THE ROLE OF CITIZEN SCIENCE PROJECT IN PREDICTING POTENTIAL HABITAT AND DISTRIBUTION OF EGYPTIAN VULTURE (*NEOPHRON PERCNOPTERUS*) IN UTTARAKHAND, INDIA.

Saurabh Purohit and S.P.Aggarwal

Indian Institute of Remote Sensing , 4, Kalidas Road, Dehradun, India

Email: saurabhpurohit10@gmail.com, spa@iirs.gov.in

KEYWORDS: ebird, MaxEnt, Citizen Science, Egyptian Vulture, Endangered

ABSTRACT

Scientific data collection by well-designed experiments and methodology provide the bedrock for most scientific studies but with geographical, financial and time constraints. Citizen science is proving to be an effective tool in collecting plethora of data across large geographical areas. It helps in raising awareness of key environmental issues, such as climate change and loss of biodiversity; while at the same time promote development of scientific temper among the population as enshrined in fundamental duties of Indian constitution. In addition, they provide valuable scientific data by which to track environmental change. Species spatial database and mapping can be an excellent management tool for predicting patterns of biological diversity and for monitoring species spatial distribution, or even identifying geographical locations of conservation significance. In this study Worldclim bioclimatic variables, elevation, land use/land cover data and 82 spatially well-dispersed species occurrence points from eBird, a global citizen science project that gathers bird observations around the world were used to predict the potential habitat of Egyptian vulture (*Neophron percnopterus*) an endangered species declared by IUCN using MaxEnt as species distribution model in Uttarakhand. Maxent model has got a statistically significant AUC value of 0.852. This approach can be an effective tool for species conservation efforts using citizen science as a potent tool.

INTRODUCTION

Science has always progressed by the active involvement of general public in scientific discoveries since time immemorial with the earliest records dating back 1,910 years for locust outbreaks in China (Tian et al., 2011). In last two decades there has been tremendous increase in public involvement in scientific research, now referred to as "Citizen Science" coined by Alan Irwin in 1994 in the context of describing expertise by lay people (Irwin et al., 1994). It is defined as "general public engagement in scientific research activities where citizens actively contribute to science either with their intellectual effort, or surrounding knowledge, or their tools and resources" (European Commission, 2013). Citizen science projects have been remarkably successful in advancing scientific knowledge by engaging the public or interested volunteers in scientific projects that are difficult to conduct solely by scientists who lack the resources to gather or analyse data on a large scale ranging from monitoring wildlife and the environment (Willett et al., 2013., Wiersma et al., 2010., Howard et al.,2010) to annotating images from past biodiversity collections (Williams et al., 2014). Project objectives range from supporting scientific investigations within academic institutions to increasing the interest and knowledge of the general population on science (Faridani., 2009).

In ecology and conservation biology citizen-science techniques have assumed great importance as it provide the opportunity to enlist the public to help survey entire landscapes over long periods (Bhattacharjee, 2005). Citizen-science engages a diversity of participants that range from trained observers to amateurs, who currently gather tens of millions of observations annually (Bonney, 2007, Kelling, 2008). Citizen science projects are typically based on the assumption that participants will willingly donate their resources, both time and money, to a project whose sole reward is the self-satisfaction inherent in doing something to benefit science. No organism lends itself more readily to the concept of citizen participation in data gathering than birds. This is because there are nearly 10,000 species that occupy all terrestrial and most aquatic environments and because birds are linked to biotic processes at many levels. Birds are largely diurnal, behaviourally and morphologically conspicuous, and plentiful; they are among the most studied of all widespread animal groups. One such citizen science project involving birds is eBird (Sullivan et al., 2009) , a program launched by the Cornell Lab of Ornithology (CLO) and the National Audubon Society in 2002, which engages a vast network of human observers (citizen scientists) to report bird observations using standardized protocols. At its most basic level eBird is a tool for birders. But at its highest level, eBird is a tool for science and conservation. eBird's mission is to harness the skills of everyday birders in an effort to better understand bird distribution and abundance across large spatio-temporal scales and to identify the factors that influence bird distribution patterns allowing scientists to generate new hypotheses and direct future research efforts based on large amounts of data. eBird data are available in real-time, creating new opportunities for rapid integration of bird data with other kinds of information. The true power of eBird lies in the strength and diversity of its users. Everyone with an interest in birds can participate, from the rank novice, to the backyard birder, to the globe-trotting expert. Moreover, as more users submit data an environment of sharing and free data exchange will become the norm between birders, scientists, and conservationists.eBird data also can be used to test and enhance species distributional models needed to prioritize areas for conservation actions and to direct species-specific management. Importantly, all eBird data become scientific knowledge by joining networked data available through larger global biodiversity initiatives such as the Avian Knowledge Network (AKN) (Avian Knowledge Network, 2008) and Global Biodiversity Information Facility (GBIF) (GBIF Data Portal, 2008).

Many raptor species around the world are declining, and avian scavengers like vultures are among the most threatened raptor species (Thiollay 2006, Virani et al. 2011, Chaudhary et al. 2012, Ogada et al. 2012).Globally, there are 23 species of vultures, of which the majority occur in the Old World and within the family Accipitridae. The remaining seven species comprise the New World Cathartidae family. India has nine species of vultures in the wild, viz.: Oriental White-backed or White-rumped Vulture *Gyps bengalensis*, Slender-billed Vulture *Gyps tenuirostris*, Long-billed or Indian Vulture *Gyps indicus*, Egyptian Vulture *Neophron percnopterus*, Redheaded or King Vulture *Sarcogyps calvus*, Indian Griffon Vulture *Gyps fulvus*, Himalayan Griffon *Gyps himalayensis*, Cinereous Vulture *Aegypius monachus* and Bearded Vulture or Lammergeier *Gypaetus barbatus* .(MoEF, 2006). Egyptian Vulture is different from other species by way of its appearance occupies a large range with isolated resident populations Typically nests on ledges or in caves on cliffs (Sarà and Di Vittorio 2003), crags and rocky outcrops, but occasionally also in large trees, buildings (mainly in India), electricity pylons and exceptionally on the ground (Gangoso and Palacios 2005). It forages in lowland and montane regions over open, often arid, country. Also scavenges at human settlements. Broad diet including carrion, tortoises, organic waste, insects, young vertebrates, eggs and even faeces (Margalida *et al.* 2012, Dobrev *et al.* , 2016). Usually solitary, but will congregate at feeding sites, such as rubbish tips, or vulture restaurants (i.e. supplementary feeding stations), and forms roosts of non-breeding birds (Ceballos & Donázar 1990). The species exhibits high site fidelity, particularly in males (Elorriaga *et al.* 2009, García-Ripollés *et al.* 2010, López-López *et al.* 2014).This long-lived species qualifies as Endangered owing to a recent and extremely rapid population decline in India (presumably resulting from poisoning by the veterinary drug diclofenac) combined with severe long-term declines in Europe (>50% over the last three generations [42 years]) and West Africa, plus continuing declines through much of the rest of its African range. (IUCN Red List).

Species distribution modeling to predict and map appropriate habitat for endangered species is critical for monitoring and restoration of their population decline in natural habitat. The Maxent model is a useful technique for predictive modeling of geographical species distribution on the basis of the most significant environmental conditions Phillips et al. (2004, 2006). This approach estimates the most uniformly distributed "maximum entropy" of sampling points compared to background locations, taking into account the constraints derived from the data. The maximum entropy algorithm is deterministic and converges to the maximum entropy probability distribution (Baldwin, 2009; Berger et al., 1996; Phillips et al., 2006). The environmental variables most closely associated with the presence of a species can be extrapolated to similar biotopes to in order to identify the probable geographical distribution of the species.

MATERIALS AND METHODS

Study Area

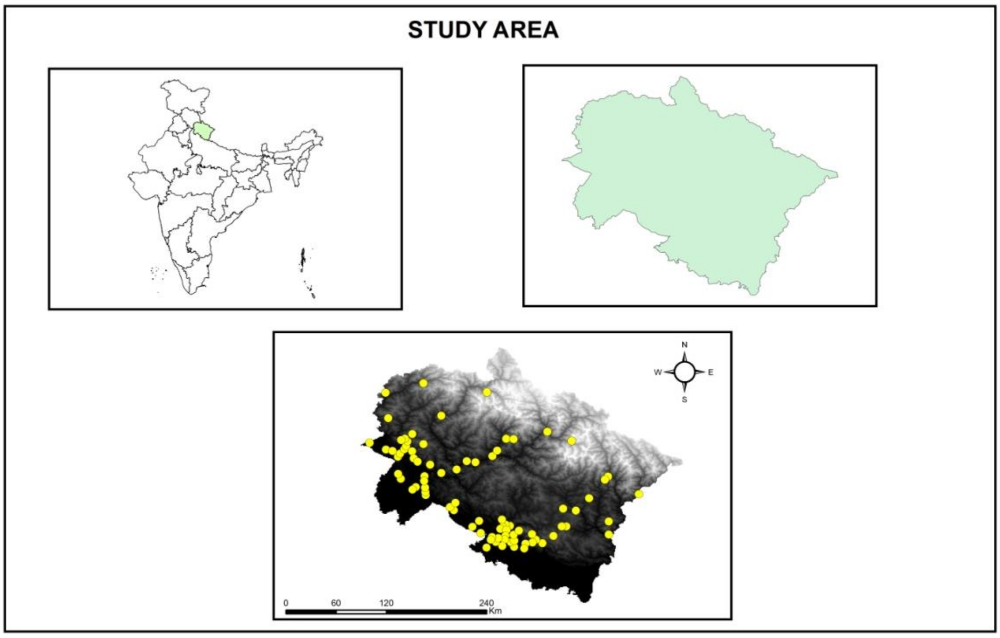

Figure 1 Study area along with sighting points of *Neophron percnopterus*

Uttarakhand mainly consists of hilly state bounded by Uttar Pradesh on the south, Nepal on the east, Himachal Pradesh on the west and the China on the North east. The state's habitat varies from the terai region in the plains, the bhabhars (the outermost foothills of the Himalaya), the Shivaliks (sub-Himalayan range), the Lower Himalayas and finally, the high altitudinal Greater Himalayas and Trans-Himalayas. Vegetation types ranges from Tropical moist deciduous forest dominated with *Shorea robusta* species to alpine meadows above which is generally the snow line with sparse vegetation and rocks.The hill state of Uttarakhand has terrific avifaunal diversity. It has 15 Important Bird Area (IBA) sites including three non-protected areas namely Asan Barrage, New Forest Campus and upper Pindar catchment,and one recently added IBA which is Pawalgarh conservation reserve.(Rahmani et al., 2016). Of the 1303 bird species recorded from India, compiled from the IOC World Bird List (Gill & Donsker, 2014), more than 50% are found in Uttarakhand. The amazing diversity in habitat from the plains up to the numerous mountain peaks that exceed altitudes of 7,000 m results in marvelous avifaunal diversity.

Species Occurrence Data

A total of 120 occurrences of *Neophron percnopterus* were taken from ebird portal recorded by bird watchers over the period of time in Uttarakhand. During the post field data assessment, all point locations collected were overlaid on the fishnet mesh of 5x5 km. Certain grids having more than one point were identified and reduce to one point per grid based on nearness to the center of the grid under consideration. As a result, a total of 82 spatially unique points per grid were finally used in the data analysis and modeling.

Environmental Variables

A total of 21 environmental variables were used. Nineteen bioclimatic variables (Hijmans et al. 2005) with 30 arc second (˜1Km) spatial resolution were obtained from the WorldClim dataset and used to detect the most influential variables associated with the present distribution of *Neophron percnopterus.* The Shuttle Radar Topography Mission (SRTM) with 1 arc second (˜30 m) spatial resolution was used to generate the slope, aspect and elevation data layers. MODIS LULC data was used for Land Use/Land Cover data. All the variables were stored in ASCII file format at 30 arc-seconds (~ 1.0 km) resolution. These datasets were finally checked for precise spatial matching as prerequisite for modeling tools. All ASCII files consisted of 416 columns, 331 rows, and 0.00833 cell size representing continuous data in ratio and interval scales of measurements and discrete data in nominal scale of measurements. Thirty percent of training sites were taken as test sites.

Model Version Used

MaxEnt Algorithm version 3.4.1 released in December 2016 (Phillips et al., 2006) was used for mapping the potential geographic distribution of *Neophron percnopterus* in Uttarakhand state.

RESULTS AND DISCUSSION

Evaluation of MaxEnt Model

Receiver Operating Characteristic (ROC) curve

A ROC plot is a plot of sensitivity and 1-specificity, with sensitivity representing how well the data correctly predicts presence, whereas specificity provides a measure of correctly predicted absences (Fielding and Bell, 1997). The ROC curve is generally used to evaluate the simulation accuracy of the model (Hanley and McNeil, 1982). The area below the ROC curve, i.e. the value of the area under the curve (AUC) indicates the predictive accuracy of the model. In the present study, the AUC of the constructed model based on the potential climatic factors affecting the distribution of *Neophron percnopterus* was 0.868 and 0.852, for training and test data respectively. This AUC value indicated that the constructed model is applicable and had good predictive accuracy and therefore it was suitable for geographic distribution of *Neophron percnopterus* in Uttarakhand.

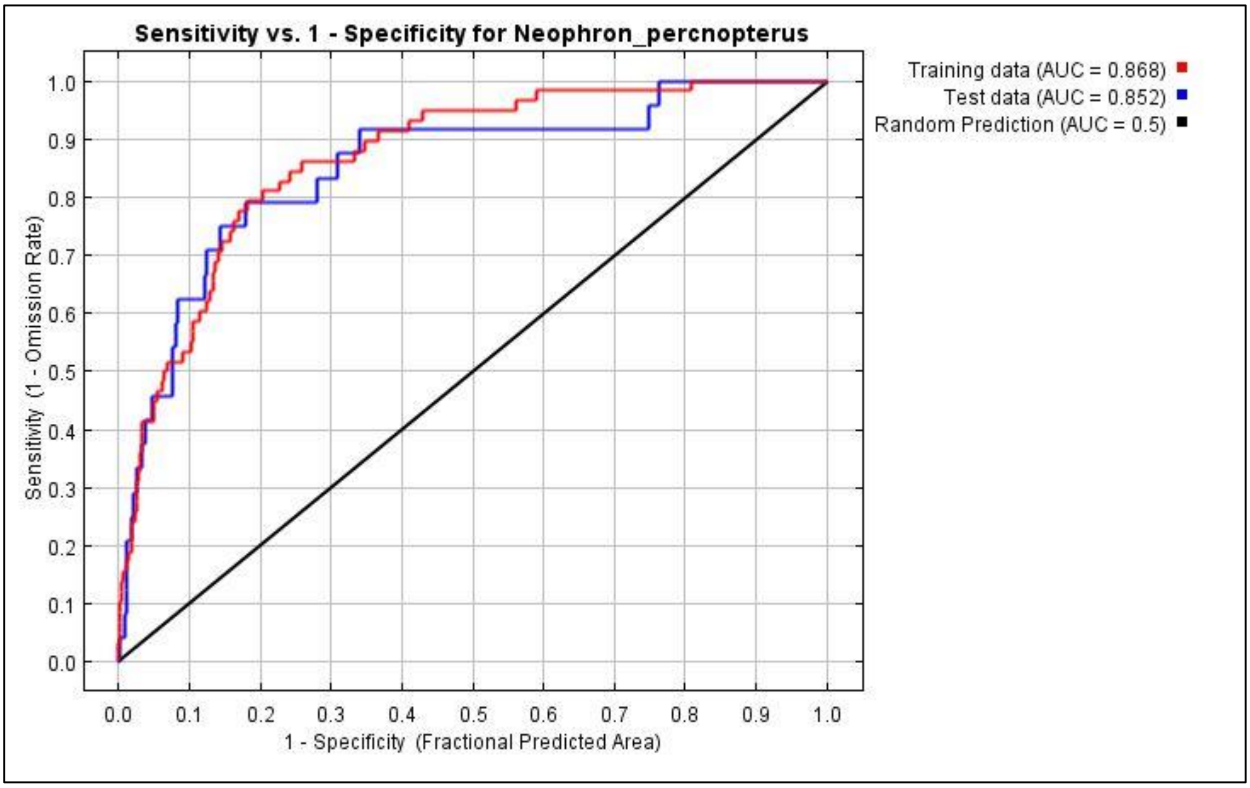

Figure 2 ROC curve of sensitivity versus specificity for *Neophron percnopterus.*

Prediction modeling

For the prediction modeling, 70% of selected data used for training and the rest 30% was used for testing. The Area under the Receiving Operator Curve (AUC) was used to evaluate model's goodness-of-fit and model with highest AUC value was considered as the best performer. The Jackknife procedure was used to assess the importance of the variables. The final potential species distribution map had a range of values from 0 to 1 which were regrouped in to five classes of potential habitats based on suitability viz., very high potential (> 0.8), 'High potential' (0.6 to .8), 'Good potential' (0.4–0.6), 'Moderate potential (0.2–0.4). Least potential (<0.2).

Table 1 Environmental variables used in the study and their percentage contribution.

Variable	Description	Percent Contribution
Bio1	Annual mean temperature	9.8
Bio2	Mean diurnal range	0.9
Bio3	Isothermality	0.7
Bio4	Temperature seasonality	2.8
Bio5	**Maximum temperature of warmest month**	**26.5**
Bio6	Minimum temperature of coldest month	1.9
Bio7	Temperature annual range	2.7
Bio8	Mean temperature of wettest quarter	2.7
Bio9	Mean temperature of driest quarter	2.3
Bio10	Mean temperature of warmest quarter	3.7
Bio11	Mean temperature of coldest quarter	0.5
Bio12	Annual precipitation	2.5
Bio13	Precipitation of wettest period	4.8
Bio14	Precipitation of driest period	2.8
Bio15	Precipitation seasonality	0.4
Bio16	Precipitation of wettest quarter	0
Bio17	Precipitation of driest quarter	0.5
Bio18	Precipitation of warmest quarter	0.7
Bio19	Precipitation of coldest quarter	8.7
LULC	**Land Use/Land Cover**	**11.1**
Altitude	**Elevation**	**14.3**

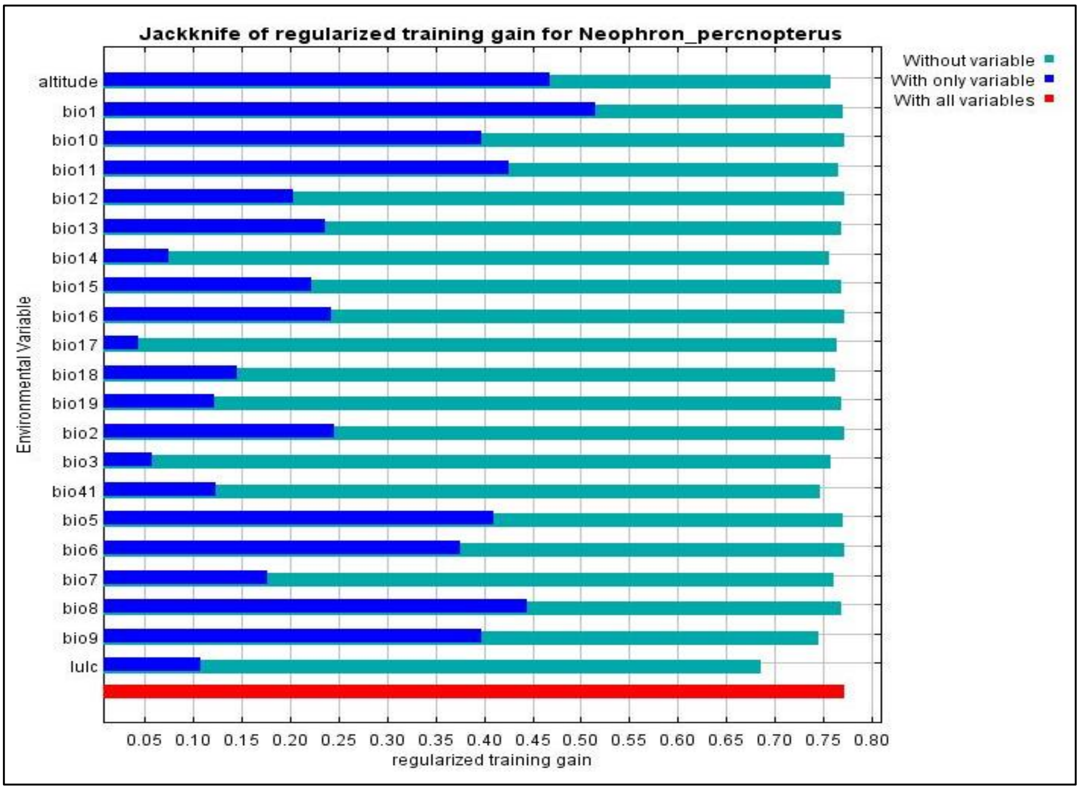

Figure 3 The Jackknife test for evaluating the relative importance of environmental variables for *Neophron percnopterus* in Uttarakhand.

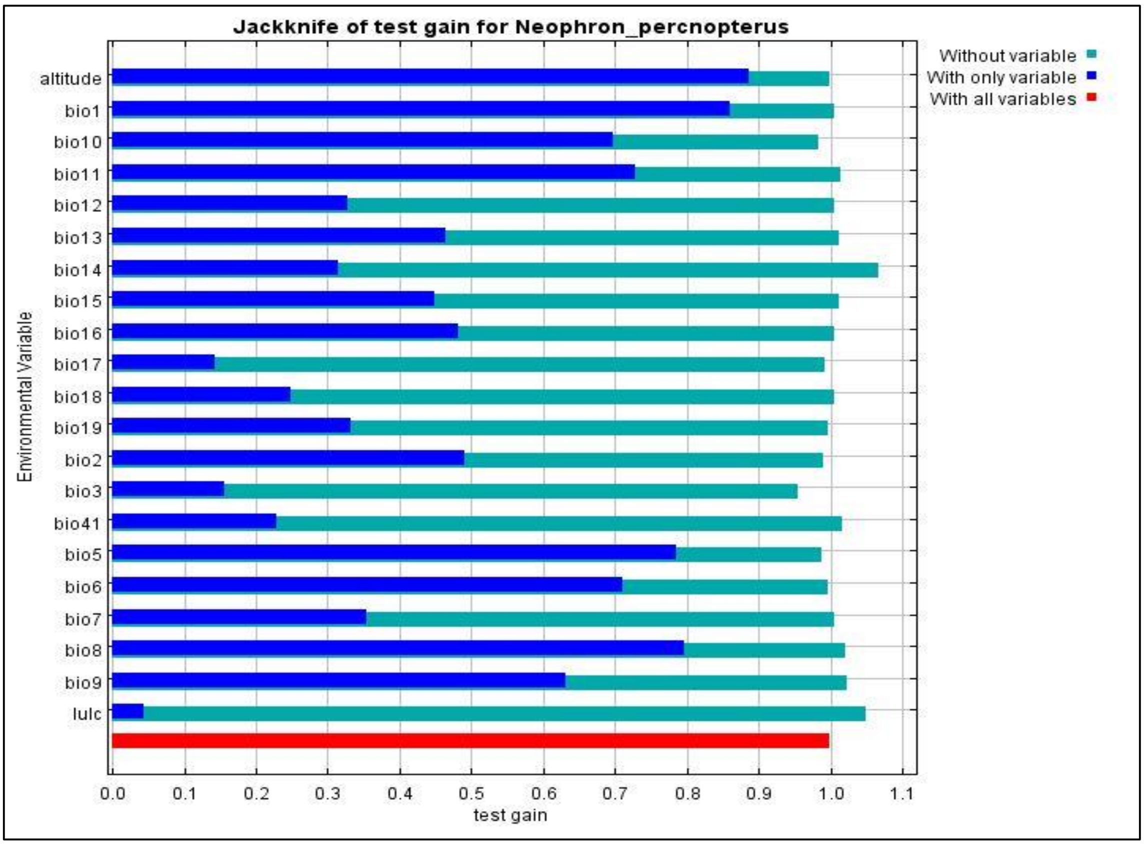

Figure 4 The Jackknife of test gain for *Neophron percnopterus* in Uttarakhand.

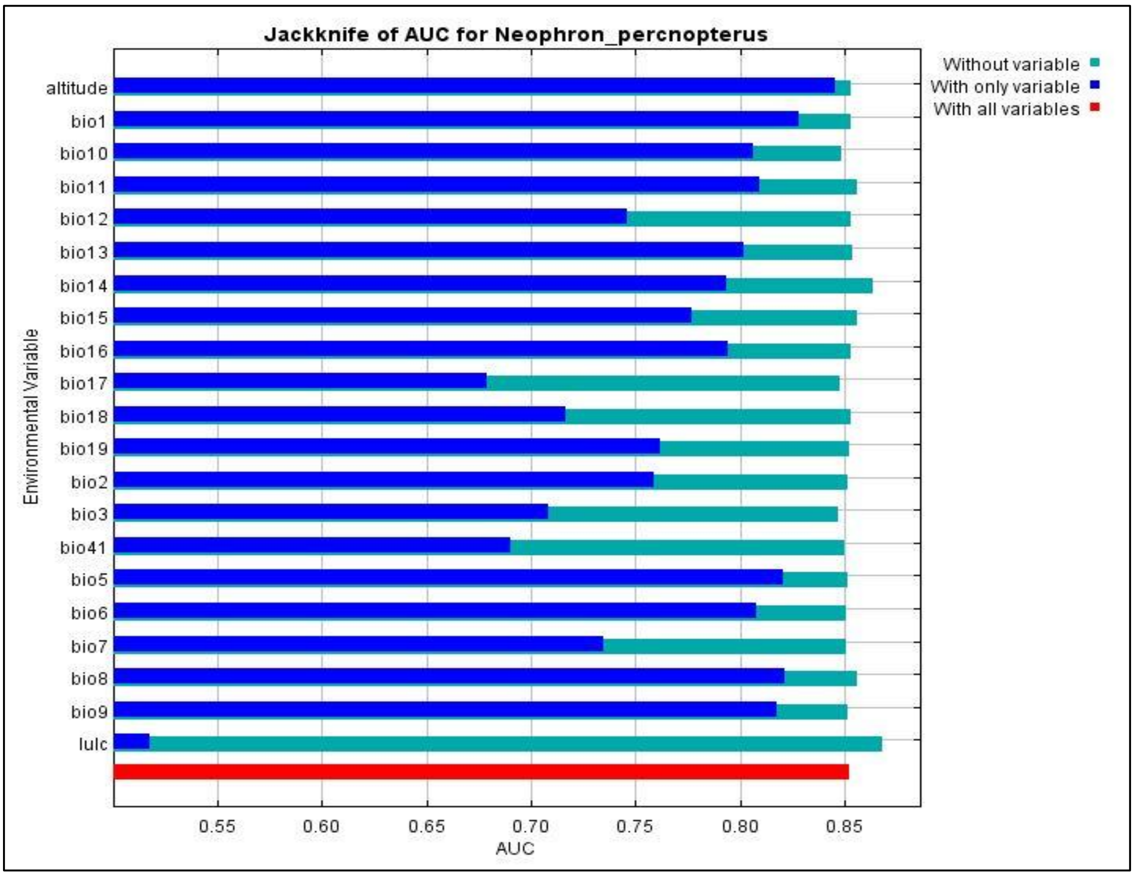

Figure 5 The Jackknife of AUC for *Neophron percnopterus* in Uttarakhand.

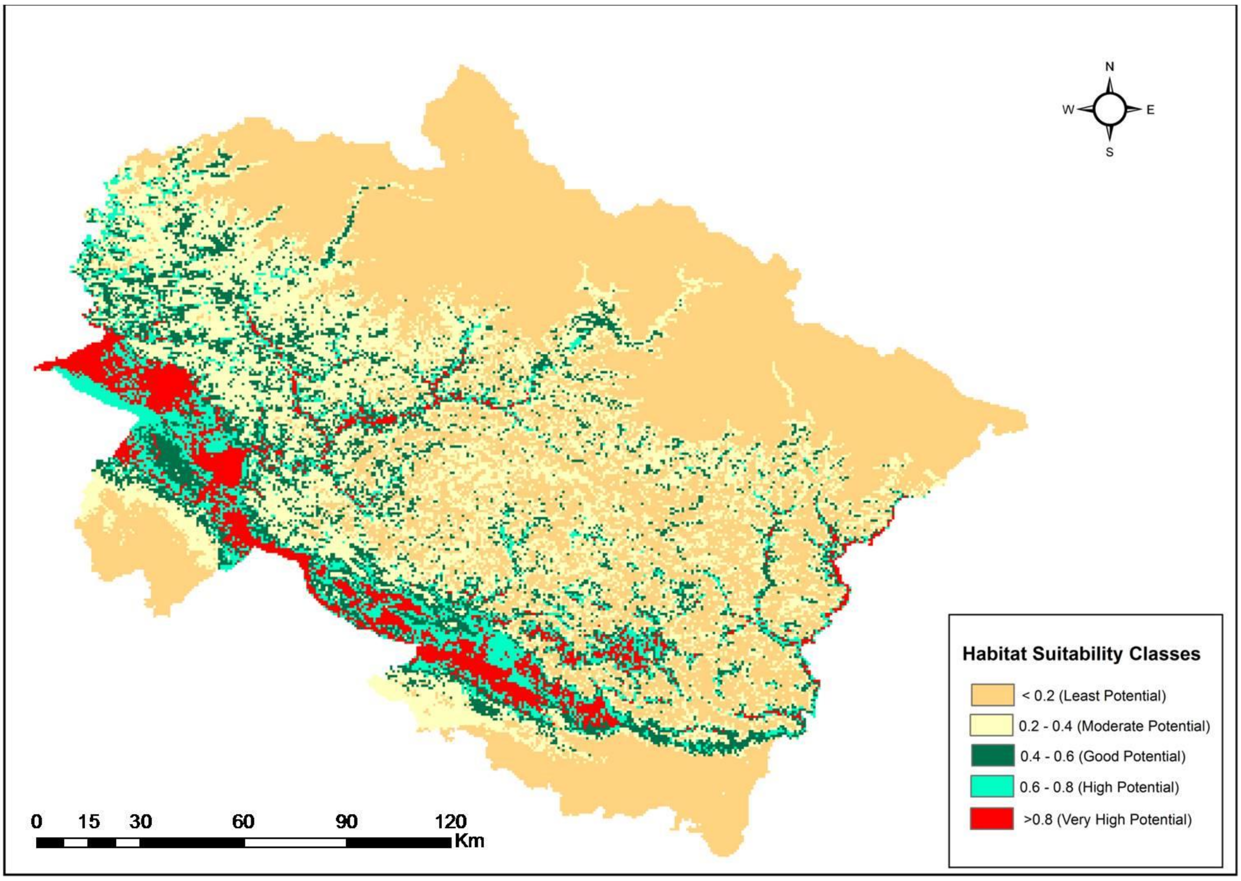

Figure 6 Predicted potential distribution of *Neophron percnopterus* in Uttarakhand

Results showed that Dehradun valley, Rajaji Tiger Reserve, Corbett National Park and Nainital district has got very high and high habitat suitability of the *Neophron percnopterus.* These areas have got ideal sites for Egyptian vulture habitat and are constantly surveyed by birdwatchers . Portions of Pauri Garhwal and Rajaji Tiger have got good to high potential. Some areas in hilly regions of Tehri, Rudraprayag and Chamoli districts are also suitable for *Neophron percnopterus* habitat.

CONCLUSION

The present study is an initial attempt to use the bird occurrence information collected by citizen scientists for species distribution modelling studies. This information can be critical in case of endangered species like Egyptian vulture which has got vast range but sparse in number. Concentration of the species habitat in protected areas as well as in non protected areas shows the adaptation of the species to different habitats.

ACKNOWLEDGEMENTS

Authors are highly grateful to ebird portal which made it possible to visualize the findings of the birds in user friendly manner. Sincere thanks to ebird community members (birdwatchers) which have recorded their findings in ebird portal.

REFERENCES

Action Plan for Vulture Conservation in India. New Delhi, 2006, published by Ministry of Environment and Forests, Government of India. Pp 26.

Avian Knowledge Network, 2008. Avian Knowledge Network: An Online Database of Bird Distribution and Abundance [web application]. Ithaca, New York.

Baldwin, R.A., 2009., Use of maximum entropy modeling in wildlife research. Entropy, 11, 854–866.

Berger, A.L., Della, Pietra., S.A., Della, Pietra., V.G., 1996. A maximum entropy approach to natural language processing. Computer Linguistics 22 (1), pp. 39–71.

Bhattacharjee, Y., 2005. Citizen scientists supplement work of Cornell researchers. Science 308, 1402–1403.

Bonney, R., 2007. Citizen science at the Cornell Lab of Ornithology. In: Yager, Robert E., Falk, John H. (Eds.), Exemplary Science in Informal Education Settings: Standards-Based Success Stories. NSTA Press. 278 pp (Chapter 16).

Ceballos, O. & J.A. Donazar.,1990. Roost tree characteristics, food habits and seasonal abundance of roosting Egyptian Vultures in northern Spain. Journal of Raptor Research 24, pp.19–25.

Chaudhary, A et al., 2012. Population trends of critically endangered Gyps vultures in the lowlands of Nepal. Bird Conservation International, 22, pp. 270-278.

Dobrev, V., Boev, Z., Arkumarev, V., Dobrev, D., Kret, E., Saravia, V., Bounas, A., Vavylis, D., Nikolov, S.C., Oppel, S., 2016. Diet is not related to productivity but to territory occupancy in a declining population of Egyptian Vultures *Neophron percnopterus*. Bird Conservation International, 26, pp. 273-285.

Elorriaga, J., Zuberogoitia, I., Castillo, I., Azkona, A., Hidalgo, S., Astorkia, L., Ruiz-Moneo, F. &Iraeta, A., 2009 First documented case of long-distance dispersal in the Egyptian Vulture (*Neophron percnopterus*). Journal of Raptor Research 43, pp. 142–145.

Faridani, S., Lee, B., Glasscock, S., Rappole, J., Song, D., Goldberg, K., editors. A networked telerobotic observatory for collaborative remote observation of avian activity and range change. Proceedings of the 2009 IFAC Workshop on Networked Robotics (Moore KL, Ed) International Federation of Automatic Control Elsevier, Oxford, United Kingdom.

Fielding, A.H. & Bell, J.F., 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environment Conservation, 24, 38-49.

Gangoso, L & Palacios, C.J., 2005. Ground nesting by Egyptian vultures *Neophron percnopterus* in the Canary Islands. Journal of Raptor Research 39, pp.186–189.

Garcı´a-Ripolle´s, C., Lopez-L opez, P., Urios, V., 2010. First description of migration and wintering of adult Egyptian vultures *Neophron percnopterus* tracked by GPS satellite telemetry. Bird Study 57, pp.261–265.

GBIF Data Portal. Global Biodiversity Information Facility. A Online Database for free and open access to biodiversity data. Copenhagen, Denmark.

Gill, F & Donske, D. (Eds). (2014). IOC World Bird List (v 4.1).

Green paper on Citizen Science for Europe: Towards a society of empowered citizens and enhanced research, 2013, published by European Commission. Pp 48.

Hanley J.A. & McNeil, B.J., 1982. The meaning and use of the area under a receiver operating characteristic (ROC) curve. Radiology, 143, pp.29-38.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., Jarvis, A., 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology, 25, pp.1965– 1978.

Howard, E., Aschen, H., Davis, A.K.,2010. Citizen science observations of monarch butterfly overwintering in the southern United States. Psyche: A Journal of Entomology, 2010, pp.1-6.

Irwin, A., Georg, S., Vergragt, P., 1994. The social management of Environmental Change. Futures, 26(3), pp.323–34.

IUCN Red List. An online portal for International Union for Conservation of Nature List of Threatened Species.

Kelling, S., 2008. Significance of organism observations: Data discovery and access in biodiversity research. Report Presented to the Global Biodiversity Information Facility, Copenhagen.

López-lópez, P., Gil, J. A. & Alcántara, M., 2014. Post-fledging dependence period and onset of natal dispersal in Bearded Vultures (Gypaetus barbatus): new insights from GPS satellite telemetry. Journal of Raptor Research, 48, pp. 173-181.

Margalida, A., Carrete, M., Sánchez-Zapata, J.A., Donázar, J.A., 2012. Good news for European vultures. Science 335, pp.284.

Ogada, D.L., Keesing, F., Virani, M.Z., 2012. Dropping dead: causes and consequences of vulture population declines worldwide. Ann N Y Acad Sci 1249, pp.57-71.

Oppel, S., Dobrev, V., Arkumarev, V., Saravia, V., Bounas, A., Kret, E., Velevski, M., Stoychev, S. &Nikolov, S.C., 2015. High juvenile mortality during migration in a declining population of a long-distance migratory raptor. Ibis, 157(3), pp. 545-557.

Phillips, S., Anderson, R., Schapire, R., 2006. Maximum entropy modelling of species geographic distributions. Ecological Modelling, 190 pp. 231–259.

Phillips, S., Dudík, M., Schapire, R., 2004. A Maximum Entropy Approach to Species Distribution Modeling. Proceedings of the 21th International Conference on Machine Learning. Banff, Canada.

Rahmani, A.R., Islam, M.Z. & Kasambe, R.M., 2016. Important Bird and Biodiversity Areas in India: Priority sites for conservation (Revised and Updated). Bombay Natural History Society, Indian Bird Conservation Network, Royal Society for the protection of Birds and BirdLife International (U.K.). pp1992.

Sara, M & Di Vittorio, M,. 2003. Factors influencing the distribution, abundance and nest-site selection of an endangered Egyptian vulture (*Neophron percnopterus*) population in Sicily. Animal Conservation, 6, pp. 317–328.

Sullivan,B.L., Wood, C.L., Iliff, M.J., Bonney, R.E., Fink, D. & Kelling, S., 2009. ebird: a citizen based bird observation network in the biological sciences. Biological Conservation, 142, pp.2282-2292.

Thiollay, J.M., 2006. The decline of raptors in West Africa: long-term assessment and the role of protected areas. Ibis 148, pp.240-254.

Tian H.D., Stige, L.C., Cazelles, B., Kausrud, K.L., Svarverud, R., Stenseth, N.C., et al., 2011. Reconstruction of a 1,910-y-long locust series reveals consistent associations with climate fluctuations in China. Proceedings of the National Academy of Sciences of the United States of America, 108(35), pp.14521–26.

Virani, M.Z., Kendall, C., Njoroge, P., Thomsett, S. 2011. Major declines in the abundance of vultures and other scavenging raptors in and around the Masai Mara ecosystem, Kenya. Biological Conservation, 144, pp.746-752.

Wiersma, Y.F., 2010. Birding 2.0: Citizen Science and Effective Monitoring in the Web 2.0 World. Avian Conservation and Ecology, 5(2),13.

Willett, K.W., Lintott, C.J., Bamford, S.P., Masters, K.L., Simmons, B.D., Casteels, K.R.V., et al., 2013. Galaxy Zoo 2: detailed morphological classifications for 304122 galaxies from the Sloan Digital Sky Survey. Monthly Notices of the Royal Astronomical Society, 435(4), pp. 2835–60.

Williams, A.C., Wallin, J.F., Haoyu, Y., Perale, M., Carroll, H.D., Lamblin, A.F., et al., 2014. A computational pipeline for crowdsourced transcriptions of Ancient Greek papyrus fragments. IEEE International Conference on Big Data (Big Data), pp.100–105.