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Distribution of Swamp Francolin *Francolinus gularis* in Assam: influence of abiotic and land cover parameters

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ABSTRACT

Francolinus gularis is a territorial bird resident of tall swampy grassland endemic to the Ganga and Brahmaputra River basins in India and Nepal. Due to its declining population IUCN has declared this species as vulnerable to extinction. Due to changes in the global climate the loss of biodiversity and changes in species composition are at its peak. In this study we tried to understand the influence of environmental variables on the occurrence probability of *F.gularis* in Assam, India through MaxEnt ecological niche modelling program. The results of the model were satisfactory with high AUC value. It showed that Assam has around 634 sq. km (0.80%) of area with high probabilities of finding the species. It was also found that land use land cover (LULC) and precipitation of driest month are the highest contributing factor for the distribution of *F.gularis.* The occurrence probabilities are higher in the LULC classes- Grassland, Deciduous Forest, wetland and Shrub land. The annual precipitation within the range of 2000-3000 millimetres and annual mean temperature of 24 ºC are found to be optimum for higher occurrence probability of the species in the study area. Increasing human population, changing climate and global warming seems to possess great threats to the survival of the species, especially in the habitats outside protected areas.

Key words : *Protected area, Gallifom, Grassland, MaxEnt, Niche, SDM*

Introduction

The moist and tall grasslands of Assam are under tremendous anthropogenic pressure (Rahmani and Choudhury, 2012). Along with agricultural conversions, overgrazing and cutting of grass are some serious threats facing by the grasslands and its native wildlife fauna (Rahmani and Choudhury, 2012). *Francolinus gularis*, swamp francolin, endemic to the Ganga and Brahmaputra River basins is a territorial bird, resident of such grasslands (Dahal *et al.*, 2009). Its specialised habitat, the tall swampy grasslands has almost vanished except in some protected areas and IBAs (Rahmani and Choudhury, 2012). In north-eastern India, the past historical range of this species extended throughout the Brahmaputra and Barak valley but according to recent records, this species is considered to be extinct in the Barak Valley (IUCN version 3.1) and has a patchy distribution throughout Brahmaputra valley (Islam and Rahmani, 2004). As per IUCN this species has a declining population trend and has been categorised as vulnerable to extinction.

Abbreviations: IUCN-International Union for Conservation of Nature, IBA-Important Bird and Biodiversity Area, SDM- Species distribution models, LULC-Land Use Land Cover, ENM-Ecological Niche Models, AUC-Area Under Curve, OP-Occurrence Probability,

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Apart from above mentioned threats, climatic change can impose physiological constraints on species and therefore can affect species distributions to varying degrees (O'Donnell and Ignizio, 2012). The recent surges in the extent of global climate changes are changing ecosystem functioning, causing loss of biodiversity and changes in species composition (Zhang *et al*., 2018). Species distribution models (SDMs) estimate the relationship between species records at sites and the environmental and spatial characteristics of those sites (Elith *et al.,* 2011). Models predicting the potential geographic distribution of species are important for a variety of applications in conservation biology (Yang *et al*., 2013). The present study is a MaxEnt based ecological niche model for the distribution of *Francolinus gularis*, here we tried to understand how different environmental variables impact the occurrence probabilities of *F.gularis* in Assam, India.

Materials and Methods

The study area, Assam state is located in the North-Eastern part of India within the geo-coordinates, 89°40′56.36"E 26° 9′49.57"N on west, 95°59′31.88"E 27°57′33.83"N on east , 94°14′23.91"E 27°38′25.50"N on north, and 92°28′11.99"E 24° 8′30.34"N on south. It covers an approximate area of 78,438 sq.km. The study area has two major river valleys, the Brahmaputra river valley and the Barak river valley. There are around 23 protected areas, out of which 5 are National parks and 18 are wildlife sanctuaries. Majority of the protected areas in the floodplains of Brahmaputra are constituted by a notable amount of grasslands. The habitat of *F. gularis* consists of grassland patches inside and outside protected area.

The climate of the Assam is sub-tropical with hot humid summer and cool dry winter. The region has four climatic seasons namely, pre-monsoon (March to May), monsoon (June to September), post-monsoon (October to November) and winter(December to February) (Saikia and Saikia, 2012). The average annual rainfall of Assam is 1807.01mm (Yadav *et al*., 2018). As per government of India census 2011, Assam has a population density of 397 people per square kilometres (Govt. of India, 2011).

Methodology

Species occurrence data

Primarily we compiled the data on species occurrences from field surveys, published literature and personal communication with researchers working different localities of Indian subcontinent. Field surveys were conducted in the areas with potential *F. gularis* habitat. Opportunistic surveys were also considered to take all presence data into account. We binned the presence localities of the species into 1-km^2 grid cell by removing multiple presence points retaining only one presence point per grid cell. A total of 96 localities were used for modelling (Figure1).

Environmental variables

We used 19 bioclimatic variables obtained from World Clim (Hijmans *et al*. 2005, land use land cover data were acquired from https://daac.ornl.gov/ (Roy *et al.,* 2016), and human population density data from World Pop (www.worldpop.org). We resampled all raster layers to 30 arc-sec (~1 km) resolution to correspond to the original resolution of the WorldClim data. Initially to avoid multi-collinearity among the bioclimatic variables, Human population density and land use land cover (LULC), we performed correlation test and discarded variables with VIF >3 (Variation Inflation Factor) (Zuur *et al.,* 2010). The variables that we included in the niche models are: BIO1 = Annual Mean Temperature, BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp), BIO4 = Temperature Seasonality (standard deviation ×100), BIO12 = Annual Precipitation, BIO14 = Precipitation of Driest Month, BIO15 = Precipitation Seasonality, BIO17 = Precipitation of Driest Quarter,Human Population Density (Hmn_pop_density) and Land use land cover (LULC).

Niche modelling

To analyse the spatial distribution of *F.gularis* and identify key environmental variables that constrain the species distributions, we used ecological niche models (ENMs). To model potential distribution of the species, we used Maximum entropy (MaxEnt *v 3.3*) species distribution algorithm (Phillips *et al*. 2006). MaxEnt is a machine learning program that estimates the probability of distribution for a species occurrence based on environmental constraints. Studies indicated that MaxEnt performs well when compared with other ENM methods (Chetan *et al*., 2014). MaxEnt is intended to make predictions from presence-only data using background environment of the study area (Phillips *et al*. 2006). We used the

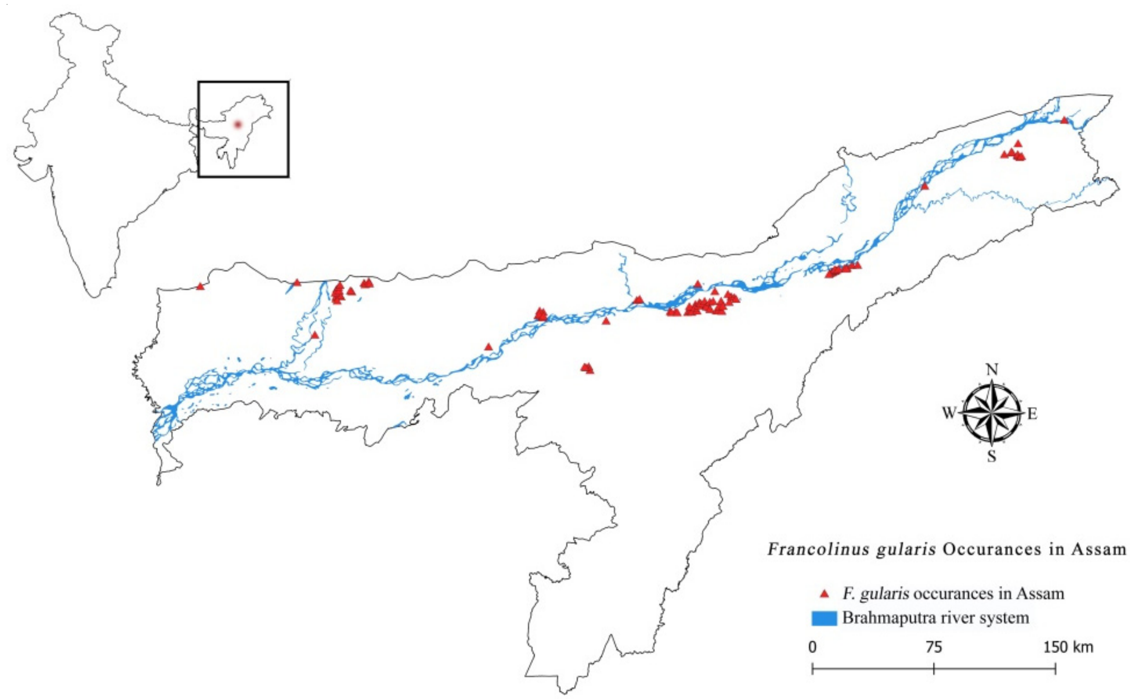

Fig. 1. Map of the study area (Assam) along with occurrences of *F.gularis*

default settings for parameters such as regularization multiplier, prevalence (Phillips and Dudík, 2008; Elith *et al.,* 2011), and density of background sampling (10000 points). We ran models with 10 bootstrap replicates, The significance of each environmental variable in explaining the distribution of *F.gularis* was calculated by the percent contribution and permutation importance as assessed by MaxEnt model.

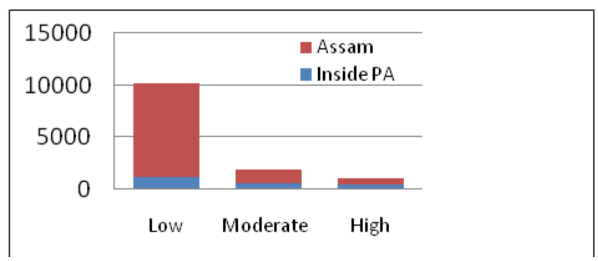

Fig. 2. Bar diagram showing areas of occurrence probabilities in Assam and within protected

Results

The ecological niche model on the distribution of *Francolinus gularis* predicts that the study area has around 10916 sq.km of suitable habitat for *F.gularis*. Of which 634 sq.km has high probabilities of finding the species, 1300 sq.km has moderate probability and 8982 sq.km has low probability. 2248 sq.km of the occurrence probable areas are within the boundaries of protected areas (National parks or wildlife sanctuary), of this 447 sq.km has high occurrence probability, 637 sq.km has moderate probability and 1164 sq.km has low probability (Figure 2 and 3).

The ENM is satisfactory with AUC value 0.956 ± .006. The Jacknife evaluation shows that LULC and Precipitation of Driest Month (BIO14) are the highest contributing factor for the distribution of *F.gularis* (Figure 4 and Table 1).

As per the response curves obtained for different environmental variables (Figure 5), the LULC class grasslands, deciduous broadleaf forest impacts strongly and wetland, shrub-land impacts moderately for the occurrence probability (OP) of *F.gularis* in Assam. The OP is directly proportional with precipitation of the driest month (BIO 14), higher the precipitation high is the OP. The probability of presence is high when the annual mean temperature (BIO 01) is 24 ºC; variations in this variable can reduce the possibilities of *F.gularis* presence in the study area. Human population density also plays an important role towards the presence of the species, as with increase in human population reduces the chances of occurrence. Meandiurnal range (BIO 02)

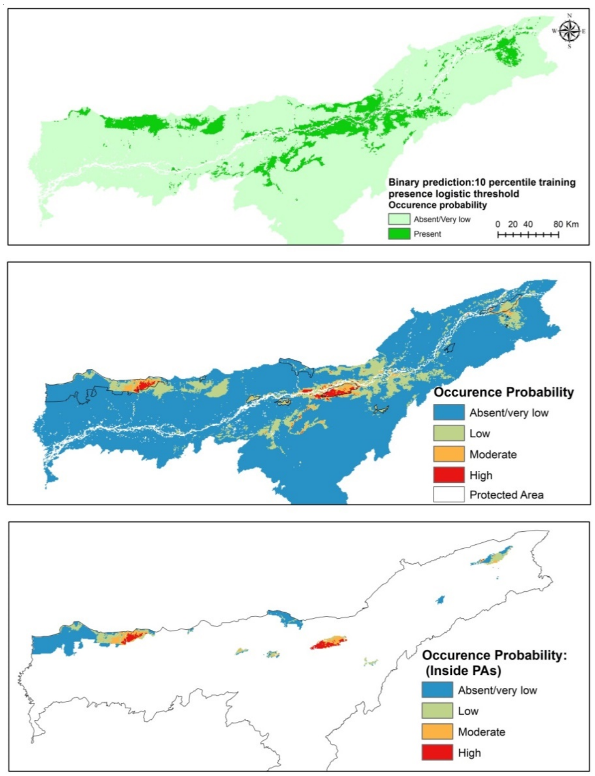

Fig. 3. Map showing occurrence probable areas in Assam and within protected areas

values beyond 10ºC and precipitation of driest quarter (BIO 17) beyond 30 millimetres reduces the OP of the species in the study area. OP of the species in the study area reduces with increase in precipitation seasonality beyond than 100%. (BIO15). Increase in the temperature seasonality (BIO 4) increases the probability of presence of *F.gularis* in the study area. Annual Precipitation (BIO 12) within the range of 2000-3000 millimetres is optimum for higher probability of occurrence of *F.gularis* in the study area.

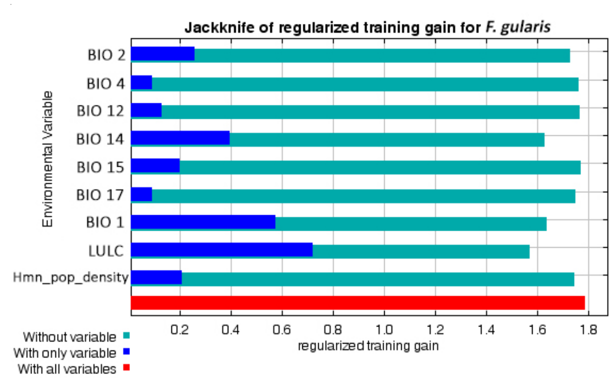

Fig. 4. Jackknife test of variable importance.

Discussion

The analysis of response curves unfolds several interesting findings on the occurrence probability (OP) of *Francolinus gularis*. It was evident from the response curves that along with grasslands, deciduous broadleaf forest, shrub-lands, and wetlands are also crucial for high OP for the species in the study area. This supports the findings of Dahal *et al.*, 2009, where they have mentioned that woodland-grassland mixed habitat is very important for the survival of *F.gularis* in Koshi Tappu wildlife reserve, Nepal. OP of *F.gularis* increases with the increase in precipitation during the driest month (BIO14) whereas, if the precipitation of the driest quarter (BIO17) of the year is more than 30 millimetres it can reduce the probability of presence. This suggests that rainfall to an extent is essential to maintain swampy grassland habitat during the driest month of the year and as *F.gularis* is a ground-nesting bird, which breeds during February to May (Ali and Ripley, 1980). Too much of rain before the breeding season may result in the flooding of nesting grounds, which will even-

Table 1. Percentage contribution of all the variables used for the Ecological Niche Model.

Variable	Contribution (%)	Permutation importance
LULC- Land Use Land Cover	40.6	7.2
BIO 14- Precipitation of Driest Month	20.7	37.6
BIO 01- Annual Mean Temperature	11.8	20.3
Human Population Density- Number of human individuals per sq.km	8.4	3.6
BIO 02- Mean Diurnal Range (Mean of monthly (max temp - min temp)	7.2	5.5
BIO 17- Precipitation of Driest Quarter	5.5	18.7
BIO 15- Precipitation Seasonality	2.4	2.4
BIO 04- Temperature Seasonality	2.3	2.1
BIO 12- Annual Precipitation	1.1	2.6

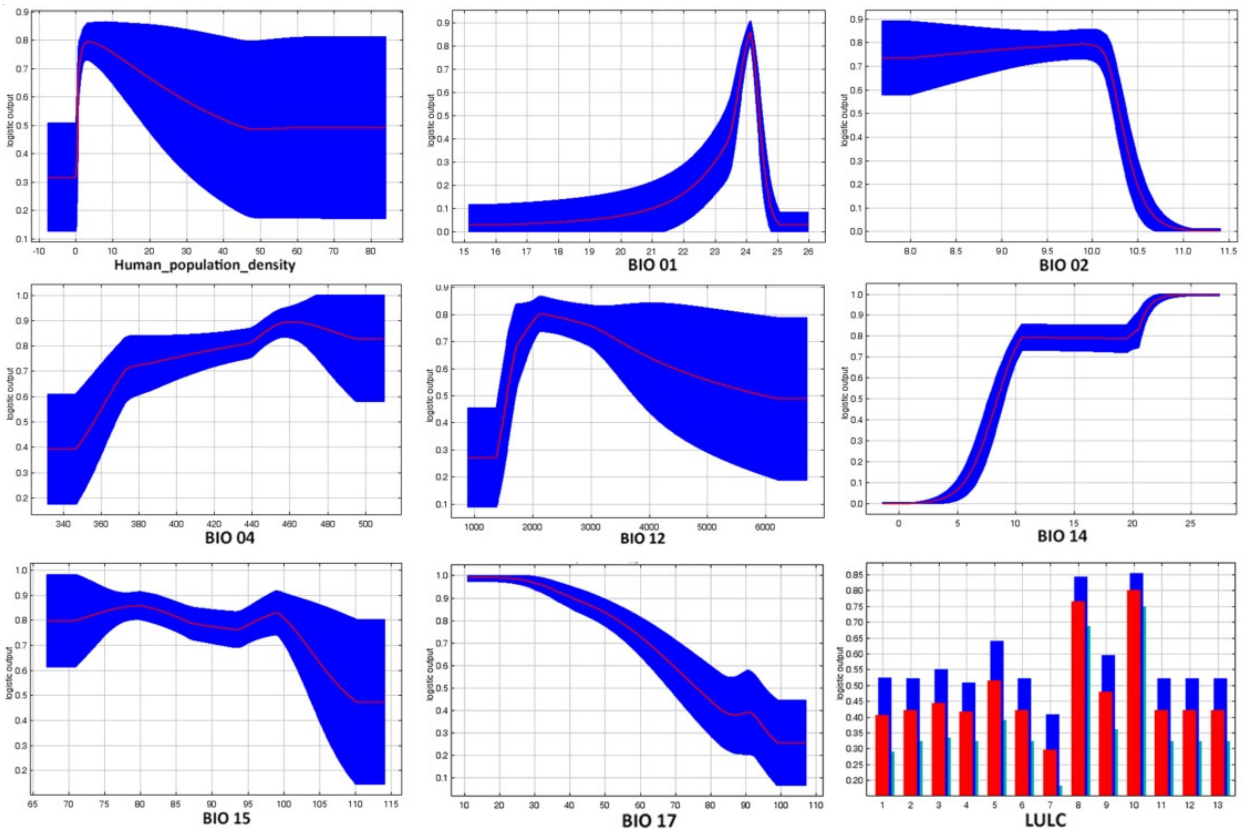

Fig. 5. Response curves of prediction probability of presence against each environmental variable. LULC code with the high occurrence probability LULC10: Grassland, LULC 9: Water body & marshes; LULC 8: Deciduous broadleaf forest; LULC 5: Shrub

tually reduce the OP of the species in the study area. It was also observed that the OP of *F.gularis* is high when the annual rainfall is within the range of 2000-3000 millimetres. OP of the species in the study area reduces with increase in precipitation seasonality (BIO15) beyond 100%. 24 ºC seems to be the optimum annual mean temperature (BIO01) for high OP of the species in the study area. Fluctuation in the mean diurnal range (BIO 2) beyond 10ºC also reduces its probability of presencein the study area. The OP of the species increases in the study area with the increase in temperature seasonality (BIO04). The greater value of temperature seasonality is an indicator of seasonal climatic variation. As *F.gularis* is a specialist species of the tall swampy and moist grasslands, which breeds during the premonsoon, seasonal climatic variations are essential for their survival. Climate change and increasing global temperatures would have an adverse effect on the distribution of the species in the near future. As per Dahal *et al.,* (2009) presence of people have negative impact on the bird as *F.gularis* abundance was lowest where people were highest. This finding of Dahal *et al*., (2009) has been strengthen by the findings of our study as from the response curves it is well evident that increase in human population density in the study area reduces the possibility of finding *F.gularis* in it. Disturbance and habitat alteration through agriculture, fishery, human settlements, collection of grasses for housing material and other economic usage etc. are possible explanations for this.

The ENM predicts that the 14% (10916 sq.km) of the study area has suitable habitat for *Francolinus gularis*. Out of this only 5.8% area has high probabilities of finding the species, 12% area has moderate probability and 82% area has low probability. 70% of the highly probable areas, 49% of moderately probable areas, and 12% of low probable areas are within the boundaries of protected areas. It is important to note that out of its landmass only 0.80% area of the Assam has high occurrence probability of *F.gularis*, which seems to reduce further with the increasing human population, changing climate, and global warming. Though there are several conservation initiatives has been taken to conserve several grassland species like *Rhinoceros unicornis, Houbaropsis bengalensis* etc. but no species specific conservation measures yet taken for the *F.gularis* in India. Conservation of *F.gularis* will eventually conserve the habitat of other threatened endemic grassland birds of Assam such as Black-breasted parrotbill (*Paradoxornis flavirostris*), Marsh babbler (*Pellorneum palustre*), and Slender-billed Babbler (*Chatarrhaea longirostris*) which shares the similar habitat types.

Conclusion

Francolinus gularis is a specialist species which need certain optimum environmental condition for its survival. It is important to note that out of its landmass only 0.80% area of the Assam has high occurrence probability of *F.gularis*. Increasing human population, changing climate and global warming seems to possess great threats to the survival of the species, especially in the habitats outside protected areas. It is a high time to take measures and actions for long term monitoring and conservation of the species in the floodplains of Assam.

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