ASSESSMENT OF

MANAGEMENT STRATEGIES OF THE

BIRD HAZARDS TO AIRCRAFT IN

SELECT INDIAN AIR FORCE AIRFIELDS

A THESIS TO BE SUBMITTED TO
MANIPAL ACADEMY OF HIGHER EDUCATION

FOR FULFILLMENT OF THE REQUIREMENT FOR THE
AWARD OF THE DEGREE
OF

DOCTOR OF PHILOSOPHY
BY
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UNDER THE GUIDANCE OF

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CERTIFICATE

This is to certify that the work incorporated in this thesis “**Assessment of Management Strategies of the Bird Hazards to Aircraft inselect Indian Air Force Airfields**”submitted by **Wg Cdr Srinidhi S** was carried out under my supervision. No part of this thesis has been submitted for a degree or examination at any university. References, help and material obtained from other sources have been duly acknowledged.

Research Guide

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<u>**ABSTRACT OF THESIS**</u>

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Bird Strike to aircraft is a serious aviation safety concern. Many aircraft and lives of pilots have been lost the past due to this hazard. In addition, airlines incur huge amounts of money to repair the damages caused by the birds. They also lose financially due to delayed departures in addition to the inconvenience to the passengers. Considering these aspects, efforts are mad to mitigate the problem through various means. These mitigation measures include simple measures like scaring away of birds using crackers to high end measures such as deploying bird detection radars. Each of these means has its strengths and limitations and its exact efficacy is not well documented.

The birds are the natural occupants of air. They have been in the air for nearly 150 million years. The human created aircraft are just about 120 years old. Hence, the birds have a right to live in the air. However, there is a need to look for ways and means to co-exist without conflict. To create such a situation, there is a need to understand the bird community and its activity over each of the airfield and its surroundings. Hence, while designing methods to mitigate bird strike hazard is an inescapable requirement.

Considering these requirements, five different studies were carried out by selecting twenty one Indian Air Force airfields/ its surroundings. A summary of the studies are given below.

BIRD COMMUNITY OF AIRFIELDS

The bird community of airfields varied extremely among the study areas, during the period of eighteen months. A total of 197 species were recorded within an activity count of 10,80,146 from 18 selected airfields studied. The species richness varied between 23 and 83 among the airfields with an average of 51. The total bird activity records during the study period over the airfields ranged between of 7,409 and 2,56,669. The airfield varied in taxonomic composition of bird community in terms of higher levels of classification such as Order and Family. The airfield with least species richness (23) stood second highest in activity counts (1,48,382).

The species frequency of presence showed that a majority of them (87 species) occur only in one airfield. And more numbers of species have very restricted distribution. This makes airfield bird communities are significantly different geographically. Very few species are widespread among the airfields of the country though the habitats are similar. Only two species were found in all the 18 airfields (House Crow and Cattle Egret), five species were recorded at 17 airfields. They were Rose-ringed Parakeet, Rock Pigeon, Black Kite, Common Myna and Black Drongo.

The phenomenal number of Rose-ringed Parakeets recorded at UPA, dominated that bird community with an overall activity count of 15.84% of all 18 airfields (Dominance D = 0.66). On the contrary, the TLA and GJJ airfields recorded more evenness in the community composition (Dominance D = 0.06) with an activity count of 7,409 and 94,393 respectively. Hence, it was very evident that each bird community is qualitatively and quantitatively different. This was further proven through SIMPER analysis. With regard to bird community comparison, the 'r' values between all airfields were found to be significantly different (<0.0001).

In the Guild composition analysis, the insectivore species dominated both in species richness as well as in the activities. However, activity of the Frugi-granivore (which included Parakeets) ranked second (with 15%), though their species contribution was limited to 3%. The species and activity among various guilds varied significantly between the airfields. Generally, the Insectivores and Omnivores dominated in the activity counts of different airfields in different proportions. In AFA-Hyderabad, the Insectivores contributed up to 60% whereas in Car Nicobar, the Omnivores made up the community up to 68%. In Jodhpur, the Frugi-granivores was dominant with the activity up to 48% with the presence of phenomenal numbers of Pigeons.

BIRD STRIKE HAZARD

It is important to understand the depth of the problem and the species which are causing highest damage and their hierarchy. An insight into activity of the top hazardous birds would make the study systematic and result oriented. Towards this, the data of species involved and the number of bird strikes in general in the country was compiled from various secondary sources and analyzed.

A comparison of the bird strikes to civil aircraft clearly indicates that the number of bird strikes is steadily growing in India. Although, the rate of bird strike and percentage of damage causing incidents to the total incidents remains generally within the accepted limits, it is of concern due to the high cost and probable accidents which may lead to loss of lives.

Vultures used to be the most hazardous species in the past. However, with the reduction of their population in the sky, the current most hazardous species in the Indian sub-continent is the Black Kite (*Milvus migrans*). (There have been seven crashes of fighter aircraft in the past one and a half decade. Black Kite has been the cause of three crashes among them). This is followed by Red-wattled lapwing and (House) Swift. The Pigeons, which are growing in cities and in many airfields due to various ecological, cultural and biological factors, are turning out to be the next most hazardous species. The parakeets, mynas, egrets and crows which dominate the activities over the airfield also contribute but to a much lesser extent for the hazards.

A study of the yearlong activity of most hazardous species namely Black Kites and Red-wattled Lapwings (*Vanellus indicus*) were undertaken at selected airfields and their past activity data were compared. Results showed that the activity counts of all these most hazardous species reach peak numbers around the similar period within an airfield. However, their peak activity period in different airfields differ significantly depending on various ecological factors. It was also seen that the Black Kite population may grow unhindered if there are no scientific garbage management procedures in practice in respective cities and enhanced meat markets. The population tends to remain low, if these factors do not support their growth. The other hazardous species, Lapwings has shown significant increase and decrease of population over a period of five years at Sirsa airfield without indicating any specific ecological factors under study as of now. In similar ways, different species may become more hazardous by increasing their population and then reduce themselves when the habitat does not support them. Hence, there is a need for constant look out for the ecological changes which is leading to extreme variations in populations of various species.

ASSESSMENT OF MANAGEMENT STRATEGIES

The aviation industry uses various strategies to mitigate the bird strike hazard around the airfield. The study took up four strategies that are used by IAF for assessing their efficacy. The results are summarized in the following table:-

1. **Keeping the Kite Source Sites such as Garbage Dumps and Meat Markets at a Distance of 10 Km.** The Indian Aircraft Rule, 1937 (Rule 91) restricts dumping waste, meat and other bird attracting materials within a distance of 10 km from the Aerodrome Reference Point. This study designed research questions to check the validity of this concept in the current scenario of having large garbage dumps which hosts unprecedented numbers of Kites. The study revealed that the Kite activity comes down significantly by seven km distance from the source site. However, the activity at the airfield may increase due to other smaller attractions factors. These factors may include smaller feeding sites nearby, attractive roosting sites or the thermals created by the airfield itself. Hence, it is important to keep the source sites beyond 10 km distance and also keep the immediate surroundings devoid of feeding opportunities. This concept is valid even whether the source location holds thousands of Kites or a smaller number in hundreds.

2. **Restrictions on Operations on Full Moon Nights.**A study was taken up to check the validity of the concept of enhanced activity/ runway occupancy of Lapwings around full moon nights. The study found that the Yellow-wattled Lapwings are occupying the runway areas more on nights around full moon nights. The study also found that the occupancy is relatively less in the time slot between sunset and 9.00 PM. Lapwing runway occupancy increases on runway on the nights of rains. It was also observed that considerable number of Lapwings use the runway shoulders for their roosting/ breeding activity. The extent of their preference to use runway is higher on nights around full moon nights. The study was carried out at a South Indian airfield where

Yellow-wattled Lapwings were present. Further studies are required to be conducted to know whether the similar activity patterns exist in Red-wattled Lapwings in North India.

3. **Planting of Dhub Grass**. Many agencies had suggested the use of grass with very small seeds which are not attractive to granivore birds (for example; Dhub grass- *Cynodon dactylon*)to avoid hazardous birds in the airfield area. A research questions was designed to test the efficacy of this grass to deter hazardous birds. The study found that the said grass does not deter the hazardous birds from using the airfield area. They were found to specially attract the insectivores such as Cattle Egrets. In this study natural grass patches with mixed local species attracted fewer birds than the selected monoculture plot.

4. **Collective Effect of General Anti-bird Measures**. IAF employs various methods on operational days to mitigate the bird hazard. It includes deployment of drum beaters, gas cannons, distress call generators, crackers, pyro-techniques, bird watchers and scarers and vehicles to push them off from the area of interest. In addition, the movements of aircraft which makes sounds of high decibels were also considered as a bird repellent. An attempt has been made to gauge the collective effect of all general methods that are employed on the bird community. The experiment was spread over sixteen airfields over five months. The results showed that the combined effect of all methods employed is not significant to alter the bird community. However, the small extent of localized reduction for some operation may be significant to create a safe window for operations. At some of the airfields, the level of activity of some species of birds was observed to be higher on the days of implementation of strategies. More studies are required to be conducted at these sites to verify the cause for increase in activity on Operational days.

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DECLARATION BY THE CANDIDATE

I declare that this thesis, submitted for the degree of Doctor of Philosophy to Manipal Academy of Higher Education, is my original work, conducted under the supervision of my guide **Dr. P Pramod**. I also wish to inform that no part of the research has been submitted for a degree or examination at any university. References, help and material obtained from other sources have been duly acknowledged.

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ABBREVIATIONS

1	BASH	Bird Aircraft Strike Hazard
2	BLKI	Black Kite
3	BNHS	Bombay Natural History Society
4	BSC	Bird Strike Committee
5	CAA	Civil Aviation Authority
6	DGCA	Director General Civil Aviation
7	FAA	Federal Aviation Authority
8	FM	Full Moon
9	IAF	Indian Air Force
10	IBSC	International Bird Strike Committee
11	ICAO	International Civil Aviation Authority
12	MoEFCC	Ministry of Environment, Forests and Climate Change
13	NN	Normal Nights
14	RWLA	Red-wattled Lapwing
15	SACON	Salim Ali Centre for Ornithology and Natural History
16	SWM	Solid Waste Management
17	TPD	Tonnes per Day
18	USAF	United States Air Force

1. INTRODUCTION

1.1. BIRD STRIKE – GENESIS AND GROWTH OF THE PROBLEM

Humans were always enamoured by the flight of birds. While they dreamt it for thousands of years and made stories of flying men with special powers, the landmark achievement towards machine assisted flying happened only in the beginning of last century. It happened with the first ‘heavier than the air’ flight by Wright brothers in 1903 in the United States of America [Anonymous (Smithsonian Institute), 2021a].

After that first successful test flight, they started developing its design to enhance its endurance and capacity. Aviation was a fledgling and was dreaming big. However, there was an unperceived problem. In 1905, while Orville Wright was flying, his aircraft struck a bird and it was the first sign of human - bird conflict in the air. Such collisions between aircraft and bird are now generally termed as Bird Strikes.

The conflict was taken to a higher level when a renowned pilot died in 1912. A Gull, (*Laurus*sp) entangled in the cables of control system. This led to the loss of control over the aircraft and caused the aircraft to crash [Anonymous (Avisure), 2021b]. The first human fatality was recorded on that day due to the aircraft-bird collision.

The birds started flying nearly 150 million years ago (Dhawan, 2002). With introduction of aircraft in the airspace, birds encountered a new competitor for in the sky.

As the time progressed, the design of the aircraft saw remarkable developments leading to increase in size and speed. The number of aircraft also increased significantly in the sky. This led to a situation where in the number of bird strikes increased. There were no major problems as the losses with slow moving aircraft mostly resulted in minimum damage to aircraft.

However, with the advent of jet engines, the speed of the aircraft increased. The vulnerability of the aircraft grew exponentially as ingestion of bird into the engine with blades that are rotating at very high speed (10,000-25,000 rotations per minute) in multiple stages resulted in massive damages. This sometimes led to the complete malfunctioning of the engine resulting in loss of power and crash of the aircraft (Blokpoel, 1976). The monumental aircraft accident on 04 October 1960 which resulted in the loss of lives of 62 passengers in Boston, USA highlighted the gravity of the problem (Blokpoel, 1976). This forced aviation authorities across the world to initiate studies to understand the bird ecology in the airfield environment and to find solutions to minimize bird strikes.

While the crashes and deaths of passengers are not routine, they do occur at regular intervals. They remind the aviation community about the existence of the problem. Some of the major accidents for civil aircraft are listed in Table 1.1 to give a broad global picture (Anonymous (Avisure), 2021b) of the problem.

Sl No	**Date**	**Location/ Country**	**Bird Species**	**Occupants**	**Killed**	**Injured**
1	4 Oct 60	Boston, USA	European Starling	72	62	9
2	12 Nov 75	Bahia Blanca, Argentina	Gulls	139	0	11
3	25 Jul 78	Michigan, USA	American Kestrel	43	0	3
4	29 Sep 86	Madras, India	Black kite	196	0	11
5	15 Sep 88	Amhara, Ethiopia	Speckled Pigeon	104	35	21
6	20 Mar 99	Equitorial Guinea	Unknown bird	33	0	0
7	19 Apr 2K	Congo	Unknown bird	24	24	0
8	29 Nov 04	Barcelona, Spain	Eurasian Buzzard	146	0	10
9	25 Jan 07	France	Northern Lapwing	54	1	Not known
10	10 Nov 08	Rome, Italy	European Starling	171	0	5
11	15 Jan 09	New York, USA	Canada Goose	155	0	1
12	28 Sep 12	Kathmandu, Nepal	Black Kite	19	19	0

Table 1.1. List of major civil aircraft accidents in the world due to bird strikes.

1.2. BIRD STRIKES IN MILITARY AVIATION

On the other hand, military aviation suffers more severely from the hazard. The smaller size of the aircraft, high speed, and the kind of maneuvers that are carried out by the military exercises make them more vulnerable to this hazard (Pfeiffer, Blackwell and DeVault, 2018). In general, fighter aircraft are more vulnerable for the aforementioned reasons. So far, as per the publicly available records, at least 286 aircraft have been crashed across the world between 1950 and 1999 (Richardson and West, 2000). While ejection is an option available for the pilot, it does not always work. An unplanned ejection can also cause casualties on the ground. Due to these limitations and added hazards, 11 civilians on ground (who had nothing to do with aviation) have lost their lives in India. However, it is also to be borne in mind that the military aircraft other than the fighter jets are also vulnerable. Table 1.2 lists the major bird strike accidents involving the military aircraft other than fighters/Bombers (Richardson and West, 2000 and Sayed, 2019).

Sl No.	Date	Location/ Country	Type of aircraft	Species	Occupants	Killed/ Remarks
1	22 Sep 1995	Alaska, USA	Boeing E-3B-AWACS	Canada Goose	24	24
2	15 Jul 1996	Preveza-Aktion Airport, Greece	Boeing E-3B-AWACS	Not known	16	NIL/ Suspected bird strike, Hull loss
3	15 Jul 1996	Eindhoven, Netherlands	C-130 Hercules CH-06	European Starling	41	34
4	10 Jul 2006	Sevastopol, Ukraine	TU-134	Not known	20	03 injured, aircraft burnt

Table 1.2. List of major bird strike accidents involving non-fighter military aircraft

Given the number of years it covers and the number of deaths involved, the hazard does not seem to be a very serious one. Considering that every year from 2015 to 2019, more than 1,51,000 people lost lives each year in road traffic accidents in India alone (in addition to injuries to more than 4.5 lakh people) (Anonymous (Min of RT&H), 2020a), the number of 18 (7 pilots + 11 on ground) in 38 years seems meager or even negligible. However, the comparison does not end just in numbers. The assets that are lost in road accidents are of low cost and can be easily replaceable (except the life). On the other hand, the loss of a fighter jet cannot be replaced so easily. India, as a country has struggled to buy 36 jet fighters for more than eleven years despite having funds at hand. The procurement process for the required fighters (Multi Role Combat Aircraft- MRCA) was initiated in 2007(Kar, 2007). The first set of five aircraft were received only in June 2020 and remaining are being assembled and delivered. Such facts force any country to analyse the problem from the perspective of intrinsic value of the assets rather than the paid cost. Seen from this perspective, these assets become invaluable and need to be conserved even at a high cost.

In addition, it is important to consider the intrinsic value of pilots as well. While each and every life in the country is to be valued as precious, it is also pragmatic to consider the amount spent for making an operational fighter pilot. According to a report (McCarthy, 2019), the cost of training a fighter pilot of United States Air Force (USAF) varies between 5 and 10 million dollars (approximately INR. 75 Crores). According to openly available resources, the basic training of two years for military pilots in India costs around INR. 13 crores. Conversion into operational pilot would cost many more crores for the next two to three years. Loosing such a pilot in an air crash due to a bird strike implies the loss of herculean effort of the country in addition to the monetary loss. Given this analysis, it is certain that every country is prepared to do anything within its limits to save its aircraft and pilots (be it civil or military) even from a single avoidable accident.

1.3. PROBABLE SOLUTIONS FOR BIRD STRIKE HAZARD MANAGEMENT

Over the years, many solutions have been thought off, tried and tested. They have been implemented and incorporated for their effectiveness or for their simplicity. The gamut of these solutions can be basically grouped into two broad categories. Each of the groups has many subcategories which have specific techniques/methods. An outline is given here for the purpose of broad understanding.

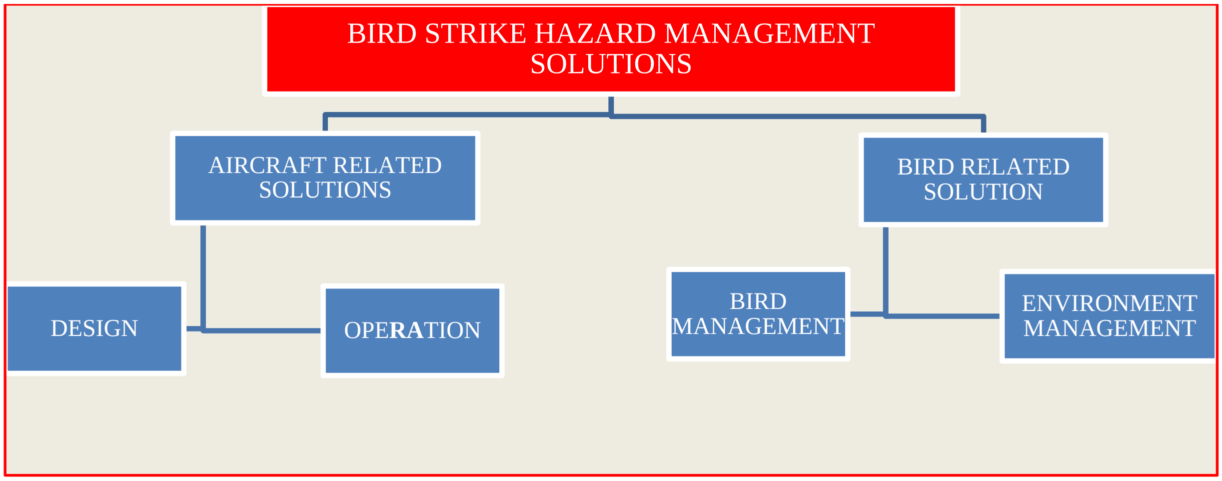


Figure 1.1. Bird strike hazard Management solutions – a schematic representation

One of the obvious ways to approach the problem for solutions is to look at the two entities involved in these events. It involves the aircraft and the bird. The aircraft related solutions can be further divided into aircraft design solutions and operational solutions. The bird related solutions have two aspects namely Bird management and Environment management.

Among the four aspects shown at the bottom level of Figure 1.1, all aspects except the 'Design' of aircraft aspect heavily rely on the inputs derived from Bird ecological studies. This is an important and inescapable activity of Bird strike hazard management solutions. While the design aspect involves engineers, other aspects involve Ornithologists (and other ecologists). There is a need to study and inventory the birds, understand their habits and activity patterns, gauge the hazard, look for possible solutions, implement the solutions and gauge their efficacy. Considering this, bird ecological studies of airfields is an ongoing process as long as the airfield is operational. The current studies involve above mentioned activities and these activities are discussed in detail in the following pages. However, for the purpose of larger understanding, a panoramic view of the management strategies is presented here.

The aircraft design is further divided into two broad categories namely Airframe and Engine. This part is not discussed further. The Operations part has many elements as depicted in Figure 1.2.

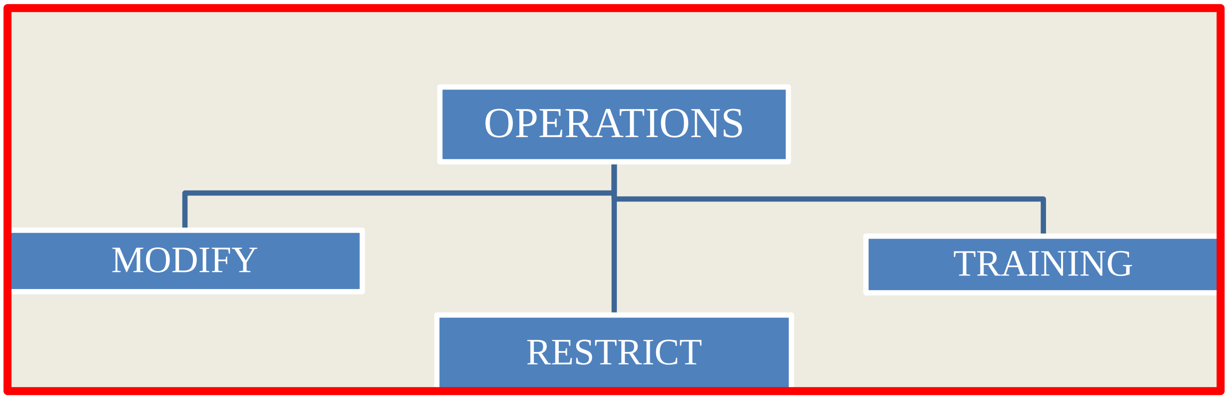


Figure 1.2. Bird strike hazard management solutions involving aircraft operations- a schematic representation

Types of Restrictions are shown in Figure 1.3. The 'Restrictions' element is of high significance for this study. Indian Air Force (IAF) imposes many restrictions on its operations at a very high cost to save its assets. These restrictions can be broadly categorized as two types namely 'Planned restrictions' and 'Vigilance based restrictions'.

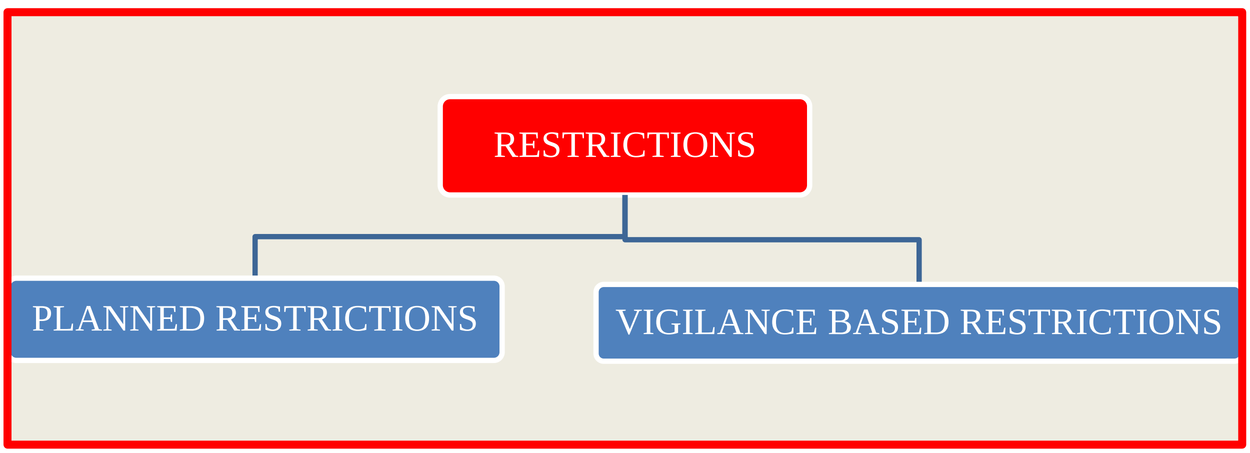


Figure 1.3. Bird strike hazard management solutions involving 'Restrictions' - a schematic representation

The current study analyses the bird ecological data for the purpose of 'Restrictions' and understanding of bird movements over larger spaces in different airfields. The Planned restrictions are based on the information from the periodic intensive bird surveys and behavioural studies. Many methods such as Point Counts, Whole day count, Trail series and Microlite based surveys are employed. The purchase of a huge fleet of Microlites for the purpose of bird activity surveys by IAF indicates the seriousness with which the problem is looked at.

The data from these surveys are analysed to declare ‘Red periods’ during which the operations are restricted. Many of the operations are not planned during this period.

IAF had initiated special restrictions (and not prohibitions) on the nights around full moon nights in 2011 at certain limited number of airfields. This was based on a study that indicated the heightened activity of Lapwings over the airfields around those nights. The first field study was done in Europe (Milson, 1984) .This was followed by secondary data analysis (Sharma and Srinidhi, 2012) before imposing restrictions. However, the concept had not been validated through a field research for Indian conditions.

Vigilance-based restrictions are restrictions that are imposed based on manual real time inputs. Generally, this input comes from the trained ‘Bird Watchers’ who are deployed for the purpose at vantage locations (Srinidhi, 2015). IAF employs a large number of personnel for this activity on daily basis with structured training. These restrictions can vary from withholding the operations for few minutes to temporary suspensions based on sporadic intense bird activity. Such decisions are taken by appropriate authorities when the bird activity reaches a level wherein it cannot be further controlled or dispersed.

The Vigilance can also be based on inputs from technologically advanced dedicated sensors such as Bird Detection and Monitoring Radars (Metz *et al*, 2020 and Phillips *et al*, 2018) or Infra-red sensors (Gurski, 2008). It can also be based on inputs from the network of Weather Radars [Leshem *et al*, 2005; and Anonymous (Cornell Lab of Ornithology), 2021d]. Employing infrared thermography to detect birds is another technological solution, especially at night (Mitchell and Clarke, 2019).

Figure 1.4 schematically represents various bird related solutions, in addition to the requirement of Bird ecological studies for implementing the same. ‘Bird related solutions’ have two divisions namely ‘Bird Management Solutions’ and ‘Environment Management Solutions’. The Bird management solutions can be further divided based on three principles of management namely Deterrence, Harassment and Exclusion. The Environment management solutions can be further classified based on the management focus area namely Airfield Environment Management and Surrounding Environment Management.

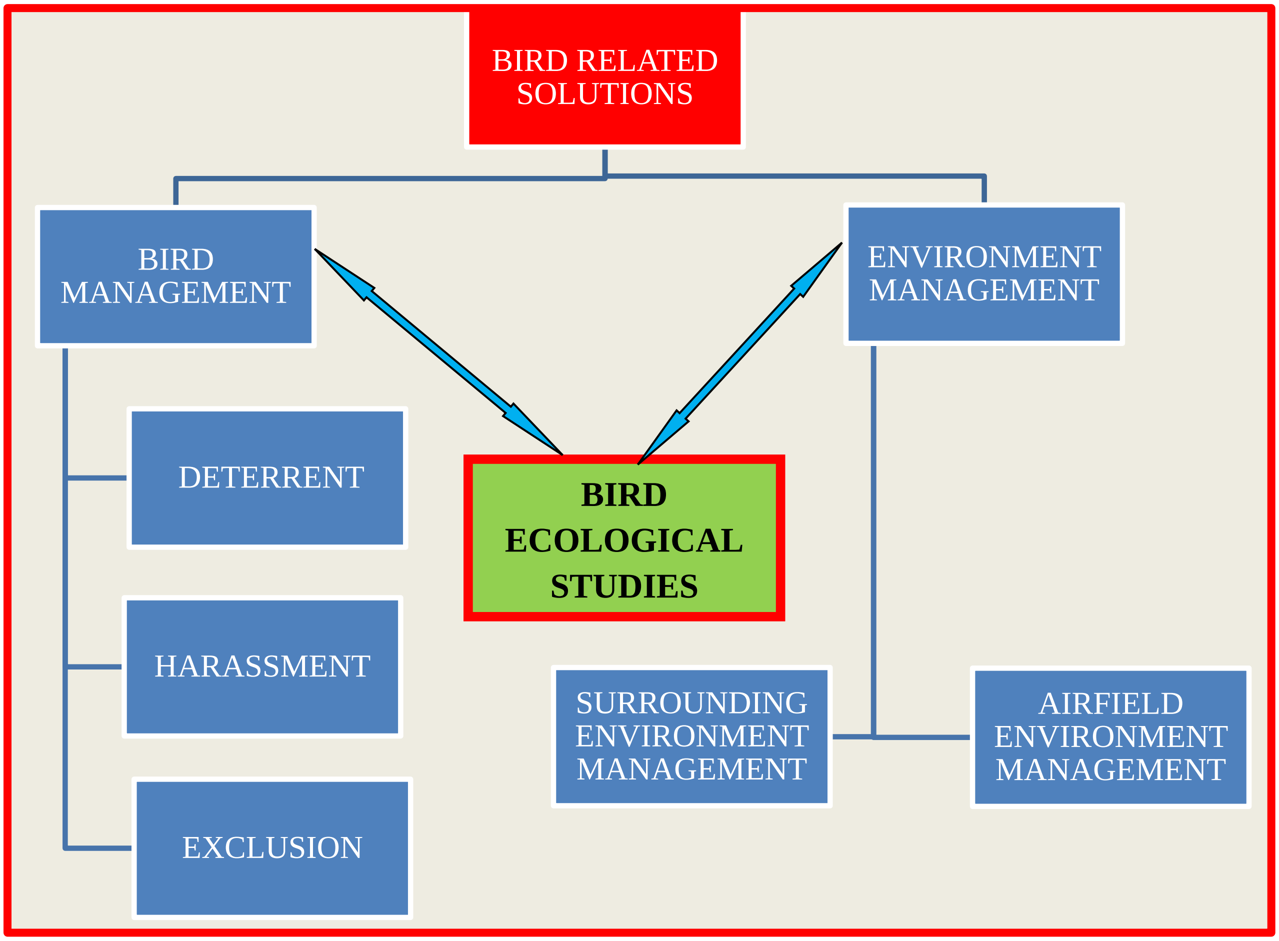


Figure 1.4. Bird strike hazard management solutions involving bird related solutions- a schematic representation

As outlined earlier, the Bird ecological studies will form an important input mechanism to design and implement both strategies. The implemented strategies will be evaluated in a suitable way. Current study is planned to evaluate some of these ongoing strategies.

The Bird management techniques can be further grouped into one of the sub-groups mentioned below under each principle of management (Martin and Belant, 2011) (Figure 1.5). One of the latest experiments in this direction is the development of Robots which can detect and harass birds (Bhatia, 2012).

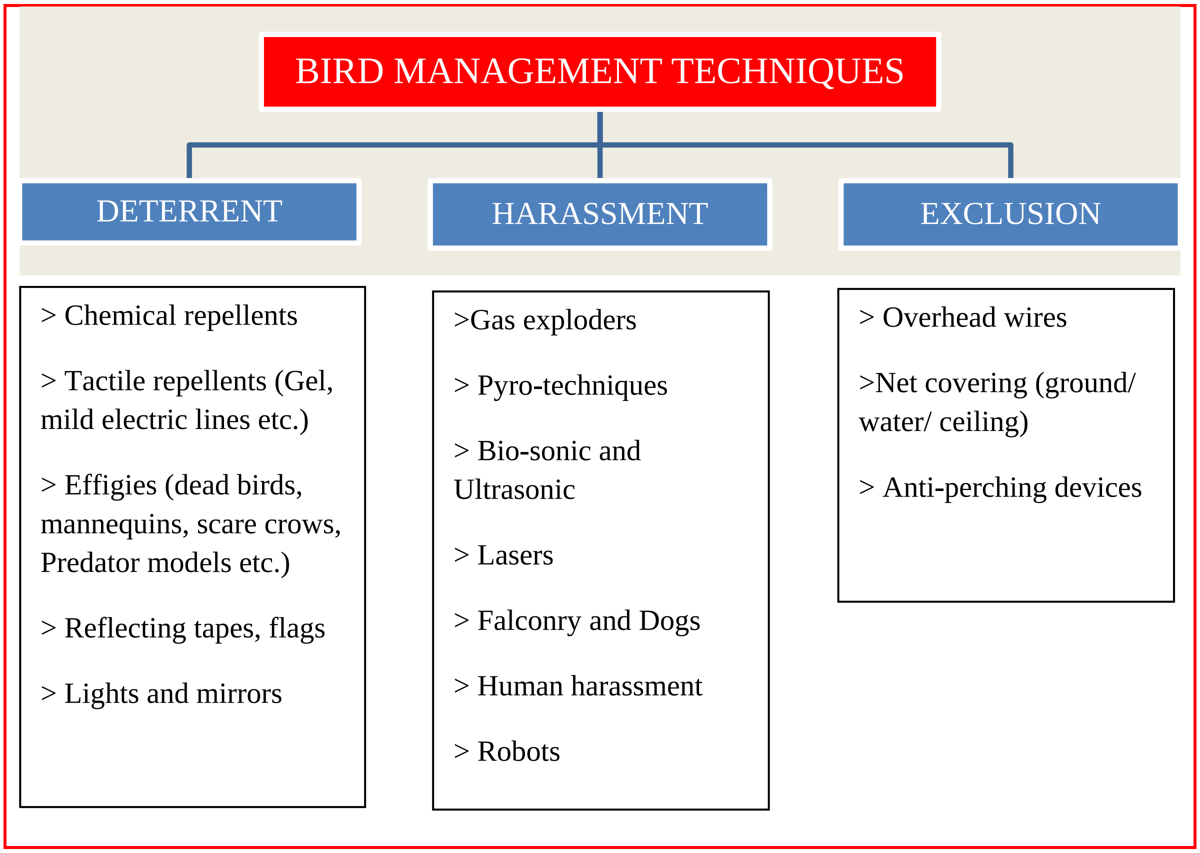


Figure 1.5. Bird strike hazard management solutions involving aircraft operations- a schematic representation

Many of these techniques may be grouped into more than one principle of management based on the perspective with which one sees it. Here they have been grouped from the perspective of the current study. Most possible techniques are listed here to give a general idea of existence of such technique rather than to argue its classification.

Various solutions under Environment Management category are placed under the two sub-groups as shown in Figure 1.6.

In the airfield management section, the idea of planting a specific species of grass which do not attract hazardous birds has been discussed for more than three decades in India. However, the idea could not be implemented successfully due to various factors. The current study took up the task of evaluating the efficacy.

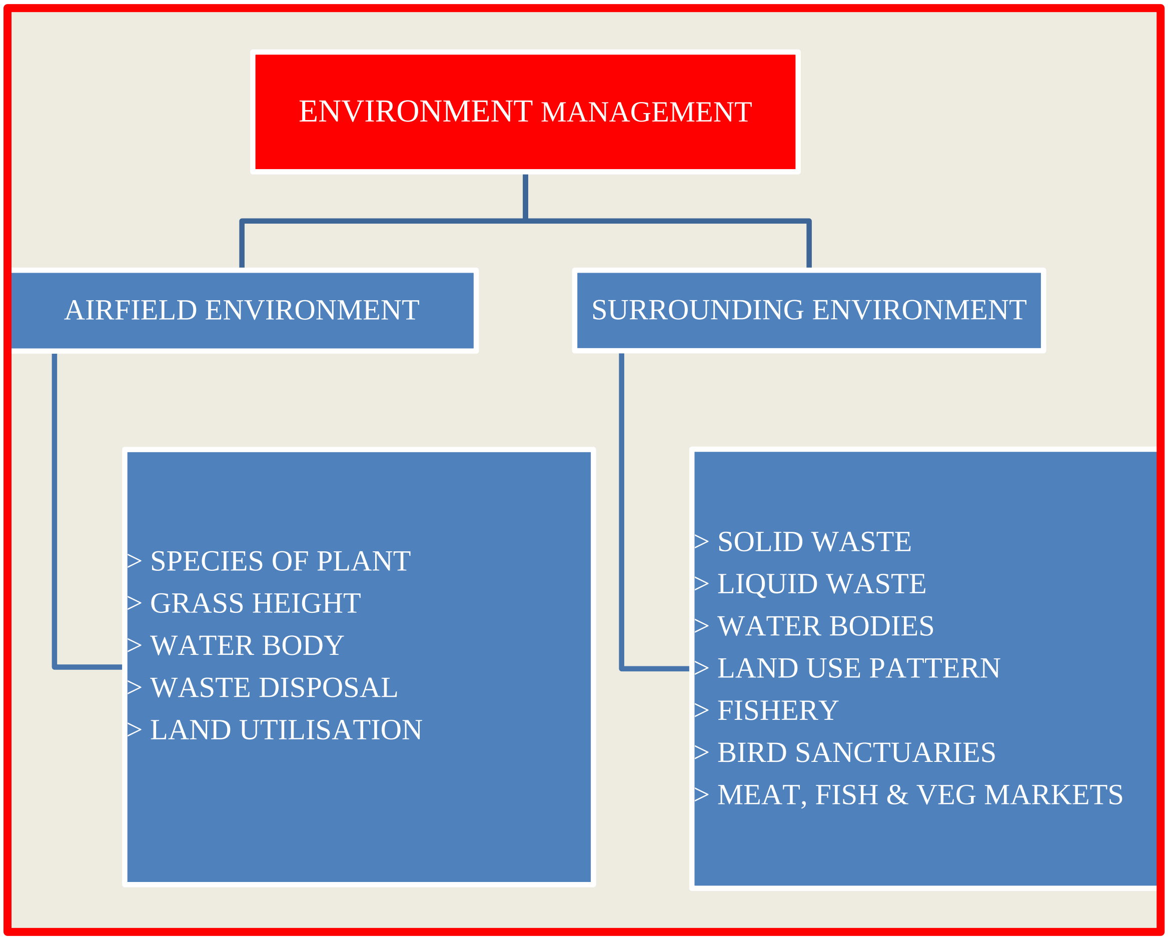


Figure 1.6. Bird strike hazard management solutions involving environment management- a schematic representation

With regard to the environmental management of surrounding areas, Meat markets, solid waste dumping, and Waste processing plants have been a cause of concern for more than four decades. A rule of the Union Government of India [Rule 90, Indian Aircraft Rule of 1937; Anonymous (2011a)] that prohibits the dumping of waste, meat and other bird attractants within a distance of 10 km from the airfield needs to be validated. Other countries also have different rules to provide safe environment to aircraft [Anonymous (South African CAA), Africa2016a; Arshad, 2015; Anonymous (UK-CAP-772), 2017d; Anonymous (UK-CAP-168), 2019b; Anonymous (USA-FAA), 2020b and Anonymous (Solid Waste Management Rules-2016, India), 2016b]. This study took up the validation of 10 km distance of source site for safe air operations.

In the Indian context, many bird ecological studies have been started as early as 1980. Till this date, IAF has already lost many aircrafts due to bird strikes [Richardson and West, 2000 and

Anonymous (Avisure.com) 2021b). While the number of losses came down due to various factors in the last three decades, the problem continues to haunt IAF. In 2007, IAF became the first force in the world to establish its own Ornithology Cell (OC) with competent members to study its airfields (Singh, 2011). The Cell has carried out certain studies and has implemented certain concepts. These concepts needs to be evaluated and their validity in the context of the Indian environment.

1.4. OBJECTIVES

In this context, the present study is designed to address the following specific objectives:-

(a) Understand the community structure, pattern of diversity and species distribution of the birds in Indian Air Force airfields.

(b) Assess and analyse the bird strike related hazards to aircraft in the Indian airfields with focus on Indian Air Force airfields.

(c) Record and scientifically gauge the effect of different methods employed for bird hazard management by different airports in India.

1.5. PLAN OF THESIS

The content of this thesis is represented in seven chapters. In Chapter I, a general introduction and the background of the present study are presented. A detailed review of literature of the chosen study topic is given in chapter II. Details of Study areas and methodology adopted are presented in chapter III. This is followed by three technical chapters, each addressing one broad objective of the study. The structure and pattern of bird diversity and distribution in selected airfields are covered in Chapter IV. Then the Chapter V gives an analysis of bird strikes to aircrafts in India, the problematic species and the extent of the problem. In Chapter VI, the results of the detailed study of the assessment of management strategies currently employed to deal with the bird hazards in Indian airfields are given. Chapter VII gives a comprehensive summary and conclusions of the overall study. Finally the references and appendices are given at the end of the thesis.

2. REVIEW OF LITERATURE

2.1. INTRODUCTION

An accident is explained as an unpleasant event, especially in a vehicle, that happens unexpectedly and causes injury or damage (as per Oxford Advanced learner's Dictionary). The same source explains an incident as something that happens, which is generally unusual or unpleasant. An undesirable meeting of bird and aircraft, especially when the aircraft is moving (or alive with engines running) can be considered as a 'Bird aircraft collision'. Unplanned events that lead to negligible negative undesirable outcomes are termed as 'incidents' and if the outcome is grossly damaging (or cause serious injury to personnel), they are called accidents (IAF internal document). These incidents/ accidents are generally called a 'Bird Strike' considering only the human perspective. This term has been defined in different ways in the available literature. Blokpoel (1976) defines in simple words- 'Any contact between a moving aircraft and a bird (or a group of birds) is referred to as Bird Strike'. A more comprehensive definition has been given in Wikipedia - A bird strike- sometimes called birdstrike, bird ingestion (for an engine), bird hit, bird aircraft strike hazard (BASH) – is a collision between an airborne animal (usually a bird or a bat) and a manmade vehicle, usually an aircraft [Anonymous (Wikipedia), 2021c]. The term is also used for bird deaths resulting from collisions with structures such as power lines, towers and wind turbines.

A technical definition with larger connotation has been given in a document named 'Recommended Practices' [Anonymous (International Bird Strike Committee), 2006] as 'A Confirmed bird strike is any reported collision between a bird or other wildlife and an aircraft for which evidence in the form of a carcass, remains or damage to the aircraft is found. It also includes any bird/wildlife found dead on an airfield where there is no other obvious cause of death (e.g. struck by a car, flew into a window etc.)'.

Many of the commonly known pest problems such as mosquitoes, rodents, termites and flies (at homes) and insects (in agricultural lands) have been persisting for long time. There are varied ways in which research has been conducted on those problems. However, given the fact that the first bird strike with aircraft took place only in 1905 (and first fatality for humans in 1912), this problem is just about 115 years old (Cleary and Dolbeer, 2005). These were seen as random accidents in the beginning. These accidents became a serious concern after 1940. Focused studies on the problem started from 1956 onwards (Blokpoel, 1966). In that perspective, the problem is only about sixty five years old. Given the limited access to the airfield (which persists to date due to security scenarios) as well as to the official data (due to commercial, safety and public sentiment issues), it is expected to have limited literature on the subject in the public domain. However, the amount of money lost in each incident and the high degree of challenge the problem poses has forced many scientific bodies and Aviation authorities across the world to initiate a study on this subject.

As the problem has various facets to it, there are multiple ways in which the problem has been studied. Most studies in this sphere begin with an analysis of the available birdstrikedata. Reviews of some of the important studies/ documents are discussed here to understand the breadth and depth of the studies done in different countries with special reference to India (civil and military aviation).This involves simple numbers as well as species involved in bird strikes. Various aspects such as trials done to mitigate the problem, technologies that are developed (or absorbed) to study the problem and other aspects are discussed here. A section is also dedicated to the study of the ecology and behaviour of Black Kites and Lapwings, which are considered as major threat species in India.

2.2. BIRD STRIKE INFORMATION AVAILABILITY

The most basic studies done in this direction is to study the statistics and make an attempt to establish the patterns of the problem. At the global level, the data for civil aircraft bird strikes is compiled and published by International Civil Aviation Organisation (ICAO). An organized data collection at the international level started in 1965 (Cardoso, 2001). Currently, the data is compiled online and published at an interval of seven to eight years by ICAO. The last two such bulletins were published in 2009 (for the incidents/ accidents from 2001 to 2007) and in 2017 (for incidents from 2008 to 2015) [Anonymous (ICAO), 2009 and 2017b]. Two countries which are affected most by numbers are the USA and the UK. These countries regularly publish their data (apart from feeding into ICAO). The Federal Aviation Authority (FAA) of the USA was compiling the data every year. But, the same is being made public since 2009 (Adams, 2020). This is generally done for the period starting from 1990 and posted on the official website of FAA (faa.gov). In UK, the Civil Aviation Authority (CAA) periodically publishes 'Reported

Birdstrikes'. The last such publication available on-line is 2012-2016 [Anonymous, (CAA) 2017a]. The publications from these three organizations (ICAO, FAA and CAA) generally cover all significant incidents/ accidents apart from some analysis such as time of the incidents, months of bird strikes, phases of flight, parts of the aircraft struck and species involved. The information with regard to the damages caused by birds on Russian aircraft is available on a website of 'Aviation Ornithology Group' (www.otpugivanie.narod.ru).

The proceedings of the meetings of Bird Strike Committees of USA and Canada are made available on 'Digital Commons' platform of University of Nebraska, Lincoln (https://digitalcommons.unl.edu/birdstrike/). The site also presents many other Bird Strike related materials.

In the Indian context, no such periodic official bulletins are published. However, the interest of the public brings out the information in different ways. Generally, some of the journalists take this information (either through interviews of individual airport authorities or through specific requests/ applications) and publish the data in newspaper articles. This does not have an official authentication. However, it is fairly reliable. The Director General Civil Aviation Safety Reviews hosted on their website gives a general overview. Some of the information and concepts are also made public in the form of Parliamentary proceedings (answers to question by parliamentarians). These are now available to public in the form of proceedings (e-parliament library) or in the form of press releases (www.pib.gov.in).

In the past, a few scientific papers have been presented by Indian scientists in International Birds Strike Committee meeting proceedings. One significant among them was titled- 'Serious Vulture hits to aircraft over the world' (Satheesan and Satheesan, 2000) gave some important figures with regard to crashes in India. However, there is no single authenticated and organized data for understanding the problem comprehensively.

However, serious damages to aircraft are fairly well recorded on the web sites such as www.avisure, www.aviationsafety.net and International Civil Aviation Authority (ICAO) website. In one of the earliest gathering of data of serious accidents, J.Thorpe presented his compilations in the International Bird Strike Committee (IBSC) meeting proceedings in 1981. A landmark bird strike accident involving an Indian Airlines aircraft at erstwhile Madras (now Chennai) in 1986 made the administration as well as the scientists look at the problem more seriously. The aircraft was written off in the accident, though, no one was hurt (aviationsafety.net).

In India, many conferences have been held to discuss the problem of bird strike. One of the earliest conferences in India on the theme of bird strikes (partly) was held in 1982 at Delhi. This was conducted as a scientific conference and many of the bird strikes data was fairly presented (Agarwal and Bhatnagar, 1982). Since 2009, at least two international conferences have been organized by Society of Indian Aerospace Technologies and Industries (SIATI) (one each at Bengaluru and New Delhi), one by Director General Civil Aviation (DGCA) and one by Mumbai International Airport (MIAL) at Mumbai. However, these conferences were mostly attended by operators and generally no conference proceedings were published. Officials from various organizations shared their data and practices in these conferences. But, the information shared is not available post conference to quote anywhere. In the recent times, a separate session was held in the conference on 'Central Asian flyways' conducted by Bombay Natural History Society (BNHS) in November 2019 (Apte, 2020). However, a detailed document on conference proceedings has not yet been produced.

In a recent communication, Ministry of Civil Aviation in India informed the Parliament that the number of aircraft- wildlife collisions had crossed 1,000 per year (in 2018) as against 607 in 2012. In an answer to a similar question in 2014, the Minister of Civil Aviation had informed the parliament that 16, 28 and 32 wildlife incursions on to runway incidents had taken place in 2012, 2013 and 2014 (till 31 Oct 2014) [Anonymous (Parliament of India), 2014b]. The data with regard to the bird hits were again given by the Minister in 2017 [Anonymous (Parliament of India), 2017c]. Given the magnitude of the problem, safety of public, financial stakes and public interest, there is a need to organize this data and make it available to the public as done by ICAO, FAA, and CAA.

The data available with regard to the bird strikes to military aircraft has been sporadic. The obvious reason is that the numbers of bird strikes indicate the problems faced by the military and sharing of these numbers gives out an undesirable advantage to the adversary. However, most of the serious accidents generally occur outside the airfield and generally get reported in the media. Further, the losses suffered and the difficulties faced will be of such high magnitude that they have to share some part of the data so that the public becomes aware and contribute to the solution. In general, this data is not the current data. Militaries also resort to giving combined data for many years rather than giving numbers each year. Academically, this meets the broader objectives of scientific inquisitiveness.

US Armed Forces share their data sporadically in different conferences and scientific papers. In a recent publication, US military bird strike data for 27 years was studied and species identified were ranked for their damage potential (Pfeiffer, Blackwell and De Vault, 2018). It is estimated that they have around 4,000 to 5000 wildlife strikes every year (Franz, 2017). US Navy has reported 16,550 bird strikes between 1981 and 2011, loosing ten aircraft and one pilot (Sayed, 2019).

Blokpoel was successful in compiling a large amount of data and included them in his monumental book (Blokpoel, 1976), Royal Netherlands Air Force is a military entity that has shared some data and presented papers in the IBSC meetings. German Armed Forces (Ruhe, 2008), Czech (Krupka, 2003), Canadian (Gurski, 2008), Israel (Carter and Cohen, 2002) and Romanian (Manoiu *et al*, 2018) Air Forces have shared their data or their experiences.

One of the most detailed studies done on bird problem and sharing of their experiences comes from Israel. After losing a few aircraft, Israel initiated a long term study with a dedicated scientist and resources. This has led to one Ph.D. in 1994 from Tel Aviv University [Anonymous (Tel Aviv University), 2021f]. Later, the same scientist continued studying the problem and wrote a book titled 'Flying with the Birds' documenting the various ways in which the study was carried out (Leshem and Bahat, 2009). A monumental work has been done by www.avisure.com which has compiled all significant accidents due to bird strikes, both for civil as well as military aircraft in the world. Though, the site does not claim to be complete, it gives one of the most exhaustive lists of bird strike accidents available to the public.

In the Indian context, IAF records varied between 67 and 131 during the period 1966 and 1973 (Blokpoel, 1976). The problem of bird strikes started rising in the late 1970s with serious damages and crashes. The first study by a dedicated set of ornithologists was initiated by Government of India in 1980 studying three airfields. This was led by the pioneer of Ornithology in India, DrSalim Ali (Ali and Grubh, 1981). Soon, the study was extended in a large scale and a long term study for 22 airfields (comprising both civil and military airfields). This study was for a period of eight years (1981-88) and has documented the bird ecology of all those 22 airfields.

This monumental study had thirteen scientists working for eight years. The study reports are available in the Bombay Natural History Society (BNHS) Library in Mumbai (Grubh, 1989). Many papers were later presented by different scientists in IBSC conferences, giving limited data on bird strikes to military aircraft.

A compilation on serious bird strike accidents to military aircraft was done by Richardson and West and presented in the IBSC conference (2000). In this vast compilation, it is stated that India has lost at least 40+ aircraft in twenty two years span (1978-2000) making it the largest losses per year recorded in public. Compilation of newspaper reports thereafter in India lists at least seven Air Force and one naval aircraft losses (Srinidhi *et al*, 2020).

Before moving on to the review of literature from other aspects, it is pertinent to mention few landmark works in the early history of global bird strike studies and also the recent ones. The first one is the book- 'Bird strike hazard to aircraft' by H Blokpoel in 1976 and the second one is the 'Proceedings of the conference and training workshop on wildlife hazards to aircraft' of the conference held in May 1984, at Charleston (South Carolina) (Harrison, Gauthreaux, and Abron-Robinson, 1984). An 'Annotated Bibliography of Bird Hazards to Aircraft: Bird Strike Committee citations 1967-1997' (popularly termed as ABBHA) was produced in the USA by Air Vehicles Directorate (Short, 1998). A recent book on the subject is titled 'Bird Strike in Aviation- Statistics, Analysis and Management' gives some latest data in addition to management strategies (Sayed, 2019). For understanding the design and development of aircraft with respect to bird strikes, the book- 'Bird Strike- An experimental, theoretical and numerical investigation' (Hedayati and Sadigi, 2016) provides necessary information, in addition to some statistics.

In the Indian context, The reports of bird ecological studies conducted by Bombay Natural History Society (BNHS), the Ph.D. thesis of 1990 from Mumbai University on Pariah Kite and proceedings of the conference on Management of Problem birds in aviation and agriculture held in 1982 at New Delhi (Agarwal and Bhatnagar, 1982) form the most important literature to understand the path in which these studies have progressed over the last half-century in India.

2.3. BIRD ECOLOGICAL STUDIES OF DIFFERENT AIRFIELDS

Successful bird strike prevention at airports requires the identification of bird species in the airfield as well as the understanding of the hazardous species and their ecology (Metz *et al*, 2020). This requires a detailed study of recording and analyzing bird species, their approximate numbers, food availability, their preferred habitats, their movements, activities (breeding, non-breeding, and migration), and many other parameters. The studies are meant to understand the reasons for the presence of birds over the airfield and its surrounding. These activities need to be carried out by qualified experts in an organized manner to facilitate comparison and analysis. Such studies are called by various names starting from a more general name such as ‘Surveys’ to technically termed ‘Bird ecological studies’.

The oldest traceable bird ecological study related to bird strikes is neither in a metropolitan city nor in an Air Force base. But it is in a naval base at Midway Islands in the North Pacific Ocean, a part of the USA. The study titled ‘Birds and aircraft on Midway Islands- 1956-57 investigations’ (Kenyon *et al*, 1958)records the activity of birds in detail and recommends practices to prevent bird strikes. The study recorded 25 Bird Strikes in 54 days comprising 388 movements at a rate of one bird strikes for every 16 movements of aircraft (with seven reported damages). However, counting 7,63,600 birds as part of population estimates (through different methods) will also stand as a unique study as such huge numbers not found over any airfield and its surroundings in any of the extensive literature review done. [Studies in Israel records millions of migrating birds over the nation, but they are not the birds which remain in the vicinity of the airfield (Leshem, 1992)].

The next such study that is formally conducted could be traced in literature was by H Blokpoel. This study was conducted from 1956 to 1965 for the Royal Netherlands Air Force (Blokpoel, 1966). This indicates the severity of the problem faced by the Armed Forces rather than civil aviation. However, as the problem grew in intensity, studying the ecology of all airfields by different experts became a need.

In general, the agricultural pest controllers were the first choice as they had some expertise in dealing with birds as pests. In the USA, the US Department of Agriculture (USDA) continues to handle these studies in coordination with US Wildlife Services. However, later wildlife experts/ bird experts and other ecology experts have conducted such studies at various airfields across the world. These reports have been referred in the following paragraphs extensively.

In most of these cases, the reports of such bird ecological studies were submitted to the airport authorities or the regulatory bodies which commission such studies. Hence, all such reports are not available in the public domain. Only a few of them are presented as scientific papers. In addition, some of the airports / authorities choose to make the document public. A review of such documents has been done and the most significant ones are presented here.

The study by Blokpoel (1966) at Netherlands was followed by a 'Biological survey of airbase Lahr, West Germany' by the same author (1967). A study of Boston's Logan airport has been recorded in 1963 by C.E.Faulkner through an article in the journal 'Pest Control'. An Environmental Impact Assessment was done at Hamilton Air Base before recommending the surplus land for other purposes (Anonymous, 1979).

Though not presented as an ecological study, the data collected has been used for different analyses in a few studies. The German Air Force used the data collected by Ornithologists at 15 airfields (one to three years) to assess the vulnerability of individual species (Hahn and Weitz, 1998). A modeling study done by Royal Netherlands Air Force (Both, Gasteren and Dekker, 2010) analyses the bird activity data of seven airfields over fifteen years. These will remain as some of the remarkable studies in terms of efforts and coordination.

A study in Namibian International airport records a bird strike rate of 7.97 bird strikes per 10,000 movements lists and ranks 27 species of birds as per the calculated hazard levels (Dukia and Gahlot, 2013) .Studies have been recently carried out at some of the South Asian countries for the first time marking the base line studies and underline the greater population of Black Kites posing threat to aircraft. (Cobanand Bahar, 2018; Arshad, 2015 and Arshad, Malik and Hussain, 2019) An interesting study at Edinburgh in Australia compares the microhabitat utilization by birds of an airfield in the surrounding areas such as Golf Course, residential areas and others in addition to the airfield (Rankine, 2010).

In the Indian context, many airfields have been studied in detail in the last forty years. One of the known intensive studies was conducted by Bombay Natural History Society (BNHS) in 1980 for Ambala, Agra and Delhi airfields (Ali and Grubh, 1981).This was followed by a project of studying 22 airfields in India (both civil and military airfields) from 1981 to 1988 (Grubh, 1989). There were a few doctoral research programs on the subject (Satheesan, 1990; Sharma, 1998; and Chaudhary, 1997). Sporadic studies have been carried out by various scientists and officers of IAF thereafter r. In 2007, Ornithology Cell (OC) was set up by IAF and the Cell started studying various airfields. The Cell also started recording bird ecology of various airfields. These reports were not available to the public or to the scientific community.

In addition, Environment Impact Assessment (EIA) studies were enforced for major projects after the issue of a government notification in 2006 (Chowdhury, 2014). Accordingly, such mandatory studies were carried out for the airports which came up in the country after 2006. This is followed up by periodic studies by a few of the environmental NGOs (ASHOKA, Vanamitra, etc.). These reports are available with respective airfields. A minimum of four conferences have been held (in the years 2009, 2011, 2012 and 2015) exclusively on the problem of bird strikes. Various airfields presented their short term/ internal studies at these conferences. However, conference proceedings are not available. Recently, Salim Ali Centre for Ornithology and Natural History (SACON), Coimbatore studied three airfields and has submitted its report to Ministry of Environment, Forests and Climate Change (MoEFCC) (Pramod and Karunakaran 2020a). SACON has also has come up with a Best Practices Guide to mitigate the bird hazards posed by birds to aircraft (Pramod and Karunakaran 2020b).

2.4. BIRD SPECIES INVOLVED IN BIRD STRIKES

While the compilation of data on bird species involved in bird strikes was initiated by ICAO in 1965, the concerted effort was not made until 1996 when Thorpe compiled the data on the species involved for civil aircraft bird strikes and presented in an International Bird Strike Committee (IBSC) Conference. Just before this, serious military accidents due to bird strike were analysed and it was found that Gulls and Buzzards are the main cause in Europe whereas Vultures were of concern at USA (Richardson, 1994). Later, the data continued to get refined year after year. After an intensive research, Richardson and West published two papers in 2000 and 2005, listing the species involved in BS accidents (data dating back to the accident in 1923). Another compilation of fatal and hull loss accidents (between 1912 and 2002) was presented in a bird strike conference (Thorpe, 2003). However, a considerable amount of data was lost by that time and many of the incidents have an entry as 'Bird' or mammal.

In the early years of aviation, the aircraft moved slowly with propeller engines. This gave a chance for some bird remnants to remain on the aircraft. Hence, the species involved could be identified to a certain extent. With the introduction of jet engines in the 1940s, the speed of the aircraft increased substantially and the birds started getting ingested in to the engines. In most cases, the bird body was fully destroyed leaving small pieces of feathers or a small mass of charred flesh or some small blood mark. The identification became difficult. Hence, the data was not available for a major portion for the aviation history.

In the earlier years, the species involved were mainly identified through carcass identification. However, due to complete destruction of the carcass in many instances, the species could not be identified. The Netherlands was the first to take initiative and make an important progress. The country used the expertise at their National Zoological Museum in Amsterdam and tried identifying the species involved through microscopic feather identification. The methods were refined and keys were developed for European birds by Brom in 1980 which enhanced the identification system. In 1984, Royal Netherlands Air Force (RNAF) species identification had gone up significantly and a deeper understanding of the species involved was available. The same lead was well used by the BNHS in India and could identify 552 samples from 1966 to 1993 (Sharma, 1998). The process has been further refined by Smithsonian University (Doveand Laybourne, 1994).

As in many cases, only the blood stains or charred pieces remained on (or in) the aircraft, a new technique of 'DNA Barcoding' was adopted for identifying the bird species with few drops of blood by bird strikes investigators. However, the exact year and the country which adopted it for the first time are not known. In India, IAF first adopted it in 2009. However, the system took a few more years to establish and it is yet to completely stabilize as a regular practice (Sharma, Bala and Srinidhi, 2012). This technology adoption helped IAF to identify species in much more cases and understand the changing ecology (Srinidhi *et al*, 2020). There is another advanced technology of 'Radio isotope' identification to identify the specific group of birds (like resident and migrated groups of Geese). This was used to trace the origin of the group of Canada Geese (migratory/ resident) which got into the aircraft in the well-known 'Hudson River' accident (Marra *et al*, 2009). This technology has not yet been adopted by many countries as a pressing need has not been felt globally.

The species identification helps in evolving strategy to avoid bird strikes with aircraft. While the same bird species need not strike always, a comparison of numbers and the amount of damage caused by each species gives a clear picture of priorities to an airport/ wildlife hazard manager. It is very important to note that the species involved in bird strikes in different geographical regions (and countries) vary substantially. However, some common species also emerge indicating the commonality of the environment and behaviour of each species. One of the earliest comprehensive compilations was done by Blokpoel in 1976.In this document, Gulls (Family-Laridae) (as a group) top the list of number of strikes in the Netherlands, the UK, Germany, Sweden, the USA and Canada (as listed for different time periods between 1966 and 1972 for different countries). In Australia, raptors topped the list with contribution up to 41% (1958-65) and in India, it was the Vultures which contributed up to 85.7% (1960-63) (Renner, and Steele, 2003).

Two Bulletins of ICAO for two periods- 2001-2007 and 2008-2015 list the species that are identified across the world [Anonymous (ICAO), 2009 and 2017b]. The nomenclatures used are not uniform in both documents making it difficult for easy comparison. However, the general comparison indicates that Passerines were involved upto 31 % in the first time period and got reduced to 22% in the second period. The Gulls struck the aircraft in 18% of incidents in the former period whereas it was reduced to 4.5% in the latter period. Another important group namely Pigeons were involved up to 10% in the former and 7% in the latter time periods.

Unlike Blokpoel's book (1976), these documents do not show the species involved in each country and all the data is combined. However, countries such as the USA, the UK, Canada, and Australia regularly publish their species data making it convenient for a region-specific understanding.

The USA generally releases annual reports. Since 2009, they have made it a policy to make it public as well [Adams (FAA), 2020] (faa.gov). Periodically, they also release special reports combining reports for several years. The last two important such reports are 'Wildlife strike to civil aircraft in the United States 1990-2005' (Cleary, Dolbeer and Wright, 2006) and 'Wildlife strike to civil aircraft in the United States 1990-2018' (Dolbeer and Richard, 2019). The species have been elaborately compiled along with the damage category and effect on flight (EOF). These reports list hundreds of species that are involved which are later grouped generally based on taxonomy. As per the summary, the Gulls topped the list in numbers in the former report with 6,201 recorded strikes. They were followed by Pigeons (3,749), Raptors (3,510) and Waterfowls (2,613). In the latter report, Pigeons took the first place with 15,483 reports. They were followed by Raptors (14,299), Gulls (11,945), Shore birds (10,098), and Waterfowls (5,816). These reports indicate the change in the birds' environment and response to hazard management strategies.

In the document 'Reported birdstrikes 2012-2016' hosted on the Civil Aviation Authority (CAA, UK) website (anonymous, 2017a), the analysis is done in a slightly different manner. However, for broad understanding, it is sufficient to know that the group of Gull species top the list here with approximately 1,100 strikes (estimated from graph). This is a huge number considering the shorter period of four years as against 28 years data of the USA. It is followed by Swallows and Martins (around 900), Pigeons and Doves (approximately 630). Thereafter, the number is almost equal between swifts and Larks (approximately 400 each). While Gulls and Pigeons trouble aviation industries in both continents, Raptors, shore birds and waterfowl trouble more in the USA. Huge raptors do not cause a huge problem in the UK and are more troubled by groups of smaller sized birds such as Swallows, Swifts, Martins, and Larks.

In the Indian context, the data has been sporadic. The book by Blokpoel (1976) refers to Vultures causing 85% strikes in India from 1960-63. Later, Sharma (1998) mentions that Vultures and Black Kites top the list for the period between 1966 and 1993. The species data is very scanty thereafter till 2010.

From the military aviation perspective, there is no agency like ICAO which can do the central co-ordination work. However, Blokpoel book (1976) presents considerable data of different Air Forces, but is limited to numbers and no species is given. While regular data is not available, a few countries have presented some data of their armed forces in the IBSC conferences in different formats. In recent times, Sayed has compiled considerable amount of military bird strike data (2019). Some of the websites of the companies like ‘Avisure’ are maintaining a good database.

In a monumental study carried out by Royal Netherlands Air Force and presented in IBSC meeting of 2010, the bird strike data of Belgium, German, British, Danish and Dutch AF bird strike species data was compiled and a mathematical model was developed to indicate a ‘Bird Hazard Index’ (BHI)(Both, Gasteren and Dekker, 2010) . As per that, Gulls top the list followed by Kestrels, Grey herons, Buzzards and Feral Pigeons. A paper studying the contribution of weather towards bird strikes in Romania has listed Seagulls, Starlings and Storks as the species which have caused damage to their military aircraft (Manoiu *et al*, 2018). Czech Republic AF has developed an IT solution to monitor the movements of Rooks, Waterfowls, Gulls, Pigeons and Starlings (Krupka, 2003).

The US military data of USAF and USN has been clubbed (for a period of 27 and 23 years) to understand the hazardous species and a scientific paper has been presented in 2018 (Pfeiffer, 2018). As per the mathematical model developed by them in which Bird Hazard scores are calculated for each species, Snow Goose topped the list followed by Common Loon. The third place was jointly shared by Canada goose and Black Vulture. The Israeli AF has published a couple of articles on its website. It mentions the crashes caused by Pelicans and Storks (Zorani, 2015). There are also mentions of losing aircraft for Golden Eagle and Honey Buzzards in the book “Flying with the birds” (Leshem and Bahat, 2009).

In the Indian context, the studies outlined in civil airfields were carried out for Military airfields as well. Threats from Vultures and Kites have been well recorded. In addition, a study of Bidar airfield was conducted in 2008 for the hazards posed by Greater-short toed Larks. In this rare recording, these migratory Larks had flooded the airfield imposing severe restrictions on operations (Mahesh, 2009). However, no major losses were caused. In sporadic studies, the problems faced by Swifts, Swallows, Lapwings and Pigeons have been highlighted. The Ornithology Cell of IAF is having relevant data of IAF, which is generally not shared. However, the knowledge gained by this scientific body looking after airfields spread across the all bio geographical regions is expected to have valuable experiences.

3. STUDY AREA AND STUDY DESIGN

3.1.STUDY AREAS

Airfields at 21 locations across the country were selected for different types of studies. It mainly included bird community analysis (18 airfields) and assessment of efficiency of different strategies (16 airfields) studies. Basic details of the selected study areas are given in Table 3.1. Study areas showing the spread of cities/ towns of selected airfields are given in Figure 3.1.

Sl No	AIRFIELD NAME	CODE USED$	STATE	BIO-GEOGRAPHIC ZONE*	ALTI-TUDE (FEET)#	POPULATION (2011)^
1	Car Nicobar	ANC	A&N UT	Islands	5	17,841
2	Sulur	TNS	Tamil Nadu	Deccan Peninsula	1250	27,909
3	Yelahanka	KAY	Karnataka	Deccan Peninsula	2912	96,21,551
4	Hyderabad-Air Force Academy	TLA	Telangana	Deccan Peninsula	2013	40,817
5	Pune	MHP	Maharashtra	Deccan Peninsula	1942	94,29,408
6	Kalaikunda	WBK	West Bengal	Gangetic Plains	200	2,99,683
7	Jamnagar	GJJ	Gujarat	Coastal	69	21,60,119
8	Jodhpur	RJJ	Rajasthan	Desert	717	36,87,165
9	Gwalior	MPG	Madhya Pradesh	Semi-Arid	617	20,32,036
10	Tezpur	AST	Assam	North-East	240	1,30,000
11	Gorakhpur	UPG	Uttar Pradesh	Gangetic Plains	259	44,40,895
12	Agra	UPA	Uttar Pradesh	Gangetic Plains	551	44,18,797
13	Chabua	ASC	Assam	North-East	367	13,26,335
14	Hindan	UPH	Uttar Pradesh	Gangetic Plains	700	46,46,732
15	Sirsa	HRS	Haryana	Semi-Arid	650	12,95,189
16	Ambala	HRA	Haryana	Semi-Arid	900	2,07,934
17	Jammu	JKJ	J&K UT	Semi-Arid	1029	5,02,197
18	Srinagar	JKS	J&K UT	Himalaya	5429	12,36,829
19	Bidar	KAB	Karnataka	Deccan Plateau	2178	17,03,300
20	Hakimpet	TLH	Telangana	Deccan Plateau	2020	2,17,910
21	Pathankot	PBP	Punjab	Semi-Arid	1017	1,56,306

$- Codes made using two letters of states and one letter of the area name.

#- Altitude information from Wikipedia / www.meteoblue.com.

*- As per Wildlife Institute of India [Rodgers, Panwar and Mathur (2002)].

^- From websites-www.census2011.co.in and http://censusindia.gov.in/Wikipedia.

Table 3.1. Basic details of the selected study areas.

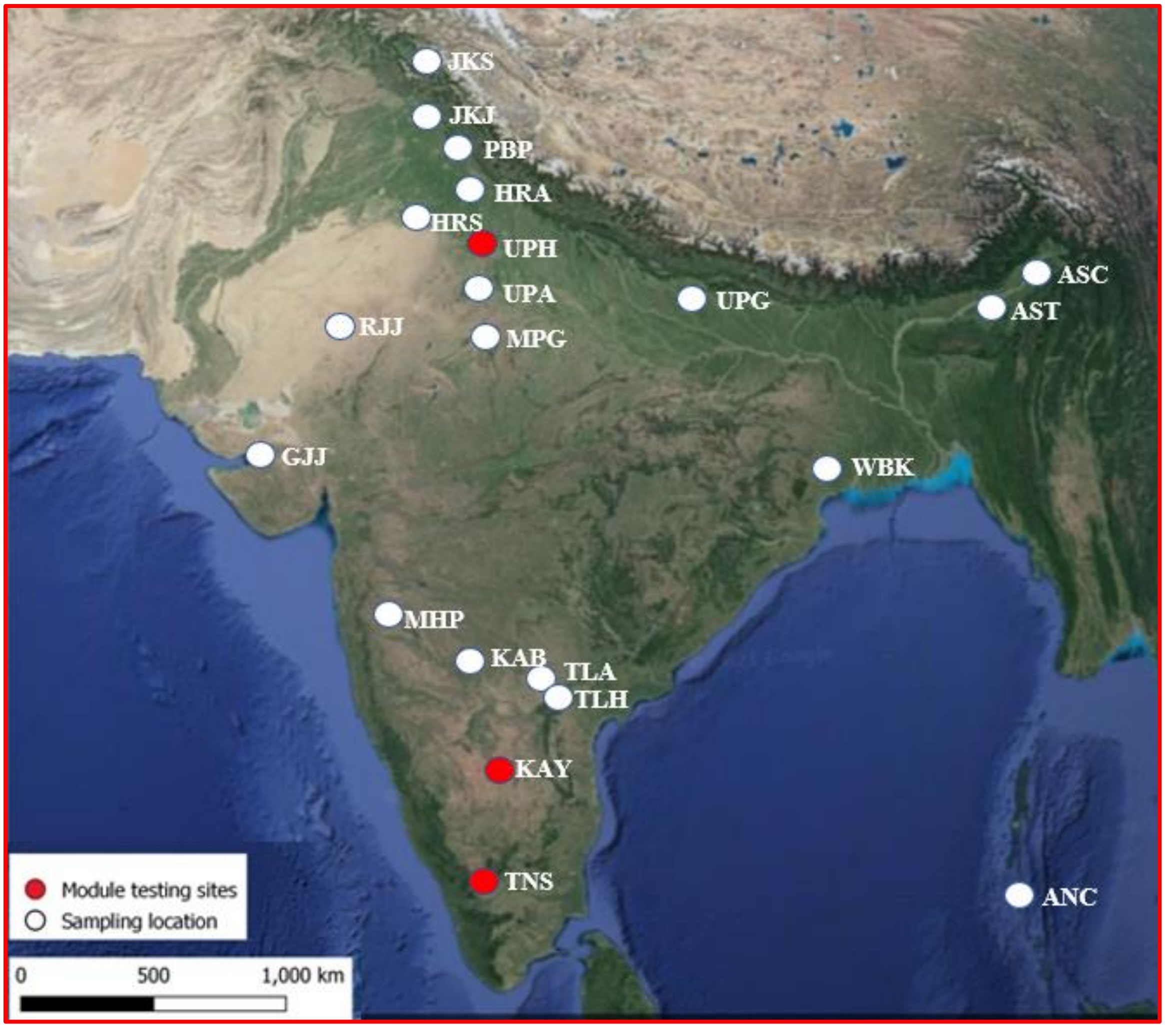


Figure 3.1. Study areas showing the spread of cities/ towns of selected airfields. (Refer Table 3.1 for codes indicating airfields)

These locations were selected after considering many aspects such as the various requirements of the study objectives, permissions to the study in the highly restricted areas of IAF airfields, category of bird hazard severity as perceived, past history of similar studies for comparison and availability of expert field staff to collect additional data.

A short description of the airfields and cities associated with them are given below:

1 **Car Nicobar (ANC).** This is the southernmost airbase of the country located in the Nicobar islands. The pristine environment and its unique location lend support to a variety of birds. With the runway nearly leading to the sea and forest like surrounding makes the spot

habitable to many species of birds. There is a small population of humans over the island and they live in a nature-friendly manner producing minimal waste in comparison with the mainland. Considering the same, there is no organized waste management site yet. Sometimes, the sea water reaches the runway itself. This is also a hop-over place for many migratory birds over the long sea route.

2 **Sulur (TNS)**. The Sulur military airfield is 26 km away from the city of Coimbatore. The nearest major urban center is Sulur which is 5 km away from the airfield. The Coimbatore-Tiruppur highway passes just on the Southern edge of the RW. The airfield is surrounded by fair urbanization on the North/ North Eastern side. South and South Western side is mainly surrounded by farmland/ fallow land and coconut groves. Sulur lake is a large water body which is at a distance of 4.8 km on the Western/North Western side. The Western Ghats are at a distance of about 32 km. The Annual average rainfall is (moderate) 618mm, mainly in the months of April, May, September, October and November. The main city Solid Waste Management (SWM) site is at 26 km from the airfield at Vellalore. But, Sulur town has a couple of transfer sites which are smaller in size.

3 **Yelahanka (KAY)**. This is a military airfield in Bengaluru. Airfield is around 18 km from the Bengaluru city on the Bengaluru- Hyderabad highway. The highway passes on the eastern edge of the runway. The airfield receives moderate annual rainfall (831mm). The nearest urban center is Yelahanka which is 5 km away. There are two main lakes in the 5 km radius namely Yelahanka lake (3.2 km on Southern side) and Baglur lake (5 km on the Eastern side). The Southern side is well urbanized at Yelahanka and fair amount of urbanization continues along the highway. However, the other three sides are a combination of farming and light urabanisation. There is a stone quarry on the Northern side. The airfield is in the vicinity of two other civil airfields namely Jakkur airfield (6.5km on South) and Kempegowda International airport (Bengaluru) (around 11km on North-west). There is a fair amount of trees in the immediate vicinity as well in small clusters. The village of Razak Palya near the Baglur lake had been a center for African Catfish farming for from 2005 to 2013. This used to be a major attraction site for the Black kites and serious bird hazard. This (illegal) activity was stopped by the Civil Administration in January 2013. However, a small population continues to remain over the village. There is a Solid Waste Management site at

Mavalipura (10 km on west/ South- Western side) which mainly processes non-biodegradable waste.

4 **Hyderabad- Air Force Academy (Dundigal) (TLA)**. The airfield is located at about 45 km from the city. The large township hosting the Air Force Academy is generally famous with its abbreviation- 'AFA'. While its surroundings remained as an agricultural landscape for long time, it is bursting in to urbanization in the recent past. However, considerable agricultural activity persists, except on the highway. There are a few water bodies in the immediate vicinity (including a large one inside the campus) which hosts some water birds. There is considerable social forest area in the vicinity as well. The nearest waste dump is about 20 km away. Ecologically, the sprawling airfield with its associated man made infrastructure is a large niche by itself.

5 **Pune (MHP)**. The airfield area is amid the urban setting though; one side of it retains a rural set up. The heavy monsoon and the agricultural fields in the region have a bearing on the bird activity over the airfield.

6 **Kalaikunda (WBK)**. Set in the typical Bengal village surrounding, this sprawling airfield has a unique environment. It is surrounded by many temporary and permanent water bodies of various sizes. The Kansabati river flows at around a distance of 7.2 km. The airfield is being visited by sizeable flocks of Asian Open-bills regularly for their breeding. These heavy birds have been a major concern for the airfield for many years. The nearest city is Kharagpur. The waste management site is at a distance of 6.5 km.

7 **Jamnagar (GJJ)**. Located on the coastal region and in the city which is considered as a paradise for bird watchers, a large diversity birds in huge numbers are known to occur in this area. While the city is on to one side of the airfield, there is a rural setting for the one part and the typical coastal water bodies and salt pans cover the immediate vicinity. With the Khijadia Bird sanctuary in the vicinity, the airfield witnesses the activity of large flocks of different migratory birds during the winters.

8 **Jodhpur (RJJ)**. The airfield is set in the desert region of the country with limited rains. However, it is on the migration path of the birds which come from Europe and does host variety of birds. The city is of moderate size. However, the cultural preference of the people

to vegetarian food has kept the meat market growth under control and does not host scavenging birds in huge numbers.

9 **Gwalior (MPG)**. This airfield is situated in the heartland of the country- Madhya Pradesh. The airfield has a typical set-up of plains with large stretches of agriculture. While the surroundings have been cleared for agriculture and other activities, the airfield has been a guard for a patch of trees which almost looks like a forest. The city has history of managing its waste very well. But, also hosts a small population of Vultures in the city which is rarely seen over the airfield.

10 **Tezpur (AST)**. This North-Eastern airfield is situated on the foothills of Himalayas and set in a forest cum tea plantation surrounding. The existence of a Sal forest right next to runway has been a unique feature. Accordingly, many of the arboreal and endemic birds of the region are spotted here. The massive Kamengriver flows at a distance of about 7 km. Waste management site is located at a distance of 14 km.

11 **Gorakhpur (UPG)**. The airfield Uttar Pradesh is set inside a forest terrain, although, there is some urbanization towards the west. A huge water body by name RamgarhTaal is at a distance of 3km in addition to the Rapti riverat about 7 km. Waste management site is located at 17 km distance. The forest surrounding has led to presence of many arboreal birds in the airfield vicinity.

12 **Agra (UPA)**. This city on the banks of Yamuna is set in a semi-urban set up with some agricultural lands in the vicinity. The city does not have well established waste management practices. The presence of leather industries and meat markets in the city had led to the presence of huge number of Kites in the city. However, airfield itself has some wooded locations. The Yamuna river is located at 7 km and nearest waste management site is a distance of 10 km.

13 **Chabua (ASC)**. This airfield is mainly set in Tea plantation surroundings on the Eastern Himalayan settings near Dibrugarh. The mighty Brahmaputra river flows to the North. The Himalayas start at about 35 km. Being in such a place naturally hosts some rare birds. The waste management site is at a distance of 30 km.

14 **Hindan (UPH)**. This is an airfield in the Ghaziabad which is politically located in Uttar Pradesh, but is a part of Delhi-National Capital Region (NCR). The Southern side of the airfield is highly urbanised whereas Northern side is mostly farmlands and villages. The Hindan River flows on the Eastern side at 2.5 km. The largest garbage dump in the country, the Ghazipur landfill (along with Ghazipur meat and fish market) is located at 9.8 km from the airfield towards the South/ South-West. This area has been known to host one of the densest population Black Kites in the world. The road (Madan Mohan Malviya Marg which passes through DaburChowk, Vaishali metro station, Sahibabad mandi) connecting the airfield also has a fruit and vegetable market (Sahibabad Sabjimandi) at about 4.5km. The river Yamuna flows on the Western side at around 12km.

15 **Sirsa (HRS)**. This is airfield located in a typical Gangetic plain. The surrounding is mostly agricultural, though a small portion towards South-East is urbanised by the Sirsa town. The Ghagrariver flows parallel to the runway at around 2.5km. The town has had a good record of managing its waste well. The waste management plant is located at a distance of 22 km. The desert area begins at about 20 km towards the South. However, it maintains its typical Gangetic plains environment.

16 **Ambala (HRA)**. This is located in the cantonment city of Ambala which is a fortified complex of Indian garrisons. While the general area is mainly agriculture oriented, the immediate surrounding is of a typical cantonment with large trees and well spread houses. The national highway towards the West draws some urbanization. There are no major water bodies in the vicinity. The waste management site of the town is at a distance of 19 km.

17 **Jammu (JKJ)**. The airfield is at the foothills of the Himalayas with the Tawi River flowing near the airfield at a distance of 1.6 km. The airfield is in a semi-urban setting and the town has a moderate population.

18 **Srinagar (JKS)**. This airfield is of highest altitude (5429 feet AMSL) among all the airfields studied. The table top runway in the valley is surrounded by huge mountains and a typical high altitude climate. There are many smaller villages in the valley. The *Jhelum* river flows at a distance of 10 km. A large number of non-vegetarian population and also being in the path of migration route of many Kites from Mongolia, the airfield witnesses a phenomenal number of Kites in addition to the huge number of Pigeons and Mynas.

19 **Bidar (KAB).** This airfield is located near the Bidar city in Northern Karnataka. There are two huge water bodies at slightly longer distance namely Karanjareservoir (10 miles, South-West) and Singur dam backwaters (25 miles, South-East). The general landscape has agricultural lands with major thrust on sugarcane. Some level of industrialisation has also been achieved with thrust on Bidri handwork and silk in the region. The airfield receives about 847 mm of annual rainfall. The general weather is that of semi-arid region with extreme summers.

20 **Hakimpet (TLH).** This is a military airfield to the north of Secunderabad (around 25 km). The immediate surrounding has some vegetation and semi-urban set up due to the large military set-up in the vicinity. Many small and medium sized lakes dot the vicinity of the airfield with largest being the Shameerpet lake at about 6 km to the North-East.

21 **Pathankot (PBP).** The airfield is located near the cantonment city of Pathankot. It is on the foothills of Himalayas. The Ravi River flows at a distance of 14 km to the North-West. Maharana Pratap Sagar dam on Beas River is at about 33 km to South-East. It is located at the entry point to India on the Central Asian migratory flyways.

3.2. STUDY DESIGN

The study was designed and conducted in 21 IAF airfields in the country (Table 3.1). Of these, for the first objective (Bird community structure and dynamics), field observation and data collection were conducted in 18 airports for 18 consecutive months through a time series-whole day survey using point counts. The second objective was addressed using the observation data of selected airports along with data of bird strikes from the available secondary literature.

To address the third objective, four bird strike management strategies were selected. The study was conducted using the experimental design with treatment and control locations/ times for the comparison, and tested the efficacy of the management strategies. The management strategies selected were the replacement of natural grass with grass (Dhub Grass), Avoidance/reduction of operations during full moon nights and rule of 10 km sanitation [Rule 90 of Indian Aircraft Rule-1937 [Anonymous (Ministry of Civil Aviation), 2011a)] for the waste dump yards from the airfield. The collective effect of all ongoing anti-bird measures was also compared with the bird activity of bird activity on days of non-implementation of anti-bird measures. For all these purposes, primary data on bird abundance and activities were collected using standard techniques and protocols. The general study design is explained in following paragraphs:-

3.2.1. Objective 1: Study of Bird Communities in IAF Airfields

Understand the community structure, pattern of diversity and species distribution of the birds in Indian Air Force airfields.

To understand the community structure and pattern of diversity, the bird activity count data of 18 selected airfields was taken for 18 consecutive months. The airfields selected represent various bio-geographical regions of the country to give a larger understanding. The activity count was taken by continuous Point Count for the whole day.

3.2.2. Objective 2: Bird Strikes and Bird Activities in the Airfield

Assess and analyze the bird strike related hazards to aircraft in the Indian airfields with focus on Indian Air Force airfields

To study the extent and the trends of bird hazards in Indian airfields and the contribution of major hazardous species the following approach is adopted. First, Bird strikes in India was assessed based on the available secondary literature and identified the major hazardous species. Then the primary data collected through the present study on these target species, their population patterns and trends were analysed in space and time in comparison with the available historic data.

3.2.3. Objective 3. Effect of Different Methods Employed for Bird Strike Management.

Record and scientifically gauge the effect of different methods employed for bird hazard management by different airports in India.

Bird Hazard Combat Teams in various IAF airfields employ a large number of techniques and practices to avoid and minimize the bird strikes. Information with regard to the locations and the specific type of studies conducted at each location is given in Table 3.2.

Sl No	Airfield name	Code used	Community structure	Anti-bird measures	Other studies
1	Car Nicobar	ANC	C	N	
2	Sulur	TNS	C	N	Full moon night activity of Lapwings
3	Yelahanka	KAY	C	C	Black Kite activity
4	Hyderabad-Air Force Academy	TLA	C	C	
5	Pune	MHP	C	C	
6	Kalaikunda	WBK	C	C	
7	Jamnagar	GJJ	C	C	
8	Jodhpur	RJJ	C	N	
9	Gwalior	MPG	C	C	
10	Tezpur	AST	C	C	
11	Gorakhpur	UPG	C	N	
12	Agra	UPA	C	C	
13	Chabua	ASC	C	C	
14	Hindan	UPH	C	C	1. Black Kite activity. 2. Dhub grass deterrence.
15	Sirsa	HRS	C	C	
16	Ambala	HRA	C	C	
17	Jammu	JKJ	C	N	
18	Srinagar	JKS	C	C	
19	Bidar	KAB	N	C	
20	Hakimpet	KAH	N	C	
21	Pathankot	PBP	N	C	

Table 3.2. Locations and the type of studies conducted at each location. (C- Conducted; N- Not conducted).

Among many techniques, most commonly employed three practices were selected to study and analyse its efficacy. Then bird activities over airfields on the days of implementation of (short term) bird strike management activities were compared with the days of without any such activities.

Usage of Dhub Grass (*Cynodondactylon*sp.) to avoid attraction to birds is widely suggested as an alternative to avoid many hazardous birds (and also a good soil binder). Avoidance/reduction of operations during full moon days to avoid the incidents and accidents from night active birds such as Lapwings is another practice in place. The rule of 10 km sanitation (Rule 90 of Indian Aircraft Rule 1937) for the waste dump yards from the airfield is also in force. All these four practices are considered here for a scientific review of its use and validity.

4. BIRD COMMUNITY OF INDIAN AIRFIELDS

4.1. INTRODUCTION

Identification of the bird species using the airfields environments as their habitat is crucial in understanding the bird hazards to aircraft. Airfields are generally extensive open grasslands and hence many birds which prefer grasslands and open places as their habitats make it as their living places. Moreover, the neighbouring locations also will have a role in dictating what species will be there over each airfield. Identification of the bird species living in the airfields and surrounding, their activity in space and timeis important in understanding the bird hazards to aircraft. Community structure and the pattern of distribution of the bird species in airfields are significant aspects.

Naturally each airfield is a habitatfor a wide range of birds. This study intended to record the variety of birds as well as the variations of habitats between the airfields which are selected from different bio-geographic regions of the country.

This chapter addresses the first objective of the study stating "understanding the community structure, pattern of diversity and species distribution of the birds in Indian Air Force airfields". Hypothesis. The stated null hypothesis for the study is as follows:-

There are no differences in the bird communities of the selected eighteen airfields.

The following research questions were attempted to answer in this chapter,

1. What are the bird species frequenting in the Indian airfields?
2. What are the bird community attributes of Airfield birds?
3. What are the most dominant birds in the Indian airfields and their distribution?
4. How Bird community differs in different airfields?
5. What are the probable factors affecting the bird diversity in the airfields?

4.2. METHODS

4.2.1 Bird Activity Data Collection

Birdsobserved near the runway were identified and counted from fixed locations (Figure 4.1) such as two end points and middle runway viewed from the Air traffic Control (ATC) tower. Time Series data was collected using Point Count method (Bibby *et al*, 2000) which is repeated for the whole day from the same point. The whole day count was done for the three predetermined area near the runway for the all the species sighted from the same location on the respective day.

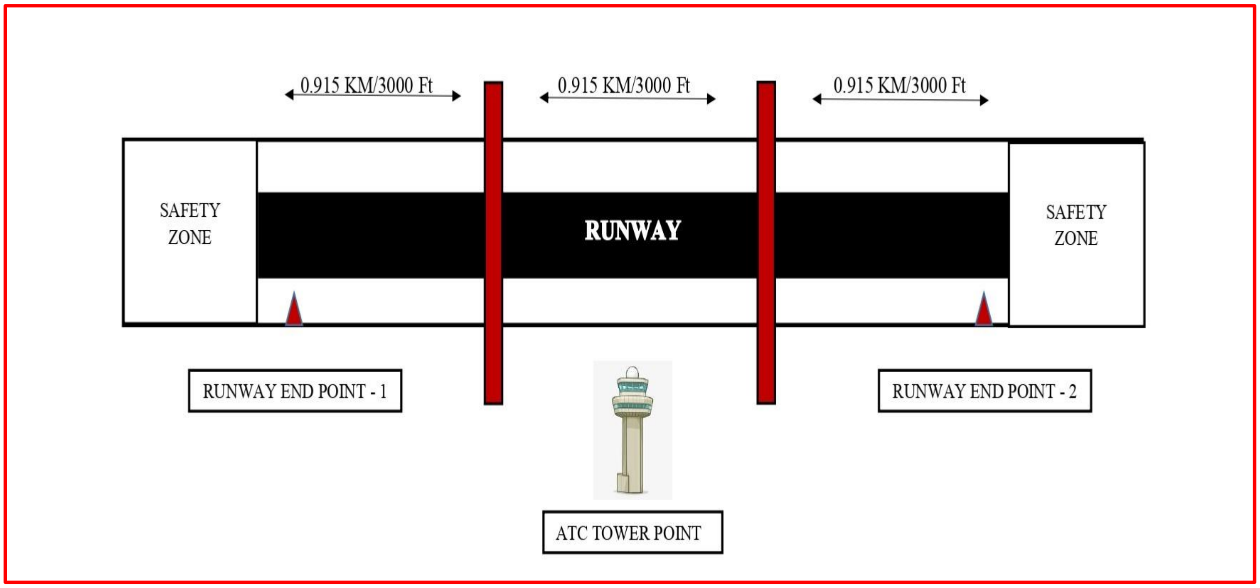


Figure 4.1. Schematic representation of points for data collections (Whole day Point count) with respect to runway.

The space / area covered for observation was earmarked *a priori* to obviate any duplication in the count. The separation of the space/observation area was made by dividing the runway into three parts of 0.915 m each (approximately). The birds were identified and counted through direct observation with the help of a pair of binoculars. The small birds observed at a distance where the species cannot be identified were also counted. The count involved recording of species, number, height at which the birds fly, activity of the bird over the airfield and perceived reason for the bird to be present in the area as remarks. Standard field guides authored by Ali (1996); Grimmett, Inskipp and Inskipp, (2016); Kazmierczak and Perlo, (2006) were used for identification of species. For analysis of taxonomy and classification, Praveen *et al* (2020) was used as the standard reference.

This temporal diurnal data was aimed to collect the presence/absence, relative abundance and detailed activity information of bird communities in the selected study location (not the population size or density of the birds in the airfield). Activity of different species at different times of the day was extracted for the day as this method permitted to look in to the data with every fifteen minutes interval. The extent of bird activity in the field is the most critical factor affecting bird hazard to aircraft in an airfield. Hence the activity of each species in the airfield is quantified as the number of time each species recorded in (about) 48 counts of a day from sunrise to sunset. So, henceforth, this measure is expressed as "*Activity counts*". These activity counts give the diurnal pattern of the species and their numbers present near the runway and hence the potential hazard to the aircraft.

All information such as species, activity counts and other parameters were collected from the field using standardized field protocols and abbreviated codes.The collected data was computerised for the further analysis. The data has been collected by the Research scholar personally at two airfields (Sulur and Yelahanka). In the other 16 airfields data with the same protocol was collected by the trained IAF staff under the regular supervision and monitoring. The trained IAF Staff who are deployed on Bird Watcher duties were either trained personally by the scholar or through a Basic Ornithology Course conducted at the Institute of Aerospace Safety, Palam (New Delhi). The data was collected on monthly basis using the same protocol prescribed above for eighteen months from May 2019 to Oct 2020 at 18 airfields (Table 2.1). Regular visits were made to these bases by the scholar to validate the procedure and to maintain uniformity.

4.2.2. Bird Community analysis

Bird assemblages within the studied airports were analysed for the taxonomic composition, guild structure, and the primary community attributes such as species diversity, its changes over time within the airport and between the airports. Apart from the basic statistics of numerical population parameters, the basic community parameters such as Species richness, diversity indices (Shannon and Simpson Indices) (Magurran, 1988 and Ludwig and Reynolds, 1988) were considered for analysis and comparison. Analyses were done using Statistical tests, analysis such as ANOSIM, SIMPER and calculations of Community attributes were conducted using the applications such as SPSS and Past 3.

4.3.RESULTS

4.3.1. Species Diversity, Abundance and Activity

Total of 10,80,146 individual observations of birds were recorded from 18 airfields during the study period of eighteen months. This records a total of 197 species of birds belongs to 21 orders and 56 families. A list of the species recorded along with their taxonomic information is placed as Appendix I.

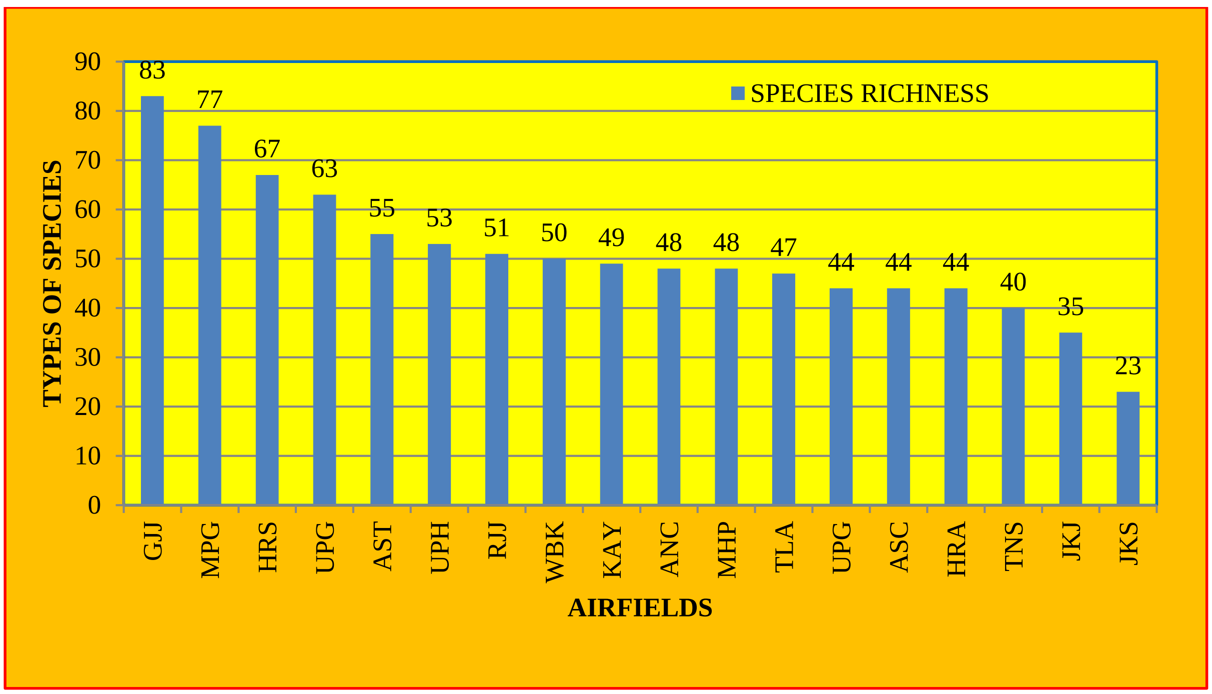


Figure 4.2. Species richness observed at selected 18 airfields over 18 months.

Figure 4.2 gives the bird richness and abundance of the 18 airports studied. The number of species recorded within an airport ranges from 23 (Srinagar) to 83 (Jamnagar). Figure 4.3 shows the total bird activities that were counted during the standard observation period (11,664 hours in 18 months). It ranges from 7409 (Hyderabad-AFA) to 2, 56,669 (Agra). While Jamnagar and Gwalior tops in the number of species recorded during the periods, Relative abundance of all birds together is very high in Agra and Srinagar.

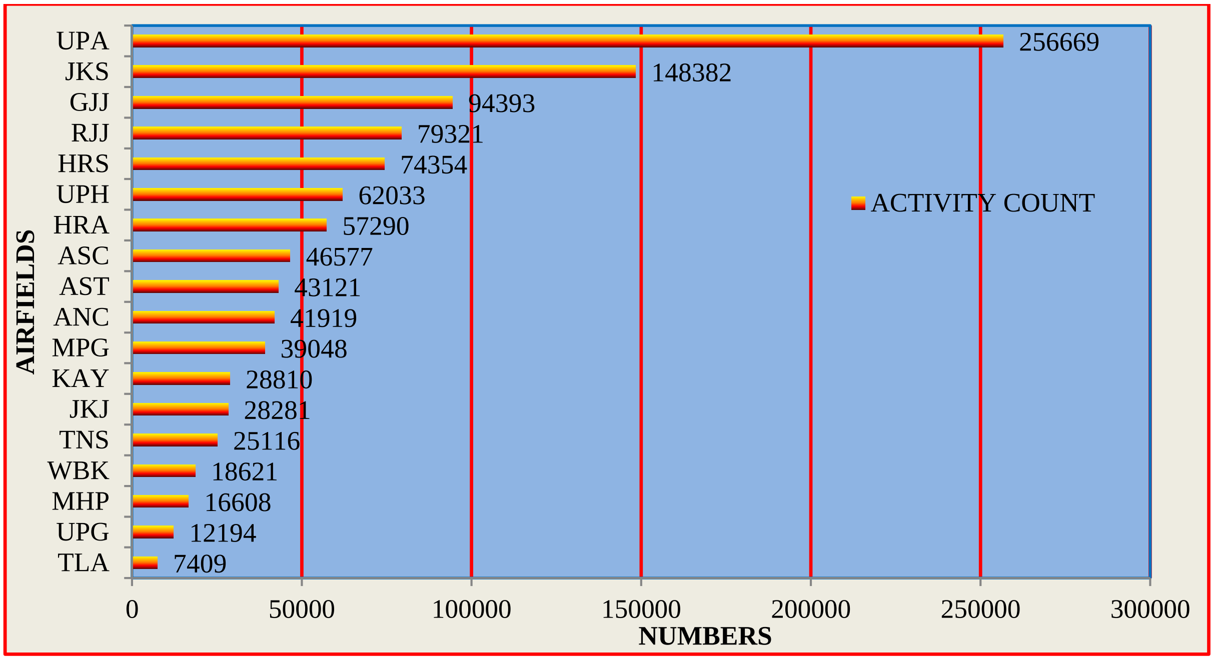


Figure 4.3. Activity counts of birds recorded at selected 18 airfields over 18months.

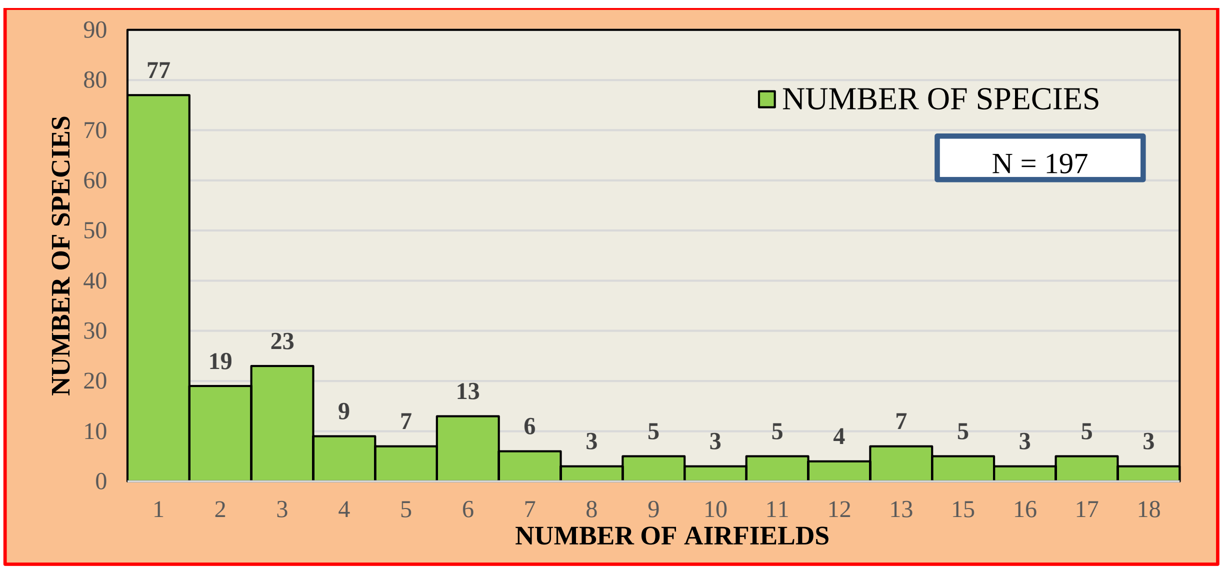


Figure 4.4. Frequency distribution of different bird species in different airfields.

Figure 4.4 shows the frequency distribution of different bird species in different airfields. Most of the birds species have a restricted distribution and only a very few species are spread out in all the airfields across country. Out of the 197 species that are recorded across 18 airfields, 77 species (39%) recorded only from one of the airfields. Just three species (House Crow, House Swift, and Cattle Egret) were recorded from all 18 airfields and five from 17 airfields.

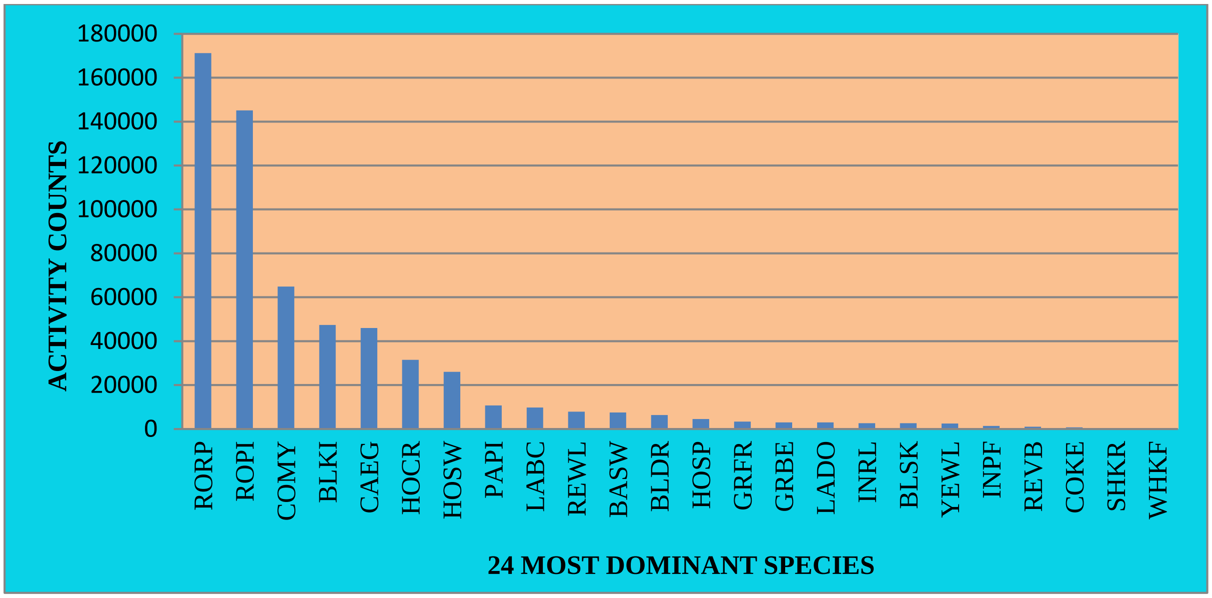


Figure 4.5. Levels of activity of major dominant species over airfields. (RORP- Rose-ringed Parakeet, ROPI-Rock Pigeon, COMY-Common Myna, BLKI- Black Kite, CAEG- cattle Egret, HOCR-House Crow, HOSW- House Swift, PAPI- Paddy-field Pipit, LABC- Large-billed Crow, REWL- Red-wattled Lapwing, BASW- Barn Swallow, BLDR- Black Drongo, HOSP- House Sparrow, GRFR- Grey Francolin, GRBE- Green Bee-eater, LADO- Laughing Dove, INRL- Indian Roller, BLSK- Black-shouldered Kited, YEWL- Yellow-wattled Lapwing, INPF-Indian Pea-fowl, REVB- Red-vented Bulbul, COKE- Common Kestrel, SHKR- Shikra and WHKF- White-throated Kingfisher)

Figure 4.5 shows the top 24 species in the combined activity counts of 18 airfields. Rose-ringed Parakeet, recorded maximum numbers and activity from Agra. The next species with highest activity is the Rock Pigeon. The level of activity of other species is comparatively much lower, relatively with less significant in the airfields. The top seven species together recorded up to 74.23% of the total activity. The top 25 species together contribute to more than 90 percent of the activity of birds in Indian airfields. This indicates that the levels of activity of other species at airfields are relatively negligible.

Most common birds of selected airfields are shown in Figure 4.6.

(a) Rose-ringed Parakeet-*Psittacula krameri*

(b) Rock Pigeon-*Columba livia*

(c) Common Myna- *Acridotheres tristis*

(d) Black Kite- *Milvus migrans*

(e) Cattle Egret - *Bubulcus ibis*

(f) House Crow- *Corvus splendens*

(g) House Swift- *Apus nipalensis*

(h) Paddy-field Pipit- *Anthus rufulus*

(i) Large-billed Crow- *Corvus macrorhynchos*

(j) Red-wattled Lapwing- *Vanellus indicus*

(k) Barn Swallow- *Hirundo rustica*

(l) Black Drongo- *Dicrurus macrocercus*

Figure 4.6. (a) to (l). Most dominant species of birds in selected airfields. (Photo credits are given in parenthesis).

Figure 4.7.shows the distribution of activity records along with the number of airfields they are present. The seven most widespread and abundant birds across the country are marked. Rose-ringed Parakeets and Rock Pigeons are highest in activity present in 17 airfields, and House Crows and Cattle Egrets, were present in all studied airfields.

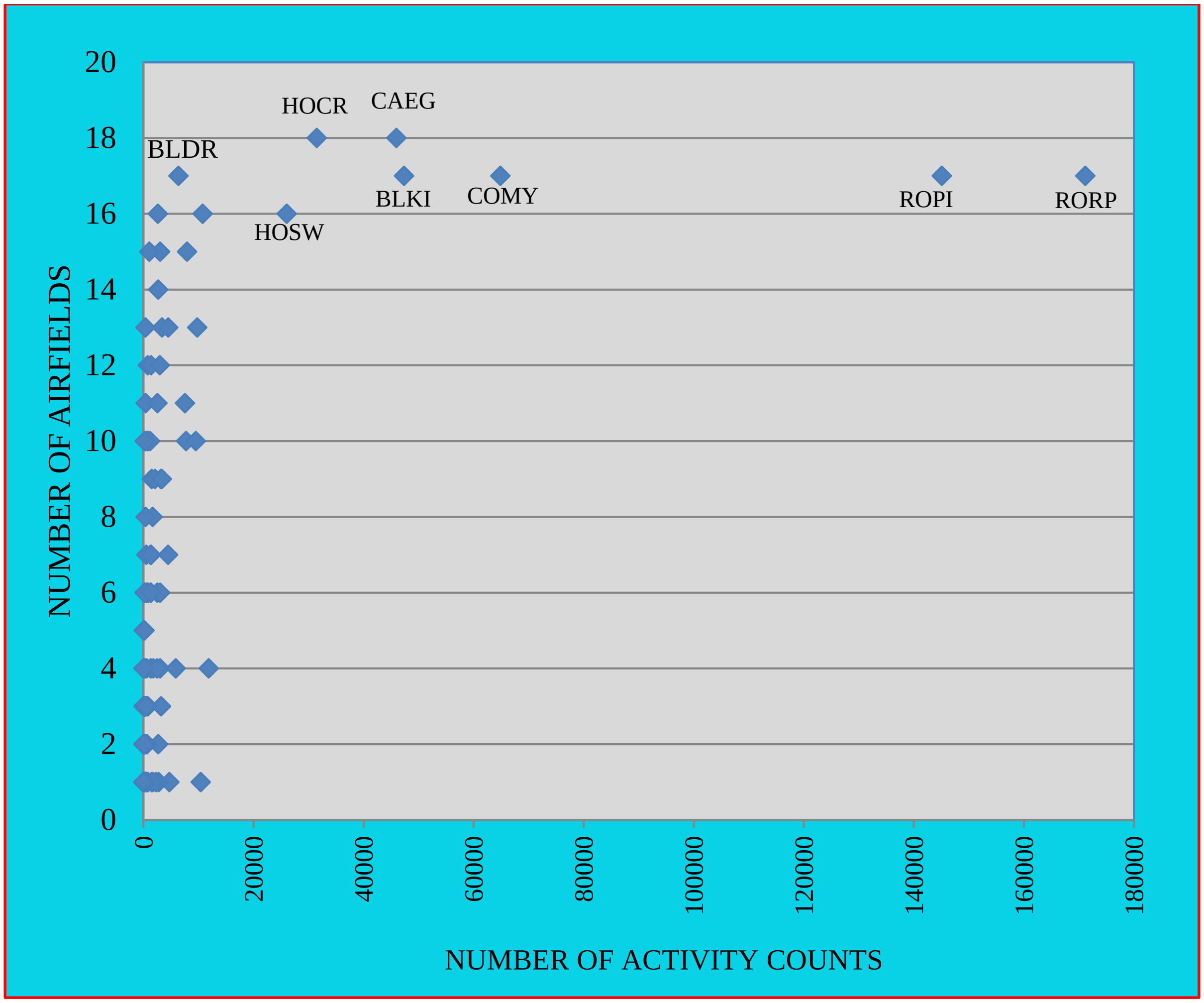


Figure 4.7. Combined levels of activity of each species spread over different airfields.

(RORP- Rose-ringed Parakeet, ROPI- Rock Pigeon, COMY- Common Myna, BLKI- Black Kite, CAEG- Cattle Egret, HOCR- House Crow, HOSW- House Swift, and BLDR- Black Drongo).

4.3.2. Taxonomic Composition

In the Order level analysis of the species observed over the airfield, the Passeriformes dominates the area/ airspace with 39% (Figure 4.7) of the total 21 Orders. Passerines, along with Charadriiformes contribute to 52% of the observations. The Accipitriformes, which includes the most of the diurnal raptors, which have contributed to some of the major losses in the Indian aviation industry through bird strike, has been recorded to be 9% of the total species. The order level comparison for activity counts is given in Figure 4.8.

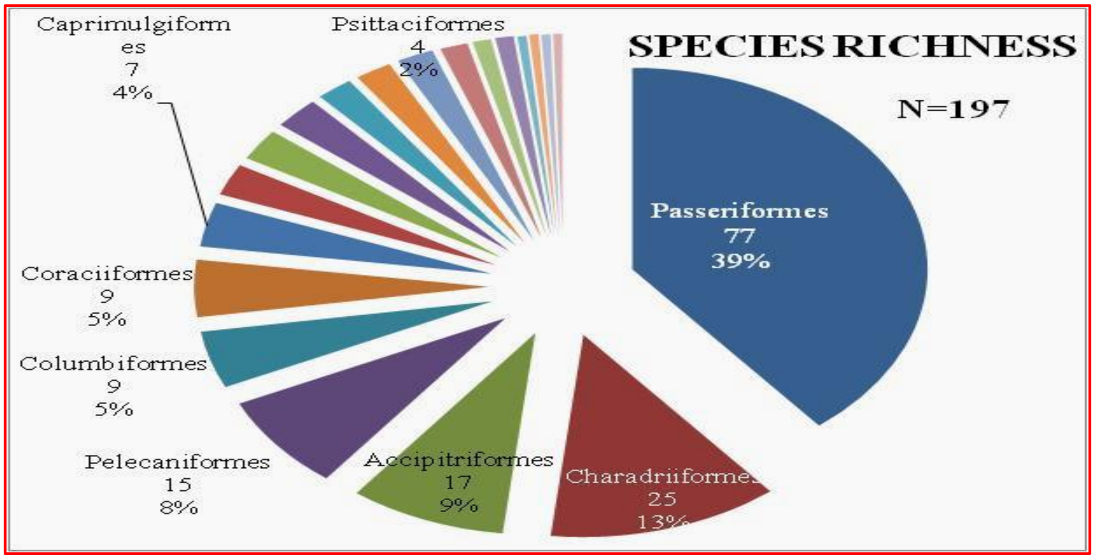


Figure 4.8(a). Percent of share of different Taxonomic Orders in the species richness at selected airfields.

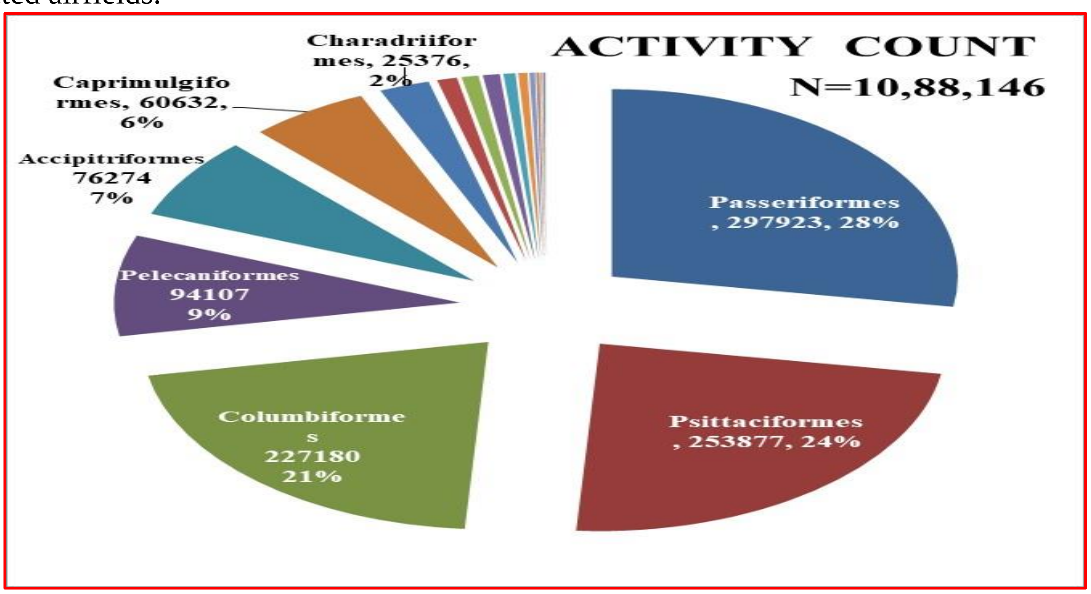
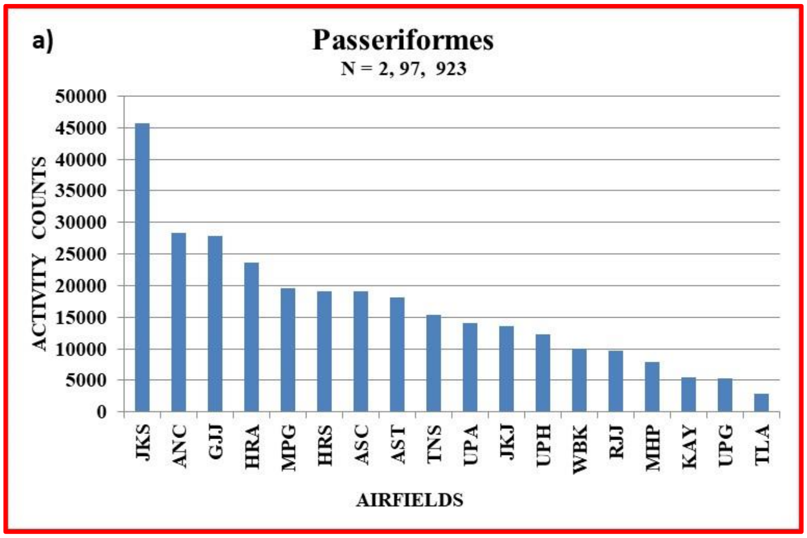
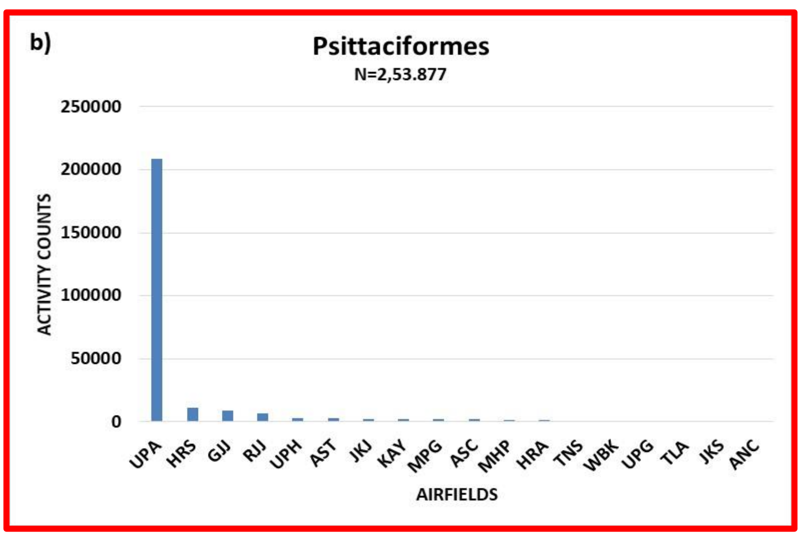
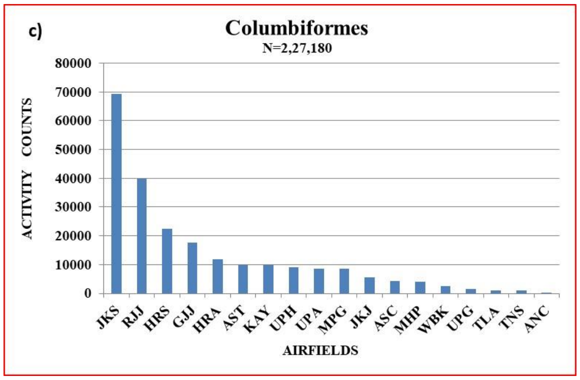


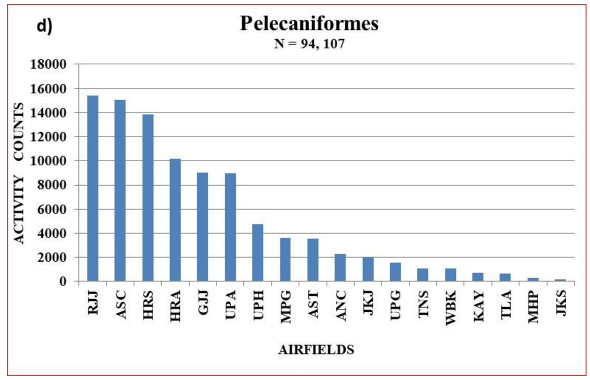
Figure 4.8 (b). Percent of share of species from each Order for the overall bird activity of selected airfields.

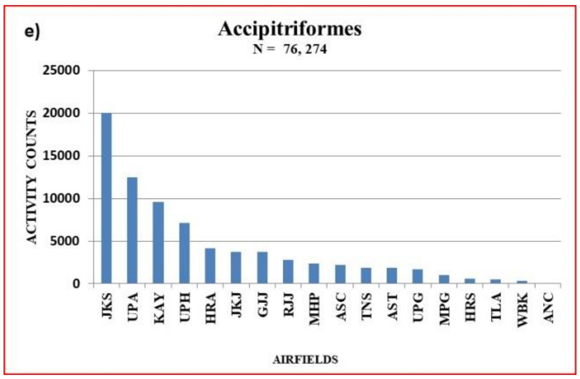
Figure 4.9(a) to (t) shows bird activity counts of different orders in different airfields. It is evident that different Orders are dominating in different locations. For example Psittaciformes was extremely dominant (mainly due to one species- Rose-ringed Parakeet) in UPA (Agra region). The Order Columbiformes has a more graded distribution at various airfields with highest activity at JKS followed by RJJ. Accipitriformes was highest at JKS and UPA . This is due to the Black Kites, an important bird strike potential species.

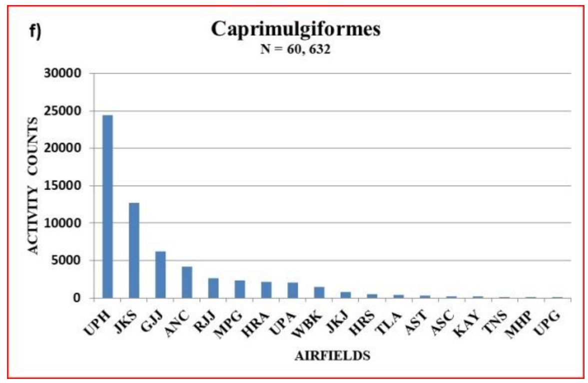


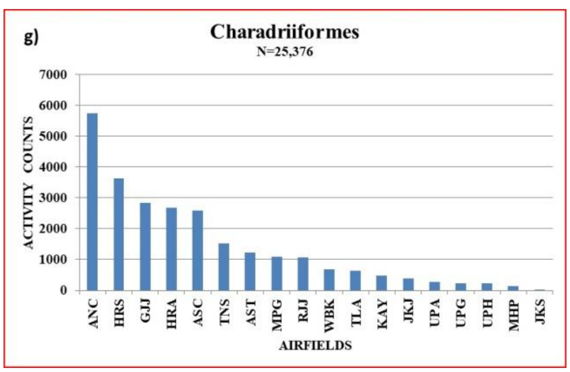


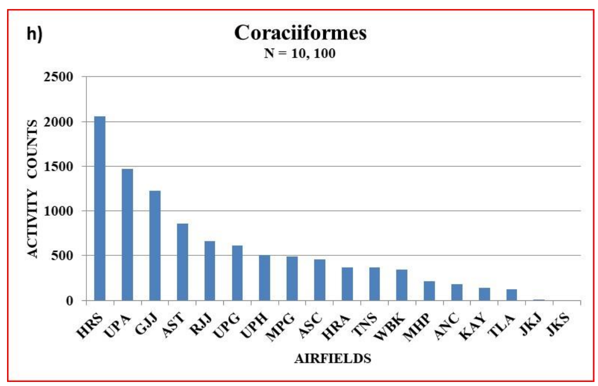

c)
Columbiformes
N=2,27,180
ACTIVITY COUNTS
0
10000
20000
30000
40000
50000
60000
70000
80000
JKS RJJ HRS GJJ HRA AST KAY UPH UPA MPG JKJ ASC MHP WBK UPG TLA TNS ANC
AIRFIELDS

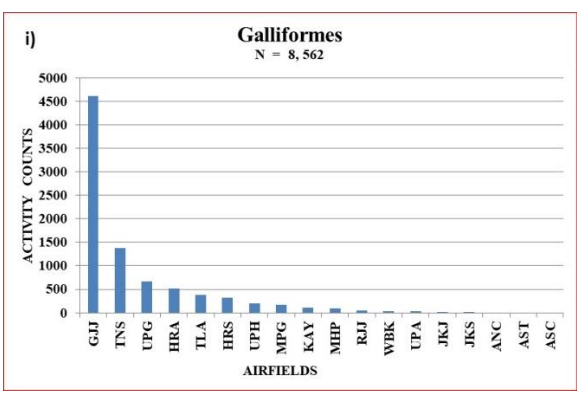

d)
Pelecaniformes
N = 94, 107
ACTIVITY COUNTS
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
RJJ ASC HRS HRA GJJ UPA UPH MPG AST ANC JKJ UPG TNS WBK KAY TLA MHP JKS
AIRFIELDS

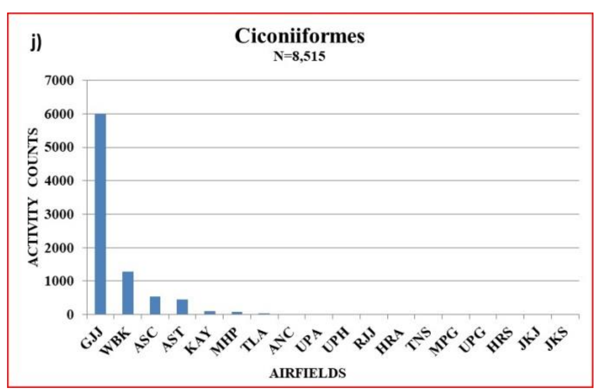

e)
Accipitriformes
N = 76, 274
ACTIVITY COUNTS
0
5000
10000
15000
20000
25000
JKS UPA KAY UPH HRA JKJ GJJ RJJ MHP ASC TNS AST UPG MPG HRS TLA WBK ANC
AIRFIELDS

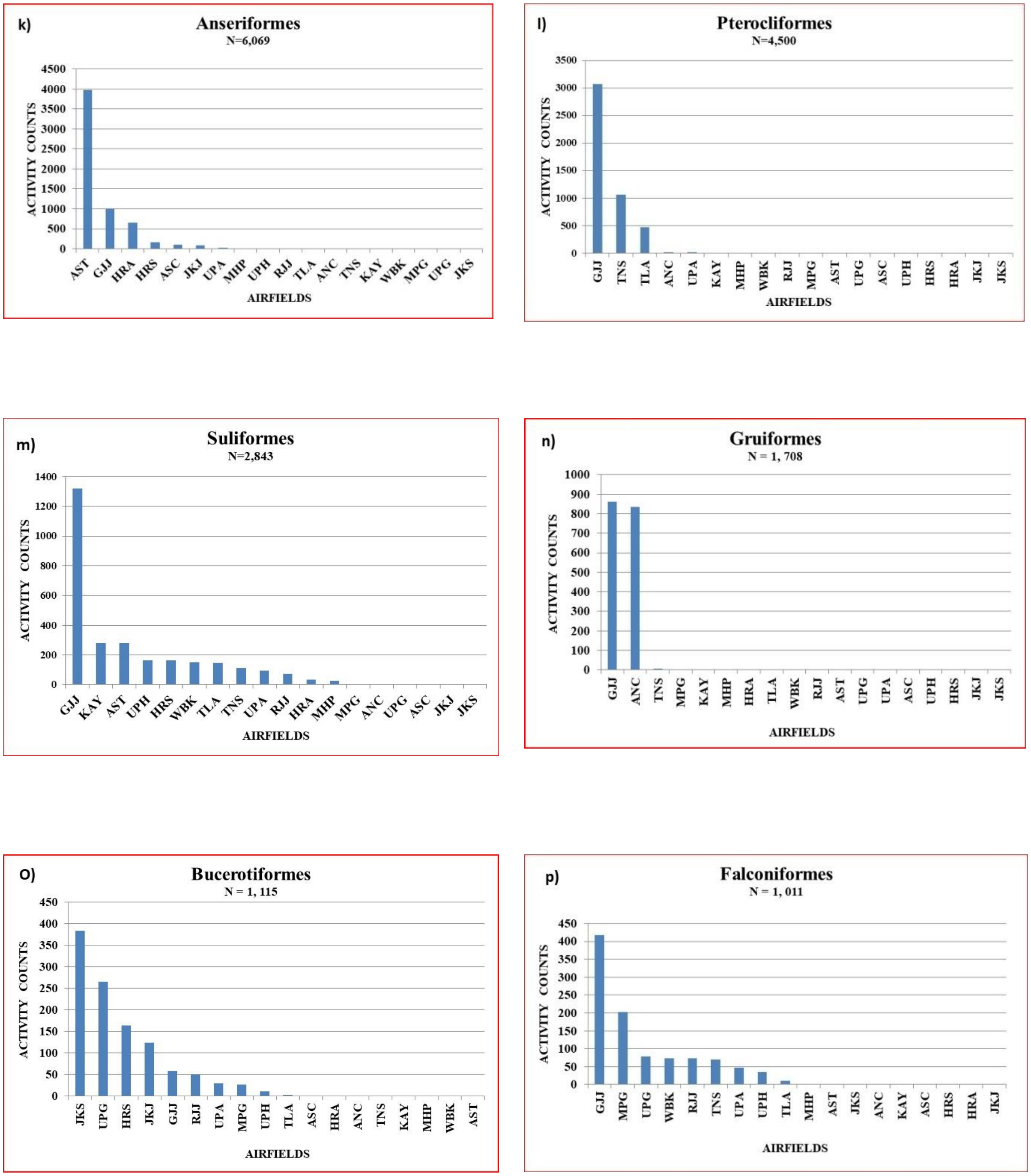

f)
Caprimulgiformes
N = 60, 632
ACTIVITY COUNTS
0
5000
10000
15000
20000
25000
30000
UPH JKS GJJ ANC RJJ MPG HRA UPA WBK JKJ HRS TLA AST ASC KAY TNS MHP UPG
AIRFIELDS


g)
Charadriiformes
N=25,376
ACTIVITY COUNTS
0
1000
2000
3000
4000
5000
6000
7000
ANC HRS GJJ HRA ASC TNS AST MPG RJJ WBK TLA KAY JKJ UPA UPG UPH MHP JKS
AIRFIELDS


h)
Coraciiformes
N = 10, 100
ACTIVITY COUNTS
0
500
1000
1500
2000
2500
HRS UPA GJJ AST RJJ UPG UPH MPG ASC HRA TNS WBK MHP ANC KAY TLA JKJ JKS
AIRFIELDS


i)
Galliformes
N = 8, 562
ACTIVITY COUNTS
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
GJJ TNS UPG HRA TLA HRS UPH MPG KAY MHP RJJ WBK UPA JKJ JKS ANC AST ASC
AIRFIELDS


j)
Ciconiiformes
N=8,515
ACTIVITY COUNTS
0
1000
2000
3000
4000
5000
6000
7000
GJJ WBK ASC AST KAY MHP TLA ANC UPA UPH RJJ HRA TNS MPG UPG HRS JKJ JKS
AIRFIELDS



k)
Anseriformes
N=6,069
ACTIVITY COUNTS
AIRFIELDS
AST GJJ HRA HRS ASC JKJ UPA MHP UPH RJJ TLA ANC TNS KAY WBK MPG UPG JKS
l)
Pterocliformes
N=4,500
ACTIVITY COUNTS
AIRFIELDS
GJJ TNS TLA ANC UPA KAY MHP WBK RJJ MPG AST UPG ASC UPH HRS HRA JKJ JKS
m)
Suliformes
N=2,843
ACTIVITY COUNTS
AIRFIELDS
GJJ KAY AST UPH HRS WBK TLA TNS UPA RJJ HRA MHP MPG ANC UPG ASC JKJ JKS
n)
Gruiformes
N = 1, 708
ACTIVITY COUNTS
AIRFIELDS
GJJ ANC TNS MPG KAY MHP HRA TLA WBK RJJ AST UPG UPA ASC UPH HRS JKJ JKS
O)
Bucerotiformes
N = 1, 115
ACTIVITY COUNTS
AIRFIELDS
JKS UPG HRS JKJ GJJ RJJ UPA MPG UPH TLA ASC HRA ANC TNS KAY MHP WBK AST
p)
Falconiformes
N = 1, 011
ACTIVITY COUNTS
AIRFIELDS
GJJ MPG UPG WBK RJJ TNS UPA UPH TLA MHP AST JKS ANC KAY ASC HRS HRA JKJ

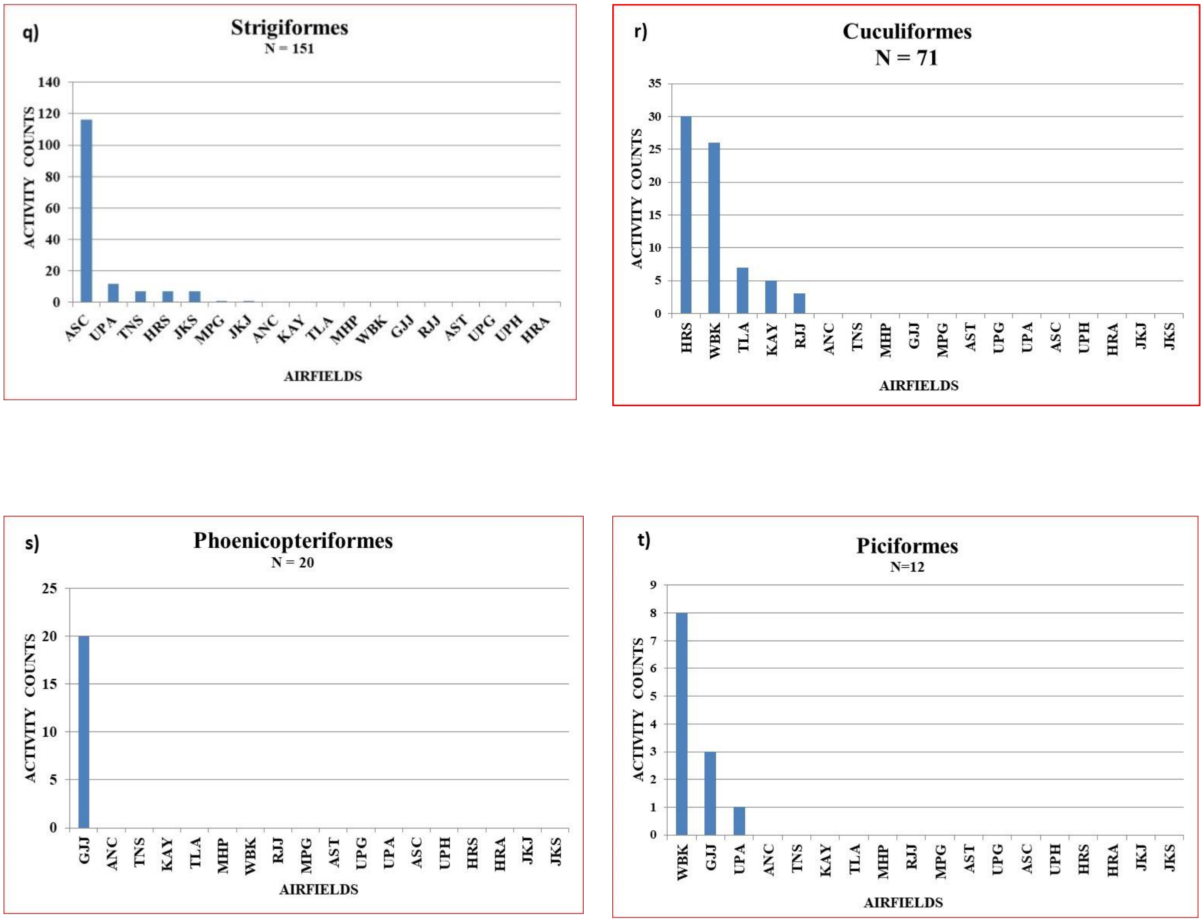


Figure 4.9 (a) to (t). Bird activity counts of different Orders over different airfields. (For airfield codes, refer Table 3.1).

4.3.3. Diversity and Bird Activity

Descriptive statistics of the bird activity counts are given in table 4.1. The mean activity at the airfields was highest at UPA (as expected) with 14,259.3 as against the lowest of 411.6 at TLA (Hyderabad). Huge variation in activity between months was observed in UPH, MHP, WBK and JKS (Standard Deviation) where as in the airfield such as GJJ, UPA, KAY, ANC and RJJ the extent of activity was more or less predictably stable.

Minimum activity per month was recorded at TLH (406) and highest Minimum activity was recorded at UPA (10,567). It is interesting to note that lowest recorded activity in 18 months at Agra is more than the total of 18 samples at TLA. These figures indicate the extreme variations of bird activity at different airfields. The lowest Maximum activity counts recorded was again at TLA with 829. The highest Maximum activity recorded was at JKS with 24,614 activities. The next Maximum activity recorded was at UPA (19,926).

Airfields	Mean	Stand. deviation	Min	Max	Coeff. variance	Variance	Std. error
ANC	2328.83	658.44	1456	4195	28.27	433554	155.19
TNS	1395.33	443.37	743	2155	31.77	196584.6	104.5
KAY	1600.55	372	1021	2341	23.24	138390.6	87.68
TLA	411.61	185.35	406	829	45.03	34354.6	43.68
MHP	922.66	859.19	526	2945	93.12	738224	202.51
WBK	1034.5	959.04	383	4332	92.7	919766.1	226.04
GJJ	5244.05	953.21	4163	7839	18.17	908620.1	224.67
RJJ	4406.72	1270.9	2309	6254	28.84	1615187	299.55
MPG	2169.33	753.28	318	3772	34.72	567438.2	177.55
AST	2395.61	1064.72	1035	4724	44.44	1133647	250.95
UPG	677.44	321.42	314	1346	47.44	103314.4	75.76
UPA	14259.39	2941.13	10567	19926	20.62	8650284	693.23
ASC	2587.61	883.78	1319	4116	34.15	781076.8	208.31
UPH	3446.27	3650.98	738	17077	105.94	13329710	860.54
HRS	4130.77	1549.8	2023	7395	37.51	2401903	365.29
HRA	3182.77	1437.92	1546	6110	45.17	2067625	338.92
JKJ	1571.16	769.4	664	2919	48.97	591980.9	181.35
JKS	8243.44	7246.23	2127	24614	87.9	52507860	1707.95

Table 4.1. Descriptive statistics of bird activity counts over different airfields.

The mean diversity of species recorded in an airfield per month (Table 4.2) ranges from 10.78 (JKS) to 35.89 (UPA). Variation of number of species recorded among the months is not very high in most of the airfield (Coefficient of Variation).

Sl No	Airfields	Mean	Stand. Deviation	Min	Max	Coeff. Var	Variance	Std. Error
1	ANC	23.72	4.47	16	29	18.84	19.98	1.05
2	TNS	18.39	4.37	12	26	23.75	19.08	1.03
3	KAY	20.44	3.68	14	29	18.01	13.56	0.87
4	TLA	21.39	10.59	12	39	49.53	112.25	2.50
5	MHP	12.83	11.27	10	29	87.84	127.09	2.66
6	WBK	25.28	3.92	20	33	15.52	15.39	0.92
7	GJJ	35.89	6.74	23	44	18.77	45.40	1.59
8	RJJ	22.44	4.31	15	29	19.22	18.61	1.02
9	MPG	27.06	4.96	19	38	18.35	24.64	1.17
10	AST	24.11	2.52	19	30	10.44	6.34	0.59
11	UPG	21.00	3.05	14	26	14.52	9.29	0.72
12	UPA	24.22	5.07	17	33	20.93	25.71	1.20
13	ASC	21.50	3.35	18	33	15.57	11.21	0.79
14	UPH	23.17	6.70	10	31	28.91	44.85	1.58
15	HRS	31.50	6.55	17	47	20.78	42.85	1.54
16	HRA	20.78	4.45	12	30	21.43	19.83	1.05
17	JKJ	14.17	2.79	10	19	19.71	7.79	0.66
18	JKS	10.78	2.58	5	15	23.93	6.65	0.61

Table 4.2. Descriptive statistics of bird species richness over different airfields.

Bird Community attributes are given in Table 4.3. All the parameters of diversity are high in GJJ (Jamnagar) very low in JKS. In UPA, dominance D value is high due to the extremely high activity of Rose-ringed Parakeets. Highest total activity counts was recorded at UPA (Agra) with 2,56,669 counts and least was recorded at TLA with 7,409 counts. In the measure of Dominance, UPA was found to have highest Dominance with 0.6656 indicating maximum contribution from a single species. On the other hand, least was observed at GJJ with a value of 0.0618. Simpson_1-D value was highest with 0.9382 indicating the even spread of species. Same was found to be least at Agra with 0.3344, recorded the least value. As expected the Shannon_H values for airfields was also ranged between GJJ airfield (3.222) and Agra (0.9147). Similarly the evenness (Evenness_e^H/S), ranged betweenTLA (0.4692) and UPA (0.0396).

Sl No	Airfield	Species Richness	Total activity	Dominance D	Simpson (1-D)	Shannon (H)	Evenness_ e^H/S
1	ANC	48	41919	0.17	0.82	2.26	0.19
2	TNS	40	25116	0.14	0.89	2.38	0.27
3	KAY	49	28810	0.23	0.76	1.93	0.14
4	TLA	47	7409	0.06	0.93	3.09	0.46
5	MHP	48	16608	0.14	0.85	2.31	0.21
6	WBK	50	18621	0.08	0.91	2.94	0.38
7	GJJ	83	94393	0.06	0.93	3.22	0.30
8	RJJ	51	79321	0.25	0.74	1.91	0.13
9	MPG	77	39048	0.10	0.89	2.68	0.19
10	AST	55	43121	0.12	0.87	2.45	0.21
11	UPG	44	12194	0.07	0.92	2.92	0.42
12	UPA	63	256669	0.66	0.33	0.91	0.03
13	ASC	44	46577	0.1763	0.82	2.25	0.21
14	UPH	53	62033	0.2035	0.79	2.08	0.15
15	HRS	67	74354	0.1447	0.85	2.55	0.19
16	HRA	44	57290	0.1179	0.88	2.46	0.26
17	JKJ	35	28281	0.09847	0.90	2.67	0.41
18	JKS	23	148382	0.2442	0.75	1.81	0.26

Table 4.3. Bird community attributes at various airfields.

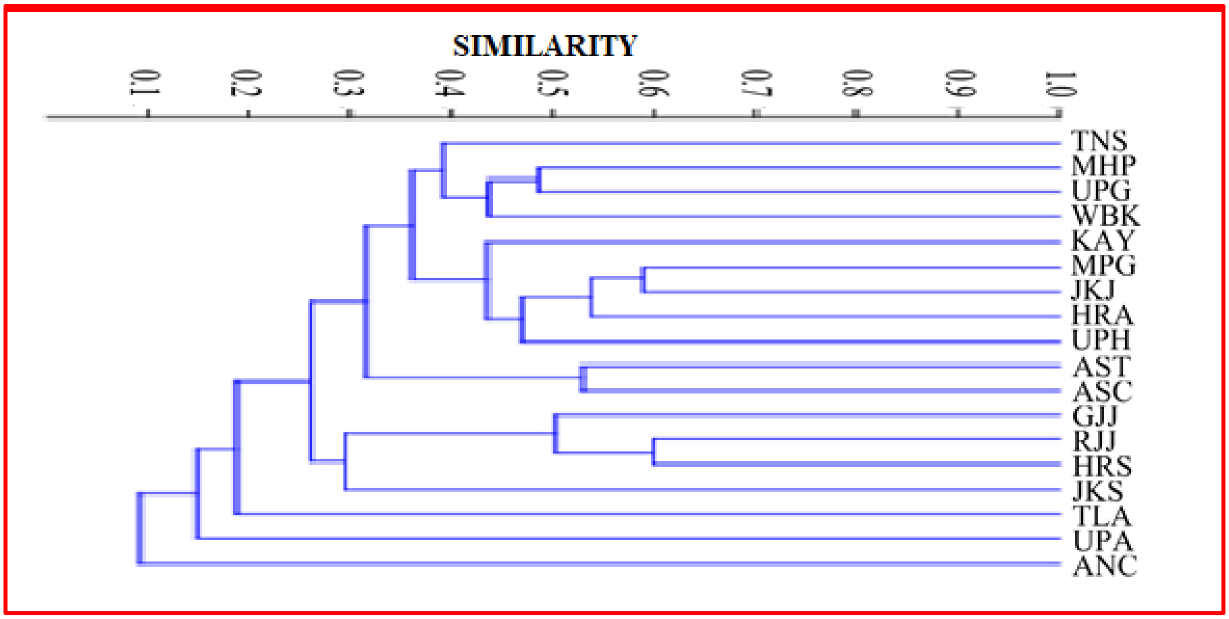


Figure 4.10. Similarity (Bray Curtis Cluster Analysis) between the bird communities of different airfields.

A Bray Curtis cluster analysis diagram (of similarity) between the bird communities between airfields is given in Figure 4.10. Bird community of Car Nicobar stands apart with least similarity with all other airfields. This is expected due to the island nature of the location. Some of the close clusters such as Tezpur- Chabua, Jodhpur-Sirsa, and Pune-Gwalior were due to the close geographical proximity and similar bio-geographical zones. However, even the closest clusters share only 50-60 percent of similarity in species composition.

Analysis of Similarity (ANOSIM) between various airfields (Bray Curtis) shows all the airfields are more dissimilar between themselves. The R values between all the pairs are significant (p value = 0.0001)(Table 4.4).

R values	CRN	TNS	KAY	TLA	MHP	WBK	GJJ	RJJ	MPG	AST	UPG	UPA	ASC	UPH	HRS	HRA	JKJ
TNS	0.754																
KAY	0.8464	0.8199															
TLA	0.7193	0.5589	0.9722														
MHP	0.6528	0.3085	0.6352	0.2754													
WBK	0.6302	0.3244	0.8022	0.4387	0.1343												
GJJ	0.8873	0.6323	0.5559	0.6639	0.5819	0.5879											
RJJ	0.7783	0.7164	0.6002	0.6927	0.6581	0.6785	0.461										
MPG	0.6021	0.3686	0.563	0.4931	0.2447	0.3281	0.4024	0.5716									
AST	0.674	0.3544	0.6523	0.8864	0.5152	0.8092	0.9484	0.99	0.8384								
UPG	0.9997	0.8874	0.9266	0.7697	0.3735	0.6895	0.9954	0.9993	0.7867	0.9118							
UPA	1	1	1	0.892	0.5469	0.9965	1	0.9999	0.9915	0.9998	1						
ASC	1	0.9837	0.9961	0.8919	0.5533	0.8785	0.9791	0.964	0.7926	0.6353	0.9571	1					
UPH	0.9946	0.8477	0.5799	0.8558	0.1939	0.7747	0.737	0.7768	0.3413	0.7394	0.7323	0.948	0.8283				
HRS	1	1	0.9717	0.892	0.5501	0.9649	0.8317	0.4405	0.8023	0.9889	0.9978	0.9999	0.9716	0.8353			
HRA	0.9988	0.9926	0.9263	0.8906	0.4172	0.8554	0.8488	0.7966	0.4187	0.8446	0.8742	1	0.8746	0.4801	0.8546		
JKJ	0.9782	0.8952	0.7567	0.873	0.2128	0.7456	0.9195	0.925	0.4084	0.9348	0.6454	0.9979	0.9489	0.4605	0.9267	0.5447	
JKS	1	0.9566	0.8051	0.892	0.469	0.9305	0.8479	0.6003	0.7874	0.9609	0.9883	0.9953	0.9647	0.6302	0.848	0.7859	0.8781

Table No. 4.4. Analysis of Similarity (ANOSIM) in bird composition between airfields using Bray-Curtis similarity index. (The pair-wise p value between all airfields is 0.0001).(Refer Table 3.1 for airfield codes).

4.3.4. Guild Composition

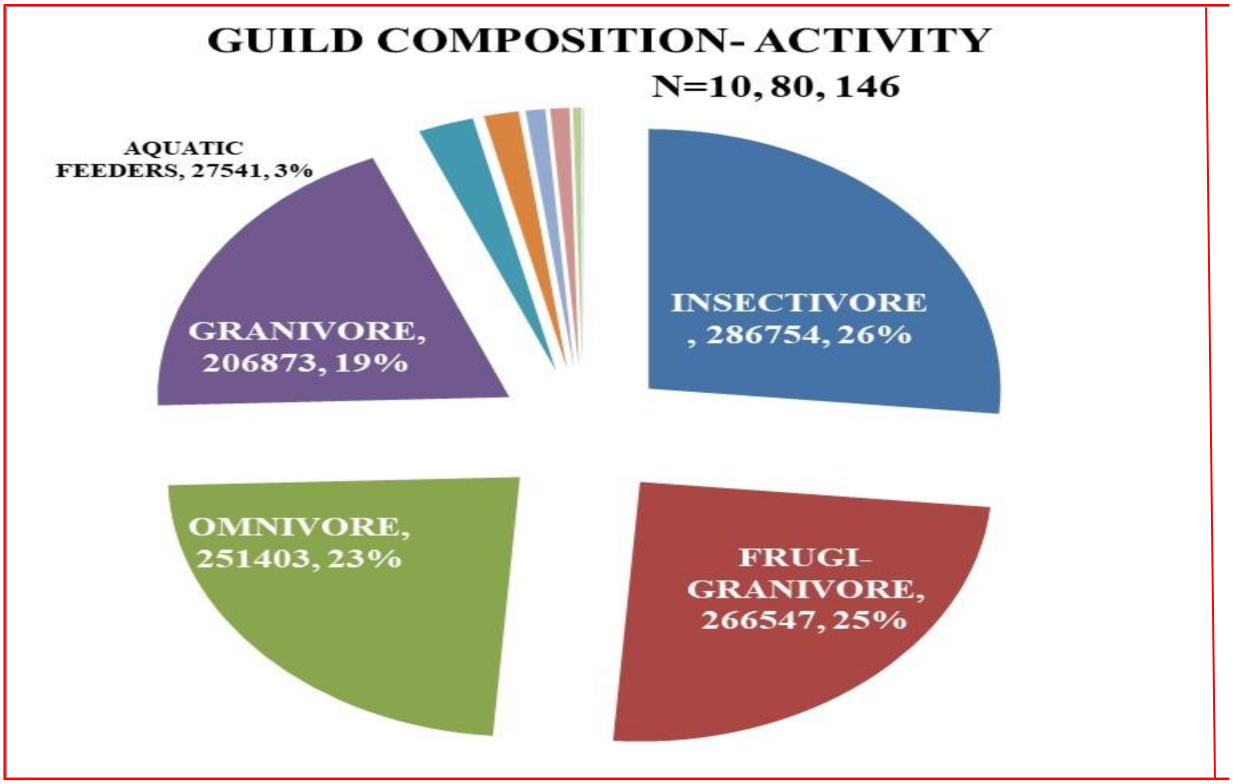


Figure 4.11. Share of activity by species of each Guild

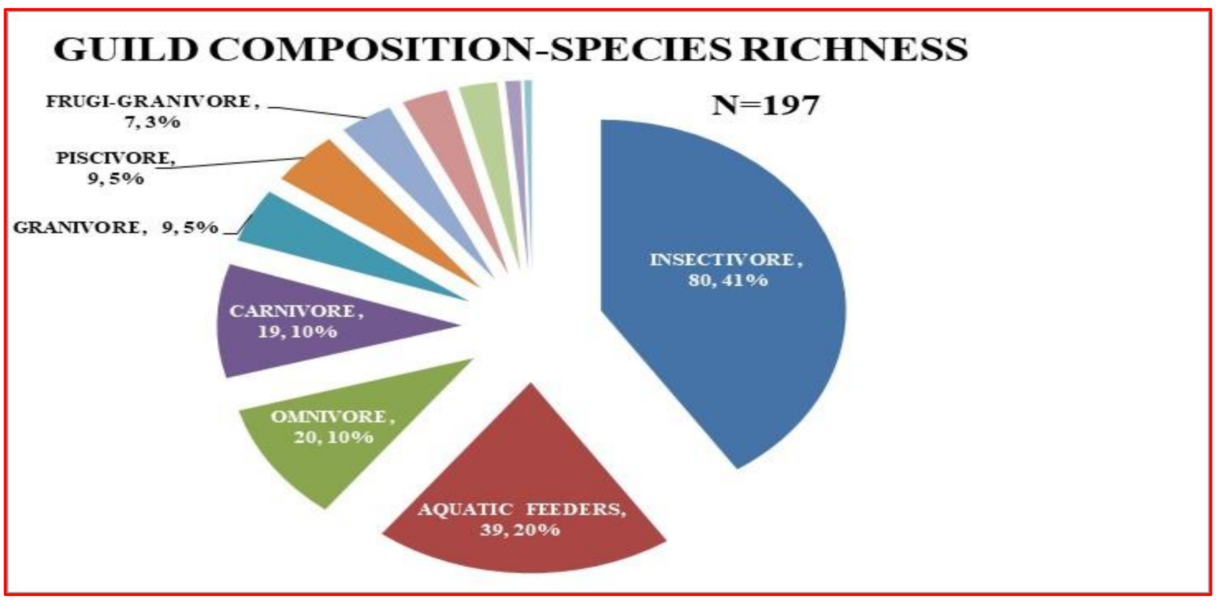


Figure 4.12. Share of species by species each Guild.

With regard to the feeding guild composition of the birds (activity and share of species) of Airfields, the data is shown in Figures 4.11 and 4.12. Insectivores dominate with 41% of the species, followed by aquatic feeders (20%), Omnivores (10%). carnivores (10%) and granivores (9%). These fivecategories contribute up to 90% of the species.

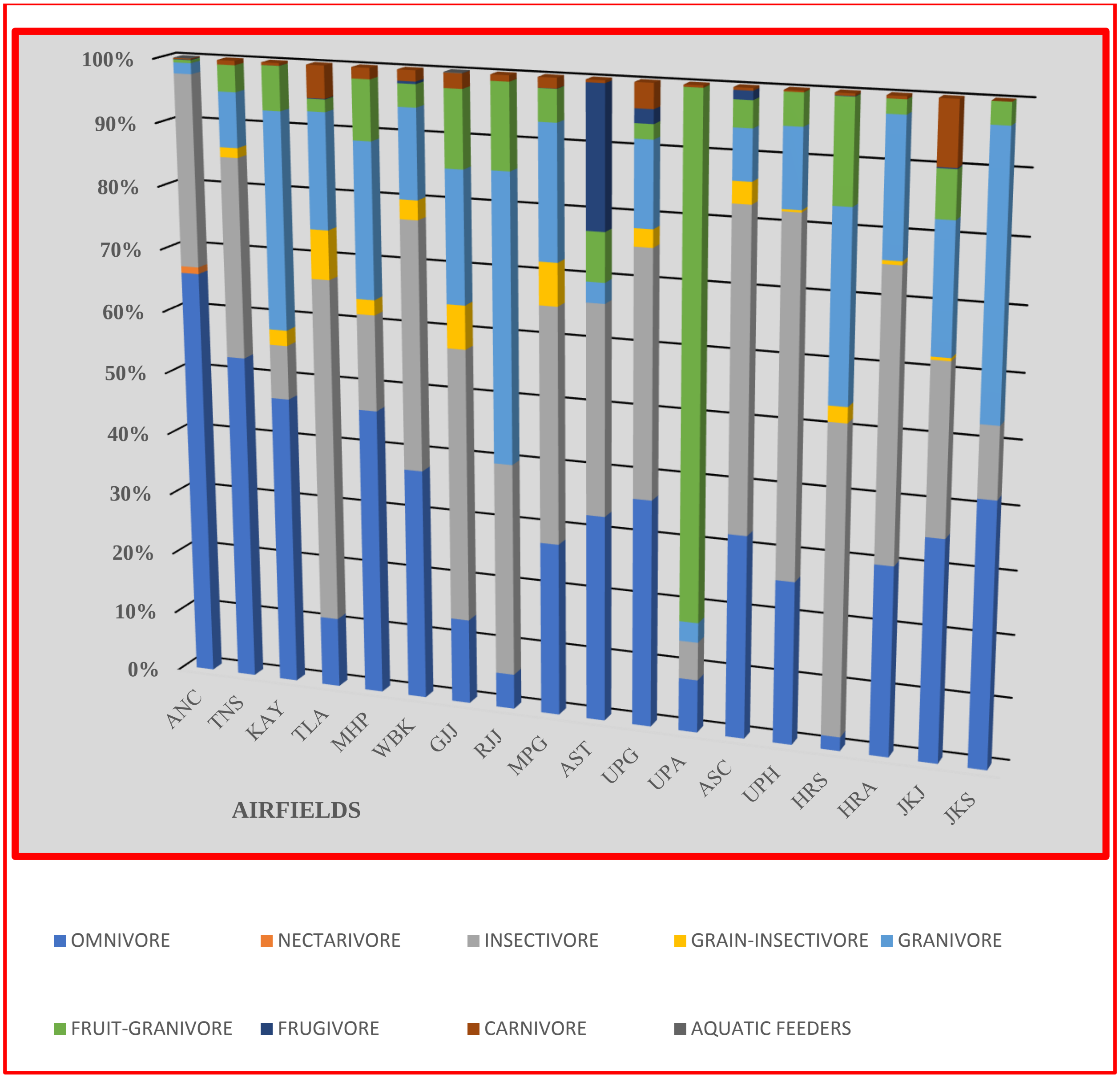


Figure 4.13. Percentage of species in various Guilds in different airfields.

Figure 4.13 gives the percentage comparison of activity counts of each Guild at all airfields. In general, insectivore, aquatic feeders, omnivore and granivore are dominating guilds. However, the variations in the percentage contribution of bird activity are evident in different airfields.

4.4. DISCUSSION

Considering the number of studies carried out with on bird communities at forests, wetlands and agricultural lands, studies on bird community of airfield is very limited. Among the available studies most of them have confined to counting of hazardous birds or to evaluation of modules at one specific airport. However, there are some studies that gives location specific data. A study at Vancouver Airport (Canada) (Halladay, 1968), at South African airports (Hauptfleisch, Avenant and Tsowaseb, 2013) and a detailed study at Namibian airport (Dukiya and Gahlot, 2012) have presented some bird community information. The studies of Indian airfields by BNHS (from 1980-88) recorded the species observed and average numbers of hazardous birds (Grubh, 1989). Few other studies (Kanwal *et al*, 2015) have recorded the bird communities in basic formats. A recent baseline survey of birds carried out by BNHS for the proposed Navi Mumbai International Airport site documents the bird communities well over five years (Narwade *et al*, 2017). A detailed study of airports that was carried out recently (Pramod and Karunakaran, 2020a) has recorded the bird communities at Coimbatore, Ahmadabad and Kannur airports. This study has brought out some characteristics of bird communities in the airport environment.

Each airfield is a grassland environment, actively managed by humans for the purpose of flight operations. Any terrestrial environment; will attract the organisms adapted to that specific environment. Flights, the airborne machines are in constant conflict with the naturally airborne creatures such as birds. Grassland ecosystems will have its own adapted bird community along with the associated and passerby visitors. Apart from the environment created within the airfield, the surroundings of the airfield are also a contributor to the type of bird ecology and levels of bird activity. Understanding the total bird community, its taxonomic structure, ecological composition, etc., is critical to understand the conflict in depth. This study shows the species diversity, guild composition and activity counts of birds in 18 airfields in India. Of the 197 species identified from IAF airfields across the country, only a very few of them are known to be causing bird strikes across the country. The problematic species in many of the different airfields are different and hence the same strategy of mitigation measures may not work everywhere.

4.4.1. Taxonomic Composition

A combined data of activities over airfields brought out that Passeriformes contributes the greatest number of species with 39% of the species. This Order is the most specious order in any terrestrial environment. Hence, the higher presence of this Order is an expected result. However, when the activity was accounted for, their activity contribution came down to 28% indicating that the members from other Orders tend to be more active over the airfields. The activity of Passerines is contributed mainly by Common Myna (and other related Starling species) and House Crows (and other Corvids) in most airfields.

The second largest Order in terms of species contribution is the Chadriiformes, with 25 species (13%). This may be due to the presence of wetlands in the vicinity of many airfields and the grassland ecosystem of the airfield itself. Just like the Passeriformes, despite a large number of species, their activity comes down to 2%. This again is mostly attributable to the increased contribution from the members of other Orders to the activity.

The third and fourth largest Orders by species are Accipitriformes and Pelecaniformes with 17 and 15 species (8 and 7%) respectively. They contribute to overall activity by7 and 9% respectively. This is considered a fair representation both by species numbers and overall activity. The number of species from other orders becomes low after these four orders.

Two orders which are not significant by the number of species, but significant by their activity counts are Columbiformes (9 species, 5%) and Psittaciformes (4 species, 2%). Though, these orders are represented by small number by species, they contribute 21% and 24% respectively of the overall activity of the birds of the airfields. The increasing number of pigeons has been a generally observed phenomenon across many cities in the recent past. Multiple factors like availability of suitable microhabitats (high rise buildings with gaps for roosting), feeding of birds as a cultural practice, and ease of making them pet coupled with its ability to breed throughout the year has been the cause for the growth in their activity. The airfield environment with large hangars, high raised safe places for nesting and roosting along with agricultural areas in the vicinity has also helped them to grow in numbers.

The large activity count of Psittaciformes is contributed by the phenomenal numbers of Rose-ringed Parakeets at a single airfield, UPA. It is important to note that they were observed to be highly active in the past record as well from 1980 to 1988 (Grubh, 1989). However, as the numbers were not recorded precisely, it is difficult to infer whether the activity has increased or decreased. The precise ecological factor for this long standing phenomenon needs further investigation.

4.4.2. Guild Composition

The analysis of Guild composition based on activity counts clearly indicates that insectivore birds dominate the airfield. This is contributed by Lapwings, House Swifts, Cattle Egrets, Black Drongos, and Barn Swallows. The next domination of Frugi-granivore was mainly contributed by the Rose-ringed Parakeets of Agra. This domination of parakeets was not recorded from any other airfield, though their numbers are observed to match the numbers of pigeons at some airfields like Sulur. The omnivore activity (24%) was mainly contributed by House Crows, Black Kites, and Common Mynas which are seen in most of the airfields with varying levels of activity counts. The Granivore activity was also considerable at 19%. This was mainly contributed by the Larks and Pipits which generally observed active on the shoulders of runway. About 3% (Aquatic feeders) activity has been recorded. This was due to birds which are active over the coastal airfields and those which were observed at airfields located near large wetlands. There is a specific contribution of Lesser-whistling Ducks (3,972 activity counts) at Tezpur in this category. This is also a rare observation unique to that airfield. Specific abundance of the species in the region and the types of wetlands around it contribute for their activity counts. The Carnivore activity counts stands at 1%. This being at the top of the food pyramid, such small numbers are expected. In fact, their activity is supported by some of the extreme numbers of Brahminy Kite at Jammu.

Percentage comparison of activity counts of Guild partners vary between the airfields. The variations in the percentage contribution of bird activity of different airfields highlight the local specific reasons of domination of activities of different species of birds.

4.4.3. Birds of Airport Habitat

An overview of combined data from all airports gives a view of the characteristic birds of the airport environment across the country. As already mentioned, the highest activity counts are contributed by Rose-ringed Parakeets and Rock Pigeons. They have the ubiquitous presence as well. While Parakeet activity was unusually high in Agra, the activity of the pigeons is well spread, making notable high numbers at extreme places like RJJ (Jodhpur) and JKS (Srinagar). The next set of high activity counts were by four species namely Common Myna, Cattle Egret, Black Kite and House Swift. It May be noted that the top seven species together contribute to 74.23% of the total activity and the top 25 species together contribute to more than 90 percent of the activity of birds in Indian airfields

Activity counts of birds of specific interest such as Red-wattled Lapwings (due to involvement in large number of bird strike incidents) were observed to be high. Being birds of grassland/open land, they use the airfield for breeding. Their constant presence, (especially during the breeding and post breeding season) leads to enhanced hazard. The other two species, Barn Swallows and Red-rumped Swallows with higher counts have a different reason to be high as they pass over the airfield in flocks. There are some birds with high activity records but limited to one airfield. For example, The Eurasian Jackdaw, Yellow-footed Green Pigeon and Asian Glossy Starling are mainly recorded only in Srinagar, Tezpur and Car-Nicobar respectively. Black Drongo and Zitting Cisticola were also are reasonably high in activity counts, but were also more evenly spread among many airfields. The rest of the 173 species have activity counts recorded less than 5,000.

4.4.4. Similarity of Bird Communities in Between Airfields

Similarity of Community by species composition reveals the influence of biogeographic zone in the clustering exercise. The hierarchical cluster analysis (Figure 4.10-dendrogram) separates the ANC airfield completely apart from all other airfield bird composition with relatively very small similarities. This is mainly due to its unique bio-geographic location in comparison with other airfields. AST and ASC shared quite an amount of similar communities due to geographic proximity in North Eastern region of India. A similar trend was seen between Jodhpur and Sirsa, as both are at the edges of the arid / desert biome. TLA and WBK also had better similarities inthe bird community, probably due to their latitudinal congruence.

4.4.5. Community Parameters.

Various Community parameters of the different airports show the bird community of all the airports are apparently different. Species richness and diversity (Shannon and Simpson indices) were highest in GJJ. The Jamnagar area boasts itself to be a Bird Watchers haven due to the presence of a large number of wetlands in the region and the unique location of being at the entry point of many migratory species movements to India. The variety of species (in small numbers) at MPG is a unique phenomenon that needs to be studied separately. JKS recorded the least species richness. This may be due to the limited number of species that are available in the landscape due to the extreme weather and altitude. However, a smaller number of species have well adapted to the conditions and they record in phenomenal numbers.

The highest activity counts in the total data was by Rose-ringed Parakeets recorded at Agra (to the tune of nearly 2 lakhs). The total records of Rock Pigeon are also very high but from multiple airfields. The high level activity of Yellow-footed Green Pigeon at AST is a special case. The important Order from the view of losses due to bird strike is Accipitriformes. Unusual high activity count of Black Kite at JKS (Srinagar) is notable for a different reason- the long distance migration.

4.4.6. Presence of the Same Species at Multiple Airfields

The Rock Pigeons and Rose-ringed Parakeets from 17 airfields mark phenomenal numbers. While Rock-Pigeons mark the successful adaptation to changing environment and exploitation of man-made ecology through culture or otherwise across the country, Parakeets make a mark with the other extreme of exploiting one location which can match the numbers in whole of the country. It is pertinent to note that all the parakeets counted were rarely repeated, the Pigeons were counted multiple times (generally twice a day- once in the morning and once in the evening). This indicated the phenomenal population which is exploiting the ecology in an extreme manner by staying there in large numbers for more than four decades. Common Myna, although less figured in the extremes discussed so far, stands at third highest. Black Kite and Cattle Egrets recorded similar number of activity, though Egrets were found in ANC as well, whereas Kites were not recorded. House Crow is another bird which was recorded at all airfields, with slightly lesser numbers. House Swifts, recorded at 16 airfields also contribute in considerable numbers.

5. ECOLOGY OF BIRDS AND BIRD HAZARDS TO AIRCRAFT

5.1. INTRODUCTION

The first aircraft fatality that can be directly attributed to a bird occurred in 1912 when a gull (*Larus* sp.) was caught in the control cables of a plane, causing it to crash (and Gahlot, 2013). Since that time, aircraft have been developed which are larger and faster. In addition, their frequency of movements has increased greatly. Consequently, the number of bird collisions with aircraft has escalated dramatically (Sayed, 2019). Globally, the problem is growing almost exponentially. As per the International Civil Aviation Organization reports [Anonymous (ICAO), 2009 and Anonymous (ICAO), 2017b) on Bird/wildlife strikes, the number of wildlife strikes increased from 42,508 (for the period 2001-2007) to 97,751 (for the period 2008-2015) registering nearly 130% growth. The serious damages increased from 3 to 17 in the same periods highlighting the seriousness of the problem.

In the Indian context, the problem of Bird Strike has been growing steadily both due to the increase in the aircraft movements and change in the environment. In the recent past, the Indian Air Force lost a fighter aircraft (with fatal injuries to pilot) in 2014 in Kashmir area (May 2014), a maritime operations aircraft in Haryana (Jan 2016) and another fighter aircraft at Bikaner sector (Mar 2019). In addition, a Naval trainer aircraft crashed near Goa (Nov 2019). All crashes are generally made public on the Press Information Bureau (PIB) website- www.pib.gov.in [Anonymous (PIB), 2021e]. The residents of Ambala had a great escape when a Jaguar aircraft dropped its external fuel tanks leading to a huge fire after one of its engines failed due to Pigeons ingestion during the take-off(Jun 2019)[Anonymous (IAF Twitter handle), 2019a].

Considering the magnitude of the problem, numerous studies have been conducted by different countries to understand the problem and find solutions from different perspectives namely- engineering, ecological, administrative, and economic. One of the obvious ways is to study the number of collisions, identify the species involved and then study the ecology of those hazardous birds.

The following research questions are attempted to be answered in this chapter:-

1. What are the trends and the extent of total bird strike incidents and incidents leading to damage in the Indian aviation sector?
2. What is the historical trend in the bird strike incidents in India?
3. What are the critical species involved in bird strikes in different time periods with their percentage of contribution to overall wildlife strikes and the damage to aircraft?
4. Are there any seasonal changes in the population of the critically hazardous bird species within a year and between the years? If so, what are the changes?
5. How the population of the critically hazardous bird species change between the studied locations?

5.2. METHODS

To study the extent and the trends of bird hazards in Indian airfields and the contribution of major hazardous species the following approach is adopted. First, Bird strikes in India were assessed based on the available secondary literature and major hazardous species were identified (by numbers and by the extent of damage caused). Then the primary data collected through the present study on these target species, their population patterns and trends were analysed in space and time in comparison with the available historic data.

5.2.1. Bird Strike Information

Bird strike Information was sourced from both published literature and the official records of IAF. Past information from 1966 to 1989 was taken primarily from published literature such as journal papers and Ph.D. theses. This includes the data from both civil and Air Force airfields. Information on the Bird Strike from 1993 to 2018 used in this analysis was mainly from IAF airfields.

With regard to the data accessed from IAF records, the species data is based on carcass identification as well as DNA barcoding data built up by IAF. The total number of Bird Strike in a year for IAF is a ‘Confidential’ data and the same is not used here. Only the data of the bird strike in which species has been identified is used in this study. Information on bird strikes to civil aircraft for the period from 2010 to 2018 was requested and collected from the Director General – Civil Aviation office [Office of Director Operations (Air safety)], through official channels. In addition, Safety Reports and records of Parliament proceedings where information was given to the House were also considered.

Within this thesis, the term 'incident' is used when strike results in negligible or no damage. The term 'accident' is used when the repair cost of the damage exceeds the 10% of the original cost of the aircraft.

5.2.2. Airfield Bird Activity

Data of airfield bird activity and ecology used in this analysis comes from three sources, one primary data and two from secondary sources. The method of primary data collection from 2019 to 2020 has been explained in the previous chapter (Section- 4.2.1). It involved monthly observation of bird species and their activity counts from sunrise to sunset through the constant observation during the day from one location. The data of the hazardous species such as kites, pigeons and lapwings were extracted from the total data pool for the focused analysis.

The other set of secondary data was collected from the records of Ornithology Cell which had been collected using the same technique in those airfields during the period between 2008 and 2019. Another set of secondary data comes from previous study reports of other agencies (Grubh, 1989).

5.2.3. Comparison and Analysis

Analyses have been carried out for three periods. The periods were identified based on the availability of data past data. The information on bird strike was available for the period between 1966 and 1988 from the published literature. The next two periods were from 1993 to 2009 and 2010 to 2018. The data was available from Indian Air Force records. In IAF, species identification was done through carcass identification by airfield staff and in addition, species identification was done through DNA Barcoding technology with the help of various labs in the country.

The following analyses have been carried out for the understanding of the growing nature of the problem, extent of damage and changes in the species involved in various periods:-

(a) General comparison of Bird Strike, fatalities and number of species involved in three periods

(b) Number of incidents involving major species and changes in their percentage of contribution in different periods.

(c) Comparison of the number of species involved in damage causing incidents and fatalities.

(d) Analyses of location of bird strike by classifying them in to three categories namely ‘Within Sanitized zone’ (area where dedicated personnel are deployed for observing, reporting and scaring away the birds- mainly constituting the runway area), ‘Outside the sanitized zone’ and at ‘unknown location’.

5.3. RESULTS

5.3.1. Extent of Bird Strike Incidents and Damages

Table 5.1 lists the recent information (from 2010 to 2017) of the bird strike from civil aerodromes of India with percent of damage per year for nine years. The number of bird strikes which leads to damage is generally around 12 percent of the total strikes.

Year	Reported bird strike*	Damaging incidents	Percentage of damaging incidents
2010	380	N/A	-
2011	621	N/A	-
2012	607	72	11.86
2013	736	71	9.6
2014	719	95	13.21
2015	764	66	8.63
2016	839	129	15.37
2017	1125	150	13.33
2018	1244	124	9.96
Total	**7035**	**707**	**11.71****

*Includes Bats and other wildlife strikes.
** For the period 2012-2018.

Table 5.1. Data of reported bird strikes in Indian civil aerodromes. (Courtesy: DGCA, India)

The recent trends in the number of bird strike incidents and strikes leading to damage in Indian civil aviation is depicted in the form of a graph in Figure 5.1. Both of them show a steady increase in these years. The exponential growth of the civil aviation sector witnessed in the recent past may be one of the reasons. While the numbers are increasing, the industry has ensured the safety of passengers through various means and ensured that the rate of bird strikes is well within the safety limits prescribed internationally. But concerns raise high, due to exorbitant costs of damage, indirect costs and operational restrictions caused by these incidents.

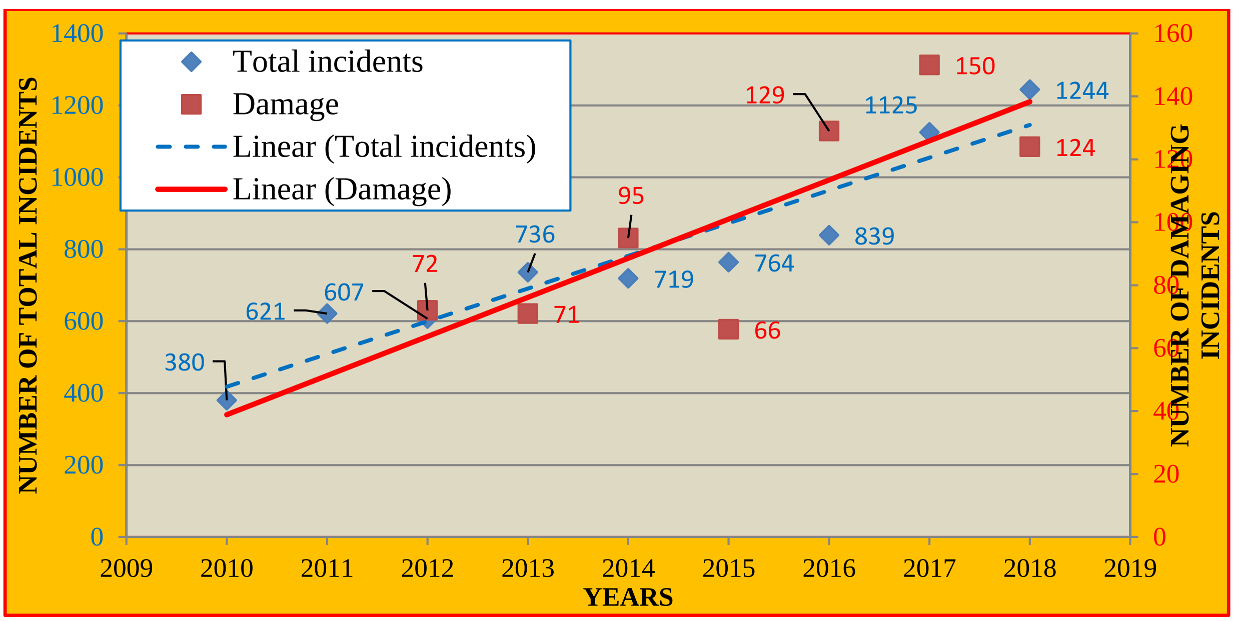


Figure 5.1.Trends in reported total incidents of bird strikes and the strikes leading to damage in Indian civil aviation.

5.3.2. Damages Caused and the Species Involved Over Different Periods

The numbers of bird strikes in which species were identified; number of species involved and other associated data in the three time periods are given in Table 5.2.

	1970-1988 (Civil &Military)	**1993-2009** (IAF)	**2010-2018**^ (IAF)
Number of bird strike reported	1,228*****	Not given	Not given
Average annual number of bird strike reported	53.39	Not given	Not given
Crashes / major damage to aircraft	50 (IAF)+ 1(Civil)	17	3
Annual average of Cat I accidents (crashes)	2.21	1	0.33
Crashes with fatal injuries(All IAF)$	7	5	1
Number of bird strike incidents considered / samples in which species identified (n)	360****** (1966-1989)	200	502
Average number of incidents in which species was identified per year for the time period	15.65	11.76	55.77
Number of species identified(Birds + Bats)	67 Birds + 03 Bats	76 Bird +05 Ground mammals	115 birds+ 12 Bat + 03 insect + 06 ground mammals

*Minimum numbers. Data compiled from different sources.

** Species identification data has been taken from a doctoral thesis (Satheesan, 1990).

^ Financial years from 2010-11 to 2018-19 data is taken.

$ In addition, at least eleven people died on ground in 1990 when an IAF aircraft crashed.

Table 5.2. Bird strikes and associated data for different time periods between 1970 and 2018.

The Table shows that the average number of crashes per year due to bird strikes in India have reduced from 2.21 in the past to 0.33 in recent times. There is a reduction in fatal injuries as well. On the other hand, species identification has progressed well and there is a marked increase in number of species identified.

5.3.3. Damage Causing Bird Species and Extent of Damage

The list of critical species identified in birdstrikes with their contribution to the overall bird strike (in which species is identified) is given in Table 5.3.

Species	**Period 1966-1989 (n_1=360)**		**Period- 1993-2009 (n_2=192)**		**Period- 2010-18 (n_3=489)**	
	Number	**%**	**Number**	**%**	**Number**	**%**
Black Kite	73	20.28	16	8.33	77	15.74
Vultures (03 sp.)	78	21.67	3	1.56	04	0.8
Bat (03 Species)	5	1.78	10	5.20	62	12.67
Cattle Egret	4	1.11	8	4.16	20	4.09
Swallows	1	0.28	08	4.16	54	11.04
Swifts	24	6.7	06	3.12	69	14.11
Lapwing Sp.	10	2.85	44	22.91	44	8.99
Thick-knee	7	1.97	01	0.5	22	4.49
Pigeon	28	7.78	10	5.2	32	6.54
Larks	3	0.84	04	2.08	50	10.22

Table 5.3. Critical species involved in bird strikes in different time periods with their percentage of contribution to overall bird strikes.

5.3.4. Damage to Aircraft.

Table 5.4 gives details of the types of damage to the aircrafts by different species of problematic birds for the period 2005-2018 as per IAF data. The species have been arranged in the descending order of number of incidents resulting in damage. Black Kites and Lapwings top the list. (Species identification has not been reasonable for this group. It is expected to include Larks, Swallows, Swifts, Sparrows and other birds. Hence, this group is excluded for comparison of percentage of damage. But, given here for an overall appreciation).

Species	Incidents with Damage	Incidents with No damage	Total incidents	Percentage of damage	Accidents /crashes	Remarks
Black Kite	52	33	85	61.17	3	02 deaths
Lapwings	27	46	73	36.98		03 species
Swifts	16	59	75	21.33		04 species
Pigeons	13	27	40	32.50		
Lark	13	39	52	25.00		08 species
Thick-knee	11	11	23	52.17	1	Night crash
Sparrow	11	11	22	50.00		
Swallows	10	50	60	20.00		06 species
Dove	7	13	20	35.00		3 species
Cattle Egrets	7	20	27	25.92		
Small birds	6	2	8	75.00#		
Indian Roller	4	14	18	22.22		
Others	89	149	238	37.39	3*	86 species.
Total	268	474	742	36.11	7**	-

***** Crashes involved a Marsh Harrier, Honey Buzzard and Plovers.

** Species has not been identified in one crash which is not included in this data

Table 5.4. Numbers of damage causing incidents involving major species. (Period 2005-2018).

5.3.5. Bird Strikes Analysis by Zones

The data with regard to the bird strike as per their management location (IAF) is given in the Table 5.5.

Zone	Number	Percentage
Sanitized Zone*	336	25.46
Outside Sanitized zone	186	13.97
Unknown location	806	60.55

* Area where dedicated personnel are deployed for scaring away the birds- mainly the runway area and approach paths.

Table 5.5. Number of bird strikes in various zones/ locations.

5.3.6. Changes in Hazardous Bird Populations

There were significant and reliable data available for three selected species that are hazardous to aircraft namely Black Kites (Includes two sub-species *Milvus migrans govinda* and

M migrans lineatus) which are difficult to be segregated in the field, especially when they are in huge flocks), Red-wattled Lapwings (*Vanellus indicus*), and Rock Pigeon (*Columba livia*). They ranked high on the hazardous birds' list given above. Figure 5.2, 5.3 and 5.4 shows the monthly pattern of activity counts of these species over the airfields of three study locations. Months of general peaking of activity counts of different species were similar in all the three locations. Such synchronous patterns in variation indicate the effect of local weather parameters in the distribution and active presence of birds in the area. The minor differences could be because of the difference in the ecology of the particular species.

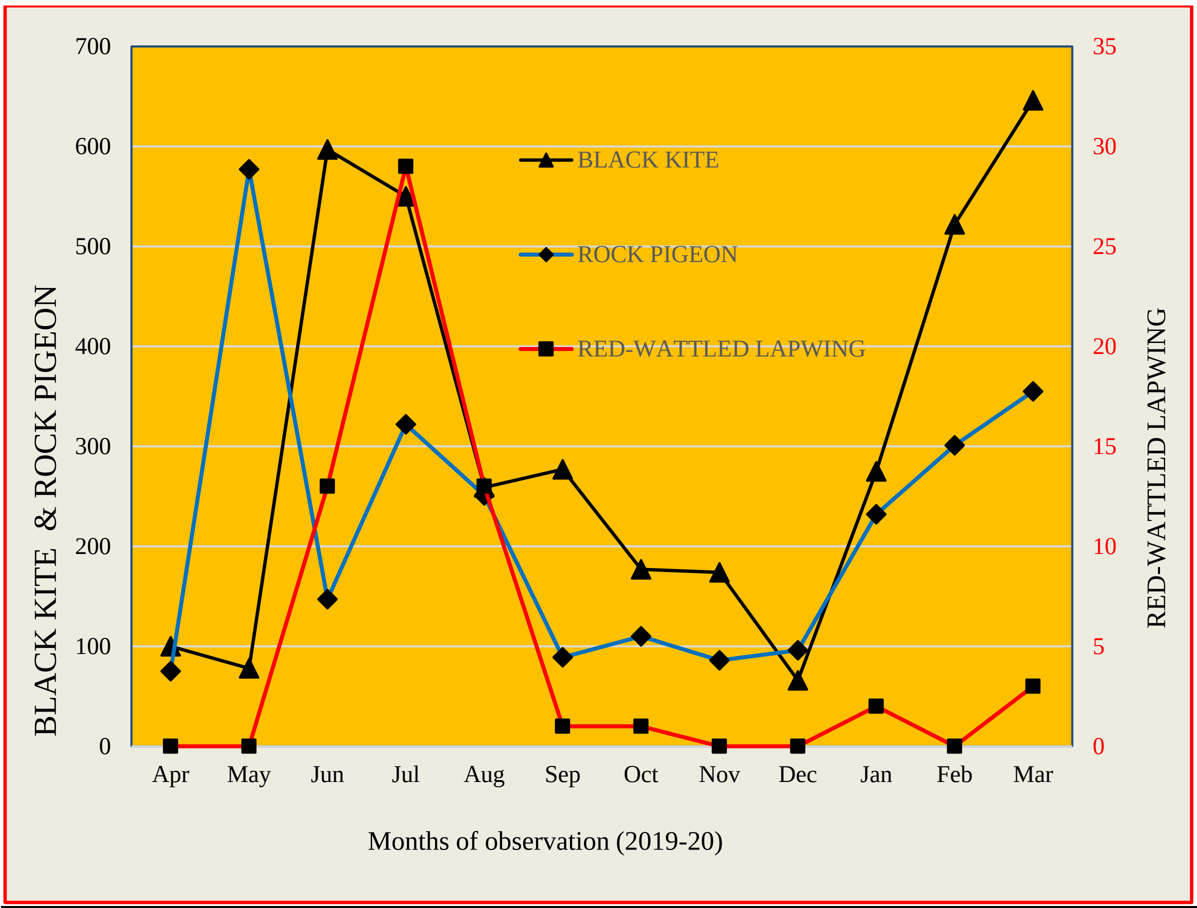


Figure 5.2. Monthly activity pattern of birds over UPA airfield (2019-2020).

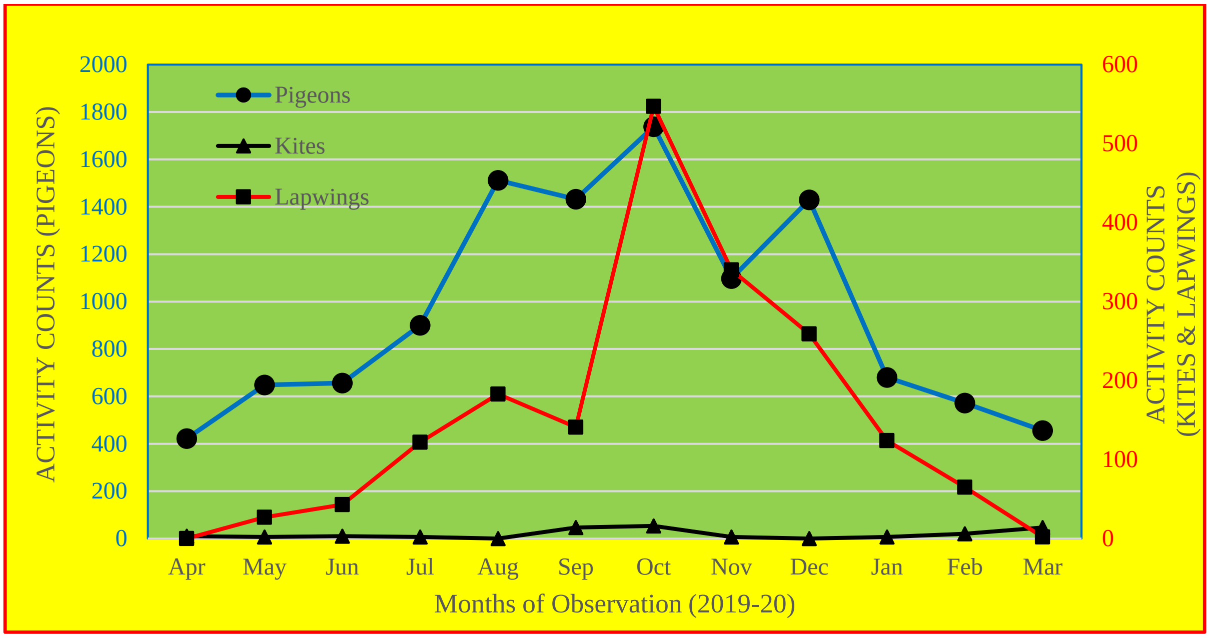


Figure 5.3. Monthly activity pattern birds over HRS airfield (2019-2020).

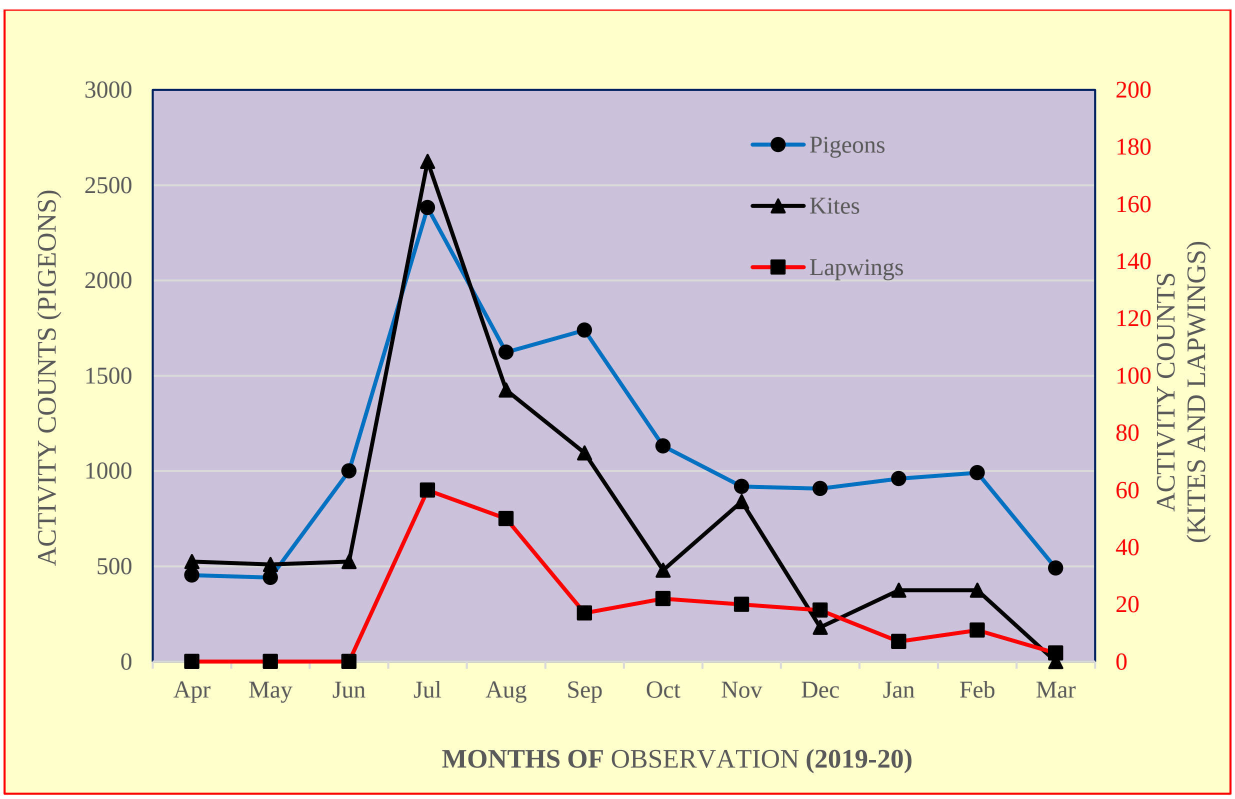


Figure 5.4. Monthly activity pattern of birds over RJJ airfield (2019-2020).

The hazardous species were found to be differently dominating in various locations. Kites and pigeons dominated at Agra and Jodhpur while Lapwings and pigeons were found to pose major hazard at Sirsa.

5.3.6.1. Black Kites

Multiple factors such as larger landscape of the airfield, local ecology, cultural practices, employment of anti-bird measures, and ecological history of the location determine the levels of bird activity over any airfield. These three airfields served as good illustrations to showcase the changes in population of Black Kites within a year and over years. Systematically collected monthly data of these three airfields for one year has been used for the comparison. The monthly activity pattern of occurrence of the Black Kites in three study sites for 2019-2020 is shown in Figure 5.5.

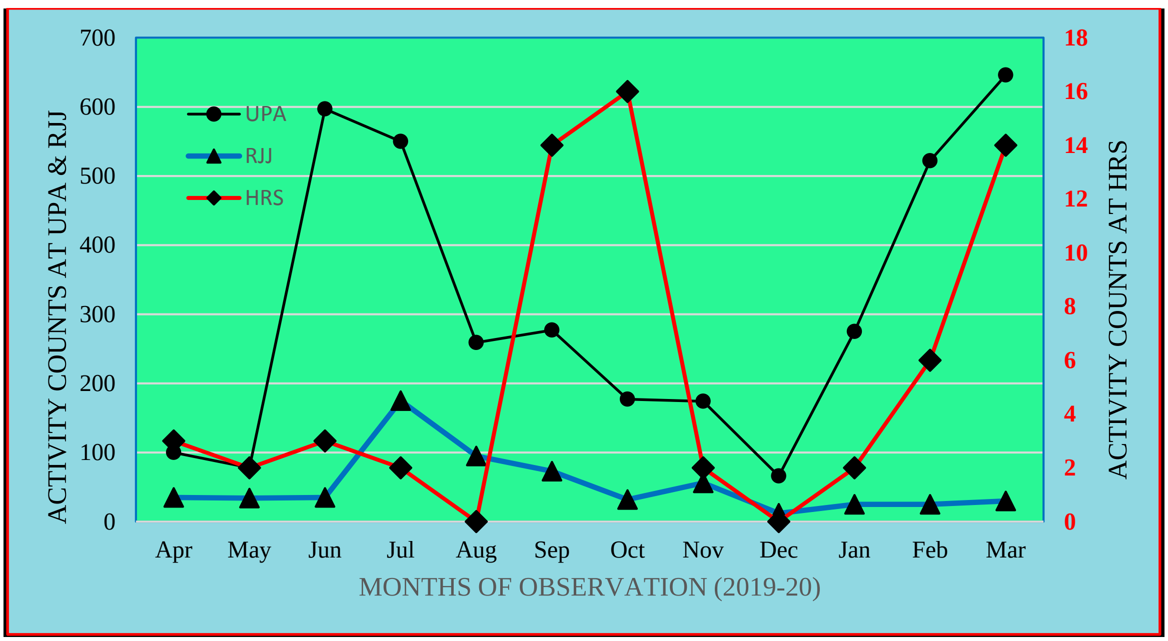


Figure 5.5. Monthly pattern of occurrence of the Black Kites in three study sites for 2019-2020.

The month-wise comparison shows that the abundance of Black Kites at Agra has increased anywhere between 1.70 to 12 times in the last four decades (Table 5.6). The reasons can be enhanced food availability (due to increasing human population) and lack of competition (due to reduction of Vulture population). There are chance records of Black Kite activity available with Ornithology Cell for Agra (120 kites in May 2008, 230 and 180 in August and November 2017).

Though this information was not systematic, it provides a few missing links to confirm the increasing trend over years.

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1980-81*	58	45	58	55	62	91	98	75	73	55	43	130
2019-20	100	78	597	550	259	277	177	174	66	275	522	646
Multiplication factor of numbers between 1980 and 2019	1.7	1.7	10.3	10.0	4.2	3.0	1.8	2.3	0.9	5.0	12.0	5.0

***** Total number counted at one post. [Source: Grubh, (1988)].

Table No.5.6. Black Kite activity counts at UPA over different years

In Sirsa, activity levels of Kites in the past (1982) is not available. Probably it was at negligible levels at that time and it was stable at those numbers for many years. Even now the numbers are not much significant (Table 5.7). The successful implementation of Solid Waste Management project in the town in the year2006 and comparatively lesser waste generation in the city could have contributed to the control of kite population growth.

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1982	Negligible numbers. Only listed in checklist and not discussed as a threat species.											
2019-20	03	02	03	02	Nil	14	16	02	Nil	02	06	14

Table No.5.7. Black Kite activity counts at HRS over different years

Though systematically collected monthly data on kite activity of Jodhpur of the past is not available, the available sporadic data indicate there was no significant activity over this airfield. However, a sporadic increase in activity (560 counts in a day) was recorded in September 2007(Ornithology Cell) This might have been due to certain stochastic events such as the influx of migratory Kites which might be transiting over the city in that year. Incidences of migrating kites visiting desert area has been recorded at Sujangarh (Rajasthan) in 2018 (Kumar *et al*, 2020).Present data shows relatively moderate kite activity over the airfield (Table 5.8).

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1983-84					64				26			
2019-20	35	34	35	175	95	73	32	56	12	25	25	30

Table No. 5.8. Black Kite activity counts at RJJ over different years.

A comparison of the abundance of vultures (in the past) and with the kites (past and present) over the airfield in Agra is given in Figure 5.6. It indicates the void created by the absence of Vultures is being filled by kite population as their niches are relatively similar in nature as the scavengers. Net amount of bio-waste in the landscape is a determinant of kite population in the region. The waste generation estimates as available on the websites of respective Municipal Corporations (Nagar Nigam)/ state web sites for the cities of Agra, Jodhpur and Sirsa are 824, 450 and 172 Tonnes per day (TPD). The variation has to do with the population, food habits of the people as well as presence of industries in those cities.

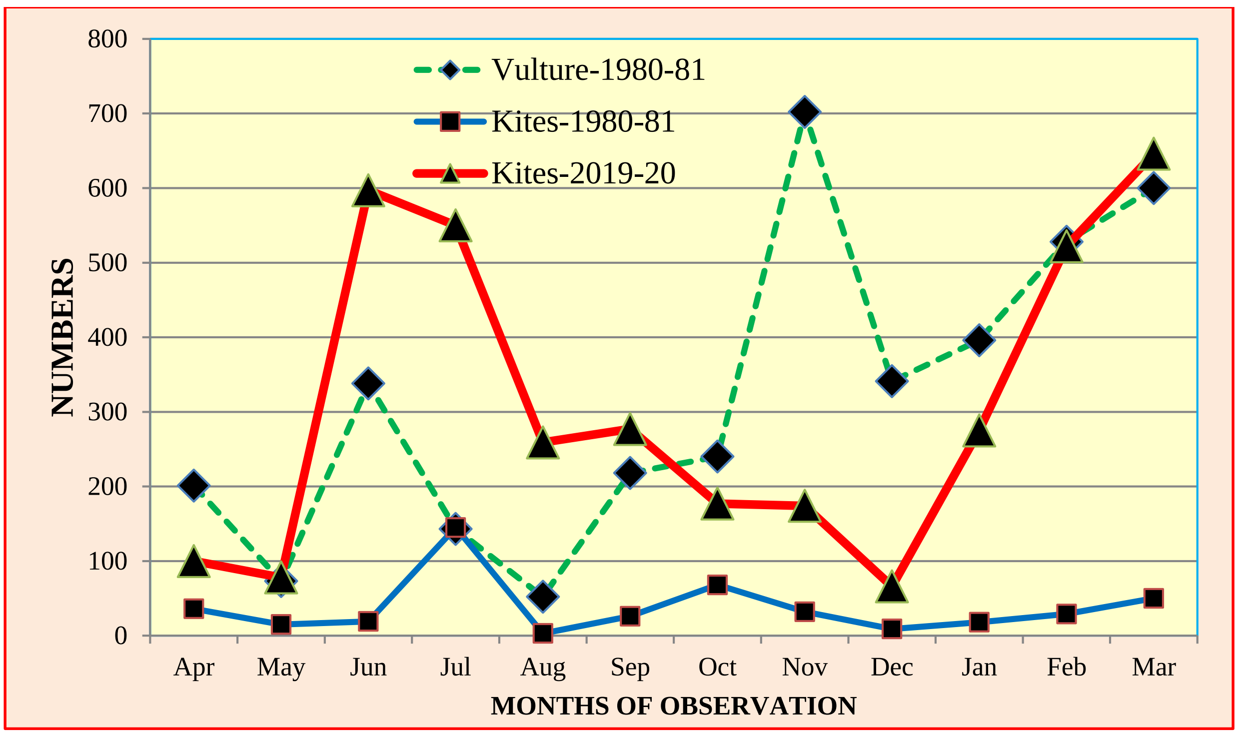


Figure 5.6. Monthly abundance of Vultures (in the past) and the Kites (past and present) at UPA.

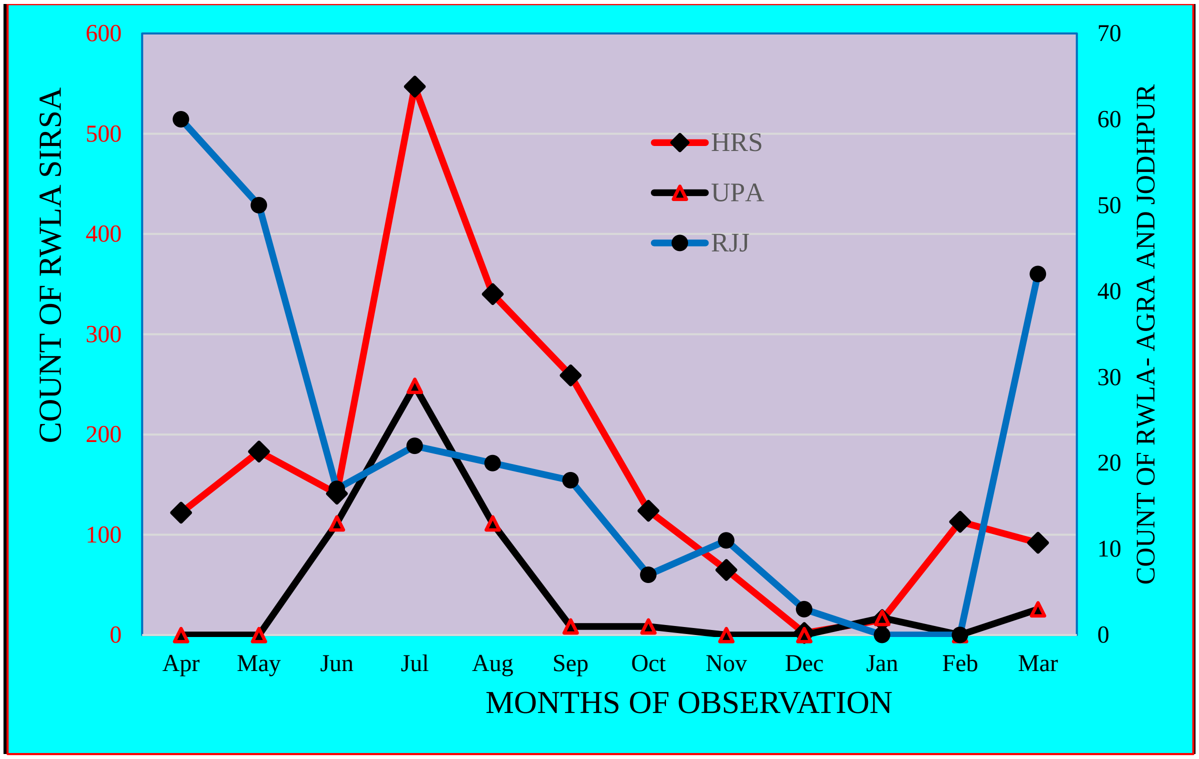


Figure 5.7. Monthly activity pattern of Lapwings over three airfields for 2019-20.(RWLA- Red-wattled Lapwing).

5.3.6.2. Lapwings

The monthly pattern of activity counts of Lapwings in the three airfields for 2019-20 is shown in Figure 5.7. The numbers of Lapwings were not precisely recorded in Agra in the 1980-81study. However, the present activity and numbers are considered moderate taking into account the availability of the ideal habitat.

The study conducted in 1980-88 in Sirsa did not record the presence of Lapwings in the region. This is an important record. However, systematic record of lapwing population was available for four months (quarterly data) consistently from 2015 onwards. The numbers are observed to have increased 13-15 times between 2015 and 2017 as per these records. The data is presented in Table 5.9.

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2009	-*	-	-	-	107	-	-	-	-	-	-	-
2010	-	104	-	-	-	-	-	-	-	-	-	-
2015	-	262	-	-	1613	-	-	-	414	-	-	9
2016	-	241	-	-	1343	-	-	-	236	-	-	3
2017	-	74	-	-	1610	-	-	-	363	-	-	11
2018	-	8	-	-	388	-	-	-	655	-	-	2
2019	0	27	43	122	183	141	547	340	259	124	65	2
2020	15	113	92									

* The symbol '-' indicates non availability of data.

Table 5.9. Lapwing activity counts at HRS over different years

The study of 1982-88 records the presence of Lapwings subjectively as 'Not in large numbers' in Jodhpur. However, their number is recorded as 31 in a study conducted by Ornithology Cell in September 2007. The numbers have reached a maximum of 60 in April 2019. The whole year data (Table 5.10) indicates that the numbers remain less than 22 for most of the years except during the months of March-April-May.

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1980-88	Not found in large numbers. No Strike recorded. But, recorded as being present around the runway.											
2019				60	50	17	22	20	18	07	11	03
2020	00	00	42									

Table No.5.10. Lapwing activity counts at RJJ over different years

5.4. DISCUSSIONS

5.4.1. Bird Species Diversity and Hazardous birds

Increased bird diversity in the airfields over the period of time cannot be validated due to the non-availability of authentic comparable data. In UPA, 75 bird species were listed on the check list in 1980 (Grubh, 1989). As per an internal study conducted by IAF in May 2009 (conducted for ten days), 92 species were recorded. Similarly, 115 species were recorded at the Gwalior airfield (Grubh, 1989). An internal study of IAF in 2007 recorded 110 species. (Observations by a Bird watcher from 2004-07 showed a total of 145 including 110 of the previous reference). However, the list didn't include 21 species which were recorded in 1989.So there are significant records of changes of additions and absences in the list. These can only be used as general indicators and not as precise scientific conclusions as only the spotting of species were recorded over different observation periods. The numbers of individuals and their frequency of each species have not been recorded in a similar way.

5.4.2. Extent of Bird Strike

There was a constant increase in bird strike in the three period considered for analysis. The number of species identified as involved in the bird strike in each time period has increased considerably from 67 in the first period of 23 years to 76 in the second time period of 17 years. The number of bird species identified nearly doubled to 115 in the third period of nine years. This may be attributed to three reasons- increase in flight operations, the actual increase in diversity of airfield birds and due to adoption of advanced identification techniques such as DNA Barcoding. There was also a marked increase in Bird strike numbers in the third period considered. The number of incidents doubled from 607 (in 2012) to 1244 (in 2018) in a span of seven years (data of civil aviation in India). On the contrary, the USA took twelve years to double their incidents from 7,046 in 2005 to 14,503 in 2017 (Dolbeer and Richard, 2019). While all the measures instituted by the USA may not be applicable in India, certainly this information needs careful analysis for reducing the pace of bird strike growth. The first step to be initiated is to establish a dedicated team to monitor the issue, analyse the data and report the results to the concerned authorities.

The other probable reason for increasing in species identified is better identification techniques such as DNA Barcoding. This has certainly contributed to the increase in number of species identified in bird strikes. The huge number of samples were identified for Swallows (60 samples involving 05 species of Swallows) and Swifts (75 samples involving four species). Most of these have been achieved with minute blood stain samples. These facts highlight the benefits accrued by adopting the DNA Barcoding technology.

5.4.3. Damage Caused by Various Species

As per the IAF records for the period 2005-2018, 196 of 535 cases resulted in damage to the aircraft. This amounts to around 36%. As per the ICAO report for the period 2008-2015, the civil aviation suffered damage in 34% of the wildlife strikes [Anonymous (ICAO), 2017b). Although, the percentage shows only marginal difference, it may be noted that the IAF data is being considered only for the incidents in which species have been identified. Considering the same, it is imperative that IAF has a larger percentage of bird strikes without damage. This may be due to higher vulnerability that exists in the Indian sub-continent or due to systematic reporting culture in IAF. It also points to the probability of involving small and less damage causing birds in bird strike while carrying out military maneuvers at low heights. The recent data of bird strikes to civil aviation in India (Table 5.1) indicate higher reporting of cases with no damage. This may be due to change in the bird environment of due to enhanced reporting culture.

The results show that 30 percent of incidents (with damage) involve just two species namely Black Kites Lapwings. These are required to be considered as 'Most hazardous species' for management purposes. Another 37% is contributed by Pigeons, Swift, Swallows, Thick-knee, Sparrows, Egrets, Rollers, and small birds (most likely includes Larks, Pipits, Munias, Swallows, and Swifts). These may be considered as 'Moderately hazardous birds' for management purpose. Considering the variety of 86 species towards which contribute to 28% of damage, all other birds may be considered as 'Least hazardous species'. This categorization will enable the wildlife hazard managers to prioritize their activity and optimize their time and resources. Similar categorization of species has been proposed by other researchers (Pfeiffer, Blackwelland DeVault, 2018; Both, Gasteren and Dekker, 2010; Anagnostopoulos *et al*, 2003, and McKee *et al*, 2016).

5.4.4. Species Involved in Bird Strikes

Since 1980, the Black Kite has been in focus and continues to be so. It was considered as the second largest hazard after the Vultures (Ali and Grubh, 1981; Grubh, 1989; Satheesan, 1990and Mathew, Palatand Kumar, 2003). With the decline of number of Vultures in the environment (Singh, 1999; and Arun and Azeez, 2004), Black Kites have become the largest threat in recent times'. Between 1980and 1988 (nine years period), it had contributed to 55 incidents. However, a sharp increase in strikes to 85 in the last thirteen years is very evident and a cause of serious concern. The transition of higher incidents due to vulture to kites may have taken place around 1997-2000 (Mathew, Palat and Kumar, 2003).The three fatal accidents of IAF involving this species reaffirm their threat for the aircraft in the skies. The available species data from civil airports also indicate the threats from Black Kites. It is rated as the highest threat in few other South Asian countries as well (Arshad *et al*, 2019 and Pincus, 2008).This species is also ranked at no.4 among hazardous species by Australian Transport Safety Bureau (Anonymous, 2015).

An attempt was made to establish the probable cause for the increased hazard. One of the probable causes that were hypothesized was the increase of Black Kites population in the environment. The available information on Black Kite counts at Agra, Sirsa and Jodhpur airfields indicate the significant increase in its activity at Agra. The probable causes could be primitive waste management system of the city, reduction of Vulture population giving more space to Kites and also contribution by the migrating kites from Mongolia and Thailand.

Black Kite population of a city mainly centers at the main garbage dumping site and meat/poultry markets as observed in Delhi, Bengaluru and other places (Grubh, 1989; Satheesan, 1990, Sharma, 1998; Mazumdar, Ghose and Saha, 2017; Sergio, Pedrini and Marchesi, 2003, Ilyas, 2018, and Kumar *et al*, 2018). A general comparison of the waste generation of three cities indicated that Agra generates around 824 Tons per Day (TPD), Jodhpur generates 450 TPD and Sirsa generates 172 TPD. Also, an official report posted on the Agra Municipal Corporation website (date not mentioned but expected to be a report of 2014(accessed Mar 2020)) clearly documents that there is only one authorized slaughter house in addition to many unauthorized slaughter houses which throw away the waste such as flesh cuttings and gobar for Municipal Corporation to collect in respective areas. The same report indicates that the scientific management of solid waste stood at almost ‘NIL’ in 2014 indicating the large amount of waste is made available for the growth of kite population. As the systematic waste management process was lacking for decades, the city has supported the growth of kites.

On the other hand, Sirsa generates relatively low quantum of waste (172 TPD). Jodhpur generates only 54% of the waste generated by Agra. This is partly because of the lesser number of industries in that city. However, an organized meat market and a much lesser meat sales in the city could have also contributed to control of kite population. A significant aspect to note here is that Sirsa and Jodhpur City Corporations were the early adopters to Solid Waste Management plant [Anonymous (Ministry of Housing and Urban Affairs), 2011b] in India in 2006. The funds for the plant were sanctioned by the Ministry of Housing and Urban affairs as a special case to mitigate the bird hazard. It can be easily concluded that the plant has achieved its purpose.

In the visits to the garbage processing site at Sirsa, few kites were sighted whereas in Agra, kites can be seen at smallest of the road junctions where some amount of garbage was thrown. This common experience seen at other major cities indicate that more than the waste generation, it is the lack of proper processing that leads to kite population growth.

In addition, UPA had a history of having open carcass dumping sites for many years. This had facilitated growth of kite population in the years between 1980 and 2000. This could have created a good source population of kite, thereafter leading to exponential growth in later years.

In 1980s, Vultures dominated avian flying space that is currently absent in Agra. One major change that is visible from the data is Black Kites are increasing in the sky. In the absence of Vultures, Kites top the list of most damaging wildlife strikes in the recent years. A comparison of monthly abundance of Vultures in the past and the Kites in the past and present at Agra (Figure 5.6) indicates that kites are eventually taking over the urban niches of Vulture as the major scavengers.

The monthly activity of Black Kites at each of the airfields differs significantly. The kite activity at UPA indicates two peaks of activity- one between June to August and another in February to March. The peak between June and August can be attributed to heightened activity due to rains which trigger the availability of invertebrates such as snails and reptiles openly available in airfields. The February-March peak corresponds to the out bound migratory movement of Kites. Record of kites in RJJ indicates only one peak in July. Airfield, being on the fringes of the desert, does not generally get affected by migrating kites which are recorded in UPA. On the contrary, HRS follows the pattern of UPA with two peaks, albeit at a much smaller scale.

The recent GPS tagged studies of Black-eared Kite from India, Mongolia and Thailand gives a glimpse into the complex dynamic nature of the movement of Kites. The Indian study (in which 19 Kites were tagged) records the movement of Black-eared Kites from Mongolia to India from mid-August to latter half of September. The return journey was recorded from mid-March to early May (Kumar *et al*, 2020). This study recorded that the tagged and migrated kites generally stayed around Delhi area [The literature does not mention Agra, but mentions that they stayed over towns and cities up to 300km which covers Agra (around 180km)]. Considering these facts, it is prudent to expect that a considerable number will reach Agra as it provides an ideal habit for the Kites.

A study from Mongolia records departure of Kites from breeding ground in September and reaching Myanmar in October. There are some ringed recoveries from North-East India as well (Balachandran, Katti and Manakadan, 2018) (Ferguson-Lees and Christie, 2001). Based on this, it is expected that considerable number of Kites which use the Central Asian fly path also leave in the breeding grounds of Mongolia in September.

While the above two migrations were fairly known well before 2001, a recent study from Thailand [Anonymous (Birds of Thailand), 2020c] indicates an influx of Black-eared Kites in to India from Thailand (from Myanmar side) from June to October. The single tagged bird covered a range of places from Eastern India to central India to Western parts (Bikaner and Mumbai sub-urban area). The study is still in progress.

A study of kites in the Kolkata urban landscape reveals an altogether different pattern i.e., a peak in summer (March-May) followed by a little lesser activity during Monsoon and post-monsoon (Mazumdar, 2013). The least activity time is winter time at Kolkata is contrary to activity at airfields of this study. A study by BNHS in 1983-84 at old Bengaluru airport also indicated higher numbers in October- November than April-May (Grubh, 1989). Similarly, two studies from the old Bengaluru airport (study by IAF) and a roosting place at Razak Palya (near Yelahanka airbase) indicated that one peak is between September to November and another is in February (data collection done during current study). The exact reasons are yet to be deciphered. This reaffirms the general pattern in Bengaluru area. A study of kites in Pune city between 1975 and 1988 also indicated that their population is highest during July. It was recorded to be least between December and February (Mahabal and Bastawade, 1985). This is different from that of Bengaluru and clearly indicated that kites may not follow any specific cycle as a species within all locations in the Indian Territory and patterns are region specific.

Given the areas covered by different individuals, the Kite migration over different airfields is a very complex phenomenon. All the studies mentioned here were conducted independently. However, there is a need to conduct the studies in a coordinated way with various agencies so as to capture qualitative data (routes) through GPS tagged individuals and quantitative data (number of individuals crossing airfields or specific cities).

Lapwings, being the birds of open grasslands have always been a part of airfield ecology. But, their numbers fluctuate due to the changes in the vegetation management techniques of airfields.

Reduction of trees and shrubs in the airfield areas to deny roosting/ resting sites to other hazardous species may have contributed to the significant increase in the number of this species of open land habitat. The data on the number of Red-wattled Lapwing (RWLA) recorded over HRS airfield (Sirsa area in Haryana) correlated with increased strikes at the airfield (IAF's internal study). While the bird is not recorded in the checklist of study of 1980s, the numbers reached 107 in 2007. It grew exponentially to 1,798 in June 2015. Later, the numbers reduced to 547 in July 2019.

The exact reason for the decline from 2015 to 2019 could not be identified. Essential ecological records are not available at present to corroborate the reason behind the changes of population. It is probable that focused effort by airfield safety authorities to reduce their numbers by harassing might have led to reduction. Another reason may be due to a mass movement of the population to a more suitable habitat. One more possibility is the growth of population beyond the carrying capacity of the airfield environment which led to reduction as part of natural population adjustments.

In UPA, the Lapwings are significantly reduced probably due to focused anti-bird measures against the species. In RJJ, the numbers have remained steady in the environment. It can be easily inferred that the desert environment (in addition to focused harassment) is not allowing the numbers to grow, despite the availability of open lands.

Ornithology Cell of IAF studied the vulnerability of Lapwings for bird strike in 2011. It was observed that there is a correlation between full moon nights and night bird strikes by Lapwings. Based on this, restrictions were placed on military operations on full moon nights which helped in reducing the numbers of strikes to some extent. In later field studies in 2015, this fact has been re-ascertained through another study (Kumar, 2015).

5.4.5. Location of Bird Strike

The percentage of bird strike among the three categories of location namely within the 'Sanitized zone' (the area where dedicated staff is deployed for observing, reporting and scaring away the birds- mainly constituting the runway area and approach paths), 'Outside the sanitized zone' and at ‘Unknown location’ were categorised. They were observed to be 25.46%, 13.97% and 60.55% respectively of the total 1331 cases analysed.

For a cursory look, the first two figures seem to contradict the concept of sanitization. It is expected that a smaller number of bird strike should take place at unknown locations. This may be due to the occurrence of bird strike outside the sanitized zone, but the impact not felt by the pilot. On the other hand, bird strikes in a sanitized zone are observed by many people on the ground who keeps vigilant eyes on the aircraft. Bird strike is accounted in sanitized zone, even if the pilot does not perceive the strike, but is observed by the Bird Watchers.

Although ICAO does not use the same terms, a report indicates 4% strikes in ‘enroute’ phase and 5% at unknown locations [Anonymous (ICAO), 2017b]. On the other hand, IAF has nearly 14% of bird strike at locations outside the sanitized zone (corresponds to a location away from the aerodrome). IAF data indicates nearly 60% of the incidents to be taking place at unknown locations whereas the civil data indicates a small quantum of 5%. There is a huge variation in this regard. The probable reasons can be involvement of smaller birds which do not give an indication when they strike, huge noise of the aircraft and deeper engagement of pilots in the cockpit towards mission.

While much of the literature on bird strike makes a statement that strikes takes place during the landing and takeoff, the actual reality may be much different as the location of strike is not known in more than 60% of the strikes, especially in the military flying. Situation of Civil aircraft and Military aircraft may be different in this case; military aircrafts have to do more low-level flights compared to civil flights. Civil aircrafts generally come in conflict with avian flying zones mostly during the landing and takeoffs only.

The number of crashes (or Hull loss accidents) and fatalities have reduced drastically within IAF. The crashes have reduced from 2.08 per year in the first block to 01 per year in the second block of period. This has further reduced to one per three year in the last block which is considered as a great improvement. The fatalities have also reduced from 17 to 5, and then to 01 in three successive time periods. (In fact, the one fatality in the last period was due to an attempt made by the pilot to man oeuvre the aircraft away from the civil population area during which he lost the height). Some of the probable causes for the reduction in bird strike are listed below:-

1. Change in the bird environment due to reduction of Vultures in the sky.
2. Increased awareness and initiation of bird ecological studies.
3. Creation of dedicated organizational structure with Safety Officers and Bird Hazard Combat Teams.
4. Extensive use of acoustic scaring devices, to create safety windows.
5. Environmental modifications within the airfield such as vegetation management.
6. Establishment of modern slaughter houses and Solid Waste Management plants in different cities.
7. Constant study of bird environment and implementation of restrictive periods (Restricted and open periods for operations) within IAF.
8. Establishment of an in-house Ornithology Cell to constantly monitor the bird environment changes and implementation of anti-bird strike strategies.
9. Adoption of latest forensic technology such as DNA Bar coding for identification of species involved so that accurate information on the problem species are available for species focused management.

While the numbers are increasing leading to damages and financial losses from the perspective of the operators, the service providers in civil sector (Airport authorities) look at the problem from a different perspective. They measure the rate of bird strike (Number of bird strike per 10,000 movements) which is fairly consistent over the years. As per DGCA's Annual safety report-2017, the target given to airports was to achieve was 4.44 bird strikes per 10,000 movements and the airports achieved 3.75 [Anonymous (DGCA), 2017e]. Nevertheless, the rising bird strike numbers and hazardous bird populations are a serious concern due to high costs of damage and indirect costs.

5.4.6. Economic Losses

While the numbers of crashes are coming down, in the records of IAF it does not really correlate to reduction in economic losses. It is pertinent to note that the economic loss for the IAF due to last bird strike accident is approximately INR. 08 crores. However, with the induction of modern aircraft with superior technologies, even moderate damage can cause considerable financial loss. For example, specific damage to certain blades of SU-30 MKI will cost us approximately INR. 07.50 crores. On similar lines, a bird strike to a F-35 B stealth bomber of US Marines on 07 May 2019 in Japan cost more than $2 million (INR. 15 Crores), though did not result in a crash (Robson, 2019). Hence, as far as economic losses are considered, we are almost at the same level or even more deteriorated, though the rate of increase in numbers of damaged incidents may seem satisfactory.

5.5. CONCLUSION

Bird strike causes severe damages to aircraft. An attempt has been made in this study to understand the temporal changes of birds in airfields with focus on two most hazardous species in India with the available data. It is clear that ecology of the larger landscape around the airfield has a significant role in the population dynamics of the birds. Bird activity over an airfield is a result of interplay between many factors such as effective waste management, ecology of other birds, vegetation, migration and levels of harassment. However, there is a need to conduct such studies more intensively to find methods to keep them away from the airfield to safeguard the valuable national assets. Systematically collected long term data is crucial to understand the supra annual pattern of bird movements and ecology. Such information will be helpful to develop predictive models of population movements with accuracy which will have great potential in designing hazard mitigation strategy.

As the number of flights increase in the airspace, the problem of their collision with birds (and wildlife in general) will also increase. Bird strike is a peculiar problem that demands constant assessment and novel methods to tackle the hazard. In the civil aviation sector, the bird strikes recorded every year is increasing. In IAF, the crashes due to bird strike are becoming less but total strikes and economical losses continue to rise. The number of species involved in bird strike is increasing making the analysis and implementation of prevention measures difficult. This study has analysed the species and damage data intensively and ranked the hazardous species. Black Kites and Lapwings top the list indicating that the measures against these birds should be given due priority. An analysis of economic losses indicated that the reduction in damage causing bird strikes does not translate in to economic benefits due to the high cost of modern aircraft.

Continued studies in this field will help aviation sector to find solutions which are economically viable and ecologically sustainable. It will also help in keeping the anti-bird measures up to date as the bird environment is highly dynamic and vulnerability of each species is keeps changing over a period of time. Establishing a dedicated national level body to collation of data in a standard manner, monitor the issue, publicize the data and develop ecological/ administrative tools after necessary analysis. The body can also be a central agency for coordinating with international organizations.

6. ASSESSMENT OF BIRD HAZARD MANAGEMENT STRATEGIES

6.1. INTRODUCTION

Numerous solutions have been attempted for managing bird hazards to aircraft. Many of them were simple ‘rule of thumb’ actions due to their simplicity. While some of them were useful and delivered success, many are rejected by the authorities for various reasons such as being costly, demands intensive monitoring or even being counterproductive. Solutions are of two kinds namely- aircraft related solutions and bird related solutions. The bird related solutions have two aspects namely Bird management and Environment management.

For both of these aspects, there is a need to study and inventory the birds, understand their habits and patterns, gauge the hazard, look for possible solutions, implement the solutions and gauge their efficacy. Indian Air Force imposes many restrictions on its operations at a very high cost to save its assets. Time and space restrictions are decided based on systematic data collection such as point counts, Whole day counts, Transect counts and Microlite based surveys. The data from these surveys are analysed to declare ‘Red periods’ and ‘No flying zones’ during/ over which the operations are restricted. The current study analyses the bird ecological data for the purpose of Restrictions.

As outlined earlier, the Bird ecological studies will form an important input mechanism to design and implement both strategies. The implemented strategies will be evaluated in a suitable way. The current study is planned to evaluate some of these ongoing strategies. This chapter tries to evaluate efficacy of certain ongoing management activities for its usefulness and improvements, if any that can be adopted.

1. Environment management can be within the airport and outside the airports. Waste dumping locations, meat markets and roosting sites of problematic birds in the immediate surrounding can pose immense problem for bird hazard management in the airport. Solid waste dumping, waste processing plants and meat markets have been a cause of concern for more than four decades. A rule of the Union Government of India(Rule 90, Indian

Aircraft Rule 1937)prohibit dumping of waste, meat and other bird attractants within a distance of 10 km from the airfield needs to be validated.

2. IAF had initiated special restrictions on the nights around full moon nights in 2011. This was a based on a study which indicated the heightened activity of Lapwings over the airfields around those nights. The first field study had been done in Europe (Milson, 1984). In India, a study based on secondary data was conducted by IAF (Sharma and Srinidhi, 2012) before imposing restrictions. However, the concept had not been validated through primary research in the field for Indian conditions.

3. In the airfield management, the idea of planting a specific species of grass which do not produce bigger seeds has been discussed for more than three decades. However, the idea could not be implemented suitably due to various factors. There was a suggestion of Dhub grass as an ideal candidate for such cases by some agencies. This strategy had been discussed repeatedly in Bird hazard management meetings, but a definitive decision could not be taken due to lack of pilot studies. Current study took up this task to test its efficacy in managing bird activity in the area

4. The Bird management solutions can be divided based on three principles of management namely Deterrent, Harassment and Exclusion. IAF employs a large number of personnel for this activity on daily basis with structured training to deter, harass and exclude birds from the operational area. They use many equipment for this. That includes gas cannon for regular blasting sounds, drum beating to make noise, crackers and so on. Even regular flight operations also can be a deterrent for some species of birds. There could be collective effect of all such bird deterrent activities. There was a need felt to know how birds are affected in general by all these activities including operations.

Hence to record and scientifically gauge the effect of some of these methods employed for bird hazard management, the following research questions were attempted to answer in this chapter:-

1. What is the extent of spread of activity counts of Black Kites from its regular feeding sites?
2. Whether the lapwings are more active and occupy runway more during the full moon nights and the nights closer to it?
3. How much effective is the usage of alternative suggested grasses (Dhub Grass – *Cynodondactylon*) to avoid attraction to birds to the airfields?
4. Is there any difference in bird activities between the days of implementation of anti-bird measures and days of non-implementation of anti-bird measures over airfields?

6.2. BLACK KITE ACTIVITY

6.2.1. Methods

Two study sites namely Yelahanka area and Ghazipur (Delhi) area were selected for studying Kite activity up to 10 km distance from one or more feeding sites. A total of four transects were laid for data collection in the two study areas [two near Yelahanka and two near Ghazipur (Delhi)]. The data was collected by counting the Black Kites seen at specific vantage points on each transect by stopping for two minutes. The points were chosen to represent a section of 1 km length from the known source location of activity of kites. These points were chosen after a pilot study in the beginning. Each transect started from the source location and moved in different directions- one towards the airfield and another in the direction of a location of interest. The feeding sites and the line transect followed for the data collection are marked in Figure 6.1 and 6.2.

Figure 6.1. (a). Black Kites at Ghazipur feeding site. (Photo credit- Nishant Kumar, WII).
(b). Black Kites soaring over the Ghazipur garbage dump and meat market area.

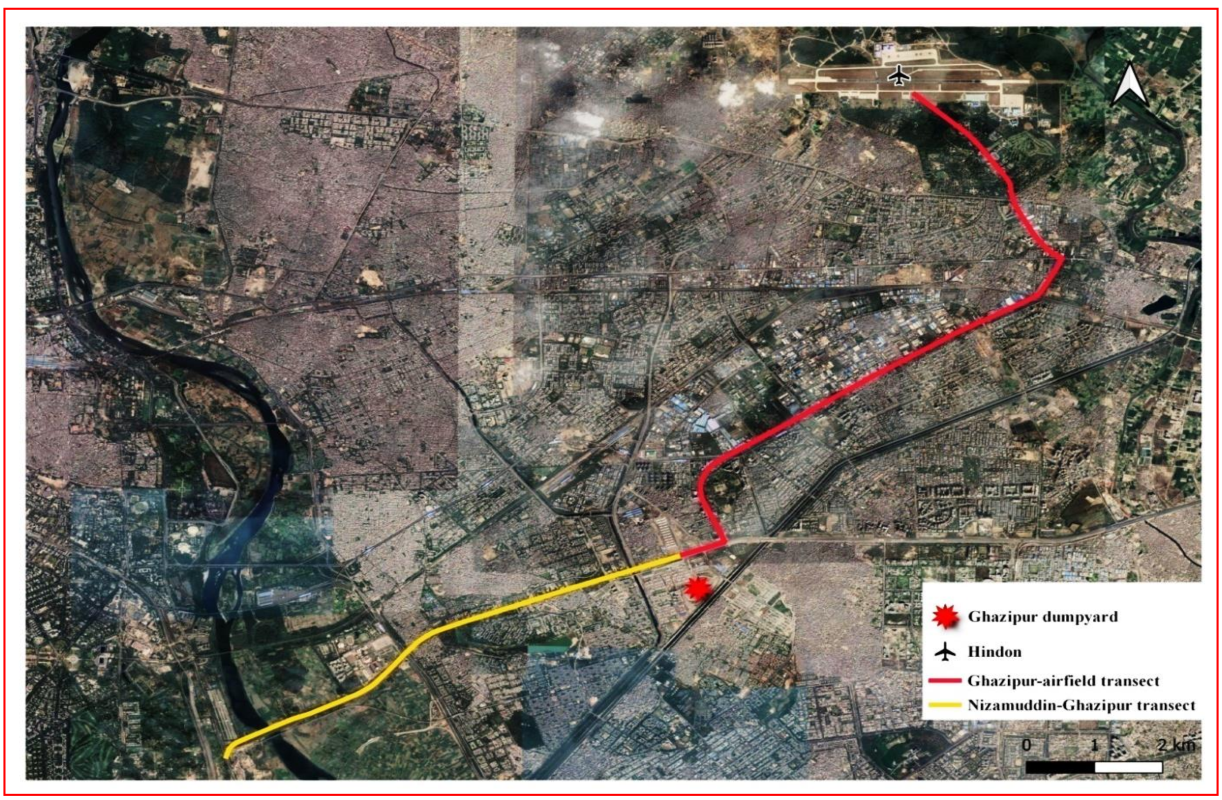


Figure 6.1. (c). Two line transects from feeding site of Ghazipur garbage dump & meat market. (UPH airfield is towards the North. Yamuna river and Railway station are on the Western side.)

Figure 6.2. (a). Black Kites over Razak Palya, currently a roosting site, which was a feeding and roosting site till 2013 (Photo of 2013).

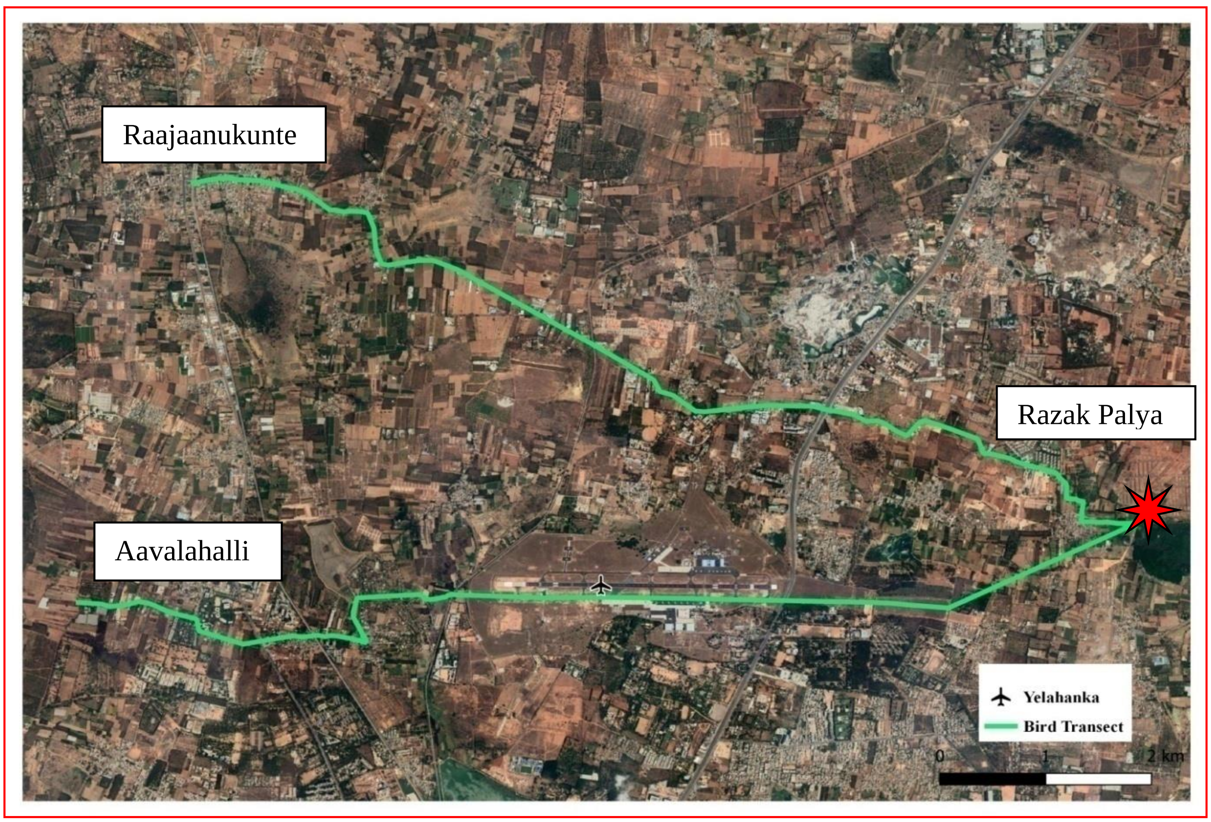


Figure 6.2 (b). Two line transects from Razak Palya (Razak Palya- Raajaanukunte and RazakPalya- airfield-Aavalahalli) in the airfield area.

A Control Transect of 10 km was earmarked from Razak Palya village to Raajaanukunte near Yelahanka. The Transect mostly consisted of rural demography and served as a Control line transect. Further details of marked transects are given in Table 6.1.

Sl No	Area	Transect No	Route
1	Yelahanka	Control	Razak Palya-Hosahalli- Hunasmaaranahalli- MV Institute of Technology- Sindhu Cargo Logistics Complex- Timmasandra- Raajaanukunte (10 km)
2	Yelahanka	1	Razak Palya- Hosahalli- Eastern Bird Watcher post of KAY- KAY- ATC Tower- runway end-Harohalli lake- Aavalahalli-Presidency School (10 km).
3	Ghazipur	2	Ghazipur meat market and Garbage Dump- Dabur Chowk- Vaishali Metro Station- Saibabad Vegetable Market- Railway Flyover- Mohan Nagar- Krishna Engineering College- UPH Airfield main gate- ATC Tower (10 km).
4	Ghazipur	3	Ghazipur meat market and Garbage Dump to Nizamuddin Railway Station. (8 km)

Table 6.1. Details of line transects for studying Kite activity up to 10 km distance from feeding / roosting sites.

A perfect straight transect could not be marked due to city demographical limitations. Minor curves in the road were considered insignificant to the results of the study.

The data was collected around Yelahanka from June 2015 to May 2016. The data was collected once each in every month in the morning (sunrise to 10.00 AM), noon (10.00 AM to 4.00 PM) and evening (4 PM to sunset) periods. A total of 36 transect runs were carried out in each Transect at Yelahanka.

The data was collected at Ghazipur area from May 2015 to April 2016 (nine months with 25 runs in each of the two transects) and from Aug 2019 to December 2020 (16 months with 31 runs in two transects). The data was collected as in Yelahanka (thrice a day) from May 2015 to April 2016).

It is assumed that the selected two source locations (in four different directions/ axes) represent the true random sample of Kite activity at different places in India. Pilot studies/ short term studies had been done at seven other locations namely Mysuru landfill, Tezpur landfill, Bagdogra and other source locations in Bengaluru (Mavali Pura-Yelahanka transect, MS Palya-Yelahanka transect, Hebbal- Jalahalli transect) and in New Delhi (Nizamuddin- Delhi Cantt, Okhla landfill- RK Puram).

Hypothesis. Considering the Indian Aircraft Rule 91, which prohibits the throwing of garbage, carcass and other bird attracting material up to a distance of 10 km from the Aerodrome Reference Point (ARP), a hypothesis has been formed for this experiment. The hypothesis is stated as

'There is significant reduction of activity at 10 km from a source location of Black Kites'.

Data was collected in two directions from the source location in transects of about 10 km. Kites counted at every km distance. Data collected at Yelahanka (Bengaluru) from May 2015 to April 2016. Data collected at Ghazipur from May 2015 to April 2016 and Aug 2019 to Dec 2020.

6.2.2. Results and Discussion

Average of kite activity observed through four transects over different time periods is shown in Figures 6.3, 6.4, 6.5 and 6.6. Number of kites sighted dropped sharply when travelled away from the source location in the entire travel axis. Transects varied in its overall settings. In Bengaluru two axis travelled from the same source point (Razak Palya, which was, an erstwhile fish farming village, and presently, a roosting place of Black Kites). There is significant chicken waste dumping going on even at present in the location. The location has a regular presence of 50-100 kites. The trend is logarithmically going down in both axes within 6 to 8 km. Only the Airfield axis at Yelahanka shows a marginal re-raise after reaching a low of zero at 6 km. This is mainly due to an enhanced activity recorded over the airfield which is at 7km. This could be probably due to the thermals over the runway.

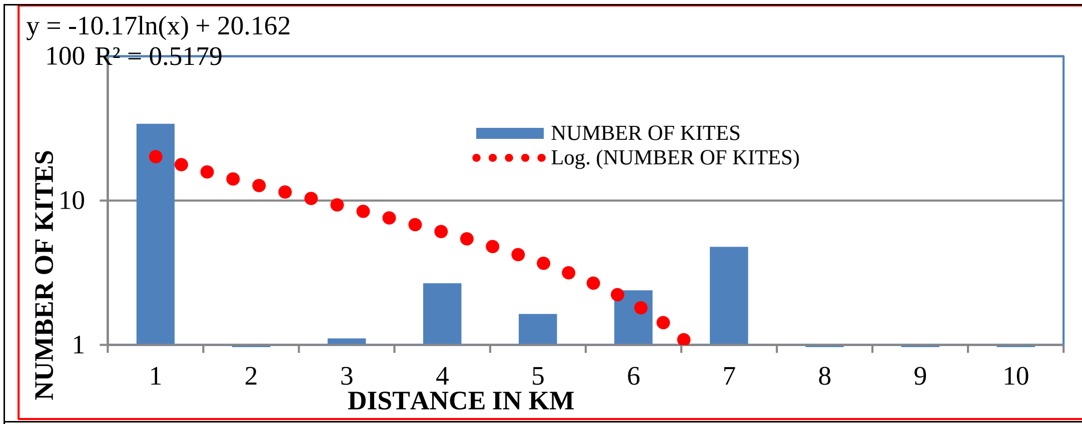


Figure 6.3. Black Kite Activity Over Razak Palya to KAY airfield axis.

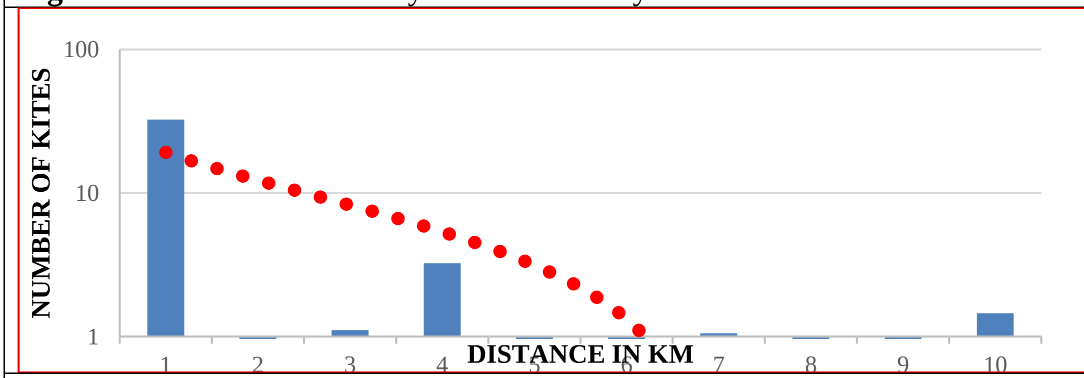


Figure 6.4. Black Kite Activity Over Razak Palya to Raajaanukunte rural (control) axis.

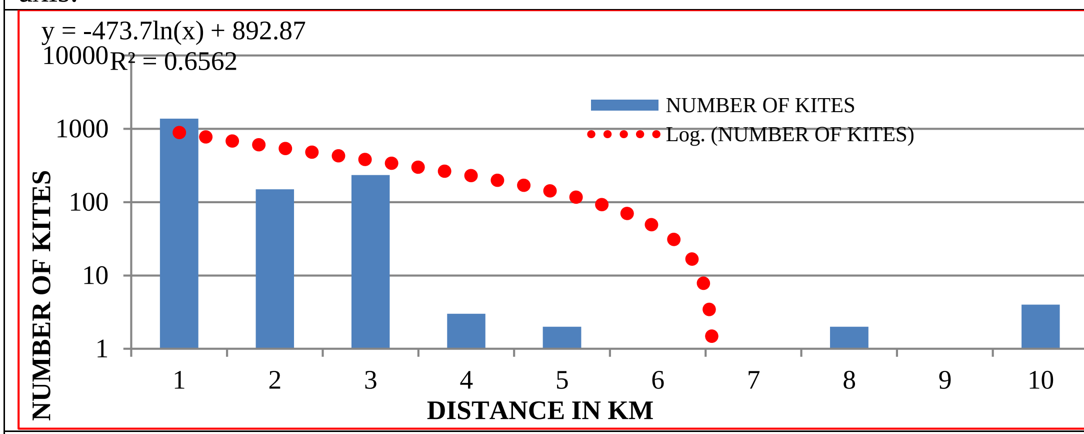


Figure 6.5. Black Kite Activity Over Ghazipur to UPH airfield axis.

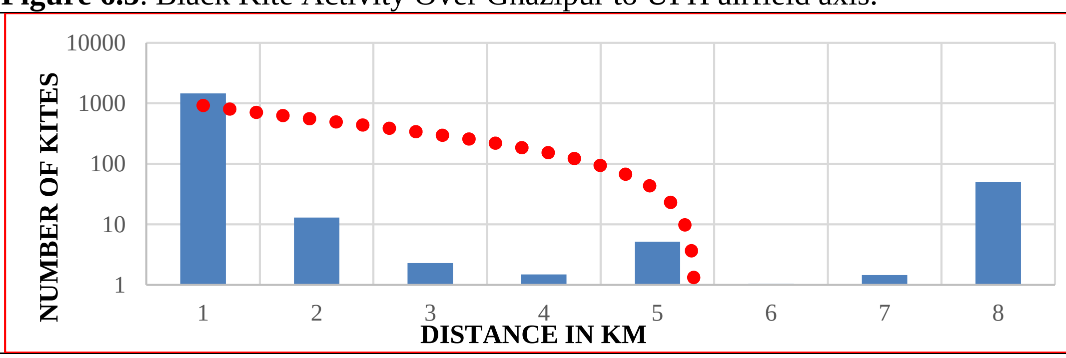


Figure 6.6. Black Kite Activity Over Ghazipur to Nizamuddin Railway station axis.

Trend in Ghazipur also gives the same results except that the spread is more than Bengaluru. This could be because of the availability of waste/food in the landscape. An increased sighting at 10 km is a location effect due to the presence of garbage/waste near Nizamuddin railway station.

The findings indicate that the Black Kite activity comes down significantly at 6-8km, if there are no other attractant factors like feeding spots, roosting site and even probably, strong sources of thermals. The preference of Black Kites to come to the airfield thermals is yet to be intensively studied. However, during the Point Count observations conducted during the current study (Chapter 4), it was very evident that they used the area mainly for soaring rather than for feeding or roosting. In Yelahanka, a green patch of trees on the Southern side (Border Security Force Camp) was seen to be used as a roost during five of months of data collection (in Aug 2015 (30 kites), Oct 2015 (13 Kites), Nov 2015 (110 Kites), Mar 2016 (11 Kites) and May 2016 (21 Kites)). In fact, those numbers varying between 30 and 110 does affect the activity over the airfield as they are seen coming in the evening and leaving the roost in the morning.

Another important observation is the raise in activity over the Nizamuddin area in the Ghazipur-Nizamuddin transect. This area harbors many meat shops in addition to the reports of Kite feeding done as a cultural practice. The increased activity count (Average of 49.43 kites) at 8km distance is a very significant observation. The Nizamuddin area used to be the garbage dump of Delhi city up to 1982 till it was shifted to Ghazipur. Although the erstwhile dump has transformed in to a beautiful 'Waste to Wonder' park, the Kites seem to have remained in the area assisted by network of trees, the meat markets of Nizamuddin area and the food offered by the huge railway station. Historically, the area is also known to be a large roosting site (Malhotra, 2012). It is of relevance to note that, a small population of Kites continues to roost over an area for long time, even after removal of the attraction factor. This statement is supported by the roosting population at Razak Palya near Yelahanka. Although, the food source of chicken waste thrown at Catfish farming site was taken off by demolishing the fish farming ponds in 2013, a sizeable Kite population of about 50 -100 was found to be roosting at the site in current study (in February 2021 also).

Yamuna River flows in North-South direction in between Ghazipur and Nizamuddin. However, the activity was minimal over the Yamuna River and the presence of water didn't seem to influence any increase of activity.

Recent satellite tagged studies on Black-eared Kites in Delhi area (Kumar *et al*, 2020) has given better understanding on the range of activity of individual kites. These migrating Kites from Mongolia and adjacent regions of Central Asia showed restricted activity range while wintering in Delhi area, may be limited by the availability of food sources. The data from 14 birds (three of them provided data in two winters- making it 17 winter data) showed that the wintering kites in Delhi were active with an average of 195 (SE = 59) km^2. Efforts were made to obtain activity area. Details of limited number of Kites were shared by the author (Nishant Kumar, Wildlife Institute of India). One image of the activity area is given in Figure 6.7.

It was seen that from the Ghazipur area, (marked with yellow triangle), the general activity area (50%) remained within 4.3 km. The extended activity area (95%) was up to 6.2 km in the direction of Hindan airfield. On the other hand, in the Nizamuddin direction, even the extended area was available only up to 2.7 km (on transect). However, this Kite spends considerable time over Nizamuddin area (a separate small circle at the bottom left hand corner). Although, this study was carried out independently, the image corroborates the data collected as part of this thesis. However, more data of the Kites that are available needs to be analysed for understanding their activity range over feeding area, roosting areas and preference for airfield areas.

A study of four Gulls in UK (Spelt *et al*, 2019) on utilization of urban landscape showed that the Gulls spent 60-80% of the time around nesting area. The Density map of GPS location fixes also shows considerable percent of fixes within 10 km range. However, Numerical assessment is not covered in the study. It also shows limited activity, but widely dispersed over a larger area. Another study in UK on Herring Gulls (Rock *et al*, 2016) showed that the home range of activity (90%) for two Gulls was within 10 Km^2 whereas the other two were recorded as 138.7 and 558.7 km^2. Such variations may be expected in Black Kites as well.

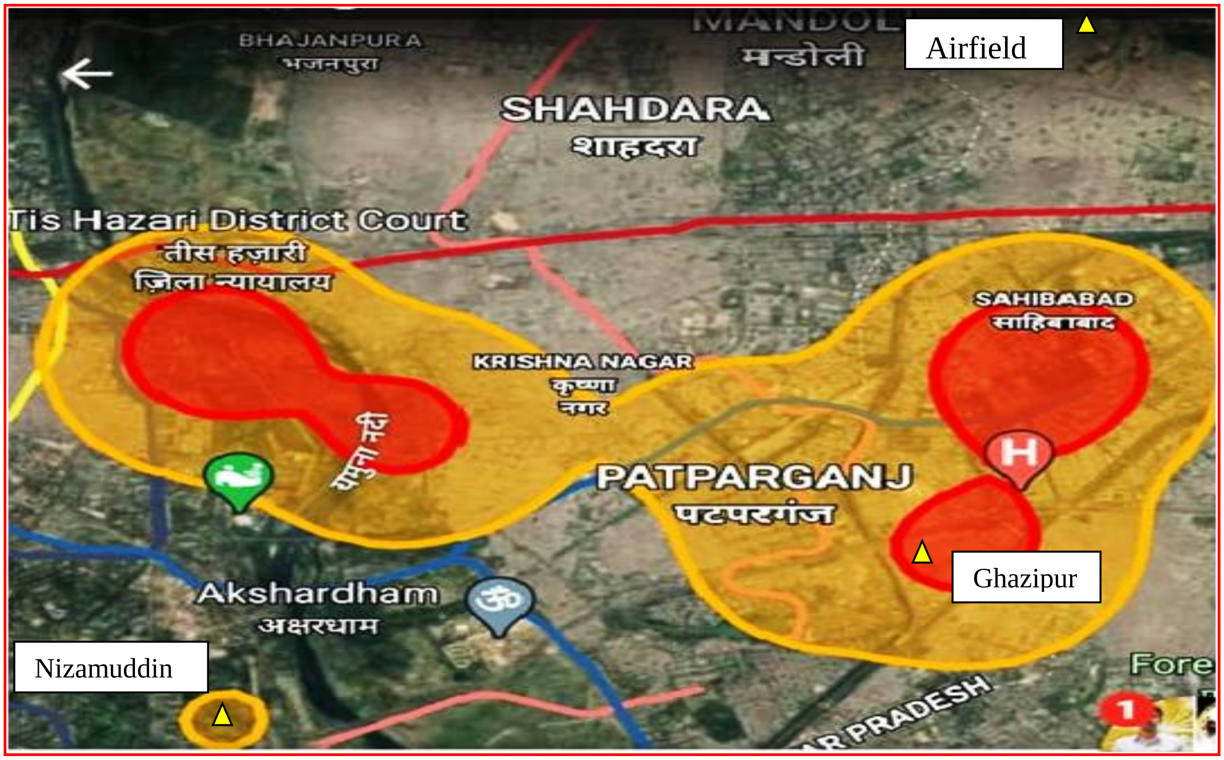


Figure 6.7. Activity area marked after processing the GPS logs of one of the Black-eared Kites (*Milvusmigranslineatus*), that was tagged by Wildlife Institute of India. (The red area represents the 50% activity and yellow areas represent the 95% activity, based on kernel density estimates for home range, during the Kite's winter stay over Delhi area). (Courtesy- Nishant Kumar, WII, Dehradun).

It is important to note that these studies are done on migrating Black-eared Kite (*Milvus migrans lineatus*) and none of them were on Black Kite (*Milvus migrans govinda)* which is the resident population of India. The migrating species is known to increase its activity range 85 folds when they return to their breeding grounds. The exact activity range of resident Kites need to be studied more intensively through satellite tagging. Observational studies in Delhi area (personal communication- Nishant Kumar) indicate that kites choose their nesting sites centrally at a location from where multiple feeding sites (garbage dump/ cultural feeding sites) within a range of 2 km radius. This area is much lesser when compared to the recorded area used by the migrating kites in their home range (Mean =57, 515; SE= 30, 151 km^2) (Kumar, 2020). In fact, airfield studies on activity counts of these birds do not show such increased kite activity during breeding season of resident species.

With these discussions, it can be safely concluded that the 10 km distance from a source location (feeding site or roosting site) is a safe distance for aircraft operations in the prevailing conditions of India. The observations hold the hypothesis valid. However, for a better long term understanding of ecology and designing airports, there is a need to study resident Kites of India with more emphasis.

6.3. ACTIVITY OF LAPWINGS IN MOON LIT NIGHTS

Being a nocturnally active bird, it is believed that Lapwings are more active during full moon and its closer nights (moon-lit nights) based on a study in Europe. Based on this concept, there is a standing instruction and practice in Indian Air Force to reduce the unnecessary and regular flight operations during the night hours of full moon days at select bases. This assumption is tested here with a systematically collected data on the activities of Lapwings at TNS (Coimbatore).

6.3.1. Methods

The data was collected for three nights around full moon nights (full moon day, full moon +1 day and full moon -1 day) to ascertain their runway occupancy under experimental conditions. The data under ‘Controlled conditions’ were collected on one random night which was at least seven nights away from the full moon nights.

Line transect counts for recording the number of Lapwings on the runway shoulders were conducted half an hour before sunset. Two trails in opposite directions were conducted in succession with a gap of fifteen minutes to ascertain their activity at the dusk. The data collection was done by scanning the Northern shoulders (area up to 50 m from the edge of the runway) at Sulur from the vehicle at less than 20 kmph in a zigzag way. A powerful light was used to scan the area to ascertain the presence of birds and their activity at night.

Thereafter, Line transect data was taken on the runway four times in the night in four different time periods. The four time periods were- sunset to 9 PM, 9 PM to 12 AM, 12 AM to 3 AM, and 3 AM to 04.30 AM. The birds were counted from the vehicle on the Northern and Southern half of the runway. In addition to the main runway, the data was also collected over ‘B’ taxi track, ‘C’ taxi track and VIP dispersal. Only one direction driving was carried out on taxi tracks. These areas are together called aircraft maneuvering areas. The transect line is shown in Figure no. 6.8.

Figure 6.8. (a). Transect (marked in yellow line) used for counting of Lapwings at night to ascertain the extent of runway occupancy. (TNS- Map of 2015). **(b)**. Yellow-wattled Lapwing (*Vanellus malabaricus*).

The data of number of birds counted over the shoulders and on aircraft maneuvering surfaces on nights of interest (days around full moon nights and a normal night). The number of birds observed on normal nights and nights around full moon nights were compared to confirm the hypothesis of enhanced activity or runway occupancy). The data was analysed for maximum runway occupancy time periods at night.

The experiment has considered the lapwing count done on a random night (at least 7 nights away from the full moon night) as the control (sample of normal night activity). The enhanced runway occupancy is expected to be on nights around full moon nights. The activity count data was on three nights around full moon and two nights as control. However, the experiment results do not tell you as to what are the generally accepted number for nights around full moon nights is problematic if it is true.

Hypothesis: The null hypothesis framed for this experiment is as follows:-

There is no difference in the runway occupation by lapwings on nights around full moon nights and on normal nights.

6.3.2. Results and Discussion

6.3.2.1. Full Moon Night Runway Occupancy by Lapwings

Lapwings are nocturnal open grassland birds. A study from Indian airfields (Sharma and Srinidhi, 2012) had observed that the Lapwing strikes to aircraft were more on nights around full moon nights. Hence, IAF has restricted the regular flight exercises during the full moon nights at selected bases. This is based on the assumption that during the moonlit nights, the lapwing activity is high. It is assumed with fair degree of confidence that runway occupancy of birds lead to bird strikes. Hence this study was planned to compare the lapwing activity between moon lit nights and other normal nights.

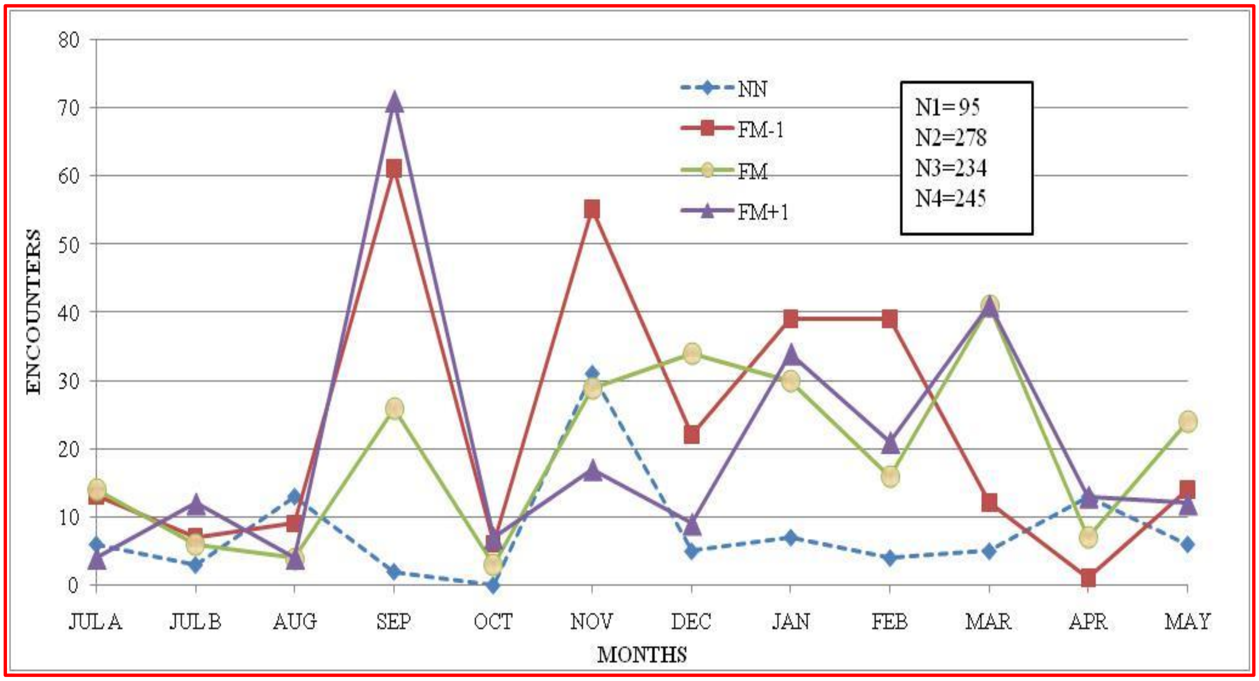


Figure 6.9. Encounters of Lapwings on normal nights and nights around full moon nights over the runway in different months. [The numbers shown represents the sum of birds counted in four transects. (NN- Normal night. FM-1 - Night preceding full moon night. FM- Full moon night. FM+1 – Night that follows the full moon night). (The month of July in 2015 had two full moon nights. They have been designated as Jul A and Jul B)].

The data collected was processed to compare the levels of runway occupancy on normal nights and nights around full moon nights. Figure 6.9 gives the monthly activity count information for all the four categories of days. It is clear that lapwing activity is high in all the days close to full moon. The data sets were subject to Students' t-test for equal means. The results are given in Table 6.2. It can easily be noted that the number of birds which occupied the runway was higher on nights around full moon nights (p <0.001 in all cases). Hence, the null hypothesis is rejected and the hypothesis that the runway occupancy by lapwings on the moonlit nights is more is accepted and this is a real cause of concern with regard to the bird strikes on those nights.

	NORMAL NIGHT	**FM-1**	**FULL MOON**	**FM+1**
Number of samples (N)	48	48	48	48
Number of Lapwings counted	93	278	232	245
Mean	1.93	5.79	4.83	5.10
Difference Between Means Of Normal Night		3.85	2.89	3.16
'p' Value		**0.0009**	**0.0005**	**0.0024**
't' Value		**-3.425**	**-3.597**	**-3.108**

Table 6.2. Comparison of runway occupancy count of Yellow-wattled Lapwing on normal nights and on nights around full moon nights and results of Students' t-test for equal Means.

Enhanced activity of animals on full moon nights has been studied by various scientists. The enhanced mental activity of humans (and in the patients in mental hospitals) has been recorded by many authors (Wang *et al*, 2020; Mittal *et al*, 2021; and Casiraghi *et al.* 2021). There are some studies contradicting this theory as well. However, there have been few studies which have definitely recorded either the increased activity or changed behaviour (such as lesser depth diving for hunting food) or increased nest guarding behaviour to protect from the predators with enhanced activity pattern. In a recent study on mammals, influence of lunar phases on Indian crested porcupine and Golden jackals indicated specific patterns. Though, the activity was not increased on full moon nights, specific patterns were observed in connection with the moon phases (Mukherjee, 2018).

In case of birds, such enhanced activity on full moon nights has been recorded in Albatrosses (Phalan *et al*, 2007) and Streaked Shearwaters (Yamamoto *et al*, 2008). Taking the concept one step ahead, Portugal *et al* (2019) recorded enhanced physiological activities (body temperature and heart beats rate) in wild Barnacle Geese on 'Super-moon' nights (full moon nights which occur when the moon is closest to the earth, giving a larger view of the moon and higher illumination). However, the same author discusses the idea of enhanced activity due to activity of prey animals to avoid being hunted by predators in the enhanced ambient light condition in addition to changed hormonal levels due to enhanced ambient light. It has been recorded that Petrels avoid returning to breeding colonies to avoid diurnal predators on moonlit nights (Yamamoto *et al*, 2008). Predatory avoidance theory may not hold good in this case as there were hardly any predators for lapwing in the airfield (except for a rare recording of Eurasian Eagle Owl).

Laurenco, (2012) from Brazil reported that Southern Lapwings (*Vanelluschilensis*) use ambient artificial light created by anthropogenic activities for foraging, but the study does not specifically ascertain whether increased moonlight also affects the activity. In the reports of Spencer (1953) and Milson (1984), the lunar cycle's influence on activity of Northern Lapwings (*Vanellus vanellus*) from England are well documented. The current study confirms the enhanced runway occupancy over airfields in case of Yellow-wattled Lapwings (*Vanellusmalabaricus*) in India through in a South Indian airfield.

This study was intended to be non-intrusive and hence, a general affirmation of the concept has been obtained through visual observations at night. However, there is a need to know their activity precisely and their preferred times of runway occupation. It is also important to mention that IAF experiences more strikes with Red-wattled Lapwing (*Vanellus indicus*). There is a need to study that species with GPS taggers and other biometric loggers.

It is well documented that the sleep and activity cycle and sleep states undergo a series of changes within a day and night in Humans (Colten and Altevogt, 2006). A different kind of sleep architecture is recorded in Asian Elephants (Tobler, 1992). More interesting sleep and activity patterns in ducks have been studied (Rattenborg, Lima and Lesku, 2012).Considering the likely variation in sleep and activity of lapwings within the night, it was expected that the Lapwings would be occupying the runway more at specific part of the night than in other parts. Understanding this activity pattern in lapwings is expected to help in facilitating the planned aircraft operations. Hence, the runway occupancy data had been collected in four time slots of each of the nights of interest (Figure 6.10).

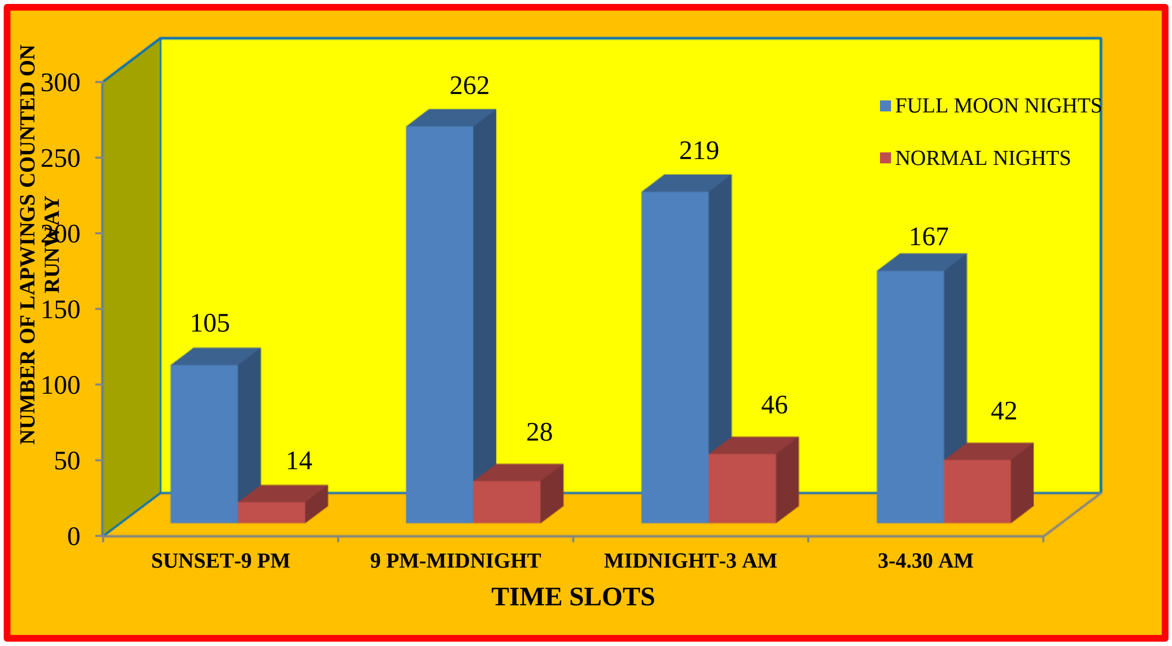


Figure 6.10. Chart showing the variation of Lapwings counted on aircraft maneuvering areas in different time-slots of night. (Full moon night data includes sum of three nights).

The Bar chart clearly indicates that the lowest activity was recorded between sunset to 9 PM (on both normal nights and nights around full moon nights). The highest activity was recorded for the time slot between 9 PM to midnight on full moon nights followed by other two time slots. However, in case of normal nights, the highest runway occupancy was seen between midnight and3 AM; followed closely by the time slot from 3 Am to 4.30 AM. The exact reasons for the same are not known. Butthis study results may be effectively used to plan night operations in the time slots when the birds are least occupying the runway to enhance the aircraft safety. More intensive studies through use of night vision devices and bio-metric data loggers may be used in future to record and ascertain different bird activities over runways at night.

6.3.2.2. Shoulder Numbers and Runway Occupancy on Full Moon Night

Table 6.3 gives the number of birds counted on runway shoulders and on runway on various nights of interest. The percentage of bird which occupied the runway is given in last column.

FM-MONTH	SHOULDER BIRD COUNT	RW-TOTAL	% on Runway	NN-MONTH	SHOULDER BIRD COUNT	RW-TOTAL	% ON Runway
2-Jul-15	44	14	31.81	21-Jun-15	47	6	12.76
26-Jul-15	52	7	13.46	17-Jul-15	35	1	2.85
29-Aug-15	20	9	45	17-Aug-15	26	7	26.92
28-Sep-15	24	26	108.33	13-Sep-15	11	1	9.09
27-Oct-15	45	3	6.66	17-Oct-15	24	0	0
27-Nov-15	14	17	121.42	13-Nov-15	20	0	0
26-Dec-15	40	9	22.5	16-Dec-15	19	5	26.31
23-Jan-16	33	30	90.9	16-Jan-15	25	7	28
23-Feb-16	45	21	46.66	10-Feb-16	18	4	22.22
24-Mar-16	40	41	102.5	3-Mar-16	38	4	10.52
21-Apr-16	45	7	15.55	10-Apr-16	44	3	6.81
22-May-16	68	24	35.29	6-May-16	46	6	13.04
TOTAL	**470**	**208**	**44.25**	**TOTAL**	**353**	**44**	**12.46**

Table 6.3. Number of birds (counted at sunset) on the runway shoulders and on the runway (sum of birds seen over four transects at night).

It can be easily seen that the number of birds that are observed are more around full moon nights. This indicates to a probability that there are birds which are around the airfield also prefer to visit airfields on full moon nights. Further, among the available birds, a larger percentage of birds were found to occupy the runway. Probable reasons could be the warmth on the runway or better visibility of food on the runway. A definitive answer can be obtained by more intensive studies, if conducted through powerful night vision devices over different nights.

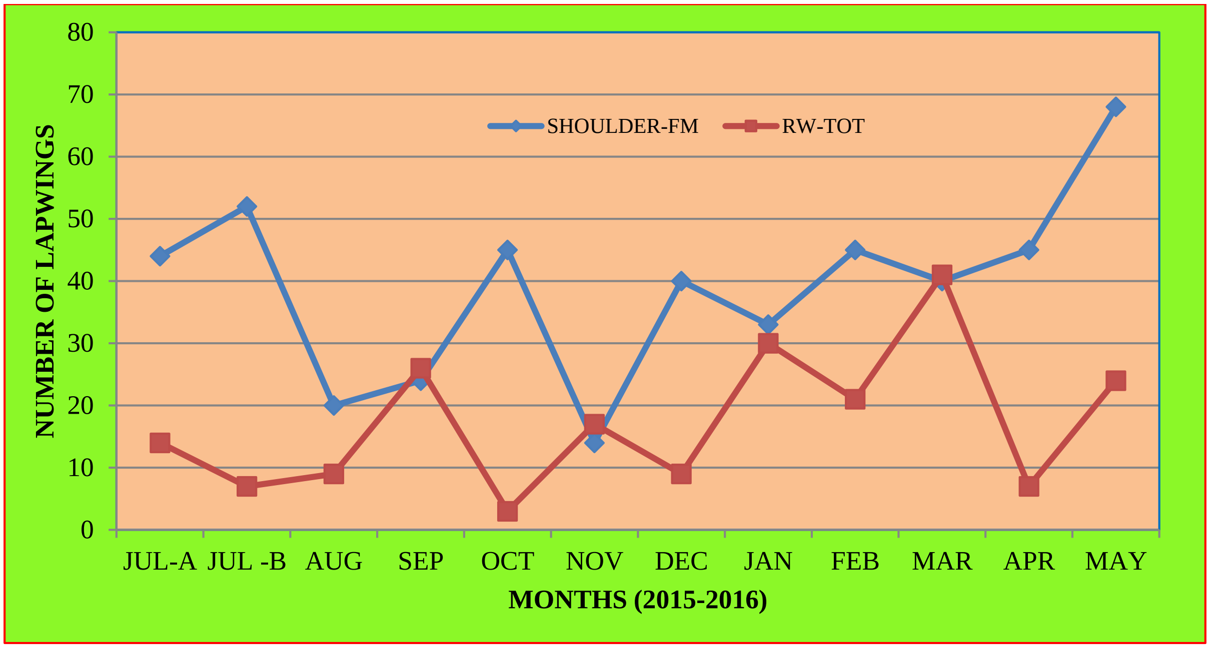


Figure 6.11. Comparison of Lapwings on shoulders and sum of birds counted on runway in four time periods on full moon nights.

Runway occupancy of lapwings in the night is expected to be a fraction of the numbers available in the nearby grassy area. Hence, a specific intensive survey was conducted on evenings of interest on the runway shoulders. The numbers of birds counted are shown in the Figure 6.11. The numbers on runway were markedly less from April to August. Lapwing numbers in runway varied very widely with 7% to 121% of the shoulder counts of the same day. On an average 44% of the shoulder numbers are sighted in runway in the moon lit nights.

6.3.2.3. Shoulder Numbers and Runway Occupancy on Normal Nights

The numbers of lapwings counted on shoulders and runway (sum of four transects in different time-slots) on normal nights are shown in Figure 6.12.

In the normal nights, percent of the birds in runway was far lesser than the numbers on the shoulders throughout the year. On an average only 12 % of birds of the shoulders were sighted on the runway during the same night with a range of 0 to 28%. This clearly indicates only a fraction of the lapwings in the area is occupy the runway during night and the occupancy rate is more on moon lit nights compared to the normal nights.

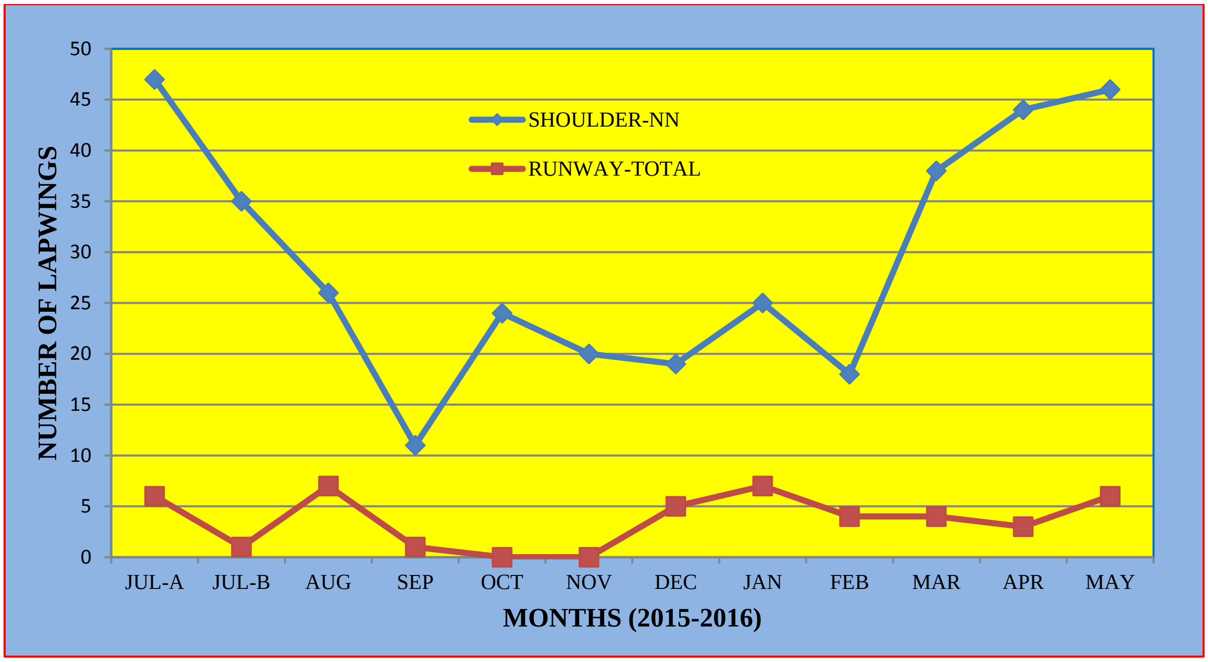


Figure 6.12. Comparison of Lapwings on shoulders and sum of birds counted on runway in four timeslots on normal nights.

6.3.2.4. Rain and Runway Occupancy

Figure 6.13 shows there is a chance of more lapwings occupying the runway during the rainy days. Although the number of insects available on the runway will be much lesser, it is expected that the birds come on to runway surface for safety. In general, the paved surface remains above the height of runway shoulders. During heavy rains the birds may prefer safer and firm locations for their roosting. While the internal circadian rhythm related lunar cycle may be keeping the bird active, external factors like rain also may influence them to occupy runway. Carrying out aircraft operations at this time is likely to lead to bird strikes as maximum birds (nearly all the population of the airfield) are likely to be on the runway during rainy days. This could be one reason for increased bird strikes during rainy season. A separate study may be initiated to look at the data from this perspective.

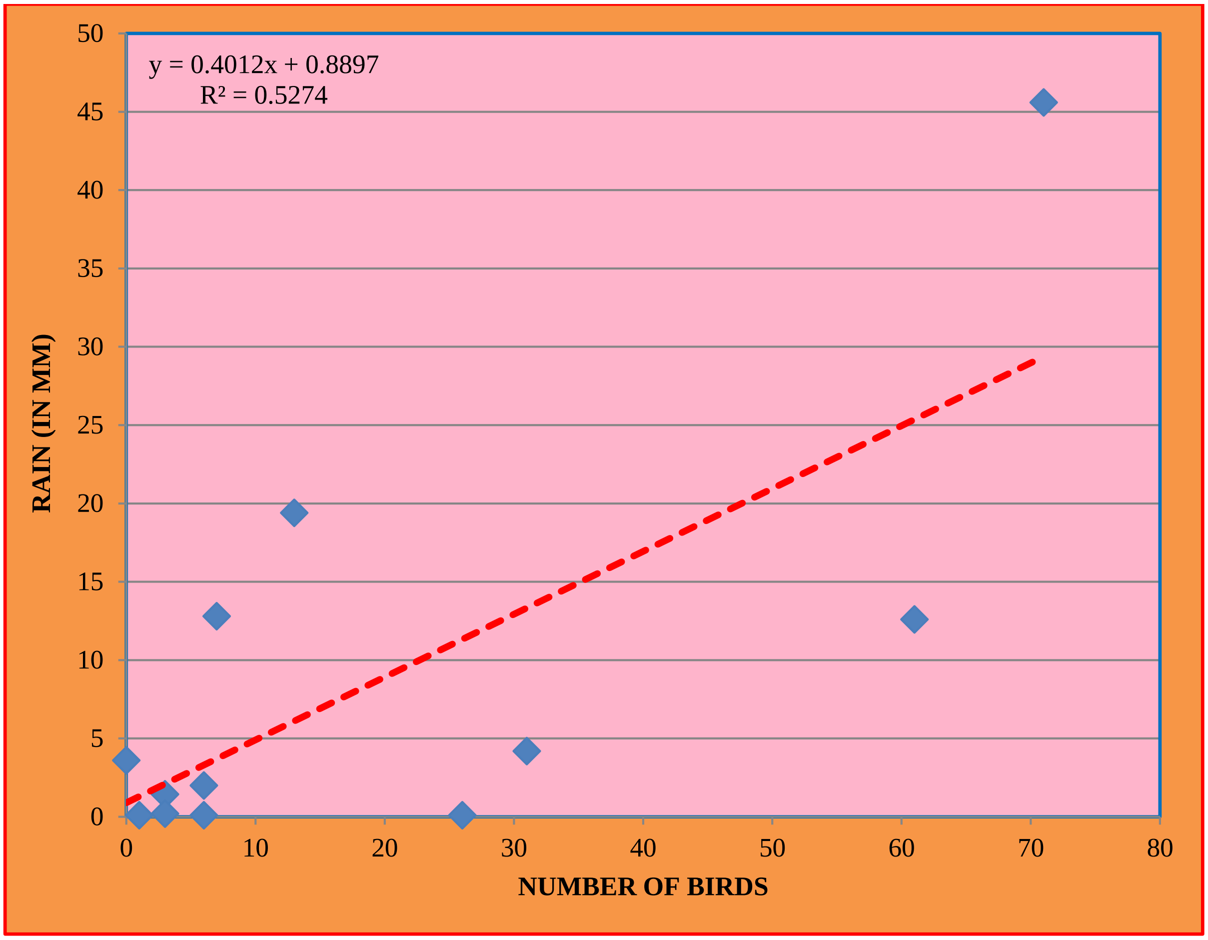


Figure 6.13. Comparison of rain quantity in a day and number of Lapwings counted on different nights.

6.3.2.5. Activities of Lapwings on Full Moon and Normal Nights

Activities carried out by the birds on the runway were observed along with the activity counts and tabulated for the full year (Figure 6.14 and 6.15). Activities were classified in to resting, walking, feeding, calling, flying and roosting (seated with belly on to the ground) and disturbed. The term 'disturbed' indicates that the original activity could not be identified as the bird got disturbed by the vehicle light or the movement. The comparison indicated that maximum birds were seen walking on full moon nights on the runway. It may be part of their foraging. However, Resting, Disturbed and feeding numbers were next in the order. Smaller numbers were seen flying, calling and roosting. On the contrary, maximum birds were recorded as 'Disturbed' while observing on normal nights. Walking stood at second followed by feeding, resting, flying, calling and roosting.

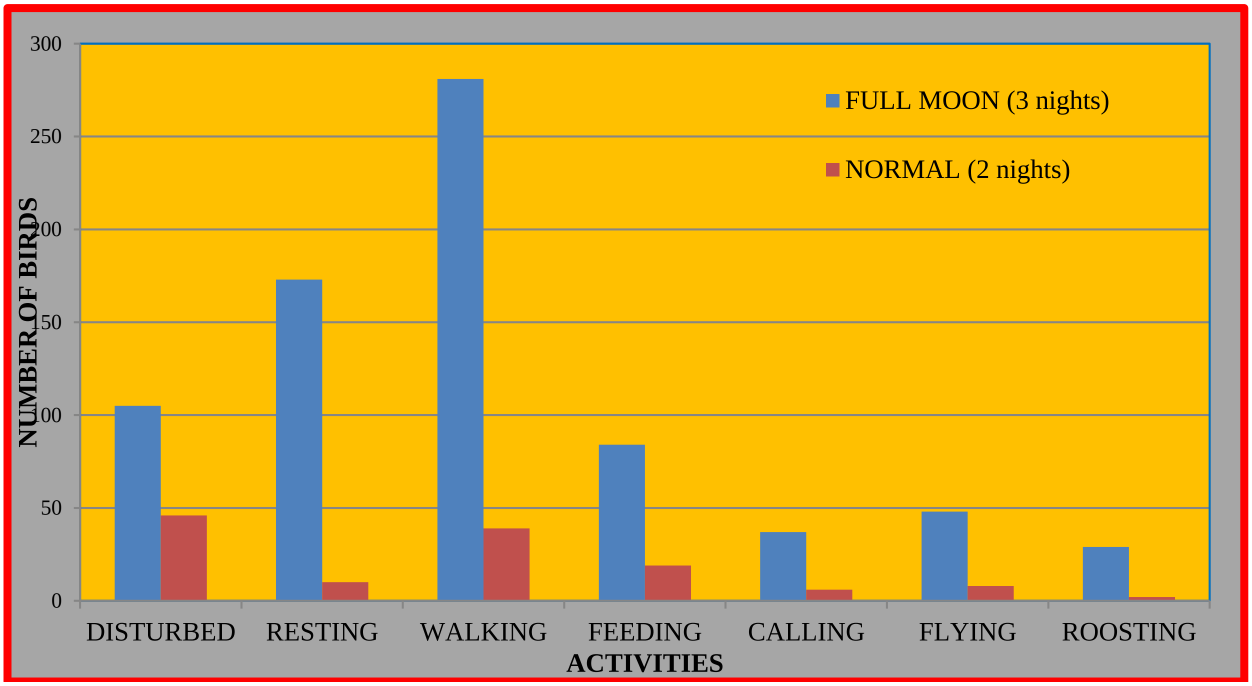


Figure 6.14. Levels of various activities on nights around full moon nights (N=470).

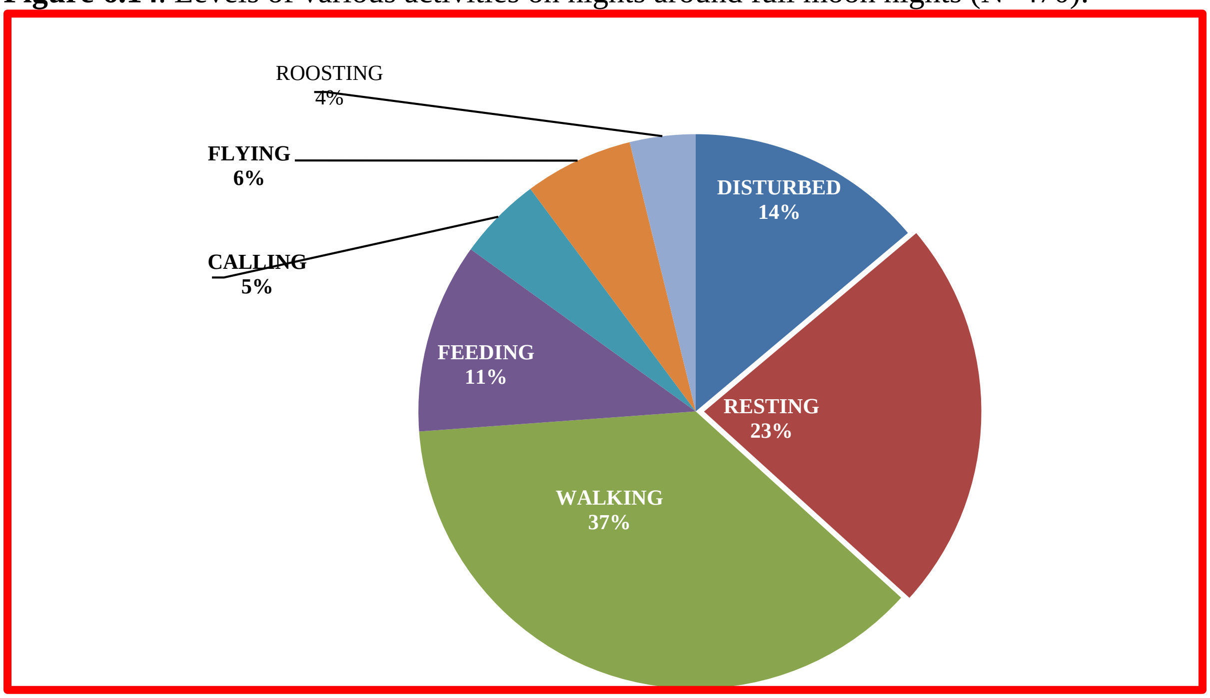


Figure 6.15. Levels of various activities on nights around full moon nights (N=470).

The varied order and degree indicates the differential usage of the runway surface area during normal and full moon nights. This data is preliminary and only indicative for further studies. A better study can only be carried out when done through night vision devices or through biometric data loggers.

6.4. EFFICACY OF DHUB GRASS

While considering food availability of birds in an airport as a reason for their presence, many early studies have suggested planting of Dhub grass (*Cynodondactylon*) in the airfield- a solution to bring down the bird activity in the area. These grasses have very small seeds which are non-viable for most of the birds for feeing and can also as a good soil binder.

6.4.1. Methods

The study of efficacy of a grass species to minimize bird activity was studied at the Delhi Military airfield (UPH). As part of airfield management, Dhub grass (*Cynodondactylon*) had been laid on the Northern side of the Northern Taxi Track (NTT) at UPH. (Figure 6.16) The grass is laid for about 2.7 km in length with a varying width between 50-60meters. This formed the 'Experimental plot' for the studies. The rest of the airfield retains natural grass. A length of 2.5 km was designated marking a 50 m area on the Southern side of Assault Strip, Link road and Southern Taxi track. This formed the 'Control plot' for the studies. The area chosen was considered to provide adequate spatial separation between the two transects. Locations of two plots in the airfield is depicted in Figure 6.16. The photographs of the Dhub grass and natural grass patches are given as Figure 6.17 and 6.18.

Figure 6.16. Areas of Dhub grass plantation (Experimental plot- marked in yellow) and area of natural grass considered for data collection (Control plot, marked in green).

Figure 6.17. Dhub grass plantation at UPA airfield (North of Northern Taxi track).

Figure 6.18. A section of the plot of natural grass plot selected for activity count of birds in 'Controlled' conditions at UPH airfield.

The bird species, number of individuals encountered and the activity of the birds was recorded by following the Line transect. Bird activity count was taken on two permanently laid transects (in Dhub grass and Natural grass areas). The transect trail was followed by driving a vehicle at slow speed of 20 km/hr at the edge of the taxi track/ Assault strip. The Dhub trail was carried out by driving the vehicle over the Northern Taxi Track. The bird encounters over the natural grass was counted by driving the vehicle on the Assault strip (birds counted on the Southern side, upto 50 meter from the edge), Link road and Southern Taxi Track.

Three line transect counts were taken in every month (in morning, afternoon and evening). This data collection was carried out for 28 months in two time periods (2014-16 and 2019-20). Eighty four data sets were collected between November 2014 to April 2016 and August 2019 – September 2020.

Analysis of the data conducted directly using descriptive statistical tools as well as student's t test.

Hypothesis. As the concept of experiment expects a reduction of bird activity counts in the experimental plot i.e., the Dhub grass, the null hypothesis is stated as follows:

There is no difference in bird activity counts over the area of Dhub grass and natural grass.

6.4.2. Results and Discussion

Observations of bird activity over the Dhub grass area over 28 months recorded 50 species on the Dhub grass and 40 species on the natural grass (Appendix II). A total of 1969 and 1033 birds were counted on each of the transect / plot at an average of 25.24 and 13.24 birds per transect count respectively. Students t test for the equal means clearly show a significant difference between two sets of data ($p < 0.005$). However, the difference is in the opposite direction of the expected line.

Comparison of bird activities between the Dhub grass and natural grass with regard to numbers and activities of birds is given in Table 6.4.Across the airfields of India as well as in Hindan, Black Kites, Lapwings, Larks and Indian Pea-fowls are known to be the hazardous species. Hence, the numbers were compared to measure the efficacy of Dhub grass (Table No 6.5).

Sl No	Parameter	Dhub grass	Natural grass
1	Species variety	50	40
2	Exclusive species	13	04
3	Encounters	346	239
4	Activity counts	1,969	1,033
5	Mean per transect	25.24	13.24
6	Breeding activity records	11	4
7	Nil birds counted transects	5	6
8	p Value	**0.005**	
	't' Value	**2.832**	

Table 6.4. Comparison of various parameters of data collected on Dhub grass and natural grass.

Sl No	Species	Dhub Grass	Natural grass
1	Cattle Egret	754	332
2	Larks	85	37
3	Indian Pea-fowl	89	4
4	Lapwings	144	99
5	Rock Pigeon	10	7
6	Black Kite	9	4

Table 6.5. Comparison of number birds of hazardous species recorded on Dhub and Natural grass.

Activity counts (along with important statistical parameters) for major hazardous birds over Dhub and natural grass is given in Table No. 6.6.

SI No	Spe-cies	Total Encounters		Total birds Observed		Avg. birds/ Transect		Standard Deviation		Min/ trans.		Max/ trans.	
		D	N	D	N	D	N	D	N	D	N	D	N
1	ASSL	11	9	85	37	7.72	4.11	5.79	2.08	1	2	14	7
2	BLKI	3	1	9	4	3	4	2.64	N/A	1	4	6	4
3	CAEG	31	16	745	332	24.03	20.8	27.64	17.4	1	1	90	57
4	COKE	7	10	7	10	1	1	0	0	1	1	1	1
5	INPF	20	2	89	8	4.45	4	3.54	0	1	4	12	4
6	REWL	26	15	119	60	4.57	4	3.4	2.44	1	1	15	9
7	ROPI	4	2	10	7	2.5	3.5	1.29	0.7	1	3	4	4
8	YEWL	10	16	25	39	2.5	2.43	1.43	1.26	1	1	5	5
	Total	**112**	**71**	**1089**	**497**	**9.72**	**7**	**17.2**	**11.1**	**1**	**1**	**90**	**57**

Table 6.6.Activity counts (along with important statistical parameters) for major hazardous birds.

(D- Dhub grass plot; N- Natural grass plot. ASSL- Ashy-crowned Sparrow-Lark, BLKI- Black Kite, CAEG- Cattle Egret, COKE- Common Kestrel, INPF- Indian Peafowl, REWL- Red-wattled Lapwing, ROPI- Rock Pigeon, YEWL- Yellow-wattled Lapwing).

More birds were recorded in Dhub grass than the natural grass plots. This is against the expectation. Total bird species and numbers recorded were more over Dhub grass. Among the species, more birds were sighted over the Dhub grass. However, there are some biases in the location of the study plots and the results to be considered discounting the effect of the same. A strip of Dhub grass was next to a scrub forest patch (for about 600 m).The planted grass area has a chain link fence for almost complete length.. The increased number of species would have some neighbourhood effect rather than just due to stand-alone habitat attraction.

To get more clarity, the species which are hazardous to the aircraft and also the exclusive species recorded in both the grass strips were specially analysed.

Dhub grass attracted 745 Cattle Egrets as against 332 birds on Natural grass. This variation of 224% (with a large number of encounters- 31 and 16 respectively) is considered significant. They were seen feeding on both grass areas. In addition, it is also pertinent to consider that Little Egrets (16 in number) were exclusively attracted by Dhub grass. This leads us to infer that Dhub grass is somehow more attractive to Egrets, though the cause for this specific preference of egrets to Dhub grass is not known. However, a study in Australia (Richardson and Taylor, 2003) showed that Cattle Egrets exploit the rice fields (a manmade single grass species ecosystem) maximum in comparison with other species of Egrets. This is seen as a cause for growing of Cattle Egrets as an invasive species there. The exploitation of one dominant species plot of Dhub grass may be attractive to egrets as in the case of paddy fields in Australia.

Larks are a grass seed feeding set of species and are known to strike aircraft quite often. While their strikes do not frequently result in damage, the sheer numbers and their presence over the airfield leads to hazard and forces safety authorities to impose restrictions. Hence, this set of species can be a key consideration for measuring efficacy. 85 birds were counted over Dhub grass as against 37 birds over natural grass. This indicates 229% more activity over the Dhub grass. If this grass is laid all over the airfield, these birds have the potential to cover whole of the airfield. Hence, the Dhub grass is considered less efficient in repelling Larks.

Pea-fowls were seen more (89) on the Dhub area when compared to the natural grass area(4). This amounts to 11 times higher activity. The presence can be directly attributed to closeness to scrub jungle and hence, no clear conclusion can be drawn with respect attractiveness of Dhub grass.

Lapwings, as a group is the most vulnerable ground dwelling bird species. Their strikes at night cause greater difficulty due to the damages caused as well as limitations to spot them. Hence, the ability of Dhub grass to avoid Lapwings will be a key consideration. As a group, 144 birds were seen over Dhub grass area as against 99 over natural grass. This indicates an increase of 45%. Considering the efforts that are put in by Safety authorities to keep Lapwings away, any increase in Lapwings by planting it all over the airfield is expected to create hazards beyond the level of management. Individually, Yellow-wattled Lapwings were seen 56%higher over the natural grass. This can be a consideration in places where only Yellow-wattled lapwings are higher in number. But, considering that most strikes are caused by Red-wattled Lapwings, Yellow-wattled Lapwings may be given limited consideration for selection of grass [at a ratio of 7.2**:**1 (study of IAF data for the period 2009-2018)].

With regard to pigeons also, marginally higher activity was seen in limited numbers in Dhub grass.

Kites are not a grassland depended species. However, kites were seen doing ground roosting in grassland area especially the airport environment. In this case also the number of birds over Natural grass (4) was found to be less compared to Dhub grass (9) area. However, this comparison is not a complete reflection of ability to avoid Kites as they generally come over the airfield for thermals. Marginal numbers recorded spread over a long period indicates that the type of grass is not a major factor to attract or avoiding Kites over airfields.

The key breeding related activities by different birds on both types of grasses were also recorded. This is particularly important that breeding leads to presence of birds over the area almost on 'round the clock' basis for about two to three months (their breeding period) in a year. These activity records were also seen significantly higher (2.75 times) on Dhub grass.

There were 13 exclusive species recorded from the Dhub grass where are only four from natural grass. After careful analysis of the diversity, overall activity counts as well as the number of hazardous species of birds in both the grass fields, it can be stated with a fair degree of confidence that the Dhub grass will certainly not decrease the hazardous bird activity.

6.5. EFFECT OF ANTI-BIRD MEASURES ON BIRD ACTIVITY OVER AIRFIELDS

On a typical Operational day over IAF airfield, various short term anti- bird measures are implemented to minimise the bird activity and to ensure vigilance. General methods include regular scanning of the runway by a vehicle, deployment of bird watchers (varying between 7 and 14), bird scarers (personnel varying between 3 and 7, equipped with crackers, six shot launchers and a limited number of shot guns), deployment of labourers for 'Drum beating module', few planned activities such as grass cutting (manual as well as by tractor), switching 'on' of various gadgets such as gas cannons, distress call generators (static as well as vehicle mounted). All of these are employed to different degrees in each airfield. The quantity of usage of crackers and other pyro-techniques varies with the levels of bird activity and operations. All scaring techniques are non-lethal and are fired away from the bird to push them away from the operational area.

There is also enhanced movement of humans with about 40 men walking over the runway in the morning for an activity called Foreign Object Removal Parade (FOR Parade). There are also enhanced movements of vehicles to check the airfield services. Over and above, the aircraft movements (with a high decibel sound it makes) by themselves are considered as a deterrent for bird activity. Most of these are absent on a Non-operational day, which is considered as days of non-implementation of anti-bird measures. These days were generally holiday or a planned maintenance day when operations are not conducted.

Most of these bird hazard management options are for the immediate result of chasing the birds away from the runway and to create a safe corridor for operations. The collective effect of all these measures on the presence and absence of the birds in the airfield is an important factor to understand. Hence, an attempt was made to compare the bird activity between the days (when all these measures are in place along with flight operations and days when these active measures are not in place.

Hypothesis. As per the understanding, a null hypothesis is formulated as *"there is no difference in bird activity counts on the days of implementation of anti-bird measures and days of non-implementation of anti-bird measures".*

6.5.1. Methods

The study was conducted in 16 selected airfields. The list of airfields where effect of anti-bird measures experiments were conducted and general techniques of short term anti-bird measures implemented in those airfields are shown in Table 6.7.

Sl No	Airfield	State	Bird Hazard Management Techniques in practice in select locations
1	TLA	Telangana	DB, GC, W&S, FWV
2	KAB	Karnataka	DB, GC, W&S, FWV, B
3	ASC	Assam	DB, GC, DCG, W&S, FWV
4	MPG	Madhya Pradesh	DB, GC, DCG, W&S, FWV
5	TLH	Telangana	DB, GC, DCG, W&S, FWV, B
6	UPH	Uttar Pradesh	DB, GC, DCG, W&S, FWV
7	GJJ	Gujarat	DB, GC, DCG, W&S, FWV
8	WBK	Orissa	DB, GC, DCG, W&S, FWV
9	PBP	Punjab	DB, GC, DCG, W&S, FWV, B
10	MHP	Maharashtra	DB, GC, DCG, W&S, FWV, B
11	JKS	Jammu & Kashmir	GC, W&S, FWV
12	HRS	Haryana	DB, GC, W&S, FWV, B
13	AST	Assam	DB, GC, DCG, W&S, FWV, B
14	KAY	Karnataka	DB, GC, W&S, FWV, B
15	UPA	Uttar Pradesh	DB, GC, W&S, FWV, B
16	HRA	Haryana	DB, GC, DCG, W&S, FWV, B

Table 6.7. The list of airfields where effect of anti-bird measures experiments was conducted and general techniques of short term anti-bird measures implemented in those airfields. (Abbreviations- DB- Drum beaters, GC- Gas cannons, DCG- Distress call generators, W&S- Watchers and scarers, FWV- Four wheeled vehicles, B-Bikes.)

Point count data for the whole day (using the same method as in the activity count for community studies; chapter 4) was collected at one of the selected posts. The data were collected on consecutive days. The days of implementation may have been prior to the day of data collection of non-operational day or vice-versa depending on the convenience of the airfield functionaries. The data collected on days of implementation of anti-bird measures was considered as ‘Experimental’ day and the data of days of non-implementation was considered as ‘Control’ day for the study purpose. Four sets of data (implementation day and non-implementation day data) from 16 airfields spanning over five months between November 2020 and March 2021 were collected for comparison. This amounted to 1,536 hours of observations.

Careful observations were made and visible effect of these measures on the movement and behaviour of the birds were recorded.

It is assumed that the bird activity was the same on two different days, except for the deviation caused due to anti-bird measures (including aircraft movements) employed. Data was collected on two consecutive days to minimize the variation caused due to daily changes (generally Friday and Saturday or Sunday and Monday). These days represented 'Test' and 'Control' data and combined data of two consecutive days were considered as one set. Four such sets of data were collected from each of 16airfields amounting to 64 sets of samples.

The following activities/ anti-bird measures are in place on an active airfield on a typical operational day:-

(a) Bird Watchers and Scarers. Trained Air Force staffis present on either sides of the runway. A typical airfield will deploy about nine personnel spread all over the airfield. The general distance between them is about two thousand feet. Some of them carry a 12 Bore gun and crackers (consisting mainly of the 'Display cracker Rockets'). These are used to scare the birds away from the path of aircraft, if they are found on the path before take-off or landing. At least one scarer mobile vehicle (usually, a Maruti Gypsy or a Tata Sumo/ Tata Xenon pick-up vehicle) is active over the airfield and carries out a scanning before each set of landings and take offs. Specific birds sitting on the runway are scared off and ensured that they clear the path up to a distance where crackers have their effect.

(b) Gas cannons are deployed at airfields for scaring birds away. They are generally known as 'Zon guns', sold commercially under various names such as Propane exploders, and LPG Exploders. These are Liquid Petroleum Gas (LPG) operated cannons which have a modified internal combustion engine to build up air pressure, a diaphragm to produce sounds (Bangs) and a nozzle to direct the sound. The general sound levels of the acoustic bursts varied between 100-120 dB in the immediate vicinity. The sound firing interval varies between 40 and 120 seconds.

(c) Drum beating module. This module typically employs labor of 4-6 persons (may employ 18 in rare cases) on the runway shoulders to beat the drums and walk in order to chase away the birds from the airfield.

Photographs of various short term anti-bird measures are given in Figure 6.19 (a) to (j).

(a). Bird watchers to report the presence of birds before take offs and landings.

(b). Use of crackers to scare away the birds

(c). Six shot launchers with cartridges.

(d). Gas cannons used to scare away birds.

(e). Drum beaters to scare away the smaller birds like Larks, Pipits and Lapwings.

(f). Labourers for vegetation management and insecticide spraying.

(g). Complement of Vehicles and other machines used for general anti-bird measures.

(h). Bird scarer.

(i). Microlite operations are specifically carried out to review the bird activity areas.

(j). Operations, by themselves are a big inhibitor for bird activity.

Figure 6.19 (a) to (j). Various short term anti-bird measures implemented on day to day basis at airfields. (Photo credits- Institute of Aerospace Safety/ IAF)

6.5.2. Results and discussion

6.5.2.1. Effect of Anti-Bird Measures on Activity Counts

A comparison of sixteen airfield total data (four sets of samples from each airfield, amounting to 64 sets samples) showed only 9.56% decrease in bird activity on an operational day in comparison with a corresponding non-operational day. Collectively, the differences in activity count between days of implementation and non-implementation of anti-bird measures are not significant ($p>0.5$). Individually, only four airfields showed significant reduction (more than

15%) in bird activity on operational days. The variation ranged between 16.57% (Gwalior) and 52.12% (Tezpur).

Table 6.8 shows basic statistics of the overall comparison. Table 6.9 shows information of the airfield-wise activity counts.

Parameters	Days of implementation of anti-bird measures	Days of non-implementation of anti-bird measures
Number of samples(N)	64	64
Mean	909.22	987.58
SD	1011.43	1002.60
Activity counts	58,190	63,655
MIN	45	44
MAX	5686	5982
Difference between means:	78.35	
'p' Value = 0.660		
't' Value = -0.440		

Table No. 6.8. Overall comparison of bird activity counts on the days of implementation of anti-bird measures and non-implementation of anti-bird measures.

The experiment has been carried out with an assumption that the bird activity will be same on two consecutive days, if no other factor is influencing it. Though overall data shows no statistical significance in variation, most of the airfields showed a marginal increase in the number of activity counts on days of non-implementation. However, two airfields (UPA and TLH) showed greater activity on days of implementation of anti-bird measures which is contrary to the general expectation. The increased variation ranged from 40.51 to 52.17%. These variations could be due to other parameters such as weather or due to attraction created by some operational activities. Although, all activities and anti-bird measures on an operational day are expected to deter the birds, results such as this demand for a critical assessment of all activities. Some of the probabilities could be the creation of thermals due to the hot air generated by aircraft exhaust or a specific sound frequency generated when the aircraft starts up. More study need to be done in this direction.

Airfields	Activity Counts on days of Implementation of anti-bird measures	Activity counts on days of non-implementation of anti-bird measures	Percentage of variation of activity counts from non-implementation day
TLA	780	811	-3.82
UPA	4,305	2,830	52.12
HRA	2,095	2,290	-8.51
KAB	314	321	-2.18
ASC	2,362	2,295	2.91
MPG	2,411	2,890	-16.57
TLH	541	385	40.51
UPH	1,709	1,980	-13.68
GJJ	7,122	7,524	-5.34
WBK	2,150	2,381	-9.7
PBP	1,717	2,794	-38.54
MHP	1,228	1,404	-12.53
JKS	4,535	4,890	-7.25
HRS	3,953	4,391	-9.97
AST	1,232	2,817	-56.26
KAY	1,827	2,325	-21.41
Grand Total	**38,281**	**42,328**	**9.56**

Table No. 6.9. Comparison of airfield-wise bird activity counts on days of implementation and non-implementation of short term anti-bird measures.

In the larger perspective, it is important to note that similar studies in other parts of the world has also shown similar results. A more intensive and focused study on the effect of Propane exploders (up to 150 m distance) showed that the reduction in activity was not significant (less than 2.5%) (Washburn, Chipman and Francoeur, 2006). A compilation of results of many experiments involving integrated use of multiple methods indicated that effectiveness of various devices was highly variable (Gilsdorf, Hygnstrom, and VerCauteren, 2002). After an extensive review of different experiments, it had been concluded that sonic deterrents should be viewed with skepticism by legislators, pest controllers, and consumers (Bomford and O’Brien, 1990). Hence, findings of these studies have re-affirmed the findings at other places.

6.5.2.2. Effect of Anti-Bird Measures on Selected Species/ Group of Species

Data on species-wise activity on days of implementation and days on non-implementation is given in Table 6.10 for comparison.

Species	Non-implementation Day	Implementation Day	Variation (%) in comparison with day of implementation
Black Kite	3000	3580	-16.20
Lapwings	324	349	-7.16
Rock Pigeon	6227	6912	-9.91
Cattle Egret	1388	2053	-32.39
Larks &Pipits	3979	4573	-12.98
Common Myna	4269	4584	-6.87
Black-shouldered Kite	513	465	10.32
Common Kestrel	52	76	-31.57
House Crow	2425	1848	31.22
Rose-ringed Parakeet	4663	4073	-14.48
Swallows & Swifts	2722	4771	-42.94

Table No. 6.10. Comparison of selected bird activity counts (species-wise)on days of implementation and non-implementation of short term anti-bird measures.

It is important to know as to what extent these measures affect the activity of each species or a group of species. As some species (as a group) are known to respond to anti-bird measures in a similar way (generally, birds of the same group), they are addressed with special focus.

Black Kites are the most hazardous birds for aviation in India. It can be seen that there is a reduction of 16.2% in activity on non-operational days. The measures against Kites mainly include scaring crackers. Although, there are a large number of Bird Watchers who are present, their presence is not likely to have any effect on the activity of Kites. Any specific study focusing on the scaring methods of kites could not be accessed. However, a focused study on the usage of crackers on the day of operation is needed.

Lapwings, as a group needs to be studied separately considering their habitat preference to open lands of the airfield. Considering that many of them breed on airfields, it is highly expected that the temporary methods used do not affect their activity. The breeding birds are either not affected by the methods employed or they get habituated. This is reflected in the marginal variation on the days of interest.

Rock Pigeons have proved to be a menace within human inhabitation. Hence, multiple studies have been conducted and many commercial products have been launched. However, there are limited studies that look for sanitization of the airfield. The occupancy of hangar by pigeons is a menace and many efforts have been made to push them out. A specific study at Trishul airport at Bareilly (Chaudhary, 1997) recorded a variation in the number of Pigeons over a year. The same study carried out air gun shot experiments within a large dome of a college. It showed that consistent firing reduced the pigeon population to zero and then, it took 34 days to return. Correlating these results and the observation that Pigeons are rarely seen on the ground over IAF airfields, it is possible to infer that the consistent crackers and gun shots keep the pigeons away from the runway area, though cannot push them out of airfield or hangars. A small increase of 9.91% is seen on implementation day indicating negligible effect on their activity.

Cattle Egrets are considered as a friend of the farmers as well as fishermen (Seedikkoya and Azeez, 2009). Given this fact, Egrets are generally not treated as pests and hence, not much research is done to keep this species to scare away. As observed during the current study, these birds are quite easily manageable with threatening postures by humans. They were not seen in the vicinity (up to 50 m) of any gas cannons. The only exception seen on airfields is when they start feeding on the disturbed insects behind a grass cutting mechanism of tractors. Hence, it is inferred that the human presence and deterrence action by the anti-bird measures has one of the highest effects on egrets. The increase in numbers on days of implementation is attributable to attraction caused by activity of grass cutting. The Bidar airfield had countedmore Egrets on days of non-implementation, but carried out grass cutting. It can be seen that the birds exploit the airfield environment by 32.39% more during the grass cutting.

Larks and Pipits generally occupy the grassy / bald soil patches on the runway shoulders. Some of them are known to exploit the water patches on the runway (seen as a rare happening over an airfield, where water used to ooze out on the runway (personal observation during the study). They also warm themselves over the runway area and can be a cause of concern. The 'Drum beating module' is specifically designed and deployed by IAF for Larks and pipits (in addition to other target birds). The results of this study shows marginal difference in the activity. The activity count was seen to increase from 3,979 on non-implementation day to 4,573 on days of implementation. The increase is mainly attributable to the enhanced activity caused by the humans who scare them away before every aircraft operation. Otherwise, it is perceived that there is no deterrence effect on them. Only, safety windows are created by the techniques employed.

Ecologically, this group of birds needs specific attention. According to Environment Information System (ENVIS) Bulletin (Rawat and Adhikari, 2015), the Grasslands of the country are shrinking due to increased human and livestock population. Given this fact, there is a high possibility that more and more Larks and Pipits will come to airfields as they form grassland habitat which will not be destroyed for many years to come. There is a need to look for ecological ways of managing these birds over the airfields more effectively through more research.

The involvement of Mynas in bird strike incidents is negligible. However, they are discussed here considering the large activity numbers that are recorded over different airfields(Table 6.10). A negligible 6.87% reduction is observed on the days of implementation. Their presence is generally seen in the morning and evening, mostly in transiting flights, though a small percentage of them feed over airfield for short time. Knowing that they are among the friendliest of humans, it is less likely that human activity brings down the bird activity significantly. They have also been observed to be feeding on grass patch when the aircraft is taking off.

Black-shouldered Kites are one of the most actively managed birds. They are easy for detection, generally remain at low heights and do not form flocks. While human presence may have a negligible effect on the activity of this bird, the bursting of crackers and other pyro-techniques are certainly expected to bring down the activity numbers. The reduction in numbers on days of implementation affirms this understanding.

Just like the management concept discussed for the Black-shouldered Kites, Kestrels are also managed with focus on individual birds. Results contrary to expectation (increase by 31.57% on days of implementation).

Swallows and Swifts are seen in the air, hawking on insects over the airfield. As per the general observations, they are neither deterred by human presence nor by any other means such as drum beating, gas cannons, and pyro-techniques. The general understanding is that they just pass over the airfield while they are feeding on insects in the air. The increase in activity to an extent of 42.94% is not easily explainable. This may be due to highly varied levels of bird movements on daily basis which is not catered in the initial assumptions.

It is clear in the overall comparison that total bird activity of the airfield is showing a reduction of only 9.56% bird activity on days of implementation. Though, it seems negligible, the anti-bird measures are useful to deter or chase birds from most critical locations such as the runway and approach path. Hence, the ongoing many anti bird measures and operations may not be successful in keeping the birds away from the airfield, but, definitely are useful in getting temporary displacement of birds from a critical location to a safe location.

7. SUMMARY

7.1. INTRODUCTION

Bird collisions with aircraft have become a serious concern all across the world. Many aircraft and lives have been lost both in civil aviation and military aviation. Different parts of the world have suffered this problem to different extent. Advanced and economically rich countries like USA and UK record the highest number of incidents and economical losses. This has forced them to have an organizational structure to record and address the problem. But, other countries have also taken the matter seriously and have started addressing the issues from various fronts. Aerodrome bird ecological studies at various countries, and passing of specific administrative rules have been passed.

India has suffered extensively in the past due to this problem. The numbers and rates of crashes of aircraft due to bird strike have come down drastically in the past two decades. However, the costly aircraft that are being bought, increasing air traffic, increasing bird hazard due to enhanced population of hazardous species near the airports have highlighted the requirement to look at the issue more closely. Both civil and military aviation authorities have instituted specific studies to look into the problem and come out with solutions which are ecologically sustainable and economically viable.

This study was initiated with three objectives; recording of the bird community structure, assessing the extent and changes in bird hazard, and evaluating the some of the current strategies to validate their efficacy. The study was conducted at 21 airfields across the country. These airfields were selected from different bio-geographic regions to provide a true sample of the varied bird ecology across the country. The study was carried out for about seven years (with a break of two years) in different phases. The findings of the studies are summarized in the following paragraphs:-

7.2. BIRD COMMUNITY OF AIRFIELDS.

The bird community of airfields varied extremely among the study areas, during the period of eighteen months. A total of 197 species were recorded within an activity count of 10,80,146 from 18 selected airfields studied. The species richness varied between 23 and 83 among the airfields with an average of 51. The total bird activity records during the study period over the airfields ranged between of 7,409 and 2,56,669. The airfield varied in taxonomic composition of bird community in terms of higher levels of classification such as Order and Family. The airfield with least species richness (23) stood second highest in activity counts (1,48,382).

The species frequency of presence showed that a majority of them (87 species) occur only in one airfield. And more numbers of species have very restricted distribution. This makes airfield bird communities are significantly different geographically. Very few species are widespread among the airfields of the country though the habitats are similar. Only two species were found in all the 18 airfields (House Crow and Cattle Egret), five species were recorded at 17 airfields. They were Rose-ringed Parakeet, Rock Pigeon, Black Kite, Common Myna and Black Drongo.

The phenomenal number of Rose-ringed Parakeets recorded at UPA, dominated that bird community with an overall activity count of 15.84% of all 18 airfields (Dominance D = 0.66). On the contrary, the TLA and GJJ airfields recorded more evenness in the community composition (Dominance D = 0.06) with an activity count of 7,409 and 94,393 respectively. Hence, it was very evident that each bird community is qualitatively and quantitatively different. This was further proven through SIMPER analysis. With regard to bird community comparison, the ‘r’ values between all airfields were found to be significantly different (<0.0001).

In the Guild composition analysis, the insectivore species dominated both in species richness as well as in the activities. However, activity of the Frugi-granivore (which included Parakeets) ranked second (with 15%), though their species contribution was limited to 3%. The species and activity among various guilds varied significantly between the airfields. Generally, the Insectivores and Omnivores dominated in the activity counts of different airfields in different proportions. In AFA-Hyderabad, the Insectivores contributed up to 60% whereas in Car Nicobar, the Omnivores made up the community up to 68%. In Jodhpur, the Frugi-granivores was dominant with the activity up to 48% with the presence of phenomenal numbers of Pigeons.

7.3. BIRD STRIKE HAZARD

It is important to understand the depth of the problem and the species which are causing highest damage and their hierarchy. An insight into activity of the top hazardous birds would make the study systematic and result oriented. Towards this, the data of species involved and the number of bird strikes in general in the country was compiled from various secondary sources and analyzed.

A comparison of the bird strikes to civil aircraft clearly indicates that the number of bird strikes is steadily growing in India. Although, the rate of bird strike and percentage of damage causing incidents to the total incidents remains generally within the accepted limits, it is of concern due to the high cost and probable accidents which may lead to loss of lives.

Vultures used to be the most hazardous species in the past. However, with the reduction of their population in the sky, the current most hazardous species in the Indian sub-continent is the Black Kite. (There have been seven crashes of fighter aircraft in the past one and a half decade. Black Kite has been the cause of three crashes among them). This is followed by Red-wattled lapwing and (House) Swift. The Pigeons, which are growing in cities and in many airfields due to various ecological, cultural and biological factors, are turning out to be the next most hazardous species. The parakeets, mynas, egrets and crows which dominate the activities over the airfield also contribute but to a much lesser extent for the hazards.

A study of the yearlong activity of most hazardous species namely Black Kites and Red-wattled Lapwings were undertaken at selected airfields and their past activity data were compared. Results showed that the activity counts of all these most hazardous species reach peak numbers around the similar period within an airfield. However, their peak activity period in different airfields differ significantly depending on various ecological factors. It was also seen that the Black Kite population may grow unhindered if there are no scientific garbage management procedures in practice in respective cities and enhanced meat markets. The population tends to remain low, if these factors do not support their growth. The other hazardous species, Lapwings has shown significant increase and decrease of population over a period of five years at Sirsa airfield without indicating any specific ecological factors under study as of now. In similar ways, different species may become more hazardous by increasing their population and then reduce themselves when the habitat does not support them. Hence, there is a need for constant look out for the ecological changes which is leading to extreme variations in populations of various species.

7.4. ASSESSMENT OF MANAGEMENT STRATEGIES

The aviation industry uses various strategies to mitigate the bird strike hazard around the airfield. The study took up four strategies that are used by IAF for assessing their efficacy. The results are summarized in the following table:-

1. **Keeping the Kite Source Sites such as Garbage Dumps and Meat Markets at a Distance of 10 Km.** The Indian Aircraft Rule, 1937 (Rule 91) restricts dumping waste, meat and other bird attracting materials within a distance of 10 km from the Aerodrome Reference Point. This study designed research questions to check the validity of this concept in the current scenario of having large garbage dumps which hosts unprecedented numbers of Kites. The study revealed that the Kite activity comes down significantly by seven km distance from the source site. However, the activity at the airfield may increase due to other smaller attractions factors. These factors may include smaller feeding sites nearby, attractive roosting sites or the thermals created by the airfield itself. Hence, it is important to keep the source sites beyond 10 km distance and also keep the immediate surroundings devoid of feeding opportunities. This concept is valid even whether the source location holds thousands of Kites or a smaller number in hundreds.

2. **Restrictions on Operations on Full Moon Nights.** A study was taken up to check the validity of the concept of enhanced activity/ runway occupancy of Lapwings around full moon nights. The study found that the Yellow-wattled Lapwings are occupying the runway areas more on nights around full moon nights. The study also found that the occupancy is relatively less in the time slot between sunset and 9.00 PM. Lapwing runway occupancy increases on runway on the nights of rains. It was also observed that considerable number of Lapwings use the runway shoulders for their roosting/ breeding activity. The extent of their preference to use runway is higher on nights around full moon nights. The study was carried out at a South Indian airfield where Yellow-wattled Lapwings were present. Further studies are required to be conducted to know whether the similar activity patterns exist in Red-wattled Lapwings in North India.

3. **Planting of Dhub Grass**. Many agencies had suggested the use of grass with very small seeds which are not attractive to granivore birds (for example; Dhub grass-*Cynodondactylon*) to avoid hazardous birds in the airfield area. A research questions was designed to test the efficacy of this grass to deter hazardous birds. The study found that the said grass does not deter the hazardous birds from using the airfield area. They were found to specially attract the insectivores such as Cattle Egrets. In this study natural grass patches with mixed local species attracted fewer birds than the selected monoculture plot.

4. **Collective Effect of General Anti-bird Measures**. IAF employs various methods on operational days to mitigate the bird hazard. It includes deployment of drum beaters, gas cannons, distress call generators, crackers, pyro-techniques, bird watchers and scarers and vehicles to push them off from the area of interest. In addition, the movements of aircraft which makes sounds of high decibels were also considered as a bird repellent. An attempt has been made to gauge the collective effect of all general methods that are employed on the bird community. The experiment was spread over sixteen airfields over five months. The results showed that the combined effect of all methods employed is not significant to alter the bird community. However, the small extent of localized reduction for some operation may be significant to create a safe window for operations. At some of the airfields, the level of activity of some species of birds was observed to be higher on the days of implementation of strategies. More studies are required to be conducted at these sites to verify the cause for increase in activity on Operational days.

7.5. CONCLUSION

For the first time, this study brought out the comprehensive structure of bird community of Indian airfields, which is significant in planning the future bird hazard management activities. Most important hazardous bird species and the species with future hazard potentials were identified based on their activity pattern over the airfields. Black Kite (which is a bird of urban ecosystem) and Lapwing (which is a bird of open grass lands) cause high levels of damage. The damage caused by Kites can be reduced by keeping all feeding sites at a distance more than 10 km. The problem posed by Lapwings can be partly mitigated by restricting the operations on full moon nights to some extent. Insights have been provided with regard to the decision on planting specific species of grass, and levels of efficacy of combined effect of anti-bird measures. Varied levels of bird activity among airfields and the diversity of species has brought out the complexity of the problem, and highlighted the fact that there is no thumb rule applicable to all airfields for all time in the country.

This study has provided a base line document to appreciate the bird activity over the airfields spread across the large Indian landscape. It has given definitive answers with regard to the efficacy of a few strategies used at airfields. However, it is a fact that all airfields have not been studied and there may be airfields with more diverse bird activity posing different types of problems. It is also pertinent to note that all strategies used by aviation industry have not been tested and validated. Some of the tested strategies have brought out more scientific questions which need to be answered by further studies. It is hoped that more rigorous studies are initiated in the country by adopting state of the art techniques to provide definitive answers to aviation industry and provide solutions which are ecologically sustainable and economically viable. That will keep our skies safe for the aircraft as well as the birds.

It is generally accepted by all aviation experts that we cannot, and should not eliminate birds to facilitate our flight movements. However, ways and means to keep them away needs to be evolved by experts who understand birds, aviation and economics through structured studies. Towards this direction, more intensive studies have to be carried out by scientific agencies across the country.

CONCLUSION OF THESIS

ASSESSMENT OF MANAGEMENT STRATEGIES OF THE BIRD HAZARDS TO AIRCRAFT IN SELECT INDIAN AIR FORCE AIRFIELDS

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MANIPAL ACADEMY OF HIGHER EDUCATION

SALIM ALI CENTRE FOR ORNITHOLOGY AND NATURAL HISTORY

MAY 2021

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