbuck in the JAC passes night time within 200 m radius of the main terminal and staying closer to areas with higher human activity. Mammals may also habituate to loud noises or activities that do not pose risk and not immediately perceive an incoming plane as a threat (Cleary and Dolbeer, 2005).

The present study revealed that spotted hyena was the second abundant species and they considered as hazardous to aviation industry, because they can cause significant damage when they are struck by aircraft. Since they are particularly active at dawn and dusk and during the night when airport operation is low they can cause considerable damage. The majority of strikes with mammalian species occur during landing at dusk, dawn or night (Cleary *et al.,* 2006). Frequently cross the runway at night to search food (prey on reedbuck and others) around terminal area including the critical safety zone. They mostly shelter themselves around the airport area in high growing dense vegetation.

The nocturnal mammals in the current study area may hazardous for aviation. The airport was planned to start the night flight, but it was cancelled or delayed due to the pandemic novel corona virus (Covid-19). If there were night flight, the population of this mammal may become hazardous to aircraft traffic, especially the Bohor reedbuck and hyenas frequently move on the runway. In Bole International airport, the evening flight was cancelled, due to a flock of hyenas on the runway (Elizabeth *et al*., 1996) and mammal's strikes (bat, jackal and hyena) occurred at night time that resulted in material damage to the aircrafts (Tsigereda, 2006). This indicated that, the present study area harbor many wildlife species that is hazardous to aviation operation and it need special consideration.

Ethiopian Civil Aviation Authority (ECAA) wildlife strike database (2014-2019) reported that, mammalian species included common jackals (11 strikes), hyena (7 strikes), serval cat (4), slender mongoose (4), porcupine (2), dog (2) were involved in strike at Addis Ababa Bole international airport (Fekadu, 2020). Dolbeer *et al.* (2012) reported that, different mammalian species involved in incidents with U.S. civil aircraft. For example; deer and coyote were the most common and other mammalian species, such as domestic dog (32 strikes), domestic cat (22), domestic horse (3) and cattle (10) were also involved in incidents. During this study, all of the above mammals were recorded from the study area and they may be causes aircraft strike. In the night time, common jackal and white tailed mongooses come to the runway area to search and feed on invertebrate such as earthworm, termites and small mammals mostly during the wet seasons. Rodents are important prey for different carnivores such as mongooses (Ejigu, 2008).

Domestic dogs were coming from the surrounding area to the airport to prey up on reedbuck and to scavenge on remains, to find rubbish from staff cafeteria; even they observed when they play on runway. Cattle such as horse, cows were observed, they graze on the grass inside and around the airport. Not only the day time, horses captured by camera trap several time during the night. The presence of such abundant mammals might be due to the natural environment and other human activities inside and near the vicinity of Jimma Aba Jifar airport attracting a wide range of mammals that may be hazardous. The food becomes available through improper waste disposal practices by nearby restaurants and kitchens from airport staff also attract wildlife to the area. The current mammalian management techniques at Aba Jifar airport were not effective to the number of species and the existed individuals. Thus additional mammalian management strategies should be implemented to mitigate mammalian incidents in the study area.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The present study surveyed mammalian fauna of Jimma Aba Jifar Airport Compound. The current study documented a total of 20 species of mammals (five small mammals and 15 medium and large sized mammals. Even though the size of the area is small, it harbors a quite number of mammalian species. The area possesses suitable places for mammal to nest, rest and a good access to food sources and water. The swampy grasslands of the area, wetland plains that inter-connected with Kitto-furdisa fragmented forest remnant provide suitable habitat including food and cover for a diverse mammalian fauna. Food wastes from staff cafeteria and kitchens attracting mammals. The presence of such abundant mammals in the airport compound may pose potential hazardous to aviation service. Finally, the finding of the study recorded mammalian species diversity of the study area and it's providing baseline information for airport managers to implement effective management measure.

6.2 Recommendation

Jimma Aba Jifar Airport Compound harbors a quite large number of mammalian fauna. The presence of these mammals is not important for the safety of airport. Thus, based on the results of the study, the following recommendations are suggested:

- Remove food wastes and other garbage from cafeterias, arriving aircrafts and security police residence within the airport.
- Rodent can pose hazard to aviation industry both directly and indirectly, so effective management measure should be undertaken to reduce their populations.
- An effective management plan and policy for reedbucks, hyena and other mammals' incursions should be implemented.
- Airport wildlife management training should be given for airport worker and concerned stakeholders.
- Translocating the dominant reedbucks is the only possible solution that may reduce repealed carnivores visit is recommended to reduce the risk and safeguard the endemic reedbuck sub-species.
- Further studies and site visits should be conducted by a qualified airport wildlife biologist to analysis the impact of wildlife to aviation safety.

7. References

Afework Bakele and Yalden, D. (2014). The *Mammals of Ethiopia and Eritrea*. Addis Ababa University Press., Ethiopia. Pp 391.

Afework Bekele (1996a). Population dynamics of the Ethiopian endemic rodent, *Praomysalbipes* in the Menagesha State Forest. *J. Zool.*, London. 238: 1-12.

Afework Bekele (1996b). Rodents of Menagesha State Forest, Ethiopia, with an emphasis on the endemic *Praomysalbipes*(Rupell 1842). *Trop. Zool*. **9**: 201- 212.

Afework Bekele and Leonid A. Lavrenchenko (2017). Diversity And Conservation Of Ethiopian Mammals: What Have We Learned In 30 Years? *Ethiop. J. Biol. Sci.* ***16****(Suppl.): 1–20, 2017*, Addis Ababa, Ethiopia.

Afework, B., A. Bekele and M. Balakrishnan, (2010). Population status, structure and activity patterns of the Bohor reedbuck *Reduncaredunca* in the north of the Bale Mountains National Park, Ethiopia. *Afr. J. Ecol.*, ***48****, 502–510*.

Aschalew, A.Yismaw, A. Hans Bauer, Meheretu, Y. (2017). Abundance and diversity of birds around Mekelle Airport, Ethiopia, and their threat to aviation safety. *J. Zool. St.*2017; **4**(3): 29-36.

Ashford, N., Stanton, M., Moore, C., Coutu, P., Beasley, J. (2013). Airport Operations, third ed. McGraw Hill, New York.

Avenant, N. and Cavallini, P. (2008).Correlating rodent community structure with ecological integrity, Tussen-die-Riviere Nature Reserve, Free State Province. *South Africa. Integr. Zool*. **2**: 212-219.

Biondi, K. M., J. L. Belant, J. A. Martin, T. L. DeVault, and G. Wang. (2011). White-tailed deer incidents with U.S. civil aircraft. *Wildlife Society Bulletin* ***35:****303–309.*

Cleary, E. C., and A. Dickey. (2010). Guide book for addressing aircraft/wildlife hazards at general aviation airports. National Academies of Sciences, Washington, D.C., USA.

Cleary, E. C., and R. A. Dolbeer. (2005). Wildlife hazard management at airports, a manual for airport personnel. United States Department of Transportation, Federal Aviation Administration, Office of Airport Safety and Standards, Washington, D.C., USA.

Cleary, E. C., R. A. Dolbeer, and S. E. Wright. (2006). Wildlife strikes to civil aircraft in the United States 1990–2005. Federal Aviation Administration, National Wildlife Strike Database, Serial Report Number 12.

Dawd Yimer and Solomon Yirga. (2013). Mammals of The Mazie National Park, Southern Nations, Nationalities and Peoples Regional State, Ethiopia.*SINET: Ethiop. J. Sci*. 2013; **36**(1):55–61.

Demeke Datiko and Afework Bekele (2012).Species composition and abundance of small mammals in Chebera-Churchura National Park, Ethiopia. *Afr. J. Ecol*. **5**(6): 95-102.

Dereje Negeri, Gadisa Tsegaye and Habtamu Tadesse (2015). The diversity, distribution and relative abundance of medium and large-sized mammals in Baroye controlled hunting area, Illubabor Zone, Southwest Ethiopia. *Intl J Mol Evol Biodiv*.**5**:1−9.

DeVault, Travis L.; Blackwell, Bradley F.; Belant, Jerrold L.; and Begier, Michael J., "Wildlife at Airports" (2017). Wildlife Damage Management Technical Series.10

Dolbeer RA, Wright SE, Cleary EC (2000). Ranking the hazard level of wildlife species to aviation. *WildlSoc Bull **28**:372–378.*

Dolbeer, R. A., S. E. Wright, and P. E. Eschenfelde. (2005). Animal ambush at the airport: need to broaden ICAO standards for bird strikes to include terrestrial wildlife. Proceedings of the International Bird Strike Committee Meeting 27:102–113.

Dolbeer, R.A.; Seubert, J.L. (2009). Canada goose populations and strikes with civil aircraft, 1990–2008: challenging trends for aviation industry. Washington, DC

Dolbeer RA, Wright SE, Weller J, Begier MJ (2012). Wildlife strikes to civil aircraft in the United States 1990–2010. U.S Department of Transportation, Federal Aviation Administration, Office of Airport Safety and Standards, Serial Report n.17. Washington, DC

Dolbeer, R.A., Wright, S.E., Weller, J.R., Anderson, A.M., &Begier, M.J. (2015). Wildlife Strikes to Civil Aircraft in the United States: 1990–2014 (Serial Report No. 21).

Dolbeer, R. A., and M. J. Beiger. (2019). Wildlife strikes to civil aircraft in the United States, 1990-2017. U.S. Department of Transportation, Federal Aviation Administration, Office of Airport Safety and Standards, Serial Report No. 24, Washington, D.C., USA. 113 pages.

Dukiya, Jehoshapha, J. Vimal, G. (2013). An Evaluation of the Effect of Bird Strikes on Flight Safety Operations at International Airport. *International Journal for Traffic and Transport Engineering, 2013, 3(1): 16 – 33*.

Ejigu, A. (2008). *Species composition, relative abundance and habitat association of rodents in Bir Farm Development (Birsheleko) and nearby natural habitat area*, M.Sc. Thesis, Addis Ababa University, Addis Ababa.

Elizabeth, Y. (1996). *Ecological Study of the Avifauna and Bird Strike Problem At Addis Ababa Bole International Airport, M.Sc.* Thesis, Addis Ababa University, Addis Ababa.

Emmons, L. and Feer F. (1997). Neotropical Rainforest Mammals. Chicago. University of Chicago Press. 380PP.

Ethiopian National Meteorological Agency Jimma Sub-Branch Office (2019). Average rainfall and temperature data from 2016–2020. Report, Jimma.

Federal Aviation Administration (FAA) (2004). Deer hazard to aircraft and deer fencing. U.S.Department of Transportation, Federal Aviation Administration, Cert Alert 04-16 Washington, DC.

Fekdu, A. Bekele, A. and Datiko, D. (2015). Comparative study of species composition, relative abundance and distribution of rodents between enclosure and control sites in the Web Valley of the Bale Mountains National Park, Ethiopia. *Punjab Univ. J. Zool.*, **30**(2): 57-64.

Fekadu Assefa, (2020*). Effect of wildlife hazard on aviation industry at Bole International Airport*, MA. Thesis, Addis Ababa University, Addis Ababa.

Flynn, J. Finarelli, J. Zehr, S. Hsu, J. and Nedbal, M. (2005). Molecular phylogeny of the Carnivora (Mammalia): assessing the impact of increased sampling on resolving enigmatic relationships. *Syst. Biol*. **54**: 317-337.

Gebrecherkos, W. and Tilaye, W. (2012). A survey on Mammals of the Yayu forest in southwest, Ethiopia.*SINET: Ethiop. J. Sci.,* ***35****(2), 135-138.*

Gleizer H, Bar P, Bahat O, Groner E, Ovadia O. (2005). The effect of habitat productivity and structure on bird spatial distribution in an airfield located at a semi-arid region. Proceedings of 27th International Birdstrike Committee. Athens.

Hauptfleisch ML, Avenant NL, Tsowaseb A .(2013). Aircraft–wildlife collisions at two major Namibian Airports from 2006–2010. *South African Journal of Wildlife Research* 43, 177–84.

Hesse, G., Rea, R. V. and Booth, A. L. (2009). Wildlife management practices at western Canadian Airport. *J. Air Transp. Manag.,* ***30:****1-6.*

Hillman, J. C. (1993). Ethiopia: Compendium of Wildlife Conservation Information. Vol.1. Ethiopian Wildlife Conservation Organization, Addis Ababa, 454 pp.

ICAO (2009). Managing wildlife hazards to aircrafts. Report, International Civil Aviation Organization, USA.

Jason P. Damm, Kelsey R. Pearman, Nicholas S. Gikas, D. W. Sparks and John O. Whitaker, Jr. (2011). Mammals of the Indianapolis International Airport Conservation Properties, Hendricks County, Indiana, With County Records. *Proceedings of the Indiana Academy of Science 120(12):96–103.*

Kingdon, J. (1974). East Africa Mammals: An Atlas of Evolution in Africa: Volume II-part B (Hares and Rodents). Academic Press, London, pp. 446.

Kingdon, J. (1997). The Kingdon Field Guide to African Mammals.AcademicPress.London and New York, 476 pp.

Lewis C. (1995). Engine Bird Ingestion.Airliner. June-March, 17-23.

MacKinnon, B. (2004). Sharing the skies: an aviation industry guide to the management of wildlife hazards.TP 13549. Transport Canada, Aviation Publishing Division, Ottawa, Ontario, Canada.

Meseret, C. and Solomon, Y. (2014). Diversity of Medium and large-sized mammals in BorenaSayintNational Park, South Wollo, Ethiopia. *IJSBAR, **15**, 95-106.*

Mugatha, M. (2002).*Influences of Land-use Patterns on Diversity, Distribution and Abundance of Small Mammals in Gachoka Division, Mbeere District, Kenya. Land use Change*, Nairobi, 46pp.

NABU (The Nature and Biodiversity Conservation Union) (2017). NABU's Biodiversity Assessment at the Kafa Biosphere Reserve. Berlin, Addis Ababa.

Ojeda, A., Blendinger, G. and Brandl, R. (2000). Mammals in South American drylands: faunal similarity and trophic structure. *Glob. Ecol. Biogeogr. 9:115-123.*

Schwarz, K. B., J. L. Belant, J. A. Martin, T. L. DeVault, and G. Wang. (2014). Behavioral traits and airport type affect mammal incidents with U.S. civil aircraft. *Envt. Mangt 54:908-918.*

Shannon and W. Weiner, (1949). The Mathematical Theory of Communication. Chicago: University of Illinois Press.

Solomon Yirga. (2008). "Atibiwochu".Ethiopian Wildlife and Natural History Society, Addis Ababa.

Tadesse, H. (2005). *The Study of Diversity, Distribution Relative Abundance and Habitat Association of Small Mammals in Alatish Proposed National Park,* North Ethiopia. M.Sc.Thesis, Addis Ababa University, Addis Ababa.

Tadesse, H., Afework, B. and Berhanu, B. (2012). The ecology and Behavior of Bohor Reedbuck in Jimma Airport Compound, South western Ethiopia. *Asia. J. Anim. Scien. 6:278-290.*

Tadesse, H. and Afework B. (2013). Species composition, relative abundance and habitat association of small mammals along the altitudinal gradient of Jiren Mountain, Jimma, Ethiopia. *Afr. J. Ecol., 51, 37–46.*

Tadesse Habtamu (2014). *Ecological Studies of the African Civets (Civettictis civetta) in Coffee Forest Habitat, Limmu Seka District, and an Assesment of Captive Maintenance as a Viable Economic Sources*. Ph.D. Dissertation, Addis Ababa University, Addis Ababa.

Tadesse Habtamu, Tsegaye Gadisa, Abebe Amha, Ayalew Zeleke (2019). Rapid land vertebrate (amphibians, reptiles, small and large mammals and birds) survey in Belete-Gera montane forest, Gera district, Jimma zone, southwestern Ethiopia Pp.69.

Tsigereda, D. (2011).*Species Diversity and Abundance of Birds of Addis Ababa bole International Airport.* M.Sc.Thesis, Addis Ababa University, Addis Ababa.

Usman, B. A., Adefalu, L. L., Oladipo, F. O. and Opeloyeru, A. R.,(2012). *Bird/Wildlife Strike Control For Safer Air Transportation in Nigeria*. *EJESM* Vol. 5 No. 3 2012.

Vaughan, T., Ryan, J. and Czaplewski, M. (2000) "Mammalogy," 4th ed. Saunders collage publishing, NewYork. USA.

Wendy, S., Engeman, R. M., Fairaizl, S., Cummings, J. L. and Groninger, N. P. (2000). Wildlife hazard assessment for phoenix sky harbor international airport. *Int. Biodete.. Biodegrad., 45:111-127.*

Wilson, D. E. and Reeder, D. M. (2005).Mammal Species of the World. A taxonomic and Geographic Reference (3rded), Johns Hopkins University Press, **2**:142 pp.

Yalden D, Largen M.J., (1992). The endemic mammals of Ethiopia.Mamm.Rev. 22: 115-150.

Yalden, D. W. (1983). The extent of high ground in Ethiopia compared to the rest of Africa. *SINET: Eth. J. Sci.* ***6:*** *35-39.*

Yalden, D.W., Largen, M.J., Kock, D., and Hilman, J.C. (1996). Catalogue of the Mammals of Ethiopia and Eritrea.Vol.7.Revised Checklist, Zoogeography and Conservation. *J. Trop. Zool.* **9**: 73 – 164.

APPENDIX

Appendix 1: Row data of mammalian species recorded among two seasons

No	**Species**	**Seasons**		
		Dry	**Wet**	**Total**
1	Abyssinian hare (*L. habissinicus)*	6	4	10
2	Bush hyrax (*Hetro h. brucei)*	1	1	2
3	Serval cat *(Felis serval)*	5	3	8
4	Bohor reedbuck *(R. redunca)*	242	260	502
5	African civets (*C. civetta*)	23	25	48
6	Warthog (*Phacochoeru africanus*)	18	22	40
7	Spotted hyena (*C. crocuta*)	63	71	134
8	Common genet (G. genetta)	8	6	14
9	Common jackal (*Canis aureus*)	6	6	12
10	Bush pig(*Potamochoerus larvatus)*	10	13	23
11	Domestic dog *(Canis l. familiaris)*	5	3	8
12	Domestic cat (Felis catus)	2	2	4
13	Horse (*Equus f. caballus)*	2	3	5
14	White tailed mongoose *(I. albicauda)*	6	10	16
15	Crested porcupine (*H. cristata)*	+	+	+
	Total number of individual per seasons	**397**	**429**	**826**
	Total number of species per seasons	**15**	**15**	**15**

Appendix 2: Relative abundance of medium and large sized mammals recorded in the study area during the dry and wet seasons.

Species	Total No. of individuals recorded		RA for each season (%)		RA for combined season (%)
	Dry	**Wet**	**Dry**	**Wet**	Both
African civet (*C. civetta*)	23	25	5.8	5.83	5.8
Bohor Reedbuck *(R. redunca)*	242	260	60.96	60.6	60.77
Bush pig (*P. larvatus)*	10	13	2.5	3.0	2.78
Bush hyrax*(Hetro h. brucei)*	1	1	0.25	0.23	0.24
Common genet (G. genetta)	8	6	2.01	1.39	1.69
Common jackal (*C. aures*)	6	6	1.51	1.39	1.45
Serval cat (*Felis serval*)	5	3	1.26	0.7	0.97
White T. Mongoose*(I. albicauda)*	6	10	1.51	2.33	1.93
Spotted hyena (*C. carcuta)*	63	71	15.87	16.55	16.22
Abyssinian hare (*L. habissinicus)*	6	4	1.51	0.93	1.21
Warthog (*P. africanus*)	18	22	4.53	5.13	4.84
Domestic dog (*Canis l. familiaris*)	5	3	1.26	0.73	0.97
Domestic cat (*F. cat*)	2	2	0.5	0.47	0.48
Horse (*Equus f. caballus)*	2	3	0.5	0.73	0.60
Crested porcupine (*H. cristata)*	+	+	+	+	+
Total	**397**	**429**	100	100	100%

Recording morphometric measurements of small mammals

Appendix 3: Medium and large sized mammals recorded during the study period

Spotted hyena

Warthog

White Tailed Mongoose

Bush pig

Common Jackal

African Civet

Serval cat

Abyssinian hare (*L. habissinicus)*

Appendex 4: Indirect indicator that observed during the study (Photo by own)