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Bird Strike to Aircrafts: An Assessment of Changing Bird Populations at Select Indian Airfields

S. Srinidhi[#,*] and P. Pramod[$]

[#]*Manipal Academy of Higher Education, Manipal - 576 104, India*
[$]*Salim Ali Centre for Ornithology and Natural History, Coimbatore - 641 108, India*
[*]*E-mail: ornithology.1@gov.in*

ABSTRACT

Bird Strikes (BS) are a significant threat to flight safety and a serious economic concern in the aviation industry. Variation of population and activity of different birds over an airfield leads to variation in their vulnerability for Bird Strike as well. In this study, an attempt was made to document the monthly variation of bird activity over three Indian airfields situated in different bio-geographical provinces in the year 2019-20. A significant activity of Black Kites (including the sub-species Black-eared Kite namely *Milvus migrans govinda* and *Milvus migrans lineatus*) and Lapwing (*Vanellus indicus*) were studied to understand their annual cycle as well as long term changes in their activity over airfields (over 30 years). Agra recorded an increase of 10.3 times in the activity of Black Kites in forty years. Black Kite data in correlation with the past information on Vultures indicate that the Black Kites are taking over the ecological niche of Vultures. Sirsa recorded an increase of 15 times in the activity of Red-wattled Lapwings in ten years and started dwindling again. The numbers of both species were stable over the Jodhpur airfield. The probable causes for long-term changes in Black Kite activity were identified as the type of waste management of the cities nearby, presence of other birds and migration. Similarly, changes in the activity of Red-wattled Lapwing could be partly attributed to the type of vegetation cover, long-term ecological changes, and intensive harassment of the bird. These findings will help airfield safety managers to initiate Solid Waste Management projects in the nearby city and monitor the bird population to control the major variations.

Keywords: Bird strikes; Black kite; Black-eared kite, Red-wattled lapwing; Airfield; Aircraft; Bird ecology and annual cycles

NOMENCLATURE

BS	Bird Strikes
BNHS	Bombay Natural History Society
OC	Ornithology Cell
SWM	Solid Waste Management
BLKI	Black Kite
RWLA	Red-wattled Lapwing
TPD	Tonnes per day
IAF	Indian Air Force

1. INTRODUCTION

The aviation industry widely recognises that the threat to safety from aircraft collisions with wildlife (wildlife strikes) is increasing[1]. Globally, wildlife strikes killed more than 282 people and destroyed over 263 aircraft[2] from 1988-2018. Several factors such as the development of fast-moving aircraft, quieter jet engines, size of the aircraft, and increasing air traffic contribute to this threat[3]. Birds, being the biological flying entities, are the most significant contributor to these wildlife strikes. Hence, Wildlife Strikes are commonly termed as Bird Strikes (BS).

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As per the National Civil Aviation Policy[4], civil aviation in India is poised to grow exponentially. The IAF is acquiring a considerable number of new aerial platforms which are very costly[5-7]. Considering these factors, both civil, as well as military aviation functionaries, are looking to keep the problem of BS under check[8-9].

In the Indian context, an attempt has been made to document the problem through studies earlier by Bombay Natural History Society (BNHS) for many years[10-11] in the years between 1980 and 1990 for 22 airfields. Such large-scale studies have not been attempted thereafter. However, many civil airports get the studies conducted by various environmental organisations. They are generally not published as scientific literature.

Sensing the need for similar studies, the Indian Air Force (IAF) established its Ornithology Cell (OC)[12] in 2007. The primary role of the Cell was to study the problem, suggest solutions and oversee implementation. Since 2007, OC has been documenting the ecology of various airfields at different intervals. These reports have been kept for IAF's internal reference.

Considering the data available, this article presents a review of the ecology of birds in three select airfields (namely Agra, Sirsa, and Jodhpur) with specific reference to the most

hazardous species. It also gives a panoramic view of the changes in ecology over three decades in these airfields.

After the study areas and methodology, the results are discussed in two parts. The first part gives the level of activity of three different species, at individual stations. Thereafter, the species-wise data (for lapwing and kite) is presented in all three stations for easy comparison. A specific comparison is made with the past population of vultures at Agra. The discussion part includes variations and probable reasons by citing corroborative information such as geographical distribution, waste management, migration, and implementation of anti-bird measures such as harassment.

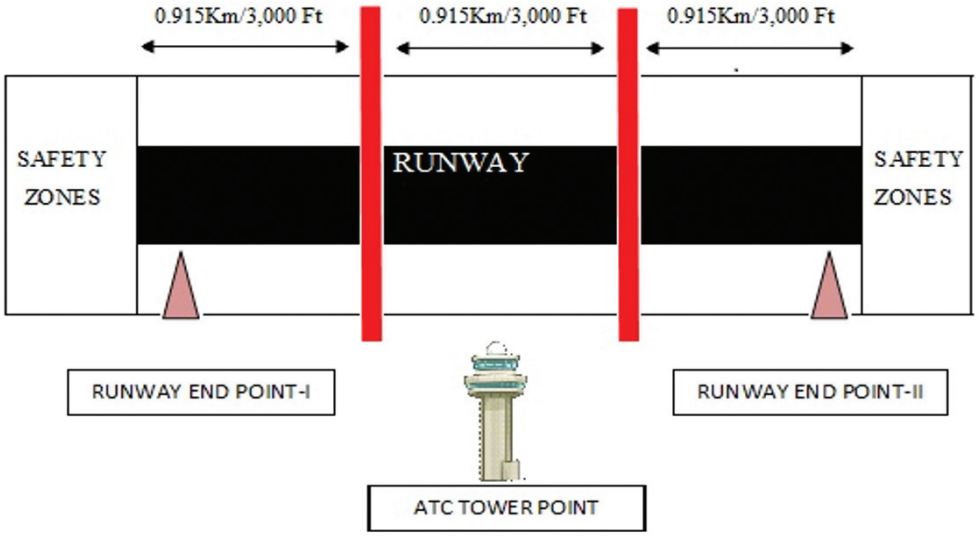

Figure 1. Schematic representation of points for total day count data collection with respect to the runway.

2. STUDY AREA

The bird activity data has been collected at three Air Force airfields in northern India, namely Agra (Uttar Pradesh), Sirsa (Haryana), and Jodhpur (Rajasthan). The airfields were chosen considering the earlier history of studies[10-11] and hence the availability of past data. These locations had been studied by BNHS in past (1980-88). They had also been studied by OC of IAF between 2007 and 2009 making certain vital inputs available.

Agra has an estimated human population of more than 1.9 millions[13] and Jodhpur has 1.86 million (2019)[14]. The human population of Sirsa is 1.82 lakhs (2011)[15]. While three cities near the airfields have similar human populations, they have varied levels of waste management and meat markets. Jodhpur and Sirsa commissioned a scientific Solid Waste Management plant more than a decade back while Agra had a primitive mechanism with no designated processing site at all till 2015. This factor could be playing a pivotal role in the growth or control of the Black Kite population in an area.

Geographically, Sirsa station is in a semi-arid location, Jodhpur is located in the arid bio-geographic zone. Agra is located in the Gangetic Plain. Some of the common weather parameters of three airfields are given Table 1.

Habitat of Agra airfield is that of a typical dry grassland with a dense patch of scrub forest on the Eastern side. The airfield has a larger proportion of cemented areas in comparison with the other two airfields. Sirsa has maintained a fairly dry and bald surface in the airfield area and the surrounded by agricultural lands. Jodhpur airfield maintains a typical desert habitat and is surrounded by a fair amount of urbanisation.

The collected data also indicated that the Red-wattled Lapwing population was markedly high in Sirsa. This species also happened to be among the most hazardous bird species for aviation in India in recent times[16]. As the study was under progress at all three airfields, the population of Lapwing was also considered for temporal analysis and to provide baseline data for future airfield studies.

Table 1. General weather information of selected airfields

Airfield	Altitude (in feet)	Avg Rainfall	Min temp (^{0}C)	Max Temp (^{0}C)	Maximum raining months
Agra	551	724	7	44	June to September
Sirsa	650	411.4	4.9	42.3	July-September
Jodhpur	717	363	7	42	June to September

3. METHODOLOGY

Data of airfield bird activity and ecology used in this analysis comes from three sources, one primary data and two from secondary sources. The primary data of the present scenario (April 2019 to March 2020) of bird activity over select airfields were collected by trained staff of airfields through the whole day count. The study employs total day count from a fixed point which is a modified version of Point count[17-18], followed elsewhere in the world. This modification was essential as the specific objective of the present study is gauging the extent of bird activity inside different airports as against the population and density estimation. A similar total day count method has been employed by employed earlier in India by Salim Ali & Robert Grubh[10] while carrying out their pioneering work in 1980.

The method involved monthly observation of the number of birds of each species from sunrise to sunset through the constant observation during the day from three fixed locations near the runway with demarcated spaces. The day is divided into 15 min. timeslots and the number of each species is counted in all the slots to estimate the presence and activity of the species in the runway vicinities. Data of bird abundance and activity has been collected for three days (one day each at three predefined points near the runway). Three points for data collection were the two ends of the runway (named 'Runway End Point-I' and 'II')

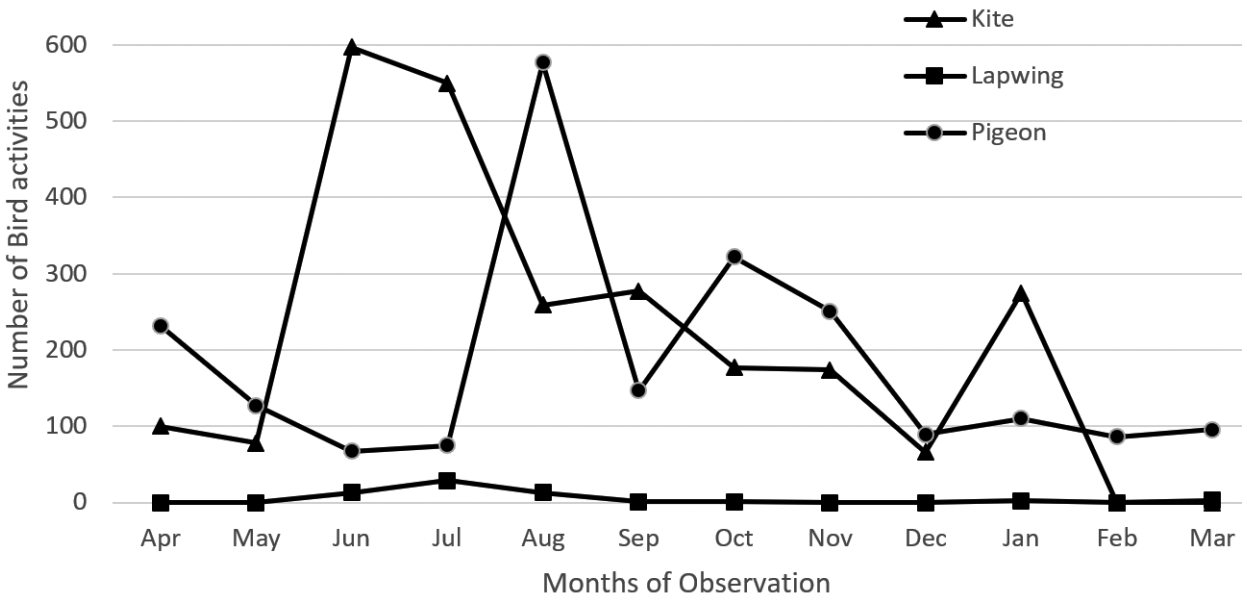

Figure 2. Monthly activity pattern of birds over Agra airfield (2019-2020).

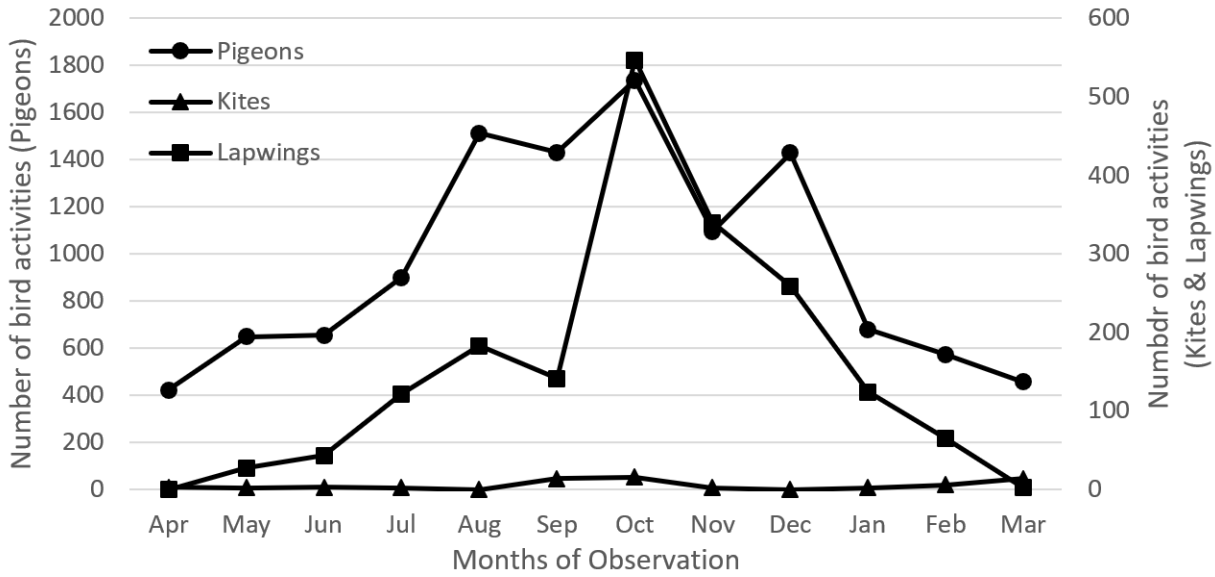

Figure 3. Monthly activity pattern birds over Sirsa airfield (2019-2020).

and the Air Traffic Control (ATC) tower point. Such towers are generally situated near the middle point of the runway. The area demarcation of area for each point (to avoid duplication of counts) is shown in a schematic diagram (Fig. 1).

The collected data has been cross-checked periodically by authors through personal visits and constant reviews. They were found to be reliable and standard. The data concerning kites and lapwings are segregated from the complete data.

The other set of secondary data was collected from the records of OC which had been collected using the same technique in those airfields during the period between 2008 and 2015. The primary author was part of most of those data collections. Another set of secondary data comes from BNHS study reports (1980-88). The data was collected by scientists over many days and the average per day count is presented in the report. The same is taken here for analysis. The waste generation data has been taken from the websites of respective municipal corporations/ state urban local bodies. Species involvement data of BS are quoted from the newspaper. But, they have been verified from the IAF data/ concerned airports.

Extensively collected data of bird activity for 432 hours/ year/ airfield gives a reasonably robust understanding of bird populations and activities. As long-term primary data is not available, this data is analysed against the reliable historical data collected from secondary sources. This is the best option available to understand the long-term trend in a limited period of study. Systematic data collection of bird activities has been initiated at IAF airfields recently. This data can fill in this gap of information in the future for the long-term trend analysis.

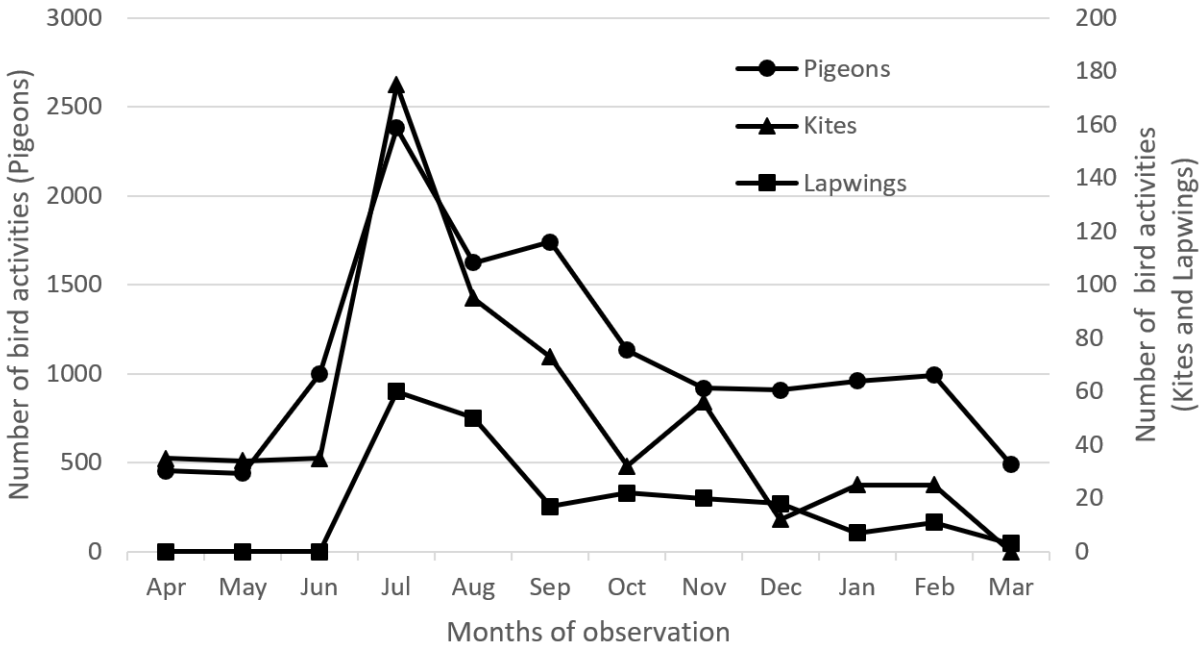

Figure 4. Monthly activity pattern of birds over Jodhpur airfield (2019-2020).

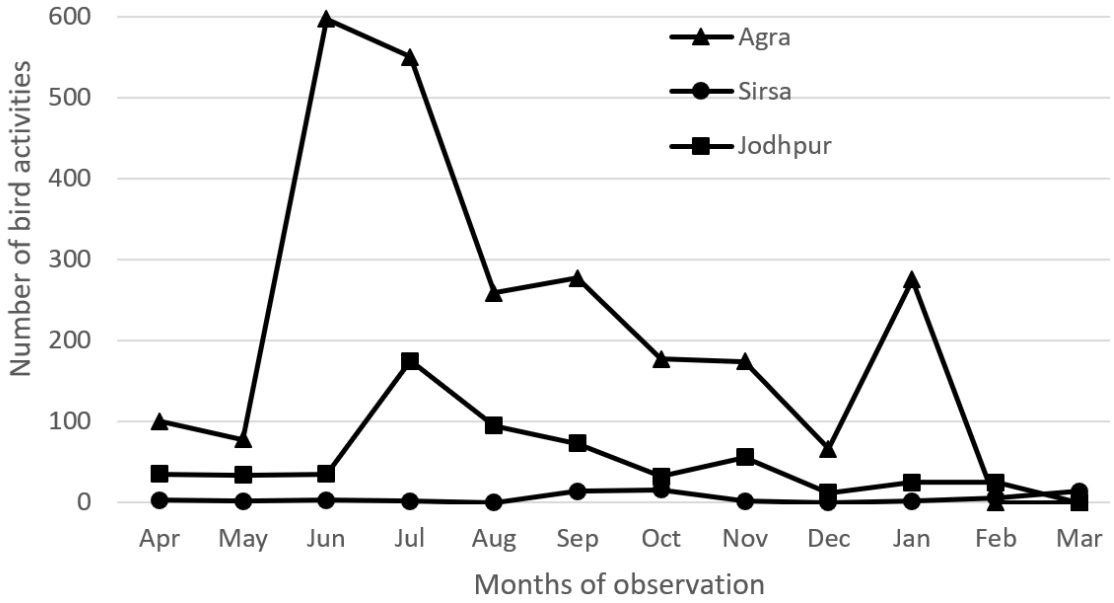

Figure 5. Monthly pattern of occurrence of the Black Kites in three study sites for 2019-2020.

3. RESULTS

3.1 Changes in 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 which are difficult to be segregated, especially when they are in huge flocks namely *Milvus migrans govinda* and *M migrans lineatus*), Red-wattled Lapwing (*Vanellus indicus*) and Rock Pigeon (*Columba livia*). They ranked high on the hazardous bird list[16] in India. Figure 2, Fig. 3 and Fig. 4 shows the Monthly pattern of occurrence of these species over the airfields of three study locations. Months of general peaking of the abundance of different species were similar in all three locations. Such synchronous patterns in variation indicate the effect of local weather parameters in the distribution and abundance of birds in the area. The minor differences could be because of the differences in the ecology of the particular species.

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 be hazardous at Sirsa.

3.2 Black Kites

Multiple factors such as the larger landscape of the airfield, local ecology, past natural history, cultural practices, and employment of anti-bird measures determine the levels of bird activity over any airfield. These three airfields served as

Table 2. Black Kite activity counts at Agra over different 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

***** BNHSdata, Total number counted at one post for the whole airfield using binoculars.

Table 3. Black Kite activity counts at Sirsa over different years

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

Table 4. Black Kite activity counts at Jodhpur over different years

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

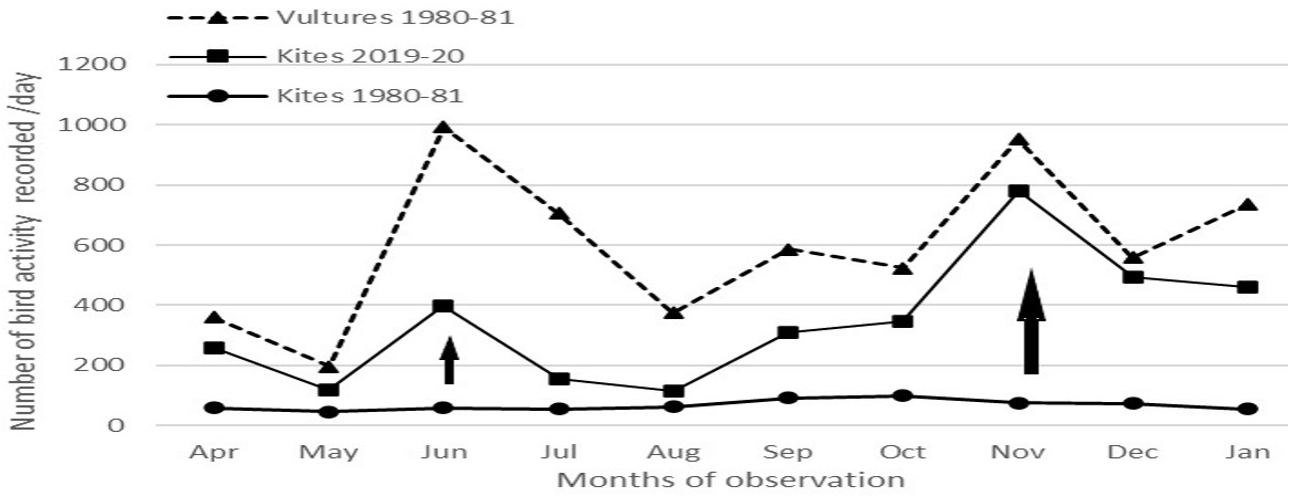

Figure 6. Monthly abundance of vultures in the past and the Kites in the past and present in Agra.

good illustrations to showcase the changes in the population of Black Kites within a year and over years. Systematically collected monthly data for one year is available from three airfields for comparison. The monthly activity pattern of occurrence of the Black Kites in three study sites for 2019-2020 is shown in Fig. 5.

The month-wise comparison shows that the abundance of Black Kites at Agra has increased between 1.70 to 12 times in the last four decades (Table 2). 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 OC 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 vital missing links to confirm the steady increasing trend over many years.

In Sirsa, the activity level 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 3). The successful implementation of the solid waste management project in the town in the year 2006 and comparatively lesser waste generation in the city could have contributed to the control of kite population growth.

Though systematically collected monthly data on kite activity of Jodhpur of the past is not available, the available

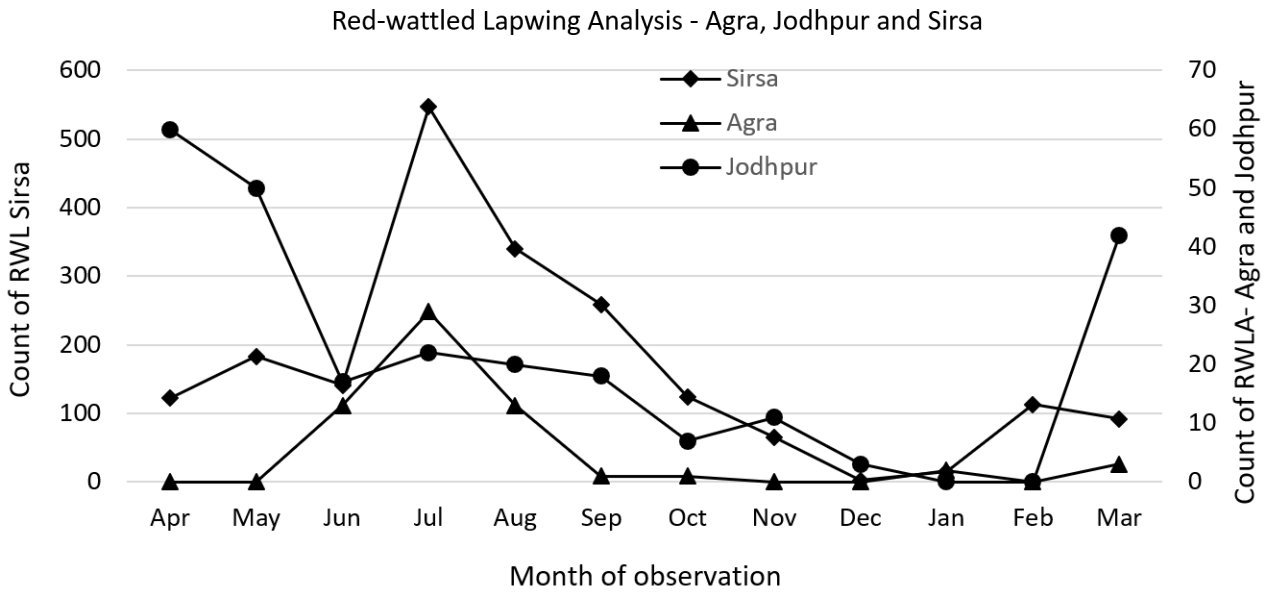

Figure 7. Monthly activity pattern of Lapwings in three airfields for 2019-20.

Table 5. Lapwing activity counts at Agra over different years

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1980-81	Species recorded as a hazard. No numbers.											
2019-20	00	00	13	29	13	01	01	00	00	02	00	03

Table 6. Lapwing activity counts at Sirsa over different years

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 7. Lapwing activity counts at Jodhpur over different years

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									

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(OC records). 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 the desert area have been recorded at Sujangarh (Rajasthan)[19] in 2018. Present data shows relatively moderate kite activity over the airfield (Table 4).

A graph showing the comparison of the abundance of vultures (in the past)[10] and kites (past[10] and present) over the airfield is given in Fig. 6. The graph indicates the growth of the kite population in the absence of vultures.

3.2.1 Waste Generation Estimates

The waste generation estimates as available on the websites of respective Municipal Corporations (Nagar Nigam)/ state websites for the cities of Agra, Jodhpur, and Sirsa are 824, 450, and 172 Tonnes per day (TPD)[20-22]. The variation has to do with the population as well as the presence of industries in those cities in India in general and the study areas in particular.

3.3 LAPWING

The monthly activity pattern of Lapwings in three airfields for 2019-20 is shown in Fig. 7. The numbers of Lapwings were not precisely recorded in Agra in the 1980-81study. However, there was a record of 50 in June 2008 (OC reports). Currently, the numbers recorded have reduced significantly in comparison with numbers recorded in 2008 numbers. There is an increase in numbers during the period between June and August, due to rains and breeding activity (Table 5). However, the numbers are considered moderate taking into account the availability of the ideal habitat. Reduction in numbers may be due to the adoption of intensive anti-bird measures by safety functionaries.

The study conducted in 1980-88 in Sirsa did not record the presence of lapwings in the region. This is a strange record. However, there was a record of 107 in May 2009. From the data in Table 6, it can be seen that the numbers increased 13-15 times between 2015 and 2017 in the records of the same month.

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 OC in September 2007. The numbers have reached a maximum of 60 in April 2019. The whole year data (Table 7) indicates that the numbers remain less than 22 for most of the years except during the months of March, April and May.

4. DISCUSSION

Since 1980, the Black Kite has been in focus and continues to be so. It was considered the second-largest hazard after the Vultures[4]. With the decline of the number of Vultures in the environment, Black Kites have become the largest threat in recent times[16,23]. Between 1980 and 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 two fatal accidents of IAF (2005 and 2014) involving this species reaffirm their threat for the aircraft in the skies[16]. The available species data from civil airports also indicate the threats from Black Kites. This species is among the top-rated hazardous birds in some of the Chinese airports also[24]. It is rated as the highest threat in a few other South Asian[25-26] and African countries[27-28] as well. This species is also ranked at no.4 among hazardous species by the Australian Transport Safety Bureau[29].

An attempt was made to establish the probable cause for the increased hazard. One of the probable causes that were hypothesised 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 for the increase could be the primitive waste management system of the city, reduction of Vulture population giving more space to Kites, and also the contribution by the migrating kites from Mongnolia[30].

The 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[10-11,30]. 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)[20] clearly documents that there is only one authorised slaughterhouse in addition to many unauthorised slaughterhouses 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 zero percent in 2014 indicating a large amount of waste is made available for the growth of the kite population. As this process has been lacking for decades (personal experience of the first author (2000-2002) and observed during later visits), the city has supported the growth of kites.

On the other hand, Sirsa generates a waste of 172 TPD. Jodhpur generates only 54 per cent of the waste generated by Agra. This is partly because of the lesser industries in that city. However, an organised meat market and much lesser meat sales in the city could have also contributed to the control of the kite population in addition to the desert ecology.

A significant aspect to note is that Sirsa and Jodhpur City Corporations were the early adopters of the Solid Waste Management plant[31] 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 achieved its purpose.

In the visits to the garbage processing site at Sirsa, no kites were seen whereas, in Agra, kites can be seen at the smallest of the road junctions where meat shops are present and some amount of garbage was thrown. This common experience seen in other major cities indicates that more than the waste generation, it is the lack of scientific processing which leads to kite population growth.

Besides, Agra had a history of having open carcass dumping sites for many years. This had facilitated the growth of the kite population in the years between 1980 and 2000.

This could have provided a larger nucleus thereafter leading to exponential growth in later years.

In the 1980s, Vultures dominated avian flying space that has been almost reduced to nil in Agra. One major change that is visible from the data is Black Kites are increasing significantly in the sky. In the absence of vultures, Kites top the list of most damaging wildlife strikes in recent years[16]. A comparison of the monthly abundance of Vultures in the past and the Kites in the past and present (Fig. 6) at Agra 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 stations differs significantly. Figure 2 showing the kite activity at Agra indicates two peaks of activity- one between June to August and another in February to March. The peak between June to August is attributed to heightened activity due to rains. February-March peak corresponds to the outbound migratory movement towards the North. Record of kites in Jodhpur indicates only one peak in July. The airfield, being on the fringes of the desert, does not generally get affected by migrating kites which are seen in Agra. On the contrary, Sirsa follows the pattern of Agra with two peaks, albeit at a much smaller scale.

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[32]. The least activity time is winter time at Kolkata is contrary to activity at airfields of this study. A study in 1983-84 at old Bengaluru[11] airport also indicated higher numbers in October-November than April-May. Similarly, two studies from Bengaluru airport (old) by OC 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 by authors. Yet to be published). This reaffirms the general pattern in the Bengaluru area. The exact reasons are yet to be deciphered. A study of kites in Pune city between 1975 and 1977 also indicated that their population is highest during July and least between December-Febuary[33]. This pattern is different from that of Bengaluru and indicated that kites may not follow any specific cycle as a species within the Indian Territory and patterns are region-specific.

The recent GPS tagged studies of Black-eared Kite from India, Mongolia, and Thailand give a glimpse into the complex dynamic nature of the movement of Kites. The Indian study (in which 19 Kites were tagged) [30] records the movement of Black-eared Kites from Mongolia to India from mid-August to the latter half of September. The return journey was recorded from mid-March to early May. This study recorded that the tagged and migrated kites generally stayed around the Delhi area (the literature does not mention Agra, but mentions that they stayed over towns and cities up to 300 km 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.

Another study records the departure of Kites from Mongolia (breeding ground) in September and reaching Myanmar in October[34]. There is one ringed recovery of Kites from Mongolia in North-East India (Manipur) as well[35]. Based on this, it is expected that a considerable number of Kites that use the Central Asian fly path also leave in the breeding grounds of Mongolia in September.

While above two migrations were fairly known well before from 2001, a recent study from Thailand[36] indicates an influx of Black-eared Kites into India from Thailand (from the 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 Ulhas river area near Mumbai sub-urban area). The study is still in progress.

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 these studies in a coordinated and synchronised way with various agencies 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 formed a part of airfield ecology. But, their numbers started growing 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 RWLA recorded over Sirsa airfield correlated with increased strikes at the airfield (internal study). While the bird is not recorded in the checklist of study of the 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 such large-scale changes in population. Probably, focused effort by airfield authorities to reduce their numbers by harassing might have led to a 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 Agra, the RWLAs are significantly reduced probably due to focused anti-bird measures against this species. In Jodhpur, 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.

OC has studied the behavior of lapwings to some extent. It was observed that there is a correlation between full moon nights and night strikes by RWLA[37]. Based on this, restrictions were placed on military operations on full moon nights which helped in reducing the number of strikes to some extent. In later field studies in 2015, this fact has been re-ascertained through another study by OC[38].

Going by the numbers, Sirsa airfield seems much safer concerning kites. It had recorded a negligible number of Kites and a moderate number of Vultures (Average of 166 kites per day) in 1986-87. It was observed in 1986, that the station had a high population of Mynas and Doves. As time progressed, RWLAs which were not recorded even in the checklist of Sirsa

in 1987, became a hazard. The interplay of all species is beyond the scope of this study.

In Jodhpur, the BLKI activity over the airfield has been moderate. RWLA numbers have also been found to be relatively less. This may be largely due to the larger landscape effect. Probably, the ecology of the arid/ desert region has a vital role in inhibiting their population. The distribution of BLKI and RWLA comes down to the west of the airfield, which is the core desert area[39]. However, the changing ecology due to man-made canals and unseasonal rains in the recent past might have increased their numbers.

4.1 Importance of The Study for the Safety of Airfields

Some stand-alone airfield ecological studies have been conducted in the past. This is the first attempt to assess the long-term population changes over airfields and analyse probable reasons for the changes focusing on specific hazardous species.

The study is novel and significant due to the following factors:-

- The selected species i.e. Black Kite and Lapwings have been proved to be significant among the most hazardous birds to aircraft in India.
- The growth of the Black kite population was not significant in two sites (Sirsa and Jodhpur) in comparison with a similar third site (Agra). The major and probable reason that can be assigned for this is the establishment of a waste management plant.
- This study also highlights that the Black Kites are now observed to be occupying the space left void by the loss of Vultures at least numerically.
- Red-wattled Lapwing has now come up as one of the most significant hazardous birds concerning Indian airfields. A study of its activity in Sirsa airfield for five years has recorded a decline in active population highlighting the success of species-specific management activities.
- The paper brings out the priority areas for bird hazard mitigation by the safety and administrative functionaries concerning the studied species.

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 a focus on the two most hazardous species in India with the available data. The study has brought out that the 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 the interplay between many factors such as effective waste management, the ecology of other birds, vegetation, migration, and levels of harassment. However, there is a need to conduct such studies more intensively in a synchronised way between various agencies to understand the complex problem and to find methods to keep them away from airfields 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 strategies.

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CONTRIBUTORS

Wing Commander S. Srinidhi is working as Joint Director (Aerospace Safety) and heading the Ornithology Cell of IAF.
Contributed in conceiving the idea, collection of data from various sources, compilation and writing of article.

Dr P. Pramod is working as Principal Scientist and Head of Division of Nature Education in Salim Ali Centre for Ornithology and Natural History, Coimbatore.
Contributed through supervision of structuring of the article, analysis and writing.