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SYSTEMATIC ZOOLOGY STREAM )

**Effect of Commercial Fishing on Avian Diversity and Activity  
Patterns of Marabou Stork and African Fish-Eagle in Lake  
Hawassa**

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Zoology

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## **DEDICATION**

This study is dedicated to the people who have been supportive and motivational anchor to me to achieve my academic ambition.

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## ABSTRACT

### **Effect of Commercial Fishing on Avian Diversity and Activity Patterns of Marabou Stork and African Fish-Eagle in Lake Hawassa**

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This study was conducted in one of the central rift valley Lakes of Ethiopia, in Lake Hawassa to assess the effect of commercial fishing activity on avian diversity and activity patterns of Marabou Stork and African Fish-Eagle in the area. Commercial fishing site was selected as one study site and an area about 2 – 3 km away from the commercial fishing site area was selected as a non-fishing study site. The study was conducted from July 2017 to March 2018 covering both wet and dry seasons. Data collection was carried out by careful and repeated observations in the selected study sites. The result of the study showed that, the avian diversity in the commercial fishing site area of Lake Hawassa was less the avian diversity in the non-fishing site of Lake Hawassa and it was significantly different between seasons ( $P < 0.05$ ). The major diurnal activity of Marabou Stork in the commercial fishing site and non-fishing site of Lake Hawassa during wet and dry seasons was foraging and it was not significantly different ( $P > 0.05$ ) between seasons and the between study sites. The diurnal activity patterns of the African Fish-Eagle during both the wet and dry seasons in both study sites of Lake Hawassa had no significant difference ( $P > 0.05$ ). The study showed that, the commercial fishing activity in Lake Hawassa had significant effect on the avian diversity ( $P < 0.05$ ). However, the commercial fishing activity did not affect the diurnal activity patterns of the selected species of birds in Lake Hawassa.

**Key words:** African Fish-Eagle, Avian diversity, Commercial fishing activity,

Diurnal activity patterns and Marabou Stork

# 1. INTRODUCTION

Ethiopia is a country with many aquatic and terrestrial ecosystems rich in faunal, floral and microbial biodiversity. The diversity of organisms in these ecosystems provides essential resources such as: foods, medicines and industrial materials. Vegetation types in Ethiopia are highly diverse ranging from afro-alpine to desert vegetation. Likewise, Ethiopia is also unquestionably a rich region in faunal diversity. With the limited studies that have been undertaken in the country, numerous categories of aquatic and terrestrial animals such as mammals ( 320 spp.) ( Afework Bekele and Yalden, 2013 ), birds ( 861 spp.), reptiles ( 78 spp.), amphibians ( 54 spp.) and fish ( 101 spp.) are recorded ( EBI, 2012 ).

The Ethiopian aquatic ecosystem has high diversity areas such as major rivers and lakes that are of great national and international importance. The country is well known for its richness in water potential. There are about 30 major lakes that are located in different ecological zones. These lakes are situated at altitudes ranging from about 150 m below sea level high up to 4000 m. The surface areas of the lakes vary considerably from less than 1 km<sup>2</sup> to over 3600 km<sup>2</sup> and mean depths range from few meters to over 260 meters. However, the major lakes that are of economic importance are concentrated in the great rift valley of the country ( EBI, 2007, 2016 ).

The Ethiopian rift valley lakes includes: Lake Abaya, Chamo, Zway, Shala, Koka reservoir, Abijatta and Hawassa. These lakes have ecological as well as economical importance. They are home for many faunal, floral and microbial organisms. Most of these lakes are highly productive and well known for their aquatic diversity, avian diversity and indigenous populations of edible fish species ( Golubtsov *et al.*, 2002 ).

Due to the presence of many edible species of fish in those rift valley lakes of Ethiopia; many people around the local areas of the lakes are engaged on commercial fishing activities to support their livelihood ( Ann *et al.*, 2013 ). There is also high avian diversity in the lakes in which some of them are dependent for food in the left over fish from the commercial fishing activity. Others depend on various food sources such as fish, insects and different other food sources in the wide home range areas of the lakes ( Carlson, 1977 ).

Lake Hawassa is one of the major commercial fishing activity sites of the rift valley lakes of Ethiopia and this aquatic ecosystem is rich in biodiversity with various avian species, fish, sundry forms of plants and micro-organisms (Tilahun Kibret and Harrison, 1989). Naturally, as long as the lake contains the necessary nutrients, the fish in it reproduce rapidly and result in increased fish population density. If this keeps going up without control, it will result in overcrowding of the fish population which might lead to scarcity of resources and cause competition among the fish for food, space and other necessities to live in the habitat. However, commercial fishing exploitation and the consumption of the birds on the fish regulate the population density of the fish in the lake. Birds play a vital role in keeping the balance of the lake ecosystem by their interaction with the fish and many other organisms in it. In this relationship, healthy population density of the fish and the birds as well as balanced ecosystem of the lake is maintained (Kalff, 2002).

Many people who live around lake areas like the resident people of Hawassa city and its nearby areas base their economic income on commercial fishing activity in the lakes (GFI, 2010). The commercial fishing activity in Lake Hawassa supply large amount of fish to the fish market in the area on daily basis. The amount of fish exploited by the fisher men from the lake varies from day to day. But they always try to harvest as many fish as they can everyday in order to get good income and satisfy the need of the local fish market (Zinabu Gebre-Mariam and Elias Dadebo, 1989). In addition to generating income to the local people and providing fish diet for the resident people of Hawassa city and tourists, the commercial fishing activity and the fish in lake Hawassa support the life of many permanent resident and seasonal migrant birds of the area. Some of the birds of the lake area feed themselves by catching fish, invertebrates; like insects and other small organisms. Others feed on left over fish from the fish market area of the lake. Due to this commercial fishing activity; many types of birds spend their time gathering at the fishing centers and fish market areas of the lake to compete for and scavenge on the left over of the fish and some other simply join the gathering to enjoy the crowd even if they feed on other food sources other than the left over fish. Because of this, it is clear that the avian diversity and activity patterns of the birds in the area can be affected by the commercial fishing activity (Carlson, 1977, Brook Lemma, 2003).

This study is conducted to assess the effect of commercial fishing on avian diversity and activity patterns of Marabou Stork and African Fish-Eagle in Lake Hawassa. In

this study, the effect of commercial fishing on the avian diversity and activity patterns of Marabou Stork and African Fish-eagle in the lake were covered.

### **1.1. Significance of the study**

The findings of this study would provide useful information about the status of avian diversity and activity patterns of Marabou Stork and African Fish-Eagle in Lake Hawassa. The analysis of the findings of this study showed the effect of commercial fishing on the avian diversity and activity patterns of Marabou Stork and African Fish-Eagle in Lake Hawassa. The findings of this study would also be relevant input for any interested individual or body who would like to conduct further study on effect of commercial fishing on avian diversity and activity patterns of Marabou Stork and African Fish-Eagle in Lake Hawassa.

## **1.2. Objectives of the study**

### **1.2.1. General objective**

To study the effect of commercial fishing on avian diversity and activity patterns of Marabou Stork and African Fish-Eagle in Lake Hawassa.

### **1.2.2. Specific objectives**

- To assess the effect of commercial fishing on avian diversity in Lake Hawassa.
- To assess the effect of commercial fishing on activity patterns of Marabou Stork and African Fish-Eagle in Lake Hawassa..

## **2. LITERATURE REVIEW**

### **2.1. Rift valley lakes and birds**

The rift valley lakes are ecosystems that provide ecological habitats for a significant array of plants and animals including many species of birds ( IUCN, 2002 ). They are important refugia to many migratory birds that travel long distances in search of food and habitat ( Jannert, 2003 ). They serve as critical breeding sites for several species of birds ( Prasad *et al.*, 2012 ). Wild birds are an integral part of any ecosystem, providing critical ecosystem services and functions. Birds have been proven to be excellent indicators of water quality ( Shimelis Aynalem and Afework Bekele, 2008 ) as in the case of assessing the ecological integrity of Prairie Wetlands ( Adamus, 1996 ). The distribution and abundance of many bird species are determined by the composition and structure of the vegetation that forms a major element of their habitats ( Shimelis Aynalem and Afework Bekele, 2008 ). Seasonality and consequent variations in the abundance of food resources also result in seasonal changes in the species richness and abundance of birds ( Williams and Middleton, 2007, Nirmala, 2016 ).

Amongst the lakes, ecosystem services and functions provided by birds are recreational and cultural which are also valuable to humans as many people derive great pleasure, fulfillment and inspiration from watching and listening to birds ( E.C., 2004 ).

Lakes equally provide multitude of uses of attracting human settlement and habitation. Despite the aforementioned direct and indirect benefits of lakes and birds, human effects on lakes are increasing everyday and their negative impacts are strongly being felt as lake ecosystem services are continuously being put in danger ( Naiman *et al.*, 1995 ). Many wetlands have been strongly degraded because of human impacts ( Verhoeven *et al.*, 2002 ). Human use of lakes includes drinking and water supply, power generation, navigation, commercial and recreational fisheries, body contact recreation, boating and other aesthetic recreational uses. This has led to humans creating manmade wetlands which have been reported to attract different types of bird species from those in natural wetland ecosystems ( Ismail *et al.*, 2012 ). Such ecosystems



are diverse in nature warranting the need to understand their influence on avifauna populations ( Sritharan and Burgess, 2012 ). The creation of an artificial wetland area is viewed as valuable measure since it can provide a new habitat for bird communities if all other factors are suitable ( Oindo *et al.*, 2001 ). Moreover, the presence of an artificial wetland habitat has been found to complement its natural counterpart by allowing more species to use different habitats in different conditions ( Kloskowi *et al.*, 2009 ). So the natural and artificial wetland areas together can create more avifauna and other species richness.

## **2.2. Threats to rift valley lakes of Ethiopia**

Nowadays, many of the Ethiopian rift valley lakes which are home for large number of species of birds and other organisms are facing threats which can gradually eliminate or change them and their biodiversity. The threats include draining of the water of the lake wetlands for agriculture, overgrazing, overexploitation of the wetland resources, deforestation, siltation and soil erosion, urbanization and industrialization, overfishing, introduction of floriculture industries, demographic pressure and climate change ( Teklu Gebretsadik and Kassahun Mereke, 2017 ).

Long term draining causes loss of large amount of water and interferes with the ecological recovery of the wetland systems and enhances its drying up. For instance, in Afar Regional State of Ethiopia, many areas of wetlands have been lost during 1960's due to the increase of irrigation practice in the area ( Keddy, 2000 ). As a result, the State has lost many of its wetlands.

Wetlands are often last destination for pastoralists during the dry season which result in overgrazing. Overgrazing is a threat when year round grazing prevents ecological recovery period of the wetlands which results in the loss of the ecosystems and its biodiversity. Compaction of the wetlands also has impact on the infiltration capacity of the soil hence affecting the hydrological and balance of the wetland itself ( Girus and Seyoum, 2013 ).

Over-exploitation: of wetland resources is at present a major threat in the rift valley lake areas of Ethiopia. It is causing the loss of the wetlands ecosystems and its biodiversities. Excessive exploitation of resources may also lead in some cases to a

drying of the wetland itself ( Morrison *et al.*, 2012 ). A good example for this, is the drying of lake.

Deforestation, siltation and soil erosion: are threatening the wetland ecosystems and its biodiversity by decreasing the water holding capacity and even may result in drying of the wetland itself. Introduction of non-native plants to the wetland areas, removal of buffering vegetation and upland forest degradation are the main causes for the loss of vegetation. This eventually result in change and loss of wetland ecosystems and its biodiversity ( Raini, 2009 ).

Due to the abundance of natural resources including water, many urban centers are located near wetlands ( Ehrenfeld, 2000 ). This may result in the release of the primary pollutants such as, fertilizers, human sewage, animal wastes, pesticides and heavy metals which threaten the wetland ecosystems and its biodiversity ( Stephen, 2004 ).

Excessive exploitation of fish from the wetland ecosystems may result in the loss of some fish species. This in return may result in the loss of many avifauna and other organisms which depend on the fish ( FAO, 2007 ).

Many of the rift valley lake wetland areas of Ethiopia are hot spots for floriculture industries. Fertile land and water is available for the production of flowers in large scale. The pollutant chemicals like fertilizers used by the floriculture industries are released to the wetlands and pollute the ecosystems. As a result the biodiversity including the avifauna and fish of these wetlands ecosystems are threatened and lost ( Teklu Gebretsadik and Kassahun Mereke, 2017 ).

Wetland ecosystems are threatened by the impacts of global climate change. The impacts of the climate change are causing the drying up wetlands. This has severe impact by resulting the loss of wetland ecosystems and its biodiversity including the avifauna and fish ( Roessing *et al.*, 2004 ).

The rapid human population growth around the wetland areas is causing high and rapid consumption of biodiversity resources resulting in the disturbance of the wetland ecosystems and loss of their biotic components including the avifauna and fish ( Teklu Gebretsadik and Kassahun Mereke, 2017 ).

All the threats to rift valley lake wetlands mentioned above are threatening the wetland ecosystems and their biodiversity including the avifauna, fish and all other organisms.

### 3. STUDY AREA

#### 3.1. Description of the study area

The study was carried out in central Ethiopia rift valley lake, Lake Hawassa which lies between  $6^{\circ} 33' - 7^{\circ} 33' \text{ N}$  and  $38^{\circ} 22' - 38^{\circ} 29' \text{ E}$ . Lake Hawassa is located 275 km away south of Addis-Ababa (Elias Dadebo, 2000). It is largely situated in the west side of Hawassa city at an elevation of 1708 m above sea level. Lake Awassa stretches 16 km from the north-east to south-west direction and 8 km from north-west to south-east direction having an approximate water volume of 1.3 billion  $\text{m}^3$ . The lake has a maximum depth of 21.6 m with a mean depth of 11 m (Elias Dadebo, 2000). The catchment of the lake has a total area of  $1455 \text{ km}^2$  of which  $93.6 \text{ km}^2$  is the surface area of the lake that may increase up to  $99.3 \text{ km}^2$  during the rainy season. The annual net ground water outflow from Lake Hawassa to adjacent basins is estimated at  $58 \times 10^6 \text{ m}^3$  (Yemane Gebreegziabher, 2004, EFASA, 2013).

Lake Hawassa is fed by Tikurwuha River, which is the main perennial river in the catchment, that joins the lake passing through Chelekleka swamp found on the east side of the lake. High discharge springs at the upstream feeds Chelekleka swamp in addition to the runoff from the eastern escarpments of the Rift Valley (Habtom Gebremichael, 2007).

Lake Hawassa is rich in biodiversity that include, animals, plants and micro-organisms. The littoral area is covered with emergent and submerged macrophytes those serve as shelter, thrashing and proliferation zones for several benthic and pelagic zooplanktons such as, protozoans, rotifers, crustaceans and several weed bed fauna like annelids, insects as well as fish. The littoral and open water of the lake is dominated by wide-ranging delivery of “qetema” (*Cyperaceae*), “fila” (*Typha* sp.), floating grass *Paspalidium germinatum* and hydrophytes such as the blue water lily (*Nymphaea coerulea*), water cabbage (*Pistia stratiotes*) and Wolfia arrhiza, considered to be the smallest flowering plant in the world (EFASA, 2013).

Lake Hawassa is one of the bird sanctuaries in the Rift Valley of Ethiopia and home land for many species of water birds, including local and Palaearctic migrants

with large population of Marabou Storks. The animal community includes hippopotamus, otters, monitor lizards, vervet and colobus monkeys surviving on the flanking lake ecosystem. Six varieties of fish are abundantly found in the lake of which the native African species, Tilapia ( *Oreochromis niloticus* ) is dominant. The lake is a major source of income through eco-tourism while the inhabitants depend on the lake for fishing and recreation ( Sairam, 2014 ) ( Fig. 1 ).

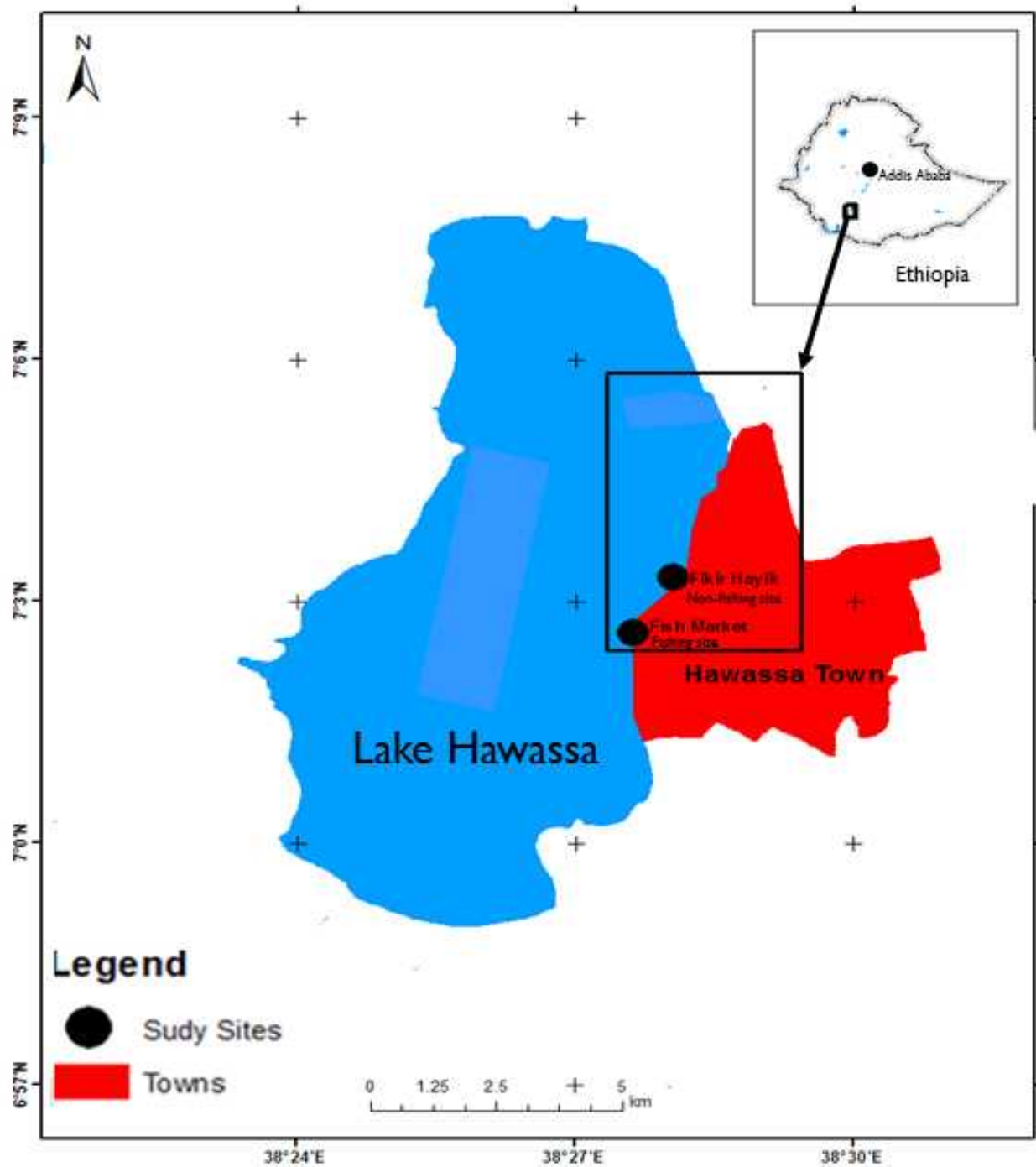
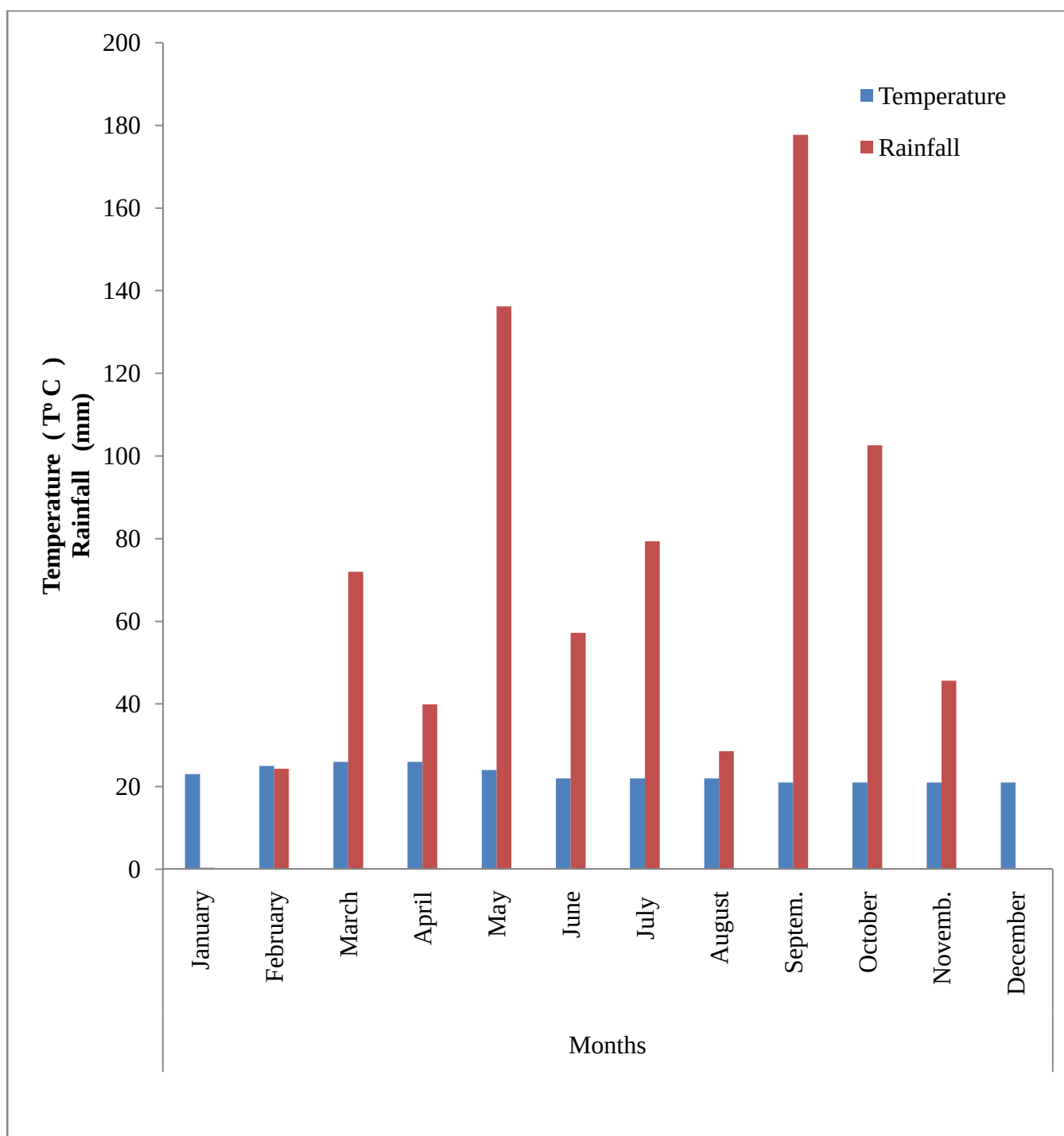


Figure 1. Map of the study area Lake Hawassa

### **3.2. Climate of the study area**

Lake Hawassa area has a tropical climate with wet season that mainly lasts from July to September and dry season that lasts from January to March with 22.8° C average monthly temperature and 63.66 mm of average monthly rainfall in 2017 ( <http://www.WorldweatherOnline.com> ).

The 2017 monthly temperature and rainfall of Lake Hawaasa area is summarized in Figure 2.



**Figure 2. Monthly average temperature and rainfall of Lake Hawassa area (2017)**

(Source: <http://www.WorldweatherOnline.com>)



## **4. MATERIALS AND METHODS**

### **4.1. Materials**

In this study, binoculars were used to observe and identify the bird species and to follow up and observe the activity patterns of Marabou Stork and African Fish-Eagle. Bird guide book ( Redman *et al.*, 2011 ) was used to identify the species and names of the birds observed in the study sites. Digital camera was used to capture photos and record videos of the birds observed in the study sites to help in the identification of the species of the birds and to make repeated observations on the activity patterns of Marabou Stork and African Fish-Eagle in the study areas. Data sheets were used to write and record the names of the identified species of birds. The numerical data of each species of birds and the activity patterns of Marabou Stork and African Fish-Eagle observed in the study sites during the field study were recorded.

### **4.2. Methods**

#### **4.2.1. Study design**

A preliminary survey was conducted around Lake Hawassa about the avian diversity and diurnal activity patterns of some birds with respect to commercial fishing activity around the lake. To carry out the study, sample areas were selected by systematic random sampling method ( Bibby, 1998 ). The area where there is commercial fishing activity was selected as one study site and an area about 2 – 3 km away from the commercial fishing site was selected as a non-fishing study site.

The commercial fishing site in this study is found in the south-eastern part of Lake Hawassa along the wide western side of the fish market area of Hawassa city ( Plate 1 ).



**Plate 1. Part of the commercial fishing site of Lake Hawassa**

The non-fishing site area in this study is located in the central-eastern locally known as yefikir hayk area of Lake Hawassa along the central-western side of Hawassa city ( Plate 2 ).



**Plate 2. Part of the non-fishing site of Lake Hawassa**

Avian diversity and diurnal activity patterns of Marabou Stork and African Fish-Eagle were studied during July 2017 to March 2018 covering both wet ( July to September ) and dry ( January to March ) seasons.

Data were collected from the study sites which covers the shores of the lake and water surface of the lake next to the shores. During the data collection the field of observation covers wide area of focus as far as the distance naked human eyes and human eyes aided by binoculars can have clear visual image of the birds and their activity patterns. The data collection was carried out by careful repeated observations and recording of the data on datasheets. In addition, visual data were recorded by using digital camera by taking pictures and recording videos for detailed observations.

#### **4.2.2. Data collection**

##### **4.2.2.1. Avian diversity in the commercial fishing and non-fishing sites of Lake**

##### **Hawassa**

During the wet and dry seasons, the type of species of birds and total number of individuals of each species observed in the commercial fishing and non-fishing site study areas were identified, counted by careful repeated observations and recorded. The study was conducted during the wet and dry seasons in the morning sessions ( 06:00 a.m. - 12:00 p.m. ) and afternoon sessions ( 01:00 p.m. - 06:00 p.m. ) of the days in both the study sites. The data were collected for three months ( July to September ) during the wet season and for other three months ( January to March ) during the dry season.

Identification of the species of birds was carried out by using a bird guide book ( Redman *et al.*, 2011 ) and binoculars to observe closely the birds in their natural habitats. The identification and counting of the total number of individuals of each species was done by moving repeatedly across the study site areas from end to end in all directions during the study sessions ( Biby *et al.*, 2000 ).

#### **4.2.2.2. Diurnal activity patterns of Marabou Stork and African Fish-Eagle in the commercial fishing and non-fishing sites of Lake Hawassa**

The study of the diurnal activity patterns of Marabou Stork which was the most abundant and African Fish-Eagle which was the least abundant species of birds was conducted during the wet and dry seasons during the morning sessions ( 06:00 a.m. - 12:00 p.m. ) and afternoon sessions ( 01:00 p.m. - 06:00 p.m. ) of the study days. For the diurnal activity patterns study, the most abundant bird species ( Marabou Stork ) and the least abundant bird species ( African Fish-Eagle ) in the study site areas were selected.

To assess the diurnal activity patterns of Marabou Stork and African Fish-Eagle in both the selected study sites, five-minutes recording intervals was applied for the diurnal activity patterns ( Bezawork et al, 2009 ). The activity of Marabou Stork and African Fish-Eagle was repeatedly observed and recorded. Major activities were recorded as foraging, flying, resting and preening. Observations of each day were compiled as percentage of Marabou Stork and African Fish-Eagle in different activities for twelve 1-h periods; i.e., 06:00 – 07:00, 07:0 - 8:00, ..., 16:00 - 17:00 h ( Seddon and Ismail, 2002). The collected data was analyzed to assess the effect of commercial fishing activity on the avian diversity and activity patterns of Marabou Stork and African Fish-Eagle in Lake Hawassa.

### 4.3. Data analysis

The collected data of the wet and dry seasons from both the selected study sites were arranged, organized and entered into Microsoft Office Excel for analysis.

To analyze the avian diversity during the wet and dry seasons in the study sites the Shannon-Weiner Diversity Index ( $H'$ ) was calculated (Shannon and Weiner, 1949).

$H' = - \sum P_i \ln P_i$  Where,

$H'$  is diversity index;

$P_i$  is the proportion of each species in sample and

$\ln P_i$  is natural logarithm of this proportion.

The collected data of the activity patterns of the most abundant and least abundant species of birds (Marabou stork and African Fish-Eagle) during both the wet and dry seasons in the study sites were analyzed by using SPSS software version 20 by applying paired  $t$  – tests.

## 5. RESULTS

### 5.1. Avian diversity in the commercial fishing and non-fishing sites of Lake Hawassa during wet and dry seasons

In this study, 17 bird species were observed in the commercial fishing site of Lake Hawassa during the wet season and 24 bird species during the dry season (Table 1).

Table 1. Avian species composition in the commercial fishing site of Lake Hawassa during wet and dry seasons

| Common name          | Scientific name                 | Wet season<br>abundance score | Dry season<br>abundance score |
|----------------------|---------------------------------|-------------------------------|-------------------------------|
| Egyptian Goose       | <i>Alopochen aegyptiaca</i>     | 94                            | 246                           |
| African Fish-Eagle   | <i>Haliaeetus vocifer</i>       | 2                             | 5                             |
| African Jacana       | <i>Actophilornis africanus</i>  | 50                            | 12                            |
| Pied Kingfisher      | <i>Ceryle rudis</i>             | 25                            | 15                            |
| Great Egret          | <i>Egretta alba</i>             | 26                            | 42                            |
| Sacred Ibis          | <i>Threskiornis aethiopicus</i> | 125                           | 302                           |
| Great Cormorant      | <i>Phalacrocorax carbo</i>      | 1                             | 1                             |
| Marabou Stork        | <i>Leptoptilos crumeniferus</i> | 953                           | 727                           |
| Grey-headed Gull     | <i>Larus cirrocephalus</i>      | 8                             | 8                             |
| Hammer kop           | <i>Scopus umbretta</i>          | 57                            | 52                            |
| Sandwich Tern        | <i>Sterna sandvicensis</i>      | 116                           | 401                           |
| Spur-winged Plover   | <i>Vanellus spinosus</i>        | 1                             | 4                             |
| Goliath Heron        | <i>Ardea goliath</i>            | 1                             | 16                            |
| Hooded Vulture       | <i>Necrosyrtes monachus</i>     | 19                            | 33                            |
| Great White Pelican  | <i>Pelecanus onocrotalus</i>    | 2                             | 8                             |
| Malachite Kingfisher | <i>Alcedo cristata</i>          | 1                             | -                             |

|                       |                                |   |     |
|-----------------------|--------------------------------|---|-----|
| Hadada Ibis           | <i>Bostrychia hagedash</i>     | 2 | 2   |
| Lesser Spotted Eagle  | <i>Aquila pomarina</i>         | - | 33  |
| Pectoral Sandpiper    | <i>Calidris melanotos</i>      | - | 15  |
| Long-toed Plover      | <i>Vanellus crassirostris</i>  | - | 27  |
| Eurasian Coot         | <i>Fulica atra</i>             | - | 124 |
| Black-winged Stilt    | <i>Himantopus himantopus</i>   | - | 20  |
| Black-headed Gull     | <i>Larus ridibundus</i>        | - | 40  |
| Long-tailed Cormorant | <i>Phalacrocorax africanus</i> | - | 26  |
| Little Egret          | <i>Egretta garzetta</i>        | - | 26  |

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In the non-fishing site of Lake Hawassa, 25 bird species during the wet season and 32 bird species during dry season were recorded ( Table 2 ).

Table 2. Avian species composition in the non-fishing site of Lake Hawassa During wet and dry seasons

| Common name           | Scientific name                 | Wet season<br>abundance score | Dry season<br>abundance score |
|-----------------------|---------------------------------|-------------------------------|-------------------------------|
| Great Cormorant       | <i>Phalacrocorax carbo</i>      | 24                            | 98                            |
| Long-tailed Cormorant | <i>Phalacrocorax africanus</i>  | 13                            | 64                            |
| Great Egret           | <i>Egretta alba</i>             | 12                            | 23                            |
| Little Egret          | <i>Egretta garzetta</i>         | 7                             | 41                            |
| Great White Pelican   | <i>Pelecanus onocrotalus</i>    | 10                            | 20                            |
| Egyptian Goose        | <i>Alopochen aegyptiaca</i>     | 15                            | 28                            |
| African Pygmy-goose   | <i>Nettapus auritus</i>         | 62                            | 52                            |
| African Fish-Eagle    | <i>Haliaeetus vocifer</i>       | 2                             | 2                             |
| African Jacana        | <i>Actophilornis africanus</i>  | 57                            | 39                            |
| Pied Kingfisher       | <i>Ceryle rudis</i>             | 22                            | 18                            |
| Malachite Kingfisher  | <i>Alcedo cristata</i>          | 26                            | 10                            |
| Spur-winged Plover    | <i>Vanellus spinosus</i>        | 7                             | 8                             |
| Hammer Kop            | <i>Scopus umbretta</i>          | 18                            | 28                            |
| Sacred Ibis           | <i>Threskiornis aethiopicus</i> | 64                            | 111                           |
| Marabou Stork         | <i>Leptoptilos crumeniferus</i> | 280                           | 296                           |
| Black Crake           | <i>Amaurornis flavirostra</i>   | 15                            | 16                            |
| Purple Heron          | <i>Ardea purpurea</i>           | 13                            | 14                            |
| Grosbeak Weaver       | <i>Amblyospiza albifrons</i>    | 77                            | -                             |
| Goliath Heron         | <i>Ardea goliath</i>            | 7                             | 4                             |
| Allen's Gallinule     | <i>Porphyrio alleni</i>         | 5                             | 3                             |
| Purple Swamp hen      | <i>Porphyrio porphyrio</i>      | 14                            | 5                             |



|                           |                                |    |     |
|---------------------------|--------------------------------|----|-----|
| Common Moorhen            | <i>Gallinula chloropus</i>     | 6  | 1   |
| Blue-headed Coucal        | <i>Centropus monachus</i>      | 6  | 8   |
| Grey-headed Gull          | <i>Larus cirrocephalus</i>     | 16 | 34  |
| Black-crowned Night Heron | <i>Gorsachius leuconotus</i>   | 1  | 56  |
| White-backed Duck         | <i>Thalassornis leuconotus</i> | -  | 8   |
| Black-tailed Godwit       | <i>Limosa limosa</i>           | -  | 6   |
| Curlew Sandpiper          | <i>Calidris ferruginea</i>     | -  | 18  |
| Long-toed Stint           | <i>Calidris subminuta</i>      | -  | 4   |
| Long-toed Plover          | <i>Vanellus crassirostris</i>  | -  | 26  |
| Eurasian Coot             | <i>Fulica atra</i>             | -  | 129 |
| Red-necked Phalarope      | <i>Phalaropus lobatus</i>      | -  | 18  |
| Lesser Spotted Eagle      | <i>Aquila pomarina</i>         | -  | 8   |
| Black-winged Stilt        | <i>Himantopus himantopus</i>   | -  | 14  |

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Overall 25 bird species in the commercial fishing site and 34 bird species in the non-fishing site of Lake Hawassa during both seasons were recorded.

The avian diversity index in the commercial fishing site of Lake Hawassa during the wet season and dry season were 1.4 and 2.1 respectively. This shows that, the avian diversity in the commercial fishing site area of Lake Hawassa was greater during the dry season than during the wet season and it was significantly different between seasons ( $P < 0.05$ ).

The avian diversity index in the non-fishing site of Lake Hawassa during the wet season and dry season were 2.3 and 2.8 respectively. This shows that, the avian diversity in the non-fishing site area of Lake Hawassa greater during the dry season than during the wet season and it was significantly different between seasons ( $P < 05$ ).

The avian diversity index in the commercial fishing site and non-fishing site of Lake Hawassa during wet and dry seasons is summarized in Table 3.

Table 3. Shannon-Weaver avian diversity index in the commercial fishing site and non-fishing site of Lake Hawassa during the wet and dry seasons

| Shannon-Weaver avian diversity index ( $H'$ ) |            |            |
|-----------------------------------------------|------------|------------|
| Site                                          | Wet season | Dry season |
| Commercial fishing site                       | 1.4        | 2.1        |
| Non-fishing site                              | 2.3        | 2.8        |

## 5.2. Diurnal activity patterns of Marabou Stork and African Fish-Eagle in the commercial fishing and non-fishing sites of Lake Hawassa during wet and dry seasons

### 5.2.1. Diurnal activity patterns of Marabou Stork in the commercial fishing site of Lake Hawassa during wet and dry seasons

The diurnal activity patterns of Marabou Stork in the commercial fishing site of Lake Hawassa during the wet season showed, 64.6% of their time was spent on foraging, 5.3% on flying, 16.5% on resting and 13.4% on preening. Foraging had the highest percentage and flying had the lowest percentage activity of the Marabou Stork during the wet season in the commercial fishing site of Lake Hawassa. During the wet season, foraging activity reaches its peak between 11:00 h and 12:00 h during the morning and between 16:00 h and 17:00 h during the afternoon ( Fig. 3 ).

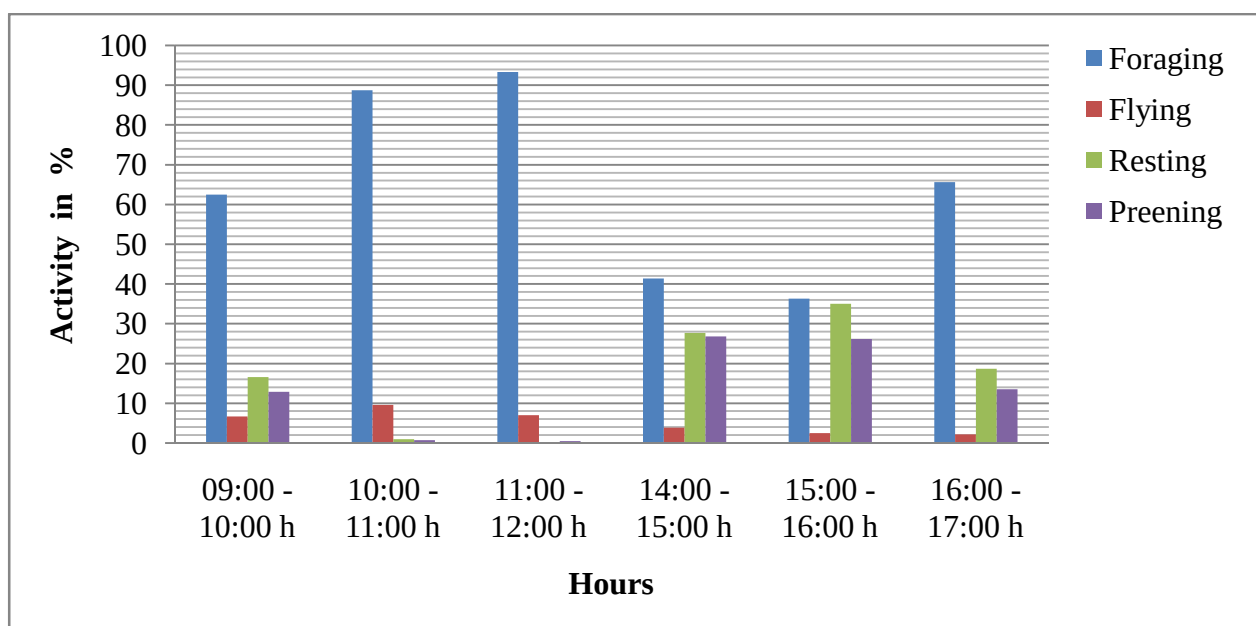


Figure 3. Diurnal activity patterns of Marabou Stork in the commercial fishing site of Lake Hawassa during the wet season

The diurnal activity patterns of Marabou Stork in the commercial fishing site of Lake Hawassa during the dry season showed, 58.6% of their time was spent on foraging, 15.6% on flying, 12% on resting and 13.8% on preening. Foraging had the highest percentage and resting had the lowest percentage activity of the Marabou Stork during the wet season in the commercial fishing site of Lake Hawassa. In the dry season the foraging activity reaches its peak between 10:00 h and 12:00 h during the morning and between 16:00 h and 17:00 h during the afternoon of

( Fig. 4 ).

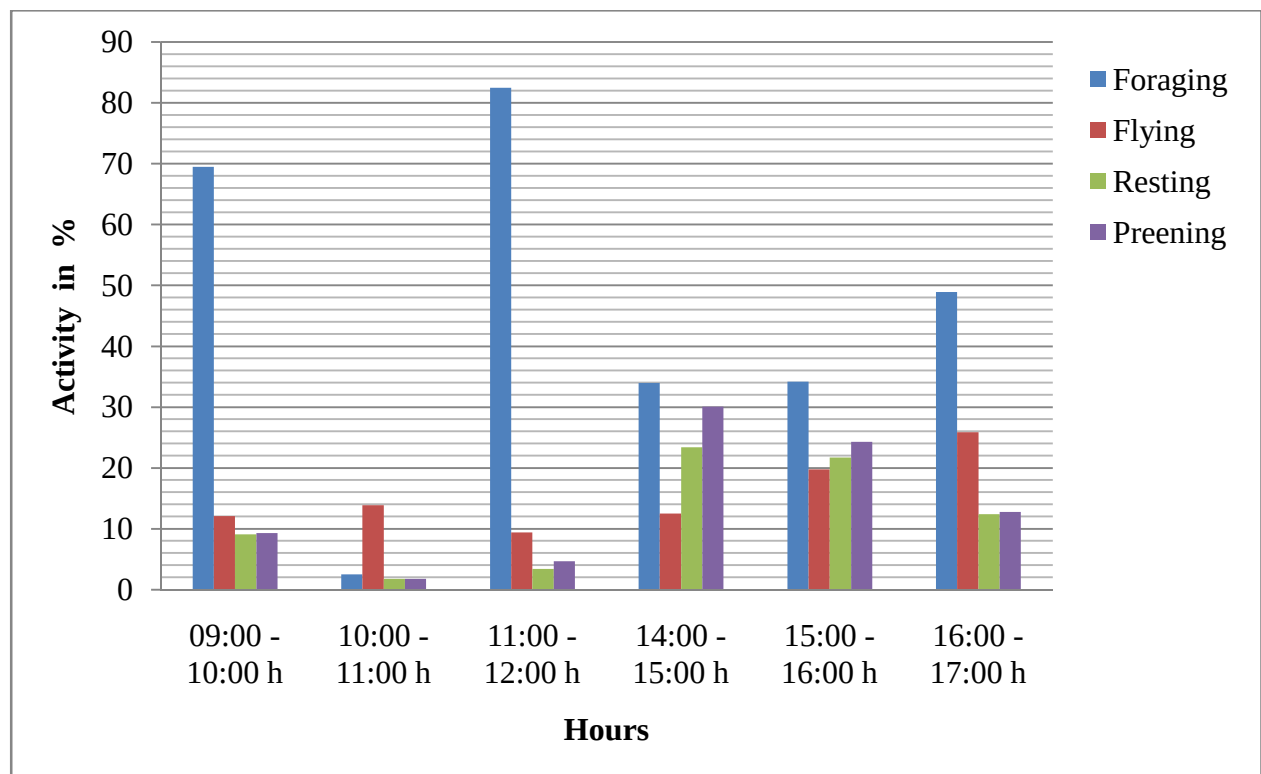


Figure 4. Diurnal activity patterns of Marabou Stork in the commercial fishing site of Lake Hawaasaa during the dry season

The major diurnal activity of Marabou Stork in the commercial fishing site of Lake Hawassa during both the wet and dry seasons was foraging. The foraging percentage of the wet and dry seasons were not significantly different ( $P > 0.05$ ).

### 5.2.2. Diurnal activity patterns of Marabou Stork in the non-fishing site of

#### Lake Hawassa during wet and dry seasons

The diurnal activity patterns of Marabou Stork in the non-fishing site of Lake Hawassa during the wet season showed, 56.8% of their time was spent on foraging, 2.9% on flying, 22.4% on resting and 17.9% on preening. Foraging had the highest percentage and flying had the lowest percentage activity of the Marabou Stork during the wet season in the non-fishing site of Lake Hawassa. during the wet season the foraging activity reaches its peak between 11:00 h and 12:00 h during the morning and between 16:00 h and 17:00 h during the afternoon ( Fig. 5 ).

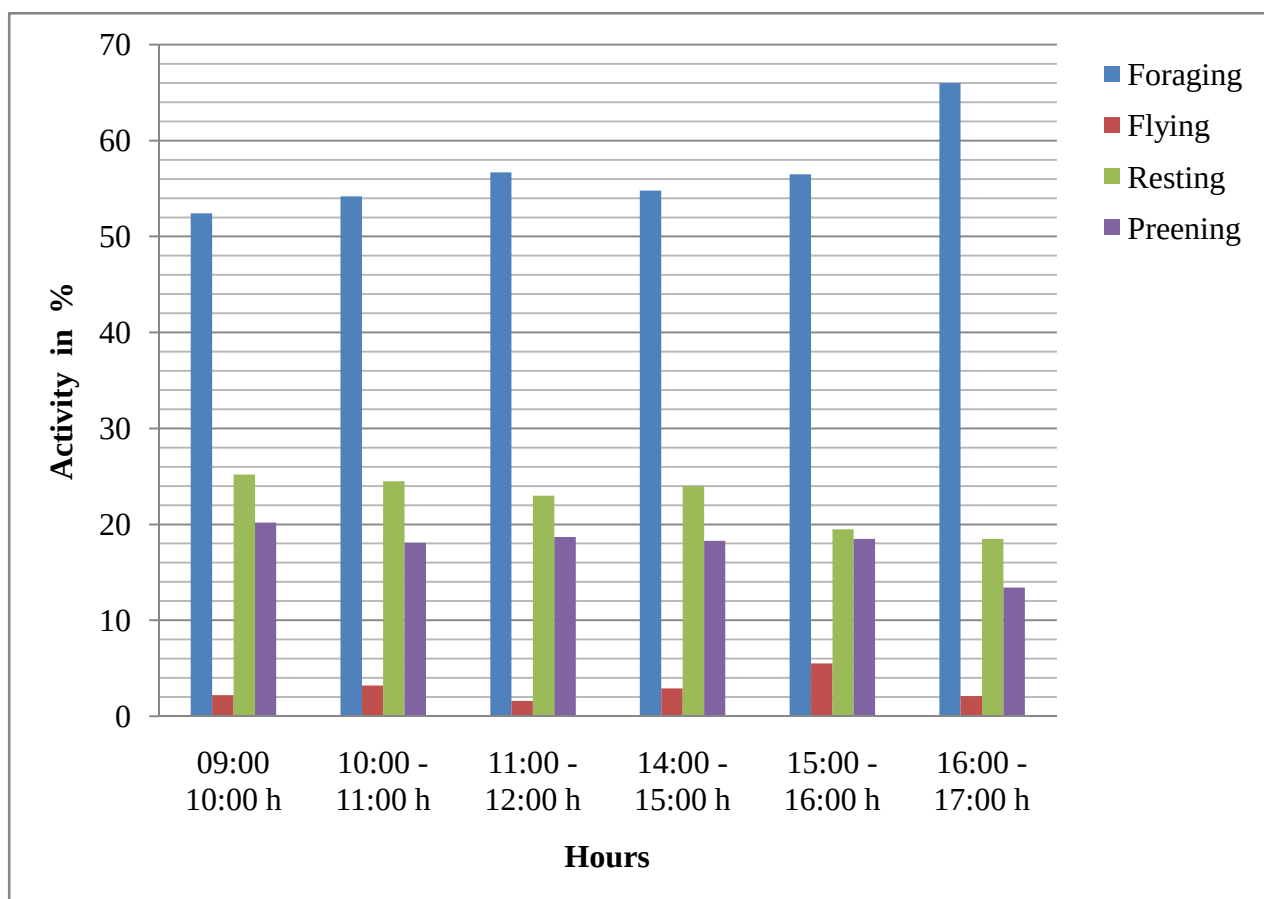


Figure 5. Diurnal activity patterns of Marabou Stork in the non-fishing site of Lake Hawaasaa during the wet season

The diurnal activity patterns of Marabou Stork in the non-fishing site of Lake Hawassa during the dry season showed, 65% of their time was spent on foraging, 11% on flying, 11% on resting and 13% on preening. Foraging had the highest percentage and, flying and resting had the lowest percentage activity of the Marabou Stork during the wet season in the non-fishing site of Lake Hawassa. During the dry season the foraging activity reaches its peak between 10:00 h and 11:00 h during the morning and between 16:00 h and 17:00 h during the afternoon ( Fig. 6 ).

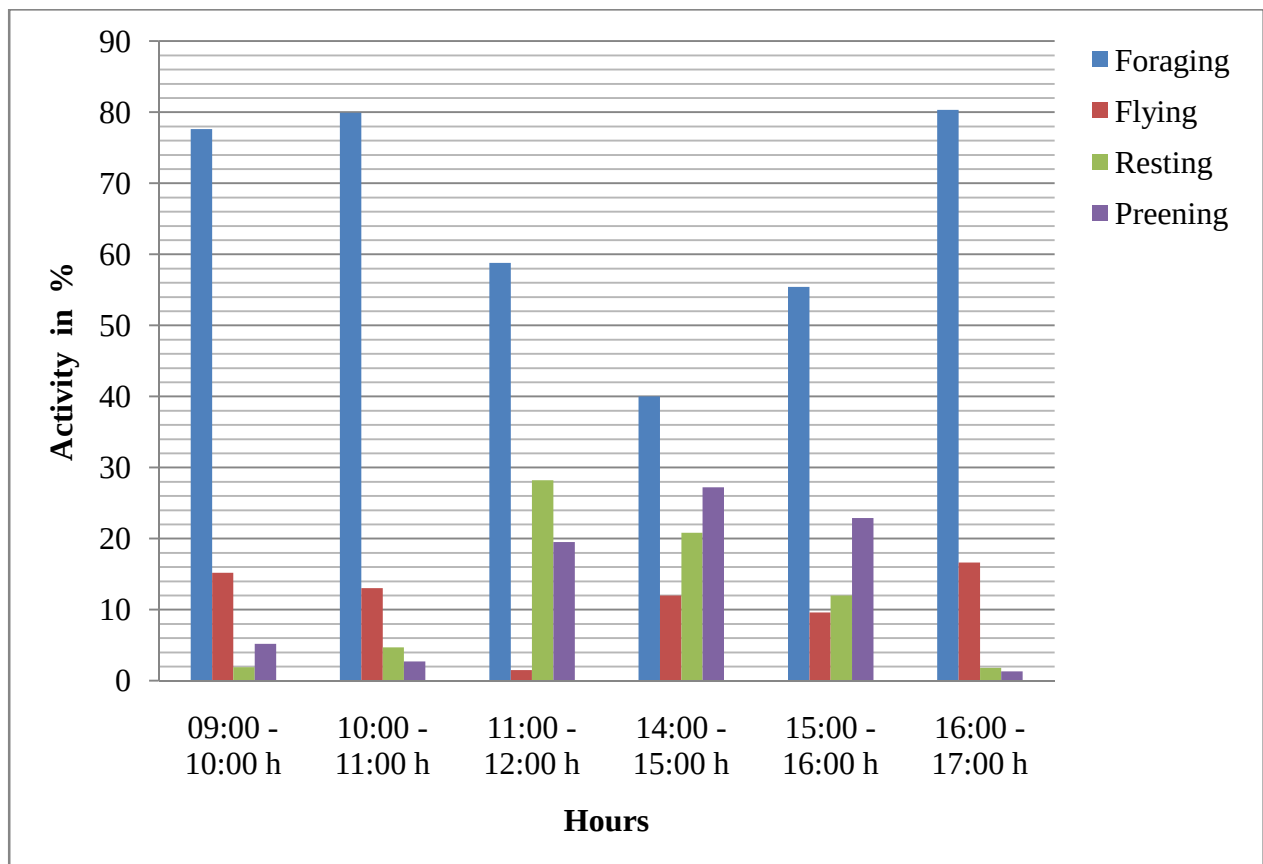


Figure 6. Diurnal activity patterns of Marabou Stork in the non-fishing site of Lake Hawaasaa during the dry season

The major diurnal activity of Marabou Stork in the non-fishing site of Lake Hawassa during both the wet and dry seasons was foraging. The foraging percentage of the wet and dry seasons were not significantly different ( $P > 0.05$ ).

### 5.2.3. Diurnal activity patterns of African Fish-Eagle in the commercial fishing

#### Site of Lake Hawassa during the wet and dry seasons

The diurnal activity patterns of African Fish-Eagle in the commercial fishing site of Lake Hawassa during the wet season showed, 31.7% of their time was spent on foraging, 35% on flying and 33.3% on resting. Flying had the highest percentage activity of the African Fish-Eagle during the wet season in the commercial fishing site of Lake Hawassa. The foraging, flying and resting percentage of the African Fish-Eagle activity patterns were not significantly different ( $P > 0.05$ ) ( Fig. 7 ).

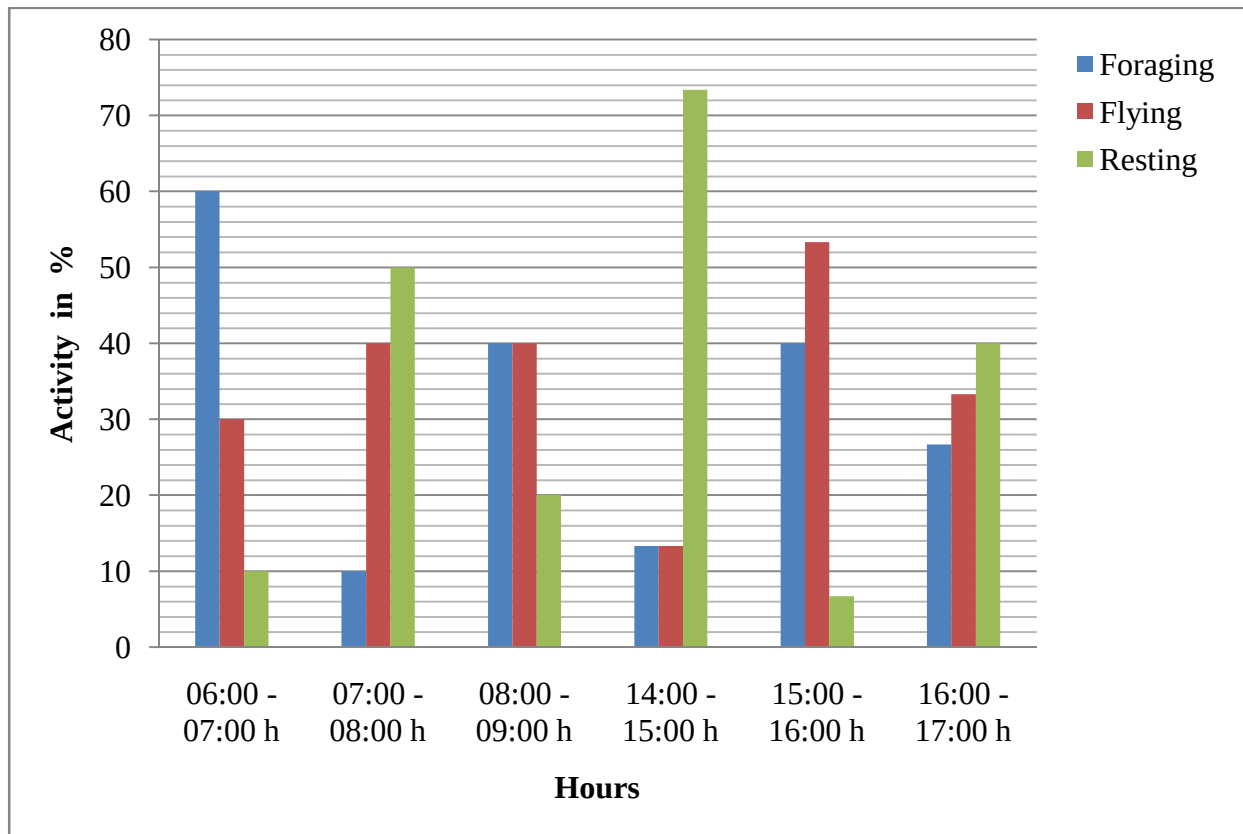


Figure 7. Diurnal activity patterns of African Fish-Eagle in the commercial fishing site of Lake Hawassa during the wet season

The diurnal activity patterns of African Fish-Eagle in the commercial fishing site of Lake Hawassa during the dry season showed, 26.7% of their time was spent on foraging, 33.3% on flying and 40% on resting. Resting had the highest percentage activity of the African Fish-Eagle during the wet season in the commercial fishing site of Lake Hawassa. The foraging, flying and resting percentage of the African Fish-Eagle activity patterns were not significantly different ( $P < 0.05$ ) (Fig. 8).

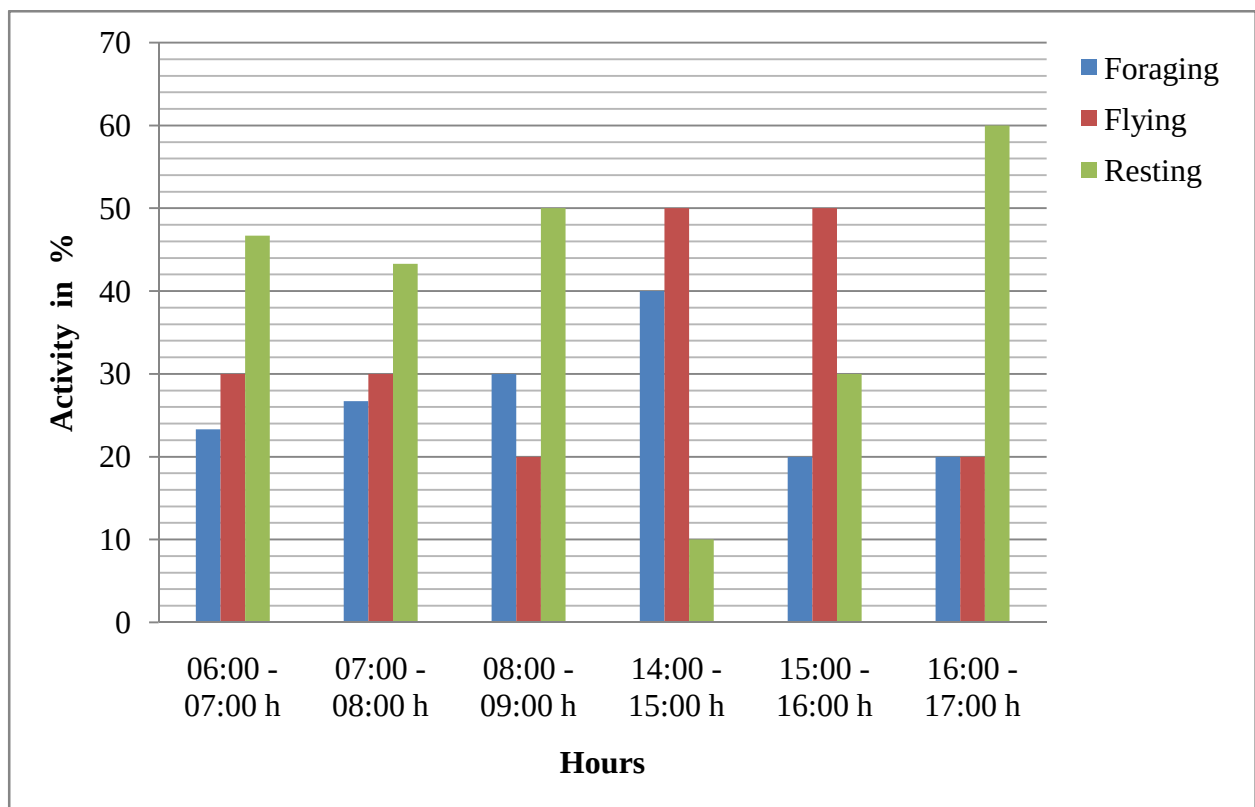


Figure 8. Diurnal activity patterns of African Fish-Eagle in the commercial fishing site of Lake Hawassa during the dry season

The diurnal activity patterns ( foraging, flying and resting ) of African Fish-Eagle during both the wet and dry seasons in the commercial fishing site of Lake Hawassa were not significantly different ( $P > 0.05$ ).



#### 5.2.4. Diurnal activity patterns of African Fish-Eagle in the non-fishing site of

##### Lake Hawassa during wet and dry seasons

The diurnal activity patterns of African Fish-Eagle in the non-fishing site of Lake Hawassa during the wet season showed, 31.7% of their time was spent on foraging, 35.3% on flying and 33% on resting. Flying had the highest percentage activity of the African Fish-Eagle during the wet season in the non-fishing site of Lake Hawassa. The foraging, flying and resting percentage of the African Fish-Eagle activity patterns were not significantly different ( $P > 0.05$ ) (Fig. 9).

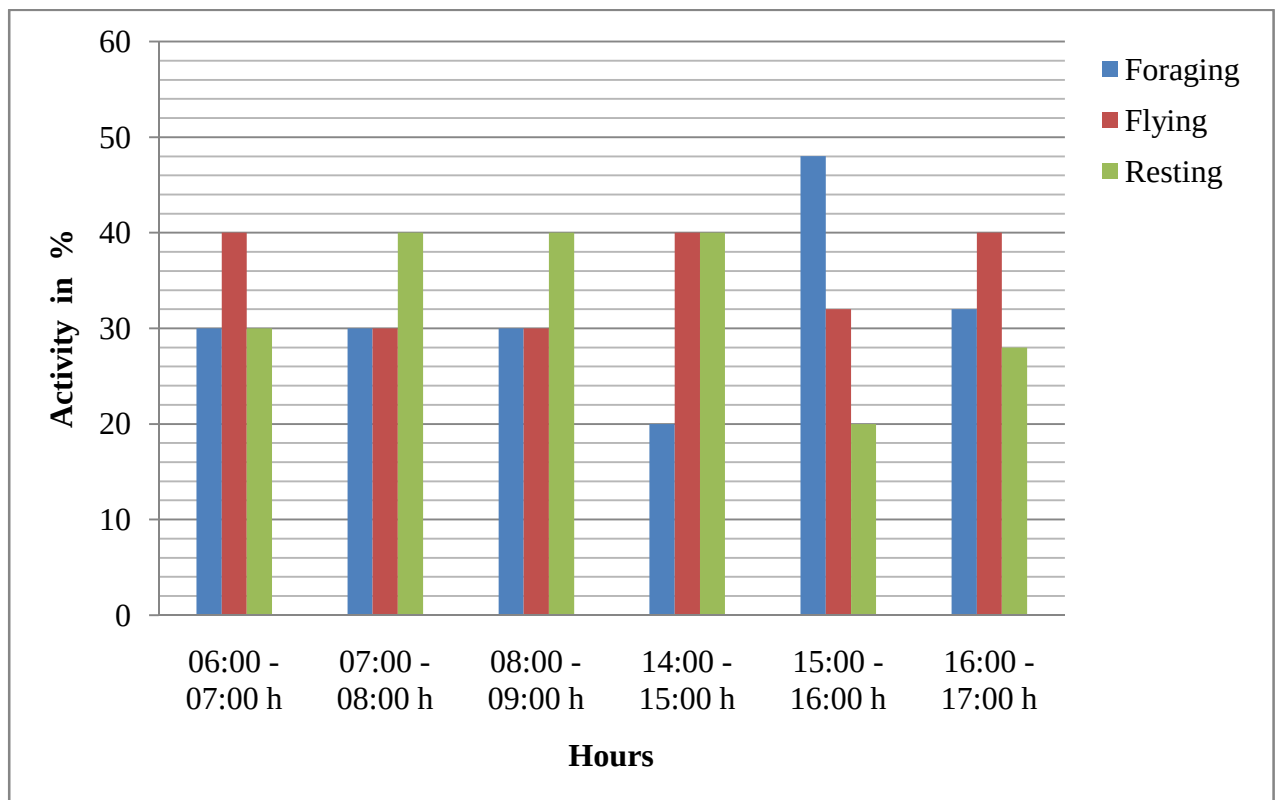


Figure 9. Diurnal activity patterns of African Fish-Eagle in the non-fishing site of Lake Hawassa during the wet season

The diurnal activity patterns of African Fish-Eagle in the non-fishing site of Lake Hawassa during the dry season showed, 32.5% of their time was spent on foraging, 35.3% on flying and 40% on resting. Resting had the highest percentage activity of the African Fish-Eagle during the wet season in the non-fishing site of Lake Hawassa. The foraging, flying and resting percentage of the African fish eagle activity patterns were not significantly different ( $P > 0.05$ ) (Figure 10).

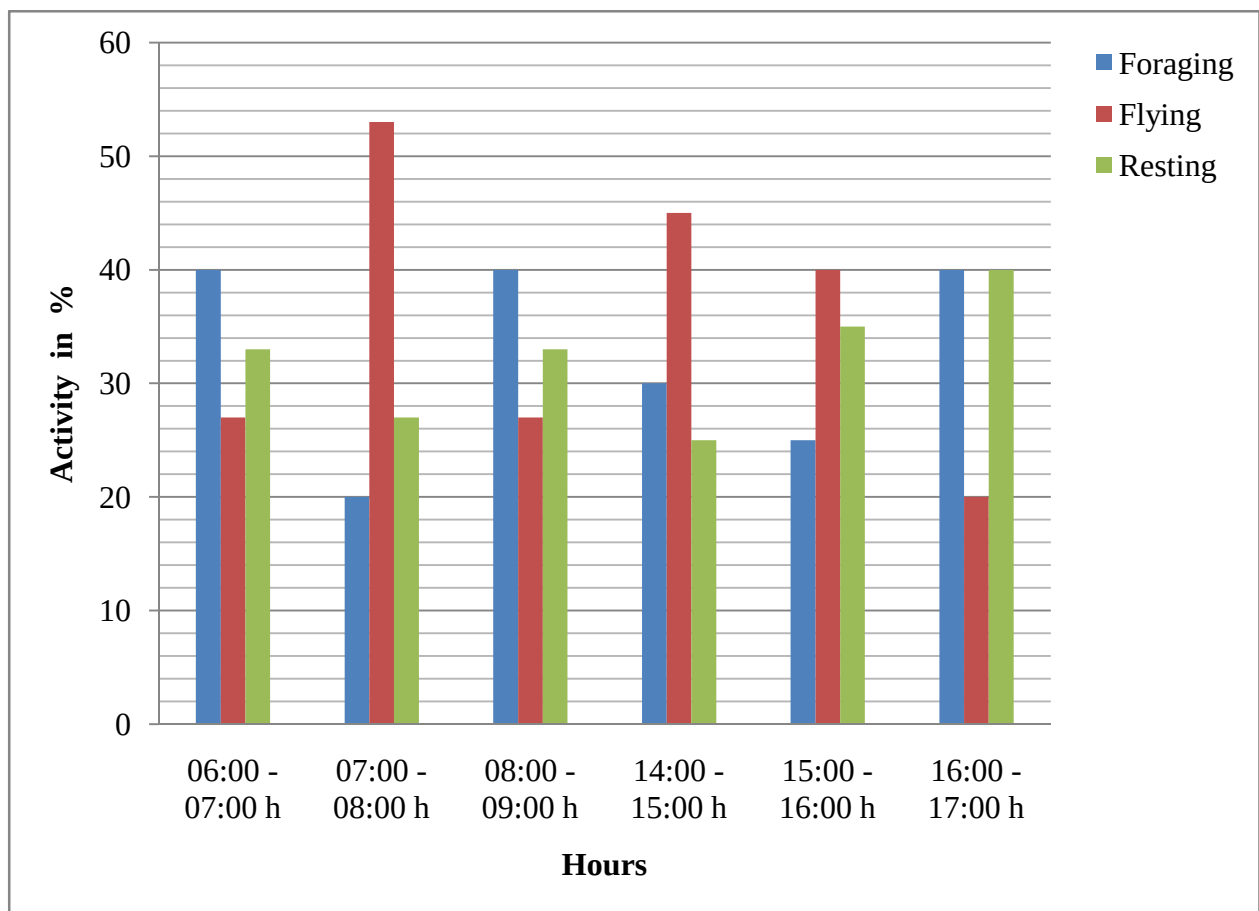


Figure 10. Diurnal activity patterns of African Fish-Eagle in the non-fishing site of Lake Hawassa during the dry season

The diurnal activity patterns ( foraging, flying and resting ) of African Fish-Eagle during both the wet and dry seasons in the non-fishing site of Lake Hawassa were not significantly different ( $P > 0.05$ ).

The result of the data analysis of the diurnal activity patterns of African Fish-Eagle in the commercial fishing activity site and non-fishing site of Lake Hawassa during the wet season and dry season, did not show significant difference ( $P > 0.05$ ). As a result, the commercial fishing activity in Lake Hawassa had no significant effect on the activity patterns of the African Fish-Eagle.

## DISCUSSION

Lake Hawassa is an ecological home for diverse avian species, from the large Marabou Stork to the glorious African Fish-Eagle. Different species of birds inhabit in the commercial fishing site and non-fishing site of Lake Hawassa. The birds diversity varies in the sites of the lake and between the wet and dry seasons. There was less avian species richness in the commercial fishing site than in the non-fishing site of Lake Hawassa. The commercial fishing site of Lake Hawassa was being altered, disturbed and exploited intensively by the commercial fishing activity in the area. These situations push away many species of birds from the commercial fishing site of the lake resulting in less avian diversity than in the non-fishing site area of the lake. However on the contrary, this situation attracts some species of birds which feed on the leftover fish from the commercial fishing activity and some species of birds which do not feed on the left over but join the crowd in the area. On the other hand, the non-fishing site of Lake Hawassa is less disturbed by human activities. This situation makes it to be peaceful and more preferable ecological home for many species of birds than the commercial fishing activity site of the lake ( Sairam, 2014 ).

There was a higher avian diversity in both the commercial fishing site and non-fishing site of Lake Hawassa during the dry season than during the wet season. This indicates that, the avian species richness in Lake Hawassa was higher during the dry season than during the wet season. In Ethiopia water bird diversity and abundance are high during dry season when resident water birds are augmented by palearctic migrants ( EWCA, 2014 )

The bird species richness in the commercial fishing site during the wet and dry seasons was less than in the non-fishing site of Lake Hawassa. Therefore, the commercial fishing activity in Lake Hawassa had significant effect on the avian diversity in the area. This was due to the disturbance of the natural ecological habitats of the commercial fishing activity site and high exploitation of fish by the commercial fishing activity in the area. Whereas, in the non-fishing site of Lake Hawassa, there was Less human interference and fishing activity in the ecological habitats of the area. As a result the non-fishing site of Lake Hawassa was relatively stable ecological home range for many avian species and other organisms. It had

higher trophic states that generally support more aquatic birds. Since it was less disturbed area, it usually had an abundance of plants and animals like fish and insects that can be used for food and shelter by aquatic birds (Mark, 2013).

Even if, many of the avian species of Lake Hawassa were permanent residents, some species of birds were seasonal migrants. For instance, the Grosbeak weaver birds were plenty and comfortable during the wet season. The males of the Grosbeak weaver birds build nests hanging on the submerged long grasses (“qetema”) in most of the shore areas of the lake during the wet season. The females of the Grosbeak weaver birds visit the nests and each female makes its own choice of any nest it likes (there would be competition among the females) and enter to achieve reproduction with the builder and owner male of the nest. However, during the dry season the Grosbeak weaver birds disappear from the Lake area. Many species of birds are seasonal migrants due to precise timing of seasonal physiological events in their body (Gwinner, 1990).

The different species of birds in Lake Hawassa vary in abundance. For instance, the Marabou storks are the dominant and most abundant species of birds in the Lake. They are found in many thousands in the area. On the other hand, others like the African Fish-Eagle are often observed in one or two total number of individuals in an observation area of the lake in a day. The relative abundance of bird species in wetlands might be related to the availability of food, habitat condition and breeding season of the species (Shimelis Aynalem and Afewerk Bekele, 2008).

The commercial fishing activity in Lake Hawassa had no significant effect on the diurnal activity patterns of the Marabou Stork and African Fish-Eagle. This is because, the result of this study showed that, the diurnal activity patterns of Marabou Stork and African Fish-Eagle in the commercial fishing and non-fishing sites of Lake Hawassa during wet season and dry season did not show significant difference. Daily activities of animals is influenced by an individual's need and its interactions with organisms, both conspecific and with other species (Corp *et al.*, 1997).

## CONCLUSION

The result of this study shows the commercial fishing activity in Lake Hawassa had effect on the avian diversity of the area. The ecological habitat disturbance and the daily large amount of fish exploitation from the area due to the commercial fishing activity cause many species of birds to move away from the commercial fishing site area to the non-fishing site area of Lake Hawassa. As a result, the avian diversity in the commercial fishing site area of Lake Hawassa was less than the avian diversity in the non-fishing site area of Lake Hawassa.

The activity patterns of Marabou Stork and African Fish -Eagle in the commercial fishing site area and non-fishing site area of Lake Hawassa did not show significant difference. As a result, the commercial fishing activity in Lake Hawassa did not affect the activity patterns of Marabou Stork and African Fish -Eagle in the area.

## RECOMMENDATIONS

The commercial fishing activity in Lake Hawassa should be carried out in a sustainable way in order to ensure the maintenance of stable natural ecological environment of the Lake and its biodiversity. As a result the Lake Hawassa can host more diversified species of birds and other species of organisms. To achieve this,

- The natural ecology of Lake Hawassa should be conserved.
- The ecosystem of Lake Hawassa should be protected from threats that can negatively affect its biodiversity.
- Ecological disturbance due to commercial fishing activity, intense human activity and interference in the ecosystem of Lake Hawassa should be minimized.
- Concerned individuals, organizations and government authorities should give attention and co-operate to conserve and protect Lake Hawassa and its biodiversity.

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## APPENDICES



Appendix 1. Representative birds of Lake Hawassa



Appendix 2. Marabou Stork in the non-fishing site ( yefikir hayk area ) of Lake Hawassa



Appendix 3. Marabou Stork in the commercial fishing site ( fish market area ) of Lake Hawassa



Appendix 4. African Fish-Eagle at Lake Hawassa