ECOLOGICAL STUDY OF THE AVIFAUNA AND BIRD STRIKE PROBLEM

AT

ADDIS ABABA BOLE INTERNATIONAL AIRPORT

A Thesis Presented to the School of Graduate Studies

Addis Ababa University

In Partial Fulfilment of the Requirement of the Degree

of

Master of Science in Biology

By

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May, 1996

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ACKNOWLEDGMENT

I am very grateful to my advisor Dr. Afework Bekele for his consistent stimulating advice and for his unreserved patience during the research and for his critical reading of the manuscript. His material support, suggestions, comments and unfailing encouragement have been very valuable. I thank him so much and owe him a lot for introducing me to the science of Ornithology.

I am also very grateful to Dr. Zerihun Woldu for his assistance in data management and analysis. I would like to express my deepest gratitude to Dr. Zerihun for allowing me to use the computers and software in his office, and for his unreserved support, advice, encouragement and patience. I am thankful to the staffs of the Flight Safety Department, CAA, particularly to Major Tefera Haile, Cols. Amare G/Hanna and Walteniguse Sinshaw. Special thanks to the Airport Manager, Ato Gabrielu Vitale, and to the Security Department Head, L.t. Negash Ashengo and Ato Daniel for solving some administrative problems, and to all the staffs of the CAA Fire Brigade for all their assistance during my study.

I would like to thank Ato Haddis Mesfin for all his support during the early stage of the study. I am particularly grateful to Dr. J.P D'Huart, the Director, WWF-East Africa for his material and moral support. My deepest gratitude to Ato Goitom Redda, Ato Eshetu Assefa, Ato Ephrem Mekonnen, Ato Mulualem Tamru, W/ro Mulualem Tamre, W/ro Almaz and the bird scaring personnel for their kind assistance during data collection. I'm highly indebted to the German Academic Exchange Service (DAAD) for its financial assistance.

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ABSTRACT

The avifauna of the Addis Ababa Bole International Airport was studied to describe the ecological relationship of the birds and bird strike problem at the airport. The bird composition and abundance were studied using a transect and modified point count method. Visitor and Transient birds were further categorized depending on their frequency of occurrence. Cluster analysis and Principal Component Analysis were employed to summarize the relationship of the birds between each other. Diversity of the birds was estimated using Shannon - Weiver Diversity Index. The Biomass and the Species Richness of the birds were computed. The duration and rate of bird strike incidents were analyzed. A preliminary investigation was made on the Vegetation, Invertebrates, Herpetiles and Small Mammals.

A total of 70 bird species were identified. The birds were classified into 12 Orders. Fifty - seven per cent of the birds belong to the Order Passeriformes. Birds of Prey comprised 15% of the bird species at Bole. Eighty - four per cent of the birds from Bole were visitors that stayed at the airport in search of food, water and/or shelter. The others were transient birds that used the airport airspace as their passage route to their feeding or nesting sites. Three of the transient birds pass across the airport frequently in a regular time of the day. Thirty of the visitor bird species appeared in the airport very infrequently while 12 were residents.

There is no clear variation in the abundance of each species in time. However, six major groups of birds were produced in the cluster analysis indicating each cluster appeared in the airport at a similar instance. The airport was found to be characterized by birds of high diversity and low

density. The vegetation structure and rainfall played important roles in determining the species diversity and richness of the birds. The invertebrates, herpetiles, and small mammals, garbage dumps and other biological and physical factors attract the birds to the airport. September and October were the worst months for aviation. No bird strike was observed in May and June. Pigeons and Black Kites played the major role in air strike incidents. Seventy per cent of the strikes occurred before noon, which is also the time for heavy air traffic. Maintaining the grass at an optimal height, prohibiting agricultural activities around the airport, clearing open garbage dumps in and around the airport and the use of insecticide spray to eliminate insects in the vegetation around the runway are suggested. However, the use of integrated approach is recommended to be even more effective.

I. INTRODUCTION

Birds are important components of many ecosystems. They are ubiquitous animals that frequent both terrestrial and aquatic ecosystems. Today, most avian scientists (e.g., Peterson, 1968; Dobinson, 1976; McFarland et al., 1979; Wilson, 1986) agree that there are approximately 9,000 different species of birds. There is no absolute number for the world population of birds. Nevertheless, ornithologists estimate the number to be in the order of 100 billion.

For centuries, man in the desire to satisfy his needs and improve his life style, has been modifying the resources of the planet earth. Man's exercise to probe into the mysteries of flight of birds by producing aircraft is one among those endeavours. This has allowed man to share airspace with birds resulting in collision between birds and aircraft which is usually termed as Bird Strike.

Bird strikes have occurred ever since the beginning of aviation. To date, more than one hundred bird species have been recorded to cause bird strike incidents world wide (ICAO, 1995). In the early days of aviation, bird strikes happened infrequently. These strikes resulted in relatively little damage, were rarely reported, and not considered to be serious. With the production of large, high speed aircraft powered by turbine engines, the safety hazards became many times greater. With the increase in air traffic, bird strikes eventually changed from a minor disturbance into a serious and costly hazard (Blockpoel. 1976; Bruderer, 1978 a; Hild, 1983 a). The resultant collision between birds and aircraft caused deaths, injuries and resulted in material damage running into millions of dollars each year in both civil and military aviation.

The first recorded fatality due to a bird strike occurred in 1912 when a Gull became entangled in an aircraft and killed the pilot (Blockpoel, 1976). Since 1912, there have been records of a number of deaths and destruction of both civil and military aircraft due to bird strikes. A number of member countries of the International Civil Aviation Organization (ICAO) reports hundreds of bird strikes annually. Appendix 1 and 2 give statistical data on ICAO Bird Strike Information System (IBIS) for ten years from 1984 to 1990 and 1991 to 1993, respectively (ICAO, 1991 a; ICAO, 1995).

Direct comparison of data from different countries has limited value because of the variation in reporting procedure and air traffic densities. Thorpe (1994 a) has briefly summarized and compared bird strike data by regions (Appendix 3) for the year 1986 to 1990. According to Thorpe (1994 b), it can be noted that 1310 engines were damaged and three aircraft were totally destroyed.

Taking Lufthansa as an example of International Airliner's experience, its bird strike statistics for the year 1982 shows a total of 322 bird strikes with 217 of them occurring in Germany. This averages 4.5 strikes per 10,000 aircraft movements. Sixty-seven per cent of its strike occurred in Europe, particularly in Istanbul, Amsterdam, Milan, Barcelona, and Brussels. Nineteen of the strikes took place in South East Asia, 50% of them at Bangkok, seven in America including three at John F. Kennedy and ten in Africa, with four of them in Nairobi (Hild, 1985).

It is impossible to set a dollar value on human life, but clearly there are costs associated with any aviation fatality. One estimate of training a Canadian pilot is US$ 315,000 (Blockpel, 1976). Total losses of life exceed millions of US dollars. These do not include considerable further losses due to injuries, such as losses of body parts and consequent inability to qualify as a productive citizen or a qualified crew.

Apart from the risk of the loss of human lives, there is a high cost of repairs to aircraft bodies and engines. The damage caused by bird strike in Europe and North America is registered to be US$ 14 million a year. Air Canada reported that for 2,400 recorded incidents between the years 1959-73, many of them minor strikes, the cost was 2,457,000 US dollars (Blockpoel, 1976). A Wood pigeon damaged engine blades at Orly Airport, Paris, had a total cost of about US$ 300,000 for repair only. Overseas National Airways aircraft with 139 passengers sucked a number of Gulls into its engines; the passengers managed to escape, but the aircraft gutted by the fire was totally lost at a cost of US$40 million (Smith, 1986). Japan's All-Nippon Airways reports a cost of US$600,000 a year (Hild, 1983 b). Indian Airliners suffered from a loss of more than US$ 27,550,000 between the years 1985-1987 (Khal, 1980). Kenya Airways Limited, between the years 1984 and 1991, has recorded more than 40 bird strike incidents with a total cost of more than 20 million USD (Kenya Airways, 1991). Data from the Nigerian Airways show damages in engine ingestion inflicting a total cost of 1,082,421 USD for the years 1983 and 1984 (Harrison, 1987).

Similar incidents are recorded from military aviation. At least one European aircraft is destroyed every year due to a bird strike. The Royal Netherlands Air Force has estimated damages due to bird strikes between the years 1956 and 1965 as US$ 250,000 a year. Norway estimated military aircraft damages of US$ 50,000-250,000 a year. The US Air Force faces an average loss of US$ 10,900,000 per year. The 350 to 400 bird strikes reported each year in the United States costs about US$ 32,000 each or US$ 1.60 per flying hour (Blockpoel, 1976).

Commercial passengers flights delayed or cancelled due to bird strikes may involve additional costs to feed and lodge passengers, and possibly to pay for alternate transportation and/or rescheduling. Airliners lose money when they are idle. A grounded aircraft brings no revenue, yet normal operational costs like salaries for crew, and parking fee for the aircraft continue to soar up. In most cases aircraft damages may not be repaired locally and the company has to ship the aircraft to overseas countries where repair is possible or cheaper. This may incur other costs like transportation and per diem.

The diversity of the bird species of Ethiopia number 861 (Urban and Brown, 1971; Tesfaye, 1990; WCMC, 1991; Abdu et al, 1991, Hillman, 1993). The country's airports share these worldwide bird strike incidents (Appendix 4). Such was the case at Bahrdar in 1988, where a 737 Boeing encountered a flock of Speckled Pigeon, (*Columbia guinea*) during take off. Ten to 15 pigeons were ingested into each of the aircraft engines. The aircraft was completely destroyed at the Nile River bank resulting in the death of 35 people (Lewis, 1995).

Records of the Ethiopian Civil Aviation Authority (ECAA) show that the Ethiopian Airlines loses more than 5 million birr every year to maintain equipment damaged by birds (Minutes, 1984; Afework and Zerihun, 1986). In one month alone, between September - October 1987, the damage caused by bird strike to aircraft is about 500,000 US$ (Zerihun, 1991). This high cost of damage and loss of life compelled the Ethiopian Civil Aviation Authority to form a national committee in 1981 to seek a way of reducing and controlling bird hazard problems at Bole International Airport. A study was undertaken that lasted a year from August 1983 to July 1984. Thirty-one bird species were identified and four groups, namely Pigeons, Kites, Crows, and Vultures were given a particular emphasis with respect to their frequency and number (ECAA Report, 1984 a and b; NCBHC, 1984; Zerihun, 1991). Nevertheless, the study was suspended without showing any fruitful measure that could reduce or control the problem. Even afterwards, Hild (1985) considered the Addis Ababa Bole International Airport, as one of the worrisome airports in East Africa with respect to bird strike problems.

Bird strike problem has then drawn a number of aircraft companies and designers to develop stronger structures to make aircraft resistant to bird impacts by "Bird Proofing" (Blockpoel, 1976). The UK and US maintain national air worthiness requirement which includes bird strike impact. The regulations have required that aircraft must be able to withstand impact from a 1.8 Kg bird at maximum height 5.5 Km. Accordingly, an engine that faced a strike with a 1.8 Kg bird must not fail catastrophically endangering passengers. Many countries followed these requirements. However, it was realized that the main threats were encountered with flocks of medium and small sized birds, several of them being ingested by more than one engine of the aircraft (Solman, 1970, Solman, 1973). Fitting guards across the intake was also considered to prevent bird ingestion. However, this was found impractical because guards would reduce engine efficiency and could be blocked by ice or debris from the runways (Thorpe, 1994 a; Lewis, 1995). Bird-proofing efforts are greatly increasing. Nevertheless, experience has made experts sceptical toward the likelihood of having a completely bird-proof aircraft that will also be able to fly (Hild, 1983 a).

With the objective of reducing and possibly eliminating bird hazards to aircraft, the aim shifted to getting rid of or reducing bird populations at and around airfields. A whole list of direct and indirect bird prevention techniques are given by Blockpoel (1976), ICAO (1978), Mudd (1988), Spence (1990) and ICAO (1991 b). Individual and combined measures have been tested in many countries under locally prevailing conditions. These have different merits and drawbacks of their own. The techniques can be broken down into chemical, biological, biotechnical, trapping and shooting (Hild, 1983 a and b; Hild, 1985).

Chemical methods use different repellents to scare and/or kill birds. However, these substances often are not in harmony with animal laws, cannot be applied to protected birds and are not usually friendly with the environment. In addition, they are not found to be very effective in scaring birds (Blockpoel, 1976; Hild, 1983 a and b).

In Canada, electric shock has been tried to scare birds away from certain buildings. The method uses electric shock with harmless voltage and amperage that have a scaring effect. However, this technique has never been used over a lengthy period of time at any other airport. The installation of electrically heated areas to stop birds from setting on certain parts of the airport has also produced little results (Hild, 1983 a and b).

Techniques aimed at the hearing and sight senses of birds showed the greatest success. Pyroacoustic methods are used in most of the world's commercial airports. These were found effective when properly handled and used in combination with other techniques. However, birds soon get accustomed to them, and achieve a medium term result only by constantly changing the sound pressure, intensity and time sequence. Similarly, Ultrasonic and Infrasound methods were used in some airports. Though the infrasound was reported to have better harassment effect, both are found effective enough only in enclosed or semi-enclosed spaces like hangars. The serious drawback in these methods, however, is that birds get used to the methods and render them ineffective shortly after their introduction.

Broadcasting artificial and natural cries of distress or alarm tapes over loud speakers (electroacoustics techniques) were used at many European and North American airports (Lischak, 1994). Unfortunately, birds often get used to it. The technique needs a constant operation by well equipped team.

A combined visual and acoustic techniques using model aircraft with silhouettes of birds of prey have also been tested at some airports in New Zealand, North America and Europe. These have been reported with satisfactory results. However, most countries reject these techniques for they need a number of well-qualified personnel and time.

Visual bird prevention methods that use scare crows or tapes, tin foil strips, dummy or live birds of prey, model aircraft were tested without a long lasting effect (Hild, 1983 a; ICAO, 1991). The Ben-Gurion International Airport in Israel, uses a noisy bright colored aircraft. This flies in and around the bird formation firing shell crackers (Yoshan, 1994). Based on safety outlooks, some airliners, particularly, Transport Air Canada forbid scaring birds with aircraft.

Better results are obtained by trapping birds. This technique has been helpful in reducing crows, birds of prey, pigeons and sparrows in Hangars. A few airports in Germany and Israel have practised trapping birds that are hazardous to aircraft (Hores and Milo, 1994). However, trapping leaves a vacuum in the habitats. This will draw new birds with less "aircraft experience" (Hild, 1983 a) and are thus more hazardous than the birds they replace.

Use of lasers, microwaves and light of radar beams have been also tried in Germany and Sweden as harassment techniques. The methods showed partial success but their use was extremely critical and not adaptable for permanent use, and it has been found difficult to assess the other effect they may induce (Hild, 1983 a and b; Bruderer, 1978 a). Radars have also been used as observation techniques for providing bird warnings (Bruderer, 1978 a; ICAO, 1991 a). Extensive experiments and observations have proved difficult to adapt such techniques practically. These methods demand high energy densities. As a result they cannot be fixed near the ground at airports.

Shooting had partial success in some airports like in UK (Stenman, 1994), South Africa (Max, 1989, Anderson and Ordinol, 1991), Finland (Chamero and Clavero, 1994), US (Dolbeer and Bucknall, 1994), and other countries. This technique is often used when danger is impending or to decrease high population of certain bird species like Gulls. However, it needs a legal provision to shoot birds and the use of shot guns around airports buildings is usually prohibited. Shooting measures cannot solve bird strike problems at airports, but can be used with various techniques.

Trained birds of prey like Falcons have been used at airports in North America, Britain and Spain. However, the practical use and maintenance of these birds are extremely expensive (Chamero and Clavero, 1994). With such techniques, a marked decrease in collisions is observed at an air force base near Pretoria, South Africa (Max, 1989). Some Air Traffic Controllers object this method at busy airports, from a safety point of view. Moreover, the method cannot be practised in every weather condition like in windy, foggy and hot days; and against large birds of prey like vultures. Though proved not practicable, the use of bird-dogs-Pomeranians bred to resemble foxes was also tried with success in Finland and Germany against Gulls (Hild, 1983 a and b).

The All-Nippon Airline of Japan has even gone so far as to paint a huge eye on aircraft engines to serve as a scaring device to birds that venture close to aircraft (Anon, 1987). However, the success of this method has not yet been determined. Other techniques like reflecting tape, suspension of fishing line or wire and remote controlled scaring methods have been suggested by Colahan (1987).

The Ethiopian Civil Aviation Authority hires people to stand along the edge of the runway to frighten birds before aircraft are allowed to take off or land. The exercise is believed to reduce the bird ingestion frequency at the airport. The savings in aeroplane and engine damage repairs was many times the cost of the workers' wages. In Britain, more than 20 full-time staffs spend much of their time scaring-off birds (Smith, 1986). Nevertheless, this technique has not eliminated bird strike problems.

The Civil Aviation Authority (CAA, 1993) and Transport Air Canada prepared a brochure to help pilots decrease the chance of bird strike incidents, as well as to minimize the consequence of a bird strike if it occurs. This includes precautions to take before the flight, at the airports, in flight and after flight. A similar bird hazard check list is prepared by the Bird Strike Committee Europe (BSCE) (Thorpe, 1994 b and c).

Despite years of effort and use of different techniques, bird strike problem has not been solved completely. Most of the attempts made to control the problem ignored ecological considerations. It is impossible to guarantee a bird free environment. Birds are usually drawn to airports by open grassland areas where they find security from predators and humans, a place to nest and loaf, and access to food and water resources.

World wide recognition of the problem's basic needs, the interaction of birds and the airport environment has come late. In the last decade, however, many airports have adopted environmental measures to make airports less attractive to birds by biological methods. At Gatwick, Manchester and London Heathrow (Thomas, 1987; Ferns, 1994), Amsterdam

Schiphol (Schiphol Airport Authority), Helsinki and Copenhagen (Stenman, 1994), Switzerland Zurich (Bruderer, 1978 b) and John F.Kennedy airports (Caccamise, 1994) environmental measures are taken against Gull problems. At Cologne Bonn, Dusseldorf (Hild, 1980), John F.Kennedy (Burger, 1985), Hong Kong (Anonymous, 1993), Singapore-Changi, Jakarta-Cengkoreng (Hild, 1985) and Bombay (Khal, 1980) airports, depriving birds off living spaces has been employed. Similar measures have been tested at Nairobi, Dakar, Bangkok, South Africa and other countries. These have reduced the frequency of bird strikes from very expensive and hazardous incidents in one year to zero ingestion in the next (Gwahaba, 1985 a and b; Anderson, 1990; Anderson and Ordinol, 1991; TAC, 1994 a and b). From 1964 to 1990, Amsterdam Schiphol Airport used most of the above-mentioned techniques in addition to biological method. The airport decreased its bird strike rate from 18% to 3% (Schiphol Airport Authority, 1991).

The best opportunity for developing an environmental approach for the management of bird strike problems requires an adequate consideration of the ecological relationship of the avifauna with the environmental setup and the type land use of the area under consideration.

The objective of the present study was to make an ecological investigation on birds and bird strike problem at Bole International Airport. The study aims to lay the necessary base line information to environmentally manage, reduce and ultimately eliminate bird hazard problem at the airport.

II. MATERIALS AND METHODS

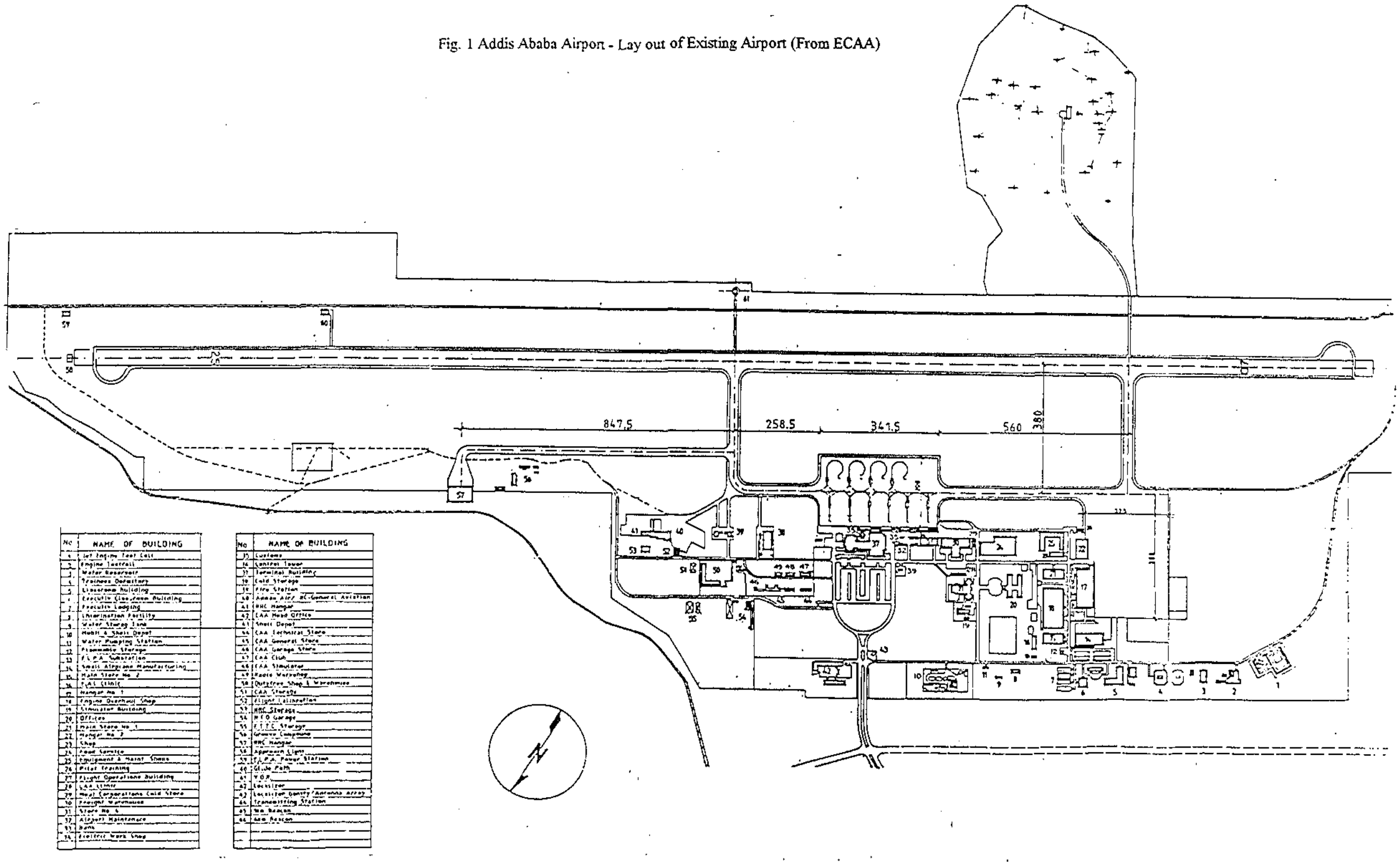
2.1 Study Area

The Addis Ababa Bole International Airport is situated South East of Addis Ababa. It has a 3.8 Km long single runway with two taxiways. The Airport has a 200 ha grassland as its major feature (Fig. 1).

2.2 Bird Identification and Determination

The study was carried out from December 1994 to December 1995 on alternate days. The absolute abundance of birds in and around the airport was studied using a transect count method and a modified point count method (Bibby et al, 1992; Pomeroy, 1992). Using the transect method, records were made on the species, number, position and activities of birds by walking along the runway for 3.8 Km and the ring road for 4 Km. This was done between about 0930 hr and 1100 hr in the mornings or 1500 hr to 1700 hr in the afternoons. The transect has a total area of 192 ha. A suitable site was selected to conduct a modified point count method (Gwahaba, 1985 a). taxa. Point count method was employed to record the type, number, flight direction and approximate ground height estimate of those birds that use the airport's airspace as their transient route. A highest point on Taxiway α was selected so as all birds crossing the runway in either direction can be easily seen and identified to the lowest possible taxa.

Fig. 1 Addis Ababa Airport - Lay out of Existing Airport (From ECAA)



No	NAME OF BUILDING
1	Jet Engine Test Cell
2	Engine Testcell
3	Water Reservoir
4	Trainees Dormitory
5	Classroom Building
6	Executive Classroom Building
7	Executive Lodging
8	Incineration Facility
9	Water Storag Tank
10	Mobil & Shell Depot
11	Water Pumping Station
12	Flammable Storage
13	E.L.P.A. Substation
14	Small Airplane Manufacturing
15	Main Store No. 2
16	E.A.L Clinic
17	Hangar No. 1
18	Engine Overhaul Shop
19	Simulator Building
20	Offices
21	Main Store No. 1
22	Hangar No. 2
23	Shop
24	Food Service
25	Equipment & Maint. Shops
26	Pilot Training
27	Flight Operations Building
28	CAA Clinic
29	Meat Corporations Cold Store
30	Freight Warehouse
31	Store No. 4
32	Airport Maintenance
33	Bank
34	Electric Work Shop

No	NAME OF BUILDING
35	Customs
36	Control Tower
37	Terminal Building
38	Cold Storage
39	Fire Station
40	Admas Air/ RC-General Aviation
41	RRC Hangar
42	CAA Head Office
43	Shell Depot
44	CAA Technical Store
45	CAA General Store
46	CAA Garage Store
47	CAA Club
48	CAA Simulator
49	Radio Workshop
50	Dutyfree Shop & Warehouse
51	CAA Storage
52	Flight Calibration
53	RRC Storage
54	R.T.O Garage
55	E.T.T.C. Storage
56	Groove Compound
57	RRC Hangar
58	Approach Light
59	E.L.P.A. Power Station
60	Glide Path
61	V.O.R.
62	Localizer
63	Localizer Gantry/Antenna Array
64	Transmitting Station
65	[illegible] Beacon
66	[illegible] Beacon

ETHIOPIAN CIVIL AVIATION AUTHORITY

TAMS CONSULTANTS, INC.
NATIONAL CONSULTANTS
&
TRANSPORT CONSTRUCTION DESIGN ENTERPRISE

DESIGNED BY:
DRAWN BY:
CHECKED BY:
NO | DATE | REVISION

SCALE - 1 : 5000

ADDIS ABABA AIRPORT
REHABILITATION AIRSIDE WORKS
LAYOUT OF EXISTING AIRPORT

The transect method has all the assumptions given by (Bibby et al, 1992).These are: -

1. Birds exactly on the route are all detected
2. Birds do not move before detection
3. Distances of the transect route are measured accurately
4. Individual birds are counted only once
5. Individual birds are detected independently
6. Bias from observer, seasons and weather is understood.

The point count method was done on early mornings and late afternoons usually at about 0700 to 0900 and 1630 to 1800 on alternative days. A pair of binoculars and a hand tally counter were employed in this study. A total of 197 such counts were made. The bird species were identified using Peterson et al, (1954), Macworth-Praed and Grant (1957) and William and Arlott (1992). The checklists of Urban and Brown (1971) and Pain et al, (1975) were also used. While making the bird census, birds like Pigeons, Vultures and Swifts/Swallows are kept by their group names. This was because on site identification of all the bird flocks up to the species level was not possible. Determination of birds was made following Hillman (1993).

Classification of the birds recorded from Bole was made following that of Karr (1977). Karr has grouped birds into three categories. These are:

RESIDENT BIRDS - Birds that could be observed almost daily during the study period. These may or may not be breeding in the area.

REGULAR BIRDS - Birds that were seen during many months, not throughout the year.

IRREGULAR BIRDS - Birds that were seen only once or a few times during the study period.

The category given by Karr (1977) does not apply to those birds recorded by the point count method. For the purpose of this particular study, another classification was proposed. The birds recorded from Bole Airport were categorized into two major groups: -

TRANSIENT BIRDS - Those that pass through the airport environment.

VISITOR BIRDS - Those that stay at the airport usually for the purpose of feeding and /or nesting. These birds may or may not be breeding in the airport.

The transient birds can further be divided into FREQUENT-REGULAR and INFREQUENT. The Frequent-Regular-Transient birds are birds that are observed in many of the months of the year in an evenly shaped time on each day. The infrequent transients are birds that used the airport air space as their transient routes a few times during the study period. The visitors were again classified to three groups; namely the RESIDENT, FREQUENT and INFREQUENT, in a similar fashion like that of Karr (1977).

2.3 Data Analysis

2.3.1 Average Abundance and Frequency

The data for each observation was edited into a database. The structure of the database included date observed, species name and count. Four thousand eight hundred twenty-seven (4827) rows of data have been edited. Structured Query Language (SQL) was used to run the various queries to summarize the data and filter out specific information. The information generated include average abundance of each bird for every fifteen days and frequency of each species over the study period. A total of 26 columns were edited. The frequency group of the bird species was computed by summing the frequency of occurrence of each species over the study period.

2.3.2 Ordination and Classification

Ordination of the bird species using Principal Component Analysis (PCA) was employed to summarize the relationship of the birds between each other. Ordination implies a summarization of the information content of a matrix whose elements define the relationship between the ecological entities. The entities are the bird species. The entities to be ordinated called individuals are visualized as points in space with their attribute scores as coordinates. Summarization is achieved by projection of the points into space which has less dimensions than the original. The original data has as many dimensions as there are individuals. The simplified geometric model obtained in such a way is interpreted in terms of the cluster of individual points. The coordinated of the summarized data matrix are arranged in order of importance. The first coordinate accounts for most of the variation in data matrix and second accounts for most of the residual information and so on. The analysis was performed using SYNTAX, a software made by Lajos Podani (1988). Cluster analysis was run to complement the scatter plot produced using PCA.

2.3.3 Diversity Index

As an attribute of a community and a measure of habitat importance, the diversity of the bird species for the 26 columns was derived using Shannon-Weiver Index. The index was run using a Program SHAN, a program written by Zerihun (1989). The number of species in the area, the species richness of the 26 fifteen days was also compared. A similar computation was used to derive the H max, the maximum expected diversity. More over, the deviation of the diversity obtained from the expected one is also derived. The average fifteen days data on Rainfall, Maximum and Minimum Temperature and Relative humidity of the Bole region was collected from the National Meteorological Service. The daily weather condition was used to compare the average abundance of birds and species richness of the study area.

2.3.4 Density and Biomass

The Density of the bird species recorded from the transect method was computed and the Biomass was derived by taking the mean count and mean weight of some of the bird species. Data on bird weight were collected from Brown et al, (1982 on wards), Cramp et al, (1983), Cordon (1985), Mundy et al, (1992) and Hoyo et al, (1994).

2.3.5 Bird Strike Records

Bird strikes observed on observation days were recorded and carcasses of any bird struck by an aircraft were collected and identified up to the lowest possible taxa. Moreover, a study was conducted on the gut content of the birds struck by aircraft, unless rendered useless. The gut content analysis was made following FAO (1986).

2.4 Vegetation, Invertebrates, Herpetiles and Small Mammals

Dominant plant species in the field were collected and taken to the National Herbarium of Addis Ababa University for identification. Voucher specimens were kept in the National Herbarium. An insect net was employed twice to collect and identify the different insects and invertebrate fauna of the airfield. Collected insects were double pinned on a board while other invertebrates were placed at 5% formalin. The insects and invertebrates were identified up to the lowest possible taxa.

Amphibians near and around the runway and taxiways were collected following the short and long rainy seasons. Reptiles were also collected whenever encountered. Specimens were placed at 5% formalin and identification was made in the Zoological Natural History Museum, Science Faculty, Addis Ababa University.

On two occasions, five randomly picked sites were selected to conduct a survey on the small mammals population types. Fifty snap traps baited with peanut butter were placed for five consecutive days on each site. The traps were checked early mornings and late afternoons. Collected specimens were identified and placed at 5% formalin. Voucher specimens were kept in the Zoological Natural History Museum, Biology Department, Addis Ababa University. Possible identification of any other wild animal was also made whenever observed at the airfield.

III. RESULT AND DISCUSSION

3.1. Birds

3.1.1 Identification, Determination and Average Abundance

A total of 70 species of birds has been identified up to the species level while one species was kept by its group name. The birds recorded were determined to 12 Orders and 31 Families (Table 1). Of these bird species, 10 were recorded from the point count method. These are the birds which used the airport airspace as their transient route. Birds recorded from point count method include, Abdim's Stork, African Goshawk, Cattle Egret, Glossy Ibis, Hammerkop, Kittilitz's Sandplover, Pigeons, Sacred Ibis, Wattled Ibis and Yellow-billed Stork.

Following Karr (1977) the Resident and Regular birds comprised 22 and 21% respectively. More than 55% of the birds recorded from the transect method were Irregular birds (Table 2). Following the classification used in this study, 16% of the total birds from Bole were Transients. Of the transient birds, 30% are Frequent- Regulars. Eighty four percent of the birds at Bole were Visitors. Twenty two percent of the Visitors were Residents (Fig 2). The bird species of the Bole region comprise 28% of the birds of Addis Ababa listed by Pain et al, (1975). Table 3 gives the list of the transient birds.

Table 1. Determination of Birds Recorded From Bole Airport.

Common Name	Scientific name	Family	Order
Cattle Egret	*Bubucus ibis*	Ardeidae	
Hammerkop	*Scopus umbretta*	Scopidae	
Abdim's Stork	*Ciconia abdimii*	Ciconiidae	CICONIFORMES
Yellow-billed Stork	*Mycteria ibis*		
Sacred Ibis	*Threskiornis aethiopica*	Threskiornithidae	
Wattled Ibis	*Bostrychia carunculata*		
Glossy Ibis	*Plegadis falcinellus*		
Egyptian Goose	*Alopochen aegyptiacus*	Anatidae	
Yellow-billed Duck	*Anas undulata*		ANSERIFORMES
Black-shouldered Kite	*Elanus caeruleus*		
Black Kite	*Milvus migrans*		
White-backed Vulture	*Gyps africanus*		
Egyptian Vulture	*Neophron percnopterus*		
Hooded Vulture	*Necrosyrtes monachus*	Accipiteridae	
African Goshawk	*Accipiter tachiro*		FALCONIFORMES
Augur Buzzard	*Buteo augur*		
Tawny Eagle	*Aquila rapax*		
Long-crested Eagle	*Lophoaetus occipitalis*		
Common Kestrel	*Falco tinnunculus*	Falconidea	
Button Quail	*Turnix sylvatica*	Turnicidae	GRUIFORMES
Black-bellied Bustard	*Eupodotis melanogaster*	Otididae	GALLIFORMES
Kittlitz's Sand plover	*Charadrius pecuarius*	Charadriidae	
White-fronted S.plover	*C. marginatus*		CHARADRIFOMES
Marsh Sandpiper	*Tringa stagnatilis*	Scolopacidae	
Speckled Pigeon	*Columba guinea*	Columbidae	
White-collared Pigeon	*C. albitorques*		COLUMBIFORMES
Red-eyed Dove	*Streptopelia semitorquata*		
Black-winged Lovebird	*Agapornis taranta*	Psittacidae	PSITTACIFORMES
SWIFTS		Apodidae	APODIFORMES
Speckled Mousebird	*Colius striatus*	Coliidae	COLIIFORMES
European Bee-eater	*Merop apiaster*	Meropidae	CORACIIFORMES

Table 1 (Contd.)

Red-capped lark	*Calandrella cinerea*	Alaudidae	
European Swallow	*Hirundo rustica*	Hirundinidae	
Ethiopian Swallow	*H. aethiopica*		
Red-rumped Swallow	*H. daurica*		
Yellow wagtail	*Motacilla flava*	Motacillidae	
African Pied Wagtail	*M. aguimp*		
Abyssinian Longclaw	*Macronyx flavicollis*		
Fiscal Shrike	*Lannius collaris*	Laniidae	
White-vented Bulbul	*Pycnonotus barbatus*	Pycnonotidae	
Pied Wheatear	*Oenanthe pleschanka*	Muscicapidae	
Red-breasted Wheatear	*O. bottae*		
White-winged Cliff-chat	*Myrmecocichla semirufa*		
Olive Thrush	*Turdus olivaceus*		
Ground-scraper Thrush	*T. litsipsirupa*		
Winding Cisticola	*Cisticola galactotes*		
Tawny-flanked Prina	*Prina subflava*		
Black-breasted Apalis	*Apalis flavida*		
Yellow-bellied Eremomela	*Eremomela ecteropygialis*		
Dusky Flycatcher	*Muscicapa adusta*		
Spotted Flycatcher	*Muscicapa striata*		PASSERIFORMES
Paradise Flycatcher	*Terpsiphone viridis*	Monarchidae	
Tacazze Sunbird	*Nectarinia tacazze*	Nectariniidae	
Yellow-crowned Canary	*Serinus canicollis*	Fringilidae	
Streaky Seed-eater	*S. Stiolatus*		
Streaky-headed Seed-eater	*S. reichardi*		
Pin-tailed Whydah	*Vidua macroura*	Estrildidae	
Purple Indigo Bird	*Hypochera chalybeata*		
Common Waxbill	*Estrilda astrild*		
Crimson-rumped Waxbill	*E. rhodopyga*		
Red-billed Firefinch	*Lagonosticta senegala*		
Bronze Mannikin	*Lonchura cucullata*		
Baglafecht Weaver	*Ploceus baglafecht*	Ploceidae	
Red Bishop	*Euplectes franciscaus*		
Yellow-shouldered Widow bird	*E. macrourus*		

Table 1 (Contd.)

Swainson's Sparrow	*Passer swainsonii*		
Slender-billed Chestnut-wing Starling	*Onychognathus tenuirostris*	Sturinidae	
Blue-eared Glossy Starling	*Lamprotornis chalybaeus*		PASSERIFORMES
Pied Crow	*Corvus albus*	Corvidae	
Cape Rook	*C. capensis*		
Verreaux's Eagle-Owl*	*Bubo lacteus*	Strigidae	STRIGIFORMES
Lesser Filamingo*	*Phoeniconaias minor*	Phoenicopteridae	CICONIIFORMES
Grey-headed Gull*	*Larus cirrocephalus*	Laridae	CHARADRIIFORMES

* Recorded outside bird census time and/or date.

Table 2. List of Resident, Regular and Irregular Birds From Bole Airport.

RESIDENT	REGULAR	IRREGULAR
Blue-eared Glossy Starling	Augar buzzard	Abyssinian Long Claw
Baglafecht Weaver	White-vented Bulbul	Red-billed Firefinch
Black Kite	Black-shouldered Kite	Yellow-bellied Eremomela
Cape Rook	Common Kestrel	Black-bellied Bustard
Common Waxbill	Crimson-rumped Waxbill	Black-breasted Apalis
Fiscal Shrike	Olive Thrush	Black-winged Lovebird
Pied Crow	Red-capped Lark	Bronze Mannikin
Pied Wheatear	Streaky-seed eater	Spotted Flycatcher
Vultures	Swainson's Sparrow	Dusky Flycatcher
Winding Cisticola	Swifts /Swallows	European Bee-eater
Yellow-shouldered Widow bird	White-fronted Sandplover	Egyptian Goose
Yellow-crowned Canary		Ground-scraper Thrush
		Button Quail
		Long-crested Eagle
		Marsh sandpiper
		Paradise Flycatcher
		Pin-tailed Whydah
		Purple Indigo Bird
		Red-breasted Wheatear
		Red Bishop
		Slender-billed Chestnut-wing Starling
		Speckled Mousebird
		Streaky-headed seed-eater
		Tacazze Sunbird
		Tawny Eagle
		Tawny -flanked Prina
		White-winged Cliff-chat
		Yellow-billed Duck
		Yellow Wagtail

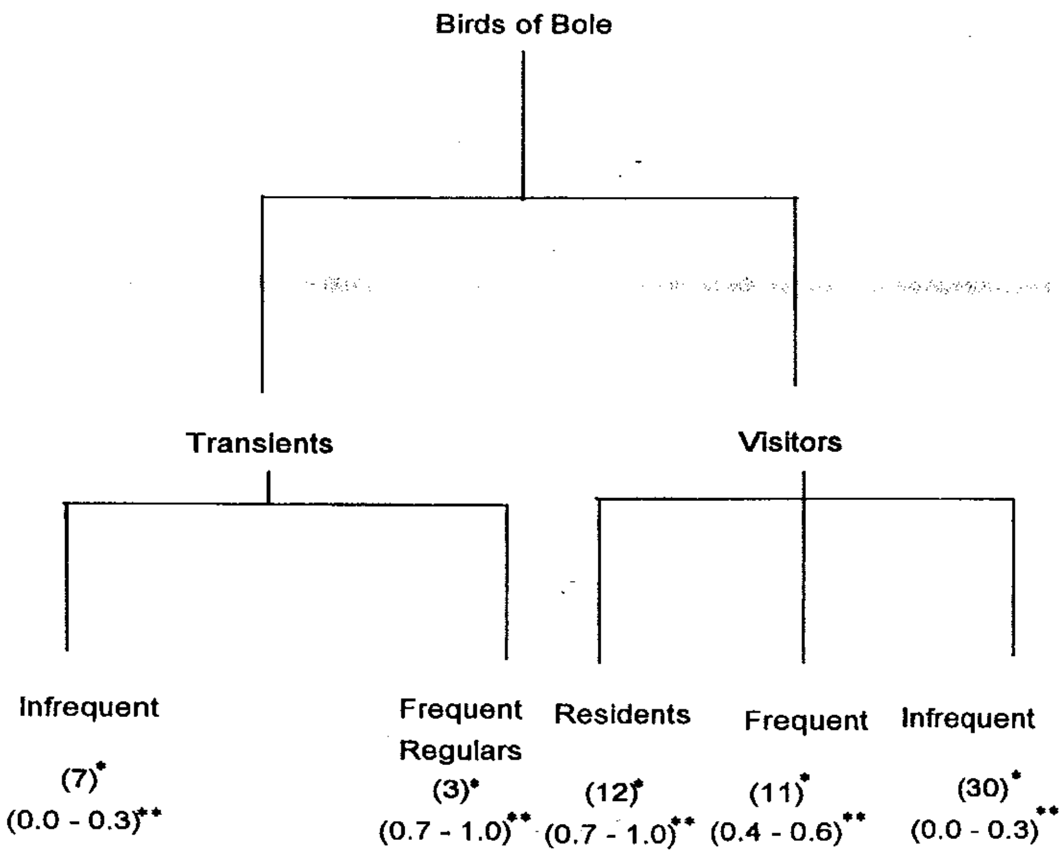


Fig. 2 Classification of Birds of Bole International Airport based on frequency of occurrence
(* number of bird species, ** frequency of birds)

Table 3. Classification of Transient Birds Recorded From Bole Airport.

TRANSIENT BIRDS

Infrequent	**Frequent Regulars**
Abdim's Stork	Pigeons
African Goshawk	Sacred Ibis
Cattle Egret	Wattled Ibis
Glossy Ibis	
Hammerkop	
Kittlitz's Sandplover	
Yellow-billed Stork	

The average abundance of each bird species, for every fifteen days is given in Figs. 3a, 4, 5a, 5b, 6a, 6b, 7a, 7b, 7c and 7d. The average abundance of each bird species is given in appendix 5a. Average abundabce varies from one (e.g., Abdim's Stork) to 1200 (e.g., Pigeons). There is no clear variation in the average abundance of each species in time. Except for some of the migratory birds, the abundance of both the Infrequent -Visitors and Transients is lower than tose of the Frequent birds.

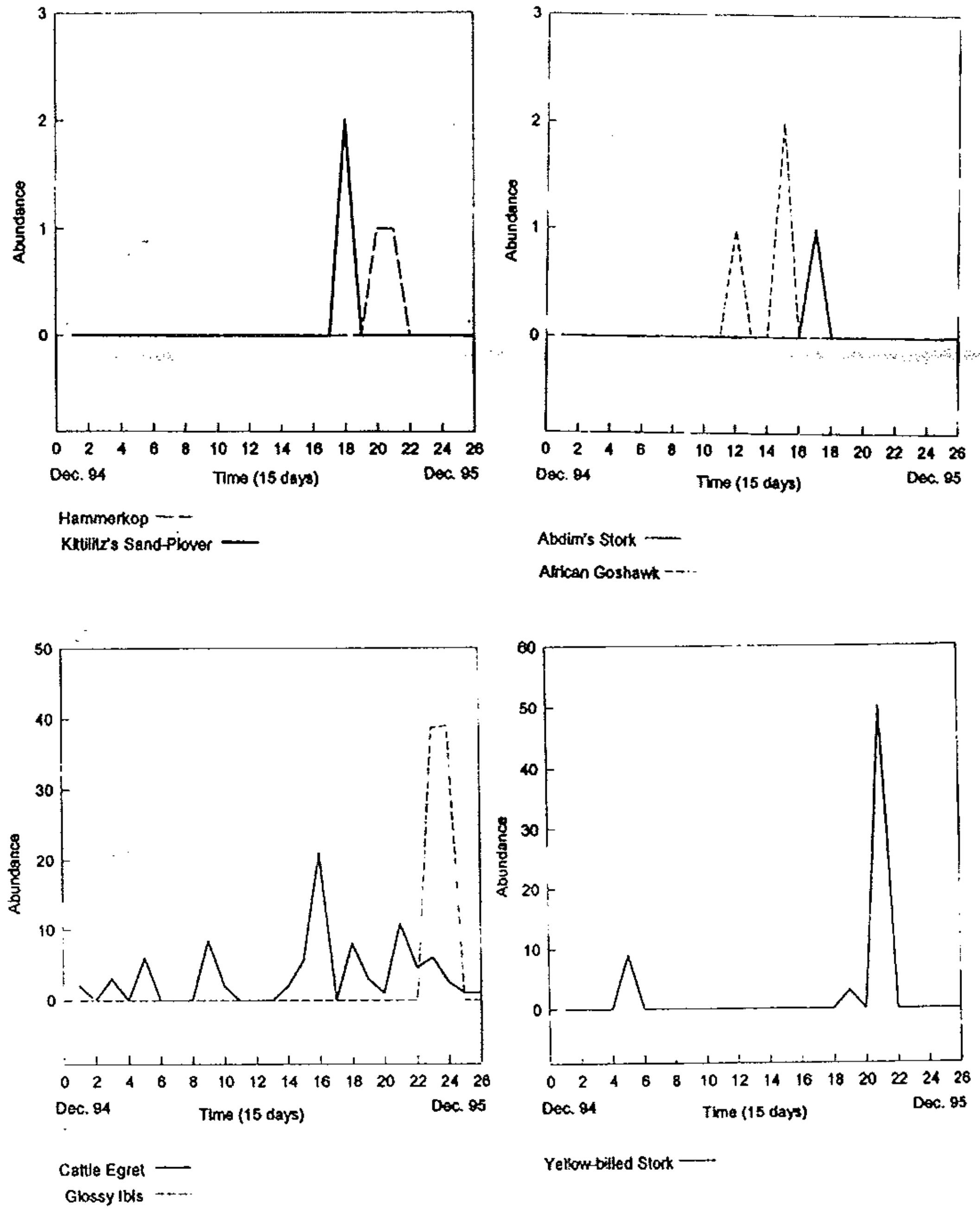


Fig. 3a Average Abundance of Birds from Bole Airport: Infrequent-Transients

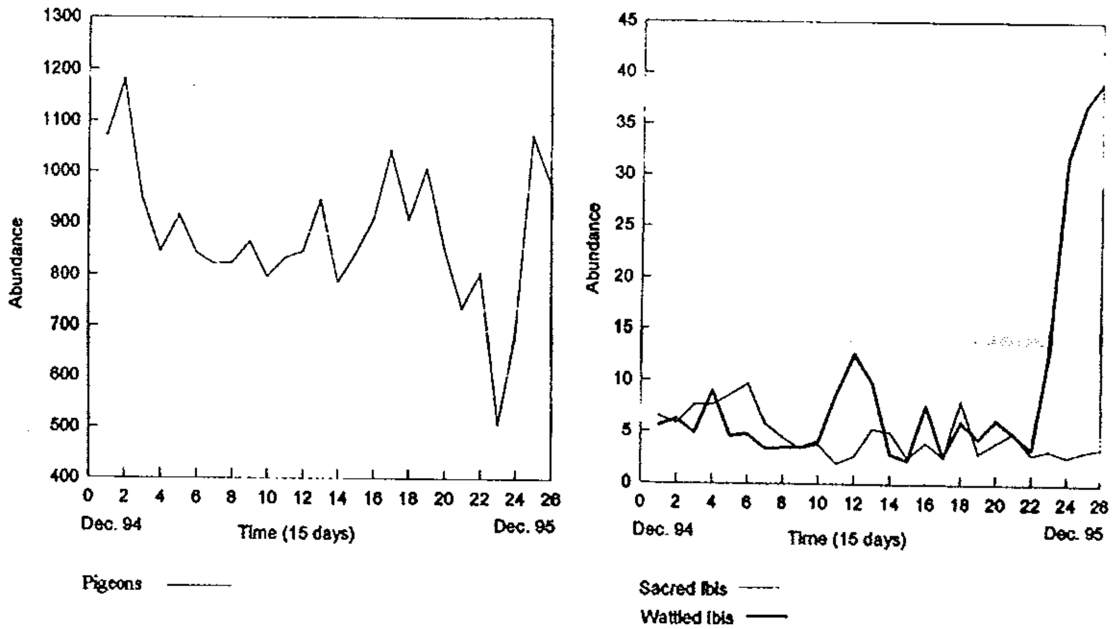


Fig. 4 Average Abundance of Birds from Bole Airport: Frequent-Regular-Transients

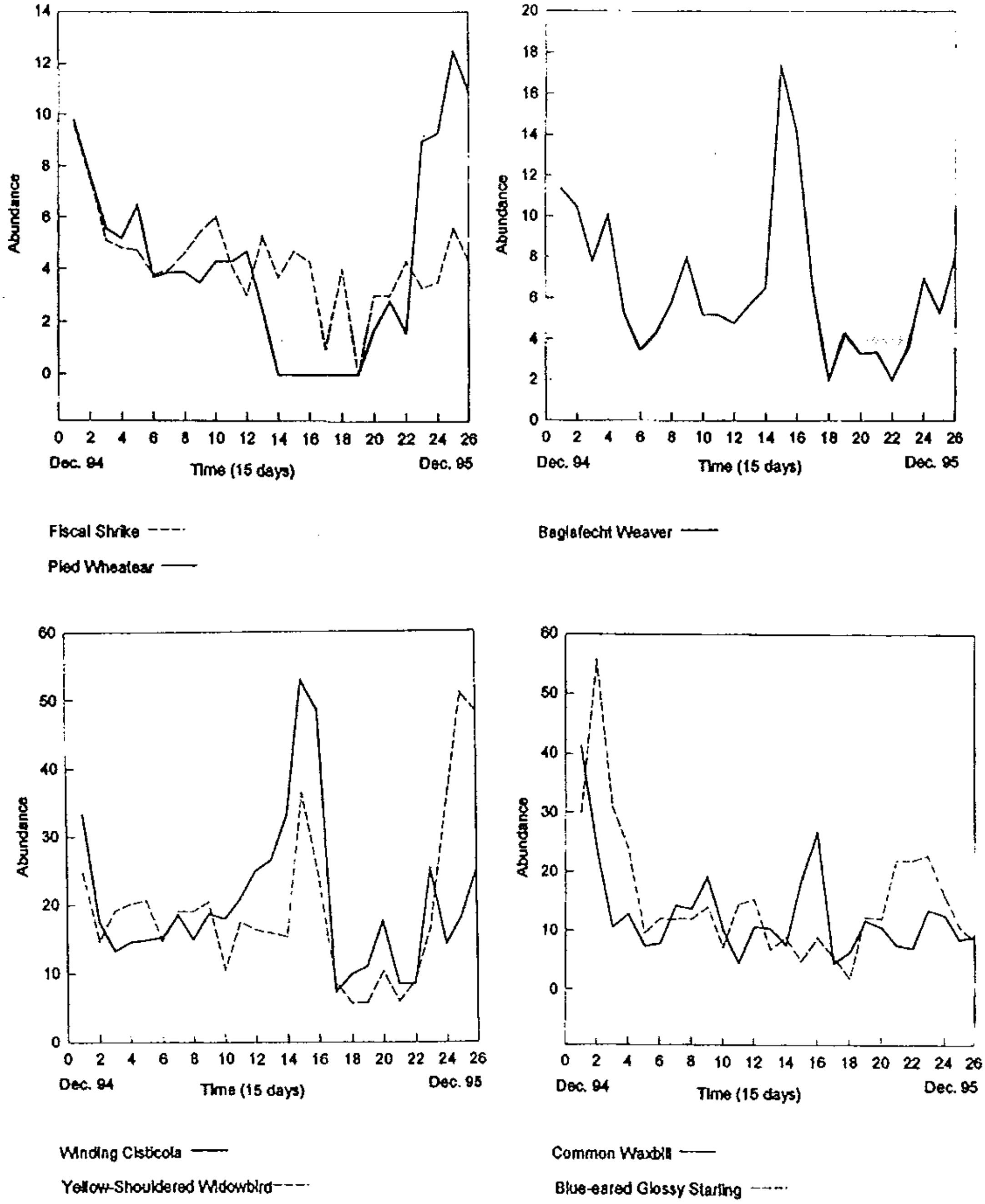


Fig. 5a Average Abundance of Birds from Bole Airport: Resident-Visitors

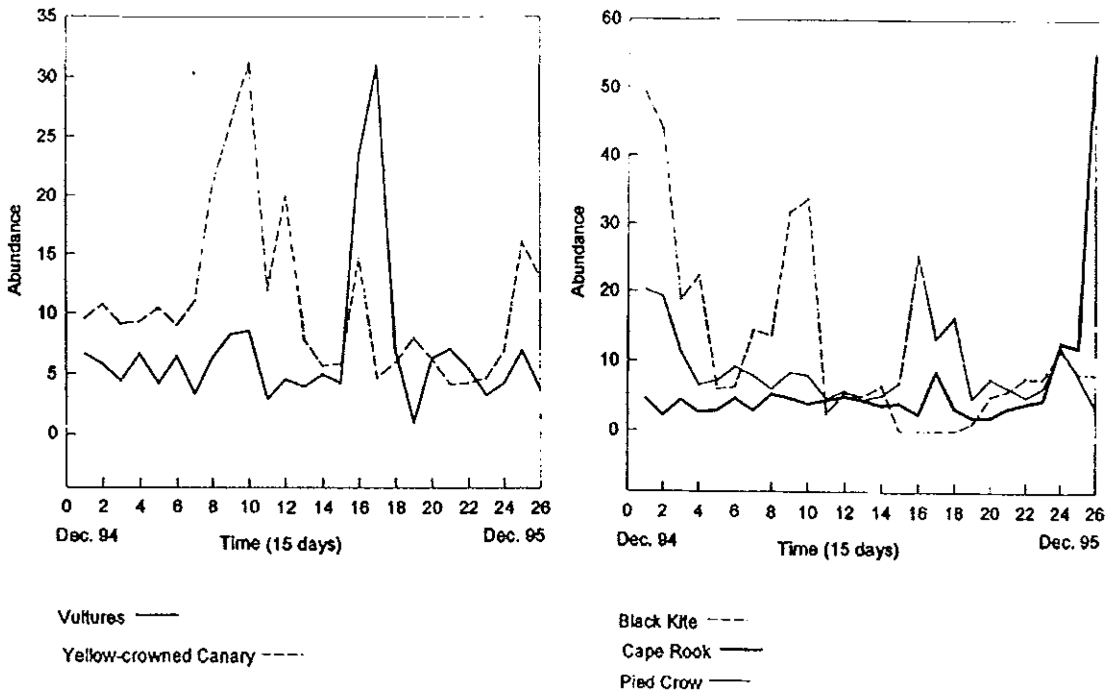


Fig. 5b Average Abundance of Birds from Bole Airport: Resident-Visitors

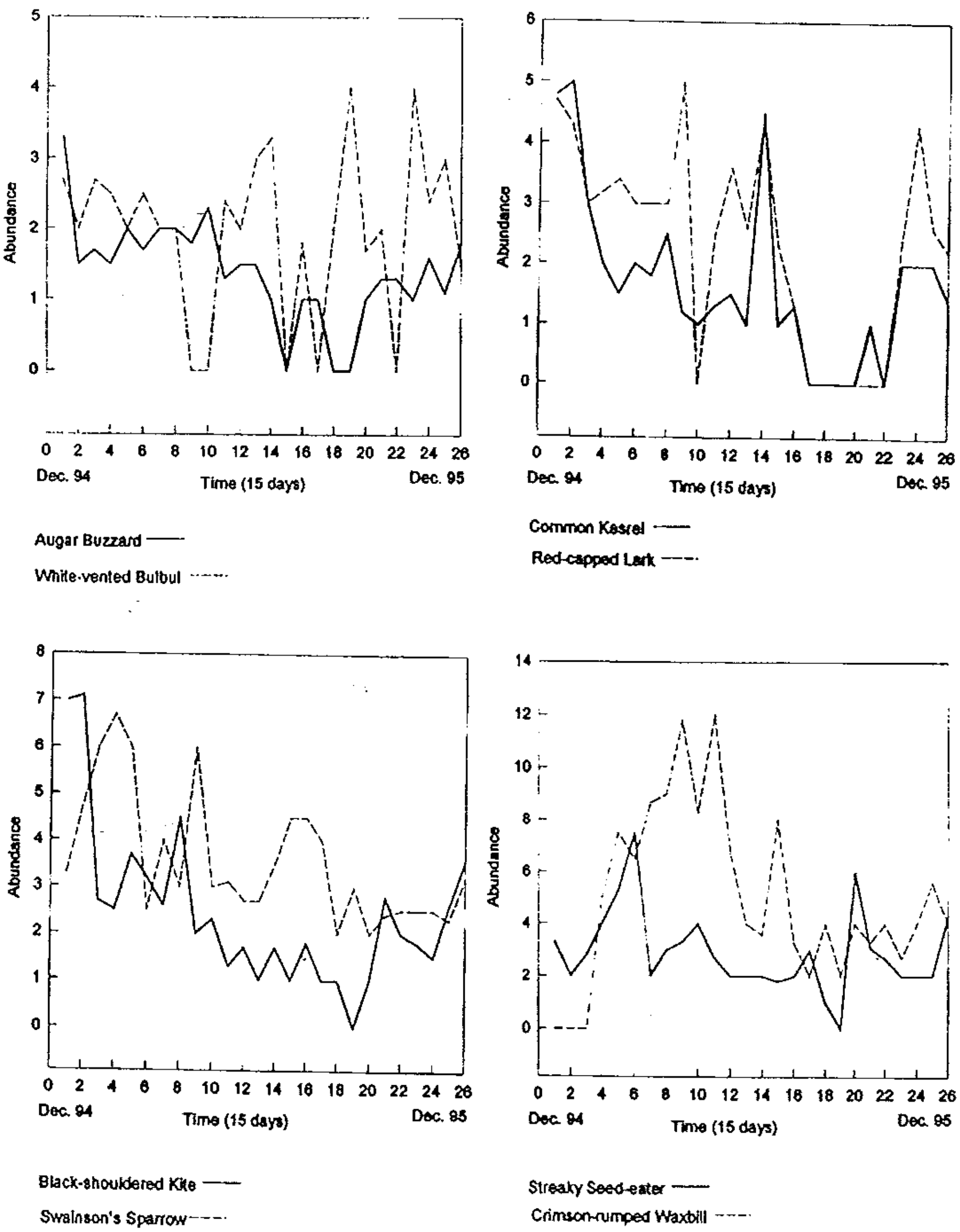


Fig. 6a Average Abundance of Birds from Bole Airport: Frequent-Visitors

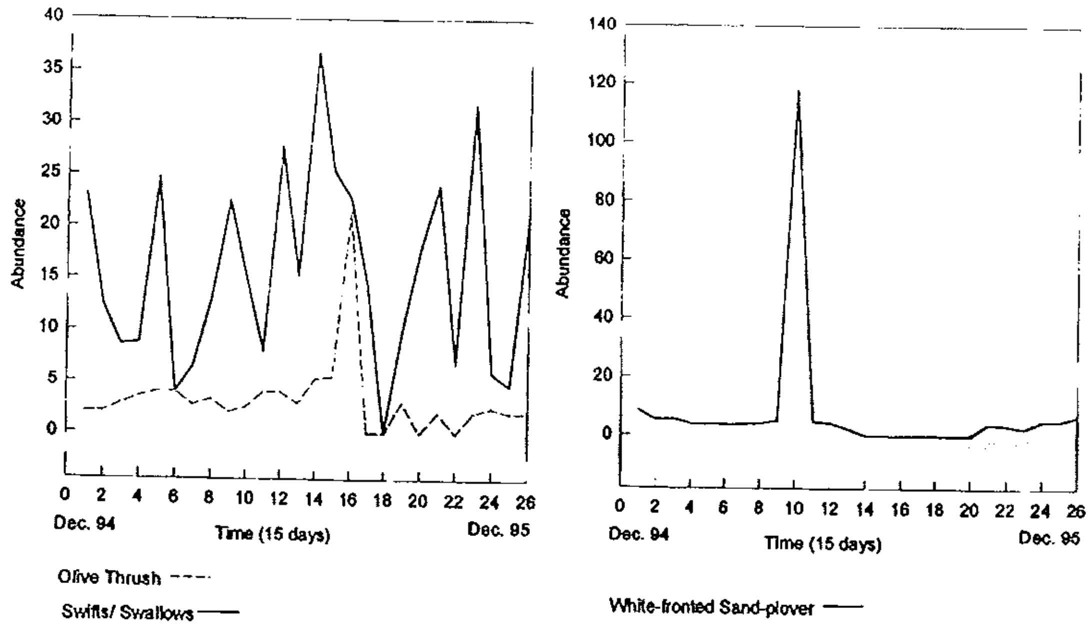


Fig. 6b Average Abundance of Birds from Bole Airport: Frequent-Visitors

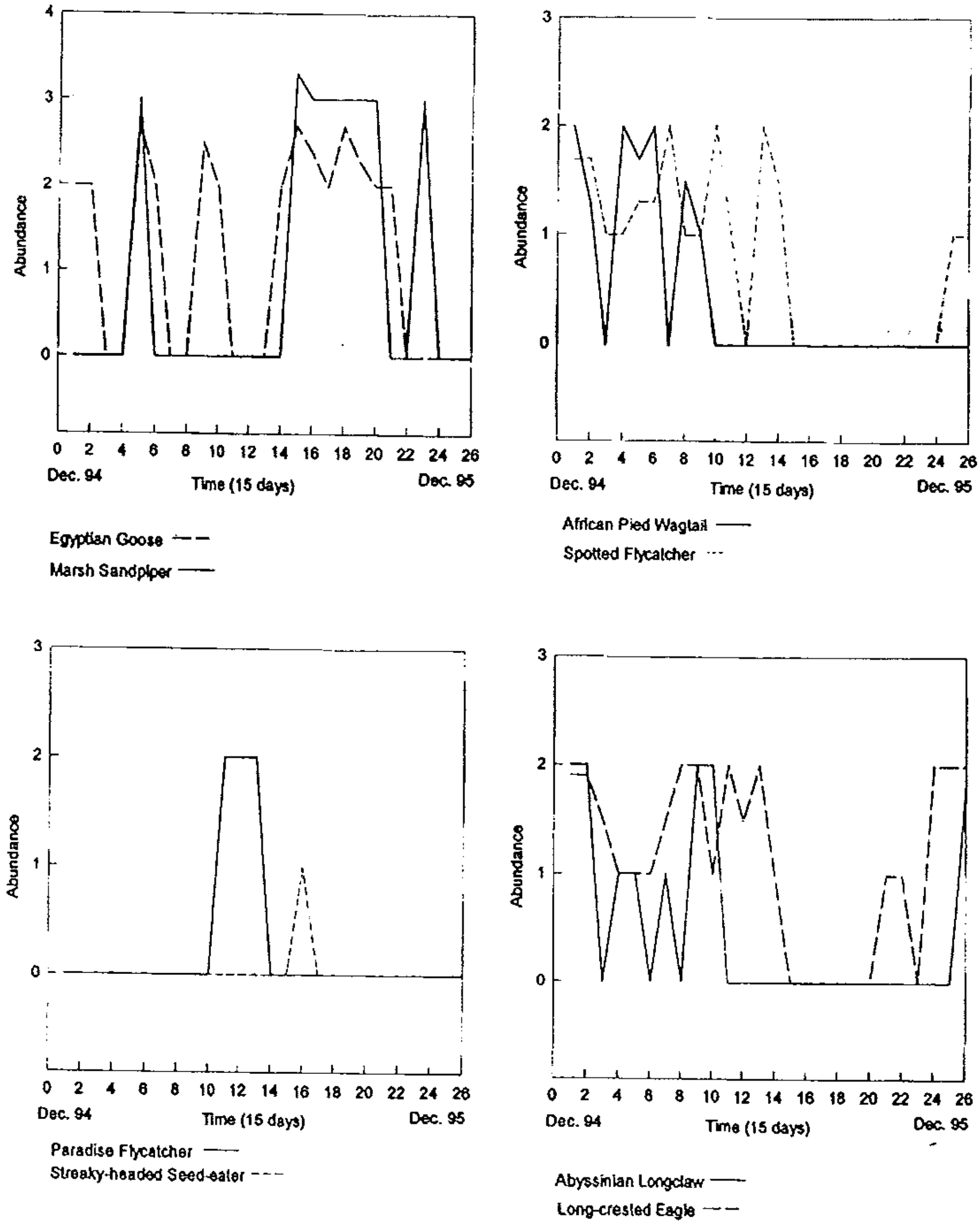


Fig. 7a Average Abundance of Birds from Bole Airport: Infrequent-Vistitors

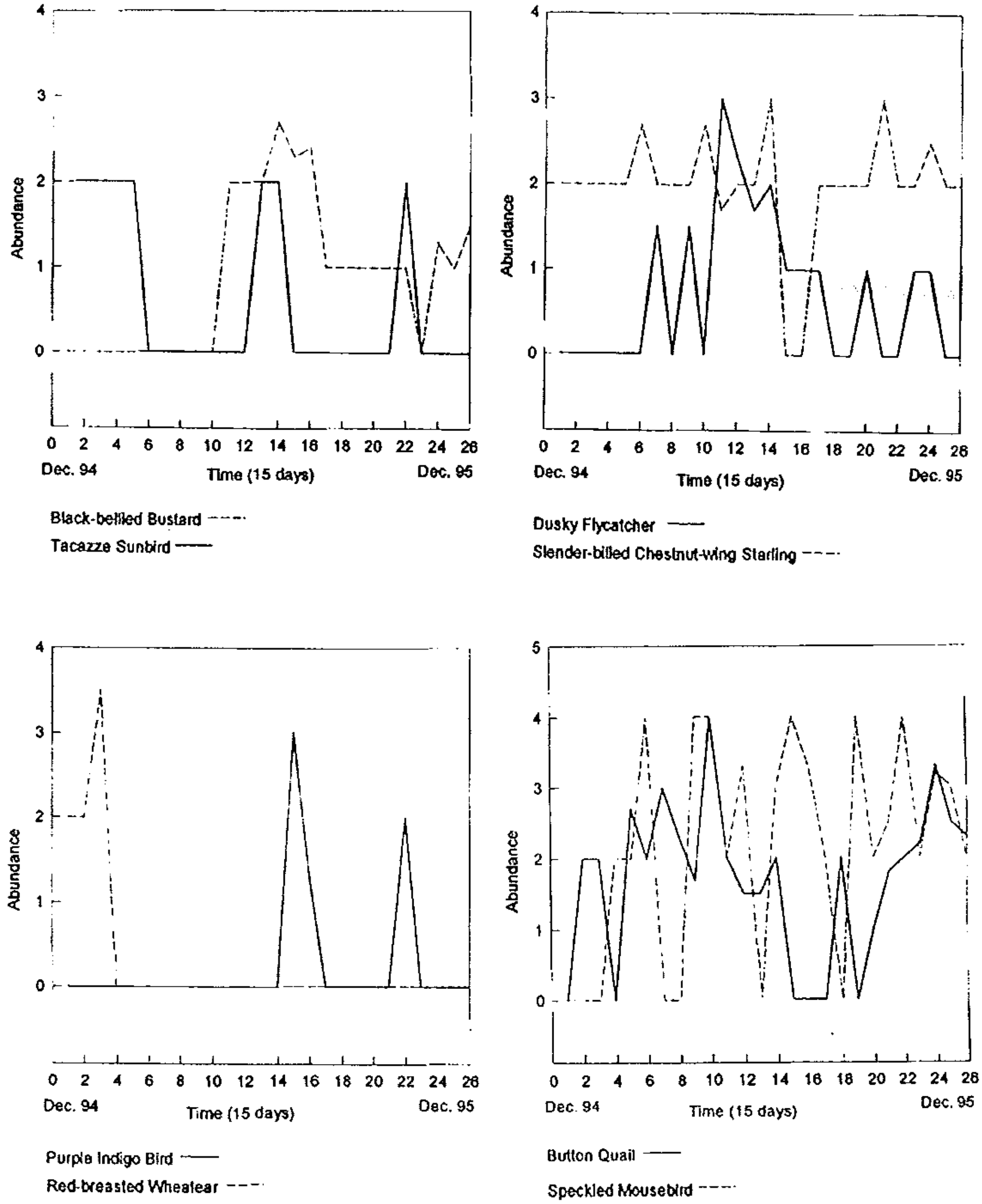


Fig. 7b Average Abundance of Birds from Bole Airport: Infrequent-Visitors

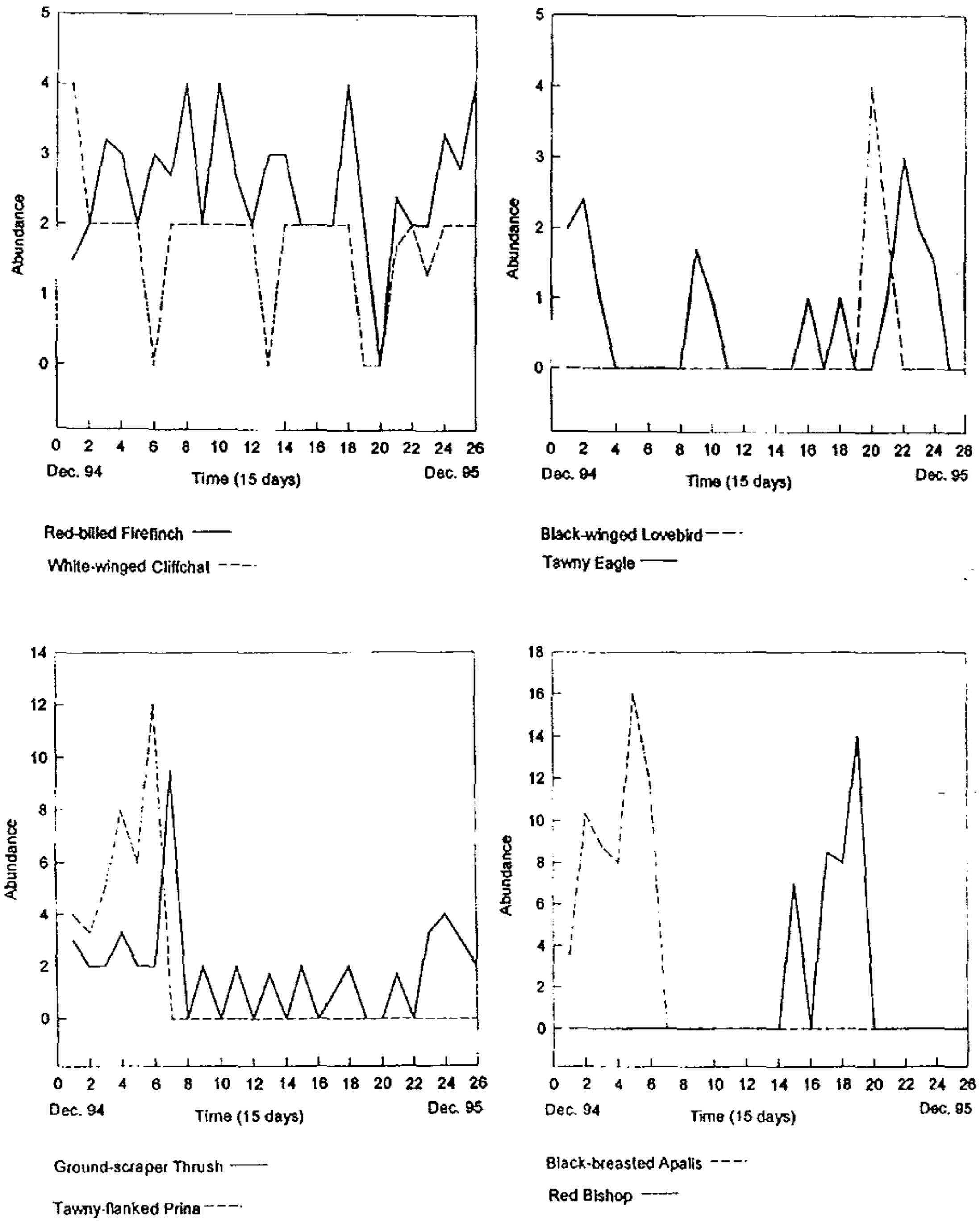


Fig. 7c Average Abundance of Birds from Bole Airport: Infrequent-Visitors

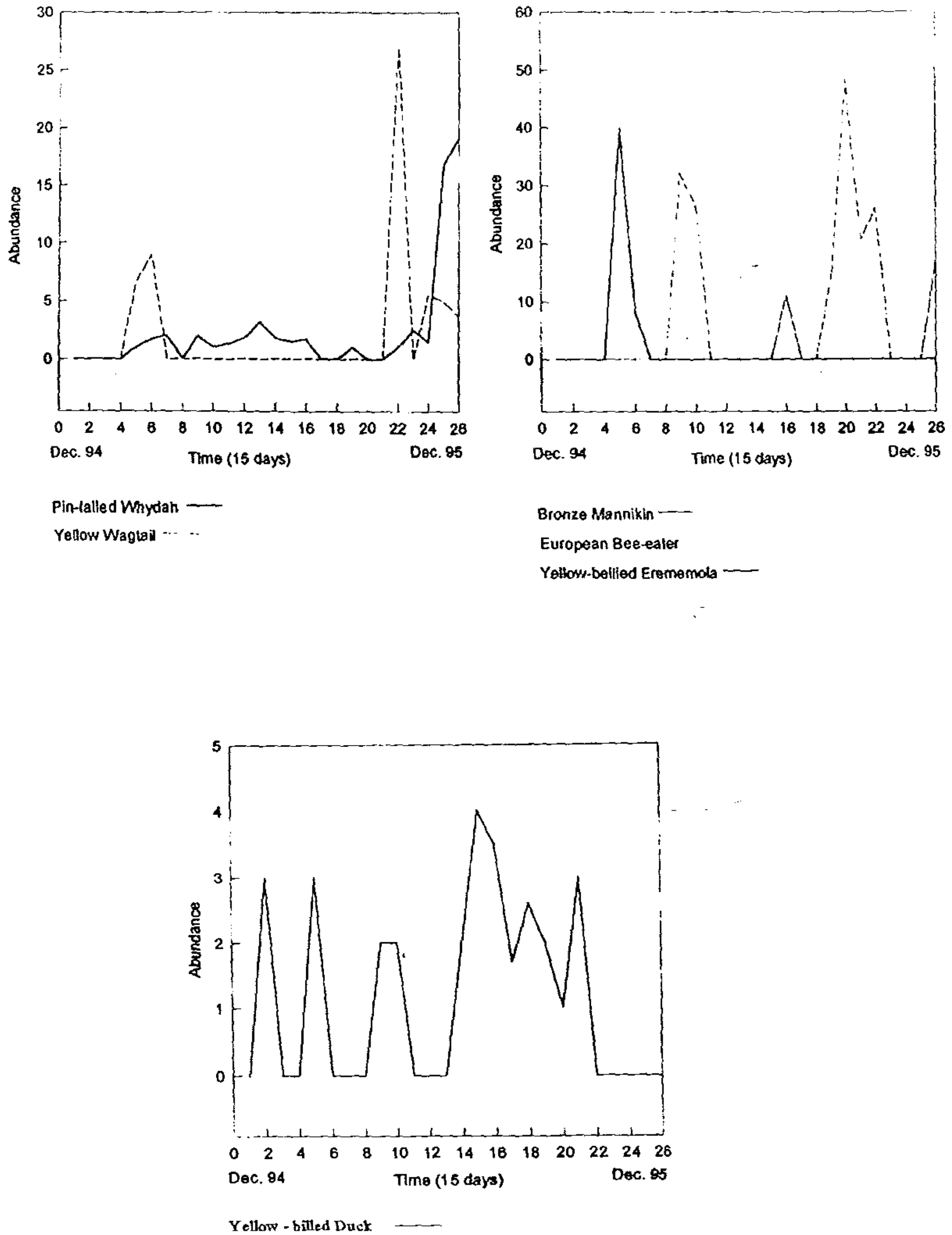


Fig. 7d Average Abundance of Birds from Bole Airport: Infrequent-Visitors

The discussion that follows is based on the sequence of the abundance of bird orders listed in Table 1. The Passerines comprised 57% of the bird species in Bole. This high percentage is not surprising because the Passerines comprise 60% of all bird species of the world (Webb et al, 1986). Most of the Passerines in Bole were small in size, though a few (like crows) were quite large. These group of birds feed on various organisms ranging from insects to seeds and other objects. Some also feed on garbage dumps inside the airport. The airport environment has been rich enough to supply for the omnivorous type of feeding.

The Resident Passerine birds comprised 83% of all the Passerines at Bole. The Winding Cisticola and the Yellow-shouldered Widow bird showed high frequency of occurrence. The Cisticolas are small and very active birds that feed on insects. The 200 ha of grassland surrounding the airport runway is capable of supporting high populations of insects. These warblers nest and lay eggs in a luxuriant grass and sedge near the ground. The airport field is thus a favorable habitat for these warblers for it provides them both with food and shelter. Nevertheless, Cisticolas have so far not caused any strike. The Winding Cisticola showed an increase in the abundance in the months of June & July. This appears to be the result of the high insect populations particularly of flies (house flies) in June and other insects in the month of July which is the beginning of the rain season. A few Cisticolas were also encountered in August and October. August being the month with high rainfall amount and intensity, the insect population was low. In October the Cisticolas spend much time on the farmlands outside the airport where flying insects could be found.

The Swallows and Swifts were exclusively aerial in habit. They fed on insects mainly, flies termites and other flying insects. These birds flock in large numbers. The acrobatic and tireless flight behavior makes them susceptible to collisions. Though rarely, some have been seen to perch on telegraph wires. Some nested under eaves of buildings inside the airport. Identification of Swifts and Swallos in the field was relatively difficult. As they appear in flocks of high numbers, counting them was equally difficult. They appeared in large numbers in the months of June, July, and December. This was due to a high insect population in the months of June and July. In December there were plenty of flying insects along the farmlands out side the airport. No Swift or Swallow was observed in August. The Swifts and Swallows used to soar over the airfields of the airport while passing to the farm lands. The high amount and intensity of rainfall in August which resulted in a low insect population also affected the number of Cisticolas in a similar way as it affected the Swifts. The rise in the insect population which followed the decrease in the quantity and intensity of the summer rain had allowed the increase in the population of birds that particularly depend on insects for food. The high populations of insects in May and June seem to account for the high population of these phenomena. Five per cent of the aircraft strikes are attributable to Swifts and Swallows. Nevertheless all these strikes occurred in October where the abundance of the Swifts and Swallow is much lower. It is important to note that there is a high risk of air strikes associated with high population of birds. Nevertheless, the bird strike problem is so stochastic that even birds with low abundance can be involved.

The Fiscal Shrikes are among the resident Passerines. This species was one of those birds perching on telegraph wires and other fence posts. The species feeds on various insects but the

Orthoptera make the bulk of the diet. Ants and earthworms constitute some of the food resource. Though the shrike frequented the airport, it has never been involved in a strike. This can be attributed to the absence of posts around the airport which the birds can use for looking out and locating preys. The Fiscal Shrike population shows an increase in December and April and a sharp decline in September. In December and particularly in April, the population of earthworms on the runway has been high. The abundance of the shrikes around the runway increased in these months with the availability of the earthworms and other invertebrates. During the other months including September, the abundance of this bird species has been relatively lower. The Fiscal Shrike is considered as a resident species of stable population size in the airport. However, the abundance of this bird was low in September. This was because the shrikes kept away from the vicinity of the runway and the transect area since the environment did not provide them with their needs such as lookout posts. This shows that some of the Resident birds that stay in the airport throughout the study period have never been involved in air strikes. In some cases, the birds get used to the aircraft movements and stay away from aircraft. Others, particularly those that can get their needs from airport fields far from the runway, do not appear to stay around the runway.

Sparrows, Weavers and Waxbills are gregarious birds. They feed on insects, grains and seeds from the farms inside and outside the airport. Males acquire a different dressing during the breeding season. None of these birds except the Yellow-shouldered Widow birds were recorded to cause a strike. The population of these birds showed an increase in the months of July and November. In July, males are seen in their breeding dress as a result of which identification becomes easy. Moreover, the males aggregate with fewer numbers of females. These are without the bright breeding dress which makes the identification of the females equally easy. They feed in flocks of 35-50 starting from November to June. In December and January, however, the birds stayed in the farmlands outside the airport. During the rest of the year, these birds stayed in the airport mainly along the teff and maize farmland north of the airport. The widow birds roosted mainly in the vegetation, *Thypha angustiflolia,* along the sewage stream that runs north-south inside the airport. They nested mainly in the grass tuft. In its breeding dress, the male possesses a long and graduated tail. In almost all cases, the male birds were involved in air strikes. They were curiously producing noise, slowly flying very low and showing sexual displays. The slow flight was mainly because of the long tail. This slow flying behavior makes the male widow birds vulnerable to aircraft collisions. The vegetation of the airport environment is rich enough to supply the Passerines with food and shelter. As a result, 5.5% of the strikes encountered were accounted by collisions with Yellow-shouldered Widow Birds.

Blue-eared Glossy Starlings occurred in the airport throughout the study period. These birds fly in flocks of 25 to 40. They are noisy and conspicuous. They dwell mainly along the garbage dumps in the airport. The starlings were observed to feed on scraps and shreds of leftovers from the cafeterias of the Civil Aviation Authority, the Ethiopian Air Lines and aircraft. Garbage from these cafeterias and particularly from the one located near the apron had attracted different birds to the apron. According to Webb et al, (1986) insects and larvae constitute the main diet of these birds. The insects that are found inside the airport can also act as an alternative food source for starlings. The starlings in the airport roost on the telegraph poles, wires and on roofs of buildings inside the airport. Their abundance, tendency to hung around the apron and flocking together contributes to their vulnerability and high risk of strike. The starlings were abundant in December. There was a mass of garbage and several pieces and piles of paper all over the airport fields in December 1994. While this study was going on, the Civil Aviation Authority took strict measures to free the airport environment from garbage dumps. The frequency of occurrence of the birds along the transect area declined immediately after then. Nevertheless, the airport has not been completely free of disposed garbage and other food sources. As a result the starlings were observed throughout the study period. However, no starling was observed to be involved in air strike. One possible explanation for this could be the fact that the starlings did not cross the runway in search of food or for any other interest. They remained mainly around the garbage dumps. The garbage inside and around the airport has attracted various birds to the airport.

The Crows and Rooks are the largest (in size) of the singing and perching birds. The crows were very common where there are open garbage dumps in the airport. These are solitary birds that occasionally aggregate into small flocks. They hover high in the air and perch on roofs, telegraph poles, fence posts inside the airport and on the runway. The rooks on the other hand, were observed in few pairs. They were generally seen along open fields and in the cultivated areas outside the airport. The rooks also perch on the telegraph poles and fence posts. They fed on termites, earthworm, molluscs and other invertebrates on the runway. They crossed the runway intermittently particularly after 1700 hr. This is the time when the bird scaring teams stop their daily duty and the runway becomes free from disturbances. This, associated with the relatively large size of these birds make them potentially vulnerable to air strikes. However, rooks have not been involved in air strike and the record of such incidences in other airports is very low compared to other birds (see appendix 3).

However, the crows and rooks are highly conditioned to the aircraft movements that these birds stay at the edge of the runway until a landing or a flying aircraft leaves the runway. There has been an increase in the number of Pied Crows in July and August. This was also true for rooks though the magnitude was lower than the Pied Crows. In addition to the good supply of food, the availability of resting and perching posts have made Bole Airport a favorable area for the perching and singing birds.

Black Kite was completely missing in July and August during which time they migrate to other places where the climate is more favorable. The Black Kite was usually observed to attack and chase away the rooks and crows violently. In July and August, when their natural enemies are absent, the crows and rooks frequent the airport to feed on the resources made available to them. The availability of insects and other invertebrates in the runway also attracted crows and rooks to the runway. In July, Vultures occurred in the vicinity of the airport being attracted by rooks and crows. Garbage from aircraft are dumped into big barrels in front of the apron. As these barrels were open and were not removed as soon as the garbage is collected, crows aggregated around the barrels to scavenge on the garbage. It seems that the birds were conditioned to the situation and approached the apron whenever aircraft approached the airport in the hope of finding newly disposed garbage. These birds have become partially dependent on the food source they obtain from the airport and it seems that they will frequent the apron for some time to come even when it is made free of garbage. Thus, they have become permanent residents of the airport. It is therefore necessary to strictly clean the airport, close open garbage barrels and remove refuse garbage as soon as garbage is dumped.

The Vultures, Kites, Hawks and Falcons comprised 15% of the bird species observed at Bole. Beginning from 0900 hr, vultures soar at great heights in the air. They come from the northwestern side where the Addis Ababa slaughter house is located. Observations made at the slaughter house showed more than 5,000 vultures, kites, crows, and other scavenging birds flocking on the huge collections of bones and carcasses. The birds were also seen roosting on the roofs of the slaughter house, trees, telegraph poles and nearby structures; and soaring in the sky over the slaughter house. All the species of Vultures observed in this study area were mainly seen soaring high in the sky. In some occasions however, some of the vultures were observed feeding on grasshoppers and termites. They happen to come down and feed on the runway following some other birds of prey (kites and crows) feeding or resting on the runway. Vultures were bold and move slowly that scaring them away from the runway had been difficult. This behavior of vultures associated with their large size and their habit of gliding high on the sky made the birds perilous for a serious strike.

A serious air strike in which vultures had been involved occurred on October 22, 1995. The collision was between a DC-6 aircraft (Flight number ET-173) and a White-backed Vulture at about 1000 hr at the western end of Addis Ababa. The strike took place at approximately 3.35 km ground height over a slaughter house at Kara Alo, road to Sendafa. The aircraft was made out of use but human casualty has not occurred. The total loss, however, was estimated to be four million US dollars. This estimate did not include the indirect loss such as the revenue which could have been generated if the aircraft was operational. The slaughter house is tidy, trim and clean without any piles of bones, dumps of garbage and unpleasant odor. Thus, the number of vultures, kites and other scavenging birds was fewer than one would expect to find around a slaughter house. Nevertheless, it has resulted in the loss of an aircraft due to a collision with a vulture attracted by this slaughter house. The Kara Alo slaughter house is situated on the approach line of aircraft to Bole International Airport. If such a neat slaughter house had birds of prey, though few in number, and had caused a loss of an aircraft, how frightening and dreadful would it be to fly over the Addis Ababa slaughter house. The Addis Ababa Slaughter house, the biggest in the city is in the base-leg zone for an approaching aircraft.

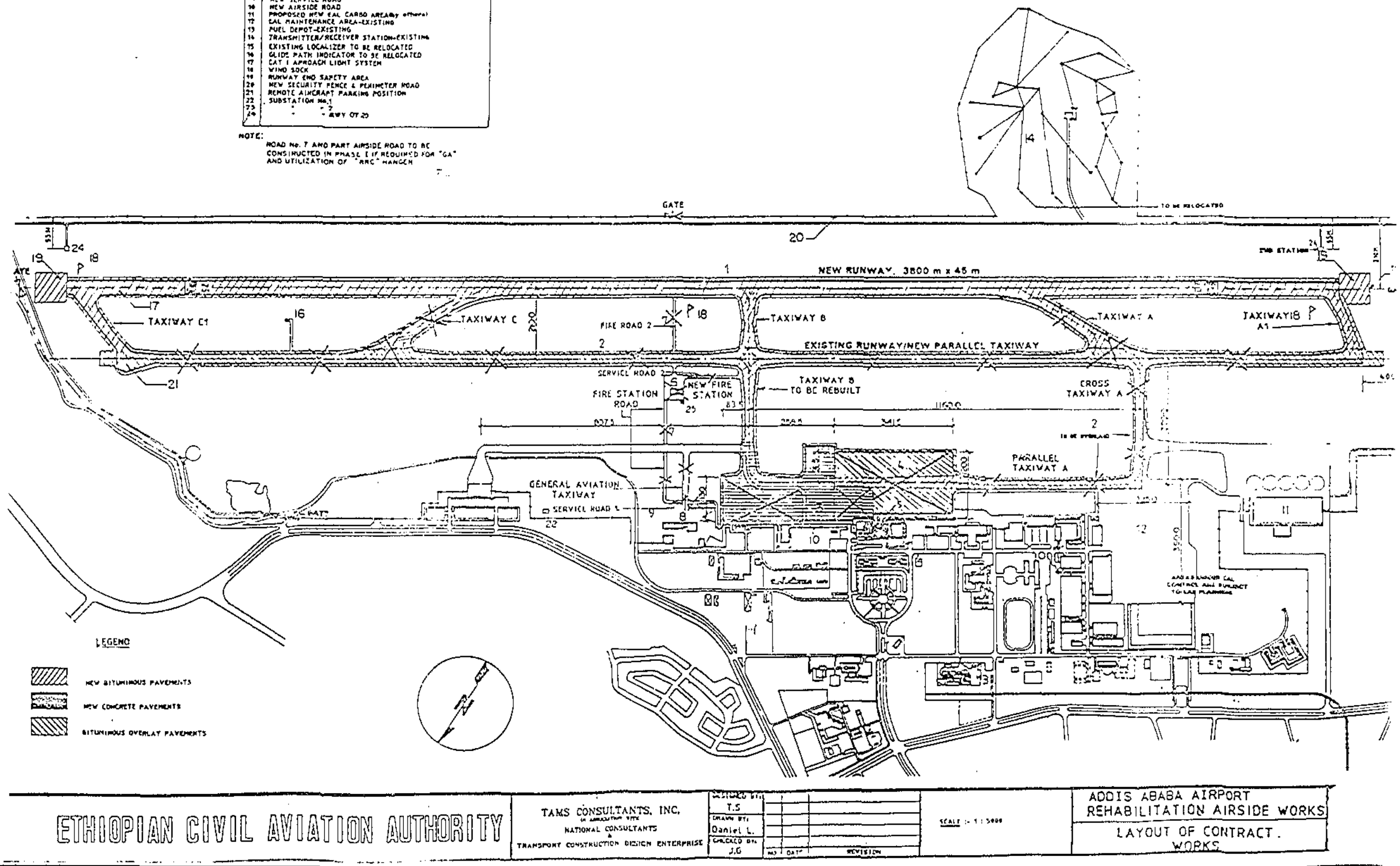
In addition to the open and semiclosed slaughter houses, the lack of proper waste disposal systems is partly responsible for the high population size of various birds of prey in the city. Thousands of birds roost and scavenge around the main slaughter house. The skies of Addis Ababa are filled by raptors coming from the slaughter house. This has become threatening for safe aviation at present and this threat will be aggravated since flight frequency is bound to increase in the future. The Ethiopian Civil Aviation Authority is developing a plan for extending the runway and its terminal which will gring about an increase in flight frequency. Fig. 8 shows the future plan of the airport.

The abundance of vultures at the airport is very low in September. On average a large number of cattle are slaughtered in September, for celebrating the two major holidays in the month. The city slaughter house thus collects a mass of fresh offal and scraps; and leftovers are disposed in the city garbage dumps. The vultures therefore may not need to soar high and far from the slaughter house in search of carrion.

Figure 8. Addis Ababa Airport Future Plan -

No	LEGEND
1	NEW RUNWAY AND LINK TAXIWAYS
2	EXISTING RUNWAY AND TAXIWAY-OVERLAID
3	NEW CONCRETE PARKING APRON
4	EXISTING APRON OVERLAID
5	EXTENSION OF CONTROL TOWER & EXPANSION OF OFFICES
6	NEW FIRE STATION
7	NEW FIRE ROAD
8	NEW GENERAL AVIATION TAXIWAY
9	NEW SERVICE ROAD
10	NEW AIRSIDE ROAD
11	PROPOSED NEW EAL CARGO AREA(by others)
12	EAL MAINTENANCE AREA-EXISTING
13	FUEL DEPOT-EXISTING
14	TRANSMITTER/RECEIVER STATION-EXISTING
15	EXISTING LOCALIZER TO BE RELOCATED
16	GLIDE PATH INDICATOR TO BE RELOCATED
17	CAT I APROACH LIGHT SYSTEM
18	WIND SOCK
19	RUNWAY END SAFETY AREA
20	NEW SECURITY FENCE & PERIMETER ROAD
21	REMOTE AIRCRAFT PARKING POSITION
22	SUBSTATION No.1
23	" " 2
24	" " RWY 07 25

NOTE:
ROAD No. 7 AND PART AIRSIDE ROAD TO BE CONSTRUCTED IN PHASE I IF REQUIRED FOR "GA" AND UTILIZATION OF "RRC" HANGER



Black Kites were among those birds of prey that were highly involved in most serious strikes. Kites are fearless birds and are observed throughout the study period except in the long rain of the summer season. According to Brown (1971), the birds migrate during the summer period. Kites are attracted by the garbage dumps inside the airport, particularly by the open garbage collection near the CAA cafeteria and the Customs office. These birds feed on flying insects, mainly the more conspicuous ones such as grasshoppers, butterflies, termites and flying ants. They also pick up offal, scraps, caterpillars, earthworms, lizards, snakes and small mammals. They pick their preys by hovering and pouncing down on the runway. While doing so, kites might consider any approaching aircraft to be a competitor and attempt to chase it away violently flapping the aircraft with their wings (Personal observation). Kites seem to enjoy the heat from the runway as they idly and fearlessly rest on the runway when the runway surface gets warmer at about noon. The birds were so bold and fearless that scaring them away from the runway is at times difficult. The fearless and quarry act towards the aircraft make kites highly vulnerable to air strikes. In most of the strikes recorded, the Black Kites were sucked into the engines. Twenty-seven per cent of the strikes recorded during the study period were the result of collision with birds of prey. Eighty per cent of these strikes were induced by Black Kites. Flights have been delayed several times to scare away kites from the runway. When the bird scaring personnel standing on either sides of the run way failed to scare away these birds, the fire brigade of CAA was summoned several time to help in the fight against kites.

Once a bird or any other organism is struck and killed on the runway, several scavengers or birds of prey get attracted by the carcass. Even cats and dogs of the neighboring homesteads also visited the airport to find flesh of birds and other animals struck by aircraft. In addition to scaring away birds, the fire brigade gets into the runway to pick up carcasses of bird or any other organism struck by aircraft. It appears that kites are conditioned to the fire brigade vehicles getting into the runway. Soon a vehicle gets into the runway with its alarm sound and lights on, the birds gather and follow the vehicle in search of the carcass. The birds were observed to soar round the vehicle circling at low height. In one occasion a fire brigade vehicle was overturned in the runway while chasing out birds. The damage was estimated to cost a total loss of more than 10 thousand US dollars.

The Black Kites were very abundant in December (1994) and April. In December (1994), several Black Kites stayed in the airport in search of food from the garbage dumps. They were also seen to be attracted by the piles of pieces of paper in the airport fields either conditioned by food thrown out rapped with paper or for display purposes. During the study period, the small rains attained maximum intensity in April. This created favorable condition for the breeding, maturity and emergence of termites, butterflies, grasshoppers and other flying insects. Black Kites stay in the fields to feed on these organisms. Moreover, before the onset of the short rain season, some of the grass and other herbaceous plants were cut short. This made it easier for grasshoppers to leap out and incidently fly into the runway. In addition, small mammals also lost their hideouts and were exposed to birds of prey which would easily capture them.

The Black-shouldered Kite and Kestrel showed similar behavior and often shared the same habitats. Both Black-shouldered Kite and the Kestrel hover over their preys with a slow wing-beats and drop down on the prey. They were usually seen in pairs or singly. They become easily scared by a moving aircraft. The Kestrels were seen to feed on insects and reptiles. The Black-shouldered Kite was also seen feeding on insects but more often on small mammals. On one occasion, a Black-shouldered Kite caused a strike while hovering over a grasshopper on the runway. These birds roost on the *Acacia* trees inside the airport compound.

The populations of Black-shouldered Kite and Augur Buzzard increased in April due to the availability of the insect and small mammals. These birds were not observed in September probably because the vegetation in the fields attained maximum height making it difficult for these birds to locate and pick prey such as small mammals and insects.

Augur Buzzards were not seen in July mainly because crows and rooks which frequented the airport in July chased them away. With the maximum amount and intensity of rainfall in July and August, the small mammals are believed to remain in their burrows. It appears that the buzzards visit the airport mainly attracted by small mammals.

The Augur Buzzards were seen feeding on small mammals, reptiles and insects. These birds hover with a slow wing beat and stay much of their time in the sky. It was seen to perch quite for long period of time on a hip of hay, telegraph or fence posts. Their behavior of spending much time in the air and their large size make buzzards hazardous to aircraft. Dogs coming from the vicinity of the airport find it easy to come to the apron and runway to scavenge for possible food sources at the garbage dumps. Cattle were also seen grazing on the vegetation inside the airport and crossing the runway. Brown (1971) has pointed out that many birds of prey in Africa use scavenging dogs to locate their food. Thus, dogs inside the airport are dangerous in two ways, i.e., in being involved in *dog strike* and in attracting birds of prey to the airport. On one occasion, a dog was struck by an aircraft and number of birds of prey rushed into the runway to scavenge on it. A similar problem was observed when a Genet (*Genetta sp.*) was hit by a landing aircraft and a Serval (*Felis serval*) was killed by people mowing the grass.

Although the Civil Aviation Authority took some measures to prevent the presence of livestock in the airport, cattle were observed grazing on the vegetation inside the airport and crossing the runway. There were bulls, sheep and goats kept in the airport fields for festivals. The slaughter of animals in the open field has caused swarming of birds of prey around the airport.

Wetland birds of the order Ciconiformes, which comprise 10% of the bird species in Bole, were invariably Transient. These birds have their feeding area Northwest of the airport in a depression which is mainly inundated by sewage and a small stream running Southeast. The birds cross the airport Northwest early mornings mostly before 0700 hr. They pass to their roosting areas in a Southeast direction during late afternoons. Fortunately this is the time when the air traffic is not heavy. Nevertheless, the time when they cross the airport varies depending on the length of the day hour and the season.

The Sacred and Wattled Ibises crossed the runway in few numbers in July and August. In these months, the birds need not travel very far since they could stay along the shores of some streams, rivers, swamps or soft grounds around their roosting area. This would decrease the frequency of crossing the airport in search of feeding ground north or south of the airport. On the other hand, the Cattle Egrets increased in abundance in the months of July and August. In these months, a number of cattle had concentrated in the fields outside the airport compound on the northern and northwestern direction. Cattle Egrets come to collect the insects which are disturbed by the hooves and breath of the cattle grazing on the grass. The availability of food and shelter in the vicinity of the airport has made these birds use the airport airspace as their transient route.

The Glossy Ibises were seen to cross the airport fields only in November. Macworth-Praed and Grant (1957) have mentioned that these birds are fairly common Palearctic winter migrants to East Africa.

Seventy per cent of the Transient birds observed belong to the Order Ciconiformes. More than 65% of the Frequent-Regulars again belong to the Ciconiformes. Thus, most of the transient birds observed at Bole were determined to be in the Order Ciconiformes. Apparently these birds find food and shelter in areas outside the airport environment and therefore do not need to stay in the airport, but pass across the runway.

Pigeons and Doves comprised 4% of all the bird species observed in the airport environment. The pigeons and doves were mainly Transient birds that cross the airport early mornings and late afternoons. They flew in the Southeast direction to their feeding area early mornings and to Northwest direction presumably to their roosting sites late afternoons. Zerihun (1991) has suggested that these birds nest in towns and on cliffs in nearby mountains. As a group, the pigeons cross the runway at about of 35 to 40 m above ground. Nevertheless, most of them fly even lower when approaching the runway probably because the mirage from the runway gives the ground a water like appearance. They return to their roosting areas earlier during short hour days. In cool and cloudy days, they travel to their feeding areas late in the mornings. In some occasions, the birds used to come earlier and stay in the airport until the air gets warmer. The variation in the apparent population size of these birds in the different months is mainly due to the difference in the day length and not due to an actual difference in the population size.

The pigeons and doves have shown some opportunistic and flexible feeding behavior. When the crop outside the airport is fully grown in November, they visited the farmlands in flocks and roosted in the airport hangars, under roofs, eves, deserted grounded planes, etc. While crossing the runway, they fly at low height and prefer to stay in the farmlands close to the airport. They cross the airport in both directions frequently when the farmers scare them off from farmlands. There was also some farming activity on the northern edge inside the airport. This farm harbored pigeons and other seed-eating birds. This made the pigeons highly vulnerable to strikes in November. During this period, no other birds except the pigeons, were involved in strikes. Plowing the soil exposes worms and insects that attract birds. When the cultivation outside the airport is harvested especially in February, the birds cross the runway flying high up from the ground and travel far from the airport. Nevertheless, small flocks are observed to feed on the seeds of the vegetation inside the airport. These birds were also observed to feed on caterpillars, earthworms and termites on the runway. The White-collared

Pigeons were usually observed in flocks. While passing to their feeding or roosting area, they stopped at the airport occasionally. When disturbed, these pigeons circle at a considerable height before descending. This circling act of the birds could expose them to strike.

Though the number of pigeons and doves that cross the runway was high during early mornings and late afternoons, the birds crossed the runway the whole day. Hundreds of pigeons use the hangar as their overnight roosting and nesting area; and their droppings spoil many items in the hangars. A few number of Glossy Starlings, Swifts and Swallows also roost inside the hangar. Similarly a deserted and grounded aircraft in front of the fire brigade and at the end of the east terminal harbor a number of pigeons and various species of birds. Pigeons and weavers nested beneath the wings of these aircraft. Generally the flexible and very opportunistic habit of pigeons and doves have made them a serious hazard to aircraft. Thirty one per cent of the strikes were reported to have been caused by pigeons and doves and 72% of these strikes occurred in early mornings before 10:00 hr. These are the hours when the air traffic at Bole is fairly heavy.

The Plovers and the Sand piper consist 4% of the total bird species at Bole. The population of these birds seems to show some association with the rainy season. In the rainy season ditches and cable holes around the runway retain water. Except the Kittiliz's Sandplover which is a transient one, the other species stayed along some of these ditches inside the airport. So far, only a single Marsh Sandpiper was found dead in the runway due to a collision with an aircraft. The Kittiliz's Sand Plover crosses the runway northwest of the airport into a depression where the other wetland birds feed. Six per cent of the air strikes observed were due to a collision with birds of the Order Charadriformes. The chance of these infrequent birds to cause air strikes was not negligible.

The ducks and geese comprised 3% of the bird species at Bole. These birds were seen to occur in small pairs. The Yellow-billed Ducks were observed throughout the rainy season. They feed on the surface of the waters retained in some ditches in the airport. The Egyptian Geese were some times found at a considerable distance from water bodies feeding on the teff cultivation inside the airport. The geese crossed the airport in a southeast direction possibly to feed on the crop in the farmlands around the airport. Their habit of resting on the runway made these birds highly vulnerable to strikes. As a result, the Egyptian Geese were involved in 3% of the strikes observed at Bole. This was a high incidence rate compared to their population size. The birds left the airport when the water retained in the ditches and holes dried out with the onset of the dry season. The ducks and geese were mainly attracted by the aquatic habitat formed during the rainy season.

Both the Galliformes and the Gruiformes at Bole consisted of one species each. The Black-bellied Bustards were observed in pairs in the open fields of the airport usually in the mornings. They picked up insects mainly grasshoppers. However, Macworth-Praed and Grant (1957) suggested that all kinds of insects, molluscs and small reptiles, weed seeds and other vegetable matters are eaten by bustards. Most of these food items were available in the airport fields.

There was a sharp increase in the number of count of Button Quails in May. May was a dry month and the quails frequented the ring road in search of a possible food source. The ring road had ditches that retained rain water during the short rainy season. Although only two species of this order were recorded, 3% of the strikes were caused by the quail.

The European Bee-eater, a Palearctic winter migrant species to Ethiopia, visited the airport at the end of September and in October. This species is highly gregarious. It feeds on flying insects, particularly bees. The airport field provides the Bee-eaters with ample supply of bees in September and October that come to collect the nectar from the various colorful flowers including the Meskel flowers (*Bidens prestinaria* and *Bidens macroptera*). These plant species are dominant in September. There were a few hives placed in the airport field by bee keepers on which the bee-eaters could easily feast. Sixteen per cent of the strikes recorded during the study period involved the European Bee-eaters. In 50% of these strikes, more than one bird were involved at a strike. Some of these birds were killed by the blast from the aircraft. The population of these birds declined with the withering away of the flowers due to the onset of the dry season. These birds were also observed in April following the short rain. In April, they feed on termites, house flies and other flying insects. According to Macworth-Praed and Grant (1957) these migratory birds arrive in Africa in September or October, passing on further South, and leave for the Northern hemisphere again between February and April. Thus, these birds visit the airport twice a year while passing to Southern Hemisphere and back to Northern Hemisphere. The gregariousness and the gliding flight of these birds expose them to strikes during this short visit to the airport. The Residents and the Frequent-Regulars are birds that frequently visited or passed in the airport airspace. These birds had a high chance of colliding with a moving aircraft. Environmental measures of controlling bird strike should therefore concentrate on these bird species.

3.1.2 Ordination and Classification

The data matrix of the occurrence of birds in time was subjected to classification and ordination techniques of multivariate data analysis using correlation as a resemblance index. The Principal Components Analysis (PCA) of the data matrix is given in Fig. 9 while the cluster analysis is shown in Fig. 10. List of the Species corresponding to the numbers in Figs. 9, 10 and in appendix 5a is given in appendix 5b. The grouping in both Figs. 9 and 10 come as a result of the correlation in the occurrence of the birds. The cluster analysis shows six groups of birds indicating their temporal relationship but not necessarily the spatial relationship. Birds that are observed to occur at the same time during the study period are clustered into the same groups.The classificatory technique therefore produced a number of groups of birds that co-occurred at a given instant. The classification technique (Group Average Linkage) gave 6 distinct clusters.

The ordination technique, Principal Components Analysis (PCA) gave tree axes (coordinates). Two of these axes were used to produce a scattergram giving only a two dimensional view. The Scatter plot of PCA result gave no clear cut groups In achieving this simplicity, a considerable loss of information could take place. This would have been avoided if the data could be viewed in multidimensional space. However, undue loss of information is minimized since the first two axes account for most of the information in the data. A general agreement could be reached that in an ecological situation involving the bird species, there can be some extrinsic environmental factors whose influence dominates the time but not the site distribution

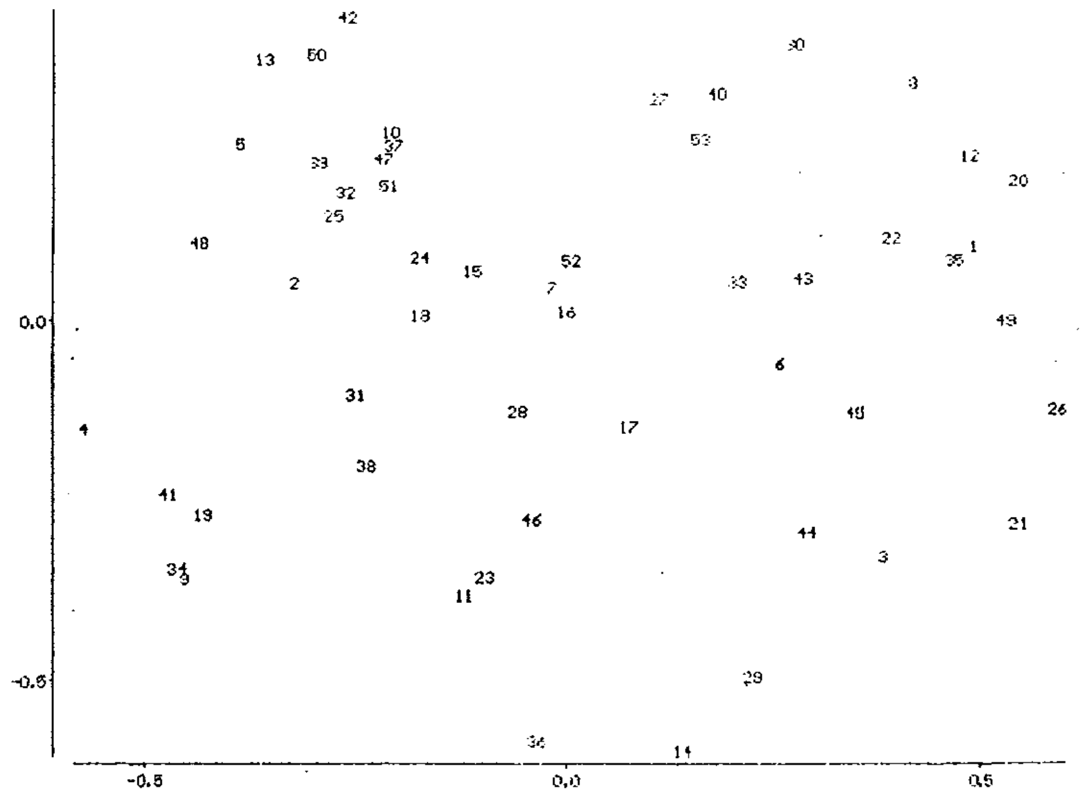


Fig. 9 Principal Component Analysis of Bird Data Matrix from Bole

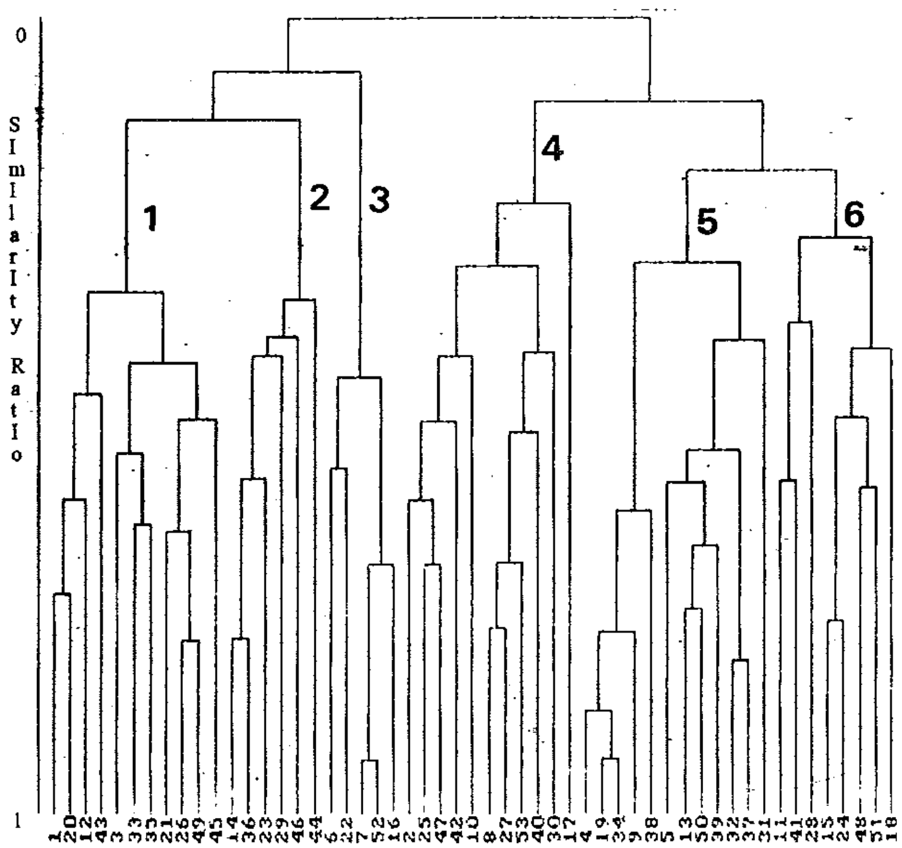


Fig. 10 Cluster Analysis of the Bird Data Matrix from Bole

of the species . Among these factors climate appears to be very important. The identification of other more factors need further investigation involving detailed behavioral and reproductive studies. It is very likely that because ordination reduces the space in which the data are to be presented, it may distort the true picture due to inadequacy of the projection. The lack of clear cut groups in the ordination space, however, indicates that there are no strong and stable factors bringing the birds together.

3.1.3. Frequency Distribution

Ideally, a random frequency distribution would show a Gaussian curve / bell shaped curve type (Sokal and Rolf, 1981). In this study the frequency distribution is inverted with very high number (14) of the species showing low frequency (Fig. 11) and a few species showing high frequency with a rise at 0.7 and 0.8. This indicates that there is an explicable reason for the birds for frequenting the airport. It is interesting to indicate that the rise at 0.7 and 0.8 is caused by the Resident and Frequent-Regular birds recorded using the transect and point count methods respectively. The classification given by Karr (1977) corresponds to the frequency group given in Fig.11. The resident birds are birds with a frequency of 0.7 to 1.0 and those irregular birds are birds with a frequency of 0.3 to 0.0.

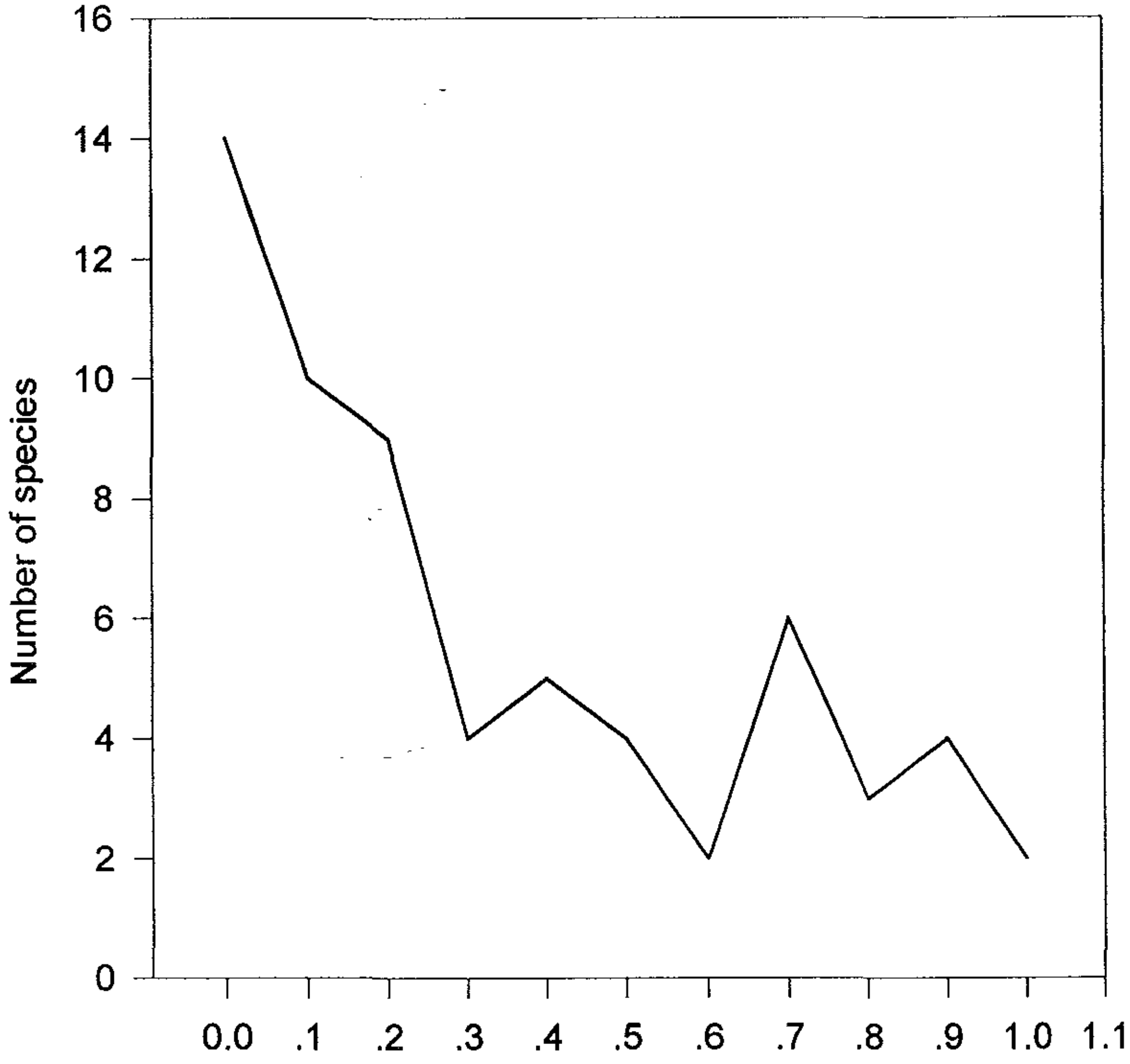


Fig. 11 Frequency Group of the Bird Data from Bole

3.1.4 Diversity Index, Species Richness and Climate

Results of the diversity index show that there is no clear variation in the number of bird species in time although the occurrence of the species may vary depending on the season. The deviation between the Diversity index (H') and the Maximum expected diversity (H'/H max) was in most cases greater than 0.5 (Table 4). This indicates that there is very little fluctuation in population and species type. This could imply that the environmental resource supply in Bole area is quantitatively stable enough to support large populations of different birds throughout the year.

High Species Richness was obtained in the last weeks of December (1994),the first week of February, April and October (1995). Table 4 gives the Species Richness for each fifteen days of the study period too. Figure 12 shows the Minimum and Maximum Temperature, Rainfall, Relative Humidity and Species Richness of the Bole region for the study period.

In December there was a huge mass of garbage dumped food items, heaps and patches of pieces of paper in the airport. In February and April, the airport had some rainfall which resulted in swarms of insects. At the same time, the vegetation in the airport produced ripened seeds. Moreover, the farming activity inside the airport was ready for harvest. Crops in the farmlands behind the airport were harvested and the farmlands became less attractive to birds than the airport.

Table. 4 Shannon - Weiver Diversity Index of Birds From Bole Airport.

Time (15 days)	Species Richness	H'	HMAX	H/ HMAX
1 (Dec,1994)	35	2.97	3.56	0.84
2 (Dec,1994)	37	2.98	3.61	0. 8
3 (Jan)	33	3.12	3.5	0.89
4 (Jan)	34	3.15	3.53	0.89
5 (Feb)	41	3.25	3.71	0.87
6 (Feb)	**36**	**3.34**	**3.58**	**0.93**
7 (Mar)	32	3.12	3.47	0.9
8 (Mar)	29	3.04	3.37	0.9
9 (Apr)	37	3.07	3.61	0.85
10 (Apr)	33	2.6	3.5	0.74
11 (May)	34	3.15	3.53	0.89
12 (May)	32	3	3.47	0.86
13 (Jun)	33	3.09	3.5	0.88
14 (Jun)	33	2.95	3.5	0.84
15 (Jul)	29	2.72	3.37	0.81
16 (Jul)	32	2.81	3.47	0.81
17 (Aug)	26	2.93	3.26	0.9
18 (Aug)	25	2.93	3.22	0.91
19 (Sep)	24	2.87	3.18	0.9
20 (Sep)	28	2.69	3.33	0.81
21 (Oct)	34	3.05	3.53	0.87
22 (Oct)	31	2.93	3.43	0.85
23 (Nov)	33	2.89	3.5	0.83
24 (Nov)	35	3.06	3.56	0.86
25 (Dec,1995)	33	2.98	3.5	0.85
26 (Dec,1995)	35	2.92	3.56	0.82

Thus, several number of birds were observed to be attracted to the airport for various reasons including food, shelter and safety. In addition, with the onset of the winter season and the small rain observed in February and April, wetland birds were observed to pass across Bole into a wet area northeast of the airport. With the increase in the amount of rainfall in the months of July and August, the variety and population of birds recorded decreased. In these months, some migratory birds moved out from the airport. Rainfall seems to play the major role in determining the species richness of the area.

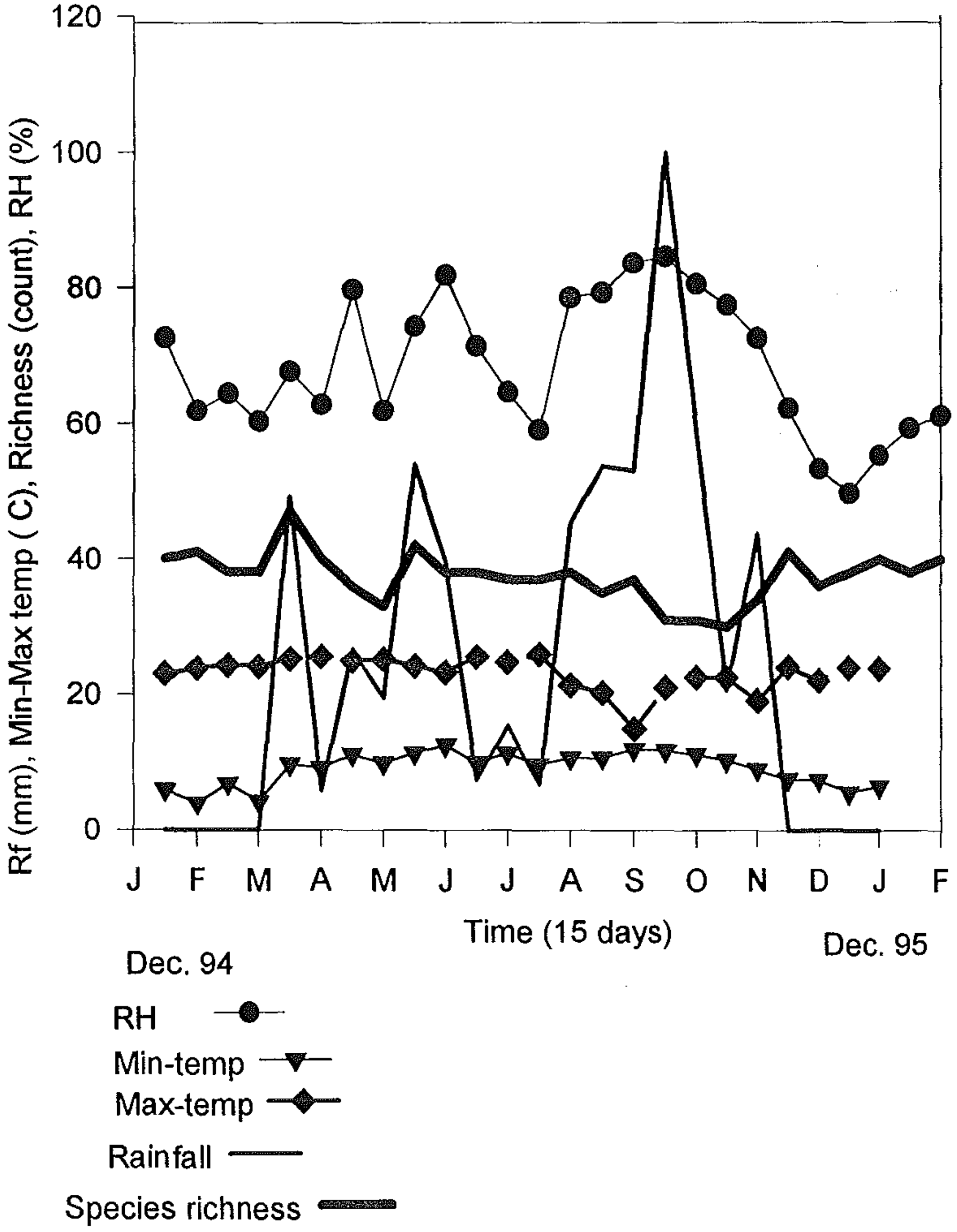


Fig. 12 Climate and Species Richness of the Bird Data from Bole

3.1.5 Density and Biomass

The biomass estimation for some of the bird species showed that only five species have a biomass greater than 10 g/ha (Table 5). Eighteen of the species have biomass less than 1 g/ha. The Yellow-crowned Canary and the Black Kites have a mean count of 11 and 12 birds respectively. However, the Black kites have a biomass of 40 g/ha which is 55 times greater than the canaries. Similarly, the Baglafecht Weaver and the Vultures as a group have a density of 0.03 birds/ha. The biomass of the Vultures is 106 g/ha, which is 95 times greater than that of the weavers. This shows that the mean count of birds is not a good index to compare different species. It can, however, be argued that large birds, which typically have larger home ranges than smaller ones, may occur at lower density. On the other hand, a bird's impact, just like the amount of food it consumes, is directly related to its size. When comparing species, biomass is therefore more informative than simply population size.

The estimation of the diversity and biomass of some of the birds observed at Bole using the transect method, shows that the area is characterized by high diversity and low density of birds. Gwahaba (1985 a and b) reported the occurrence of only 26 bird species at Entebbe Airport which has an area equivalent to that of Bole. However, 73% of the birds from Entebbe Airport were birds of high biomass. Though the main features of the Entebbe Airport are similar to that of Bole Airport, it is important to note that the airport is located on the Northern shore of Lake Victoria in Uganda.

Table 5. Estimation of the Biomass of some of the Birds Recorded From Transect method.

BIRD TYPE	MEAN COUNT	MEAN WEIGHT (g)	BIOMASS (g/ha)
1.Abyssinian Longclaw	0.49	----	----
2. Red-billed Firefinch	2.56	11.5	0.15
3. African Pied Wagtail	0.44	26.7	0.06
4. Augur Buzzard	1.39	1109.8	8.05
5. Baglafecht Weaver	6.59	32.4	1.11
6. Black-brested Apalis	2.24	10.5	0.12
7 .Black Kite	12.11	641.5	40.47
8. Black-bellied Bustard	0.89	2950.0	13.71
9. White-vented Bulbul	1.98	34.6	0.36
10.Black-shouldered Kite	2.44	259.0	3.29
11.Black- winged Lovebird	0.23	----	----
12.Blue-eared Glossy starling	15.46	76.0	6.12
13.Bronze Mannikin	1.08	10.4	0.06
14.Cape Rook	6.59	58.5	2.01
15.Spotted Flycatcher	0.79	----	----
16.Common Kestrel	1.69	417.0	3.66
17.Common Waxbill	12.85	8.00	0.54
18.Crimson-rumped Waxbill	5.00	----	----
19.Dusky Flycatcher	0.69	----	----
20.Egyptian Goose	1.20	2270.0	14.19
21.European Bee-eater	1.46	44.3	0.34
22.Fiscal Shrike	4.33	32.9	0.74
23.Ground scraper Thrush	1.87	----	----
24.Button Quail	1.69	75.5	0.66
25.Long-crested Eagle	1.13	1860. 0	10.92
26.Marsh Sandpiper	0.94	----	----
27.Olive Thrush	3.29	56.0	0.96
28.Paradise Flycatcher	0.23	14.4	0.02
29.Pied Crow	9.24	----	----
30. Pied Wheatear	4.36	19.4	0.44

Table 5 (Contd.)

31.Pin-tailed Whydah	2.35	----	---
32.Purple Indigobird	0.24	----	----
33.Red Bishop	1.44	----	----
34.Red-breasted Wheatear	0.29	----	----
35.Red-capped Lark	2.34	----	----
36.Slender-billed Chestnut-wing Starling	1.99	----	----
37.Speckled Mousebird	2.17	45.6	0.51
38.Streaky Seed-eater	2.92	20.8	0.32
39.Streaky headed seed-eater	0.04	20.1	0.01
40.Swainson's Sparrow	3.56	----	----
41.Swift/Swallows	15.83	----	----
42.Tawny Eagle	0.68	2398.0	8.46
43.Tawny-flanked Prinia	1.47	11.7	0.09
44.Tacazze Sunbird	0.61	13.8	0.04
45.Vultures	7.00	2897.5	105.64
46.White-fronted Sand Plover	7.65	----	----
47.White-winged Cliff chat	1.73	----	----
48.Winding Cisticola	20.49	----	----
49.Yellow Wagtail	2.21	16.4	0.19
50.Yellow-bellied Eremomela	1.85	----	----
51.Yellow-billed Duck	1.15	----	----
52.Yellow-crowned Canary	11.05	12.6	0.73
53.Yellow-shouldered Widow bird	19.40	----	----

The community assemblage of bird population at Bole consists of collection of populations of different densities that require similar environmental condition. The low deviation from the estimated and maximum expected diversity could imply that the environment is in a more or less complex condition. According to Krebs (1995), the more heterogenous and complex the physical environment, the more complex are the plants and animal community, and the higher is the species diversity. The Spatial heterogeneity implies the presence of more habitats. Krebs (1995) has also suggested that the vegetation structure seems to be more important to birds in determining their diversity. Bole Airport and its vicinity, therefore, have a number of habitats per unit area available to support such diverse bird species. Since most of the birds registered at Bole have lower biomass, they depend on the lower trophic levels, mainly on the vegetation. The relatively low level of disturbance may also have contributed to the high species diversity. In this case, Bole International Airport, being a highly secured area, gets less interference compared to other places elsewhere in the city. Moreover, the limited human activity inside and outside the airport has become favourable enough to supply the food, water and shelter requirements of various bird species.

3.2 Incidents of Bird Strikes

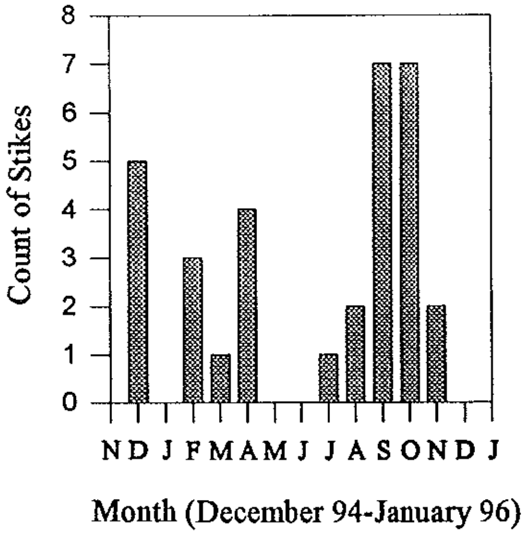
Bird strike incidents reported during the study period are given in Table 6 . Figure 13 and 14 summarize bird strike incidences in month, time of the day, type of bird and the average number of flights (arrivals and departure). A total of 80 birds were found dead in 36 strikes observed. Fifteen species of birds were involved in these strikes of which a single nocturnal owl (Verreaux's Eagle-owl) was also engaged. Pigeons, Black Kites and European Bee-eaters caused 31, 20 and 17% respectively of all the strikes registered in the study period.

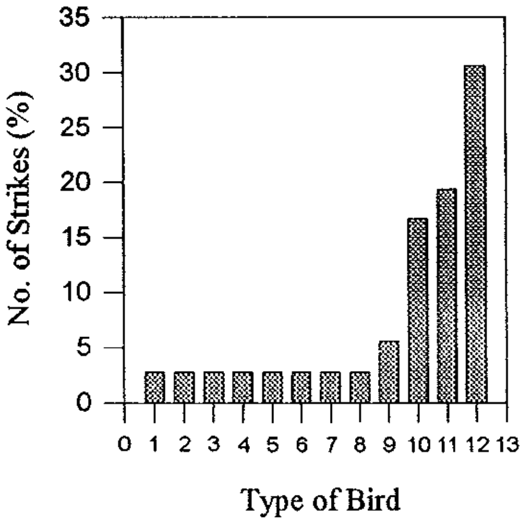
September and October were the months in which the aviation had a high number of strikes. A total of 44 birds were struck in September and October. The migratory European Bee-Eaters accounted for 42% of the strikes in each of these two months. Pigeons were responsible for 29% of the strikes in September and 42% of the strikes in October. Pigeons were involved in 60% of the strikes in December (1994) and 100% of the strikes in November. In May and June the number of strikes were much lower than the rest of the months. These months could be considered as the safest months as far as strike is concerned.

Next to Pigeons, Black Kites were the species causing the highest number of strikes. It is important to remark that the larger the size of the flock, the greater is the risk associated with it. In this respect, Swifts and Swallows should also be considered hazardous mainly because they flock in very high numbers.

Table 6. Bird Strike Records from December 1994 to January 1996 at Bole Airport.

Date	Time	Species	Count	Gut Analysis
12/07/94	1400 hr	Marsh Sandpiper	1	–
12/07/94	0700 hr	Button Quail	1	–
12/09/94	0830 hr	Speckled Pigeon	1	–
12/19/94	0930 hr	Red-eyed Dove	1	Empty
12/23/94	1600 hr	Speckled Pigeon	1	Wheat
02/03/95	0800 hr	White-collared Pigeon	1	Empty
02/11/95	1000 hr	Egyptian Goose	1	–
02/13/95	1100 hr	Black Kite	1	Empty
03/15/95	1100 hr	Black Kite	1	Empty
04/08/95	1200 hr	Black Kite	2	Empty
04/10/95	1200 hr	Black Kite	1	Empty
04/13/95	–	Black Kite	2	Empty
07/17/95	1200 hr	Yellow-shouldered Widowbird	1	Empty
\08/16/95	1300 hr	European Bee-eater	1	Empty
08/24/95	--	*Bat (Mammal)*	*1*	--
09/06/95	0900 hr	Yellow-shouldered Widow bird	1	–
09/15/95	0700 hr	White-collared Pigeon	1	–
09/25/95	0700 hr	White-collared Pigeon	1	–
09/26/95	1000 hr	European Bee-eater	26	–
09/27/95	0700 hr	Lesser Flamingo	1	–
09/27/95	1000 hr	European Bee-eater	16	–
09/29/95	0900 hr	European Bee-eater	3	Empty
10/04/95	0800 hr	Speckled Pigeon	1	–
10/04/95	0900 hr	European Bee-eater	1	–
10/10/95	0900 hr	European Bee-eater	1	–
10/14/95	1000 hr	Swallow	1	Empty
10/18/95	0900 hr	Red-eyed Dove	1	Empty
10/22/95	1600 hr	Red-eyed Dove	1	Wheat
10/22/95	1600 hr	Swift	1	-
10/22/95	1520 hr	White-backed Vulture (Out side the airport)	1	
11/05/95	0900 hr	Speckled Pigeon	1	Empty
11/08/95	1200 hr	Speckled Pigeon	1	Wheat
12/20/95	1800 hr	Black-shouldered Kite	1	Empty
01/02/96	1200 hr	Black Kite	1	–
01/02/96	–	Verreaux's Eagle-owl	1	–





LEGEND

1 - Swift
2 - Swallow
3 - Button Quail
4 - Lesser Flamingo
5 - Verreaus's Eagle-owl
6 - Black shouldered Kite
7 - White-fronted Sand-plover
8 - Egyptian Geese
9 - Yellow-shouldered Widow bird
10 - European Bee-eaters
11 - Black Kite
12 - Pigeons

Fig. 13 Bird Strike Incidents in Month and Type of Bird

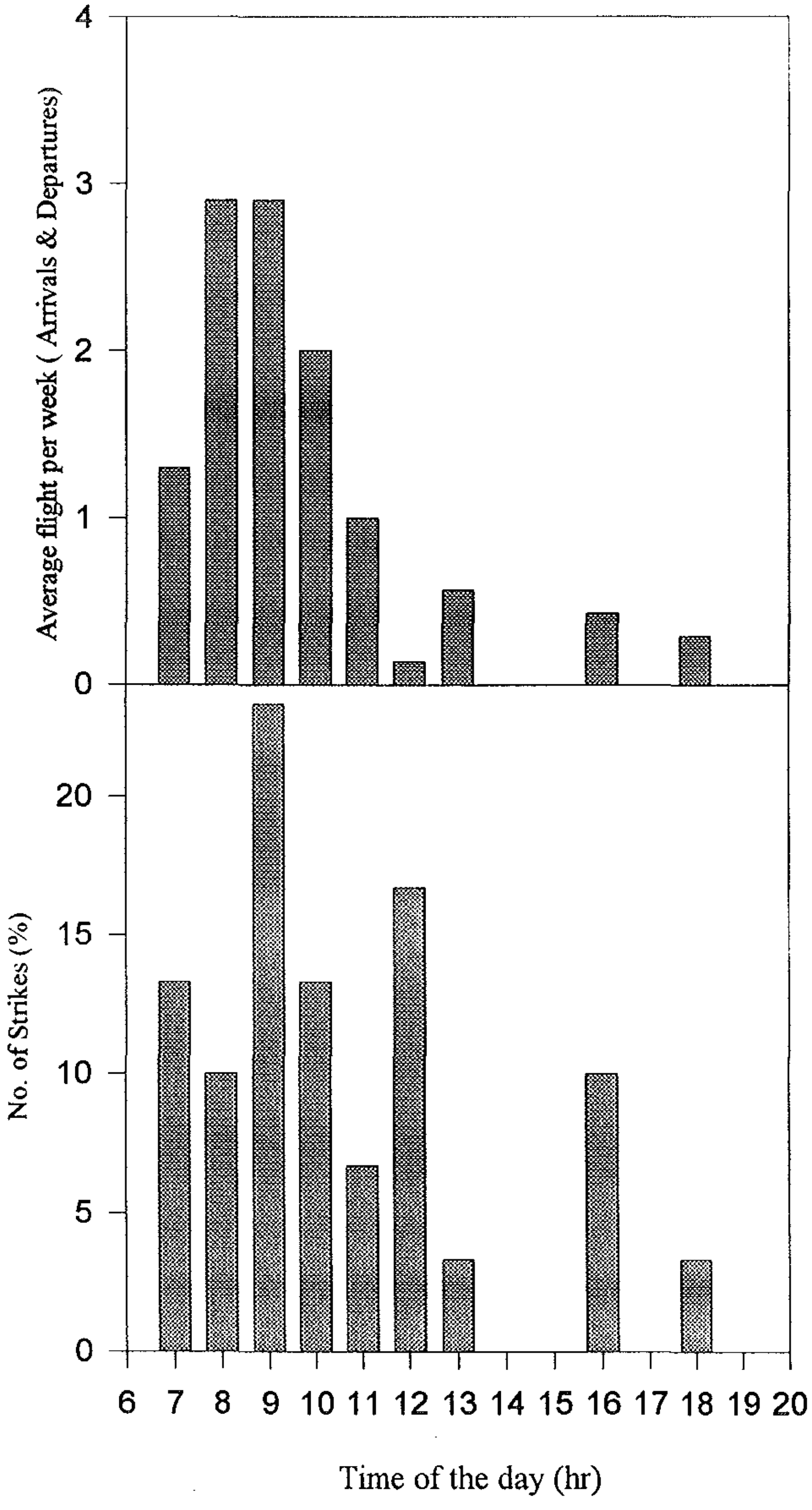


Fig. 14 Bird Strike Incidences and Flight Schedules

The analysis on bird strike incidents of this particular study corresponds with the regional data analysis given by Thorpe (1994 c) in appendix 1. Appendix 1, shows that December was the worst and May was the best month as far as safe aviation in Africa is considered. He also showed Swallows to be the worst species and Black Kites to cause most of the aircraft damages. However, it is important to note that incidence of bird strike varies with weather conditions and air traffic.

Most of the bird strikes occur in the early mornings and late afternoons. Seventeen per cent of the strikes occurred before noon. Sixty per cent of the strikes in the afternoon and 36% of the strikes in the mornings were due to Pigeons. Seventy-five of the strikes at noon were caused by Black Kites. There seems to be a clear association between the time of strike and behavior of the birds.

Pigeons cross the runway in the early mornings and late afternoons. Black Kites and other birds of prey soar in the sky for a while and rest standing on the runway until the air gets warm enough, mostly until 1000 hr. Gwahaba, (1985 a and b) also indicated that the highest incidents of strikes on Entebbe Airport, Uganda occurred in the early mornings and late afternoons. The time between 1300 and 1600 hrs seems to be relatively safer for aviation traffic in the airport. This may be due to the less traffic density and low bird activity at these hours of the day. As a result of the inadequate attention given by the Ethiopian Airlines and Civil Aviation Authority to bird strike data collection and handling using the ICAO data sheet, it was difficult to reinforce the bird strike data by other information such as cost incurred and damages inflicted.

In most cases, only feathers were used to identify the birds after the accident. In other cases, particularly with the Black Kites, the whole body of the birds was sucked and ingested by the aircraft engines. Such incidents were recorded from personal observations. Fifty four percent of the birds struck by aircraft were rendered useless for conducting gut content analysis. In those cases where gut analysis was possible, the birds were found to be struck either by the wing, nose, propellers of the aircraft or the birds were killed by the blast only. In 78% of the gut analysis carried out, the crop was found empty. This was because most of the strikes (70%) were observed during early mornings, before the birds had fed. Wheat was found in all the analysis made on Pigeons struck in the afternoons.The incidents occurred while the birds were crossing from southeast to their roosting areas in the northwest. This indicates that the pigeons feed on wheat from farmlands elsewhere southeast of the airport.

Nocturnal animals such as owl and bat were also involved in strikes. Though it is known that owls feed on small mammals, reptiles and amphibians, in a few observations made in the evenings, were observed feeding on insects swarming around the Instrumental Landing System (ILS) lights in the runway. Interestingly, very infrequent birds such as Flamingos and Gulls, not recorded by the bird count techniques were also involved in the strike. The birds simply happened to traverse the airport at that particular time. These birds were less adapted to the movement and the noise from the aircraft than those that frequently appear in the airport. Mammals such as bats and dogs were also reported to cause strikes.

3.3 Vegetation, Insects and Other Invertebrates

A total of 41 species of grasses and herbs were collected from the airport and their identity determined (Table 7). The herbaceous plants have been good sources of food and shelter to the birds at Bole International Airport. Most of the Resident Passerines were observed feeding on the seeds of *Scleria clathrata* and *Scleria hispidior*. The vegetation also supported various insects, invertebrates and vertebrates. The flowering plants also attracted a number of insects which in turn attracted birds.

Moreover, 15 arboreal plant species have been recorded inside and around the airport environment (Table 8). The arboreal plant species are found around the vicinity of the airport and not around the runway. These include the ornamental trees as well. These plant species have been favourable sites of perching and nesting for various birds. Flowers of these plants such as the *Jacaranda mimosifolia* also attracted some nectivores birds like the Tacazze Sunbird.

An assemblage of insects such as Termites, Grasshoppers, (Order Acrididae and Tettigonuiidae), Butterflies, Bees and wasps (Order Lepidoptera) and ants were recorded from the airport environment.

The insects, mainly grasshoppers were observed jumping out from the short vegetation of the airport fields. Termites were seen flying out of their mounds usually following the rain.

Butterflies, beetles and wasps were actively flying throughout the study period. The Butterflies were seen resting on the runway. There was a high population of bees in September and October when the vegetation in the field flowered. Caterpillars, earthworms and molluscs crawled out of the vegetation into the runway particularly during the wet season. Molluscs find the ditches in the airport fields and cable holes at the edge of the runway to be suitable breeding and feeding grounds. The high diversity of these invertebrates would undoubtedly attract different species of birds.

Table 7. List of Herbaceous Plant Species from Bole Airport.

Achenomene abyssinica	*Fimbristylis complanata*
Achyranthus aspera	*Guizota scabra*
Alchemilla gracilis	*Harpachne schimperi*
Andropogon abyssinicus	*Hyparrhenia rufa*
Aristida adovensis	*Hyparrhenia hirta*
Astragalus atropilosus	*Kyllinga appendiculata*
Bidens macroptera	*Lotus corniculatus*
Bidens prestinaria	*Medicago polymorpha*
Bothriochloa insculpta	*Meliolotus saveolens*
Brachiaria semiundulata	*Pennisetum sphacelatum*
Carduus chamaecephalus	*Pennisetum vilosum*
Cenchrus ciliaris	*Pennisetum glabrum*
Cyanotis barbata	*Physalis peruviana*
Cynodon dactylon	*Scleria inclinatus*
Cyperus rigidifolius	*Scleria clathrata*
Digitaria velutina	*Snowdenia polystachya*
Echinops pappii	*Sporobulus africanus*
Eleusine floccifolia	*Sporobulus discosporus*
Eragrostis tenuifolia	*Tagetes minuta*
Eragrostis botroydes	*Typha angustifolia*
Eriochloa nubica	

Table 8. List of Arboreal Plant Species from Bole Airport.

Acacia saligna	*Jacaranda mimosifolia*
Acacia abyssinica	*Juniperus procera*
Acacia nigrii	*Nerium oleander*
Acacia melanoxylon	*Phoenix reclinata*
Causuarina equisetifolia	*Pinus patula*
Cupressus lucitanica	*Podocarpus gracilior*
Eucalyptus globulus	*Spathodea campanulata*
Grevillea robusta	

3.4 Herpetiles and Mammals

The Amphibians collected during the study period include True Frogs and Toads of the Family Ranidae and Bufonidae, respectively. Ditches in the airport fields and cable holes at the edge of the runway retain water in the rainy seasons. This has created a good habitat for amphibians and a variety of animals which would attract a number of predators including birds.

Snakes have been encountered twice through the study period. The snakes were determined as *Pseudoboodon irregularis.* Both belong to the aglyphous species of the Family Colubridae, which are totally harmless. Moreover, a number of lizards have been observed in the airport field. The Snakes and lizards were also seen inside cable holes at the edge of the runway and the ditches along the ring road.

A total of four species of small mammals has been captured. These are the *Praomys albipes, Arvicanthis abyssinicus*, *Mus mahomet* and *Crocidura* sp. In addition, larger mammals like Hare (*Lepus starcki*), Spotted Hyena *(Crocuta crocuta),* Serval (*Felis serval)* Genet (*Genetta* sp.) and Mongoose (*Ichneumia* sp.) were observed. The presence of Porcupine (*Hystrix* sp.) was also traced by the shed off quills and piles of droppings.

These animals stayed in the grassland vegetation of the field. The grassland in addition to being a source of food it is also used as an effective shelter from predators. In few occasions, some birds of prey were observed to pick up these small mammals. Most of the larger mammals found in the airport were seen crossing the runway. There were a few occasions in which evening flights were delayed due to flocks of hyenas on the runway. There were also occasions in which other large mammals were struck by aircraft while crossing the runway. This has again attracted number of scavengers including dogs and cats to the runway creating a chain of reactions which again caused a hazardous situation to aircraft traffic.

IV. SUMMARY AND RECOMMENDATION

The Addis Ababa Bole International Airport supports a diverse avian community. The birds of the Bole Airport range from small sized Passerines to large sized birds of prey. The airport has a number of features that attract birds. The area supplies the avian populations with security from predators and disturbance by humans. It has favorable places to nest and loaf and a good access to food and water resources. These and other factors attracted large numbers of diverse species of birds to visit the area at different instants and to use the airspace as a transient route.

Most of the birds registered from Bole visit the airport infrequently. A few bird species are Resident while a few others pass across the airport airspace frequently in a regular time of a day.

Birds at the Bole Airport are attracted by the vegetation, invertebrates, vertebrates and other food and water resources in and around the airport. The availabilities of food and shelter in the vicinity of the airport compound attract the transient birds to pass across the runway.

The data of the bird species show that there is very little fluctuation in number and species type. Estimation of the biomass has been more informative than simple population count. The birds from the airport showed high diversity and low density. The assemblages of the different bird species at Bole are observed to depend on similar environmental conditions. Results of the diversity index suggest that the airport is complex and heterogenous in having number of different habitats. The vegetation structure has been found to be more important in determining the diversity of the bird population.

High species richness was observed on the months when there was a huge mass of garbage dumps, swarms of insects, vegetation with ripened seeds and flowers and a good supply of water. The species richness decreased when the migratory birds left the airport. Rainfall played the major role in determining the species richness.

Pigeons and Black Kites were responsible for most of the strikes. The time from 0800 to 1200 hr and from 1600 to 1800 hr was the worst concerning air traffic. This was because most of the transient birds cross the runway early mornings and late afternoons. In addition, the air traffic operation is relatively heavy in the morning. September, October and April were the worst months for aviation. A few strikes were reported in May and June. The most prevalent bird strikes occurred when the abundant insect food (mainly grasshoppers and termite larvae) was available and when the crops in the farm outside the airport fields were harvested.

Resident and Frequent Regular birds have a high chance of colliding with aircrafts. Nevertheless, incidents from infrequent visitors and infrequent transient are not negligible. However, ecological measures of controlling bird strikes should concentrate on birds that frequently visit or pass across the airport. The frequent birds have defined reasons to appear in and around the airport frequently.

Modification of the airport environment with the aim of removing the features that attract birds is vital. When such environmental measures are fully implemented, the airport and its surrounding will have little attraction to birds. Under such conditions, there will be very few birds on and around the airport. Bird hazards to aircrafts will be correspondingly reduced to insignificant level by all standards. Ecological studies, therefore offer the best available option for reducing bird hazards on the airport. Scaring birds should be practiced as a temporary prevention technique. Environmental management based on a detailed ecological survey has to be used as the basic remedy for the bird strike problem. Based on this preliminary ecological investigation of the bird strike problem at Bole, the following recommendations are forwarded.

- Garbage and refuse dumps found at and in the vicinity of the airport have attracted birds which are potential hazards to aircrafts. It is important to note the location of the refuse dumps in relation to aircraft movements, the type of refuse and the type of bird expected in the vicinity of the dumps. Prompt clean up of garbage dumps as soon as they are dumped and use of proper garbage disposal system should be realized. Garbage barrels should never be left open.

- Insects such as grasshoppers, beetles and other larvae that jump out to the runway following a spell of rain should be controlled by spraying at suitable intervals. Advice can be obtained from an agricultural specialist on the insecticide to be used, dosage and safety precautions.

- Often the seeds that attract birds to an airport are those of the farm crops inside and around the airport. Regardless of the crop farmed, it should be noted that plowing and cultivation of the soil exposes worms and insects which will attract birds. It is desirable that crop farming inside the airport should be prohibited. It makes little sense to restrict agriculture in the airport when, on the other side of the fence, land is being farmed. However, it should be noted that, due to the flight distance and the continuous noise and movement of airport operation, the birds are in a regular disturbance. Their flight movements when frightened are unpredictable. In the surrounding areas, however, birds may feed in a relatively undisturbed condition.

- The existence of agricultural land in the surroundings of airports is observed in many countries. During harvest however, flight operations in these airports are endangered. Cultivation of crops and other agricultural activities such as bee keeping and livestock grazing on plots close to an airport should be avoided as much as possible. Farmlands close to the airport attract large number of birds of the same species such as Pigeons and Doves and increase flight safety risks. However, considering the fact that agriculture is the major engagement of the population, it may not be practical to stop farming activities around airports in Ethiopia. Personnel of the airport operations and pilots should be made aware of the bird activity calender so that relevant preventive and avoidance techniques could be suggested.

- Grass should be cut to a height sufficient to inconvenience the birds which would otherwise aggregate. Short grass discourages the presence of small mammals and other animals which are food for both diurnal and nocturnal birds of prey. If grasses are permitted to grow to full height, seeds will develop and these will attract seed-eating birds. Keeping the grass short sounds safe and seems the best available method. A serious disadvantage of short grass is that it exposes earthworms, insects, other invertebrates and vertebrates. These will in turn attract birds.

It has been proven that most bird species involved in bird strikes prefer short grass, only some small species frequent long grass (Hild, 1985 b). From this it is possible to conclude that long grass, because of the relatively light weight species that it attracts, is less of a risk to flight operations than short grass with its "heavy weight species" it supports. On the other hand, long grass is a risk for fire accidents around airports. Many birds like to be able to see all around them and to visit others of their kind. Therefore, they prefer short cut grasses.

If the vegetation is cut short, worms and insects will be exposed. It will produce seeds if it is allowed to grow to maturity. Rodents and other mammals will be harbored in it and birds of various types will be attracted. It may not be an easy task to keep the grass at optimal height permanently. However, Hild (1980) and ICAO (1991 a) recommend maintaining the grass height at 15-25 cm. The height of the grass should be determined only through studies of the growth fluctuations and periodicities of the area and the vertebrate and invertebrate fauna found in it. Removal of the biomass should be made soon after the mowing is made effective.

- Trees provide food, protection and nesting sites for birds and they also serve as lookout perches for predator birds. Trees should be cut out from the vicinity of the runway and taxiway. Decorative trees and shrubs planted around the airport produce seeds, flowers and berries that are attractive to birds. Trees should be removed from the airport environment.

- Ditches should be drained or filled with solid materials. They should be cleared at regular intervals and graded in such a way that the water will runoff as rapidly as possible. Grasses and other vegetation should be cut on the sloping banks. Where practicable, the situation can be greatly improved by replacing the ditches with buried drained pipes. Even quite small depressions in the ground collect appreciable amounts of water during rain seasons. These should be filled in with solid materials. Open cable holes around the edge of the runway and taxiway should be plugged.

- Small mammals and Herpetiles attract birds of prey. The larger mammals are not likely to be attractive to birds of prey. However, some birds of prey follow scavenging mammals to locate their prey. Moreover, the offsprings of larger mammals are eagerly sought by predators. There have also been instances when a mammal such as a dog has been struck by a jet. The only safe procedure is to remove harboring areas such as tall grasses, sedges and water logged areas which encourage the presence of Small mammals and Herpetiles. Reinforcement of the fence surrounding the airport will protect the intruding of wild and domestic animals from the premises of the airport.

- Open field slaughtering of cattle along the airfields should be avoided, and proper care has to be taken on all the leftovers. Abandoned crushed planes in the airport, possible perching and posting sites (including electric wires and telegraphic poles) should be removed from the vicinity of the airport. Electric wires can be made to pass through the ground. Covering the ceiling of the hangar with wire mesh and to scare those birds that come to roost will reduce the number of birds that roost in the hangar. Cafeterias near and around the apron should be moved to another suitable place or strict regulations should be imposed to maintain the cleanliness of the cafeterias and the apron.

- The bird scaring practices using bird scaring personnel can be made more effective by altering the number of the personnel and the location of their standing point depending on the season, abundance and behavior of the birds. Motivation, guidelines, orientation and a rewarding payment could help a lot in managing the personnel.

- Removal of open garbage dumps and slaughter houses in the city and the surrounding will prevent serious bird strike problems. ICAO (1991 b) recommends not to put huge garbage disposal dumps and abattoirs within 13 Km of the airport reference point. Deposits in critical airport zones should not be tolerated. Therefore, the Ethiopian Civil Aviation Authority should take the necessary initiatives to negotiate with the regional government for the removal of garbage deposits and slaughter houses in the city to another suitable place.

- Integrated bird strike protection measures should be considered in the future plan of expanding the existing airport. The bird scaring technique should be supported by environmental measures of combating the problem. Therefore, ecological knowledge of bird strike threats should be taken into consideration. Public awareness on bird strike problem has to be raised. The Ethiopian Civil Aviation Authority has to give the necessary education to people living in and around the airport regarding the bird strike problem and the roles the people can play in reducing the problem. These include the use of proper garbage disposal systems. The issue has to come out from the runway to the city.

Even if it is possible to realize all the changes recommended, it will not ensure that the area will be permanently free of birds. Grasses continue to grow, trees and bushes sprout from the roots, drainage ditches clog up and new garbage dumps are established. The battle should be a continuous one. There is a need of issuance of directives for bird strike preventions based up on national needs. The Ethiopian Airlines should report detailed bird strike statistics as well as incidents without damage (naming the bird species) and establish worldwide exchange of this report. Close cooperation should be established between the Civil Aviation Authority, the Ethiopian Airlines and environmental protection authorities. The airport should establish ecologically based lists of biotic and abiotic data as the basis for prevention programs.

Establishment of a national committee for prevention of bird strike which would perform specialized tasks rather than acting as a management organization is desirable. The airport will need a full-time biologist since the ecological setup of this international airport will become complex and multi-layered with the forthcoming expansion of the airport. It is, however, a fundamental biological knowledge that nature does not react mechanically like a simple machine. Its reactions may take much longer. Expecting quick solutions will frustrate efforts to bring about a long lasting effects. Detailed ecological surveys therefore have to continue so that earlier findings could be verified and new observations could be recorded. Integrated bird strike protection measures should be implemented as much as possible.

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Appendix 1. Statistical Data on ICAO Bird Strike Information System (IBIS)
Summary of Bird Strike By Region for the years 1984 to 1988.

SS - No. of significant strikes
TS - No. of total strikes
SR - No. of States reporting
SO - No. States of occurrences

Region	Year	1984				1985				1986				1987				1988			
	No. of States	SS	TS	SR	SO	SS	TS	SR	SO	SS	TS	SR	SO	SS	TS	SR	SO	SS	TS	SR	SO
1. AFI	33	17	202 (5.3%)	4	30	19	159 (3/9%)	5	28	17	162 (3.6%)	9	31	24	214 (4.2%)	10	34	22	191 (3.6%)	7	30
2. ASIA	26	59	1 033 (27.9%)	11	17	53	920 (22.7%)	9	18	39	1 016 (22.8%)	10	16	34	985 (19.7%)	8	18	39	809 (15.4%)	7	16
3. CAR	21	0	9 (0.2%)	0	4	2	10 (0.3%)	1	7	2	15 (0.3%)	1	8	0	17 (0.3%)	1	7	1	15 (0.3%)	2	7
4. EUR	30	148	1 953 (51.5%)	17	26	127	1 665 (41.2%)	17	27	94	1 755 (39.5%)	21	28	102	2 193 (43.4%)	18	28	135	2 333 (44.5%)	16	28
5. MID	15	7	40 (0.5%)	4	9	6	42 (1.0%)	6	8	7	70 (1.6%)	7	12	6	55 (1.1%)	6	12	6	56 (1.1%)	4	11
6. NAM	2	27	507 (11.9%)	1	2	65	1 192 (29.5%)	2	2	56	1 377 (31.0%)	2	2	45	1 515 (29.9%)	2	2	15	1 748 (33.3%)	2	2
7. NAT	1	3	7 (0.2%)	1	2	0	8 (0.2%)	1	2	0	4 (0.1%)	1	1	0	14 (0.3%)	1	1	2	4 (0.1%)	1	1
8. PAC	8	1	19 (0.5%)	1	3	1	12 (0.3%)	2	4	3	17 (0.4%)	3	4	0	11 (0.2%)	1	3	5	18 (0.3%)	1	3
9. SAM	8	2	8 (0.2%)	1	3	4	12 (0.3%)	2	4	1	8 (0.2%)	2	5	0	12 (0.2%)	3	4	11	40 (0.8%)	3	5
Unknown			45 (1.8%)				25 (0.6%)			2	24 (0.5%)			4	33 (0.7%)			1	30 (0.6%)		
TOTAL	164	265	3 823 (100%)	40	96	278	4 045 (100%)	45	100	221	4 448 (100%)	56	107	215	5 059 (100%)	50	111	235	5 244 (100%)	43	103

Note: Significant strikes are those which resulted in substantial damage to aircraft, aborted take-off, precautionary landing, etc.

Appendix 2. Statistical Data on ICAO Bird Strike Information System (IBIS) Summary of Bird Strike By Region for the years 1989 to 1993.

SS - No. of significant strikes
TS - No. of total strikes
SR - No. of States reporting
SO - No. States of occurrences

Region	Year	1989				1990				1991				1992				1993			
	No. of States	SS	TS	SR	SO	SS	TS	SR	SO	SS	TS	SR	SO	SS	TS	SR	SO	SS	TS	SR	SO
1. AFI	47	31	210 (4.4%)	10	33	18	159 (3.1%)	9	33	19	198 (3.8%)	7	27	12	120 (2.1%)	6	26	9	159 (4.6%)	5	33
2. ASIA	25	38	962 (20.1%)	8	14	28	810 (15.9%)	8	20	45	1 320 (25.3%)	10	19	28	939 (16.8%)	6	15	18	873 (25.5%)	7	16
3. CAR	18	3	25 (0.5%)	3	8	6	31 (0.6%)	3	7	5	24 (0.5%)	2	6	2	12 (0.2%)	2	7	1	36 (1.0%)	2	4
4. EUR	50	142	2 219 (46.5%)	14	27	119	2 161 (42.5%)	17	28	99	1 873 (36.0%)	14	27	95	1 978 (35.4%)	17	32	60	1 565 (45.7%)	18	34
5. MID	19	9	45 (0.9%)	5	9	8	50 (1.0%)	5	10	14	57 (1.1%)	6	8	8	57 (1.0%)	4	8	5	33 (1.0%)	3	7
6. NAM	2	12	1 230 (25.8%)	1	2	16	1 659 (32.7%)	1	2	3	1 580 (30.3%)	2	2	38	2 289 (41.0%)	2	2	5	478 (13.9%)	1	2
7. NAT	1	–	4 (0.1%)	1	1	1	5 (0.1%)	1	1	–	–	–	–	–	1 (0.0%)	1	1	0	3 (0.1%)	1	1
8. PAC	8	1	11 (0.2%)	1	6	–	7 (0.1%)	1	1	4	15 (0.3%)	1	2	–	2 (0.1%)	1	2	1	12 (0.3%)	2	2
9. SAM	13	2	26 (0.5%)	2	4	3	53 (1.1%)	4	6	1	19 (0.4%)	2	3	1	22 (0.4%)	1	4	1	98 (2.9%)	2	4
Unknown	–	5	47 (1.0%)	–	–	3	148 (2.9%)	–	–	1	118 (2.3%)	–	–	1	166 (3.0%)	–	–	–	170 (5.0%)	–	–
TOTAL	183	243	4 777 (100%)	45	104	202	5 083 (100%)	49	108	191	5 204 (100%)	44	94	186	5 586 (100 %)	40	97	100	3 427 (100 %)	41	105

Note. – Significant strikes are those which resulted in substantial damage to aircraft, aborted take-off, precautionary landing, etc.

Appendix 3. Analysis of a different sample sized data by regions between the years 1986 to 1990

(From Thorpe, 1994 a & b).

	Africa	Asia / Pacific	Caribbean / S. America	Middle East	Europe	North America
No. of strikes	887	4131	204	217	9980	6922
% Birds identified	26	40	35	26	40	47
Worst Species	Swallows	Gulls	Vulture	Kites	Gulls	Gulls
2nd worst species	Birds of prey	Kites	Gulls	-	Swifts / Swallow	Sparrow
Birds causing damage	Black Kite	Kites	Gulls	Kites	Gulls	Gulls
% below 101 ft	72	67	59	65	4	53
% above 250 ft	5.5	6.2	8	13	7	12
% at night	34	14	16	29	14	26
% single bird	77	80	59	79	77	73
Worst Month	December	April May	November December	October November	June October	August October
Best Month	June	July	January	December	February	February
Engines damaged	99	170	26	32	695	288
Aircraft destroyed	1	1	1	-	-	-

Appendix 4. Analysis of Bird Strikes in Ethiopia Between the Years 1982 -1993.

(From Records of the Civil Aviation Authority).

No. of Strikes	105
% Bird species identified	47%
Birds causing damage	Vulture / Pigeons
% at take off	64%
% single birds	38%
Worst months	March / April September / October
Best months	May to August
Engines damaged	75
% Ethiopian Aircraft involved	87%
% At Bole Airport	60%

Appendix 5a. Average Abundance of Birds from Bole Airport.

Time (15 days)

Sp. Type	1	2	3	4	5	6	7	8	9	10	11	12	13
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	2.0	2.0	.0	1.0	1.0	.0	1.0	.0	2.0	2.0	.0	.0	.0
3	1.5	2.0	3.2	3.0	2.0	3.0	2.7	4.0	2.0	4.0	2.7	2.0	3.0
4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.0	.0
5	2.0	1.3	.0	2.0	1.7	2.0	.0	1.5	1.0	.0	.0	.0	.0
6	3.3	1.5	1.7	1.5	2.0	1.7	2.0	2.0	1.8	2.3	1.3	1.5	1.5
7	11.4	10.5	7.8	10.1	5.3	3.5	4.3	5.8	8.0	5.2	5.2	4.8	5.7
8	3.6	10.3	8.8	8.0	16.0	11.5	.0	.0	.0	.0	.0	.0	.0
9	49.3	43.8	18.8	22.3	6.0	6.3	14.5	13.8	31.8	33.7	2.6	5.6	5.0
10	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	2.0	2.0	2.0
11	2.7	2.0	2.7	2.5	2.0	2.5	2.0	2.0	.0	.0	2.4	2.0	3.0
12	7.0	7.1	2.7	2.5	3.7	3.2	2.6	4.5	2.0	2.3	1.3	1.7	1.0
13	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
14	30.0	55.6	30.9	23.9	9.6	12.0	12.0	11.9	14.1	7.3	14.6	15.4	7.0
15	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
16	4.8	2.4	4.6	2.8	3.1	4.8	3.1	5.4	4.8	4.0	4.5	5.0	4.5
17	2.0	.0	3.0	.0	6.0	.0	.0	.0	8.4	2.0	.0	.0	.0
18	1.7	1.7	1.0	1.0	1.3	1.3	2.0	1.0	1.0	2.0	1.0	.0	2.0
19	4.8	5.0	3.0	2.0	1.5	2.0	1.8	2.5	1.2	1.0	1.3	1.5	1.0
20	41.2	24.3	10.7	12.9	7.5	8.0	14.3	13.8	19.3	10.3	4.6	10.8	10.5
21	.0	.0	.0	5.0	7.5	6.5	8.7	9.0	11.8	8.3	12.0	6.7	4.0
22	.0	.0	.0	.0	.0	.0	1.5	.0	1.5	.0	3.0	2.3	1.7
23	2.0	2.0	.0	.0	2.7	2.0	.0	.0	2.5	2.0	.0	.0	.0
24	.0	.0	.0	.0	.0	.0	.0	.0	32.0	26.4	.0	.0	.0
25	9.6	7.5	5.1	4.8	4.7	3.8	4.0	4.6	5.4	6.0	4.1	3.0	5.3
26	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
27	3.0	2.0	2.0	3.3	2.0	2.0	9.5	.0	2.0	.0	2.0	.0	1.7
28	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
29	.0	2.0	2.0	.0	2.7	2.0	3.0	2.3	1.7	4.0	2.0	1.5	1.5
30	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
31	1.9	1.9	1.5	1.0	1.0	1.0	1.5	2.0	2.0	1.0	2.0	1.5	2.0
32	.0	.0	.0	.0	3.0	.0	.0	.0	.0	.0	.0	.0	.0
33	2.0	2.0	2.8	3.5	4.0	4.0	2.7	3.3	2.0	2.5	4.0	4.0	2.9
34	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	2.0	2.0	2.0
35	20.3	19.4	11.4	6.7	7.3	9.3	8.0	6.1	8.4	8.0	4.8	5.8	4.6
36	9.8	7.7	5.6	5.2	6.5	3.7	3.9	3.9	3.5	4.3	4.3	4.7	2.5
37	1072.1	1181.0	949.5	845.3	915.4	843.5	822.3	823.9	865.0	796.8	833.8	846.0	945.5
38	.0	.0	.0	.0	1.0	1.7	2.0	.0	2.0	1.0	1.3	1.8	3.2
39	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
40	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
41	2.0	2.0	3.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
42	4.7	4.3	3.0	3.2	3.4	3.0	3.0	3.0	5.0	.0	2.5	3.6	2.6
43	6.5	5.8	7.6	7.6	8.6	9.7	5.8	4.5	3.4	3.8	2.0	2.7	5.3
44	2.0	2.0	2.0	2.0	2.0	2.7	2.0	2.0	2.0	2.7	1.7	2.0	2.0
45	.0	.0	.0	2.0	2.0	4.0	.0	.0	4.0	4.0	2.0	3.3	.0
46	3.3	2.0	2.8	4.0	5.3	7.5	2.0	3.0	3.3	4.0	2.7	2.0	2.0
47	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
48	3.3	4.7	6.0	6.7	6.0	2.5	4.0	3.0	6.0	3.0	3.1	2.7	2.7
49	23.1	12.4	8.6	8.8	24.7	4.0	6.5	13.0	22.5	15.0	8.0	27.7	15.3
50	2.0	2.4	1.0	.0	.0	.0	.0	.0	1.7	1.0	.0	.0	.0
51	4.0	3.3	5.0	8.0	6.0	12.0	.0	.0	.0	.0	.0	.0	.0
52	2.0	2.0	2.0	2.0	2.0	.0	.0	.0	.0	.0	.0	.0	2.0
53	6.7	5.9	4.5	6.7	4.3	6.5	3.4	6.4	8.3	8.6	3.0	4.6	4.0
54	5.6	6.2	4.9	9.0	4.6	4.8	3.4	3.5	3.5	4.1	8.8	12.6	9.8
55	8.3	5.1	5.4	4.0	3.8	3.8	3.9	4.1	5.0	117.6	4.6	4.3	2.4
56	4.0	2.0	2.0	2.0	2.0	.0	2.0	2.0	2.0	2.0	2.0	2.0	.0
57	33.3	17.6	13.3	14.6	14.9	15.3	18.6	15.0	18.7	18.0	20.9	25.0	26.6
58	.0	.0	.0	.0	6.7	9.0	.0	.0	.0	.0	.0	.0	.0
59	.0	.0	.0	.0	40.0	8.0	.0	.0	.0	.0	.0	.0	.0
60	.0	3.0	.0	.0	3.0	.0	.0	.0	2.0	2.0	.0	.0	.0
61	.0	.0	.0	.0	9.0	.0	.0	.0	.0	.0	.0	.0	.0
62	9.6	10.7	9.1	9.3	10.4	9.0	11.0	20.8	25.9	31.1	12.0	20.0	7.9
63	24.6	14.8	19.0	20.0	20.5	14.8	18.9	18.9	20.3	10.4	17.4	16.4	15.9

Appendix 5a (Continued)

Time (15 days)

Sp. Type	14	15	16	17	18	19	20	21	22	23	24	25	26
1	.0	.0	.0	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.8
3	3.0	2.0	2.0	2.0	4.0	2.0	.0	2.4	2.0	2.0	3.3	2.8	4.0
4	.0	2.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6	1.0	.0	1.0	1.0	.0	.0	1.0	1.3	1.3	1.0	1.6	1.1	1.8
7	6.5	17.4	14.2	6.5	2.0	4.3	3.3	3.4	2.0	3.6	7.0	5.3	8.1
8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
9	6.5	.0	.0	.0	.0	1.0	5.0	5.8	7.6	7.5	11.6	8.3	8.1
10	2.7	2.3	2.4	1.0	1.0	1.0	1.0	1.0	1.0	.0	1.3	1.0	1.5
11	3.3	.0	1.8	.0	2.0	4.0	1.7	2.0	.0	4.0	2.4	3.0	1.5
12	1.7	1.0	1.8	1.0	1.0	.0	1.0	2.8	2.0	1.8	1.5	2.6	3.6
13	.0	.0	.0	.0	.0	.0	4.0	2.0	.0	.0	.0	.0	.0
14	9.0	5.0	9.0	5.7	2.0	12.4	12.2	22.1	22.1	22.9	16.0	10.8	8.4
15	.0	.0	11.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	17.0
16	3.7	4.0	2.5	8.6	3.3	2.0	2.0	3.3	4.0	4.5	12.7	12.0	54.9
17	2.0	5.6	21.0	.0	8.0	3.0	1.0	10.9	4.6	6.0	2.5	1.0	1.0
18	1.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.0	1.0
19	4.5	1.0	1.3	.0	.0	.0	.0	1.0	.0	2.0	2.0	2.0	1.4
20	7.7	18.6	26.8	4.7	6.5	11.8	10.7	7.7	7.2	13.6	12.7	8.6	9.2
21	3.6	8.0	3.3	2.0	4.0	2.0	4.0	3.3	4.0	2.7	4.0	5.6	4.0
22	2.0	1.0	1.0	1.0	.0	.0	1.0	.0	.0	1.0	1.0	.0	.0
23	2.0	2.7	2.4	2.0	2.7	2.3	2.0	2.0	.0	.0	.0	.0	.0
24	.0	.0	.0	.0	.0	14.5	48.3	20.8	26.0	.0	.0	.0	.0
25	3.7	4.7	4.3	1.0	4.0	.0	3.0	3.0	4.3	3.3	3.5	5.6	4.3
26	.0	.0	.0	.0	.0	.0	.0	.0	.0	38.7	39.0	.0	.0
27	.0	2.0	.0	1.0	2.0	.0	.0	1.7	.0	3.3	4.0	3.0	2.0
28	.0	.0	.0	.0	.0	.0	1.0	1.0	.0	.0	.0	.0	.0
29	2.0	.0	.0	.0	2.0	.0	1.0	1.8	2.0	2.2	3.3	2.5	2.3
30	.0	.0	.0	.0	2.0	.0	.0	.0	.0	.0	.0	.0	.0
31	1.0	.0	.0	.0	.0	.0	.0	1.0	1.0	.0	2.0	2.0	2.0
32	.0	3.3	3.0	3.0	3.0	3.0	3.0	.0	.0	3.0	.0	.0	.0
33	5.3	5.5	21.5	.0	.0	3.0	.0	2.0	.0	2.0	2.5	2.0	2.0
34	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
35	5.1	7.0	25.4	13.4	16.3	4.8	7.5	6.3	4.9	6.2	12.0	8.0	3.3
36	.0	.0	.0	.0	.0	.0	1.7	2.8	1.6	9.0	9.3	12.5	10.9
37	786.9	840.3	908.0	1042.9	907.6	1007.8	849.5	736.6	803.9	507.1	684.1	1073.1	975.7
38	1.8	1.5	1.7	.0	.0	1.0	.0	.0	1.0	2.5	1.5	16.8	19.2
39	.0	3.0	1.3	.0	.0	.0	.0	.0	2.0	.0	.0	.0	.0
40	.0	7.0	.0	8.5	8.0	14.0	.0	.0	.0	.0	.0	.0	.0
41	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
42	4.4	2.3	1.3	.0	.0	.0	.0	.0	.0	2.4	4.3	2.6	2.2
43	5.0	2.5	4.0	2.7	8.0	3.0	4.0	5.0	2.9	3.3	2.7	3.2	3.5
44	3.0	.0	.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0	2.5	2.0	2.0
45	3.0	4.0	3.3	2.0	.0	4.0	2.0	2.5	4.0	2.0	3.2	3.0	2.0
46	2.0	1.8	2.0	3.0	1.0	.0	6.0	3.1	2.7	2.0	2.0	2.0	4.3
47	.0	.0	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
48	3.5	4.5	4.5	4.0	2.0	3.0	2.0	2.4	2.5	2.5	2.5	2.3	3.2
49	36.8	25.5	22.8	14.3	.0	10.0	18.0	24.0	6.8	31.8	6.0	4.7	21.3
50	.0	.0	1.0	.0	1.0	.0	.0	1.0	3.0	2.0	1.5	.0	.0
51	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
52	2.0	.0	.0	.0	.0	.0	.0	.0	2.0	.0	.0	.0	.0
53	5.0	4.3	23.5	31.0	7.0	1.0	6.3	7.1	5.5	3.3	4.3	7.0	3.8
54	2.9	2.3	7.6	2.7	6.0	4.4	6.2	4.9	3.4	12.9	31.7	36.8	39.0
55	.0	.0	.0	.0	.0	.0	.0	4.0	3.5	2.5	5.0	5.0	6.6
56	2.0	2.0	2.0	2.0	2.0	.0	.0	1.7	2.0	1.3	2.0	2.0	2.0
57	33.1	53.0	48.6	7.3	9.9	11.0	17.7	8.5	8.5	25.3	14.3	18.4	25.3
58	.0	.0	.0	.0	.0	.0	.0	.0	27.5	.0	5.5	5.0	3.7
59	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
60	2.0	4.0	3.5	1.7	2.6	2.0	1.0	3.0	.0	.0	.0	.0	.0
61	.0	.0	.0	.0	.0	3.0	.0	50.0	.0	.0	.0	.0	.0
62	5.7	5.9	14.7	4.7	6.0	8.0	6.3	4.2	4.3	4.7	6.9	16.1	13.1
63	15.4	36.4	24.7	8.8	5.7	5.8	10.3	6.0	9.0	16.7	34.3	51.0	48.3

Appendix 5b. List of Species corresponding to numbers in Figs. 8, 9; and in appendix 5a.

1.Abyssinian Longclaw
2.Red-billed Firefinch
3.African Pied Wagtail
4.Augur Buzzard
5.Baglafecht Weaver
6.Black-breasted Apalis
7. Black Kite
8.Black-bellied Bustard
9.White-vented Bulbul
10.Black-shouldered Kite
11.Black-winged Lovebird
12.Blue-eared Glossy Starling
13.Bronze Mannikin
14.Cape Rook
15. Spotted Flycatcher
16.Common Kestrel
17.Common Waxbill
18.Crimson-rumped Waxbill
19.Dusky Flycatcher
20.Egyptian Goose
21.European Bee-eater
22.Fiscal Shrike
23.Ground-scraper Thrush
24. Button Quail
25. Long-crested Eagle
26.Marsh Sandpiper
27.Olive Thrush
28. Paradise Flycatcher
29. Pied Crow
30.Pied Wheatear
31.Pin-tailed Whydah
32.Purple Indigo Bird
33.Red Bishop
34.Red-breasted Wheatear
35. Red-capped Lark
36.Slender-billed Chestnut-wing Starling
37. Speckled Mousebird
38.Streaky Seed-eater
39.Streaky-headed Seed-eater
40.Swainson's Sparrow
41.Swifts/Swallows
42.Tawny Eagle
43.Tawny-flanked Prina
44.Tacazze Sunbird
45.Vultures
46.White-fronted Sandplover
47.White-winged Cliff-chat
48.Winding Cisticola
49.Yellow Wagtail
50.Yellow-bellied Eremomela
51.Yellow-billed Duck
52.Yellow-crowned Canary
53.Yellow-shouldered Widow-bird

I, the undersigned, declared that this thesis is my work and all sources of material used for the thesis have been duly acknowldeged.

Name Elizabeth Yohannes Signature -------------------------

Place and Date of Submission

Addis Ababa University

Addis Ababa

May, 1996.