भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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A Study of Resource Selection by Black Kites *Milvus migrans* in the Urban Landscape of National Capital Region, India

2014

FINAL PROJECT REPORT

A Study of Resource Selection by Black Kites *Milvus migrans* in the Urban Landscape of National Capital Region, India

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Executive Summary

Black Kites, *Milvus migrans,* serve as a major scavenger and predator in the cities of the old world. In India, they are synanthropic and perform the ecological role of city cleaners by removing decaying animal remains from garbage dumps. Abundance and distribution of these birds depends on the differential availability of food resources, e.g. rubbish in the garbage, from human origin and the nesting habitat. Indian sub-continent almost lost its main scavenger, white backed vultures, in the last century. After this loss; existence of Black Kites, the most abundant raptor of the old world, proves very vital.

On these lines I carried carry out this study from December 2012 to March 2014. It focused on **a)** estimating the abundance of Black Kites on the Ghazipur dump site and the abundance of nesting pairs in National Capital Region (NCR), **b)** evaluating factors influencing nesting habitat selection combined with a broad understanding of its foraging habits and **c)** estimating nest survivorship in the urban landscape. We studied these parameters at selective study sites in NCR by intensive counts of birds at Ghazipur and breeding pairs at nest sites across eight study sites. Nests were searched intensively at each site while I tried to develop and test a new method to count the kites on the Ghazipur dump using photographic counts and software ImageJ. Data from 116 nests and nest sites covariates were used to model nest survivorship under Known Fate scheme in Programme MARK.

I estimated the current abundance of nesting pairs of Black Kites at 7 study sites. The mean nest density was 15 nests/ km^2 (se: 7.94) and it ranged from 0 nests / km^2 in Mahipalpur to 67 nests / km^2 in North Campus area. Nesting kites were selective while choosing a nest site, as evident by significant partial correlation between nest density, food index and green cover (partial r = 0.64, p = 0.06). The sites at the best trade-off between green cover and food availability had the highest nest densities. While developing a new methodology, I estimated more than 2400 kites on the Ghazipur dump. Through behavioural observations and broad examination of regurgitated pellets, I could confirm scavenging as well as predacious nature of Black Kites. The overall probability of a nest to produce a viable fledgling was 0.45 (95% CI: 0.21- 0.61). The nest survivorship was stage specific for pre-laying (0.60, se: 0.014), incubation (0.84, se: 0.014) and nestling stage (0.90, se: 0.009). The lower survival probability of 0.60 at pre-laying stage is likely because of surplus nest formation at sites with good foraging opportunities. Understanding the importance of kites in urban ecology, further studies using individually marked kites will reveal vital details of their behavioural and physiological adaptations.

This ideal model system of a top trophic level species living in such close contact with humans is extremely rare and almost non-existent in the wild in terms of sample size availability and ease of manipulative experiments. The tolerance of the species for nest condition manipulations observed during my field work will make the ecological inferences of this study accurate and applicable. There are added benefits of these birds being a city scavenger and a valid model to propagate conservation education amongst the general in India. The dramatic loss of secondary scavengers after the population crash of vultures in

our sub-continent will make poor sectors of the society susceptible to numerous diseases in case of further decline in sanitation-levels. The study will help in generating thorough understanding of the ecology of Black Kites essential for their conservation and management. It will also help in evaluating the role of birds in a changing world of human development.

1. Introduction

Increasing rate of global urbanization and awareness has created new interests for the urban biodiversity (Magle *et. al*.2012). Although urbanization in general tends to reduce species richness at a place, in a context, it is not true for certain plants and animals (Luck *et. al* 2011). Amongst these, the Black Kite (*Milvus migrans),* a medium sized accipitrid, is the most common scavenging and predacious raptor of the old world. It lives amidst human habitation in India; thriving on dump sites (Ferguson-Lees and Christie 2001).

Black Kites and congeneric Red Kites belong to the family *Milvinae* or old world kites. *Milvinae* kites evolved in the Miocene Epoch in Tertiary Period of Cenozoic Era, 25 million years ago. Species belonging to the genus *Milvus* and *Haliastur*, in this family, are known to be notorious scavengers (Grossman *et al.* 1964). Kites have featured in literature over the world, depicting their ecological relationships with human since centuries (Gotch 1981, Table 1). The dependency of Old world kites on the human refuse has a regulatory effect on their abundance and distribution. The urban infrastructure changes to promote better waste management towards improvement of hygiene ultimately reduce or clumps the scattered food resources (Schreiber *et al.* 2000).

Table 1: Summary of the relationship of kites and human beings as mentioned in old literature (Source- Grossman *et al.* 1964)

Bird	Time period	Text	Remarks
Red Kite	Before Christ	*Republic by* Plato	Kites termed temple thieves
Red Kite	Henry VI	Shakespeare's poems	Snatchers of kills of other raptors
Red Kite		• Shakespeare's *Julius Ceaser* • *Hamlet*	I. 'Kite' used to define a person's black character. II. Commonly called 'Puttock'.
Brahminy Kite and Black Kite.	BC	• Sanskrit (Shiv Purana) • Battle records of Ancient India	I. Br. Kite signified good omens and the Bl. Kite the bad ones. II. First scavengers to arrive during battles.
Brahminy Kite	BC	Ancient bird Classification, source: Dave (1985)	The fishing eagles, greater adjutant stork, common heron, Br. Kite were classified together as *jalpars* or water birds.

The abundance and distribution of these birds is currently suffering declines (Sergio and Boto 1999) and shrinkage due to rapid infrastructural changes in the developing cities, which likely limit or change the spatial layout of the available habitat and food sources (Ferguson-Lees and Christie 2001). Many cities in the old world (London, Cape Verde, Istanbul) have experienced historical declines in the population of *Milvus* kites owing to rapid changes in their landscape (Ferguson-Lees and Christie 2001, Grossman *et al.* 1964, Parry and Putman 1979, Schreiber *et al.* 2000).

It is noticeable that abiotic, biotic and cultural components of an urban landscape produce a great diversity of habitats ranging from near natural to completely artificial. These habitats are characterized by small patch size of vegetation, varied ownership, unexpected juxtaposition, intensive human management, abrupt change in structure and high anthropogenic interference (Bookhout 1996). In the above context Delhi, the capital of India, has undergone rapid urban development since the country's independence (Mehta 2011).

Development in Delhi has changed the availability and accessibility of resources for the urban fauna. Kite distribution and abundance has likely responded to the changed spatial distribution of habitat and food sources within the city. I gathered it from a questionnaire survey circulated among old age citizens in June 2012 as a part of reconnaissance for this thesis. It holds even more importance after Indian sub-continent has almost lost its primary scavenger, white backed vultures, since 1990s from most of its distribution range (Pain *et al.* 2008; Prakash *et al.* 2003).

The existence of Indian Black Kites, the *govinda* sub-species, as the secondary scavenger proves vital. Therefore, it is important to understand the behavioral characteristics that allow kites to adapt to a highly urban landscape, nest amidst human habitation and forage on dump refuse. Black kites have most likely acquired a portion of the niche recently vacated by vultures in the Indian Sub-Continent, while they may also limit rodent pests within the city, with potential beneficial effect on human health-risks (Malhotra 2007).

I hereby report the results of a 5 month study on Black Kite population in the state of Delhi and its adjoining areas in India called National Capital region (hereafter referred to as NCR). The aim of this study was to provide quantitative data on Black Kite abundance, nest site selection and nest survivorship. The intensive study was conducted at 8 study sites distributed in NCR.

1.1. Literature Review

Long term monitoring of Black Kites in Europe since last 40 years makes it the most intensively monitored-studied raptor population in the world. Researchers out there monitor more than 500 pairs each year, have ringed 7000 individuals, trapped about 2000 birds and have satellite-GPS tagged more than 100 birds till date (Pers comm, Sergio F. 2013). These studies report the importance of marsh, riverine area, open woodland and wooded cliffs, all associated with water bodies as favoured habitat for the kites (Hille 2000; Sergio *et al.* 2003a, b; Schreiber *et al.* 2000). Kites also adjust in urban territories, agricultural areas and grasslands with adequate nesting facilities. They have rarely been reported to nest on the buildings (Ferguson-Lees and Christie 2001). Their extended adaptation to nest amidst human settlement in the India and Africa highlights their ecological plasticity (Ferguson-Lees and Christie 2001, Schreiber *et al.* 2000).

In contrast to other raptors, the breeding and non-breeding segments in the Black Kite population do not share much of their habits and habitats (Blanco 1994, 1997; Newton 1979). This aspect of breeding biology with respect to the intersections between the floaters and breeding conspecifics has been little studied in raptors while it is known to have a potential influence on their population dynamics (Newton 1979). Floaters roost in the woodland area near the dump sites and are exclusive consumers of refuse and seldom take wild prey whereas the breeders which are largely predators sporadically visit the dumpsites (Blanco 1997). In Italy Sergio and Boto (1999) identified 307 items of prey through the analysis of regurgitated pellets and prey remains. Fishes constituted 62% of diet against 28% from avian sources. All vertebrate classes were represented in the diet with some occasional invertebrate prey.

Black kites in Europe, against the resident Red Kites, are trans-Saharan migrants from Africa and breed in relatively natural setup (Schreiber *et al.* 2000, Sergio and Boto 1999, 2003a, b, Vinuela 1999). The diet of both *Milvus* kites is highly influenced by their habitats. (Schreiber *et al.* 2000, Sergio *et al.* 2003a, Vinuela 1999). However, Black Kites are comparatively less specific and utilize even unstable food sources. In Europe, this enables Black Kites to successfully raise more fledglings than their conspecifics (Vinuela 1999). It is noticeable that even though they show greater opportunism in utilization of both prey and human refuse, their breeding success was found much lower against Asian or African populations (Sergio and Boto 1999).

Comparatively less studied Indian Black kites, which are residents, form the largest and the densest population than any raptor for its distribution range. Raptor reference sources have mentioned them to be the most successful birds of prey, based on their opportunistic utilization of garbage at the dumpsites (Ferguson-Lees and Christie 2001; Grossman *et al.* 1964; Veiga *et al.* 1990; del Hoyo *et al.* 1994). Aquatic prey base in Indian sub-continent is mostly harvested by the Brahminy Kite, *Haliastur indus* (Ferguson-Lees and Christie 2001; Grossman *et al.* 1964). In Afro-Asia the adaptability of these birds to forage amidst human establishment has made it the greatest menace at the airports. Satheesan (1996) found Black Kites to be responsible for 21% of all Indian air hazards. It is a result of unplanned management of the airport areas as many of these are associated with dumpsites (Satheesan 1996; Owino 2004).

There are several reports based on anecdotal observations on Black Kites in India in several volumes of *Journal* of Bombay Natural History Society, emphasizing their natural history. From these sources, we know the occasional predacious behavior of kites. They have been reported to prey on the birds of the size of common kingfisher and rodents. Ali (1926) and D'Abreu (1911) reported their breeding behavior for the first time through keen observations. Many birds start the nest building activity, one or two months in prior to the normal season (Ali 1926). Mahabal and Bastawade (1985) studied communal roosting behavior of these birds in Pune city. They reported the seasonal fluctuation in the number of birds on the roosts. These roosting places were of both permanent as well as temporary nature in terms of usage by the kites in one annual cycle.

However, apart from Galushin (1971), no other concrete quantitative attempt, reporting their abundance and distribution in a landscape has been made. Desai and Malhotra (1979) studied their breeding behavior at Delhi Zoological Park, monitoring nesting success for a total of 60 nests in the area. At Delhi Zoo, average hatching success (55%) was found way below other studies (Sergio and Boto 1999). Malhotra (2007) also mentioned large congregation of non-breeding Black Kites inside the park area. Apart from scavenging on garbage, Malhotra (2007) also established the importance of rodents and fishes in the diet and published his thesis in the form of a book titled “Tigers of the sky: Black Kite” with nest monitoring and chick growth data. It will be important to compare growth patterns of chicks over a gap of 30 years.

1.2. Objectives

Following were main objectives of the study-

Objective 1: To estimate the abundance and distribution of Black Kites in the urban landscape of National Capital Region, India.

a. Abundance of nesting pairs in the study sites.
b. Abundance of kites at foraging sites.

Objective 2: To evaluate factors influencing nesting habitat selection

Objective 3: To assess the nesting success of Black Kites across different ecological settings in National Capital Region, India.

2. Study Area

I conducted the study in NCR and covered 1500 km^2, most of which falls in the state of Delhi. It included eight intensive study sites, each of 3 km^2, distributed along the increasing scale of urbanization based on collective account of vegetation cover, built up area and human population levels. The scaling has been discussed in detail in the method section. These sites were selected on the basis of Mehta (2011) to represent the maximum variation of land use land cover (Table 2, Figure 1).

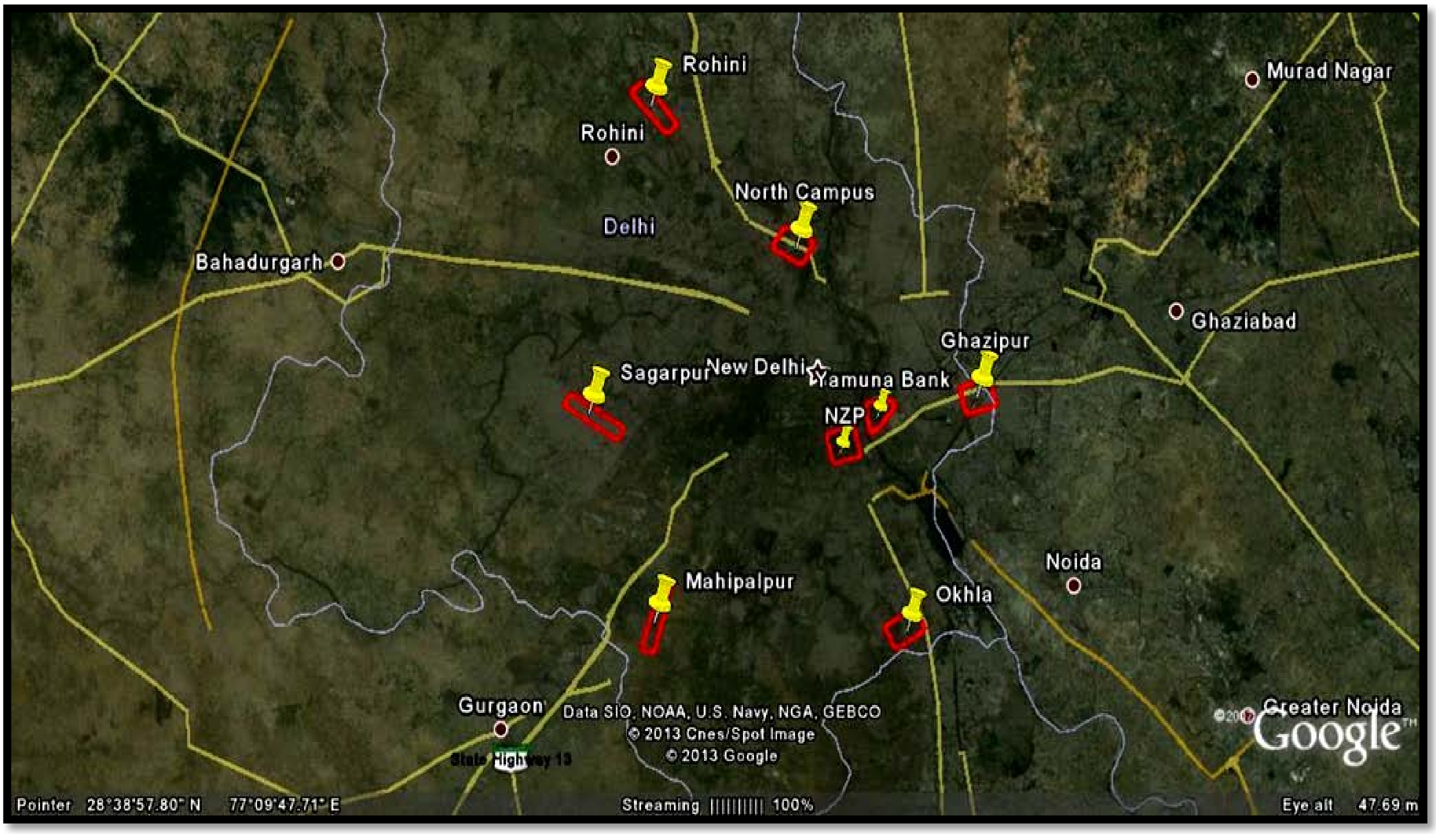

Figure 1: Eight intensive study sites, marked on the Google Earth Map of National Capital Region (NCR).

A. Mahipalpur: is near Indira Gandhi International airport in the south-west of Delhi. It comprises of thorny forest of *Prosopis juliflora*. The land is primarily rocky with almost no human habitation (Figure 2).

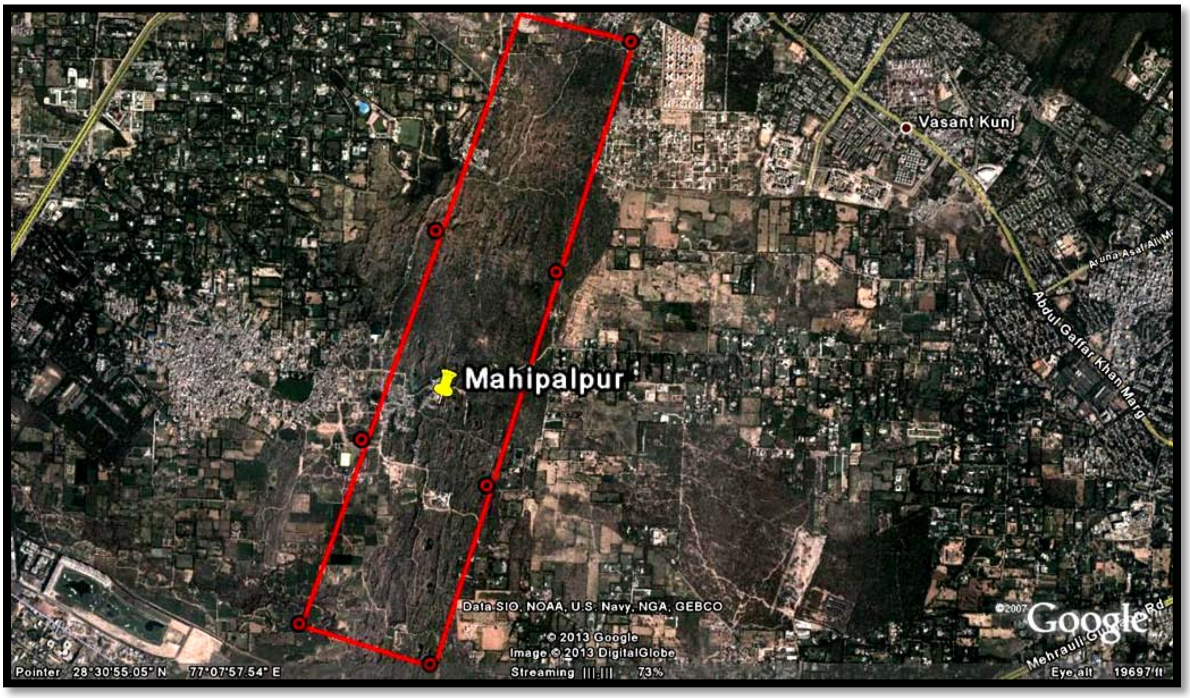

Figure 2: Mahipalpur area study site with its boundary in red.

B. Yamuna Bank: in Eastern Delhi, this area holds plantation of Eucalyptus with adjoining agricultural patches in the river floodplains and few settlements (Figure 3).

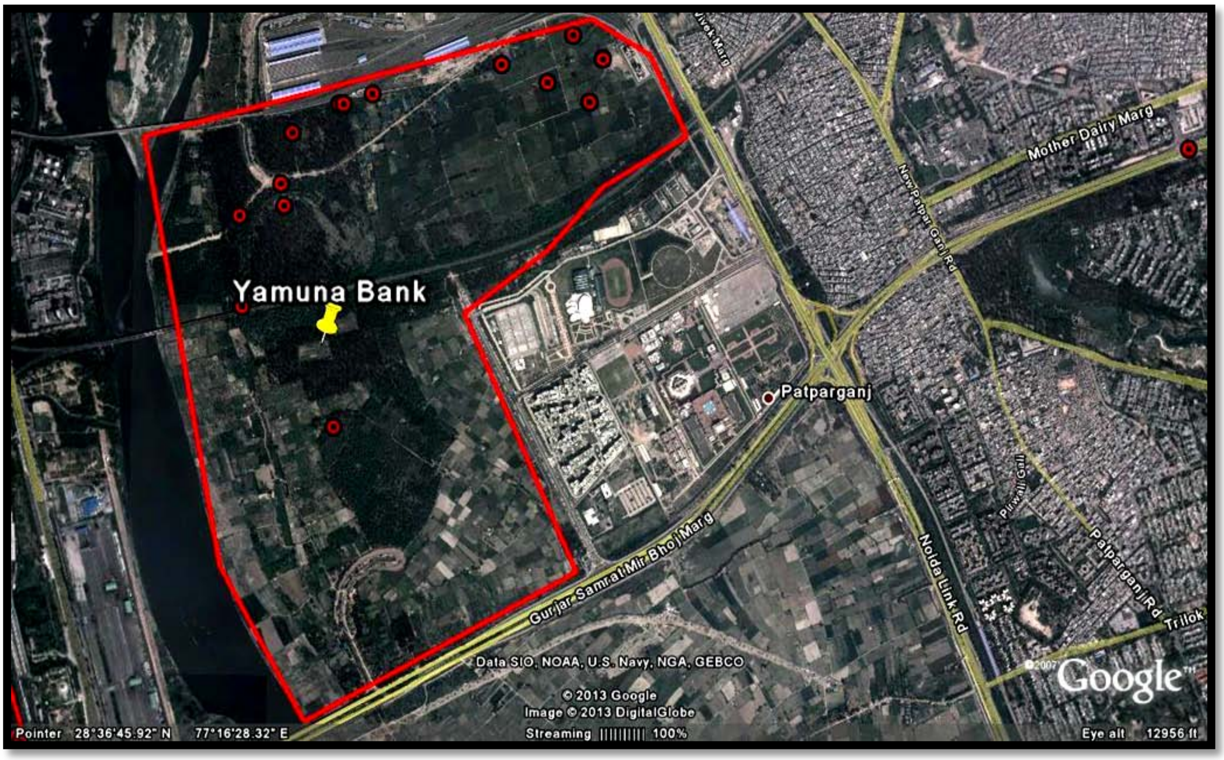

Figure 3: Yamuna Bank study site with its boundary in red and nest locations as red dots.

C. National Zoological Park (NZP): is semi-forested protected area in the heart of the city beside river Yamuna with modern settlements (Figure 4).

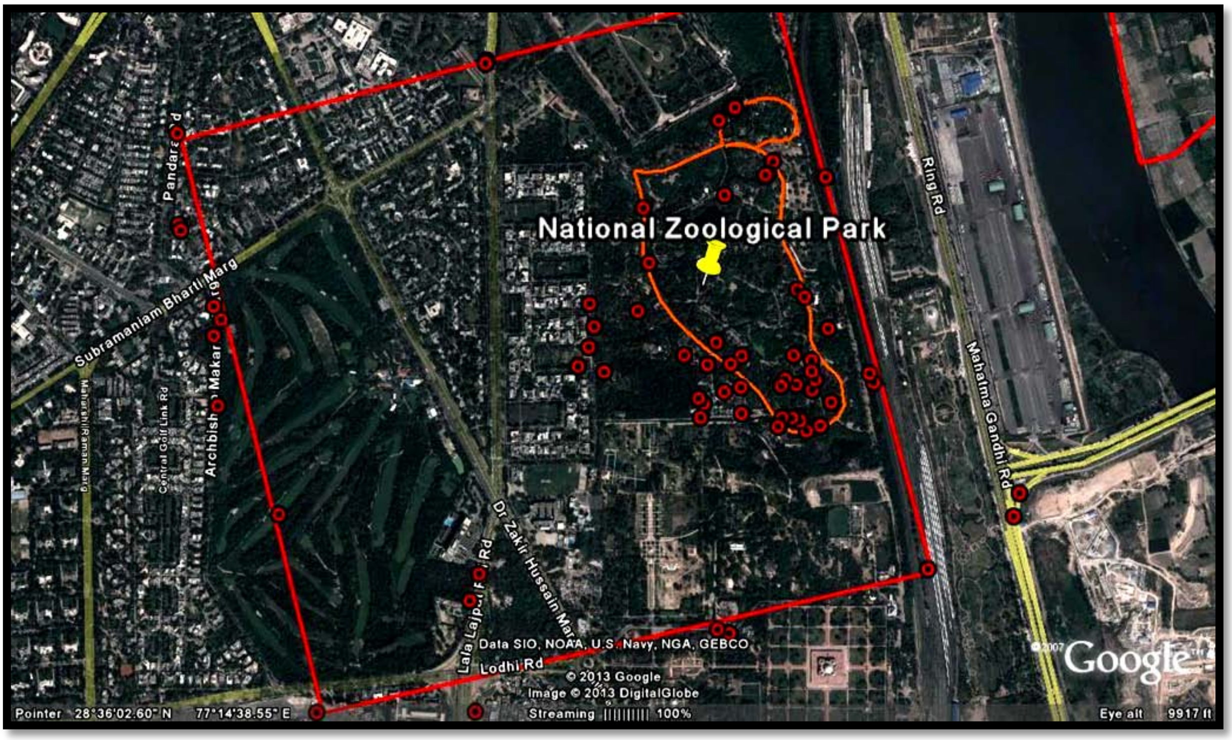

Figure 4: NZP study site with its boundary in red and nest locations as red dots.

D. Rohini: in north- western part of Delhi has wide open agricultural fields, fruit orchards and Eucalyptus plantations with no settlements (Figure 5).

Figure 5: Rohini study site with its boundary in red and nest locations as red dots.

E. North Campus of University of Delhi: is an area with mixed blend of greenery and modern built up space (Figure 6).

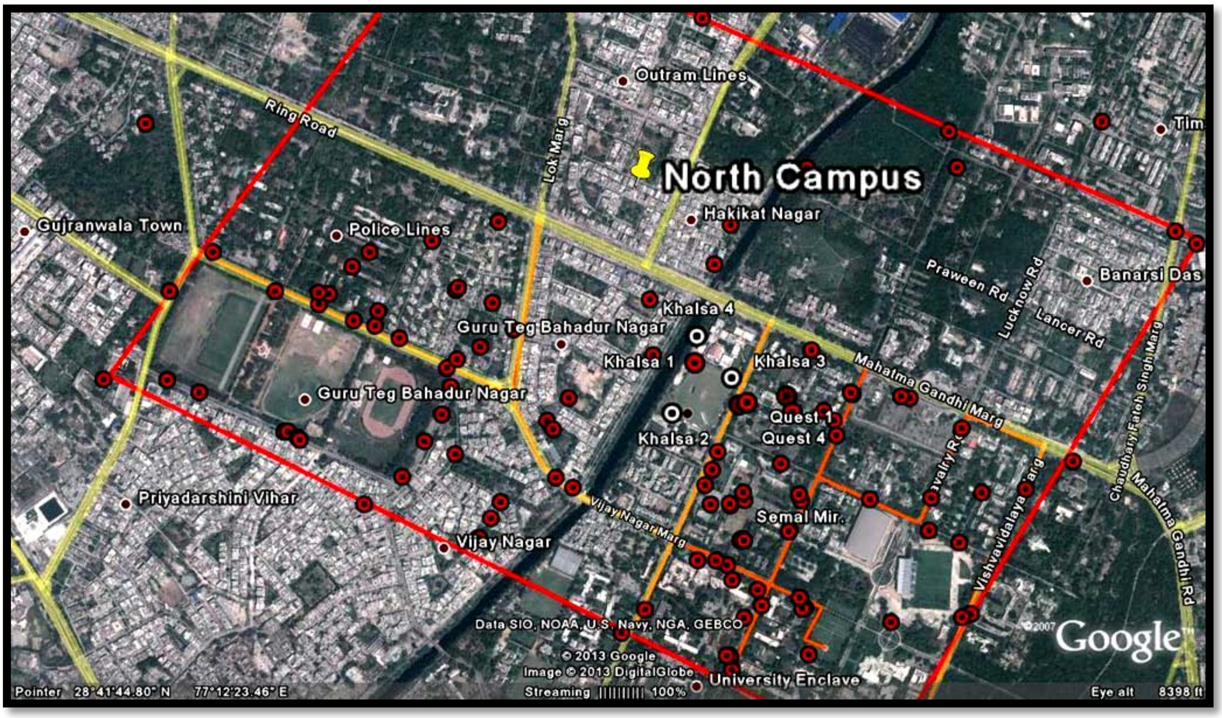

Figure 6: North campus study site with its boundary in red and nest locations as red dots.

F. Okhla: This site in extreme south has a passive landfill site where kites used to congregate in past. There is a good stretch of open land combined with human settlement and patch of *Prosopis juliflora* (Figure 7).

Figure 7: Okhla study site with its boundary in red and nest locations as red dots.

G. Ghazipur: is in the extreme east of the city with an active mega-dump. I selected this site, keeping the dump at the focal centre, to understand the response of kites to super abundance of food. The huge congregation of kites at this place is discussed in numerous raptor literatures (Brown 1976, Ferguson-Lees and Christie 2001, Malhotra 2007 and Newton 1979) (Figure 8).

Figure 8: Ghazipur study site at centre with its boundary in red and nest locations as red dots.

H. Sagarpur-Uttam Nagar stretch: in west Delhi is semi-urban with unplanned architecture. The houses are densely set side by side. This leaves very little or no green space. However, poor waste management provides foraging opportunities to the kites (Figure 9).

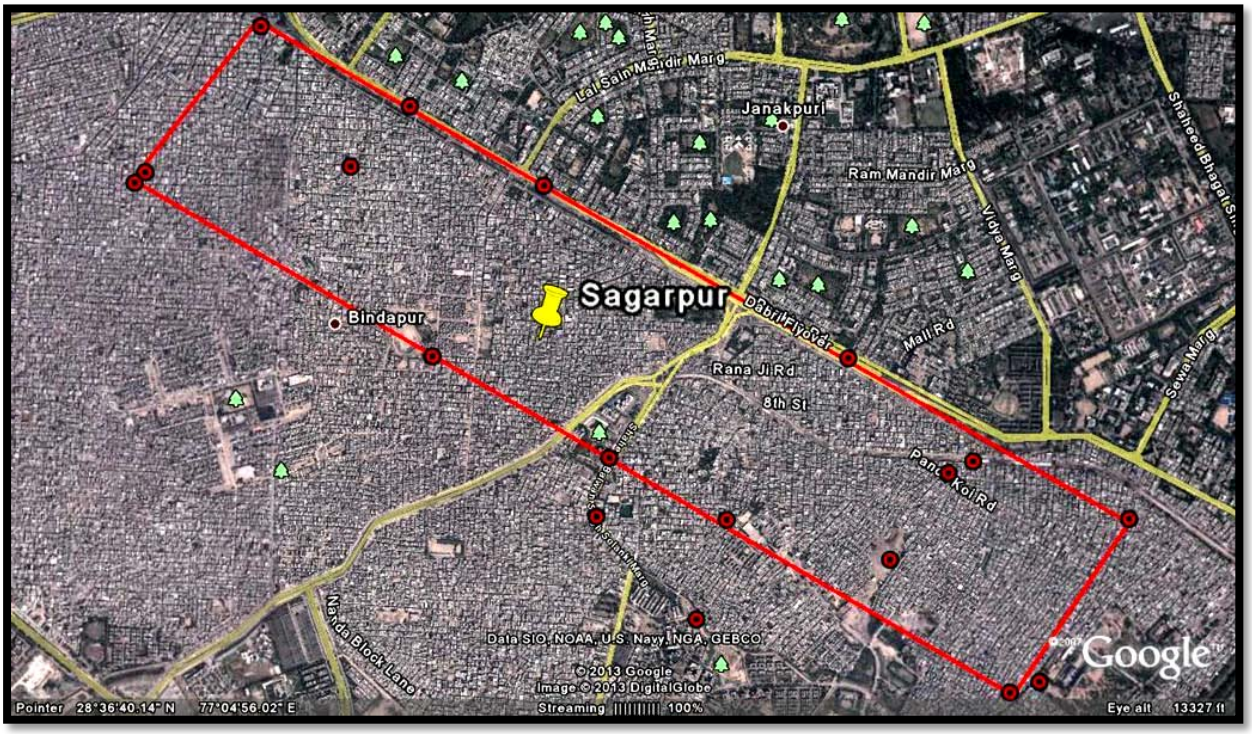

Figure 9: Sagarpur study site with its boundary in red and nest locations as red dots.

NCR falls in the semi-arid zone with 60 cm of annual rains, mainly in the two months of monsoon. The capital city lies at the farthest eroded *Aravali* ranges at an altitude of 200 odd meters. Being in the Northern belt, it experiences both temperature extremes (touching 47° C in summer to less than 1° C in winter) (Krishen 2006). Vegetation of Delhi falls in typical Northern Tropical Thorn Forest category (Champion & Seth 1968). (*Prosopis* spp., *Acacia* spp.) and few patches of dry Monsoon forests (Krishen 2006). The prominent vegetation is comprised by Acacias such as *A. nilotica*, *A. leucophloea*, *A. catechu*, *A. modesta*, *Butea monosperma*, *Cassia fistula*, *Salvadora persica*, *Anogeissus latifolia* with abundant *Prosopis juliflora* (http://www.delhi.gov.in). The trees around human establishment are of *Sygizium* spp., Neem (*Azadiracta indica*), Arjun (*Terminalia arjuna*), *Eucalyptus* spp. *and Ficus* spp. from the plantation movements in the city planning over the years (Champion & Seth 1968, Krishen 2006).

3. Methods

3.1. Black Kite nest counts

My field work spanned from December 2012 to March 2014 after I did few reconnaissance surveys between June 2012 and December 2012. This tenure encompassed the two breeding seasons of the Black Kites in NCR (Ali and Ripley 1968; Malhotra 2007). At each study site I chose a representative polygon of 3 km^2, homogenous in terms of landscape features. Later, I subdivided each study sites into smaller grids of 1 km^2 to put uniform effort while doing nest search. Here, I involved a team of 25 trained volunteers to do grid wise nest search on pre determined paths for all study sites initially for one month. I was not able to cover the full area of most of the study sites due to involvement of private property permission issue and inaccessibility. Therefore, while computing the nest density for each study site, only the net sampled area value was used.

The landscape features for each of these sites was not uniform. In order to validate accuracy of total count of nests and to find out the probability of non-detection, I did fixed-width road transect to locate nests in a Mark-Recapture framework (Cooch & White 2013). I used two different teams, each comprising four members, including one trained person to identify the kite nests. Such nests are quite different from common urban birds nest in terms of the gross size and thickness of long twigs used (Figure 10). Both teams were unaware of the nest locations. I sent the first team to locate and mark the nests found along pre-designed paths for which the total number of nests was already known from the intensive search. The second team was sent on the same path to try and recapture the nests marked earlier.

Figure 10: Typical nest of a Black Kite showing gross structure, size and thickness of twigs.

This exercise was performed at three selected sites, namely North Campus, NZP and Rohini with high, medium and low nest density respectively. For data analysis, with the total count already known, the nests reported by Team ‘A’ were taken as marked nest while the ones reported by Team ‘B’ were taken as recaptured nests. This exercise generated a single event mark-recapture data of nest detection along a path. I analysed the data under closed capture framework in the Programme MARK (Cooch & White 2013).

3.2.Abundance of kites at Ghazipur dump site

Black Kites congregate in thousands at the mega landfill sites of NCR to forage opportunistically on garbage produced by residents of Delhi and the slaughter houses located in the vicinity. It is almost impossible to visually estimate the number of these birds on the dump, either through total counts or through the common estimation methods. These birds, apart from hovering over the dump are also seen foraging on the garbage. Therefore, to estimate the total number of birds at a time, one also needs to compute the number of birds sitting on the dump.

To come up with the minimum number of kites on a dump, I tried a new method of photograph based count of the birds present on Ghazipur dump. The number of kites on the dump does not remain uniform throughout the day. It undergoes through major fluctuations as the day progresses. I determined the time of maximum congregation in a day through repeated photo shoots of the dump from a fixed vantage point at every hour between 0500 hours and 1830 hours.

Analysis of these photographs in software ImageJ (http://rsbweb.nih.gov/ij/) gave the period of maximum congregation between 1530 and 1700 hours (Figure 11). This was also cross verified with the workers on the dump site. This software is not able to count the kites sitting on the dump which are to be counted manually in a photograph. Therefore, I tried to obtain an average proportion of kites sitting on the dump to the kites in flight. It was to be used to estimate the kites sitting on the dump with the knowledge of kites in flight through the analysis of panoramic shot from the top of the dump.

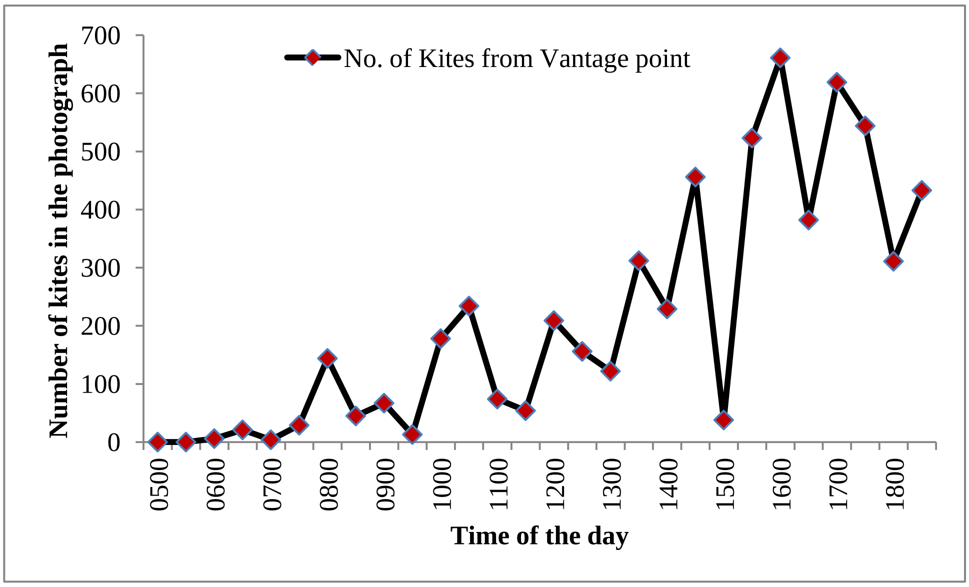

Figure 11: Count of the kites found over the dump in photo shots taken from a vantage point. The photographs clicked between 0500 hrs and 1830 hours were analysed in software ImageJ.

Using above clue, I stationed 10 persons, each with a camera, at uniform systematic locations on full face of the dump around 1600 hours on 15th February 2013 (Figure 12). Each person first clicked the kites sitting on the dump (Click 1) followed by tilting the camera upwards to shoot the kites in flight (Click 2). This was be followed by a 60˚ turn and repeating the earlier step with no overlap with previous frame (Click 3 to 6). The said person continued this till he completed shooting all kites in his 360^0 view through 5 replicates of first step. In the end, kites flying over his head were captured with an overhead shot. Thus, at an average, 6 clicks of kites sitting on the dump and 7 clicks of the kites in flight completed the shooting of kites available for a person from a given point on dump. Other nine persons followed the same at their respective points. Their activity was synchronized for each point using cellular phones to avoid double counts of birds as they change locations within seconds. Simultaneously, we captured seven panoramic 360^0 views of all birds in flight between 1530 hours and 1700 hours from the top of the dump (Figure 14).

I obtained the proportion of kites sitting on the dump to the kites in flight for each of these points. Using these values, I came up with an average proportion for whole dump. I used freely available java based software ImageJ (http://rsbweb.nih.gov/ij/) to count the number of kites in flight in a photograph. The use of this software use was validated by analysing different photographs through manual counts of kites. In all the photographs, the kites sitting on the dump were counted manually.

Figure 12: A view of the Ghazipur dump around 1600 hrs in evening during breeding season to show congregation of the Black Kites.

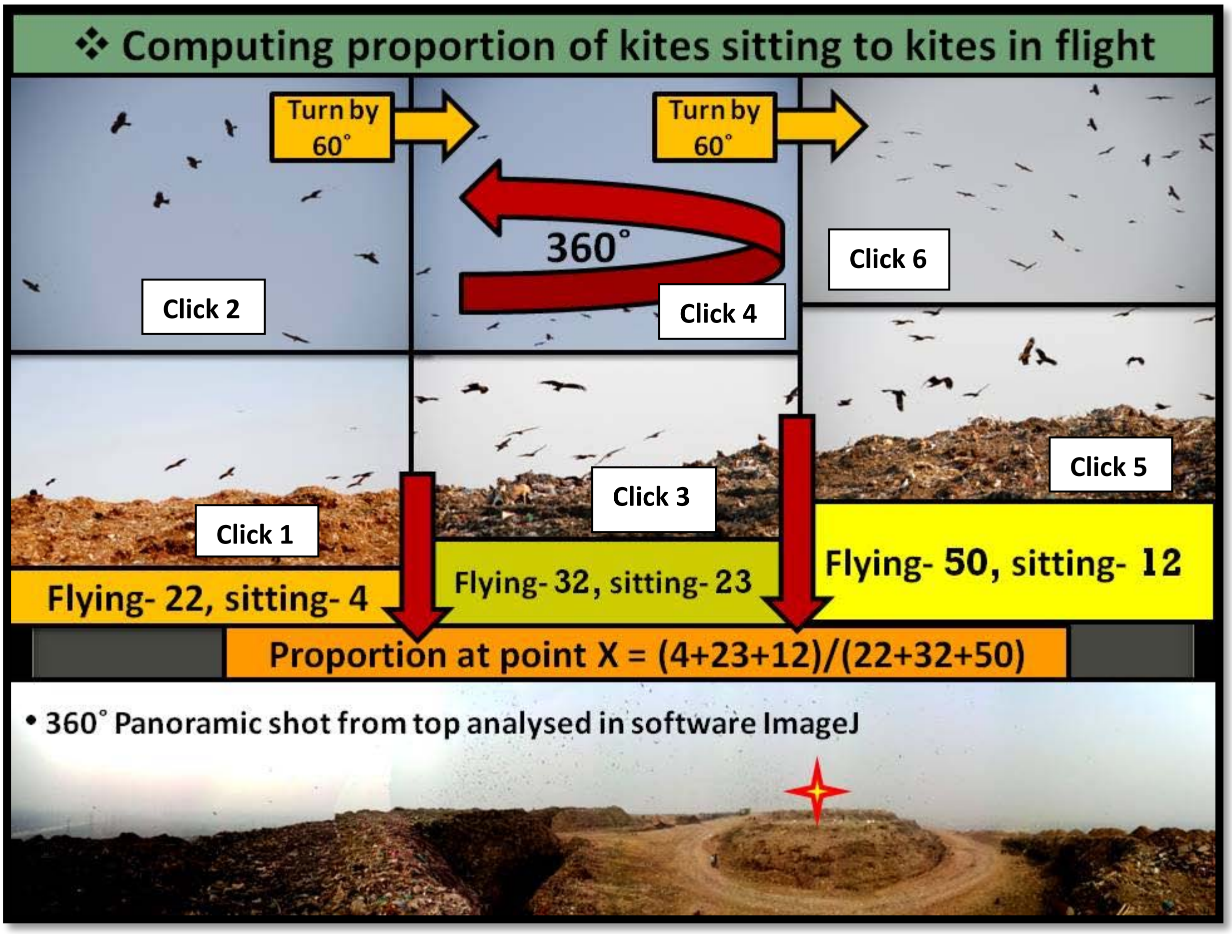

Figure 13: The photograph shooting scheme to count the kites at Ghazipur.

Figure 14: Panoramic 360˚ shot from the top of the Ghazipur dump analysed in software ImageJ to estimate kites in flight.

3.3. Nesting habitat selection

In order to evaluate the factors which regulate the nesting behaviour, I estimated the availability of green cover, built up area and food, specific for each study site. The landscape variables, proportional green cover and built up area were obtained using latest Google Earth imagery of the study area. It was done by subdividing each study site into smaller grids of 25 hectare. This divided each study site into 12 grids of 25 hectare blocks which is quite close to the median as well as mode of kite territories in the study sites (Table 3). For NCR, I assumed foraging radius of breeding birds at 300 m because of the easy food availability and regular vigilant presence of parent birds during the nest checks. It is unlike the European sub species foraging radius of one kilometre (Sergio *et al.* 2003a).

Further, I used smaller grids of Google Earth which subdivided each 25 hectare grid into 30 smaller grids (Figure 15). I assigned each of the 30 Google Earth grids a status of either built up, green, open or mixed after visually judging percent extent of each category. The built up or green status was assigned only when the percent extent of each category was more than 60. Mixed status was for the percent extent of built up or green from 40 to 60 while open was used for areas which were fallow.

Later, the mixed category grids were equally distributed to built up and green categories. Therefore, from total 360 Google earth grids for each study site, I obtained the percent built up and green space on their built up or green status (Table 2).

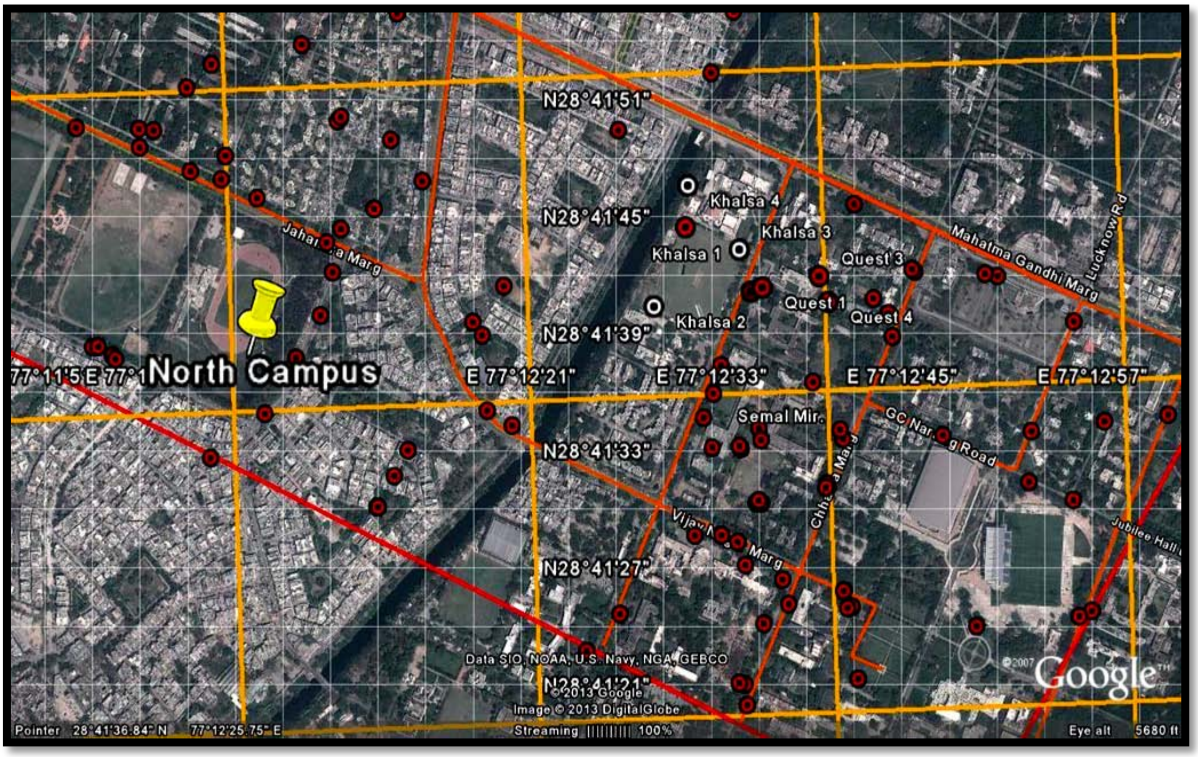

Figure 15: Division of each study area into 12 yellow grids of 25 hectares each. Further, each yellow grid was subdivided into 30 smaller grids using Google Earth grid view.

During the field work, I could not quantify the availability of the food for Black Kites. Therefore, on the basis of repeated visits to each study site, I logically developed the Food Index under the following framework: {(**built up area proportion) x (waste disposal rank) + Presence of open dump rank}**. Waste disposal level was given index value ranging from 0 to 2, allotted on the basis of regularity of clearance of garbage from colony based small dumps in each study area. Study areas with no dumps received a score of zero. The areas with most irregular or no disposal of garbage from the colony based dumps received a score of two. The built up proportion was taken analogous to the population level in a study area. Therefore, poor waste disposal areas with high built up proportion most likely interact to give best foraging opportunities to the kites. To this value, I added the index value of direct food availability (in terms of large dump site, left over from slaughter houses) which ranged from 0 to 2 on the increasing scale. Thus, study areas with the poor waste disposal mechanism, high built up area and with good availability of the direct food were the best foraging areas for the kites (Table 2).

To understand the relationship between the nest densities, proportional green cover and food index in a study area, I performed partial correlation between the nest density and the food index, keeping the value of green cover constant. Partial correlation was decided after the bi-variate correlation between the green cover and food index.

Table 2: Land use land cover specifics of 8 intensive study sites in NCR (with proportional green cover and logical derivation of Food Index for each site).

Study area	Waste disposal regularity 'a'(0 =no waste, 1 =high / 2= low)	Proportional Built-up area 'b'	Food indirect '(a*b)'	Direct food availability index 'c' (0 = absence/ 1= moderate/ 2= high)	Food Index (a*b + c)	Proportional Green Cover
Mahipalpur	0	0	0	0	0	0.91
Yamuna Bank	2	0.08	0.16	1	1.16	0.42
Delhi Zoo (NZP)	1	0.41	0.41	2	2.41	0.67
Rohini	0	0	0	1	1	0.17
North Campus	1	0.52	0.52	2	2.52	0.54
Okhla	2	0.62	1.24	1	2.24	0.38
Ghazipur	2	0.6	1.2	2	2.20	0.13
Sagarpur	2	0.98	1.96	1	2.96	0

a: The index of regularity of waste disposal from a study area. 0= no waste present, 1= regular waste removal, 2= irregular removal of waste

a*b: indirect index of food which gives the quantum of interaction between the built up area (analogous to population) and waste removal regularity. The high built up area and irregular waste disposal shall generate high amount of food.

c: Direct food availability index to represent the direct sources of food which were regularly seen in a particular area, like large dumps, slaughter house waste

3.4. Monitoring nesting success

I monitored all 150 reported nests for their contents at a gap of 5 to 10 days. New nests, as and when reported, entered monitoring protocol at all stages of maturity i.e. pre-laying, under incubation and nestling. The criterion for nesting success was successful fledging of at least one nestling by the parents (Sergio and Boto 1999). I used an 8 meter long telescopic metal rod mounted with a mirror and small spy video camera on its top to collect the data on nesting success on subsequent visits to the nests (Figure 16).

Figure 16: Volunteers using telescopic rod to monitor a kite nest using the mirror mounted on top to instantly view the contents and a small camera attached on top to record the video footage.

In order to minimize any disturbance to the chicks, I collected field data on the important nest site covariates (nesting tree species, nest height, nesting tree height, nest area canopy, nesting tree canopy, nesting tree GBH, central or peripheral position of nest in the tree canopy and study site) after majority of the chicks fledged. The nest height was measured using a laser range finder. Tree height was ascertained applying Pythagoras theorem using range finder. The nesting tree canopy was measured through standard protocol of using a spherical forest densitometer (http://www.cdpr.ca.gov/docs/emon/pubs/sops/fsot00201.pdf). Nesting area canopy was measured within the 12 m radial area of the nesting tree (Sergio *et al.* 2003a).

The continuous scale data of the nesting tree canopy cover and the nesting area canopy cover was transformed to categorical data to incorporate the interaction of these two different covariates while modelling the nest survivorship. For nesting area canopy cover, all the data points with canopy cover from 0 to 25 % were categorized '0', data points with canopy value of 26 to 50% were categorized '1' and the points with canopy value more than 50% were categorized '2'. For nesting tree canopy cover, values ranging from 0 to 33% were categorized 0.3; points falling within 33 to 66% were categorized 0.6 while the points with canopy value more than 66% were categorized 0.9. The canopy covariate was represented as (nesting area canopy category) × (nesting tree canopy category) to contain maximum information in least possible number of parameters. This transformation was done under the assumption that nesting area canopy has greater impact on the nest survivorship than nesting tree canopy.

Likewise, I also combined the tree species categories on the basis of similarity of their structure with respect to supporting a kite nest. All the nesting trees were assigned to following groups *Eucalyptus*, *Ficus* spp., Keekar, Neem + Jamun, Tower and Others. For each nest, I made dummy covariates for the specific tree species group and central / peripheral position of the nest in a tree in 1, 0 frameworks. The study sites were also combined according to habitat similarity as following categories: Sagarpur, North Campus, NZP, Ghazipur + Okhla, Mahipalpur and Yamuna Bank + Rohini. They were used in modelling nest survivorship in 1, 0 framework as well. All re-categorization was done to represent maximum information through least number of parameters, leading to higher fitness of the models during analysis.

The nest survivorship data was analysed using Known Fate scheme in Prog. MARK (Cooch & White 2013) which estimates the interval specific and overall survival index of a nest under log likelihood framework. The programme works under assumption that encounter probability of a nest is 1.0. The resultant nest survivorship (Cooch & White 2013) estimate is very close to the classic Mayfield estimator (http://www.dodpif.org/kiwa/kw-papers/1961%20Mayfield.%20Nesting%20Success%20Calculated.(Wilson%20Bulletin).pdf. The estimated parameter signifies the chance that the nest will survive from one interval of nest check to the other. As new nests entered the analysis scheme at different stages of construction and maturity, only those 116 nests which were monitored since nest building stage were put into analysis. The Known fate data was arranged in a staggered stage specific pattern of pre-laying stage, incubation stage and nestling stage.

Pre-laying stage was defined as the period between first day on field and the last day an egg was laid in a nest (first 84 days of field work). The nests which did not bear eggs post this stage were taken as failed nests. The incubation stage was defined as the time taken by the last laid egg to successfully hatch (85^{th} to 119^{th} day of field work). All the nests under incubation with no resultant hatchling post this period were taken as failed nests. The nestling stage was defined as the approximate time taken by the youngest nestling to fledge out (50 days from the 120^{th} day on the field).

Thus, I modelled the nest survivorship in Programme MARK using the encounter history of 116 nests along with their nesting covariates. I began with the null model which assumes the nest survivorship to be uniform throughout the season, with no incorporation of covariates. The null model was used as datum to further model nest survivorship using various sets of covariates. This ultimately helped in deciding those specific nesting site covariates which significantly influence nest survivorship.

Collection of regurgitated pellet and prey remains of kites

I also collected the regurgitated pellets during each nest check from the nesting and communal roosting sites for further examination in laboratory. Regurgitated pellets are compact balls, around 2 – 2.5 cm in diameter, of undigested remains of the prey consumed by the kites. They provide a reliable means to assess diet consumed by the birds (Malhotra 2007, Sergio and Boto 1999). Based on Sergio and Boto (1999), I bagged these pellets separately for each nesting and roosting site in tagged plastic bags. In case of large roosting sites where I encountered heap of pellets, I bagged all pellets falling within five randomly drawn 50 cm radius circles. Whenever possible, I also collected the prey remains (body parts, scales, bones, feathers) from inside and below the nest to better understand their diet (Figure 17).

Figure 17: Clockwise from top left: 1. Systematic collection of regurgitated pellets at communal roosting site 2. & 4. Scan sampling of Black Kites foraging on the dump 3. A kite's nest with chicks and prey remains (pigeon).

3. Results

Nest density

I could find a total of 244 nests in all the 8 study sites. I collected data from 150 nests across 7 study sites chosen at random (Table 3). No nests were found in Mahipalpur area. Nest substrates were quite variable for the 150 nests under regular monitoring. Of these, 23.3 % were on *Eucalyptus*, 17.3% on *Ficus* spp., 12.6% on Keekar *(Prosopis* spp.), 16% on Neem & Jamun, 11.3% on pylons & towers and rest on other tree species.

Total nest counts on specific paths for three study sites, where I employed double observer Mark Recapture, were within the 95% CI of the Prog. MARK estimate of nest counts (Table 4, Figure 18). The densities of kite nests for 8 study sites varied from 0 nests / km^2 at Mahipalpur to 67 nests / km^2 at North Campus (Table 3). I found nest densities to be correlated with the Food index, once the effect of proportional green cover was controlled for 8 study sites ($\alpha = 0.1$, partial $r = 0.636$, $p = 0.06$) (Figure 19). There was non-significant negative correlation between Food Index and proportional green cover ($\alpha = 0.1$, $r = -0.45$, $p = 0.14$) for 8 study sites.

Table 3: Number of nests, net area sampled for nest search, nest density and number of nests used for data collection on nesting success

Area	Total No. of Nests	Net Area Sampled (km^2)	Nest Density (Nests / km^2)	Number of nests used for nest survivorship data
Mahipalpur	0	2.03	0	0
Sagarpur	9	2.08	4.33	9
Rohini	13	2.70	4.81	13
Yamuna Bank	15	3.00	5.00	7
Okhla	15	2.60	5.73	8
Ghazipur	16	2.18	7.34	6
NZP	70	2.65	26.42	46
North Campus	106	1.58	67.09	59

Table 4: Comparison between double observer based Mark-Recapture estimate and actual nest count along fixed paths in three study sites

Study Area	Mark-Recapture estimate	LCL (95%)	UCL (95%)	Total nest count on path
NZP	30.66	30.09	34.75	31.00
Rohini	7.16	7.02	9.58	8.00
North Campus	41.91	41.15	46.51	41.00

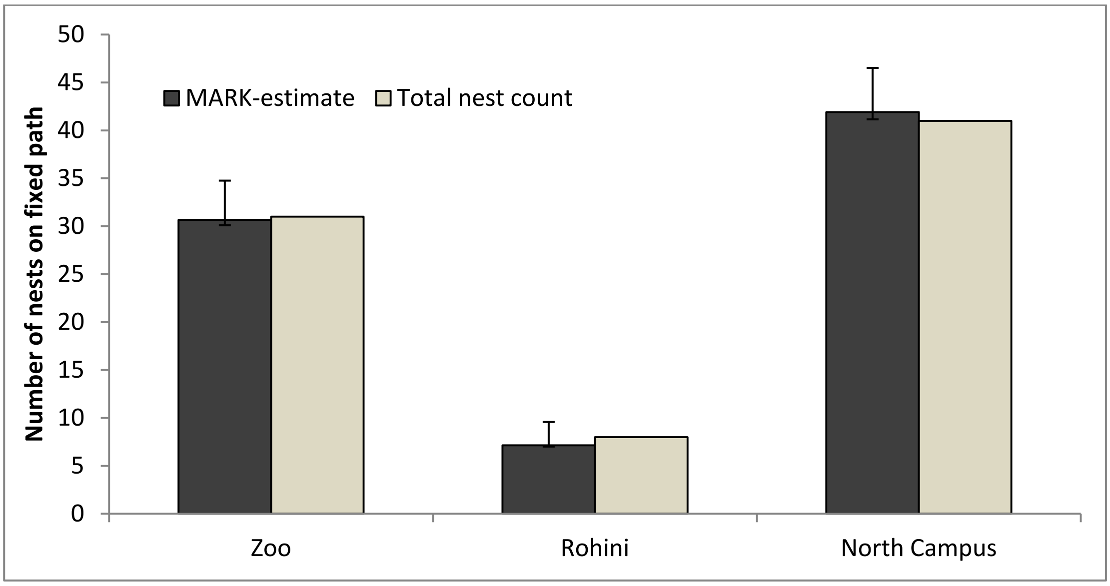

Figure 18: Comparison between estimated numbers of nests using Prog. MARK and total nest counts on fixed paths in three study sites to show the accuracy obtained through one month intensive nest search.

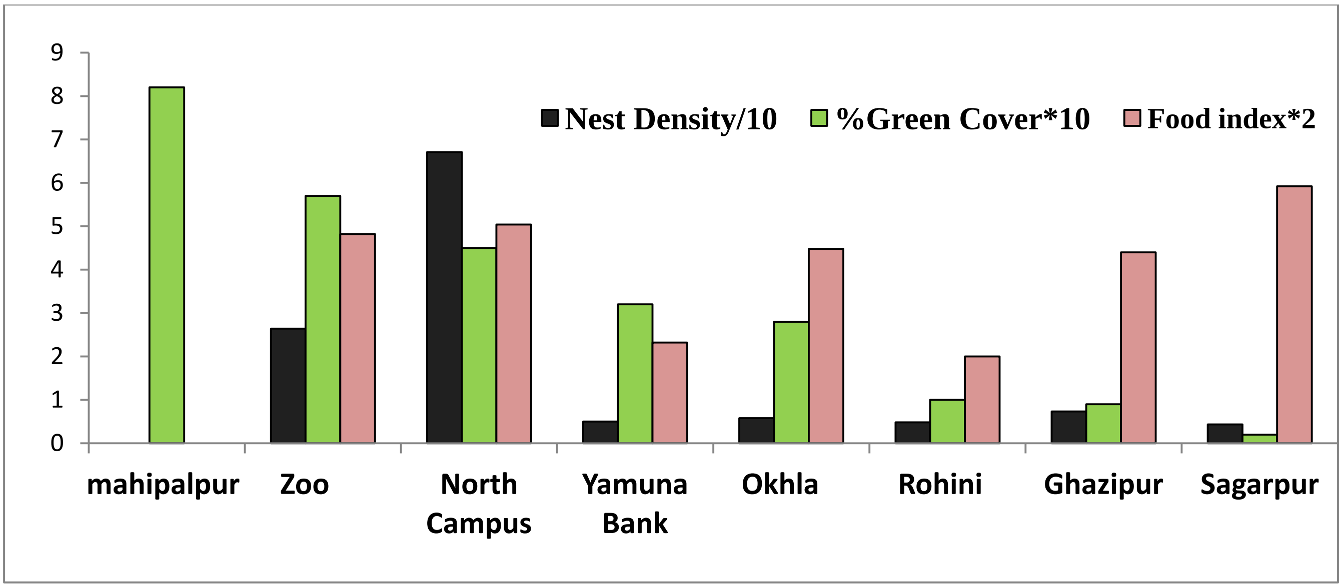

Figure 19: Comparison of trade off between proportional green cover and food index which accounts for variation in the nest density across study sites (scales adjusted for comparison of three parameters)

Abundance of kites at Ghazipur dump site

I estimated the proportion of kites in flight to those sitting over the dump site at Ghazipur by photographing the 360˚ view from 10 uniformly chosen positions. A total of 2,121 kites in flight were estimated analysing the 360˚ panoramic shot taken from the top of the dump (Figure 14). I used average proportion (0.118, S.E. = 0.036) of the kites sitting on dump to the kites flying over at 10 different locations to correct this estimate of total kites. Thus, with 250 (95% CI = 75) sitting birds, the total kites on the dump were estimated to be 2,371 (95% CI = 75).

Nesting success

Average clutch size in NCR was 2.1. Height of the nests on natural substrates ranged from 5.7 to 19 meters while on towers and pylons it ranged from 8 to 42 m. The Sagarpur area lacked mature trees but had good foraging opportunities. It eventually resulted in utilization of towers as nesting substrates. The artificial structures, like towers, pylons, were highly utilized in the areas where green cover was low. Moreover, at North Campus, with the highest nest density, kites only used 5% artificial substrates. This signifies their preference for the natural substrates. The differences in the proportional nesting success (direct estimation on the basis of release of one fledgling) on the natural and artificial substrates is summarised in Table 5.

Table 5: Direct estimation of breeding success on the basis of successful fledging of one chick from a nest to compare the fate of a nest on natural and artificial substrate (towers and electric poles).

Study Area	No. of nests	Nests on trees (% nests)	Success % on trees (only for nests monitored)	Nests on artificial structure (% nests)	Success % on artificial structure (only for nests monitored)
Mahipalpur	**0**	**-**	**-**	**-**	**-**
Yamuna Bank	**15**	**15 (100)**	**83.3**	**0 (0)**	
Delhi Zoo (NZP)	**70**	**70 (100)**	**43.5**	**0 (0)**	
Rohini	**13**	**13 (100)**	**53.8**	**0 (0)**	
North Campus	**106**	**100 (94.3)**	**45.3**	**6 (5.7)**	**33**
Okhla	**15**	**10 (77)**	**40**	**5 (33)**	**40**
Ghazipur	**16**	**13 (81.3)**	**50**	**3 (18.7)**	**-**
Sagarpur	**9**	**2 (32.2)**	**50**	**7 (77.8)**	**14**
Total	**244**	**223 (91.4)**	**45.9**	**21 (8.6)**	**27.8**

Under Known Fate scheme, the interval specific nesting success was found non- uniform across the different stages of the nesting event during the study period. The null model assuming uniform survival for the duration of the study was not selected. Models with stage specific survival had lower AICc values (Table 6). The incorporation of canopy cover and species of trees used for nesting increased the performance of stage specific model and such models were best selected on the basis of delta AICc values (Table 6). The impact of the canopy on the nest survivorship is exponential with the value of beta coefficient of Logit-link function at 0.56.

The top four models were equally fit and did not differ in terms of their AICc scores. Thus, I averaged the estimates of each to predict the stage specific nesting success. The overall survival probability for a nest under construction to be able to successfully release a fledgling was estimated by multiplying the stage specific nest survivorships, i.e. 0.60 × 0.84 × 0.90 at 0.45 (Table 7) .

Table 6: Summary of the selected models to estimate the survival parameters for the Black Kite nests in NCR (December 2012- April 2013), using Prog. MARK. Data from 116 nests was used for this analysis.

Model	AICc	Delta AICc	AICc Weights	Num. Par	Deviance
S (Stage) x (C.Cover)	**480.12**	**0**	**0.37**	**4**	**472.08**
S (Stage) x (Imp Spp.)	**480.65**	**0.52**	**0.28**	**5**	**470.59**
S (Stage) x (Imp Spp. +C.Cover+ Imp area + Nest ht)	**481.35**	**1.23**	**0.2**	**11**	**459.09**
S (Stage) x (C.Cover + Position)	**482.12**	**2**	**0.14**	**5**	**472.06**
S (Stage)	**487.4**	**7.28**	**0.01**	**3**	**481.38**
S(.)	**528.7**	**48.58**	**0**	**1**	**526.7**

Table 7: Results of the nest survivorship estimated by averaging the estimates of top four models (Table 5) on the basis of delta AICc cut off.

Nesting Stage	Interval (average 7 day) specific survival Estimate (n)	LCL (95%)	UCL (95%)	Stage survival estimate (avg. no. of intervals = y) n^
Pre-laying	**0.88**	0.85	0.90	**0.60** (LCL: 0.52 UCL: 068; **y = 4**)
Incubation	**0.96**	0.92	0.98	**0.84** (LCL: 0.68, UCL: 0.93, **y = 5**)
Nestling	**0.98**	0.95	0.99	**0.90** (LCL: 0.62, UCL: 0.98, **y = 9**)
Probability of a nest to successfully pass all Stages = 0.60 × 0.84 × 0.90 = 0.45				

Diet of Black Kites

In the absence of the reference samples (Sergio and Boto 1999), the pellets of Black Kites could not be analysed to detail. However, the gross examination of the pellets and the prey remains gave important information regarding the difference in the diet spectrum of the breeding and non-breeding roosting birds (Table 8, Figure 20). In future, as I built up the reference samples of my own for the Indian Black Kites, these regurgitated pellets can then be thoroughly analysed.

Table 8: Diet of breeding and non-breeding Black Kites in NCR, ascertained from direct observations and rapid analysis of regurgitated pellets and prey remains which were sourced from the nesting sites and the communal roosting sites respectively.

Diet Source	Nesting kites' pellets and prey remains + predation events	Non- Breeding roosting birds pellets and prey remains
Birds	Pigeon, Domestic Fowl, Collared Dove, Indian Roller, Moor-hen.	Domestic Fowl
Others	Rodents, Lizards, Frogs, Fishes, Squirrel, red meat chunks	Mammalian bones and large fish skin sourced from slaughter house

Figure 20: Prey remains from a nest at NZP (Left: Red meat and Right: partially eaten fish commonly found in NZP moats).

4. Discussion and Conclusion

Black Kite nest densities are highly uneven for the eight study sites. This shows the selectivity of the breeding Black Kites for nesting areas (Sergio *et al.* 2003a). The high use of *Eucalyptus* for nesting is likely justified by high relative availability of this species at all the sites. Both extremes of habitat suitability in terms of green cover (Mahipalpur) and Food availability (Ghazipur) were not favoured for nesting. While the scarce food could be the reason of absence of nests at Mahipalpur, presence of few trees and competition for space from the roosting non-breeders likely limits the nesting opportunity. The Black Kites exhibiting high densities at 67 nests / km^2 in North Campus and at 26 nests / km^2 in NZP is at the best trade off between the Food index and proportional green cover (Figure 19).

Comparison of current nest densities with the records from 1970 shows remarkable stability, except for the fluctuation in the population of NZP. The nest density at North Campus, which falls in the old Delhi zone, has remained quite same since Galushin (1971) studied them to be 50-80 nests / km^2. From the survey done by Malhotra in 2003, where he reported nest densities at 4 nests /km^2, kites in NZP area have shown recovery at the current density of 26 nests / km^2. The nest density during his earlier study was 25 nests / km^2 (Desai and Malhotra 1979, Malhotra 2007, http://www.hindu.com/2007/04/18). This can be attributed to loss of mature old trees from the city which appears to have forced Black Kites to overuse left over green refugia. Thus, even when the green cover shows increasing trend from last few decades due to plantation drives (http://www.delhi.gov.in), there has been considerable loss of mature trees to various constructions (Malhotra 2007).

Even though the nesting densities and the nesting success estimates are encouraging in the North Campus and NZP, the decreased in mature tree cover raises caution. According to my questionnaire survey and field observations during this study, Black Kites as an opportunistic species (Sergio and Boto 1999) is increasingly becoming tolerant towards humans. This has serious implications in disease spillage from dump sites to humans in case of increasing use of human habitation for roosting and nesting. Future studies focusing on behavioral characteristics that facilitate adaptation to an urban environment, e.g. by comparing the fleeing distances from humans of birds living in different scenarios of proximity to humans will allow us to better understand their changing distribution patterns.

I tried and developed a new method to estimate the huge congregation of the kites on the dump site. Through this photo based count, I estimated the number of Black Kites on the dump to be 2,371. This is a point estimate during the period of their maximum congregation on dump in a day. Due to the lack of time and man-power, I could not replicate this effort. The preliminary estimate has yielded positive results. Although, the estimated number looks below the expectation, the exercise will surely be helpful in future to better design the photo capturing strategy. Availability of good quality cameras with each team member will also enhance the accuracy of the results.

Raptors of the size of kites consume about 100 g of food daily (www.birdcare.asn.au). Thus, at a point they are removing about 250 kg of dead and decaying garbage from the dump. The number of kites at the dump site is most likely to turn over several times in a span of the day which will eventually increase the free scavenging service by these birds by several folds. The availability of kites as city scavenger is of vital importance (Blanco 1997) as they dispose of the decaying carcasses and other dump, which could otherwise rot and lead to spread of diseases. In future, to quantify the ecological service of the kites, it will be necessary to tag many individuals, both away and at the dump. Individually marked kites will reveal their turnover number through the day. Specified studies focussing on their foraging behaviour on the dump will also give better insights in case they show fluctuations in number in future.

Black Kites in NCR show a wide range of foraging habits. In addition to being scavengers on the dump sites and streets, these birds have an important niche in the urban ecosystem as predators (Malhotra 2007). During this study, I observed them preying on rodents, squirrels, , fishes, insects, amphibians, reptiles and birds of the size of pigeon or smaller (Malhotra 2007, Ferguson-Lees and Christie 2001). In field I often found chunks of red meat, most likely from a nearby slaughter house, weighing 50-200 gram in most of the active nests. On the dump sites they feed on carcass and gross gulp chicken feathers; a by-product of meat dressing.

On a broad examination, I found high representation of chicken feathers in the regurgitated pellets of the non-breeding roosting kites. The pellets and prey remains of the breeding birds collected from the nesting territory have mixed representation from the predated and the scavenged food. It was also supported from the fresh kills I recovered from the nests and through observations of direct event of predation by me and people residing near nesting territory. The occurrence of such prey in the nests increased once most eggs hatched after mid-February 2013. Although the analysis of pellets gives a good insight to what the birds eat, it is mostly the representation of the undigested remains (Sergio and Boto 1999). In NCR where kites forage on carcasses and chunks of meat, studies trying to understand their foraging behaviour solely through the pellets will be highly biased.

Modelling of stage specific nest survivorship with constant impact of canopy cover had the lowest score of AICc. However, this model did not differ much from the other top three models, based on their delta AICc values (Table 7). Thus, better fitness of smaller model is likely explained by the representation of 67% of the total nests only from North Campus and NZP study areas. Both study sites have high mean canopy cover and most nests found there were on the important nesting tree species. Canopy is important as it shields the eggs under incubation and the growing chicks from extreme weather of NCR, apart from providing protection from potential predators. According to the present and earlier studies, *Milvus* kites choose trees which provide stable nesting platform and have good canopy cover as well (Desai and Malhotra 1979, Newton *et al.* 1981, Sergio and Boto 1999, Sergio *et al.* 2003a).

According to the current study, the breeding success of the Black Kites in NCR is 72% starting from the incubation stage. It is higher than the 55% breeding success found in Italy but lower than the values from Spain and Germany and similar to the estimates from Japan (Sergio and Boto 1999). Nests on artificial structures were comparatively more exposed and all which failed (73%) could not reach incubation stage. Comparatively exposed nests face far greater destruction threat from the avian predators like crows, other Black Kites, rhesus macaque, and humans (Malhotra 2007, Sergio and Boto 1999). This can be attributed to large areas under poor sanitary conditions and ill management of solid waste, providing ample foraging opportunities for breeding kites.

However, Indian Black Kites dwell in the cities at extremely high densities. The limitation of green cover for nesting and roosting birds likely puts an upper cap to their overall breeding success. Therefore, just the ample availability of food does not make all the occupied nesting sites equally suitable. It is signified by overall low success probability ($p = 0.60$) of a nest to reach incubation stage. Newton *et al.* (1981) have reported the probability of a nest to reach incubation stage for Red Kites in Wales. It ranged from 0.56 to 0.85 in a span of 30 years.

In case of raptors, young adults do practice nesting (Brown and Amadon 1968, Newton 1979) while best territories are occupied by more experienced birds (Sergio and Vincenzo 2005). Black Kites, along with other raptors, show site fidelity in terms of utilizing previous nest substrate as base of a new nest or using same tree for nesting in successive years (Malhotra 2007). Thus, after the initial moderate survival rate of nests in the pre-laying stage, there is a considerable increase in the survival value of nests which reach the incubation stage. The value increases even more once the selective nests enter the nestling stage. Regarding raptors in general, only the best (e.g. oldest) individuals make it to the end of reproduction. Therefore, the percentage of high-performers progressively increases through the consecutive breeding stages through time (Newton 1979).

In future, it is necessary to understand the impact of urban ecosystem on kites by linking individual quality and status (breeder .vs. floater) with movement behavior through satellite telemetry (Tanferna *et al.* 2012). This shall be dealt with the final objective of studying how potential resources (food, refuse from garbage dumps, nest-sites, and partners) and threats (human interference, predators, and contaminants) shape the adaptation of a species to a highly urban landscape through telemetry.

Studying the relationship of distribution, density, breeding success and survival of individually marked kites shall enable us to better understand the impact of urban landscape structure and resource distribution, such as garbage dumps. Examination of the eco-physiological and eco-toxicological consequences of urban life (Bird *et al*. 1996) (e.g. by studying the Corticosterone-stress levels and pathogens of birds using the garbage dumps to different degrees: heavy metals from feathers, pesticides from egg shell and egg shell thinning) will provide insight to know the impact of garbage consumption on these birds (Tenan *et al.* 2012). Moreover, it will also be necessary in judging their role as potential carriers of diseases from such dumps.

Apart from emphasizing their importance in the ecosystem as scavengers and predators, Sergio *et al.* (2003a, b) have successfully advocated the use of Black Kites in Europe as valid conservation model species. In India, the concept of urban ecosystem and urban wildlife remains neglected. Black Kites, being an urban scavenger and top trophic level species, provide important ecological service to mankind. Kites in India are also very tolerant to human intervention, as found during my nest inspections.

This enables them to be a good model for experimental ecology with respect to nest condition manipulations. These birds also occur at high densities which make them a valid model species to test ecological hypothesis with higher precision and accuracy. Eventually, studies validating above ideas will establish Black Kites as an umbrella species for urban ecology (Bird *et al*. 1996, Luck *et al.* 2011, Magle *et al.* 2012).

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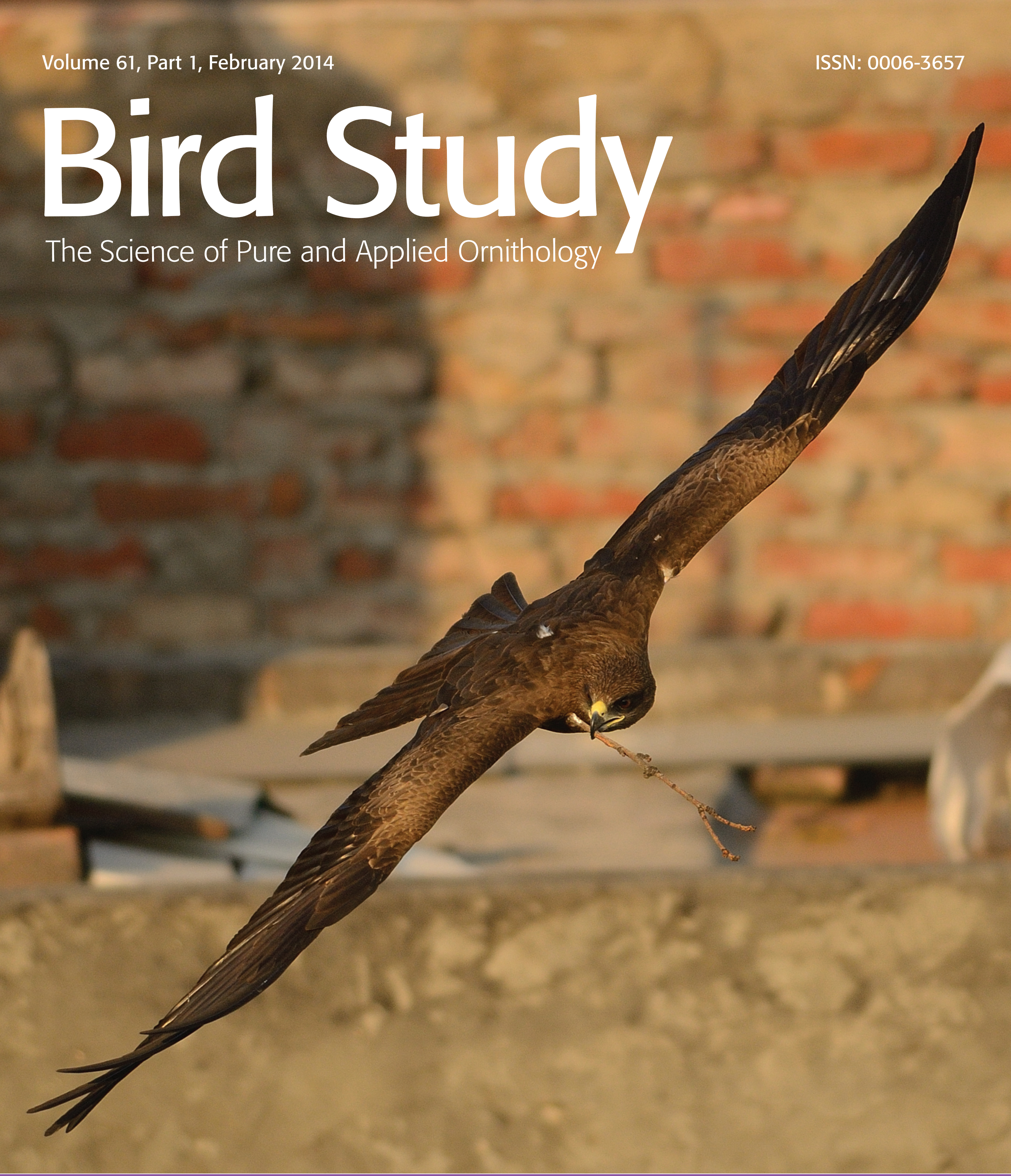

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Density, laying date, breeding success and diet of Black Kites *Milvus migrans govinda* in the city of Delhi (India)

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Capsule The density of Black Kites in Delhi, India, may represent the highest concentration of a raptor recorded in the world and has not declined since the 1960s.
Aims To estimate the density, phenology, breeding success and diet of Black Kites in Delhi.
Methods During 2013, Black Kite nests were surveyed in 24 plots of 1 km^2 distributed throughout Delhi. A sample of 151 nests was checked regularly to record laying date, breeding success and diet.
Results The average density was 15 nests/km^2. The majority of nests were on trees (91%) and the rest on artificial structures. Mean laying date was 31 January and the laying season was protracted over four months. Mean number of fledged young was 0.73, 1.09 and 1.53 per territorial, breeding and successful pair. Diet was dominated by scavenged meat and by rats, pigeons and doves abundant in the city.
Conclusions Density has been stable since 1960–1970s and probably represents the highest ever recorded for a raptor. This is probably promoted by a combination of (i) availability of rubbish, (ii) few predators and (iii) high tolerance by people. The conservation status of this raptor seems satisfactory, but removal of mature trees for rapid development may result in local declines or re-distributions, suggesting the need for continued monitoring.

The Black Kite *Milvus migrans* is a medium-sized raptor, currently considered as one of the most numerous and successful birds of prey of the world (Ferguson-Lees & Christie 2001). It is a generalist, opportunistic feeder, capable of reaching extremely high densities where food concentrations allow it (e.g. review in Sergio *et al.* 2005, Malhotra 2007) and may occupy habitats which range from fully natural to completely urban (Ortlieb 1998, Ferguson-Lees & Christie 2001). Such opportunism and capability to exploit human-modified habitats has afforded this species a generally favourable conservation status, with frequent reports of recently increasing populations, despite some local declines (Bijlsma 1997, Sergio *et al.* 2003, Thiollay & Bretagnolle 2004).

This capability to adapt to human landscapes reaches its extreme in populations that nest in fully urban conditions, as frequently observed in Asia and Africa (Desai & Malhotra 1979, Brown *et al.* 1982, Ali & Ripley 1983, Naoroji 2006). In these settings, kites are reported to use the urban ecosystem not only for nesting but also for feeding on human offal, road kills, animal carcasses and rubbish, sometimes forming spectacular concentrations of thousands of individuals at rubbish dumps of large cities (Brown *et al.* 1982, Owino *et al.* 2004, Naoroji 2006, Malhotra 2007). When these dumps are located in the proximity of airports, the concentration of kites often generates serious management problems because of the risk of collisions with planes (Satheesan 1996, Owino *et al.* 2004). It is remarkable that, despite their overall abundance and frequent proximity to humans, Black Kites have been very rarely studied, except for two or three intensively investigated populations, all of them located in Europe and in non-urban settings (Viñuela *et al.* 1994, Blanco 1997, Sergio *et al.* 2003, 2011).

In the Indian subcontinent, where we conducted our research, the *govinda* sub-species is well distributed with dense populations in all the major urban centres (Naoroji 2006), which has attracted many anecdotal observations, as reported in several issues of the *Journal*

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of the Bombay Natural History Society (Hanxwell 1892, Fischer 1906, Ali 1926, Abdulali 1968, 1972, Mahabal & Bastawade 1985, Malhotra 1991). However, quantitative data for this biogeographic region are extremely scarce and previous studies, all of them conducted in the 1970s, have focused on: (1) a coarse estimation of the size of the overall Delhi population (Galushin 1971) and (2) data on the breeding ecology of the high-density colony of the Delhi Zoo (Desai & Malhotra 1979). Here, we report comprehensive quantitative data on the density, nest spacing, phenology, breeding success and diet of a fully urban population located within Delhi, India. We then compare the current estimates with historical records and with studies on other kite sub-species.

METHODS

Study area

Black Kites were surveyed in 2013 in 24 plots (details below) within an overall area of 1500 km^2 pertaining to the city of Delhi, India. Delhi is a mega-city of 16 million inhabitants in constant, rapid expansion (Census Organization of India 2011). The overall city comprises both urban and semi-urban areas under poor solid waste management, which affords plenty of food to Black Kites in the form of rubbish, carrion and remains from slaughterhouses. The climate is semi-arid, with 64 cm of annual precipitation, mainly concentrated in July and August. Temperature ranges from a mean maximum of 39.6°C to a minimum of less than 8.2°C in the winter (India Meteorological Department 2013). The vegetation of the general region falls within the 'northern tropical thorn forest' category (Champion & Seth 1968).

Field procedures

Because many areas of the city were private properties not accessible to the public, it was impossible to design a very large continuous study area. Also, because Black Kites in our area can attain extremely high densities, small-sized plots distributed over a wide area were judged to be better suited to sample all available conditions than a single continuous plot of necessarily limited extent. Therefore, we designed a network of 24 sample plots, each one of approximately 1 km^2 of homogenous accessibility and distributed throughout the city covering all types of potential nesting habitats. However, a standardized shape or a standardized surface of 1 km^2 could not be attained for all plots because of constraints imposed by private properties and logistical difficulties of access. Private properties had similar landscape features to the surrounding areas of the city and we are confident that their exclusion did not bias our density estimates. However, because of the above, nests which were located at the periphery of each sample plot were not employed to generate estimates of nest spacing (nearest neighbour distance henceforth referred as NND), unless a complete nest census had been conducted also for the area bordering the quadrat.

We surveyed each quadrat repeatedly every few weeks, starting from the pre-incubation period, by walking slowly and carefully inspecting all potential nest structures (trees, buildings, towers, etc.). Structures were classified as active nests when a kite individual or pair was repeatedly observed to perch in the nest or its immediate surroundings, or to add material to the nest. Once found, nests were checked by climbing to them, observing them from nearby vantage points, or through an eight-meter telescopic rod equipped with a video-recording camera. Nests were checked approximately every eight days. However, because of time, safety, accessibility and manpower limitations, data on breeding success were collected only at a sub-sample of nests.

A nest was classified as depredated when we found remains of plucked chicks. Cases of brood reduction (death of one chick, often caused by its siblings, subsequently fed to other nestlings) were not classified as predation events. Hatching date was calculated by backdating from the feather development of nestlings first observed when <15 day old and by comparison to reference information in Desai & Malhotra (1977), Cramp & Simmons (1980), Hiraldo *et al.* (1990) and personal data by one of the authors (F.S.). Laying date was estimated by subtracting 30 day, the average incubation period (Viñuela 1997), from hatching date. During each visit, we collected prey remains found inside and under nests and identified them to the genus or species level assuming the smallest possible number of individuals. These items were used to estimate each prey percentage contribution by number or by mass to the diet of Black Kites.

Terminology follows Steenhof (1987): a territorial pair was one that built a nest and then did or did not lay a clutch; a breeding or reproductive pair was one which laid eggs; a successful pair was one which raised at least one nestling until it was 40 day old; and breeding success was the percentage of successful territorial pairs. There was no need to correct the estimates of breeding success through Mayfield estimators, because all plots were surveyed repeatedly from the pre-laying period onwards, and because nests were easy to find and were checked very frequently (approximately every eight days). Density was calculated as number of territorial pairs per unit area and expressed as number of pairs/km^2. The difference in breeding success between nests located in trees and nests built on artificial structures was tested by means of a Z-test (Zar 1984). Throughout, means are given ±1 se, tests are two-tailed, and statistical significance was set at $\alpha \leq 0.05$.

RESULTS

Cumulatively, we censused 244 Black Kite nests in 2013. Out of these, 223 (91.4%) were located on trees and the rest on artificial structures (17 on electricity pylons and 4 on telephone metal towers). Out of 223 tree nests, 35.5% were built on *Eucalyptus* spp., 23% on *Ficus* spp., 13.8% on Neem (*Azadiracta indica*), 12.7% on Jamun (*Syzygium cumini*) and 8.3% on Keekar (*Prosopis juliflora*). The mean nest density was 15.1 ± 7.9 pairs/km^2 and varied between 0 and 67.1 nests/km^2 (n = 24 plots). Mean NND for the whole population was 133 ± 15 m and ranged between 5 and 2315 m (n = 207 pairs).

A subset of 151 nests was closely monitored for breeding success. The overall mean laying date was 31 January (n = 65, se = 3.3 days; range 19 December–13 April) and the laying season lasted almost 4 months (115 days), with a pronounced peak between the second half of January and first half of February (Fig. 1). When mean monthly temperature and rainfall were super-imposed on the laying frequency (Fig. 2), kites seemed to concentrate clutch initiation before the temperatures became excessively high and before the start of the Monsoon rains in June–July. The percentage of clutches initiated each month was negatively related to the minimum monthly temperature (linear regression: $B = -1.37 \pm 0.35$; B for constant = 34.21 ± 7.14; n = 12; Bonferroni-corrected $P = 0.006$; $R^2 = 0.56$) and quadratically related to the maximum monthly temperature (quadratic regression: B for linear term = −11.86 ± 3.66; Bonferroni-corrected $P = 0.02$; B for quadratic term: =0.17 ± 0.06; Bonferroni-corrected $P = 0.02$; B for constant = 211.37 ± 54.04; n = 12; $R^2 = 0.77$), while egg laying stopped with the commencement of the rains and was initiated again only after the monsoon season. Finally, the number of young fledged by each pair declined with laying date (linear regression: $B = -0.13 \pm 0.03$; B for constant = 1.66 ± 1.77; n = 65, $P = 0.001$; $R^2 = 0.17$).

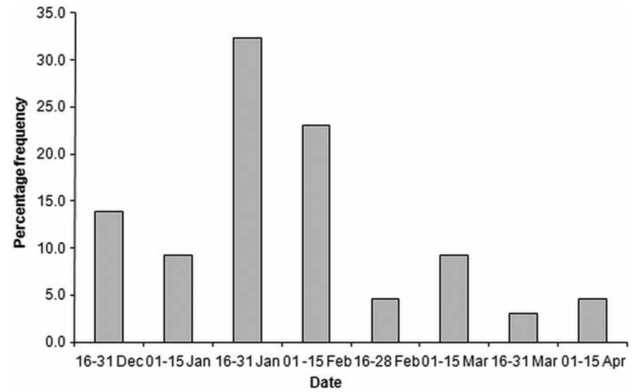

Figure 1. Temporal frequency of laying dates in the Black Kite population of Delhi (India) in 2013 (n = 65).

Mean clutch size was 2.09 ± 0.06 (n = 100). Mean hatching success was 64.6 ± 4.65% (n = 72 nests). Of 137 chicks first observed when less than five days old, three were depredated (all from a single nest) and six were subsequently observed dead in the nest or simply disappeared, probably because of sibling aggression (Viñuela 2000). The mean percentage of nestlings lost by brood reduction was 0.16 ± 0.04 per brood (n = 91 nests). The mean number of fledged young was 0.73 ± 0.07 per territorial pair (n = 151), 1.09 ± 0.06 per breeding pair (n = 100) and 1.53 ± 0.04 per successful pair (n = 72). Forty-eight per cent of territorial pairs successfully raised their nestlings to fledging age (n = 151). There was a trend for breeding success to be higher for nests on trees than for nest on the artificial structures (46% vs. 27.8%; $Z = 1.8$, $P = 0.07$, n for tree nests = 130, n for artificial substrate = 21).

Black Kite diet included all vertebrate classes but was strongly dominated, both by mass and number, by three main items: (1) remains from slaughterhouses, mainly in the form of compact chunks of meat; (2) rats and (3) medium-sized urban birds, such as doves and pigeons (Table 1).

DISCUSSION

Our study confirmed that Black Kites maintained extremely high breeding densities throughout the city of Delhi, as already observed in the 1970s (Galushin 1971). When compared with data from other populations (reviewed in Table 2), the density observed in the urban environment of Delhi was

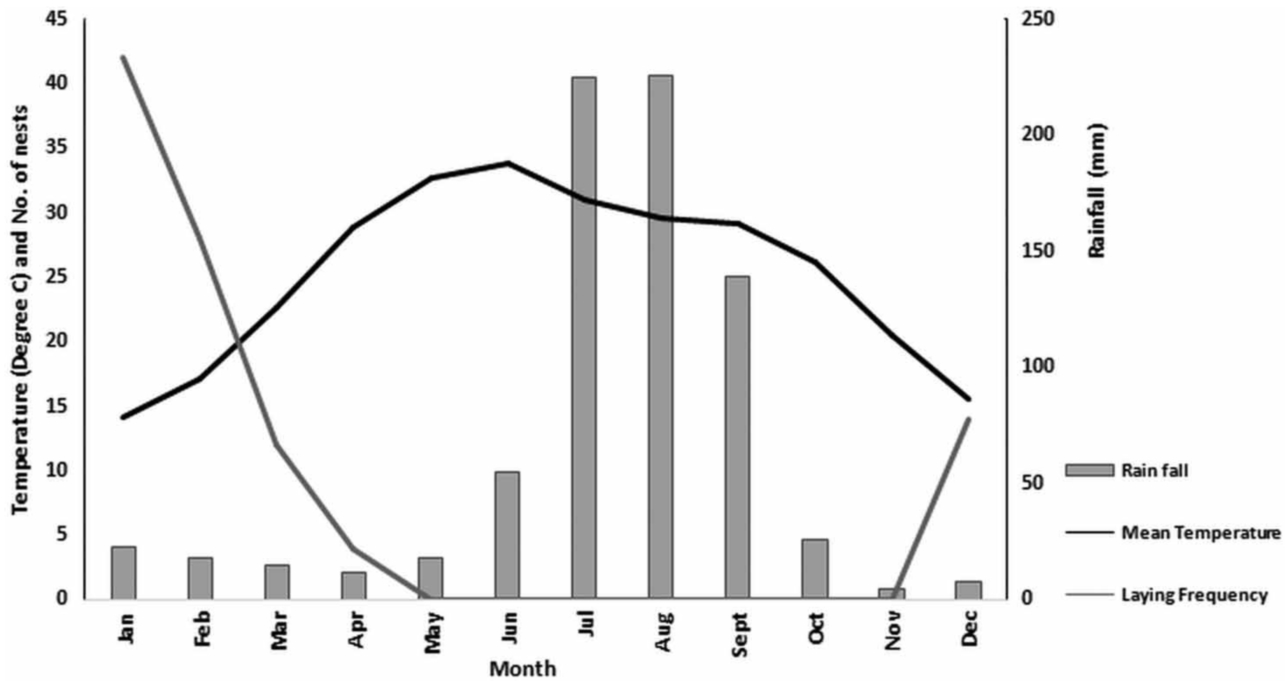

Figure 2. Mean temperature, monthly rainfall and Black Kite laying frequency in Delhi (weather data from India Meteorological Department 2013).

Table 1. Diet of breeding Black Kites in Delhi, India (2012–2013), as estimated by food remains collected inside and under the nest.

Prey category	Frequency by number (%)	Frequency by mass (%)
Fish[a]	0.8	1.0
Amphibians[b]	0.7	0.7
Reptiles[c]	0.7	0.3
Birds	24.6	31.9
(i) Rock Pigeon (*Columba livia*)	13.1	16.2
(ii) Collared Dove (*Streptopelia decaocto*)	4.1	3.3
(iii) Other birds[d]	7.4	12.4
Mammals[e]	9.8	20.2
Scavenged meat[f]	63.4	45.9
(i) Meat scraps	47.1	35.6
(ii) Domestic chicken	11.5	6.1
(iii) Cattle[g]	4.1	3.5
(iv) Fish[h]	0.7	0.7

[a]Unidentified fish ($n = 1$).
[b]Indian bull-frog ($n = 1$).
[c]Common house gecko ($n = 1$).
[d]Moorhen (*Gallinula chloropus*) ($n = 1$), Indian Roller (*Coracias benghalensis*) ($n = 1$), Unidentified birds ($n = 7$).
[e]Mammals which were unlikely to be consumed as carrion. Includes: Norway rat (*Rattus norvegicus*) ($n = 11$) and Palm squirrel (*Funambulus pennantii*) ($n = 1$).
[f]Prey items that were considered to have been collected as carrion from local rubbish dumps and slaughterhouses.
[g]Buffalo ($n = 2$), Goat ($n = 3$).
[h]Large unidentified fish skin, likely from fish market.

higher than any previously published estimate. This is then, probably, the highest density ever recorded over a large, continuous area for any bird of prey of this size. The capability to attain such a high population-level over such a large region is likely to be promoted by a combination of at least three factors. (1) First, the rubbish management plans of such a rapidly developing mega-city are inevitably poor, which results in a network of enormous, legally authorized rubbish dumps coupled with hundreds of smaller, and often illegal sites where garbage is dumped daily. At an even finer-scale, private individuals, families and shops often leave their daily garbage directly in the streets, resulting in a network of ephemeral, small piles of food. In turn, these must promote large populations of potential prey species, such as rats and pigeons. All the above, coupled with the high abundance of meat and fish shops throughout the city, sets an ideal scenario of enormous food availability for an opportunistic predator and facultative scavenger. (2) Second, the attitudes of local people towards kites, and wildlife in general, are extremely positive and tolerant, even despite the fact that some kites can be very aggressive in defending their nest against nearby passers-by. We are not aware of any cases of persecution of kites in Delhi, which is confirmed by the relative absence of

Table 2. Breeding density and nest spacing of Black Kite populations in Europe and India (Delhi), 1966–2013.

Area (period)	Habitat	Density (pr/10 km^2) (*n*)	NDD in meters (*n*)
Delhi, India (2013)[17]	U	150 (244)	133 (207)
Delhi, India (1967–1969)[3]	U	161 (~560)	–
NZP, India (1979)[16]	U	250 (18–21)	–
NZP, India (2013)[17]	U	264 (70)	–
Matas Gordas, Spain (1987–1989)[10]	M	70–150 (21–45)	–
Matas Gordas, Spain (1992–2000)[15]	M	100.8 (515)	–
Doñana, Spain (1981–1984)[8]	M	26.7 (80)	206 (47)[a]
RBD, Spain (1989–2000)[15]	M	15.1 (1059)	–
Lac Leman, Switzerland (1975–1990)[11]	F	10.1 (319)	–
Neuchatel, Switzerland (1968)[5]	FL	7.1 (337)	–
Lorraine, France (1966)[1]	WP	4.5 (66)	–
Rhône Plain, France (1970)[5]	RP	60.9 (140)	–
Limousin, France (1976–1978)[4]	PW	1.0 (21)	–
Lake Lugano, Italy (1992–1996)[13]	WL	2.4–3.8 (27–41)	441 (175)
Lake Lugano, Italy (1992–2003)[15]	WL	2.9 (365)	–
Lake Maggiore, Italy (1996–2000)[14]	WL	–(24)	–
Lake Como, Italy (1996–2000)[14]	WL	4.7 (40)	–
Lake Iseo, Italy (1996–2000)[14]	WL	3.5 (48)	–
Lake Idro, Italy (1997–2001)[14]	WL	6.7 (37)	–
Lake Garda, Italy (1997–2000)[14]	WL	1.5 (18)	–
Sarca Valley, Italy (1997–2003)[14]	WL	1.3 (88)	–
Castelporziano, Italy (1991–1992)[9]	WF	3.3 (16)	103 (16)[b]
Monti della Tolfa, Italy (1973–1980)[7]	WP	0.5 (42)	–
Constance Lake, Germany (1968–1969)[2]	FL	1.9–2.2 (25–30)	–
Drömling, Germany (1993–1994)[12]	F	0.7 (8)	2330 (8)[c]
Brandenburg, Germany (1979)[6]	F	0.7 (215)	–

Notes: Density was expressed as territorial pairs/10 km^2 for clarity of presentation. The 2013 data from the current study are presented twice in the table: (i) for the whole study area, i.e. representative of the whole Delhi population; and (b) for the high-density sector of the New Delhi National Zoological Park (NZP), in order to make them comparable to historical data from the 1970s by Malhotra (2007). Habitats are U, Urban; M, Marshland; FL, Farmland and Lake; WL, Woodland and Lake; F, Farmland; WP, Woodland and Pasture; WF, Woodland and Farmland; FL, Farmland and Lake; PW, Pasture and Woodland; RP, River Plain.
[a]Estimate from Bustamante & Hiraldo (1990), for the period 1985–1988.
[b]A single colony.
[c]Calculated from the published map.
[1]Thiollay (1967), [2]Heckenroth (1970), [3]Galushin (1971), [4]Nore (1979), [5]Sermet (1980), [6]Fiuczynski (1981), [7]Petretti & Petretti (1981), [8]Hiraldo *et al.* (1990), [9]De Giacomo *et al.* (1993), [10]Viñuela *et al.* (1994), [11]Henrioux & Henrioux (1995), [12]Seelig *et al.* (1996), [13]Sergio & Boto (1999), [14]Sergio *et al.* (2003), [15]Sergio *et al.* (2005), [16]Malhotra (2007), [17]This study.

fear of humans by most kites in comparison to European conspecifics. (3) Third, the city provides an environment with a low abundance of potential predators. The only potential nest predators known to occur locally are Indian Eagle Owls *Bubo bubo bengalensis*, House Crows *Corvus splendens* and Rhesus Macaques *Macaca mulatta*. The latter two species can be locally abundant, but are often deterred by the very aggressive and effective nest defence behaviour of parent kites.

When compared to historical records, the high density we recorded seemed remarkably stable over several decades. Rapid city-wide surveys and data from the New Delhi Zoological Park suggested only slightly higher densities in the 1970s than currently observed (Galushin 1971, Desai & Malhotra 1979; see Table 2). This is despite enormous changes in the city's dimensions, population size and management, and despite the recent, virtual extinction of the locally abundant populations of a potential trophic competitor, the White-rumped Vulture *Gyps bengalensis*, the former primary scavenger (Prakash *et al.* 2003, Naoroji 2006). The kite population thus seems very resilient to change in terms of overall density.

The laying season was protracted over almost four months, probably as a result of the long period of warm, favourable climate and of the stable food supply provided by the urban environment (Fig. 1). The temporal peak and range of laying dates seemed to be arranged so that most nestlings fledged well before the high temperatures and the marked peak in precipitation caused by Monsoon rains in July–August (Fig. 2). The negative effect of high temperatures and rainfall on kite foraging performance, egg viability and breeding success has been reported for various European populations (Hiraldo *et al.* 1990, Viñuela 2000, Sergio 2003). The observed, lengthy range of laying dates compares to a duration of the laying season of 28 days for kite populations of the Italian Alps and to 2.8 months for the population of Doñana National Park, in the extreme south of Europe (F. Sergio, pers. data). This suggests a North-South latitudinal gradient in the length of kites' breeding seasons. Protracted breeding seasons are increasingly reported as progressively more studies of birds of prey are conducted in tropical or more southern latitudes (Simmons 2000, Ogada & Kibuthu 2012).

When compared to other populations (review in Table 3), our estimates of breeding success were lower than in other studies and this may be a consequence of density-dependent processes in a crowded, saturated population (Newton 1998). The fact that similarly low levels of reproduction were reported for another saturated population (Doñana, Sergio *et al.* 2011) lends support to this impression. However, in the absence of more information, other alternative explanations

Table 3. Productivity of Black Kite populations in Europe and Asia, 1966–2013.

					Mean number of fledged young		
Area (period)	Habitat (*n*)	Clutch size	Hatching success[a] (eggs)	Breeding success (%)	Territorial pair	Breeding pair	Successful pair
Delhi, India (2013)[11]	U (151)	2.09 (100)[b]	68% (157)[b]	48	0.73	1.09 (100)[b]	1.52 (72)[b]
NZP, India (1973–1976)[2]	U (45)	2.3 (60)[b]	55% (102)[b]	–	0.98	–	–
NZP, India (2013)[11]	U(46)	2.04 (36)	62% (55)[b]	59	0.78	0.95 (38)[b]	1.44 (25)[b]
RBD, Spain (1989–2000)[10]	WL(1059)	2.02	67.4 (416)	41	0.59	0.71	1.43
Matas Gordas, Spain (1992–2000)[10]	GM(515)	2.12	70.3 (232)	44	0.61	0.85	1.46
Germany (1992–1995)[7c]	– (599)	–	–	79	1.63	–	2.07 (471)[b]
Limousin, France (1976–1978)[3]	PW (22)	–	–	68	–	1.32	1.93 (15)[b]
Berlin, Germany (1940–1979)[4]	F (215)	–	–	62	1.20		1.90 (133)[b]
Lake Lugano, Italy (1992–1996)[9]	WL (143)	2.29 (42)[b]	84% (96)[b]	55	0.97	1.1 (95)[b]	1.78 (78)[b]
Lake Lugano, Italy (1992–2003)[10]	WL (315)	2.3	74 (88)	50	0.90	1.24	1.80
Lake Maggiore, Italy (1996–2000)[10]	WL (30)	–	–	50	0.87	–	1.73
Lake Como, Italy (1996–2000)[10]	WL (40)	–	–	48	0.75	–	1.58
Lake Iseo, Italy (1996–2000)[10]	WL (48)	–	–	38	0.48	–	1.10
Lake Idro, Italy (1997–2001)[10]	WL (37)	–	–	59	1.05	–	1.63
Lake Garda, Italy (1997–2000)[10]	WL (18)	–	–	44	0.83	–	2.14
Sarca Valley, Italy (1997–2003)[10]	WL (88)	–	–	40	0.63	–	1.62
Slovakia (1975–1989)[5]	– (162)	2.98 (44)[b]	–	–	–	2.31	–
Lac Leman, Switzerland (1975–1990)[8]	FL (165)	2.25	–	–	–	2.02	–
Lorraine, France (1966)[1]	WP (66)	2.26 (45)[b]	–	–	1.32	1.58 (55)[b]	–
Nagasaki, Japan (1983–1986)[6]	FP (32)	2.18 (28)[b]	79% (61)[b]	75	1.00	1.14 (28)[b]	1.33 (24)[b]

Notes: The 2013 data from the current study are presented twice in the table: (i) for the whole study area, i.e. representative of the whole Delhi population; and (ii) for the high-density sector of the New Delhi National Zoological Park (NZP), in order to make them comparable to historical data from the 1970s by Desai & Malhotra (1979). Habitats are U, Urban; GM, Grassland and Marshland; FL, Farmland and Lake; WL, Woodland and Lake; F, Farmland; WP, Woodland and Pasture; FL, Farmland and Lake; PW, Pasture and Woodland; FP, Fishing Port.

[a]Data on hatching success not shown in the table: 75% (n = 36 eggs from 14 nests, Hakel, Germany, 1957; Stubbe 1961) and 64% (n = 28 eggs from 10 nests, Lazio, Italy, date unknown; Petretti 1992).

[b]Sample size (when different from that in column 'Habitat (*n*)').

[c]Data also from Mammen & Stubbe (1995, 1996).

[1]Thiollay (1967), [2]Desai & Malhotra (1979), [3]Nore (1979), [4]Fiuczynski (1981), [5]Danko (1989), [6]Koga *et al.* (1989), [7]Gedeon (1994)[c], [8]Henrioux & Henrioux (1995), [9]Sergio & Boto (1999), [10]Sergio *et al.* (2005), [11]This study.

cannot be discounted: for example, it is not known whether a diet based in large portion on rubbish and meat produced for human consumption could spread pathogens or toxic substances among the offspring.

Finally, the observed diet composition confirmed the full dependence of the local kite population on urban resources, such as meat scraps from slaughterhouses or prey species which were extremely abundant within the city, such as rats, pigeons and doves. The current picture of the diet does not suggest that kites range frequently, if at all, out of the city to capture wild prey in surrounding rural areas. This confirms that the high density attained within the urban setting is likely promoted by attraction to a dense food source.

In summary, extensive foraging opportunities, a stable favourable climate, absence of human persecution and low density of potential predators have probably contributed to one of the densest raptor populations of the world. The current conservation status of the studied population seems satisfactory, but recent urban development is causing extreme and almost complete removal of mature trees in some sectors of the city. In turn, this could limit the kite population in the future, or trigger local declines and re-distributions, especially when considering that artificial structures do not seem to fully compensate for tree absence (authors' pers. data). Thus, given the abundance of the species and the current urban sanitary levels, the ecological service provided by kites through removal of organic rubbish must be valuable, suggesting the need for ecologically sensitive urban planning of the remaining green areas. This calls for the importance of continued monitoring of the population and its nesting requirements in future years.

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