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RECENT TRENDS OF POPULATION AND NESTING OF THREATENED VULTURE SPECIES IN THAR DESERT OF RAJASTHAN, INDIA

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AUTHORS' CONTRIBUTIONS
This work was carried out in collaboration among all authors. Author RPS designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author RK managed the analyses of the study. Author AP managed the literature searches and supervised the study. All authors read and approved the final manuscript.

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ABSTRACT

The data obtained the population fluctuation between seven species of vultures in the Thar Desert of Rajasthan is of great significance. A systematic study carried out the objective of demography, breeding, and nesting records of vulture species in Thar Desert of Rajasthan starting from 2016 and over three successive years. Linear regression used to determine a trend in the population of residents and migratory vulture species. Egyptian vulture observed the highest and White-backed vulture resulted in the lowest population trends. Potential records of nesting of resident vulture species also gathered at the right proportion. The patterns of declines and the presence of dead birds, various accidental tragedies, habitat loss, and windmills indicate some possible cause even after the ban on Diclofenac in 2006.

Keywords: Demography; nesting; thar desert; vulture.

1. INTRODUCTION

Grass root level information such as long term population monitoring, availability of adequate food, favourable ecological conditions, and geographic distribution are the new parameters that rely upon the proper application of appropriate conservation action used in research for the threatened species such as vultures [1]. Demography estimated as the addition (births and immigration) and loss (deaths and emigration) of individuals from a population which is regulated by intrinsic factors (i.e., life-history, first breeding, fertility, longevity, and dispersal) and extrinsic (i.e., food resources, topography and abiotic factors [2].

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In India, nine species of vultures recorded, of which five belong to the genus *Gyps* [3]. This genus represents eight species worldwide; among them, four are resident species in Asia (*G. bengalensis, G. indicus, G. himalayensis*, and *G. tenuirostris*), three are found primarily in Africa (*G. africanus, G. coprotheres*, and *G. rueppellii*), and one breed in Eurasia but migrates into Africa and South Asia (*G. fulvus*) [4]. Other than, *Sercogyps calvus* and *Neophron percnopterus* are the other vulture species present in India and Asian boundaries [5].

Indian continent witnessed the severe dramatic fall down in *Gyps* vulture population since 1990 [6,7]. This declination affects on the whole of three vulture species (Oriental White-backed *Gyps bengalensis*, Long-billed *G. indicus*, and Slender-billed *G. tenuirostris)* by more than 97% and assigned as "critically endangered" not only in India but in the entire south Asian region on the verge of extinction [8, 4]. The primary cause of this catastrophe identified the use of Non-steroidal anti-inflammatory drug Diclofenac to treat livestock [9,10] and perhaps other birds of prey those scavenge on the carcasses of freshly treated livestock [11, 12].

Population estimation of *Gyps* vulture in Keoladeo national park of Bharatpur in Rajasthan recorded >95% disappearance of the entire Gyps vulture population from 1988 to 1999 came into noticed[3]. Similarly, Malaysia, Thailand, and Indonesia of the Indian continent also witness the same declination in the same period [13, 14, 15]. Recently, Cambodia is also facing a similar decline in vulture populations due to poisoning [16].

Rajasthan state harbours seven species of vultures. Four of them are resident (*Gyps bengalensis, Gyps indicus, Sarcogyps calvus,* and *Neophron percnopterus*) while three are winter migratory (*Gyps fulvus, Gyps himalayensis,* and *Aegypius monachus*) [17]. The Thar Desert is a biodiversity-rich, open, semi-arid agro-grass habitats due to wild and adequate domestic livestock. This region represents xeric vegetation and resources but limited human infringement. Very few studies undertook in the region in context to these highly sensitive scavengers in the Thar area.

Baseline information on Demography, Breeding, and nesting ecology is rather scanty [18, 19]. Our survey covered the potential vulture's habitat in Barmer, Bikaner, and Jaisalmer and Jodhpur districts in Thar are the primary focus. In this study, we intended an unparalleled collection of population dynamics and nesting records of residents and migratory species. Additionally, we describe previously unreported colonies of White-backed Vultures, Red-headed vultures, Long-billed Vulture, and Egyptian vultures in the Thar area. Based on fieldwork from 2016 to 2018, we describe spatial and temporal population dynamics, nesting records, and discussing the recent threats and future conservation possibilities.

2. MATERIALS AND METHODS

Barmer, Jaisalmer, Bikaner, and Jodhpur districts divided into eleven sampling blocks into Thar. Each of these sampling blocks divided as field-stations, Nagana hills, Kundal hills, Balotara, Nokha, Jorbeer, Sam, Lathi, Myajlar, Mehrangarh, Arna and Keru dumping. The significant sites noted as represented in (Fig. 1). During the investigation, nesting vulture was thoroughly searched for by scanning potential cliffs and nesting trees in open areas.

To estimating accurate annual fluctuation in population, regular monitoring performed from January 2016 to December 2018 in respective localities. All visits to observe seasonal variation were spaced out by every alternate week to cover all fluctuations homogenously; more attention given on feeding sites and roosting adjacent to restaurants. Annual fluctuations in the colony examined by assessing vulture numbers in the same sites (roosting & nesting) site from sunrise to sunset at a rate of three-eight visits per month. Departure time was when more than 50% of the vultures in the colony left the study site, whereas arrival time was when at least two by three of the birds counted in the morning returned to the selected site.

2.1 Statistical Analysis

The data comparison takes off all the three-year from 2016 to 2018 for the crude population. Analysis carried out of resident and migratory species of half-yearly (January to June) and (July to December). Average mean values used to make a histogram and scatter plot by single vulture species with the standard error value**.** Linear Regression in Microsoft Excel 2010 was used to determine a trend in the population of resident vulture species (*Gyps indicus, Gyps bengalensis, Sercogyps calvus*, and *Neophron percnopterus*) and migratory vulture species (*Gyps himalyensis, Gyps fulvus*, and *Aegyous monachus*) throughout 2016 to 2018). The map created with the help of the QGIS software desktop version 2.18.6.

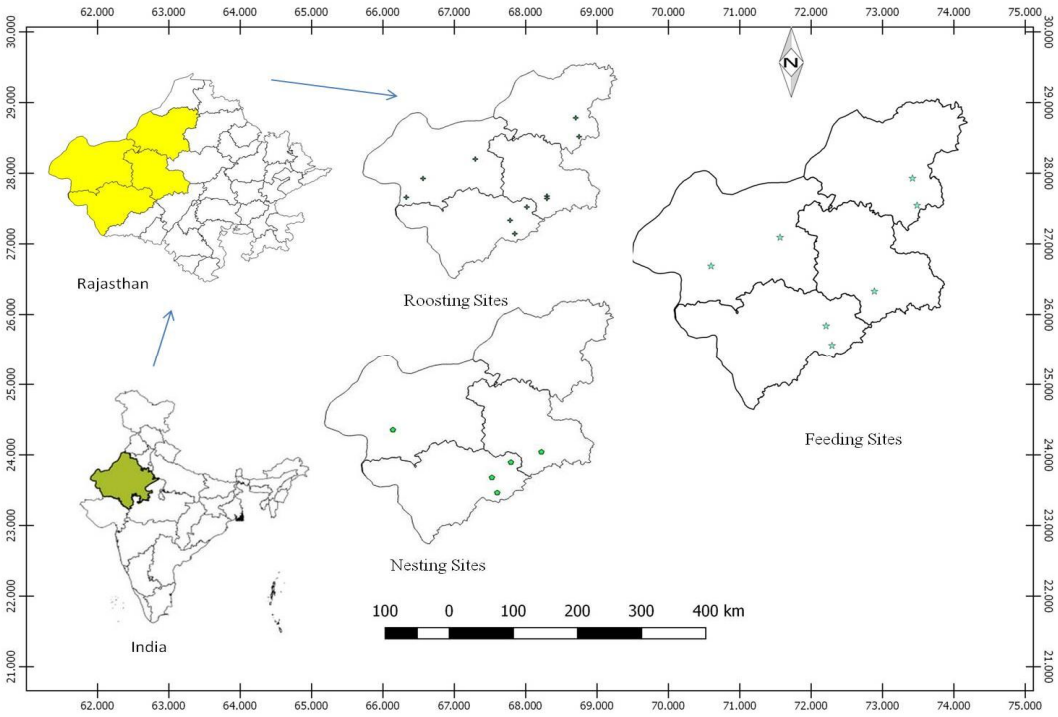

Fig. 1. Depiction of Major roosting sites (n=10), nesting (n = 5), and feeding sites (n = 7) at various points in the four districts of Thar desert(Barmer, Jaisalmer, Bikaner, and Jodhpur)

3. RESULTS

3.1 Roosting

Roosting sites support a greater extent to evaluate the population study in vultures. At the heterogeneity of varied habitat, we identified various roosting sites in these four districts of Thar Desert. The water body in Jodhpur (Badli pond) and Nabhdungar and Myajlar (Jaisalmer) revealed many residents and migratory species in this area. Open land as in Jorbeer (Bikaner), Keru (Jodhpur), Nokha (Bikaner), and Lathi (Jaisalmer) also support a number in the whole year, specifically in the winter season. At the same time, high tension light poles and windmills located as a roosting place of the vultures in the Desert national park area in Jaisalmer. The semi grassland of Lathi, Jorbeer, and Sudasari also inhabit the roosting place of vulture species. The roosting pattern is somehow different in all the species as Egyptian vulture, red-headed vulture, long-billed vulture, and Cinereous vulture prefer to roost in single, but in the case of the Eurasian griffon, Himalayan Griffon and White-backed vulture roost in colony observed at various instances (Fig. 2).

3.2 Feeding

For demography, we have accessed both the wild and artificial dumping sites. Keru (Jodhpur), Lathi (Jaisalmer), Jorbeer, and Nokha (Bikaner) are known as dumping sites where these large scavengers show a significant population extent. These sites were convenient places for counting the birds in large flocks. The migratory vulture species Eurasian griffon, Himalayan griffon, and cinereous vulture often counted on these dumping sites in the winter season starting from October to March in the subsequent year of study. Whereas vast arid land of Desert national park show wilder habitat and the presence of enormous number of vultures while occasionally feeding on the field or at neighborhood countrysides (Fig. 2).

3.3 Nesting

Specific targeted surveys identified vulture nesting sites throughout the year, particularly in summer (April to August). Nest surveys concentrated on known breeding locations, areas with emergent trees along watercourses, and small hills used by vultures in the Thar Desert. Data recorded on vulture species such as location, habitat roosting and nesting sites. Monitoring vulture population size and trends Species populations monitored at supplemental feeding stations established at Lathi, Keru, Jorbeer, and Nokha. One of the supplemental feeding sites initiated by Municipal Corporation and declared a protected "Vulture Conservation Reserve."

Nesting recorded in tall trees like *Prosopis cineraria, Acacia nilotica, Acacia tortalis, Anogeissus pendula, Tecomella undulata Azadirachta indica* in Jodhpur and Jaisalmer and high cliffs in Barmer and Jodhpur. On comparing to other vulture species at feeding sites, Red-headed vultures and Long-billed vulture are relatively timid and solitary birds and often found in breeding pairs (Fig. 3).

Sam, Kundal Hills, Kumbharkotha, Sudasari, Ramgarh utilised for Red-headed vulture and Mehrangarh, Nagana Hills and Kundal hills were utilized for nestlings of Long-billed vulture in study area. All these sites are located in the core area of Thar Desert. The most of nest of RHV built on top of the Khejri tree, where LBV saw at rocky cliffs. Breeding and nesting records observed in more or less138 nests were identified as active and abundant in the study period. There are 76 found active and productive on cliffs and trees. Among them, 30 identified as Red-headed vultures, 30 of Egyptian Vultures, 13 of Long-billed vultures, and three were of White-backed vulture**.** The monitoring of an active nest and search for new nests in the region are the next phase. The high breeding records and occupancy of the nest are a positive indication of the increase in these scavenger populations.

The demography compared after every six months of counting the vultures starting from January 2016 to December 2018. The study showed the existence of 4332 ± 344 Egyptian vultures, 100 ±36 of Red-headed vulture, 126 ±29 of Long-billed Vulture, 142 ± 53 of White-backed vulture, 588 ± 67 of the Eurasian griffon, 332 ± 78 of Himalayan and 218 ± 65 of Cinereous vulture counted during on an average of six months. The population of vultures within the primary study areas was recorded per month from January 2016 to December 2018. Egyptian vulture shows the highest richness, and the Red-headed vulture shows lowest in the study. In migratory vulture species, Eurasian griffon shows the highest count, whereas Cinereous vulture shoes lowest in the study area. Demographical data were collected separately from each of the vulture species.

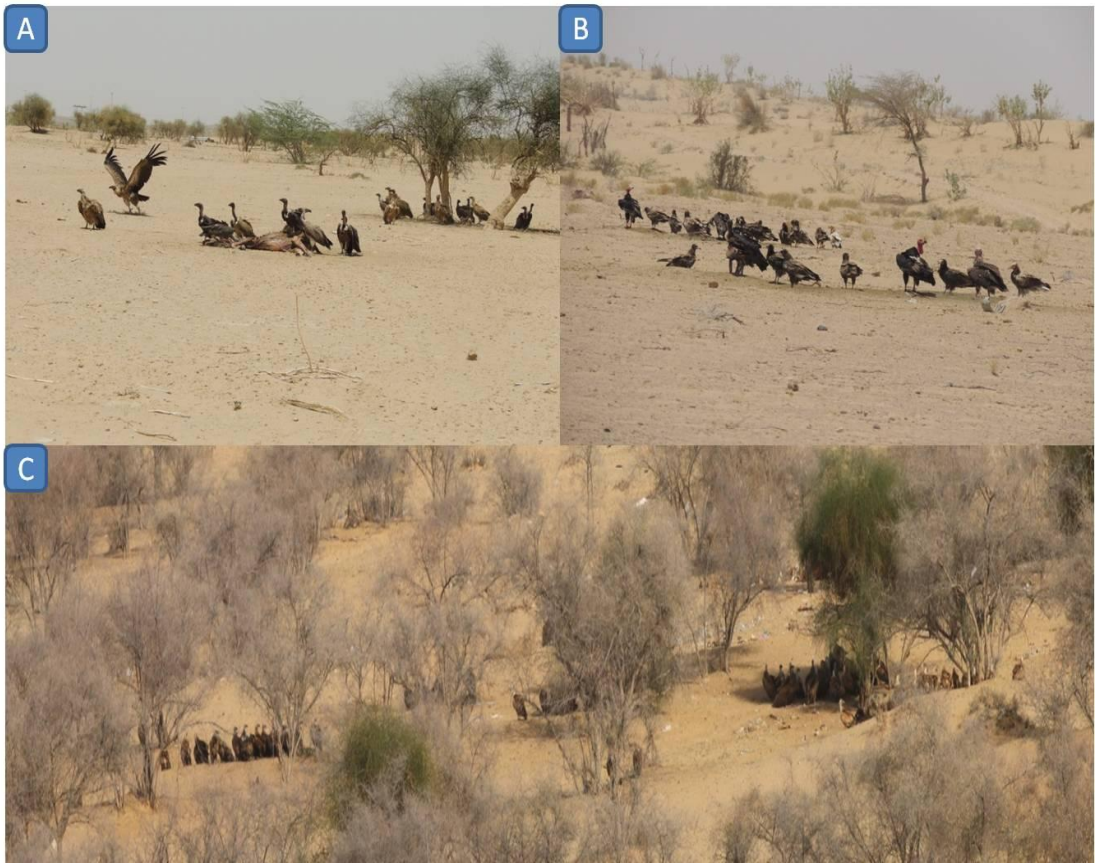

Fig. 2. Feeding and Roosting: (1A & 1B) carcass feeding of Migratory vultures in Myajlar area in May. (1C) Migratory vultures were roosting under the *Ziziphus* tree at Lathi

Fig. 3. Nesting and Breeding. (3A & 3B) Active nest without and with egg on a Keekar tree at Gangha (Desert National Park, Jaisalmer),(3C & 3D) LBV chick and nesting sites at Mehrangarh, (Jodhpur) and Kundal Hills (Barmer), (3E & 3F) Active nest and fledge of RHV with on Khejri tree at Khumbharkotha, (Jaisalmer)

Presence of resident vulture in the Thar region was not unvaryingly observed in this study. Red-headed vulture was recorded in the Jaisalmer and Bikaner area on an average of 100 ±36. A minimum of 18 recorded in July 2016 to December 2016, and the maximum number counted 234 in July 2017 to December 2017. The Egyptian vulture is the most dominating and commonly occurred vulture in all the four districts. Overall, 4332 ± 344 of Egyptian vulture was recorded in the six months of average. Minimum of 3297 vultures recorded in January 2016 to June 2016 and a maximum of 5406 in July 2018 to December 2018. Overall, on the average of 126 ±29 Long-billed vulture recorded in a half year as Minimum of vulture recorded 67 July 2016 to December 2016 and the maximum recorded as 239 in July 2017 to December 2017**.** White-backed vulture was recorded as 142 ± 53 in all the districts. The minimum of vulture recorded 17 in January 2016 to June 2016 and the maximum recorded as 316 in July 2018 to December 2018.

Similarly, migratory vulture's Eurasian griffon is a regular visitor to the study is in the Thar Desert of Rajasthan. 588 ± 67 of vultures recorded on the average as Minimum of vulture recorded 380 July 2016 to December 2016 and maximum recorded as 820 in July 2017 to December 2017**.** Himalayan Griffon recorded 332 ± 78 numbers in six month of the period. A Minimum of vulture recorded 165 July 2018 to December 2018 and the maximum recorded as 680 in July 2017 to December 2017. Cinereous Vulture recorded on an average of 218 ± 65 cinereous vultures counted in the three years. A Minimum of vulture recorded 74 in January 2017 to July 2017, and maximum recorded as 501 in July 2017 to December 2017 (Fig. 4).

The population trend was calculated from all three years of study. Trends in capture rates for Resident species as *Gyps indicus* (R^2= 0.2001), *Gyps bengalensis* (R^2 = 0.3239) and for *Neophron percnopterus* (R^2= 0.7632). The linear population trend observed in Egyptian vulture throughout the subsequent study period is increasing. The trend concluded in the range of 0 to 1000 populations in numbers **(**Fig. 5). Population trends in capture rates for Migratory Species as *Gyps himalyensis* (R^2= 0.2741), *Gyps fulvus* (R^2= 0.0417), and for *Aegypus monachus* (R^2= 0.0111) from 2016 through 2018. The trend concluded in the range of 0 to 200 populations in numbers (Fig. 6).

4. DISCUSSION

The Thar Desert provided arid and semi-arid biogeography with highly specific traditional agro-pastoral livelihoods in a meaningful manner. Vulture species and population composition at the Thar landscape given utmost attention in this study. Systematic surveys conducted in 11 primaries and opportunists' observation in Jodhpur, Jaisalmer, Bikaner, and Barmer district of Thar Desert. These study sites hold abundant vulture movement in their vicinity (Table 1).

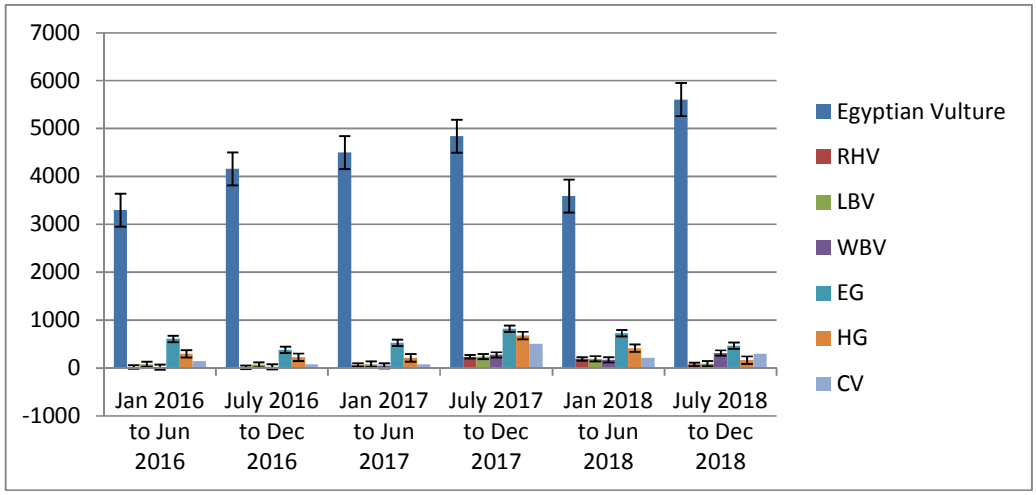

Fig. 4. Collective comparative graphical presentation of the vulture population in the thar desert

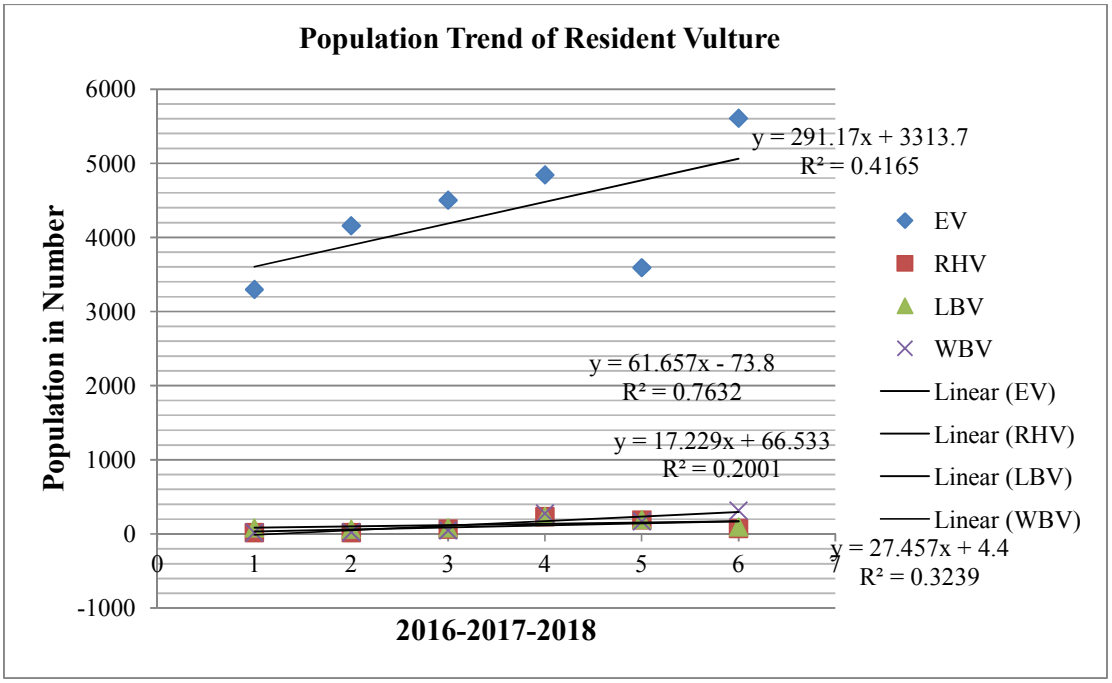

Fig. 5. X-Axis represented years from 2016 to 2018 in which the study conducted, and Y-axis denoted as the graphical representation of average population number 0 to 1000 for the resident vulture specie

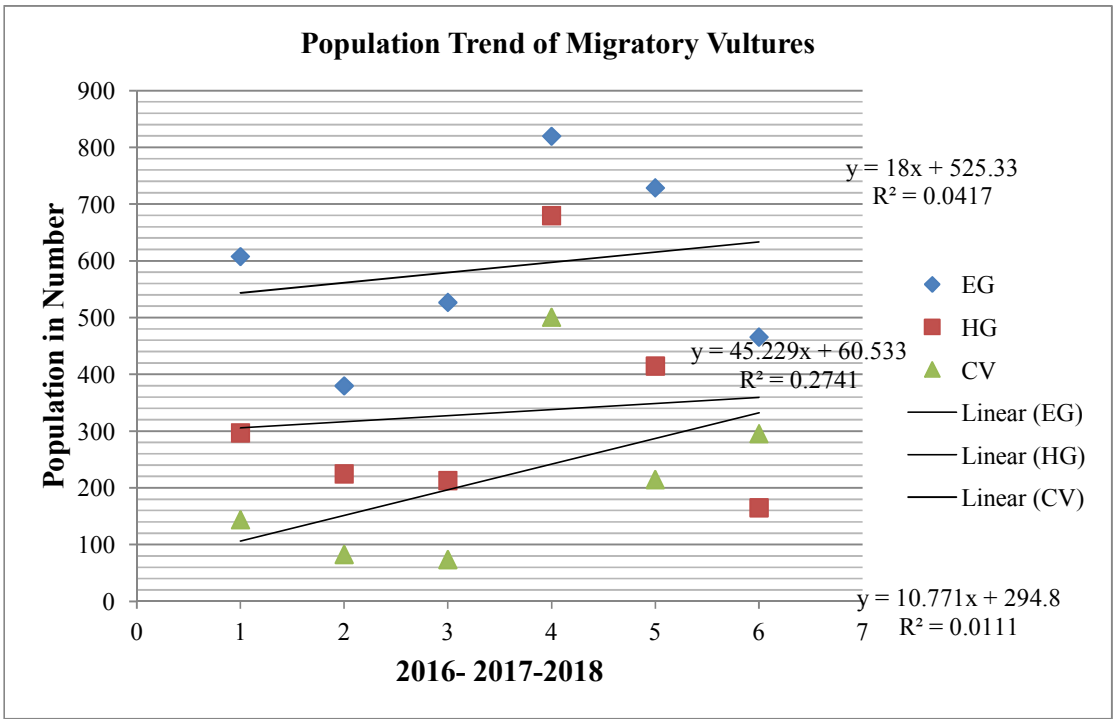

Fig. 6. Graphical representation of average population number 0 to 900 for the migratory species

Table 1. Details of various roosting, nesting, and feeding sites of vulture species in the 11 localities of study area

S. N.	Name of Place/ Natural or artificial site	Location	Activity	Vulture species
1.	Mehrangarh/ Natural	26.29689 E 73.01741 N	Nesting	LBV
2.	Keru dumping Site/ Artificial	26.32798 E 72.88699 N	Feeding, Roosting	EV, EG, HG, CV
3.	Arna Jharna and Badli/ Natural	26.28387 E 72.88677 N	Roosting	EV, EG, HG, CV
4.	Balotara/ Natural site	25.83663 E 72.20978 N	Nesting, Roosting	LBV
5.	Nagana Hills/ Natural site	26.10356 E 72.51669 N	Nesting, Roosting	LBV, EV
6.	Kundal Hills/Natural Site	25.55860 E 72.29283 N	Nesting, Feeding, Roosting	LBV, WBV, EV, EG,HG
7.	Jorbeer Vulture conservation reserve/ Artificial	27.92728 E 73.42121 N	Feeding, Roosting	EV, LBV, WBV, KV, EG, HG, CV
8.	Nokha Dumping/ Artificial	27.54331 E 73.48576 N	Feeding, Roosting	EV, EG, HG, LBV, CV
9.	Sam, Sudasari, Khumbhar khota, Khuhri	26.68553 E 70.59755 N	Feeding, Roosting, Nesting	EV, LBV, WBV, KV, EG, HG, CV
10.	Myajlar	26.30740 E 70.28433 N	Roosting	EV, EG, HG, LBV, CV, WBV, KV
11.	Shri Bhadariya Lathi	27.09106 E 71.56485 N	Feeding, Roosting	EV, EG, HG, LBV, CV, WBV

Demography and distribution are mostly affected by anthropogenic activities [20]. One of these activities involved nowadays establishing artificial dumping sites of dead cattle that support significant vulture populations [21]. Similarly, in the wild areas of Thar hold the large size of livestock that directly affects the occurrence, breeding performance, and demography of the vultures [22].

During the present study, the data on vulture population dynamics, nesting sites, and potential roosting sites were collected. For the exact population status and boundaries of presence, an extensive investigation required, much of which carried out through analysis of photo capture data, videography, and regular monitoring of potential areas of Thar Desert. A recent study conducted at Jodhpur carcass dump estimates the significant number of both resident and migratory vulture species [23].

Scavengers are other than Vultures such as Steppe eagle, Eastern imperial eagle, Black-headed White Ibis, Common crow, Large-billed crow, and Black kite invaded on food their large density. This effect may be responsible for the reduction in vulture population except for Egyptian vulture. Feral and unmanaged dogs hunting, electrocution, and trichobezoar are reasons for vulture death in the Thar region [24, 25, 26]. At some point in the study, we examined semi-arid forest, open scrub area, rocky, barren land, grasslands, Barren and shifting dunes, dead carcass in wild and artificial feeding stations. We have also observed the mortality cases of these birds. The study finds vulture's mortality in various ways, such as Himalayan griffon trapped in a Khejri tree at Lathi, A Cinereous vulture injured due to wind turbines near Sam. Several times road crushed Egyptian vulture noted along the Khuhri –Myajlar road in difference visits during the study, feral dog hunting in Keru dumping Jodhpur, Eurasian griffon at Lathi, electrocuted Egyptian vulture in Jodhpur, trichobezoar in Eurasian griffon in Jodhpur, and mortality at railways tracks in Jorbeer and Dholiya (Jaisalmer) were also recognized.

5. CONCLUSION

This study reported an interesting increasing trend of *Neophron percnopterus* at a significant level, but the constant trend of *Gyps bengalensis*, *Gyps indicus, Gyps fulvus*, and *Gyps himalyensis*, while *Aegypus monachus* showed a dismal number in the study area. Keru biological treatment plants in Jodhpur, Jorbeer vulture conservation reserve in Bikaner, and Lathi

carcass dump in Jaisalmer are the significant sites where a vast population of vultures moves to find food in throughout the year. Instead, the resident vultures show ubiquitous presence across the region.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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