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From human settlement region to bird dominated grassland: Avian diversity in the Padampur grassland of Chitwan National Park, Nepal

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Abstract: Mosaics provide productive ecosystems that include foraging opportunities, breeding grounds and protection for birds, particularly within mosaics of grassland, wetland and savanna habitats. This study explored the status of species diversity, richness and seasonal population rate of avian species within the mosaics of the Padampur grassland of Chitwan National Park (CNP), Nepal. Point count surveys were performed in 10 randomly selected plots by walking transects or riding on elephant back during the rainy season. A total of 118 bird species and 4905 individual birds belonging to 43 families was recorded. Surveys and regression analysis revealed species preferred diverse ecotone habitats interspersed with mosaics of tallgrass prairie, shrubby grassland, savanna and marshy grassland. Regression models also revealed occupancy rates were relatively consistent across seasons, however, months within the rainy and the summer season were lower than autumn and winter. Rarefaction curves showed sampling efforts of approximately 10 months to produce accurate estimates of species richness. Although the diversity indices resulted in insignificant differences between the plots, the CNP appears to provide preferred grassland habitat to bird species all-year round. This study suggests conservation efforts to consider these survey methods and estimates when implementing initiatives. This paper recommends concerned authorities to prioritize and give continuity to bird conservation, including grassland management alongside the wetlands within the CNP.

Keywords: Mosaics; Grassland; Species diversity; Occupancy rate; Species richness; Rarefaction.

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1 Introduction

Nepal contains high avian richness with a total of 887 bird species documented; these bird species constitute almost 8% of all bird species found throughout the world (Grimmett et al., 2016, Inskipp et al., 2016). Within Nepal there are 454 forest bird species, which account for 51% of the total bird species (Inskipp and Baral, 2019); 200 wetland bird species (Baral, 2009) (23%) and 186 grassland bird species recorded (Baral, 2001) (21%). Avian species are distributed throughout distinct ecological regions of the country; populations of these species vary with habitat classification, altitudinal gradients and seasonal variation (Katuwal et al., 2016). Broadleaf forests, wetlands and grasslands are the prominent habitats of bird species in Nepal (BCN and DNPWC, 2011). Furthermore, thirty-seven Important Bird and Biodiversity Areas (IBAs) have been identified which includes forests, grasslands and freshwater ecosystems (MoFE, 2018). Most of Nepal's IBAs lie at relatively low altitudes (78–1000 m), including three of the most important protected areas including Chitwan, Koshi and Shuklaphanta National Park (BCN, 2020). These protected areas in Nepal are playing a crucial role in the conservation and promotion of the IBAs (Inskipp et al., 2013). Avian species provide key ecological benefits such as pollination and insect control (DNPWC, 2011); these species also represent moral, religious, social and cultural significance to the country's citizens (BCN and DNPWC, 2011). Despite having notable value, many bird species face population declines attributed to causes such as habitat degradation, inappropriate agricultural practices, pollution, loss of habitat linkages, hunting, trapping, and invasive species (Inskipp et al., 2016). Previous records have shown 168 species are nationally threatened, of which 68 are critically endangered species, 38 endangered species, 62 vulnerable species, 62 near threatened and 22 species are data deficient. Of all nationally threatened species, 55% of them are lowland grassland specialists, 25% are wetland birds and 24% are tropical or subtropical broadleaved forest birds (Inskipp et al., 2017). Currently the main conservation efforts made by the government are legislative. For example, the National Parks and Wildlife Conservation Act, 2029 (1973) or NPWC has enlisted 9 species as protected bird species in Nepal as well as establishing several protected areas ranging from lowland to high mountains (DNPWC, 2019). Multi-stakeholder agencies including government departments, I/NGOs, community-based organizations and local citizens are engaging in conservation efforts (Acharya, 2016).

Chitwan National Park (CNP) has been found to contain essential habitat for migratory bird species; most of these species winter throughout the park predominantly within the wetlands (BES, 2018). In contrast, the majority of summer visitors are forest and grassland birds (Inskipp et al., 2016). During the rainy and winter seasons, several partial migratory bird species migrate from the hilly region to lowlands (Ali and Ripley 1987). Additionally, the river system plays an important role in forging habitats which harbors unique flora and fauna that vary from adjacent habitats (Remsen and Parker, 2004). The Padampur grassland area in CNP has been rapidly converted into mixed broadleaved forests. Before 1975, grassland areas covered approximately 23% of CNP (Bolton, 1975) but have recently been reduced to 9.6% (CNP, 2016). A paucity of research has been conducted on grassland birds specifically species that inhabit the Indo-Gangetic plains in northern India and southern Nepal (Baral, 2001). In this paper, we explored the avian bird species richness, abundance and diversity in Padampur grassland, one of the major mosaic grassland habitats inside CNP. The seasonal occupancy for all plots was investigated as well as detection of birds in particular habitats. This study was conducted over the course of a year from December 2014 until November of 2015.

2 Materials and Methods

2.1. Study Area:

CNP possesses above 70% area of Shorea robusta forest and the remaining area comprises grasslands, open wooded forest, riverine forest, floodplains, and wetlands (CNP 2018). The surveys for this study were conducted in the Padampur grassland lying within the southern part of CNP's Sauraha (Fig. 1). The Padampur grassland (Latitude 27.54876, Longitude 84.49896) was formed after the relocation of the village of Padampur. Previously a renowned village, it is now recognized as a grassland due to conservation measures carried out by the park. Currently this region is considered the largest grassland of CNP with an area of 1579.88 hectares (CNP, 2016). The Padampur grassland encompasses a diverse assemblage of habitats including tallgrass prairies, savanna grassland, shrubby grassland and marshy grassland (CNP, 2016). Due to the previous settlement of the village, Padampur also possesses fruit trees which are scheduled to be gradually replaced by dense woody vegetation (CNP, 2019).

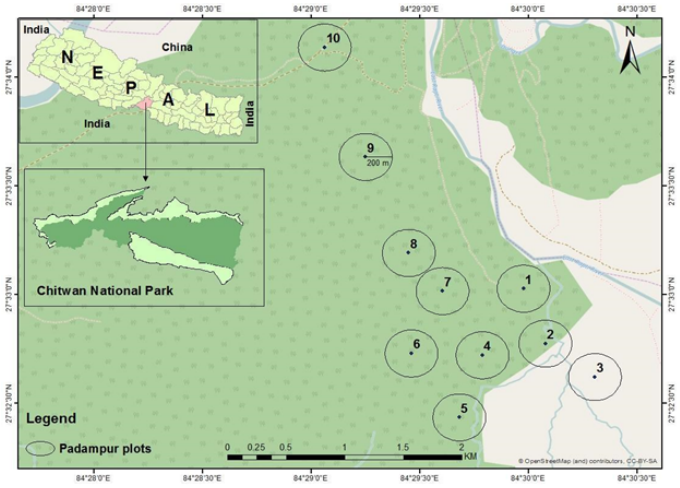

Figure 1: Location of sample plots in Padampur grassland, Chitwan National Park.

2.2. Method:

During a preliminary survey, study plots were determined and recorded by GPS. Ten plots were fixed randomly in Padampur grassland from the southern part of Sauraha in Chitwan National Park. These plots were selected due to previous sightings of bird species by park officials and guides as well as the variability of habitat across plots. Additionally, in this region, Adhikari et al. (2019) studied the factors affecting diversity and distribution of threatened birds in Chitwan National Park. They found considerable variation in avian species diversity, particularly of threatened species, sighted within the plots where this study was conducted.

All selected plots were heterogeneous including mosaics of tallgrass prairie, shrubby grassland, savanna and marshy grassland. All plots were accessed on foot during the dry months, while trained domesticated elephants were used to survey the flooded plots during the rainy and autumn seasons. Birds were surveyed using the point count method (Ralph, Sauer and Droege, 1995). Surveys were carried out within the first four hours of the local sunrise (6:00 AM) and all species heard or seen were recorded as present. The bird count data was recorded within a 200-meter radius of circular plot (Fig. 1) and the average time spent in each plot was 20 minutes. To verify

identification of species, field recordings were cross referenced with manuals (Birds of Nepal, 2003). Data regarding the habitat characteristics within the plots were also noted simultaneously during the surveys (Table 1). The field surveys began in December 2014 and ended in November 2015 generating 12 months of data. The months were categorized by four seasons: summer (March-May), winter (December-February), rainy or monsoon (June-August) and autumn (September-November)(MoFA, 2021).

2.2.1. Species Richness and Abundance:

2.2.1.1. Fisher and Preston for Abundance:

The survey data was recorded and standardized with the program R version 5.3.2 (R core Team, 2018). The R package "vegan" was used to run Fisher's log-series model with the calculation of $f_n = (\alpha x^n/n)$ the expected number of species as f with n counts, α as the diversity parameter, and x as a nuisance parameter defined by α and total number of individuals N in the plot x = $\frac{N}{(N-\alpha)}$. Preston's log normal model was also run by binning species into frequency classes of increasing size.

2.2.1.2. Species Richness Rarefaction:

The cumulative and average species richness across all plots were calculated using the R package "rich", including bootstrap statistics. A rarefaction curve was also performed for each survey plot in order to compare species richness across plots while including variation between sample sizes (Hurlbert, 1971). The expected number of species in CNP were rarefied from N to n individuals with the calculation of $S_n = \sum_{i=1}^{\S}(1 - q_i)$ where qi gives the probabilities that species i does not occur in a sample of size n.

2.2.2. Species Diversity Indexes:

The species diversity was investigated within all survey plots as well as total counts within those plots. Subsequently, the various indices of species diversity such as Shannon's index, Simpson index and Jacob equitability evenness index were utilized to evaluate species diversity.

2.2.2.1. Shannon-Weiner index:

The Shannon-Weiner index was developed from information theory and is based on measuring uncertainty. The degree of uncertainty of predicting the species of a random sample is related to the diversity of a community (Shannon 1948). Shannon-Weiner Index:

$$H = -\sum_{i}^{\S} = 1\frac{ni}{N} ln \frac{ni}{N}$$

The ni denotes the number of individuals of one particular species, N is the total number of individuals, and s represents the number of species, all of these are represented at the plot level. The value ranges from 0-5, where 0 signifies no diversity and 5 is the highest level of diversity.

2.2.2.2. Simpson's Index of Diversity:

Simpson's index is a weighted arithmetic mean of proportional abundance and measures the probability that two individuals randomly selected from a sample will belong to the same species (Simpson 1949).

$$\text{Simpson's Index of Diversity: } D = 1 - \frac{\sum_{i=1}^{\S} ni(ni-1)}{N(N-1)}$$

The ni is the number of individuals of one particular species, N is the total number of individuals and s is the number of species, all of which are represented at the plot level. The values range from 0-1 where 1 means the highest level of diversity and 0 denotes the lowest level.

2.2.2.3. Jacob's Equitability (J):

It is used to measure the evenness among the taxa that is studied.

$$\text{Equitability (J)= H'/lnS}$$

The H' is the Shannon's index of diversity and S is the number of taxa within each plot. The value ranges from 0-1; 0 denotes no evenness and 1 is complete evenness.

2.2.3. Seasonal and Plot Occupancy Rates:

To verify the seasonal occupancy rate of all bird species in CNP, regression models were utilized to analyze the count rates. The regression models incorporated significant variables including the use of elephant back, plot location and species type that would influence the overall counts of species during surveys.

2.2.3.1. Mixed Effects Regression Models:

The glmmTMB package in R was used to execute a truncated negative binomial mixed effects regression model in order to observe variation in the seasonal count rate (occupancy). The negative binomial model was used in order to correct for overdispersion of the response variable (Sampford, 1955). To account for the observation of yi$\geqslant$ 1, the zero-truncated model is effective in order to increase each unconditional probability by the factor [1-f(0)], so the probability mass of the truncated distribution sums up to 1.

$$\text{P(yi = j|yi} > 0, \text{ Xi)} = \frac{(P(y_i=j \& y_i>0|X_i))}{P(y_i>0|X_i))} = \frac{(P(y_i=j|X_i)}{[1-P(y_i=0|X_i)])} = \frac{(exp(Xi\beta)j^e-(X,\beta))}{j![1-e-(X_i\beta)])}, j = 1, 2, 3$$

The P denotes the probability of the bird counts or presence within the plots. X represents the total number of bird counts within the park during the survey period.

2.2.3.1.1. Model 1: Seasonal Occupancy Rates:

The fixed effects (denoted by j) used for the model were counts conducted during the summer season, rainy season, autumn season, winter season and counts conducted using elephants. All fixed effects were scaled before inputting into the model. The random effects terms selected were plot number and species (nested within family) to account for the variation across plots and between species.

2.2.3.1.2. Model 2: Monthly Occupancy Rates:

A truncated negative binomial mixed effects regression model was run to observe variation (of all species) in the monthly count rate. The model contained the same response variable as Model 1, twelve fixed effects (one for each month of the year) and two random effects including plot number and species (nested within family).

2.2.3.1.3. Model 3: Plot Selection of All Species:

AA negative mixed effects regression model was run to investigate plot occupancy of all species. The model's response variable was total bird counts for the entire study period and the fixed effects included was plot number and elephant back usage. The random effect was species (nested within family). .

3 Results and Discussions

3.1. Habitat Characteristics of Plots:

Habitat surveys resulted in observable variation of vegetation structure between plots (Table 1). The dominant type of grassland was savanna (4 plots), followed by marshy grassland (3 plots) with shrubby grassland, grassland prairie and tallgrass prairie characterizing a single plot. Most of the plots (5, 6, 9, 10) included invasive species.

Table 1. List of the plots, location and characteristics.

Plot	Location	Characteristics	Plants Species	Habitat
1	84.49896, 27.54876	A smaller wet meadow in dry months but becomes larger and wetter during the rainy season.	*Phragmites karka*, *Saccharum spontaneum*, *S. munja*, *S. bengalense*, *Bambax ceiba*	Shrubby Grassland
2	84.50128, 27.54623	A wet meadow during the dry season but is inundated during the rainy season. This meadow is characterized by grass species.	*Phragmites karka*, *Saccharum spontaneum*, *S. munja*, *S. bengalense*, *Mangifera indica*, *Ficus religiosa*, *Mikania micrantha*.	Marshy grassland
3	84.50507, 27.54367	All months are dry except the monsoon season.	*Saccharum spontaneum*, *S. munja*, *S. bengalense*, *Mikania micrantha*.	Grassland Prairie
4	84.49684, 27.54608	Area covered by a large water body with the presence of aquatic weeds, reeds, and scrubs.	*Phragmites karka*, *Saccharum spontaneum*, *S. munja*, *S. bengalense*, *Mikania micrantha*.	Marshy Grassland
5	84.49468, 27.54057	Mainly occupied by grass and invasive species.	*Saccharum spontaneum*, *S. munja*, *S. bengalense*, *Imperata cylindrica*, *Mangifera indica*, *Mikania micrantha*, *Lantana camara*, *Eupatorium odoratum*.	Savanna

Continued Table 1.

Plot	Location	Characteristics	Plants Species	Habitat
6	84.49101, 27.54547	Wet marshy area covered with invasive species and other aquatic weeds.	*Narenga porphyrocoma*, *Saccharum spontaneum*, *S. munja*, *S. bengalense*, *Bombax ceiba*, *Mikania micrantha*.	Marshy Grassland
7	84.49339, 27.55025	All months are wet but drier in the summer season.	*Phragmites karka*, *Saccharum spontaneum*, *S. munja*, *S. bengalensis*, *S. bengalense*, *Bombax ceiba*, *Mikania micrantha*.	Tallgrass prairie
8	84.4908, 27.55317	Wet in the rainy season but dry in summer months.	*Saccharum spontaneum*, *S. munja*, *S. bengalense*, *Bombax ceiba*, *Mikania micrantha*, *Parthenium hysterophorus*.	Savanna
9	84.4875, 27.56053	Covered with invasive species.	*Saccharum spontaneum*, *S. munja*, *S. bengalensis*, *Narenga porphyrocoma*, *Bombax ceiba*, *Mikania micrantha*, *Lantana camara*, *Parthenium hysterophorus*.	Savanna
10	84.48436, 27.56893	Covered with invasive species.	*Saccharum spontaneum*, *S. munja*, *S. bengalense*, *Narenga porphyrocoma*, *Bambax ceiba*, *Mikania micrantha*, *Lantana camara*, *Parthenium hysterophorus*.	Savanna

*Wet= Moist ground

3.2. Plot-wise distribution:

In all ten plots which constitute an area of 126 hectares, a total of 118 bird species and 4905 individual birds belonging to 43 families were observed (Figure 2). Of the total 118 bird species recorded, 10 (8.47%) of the species utilized grassland, wetland and savanna habitats. A total of 50 bird species (42.37%) utilized only grassland and wetland habitats. Approximately, 9 of these bird species (7.62%) occupied wetland and savanna habitat. Species observed occupying only a single habitat were recorded and resulted in 20 species in grassland (16.94%), 3 in wetland (2.54%) and 32 in grassland (27.11%)(Appendix I).

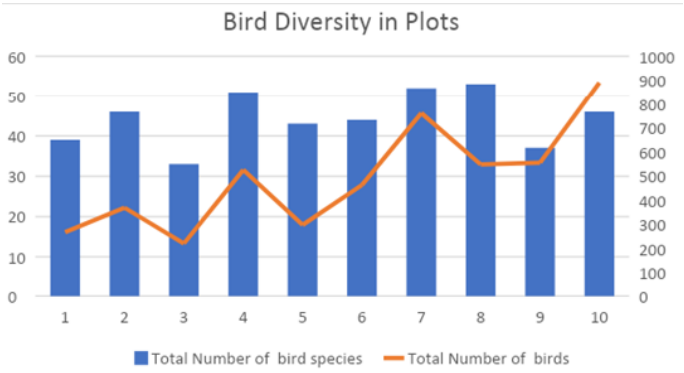

Figure 2: Plot-wise distribution of bird species and their number.

3.3. Month-wise species richness across plots:

The highest number of species was observed in June with 51 species recorded in contrast to the mean of 45 bird species across different months (Figure 3). The bird species with only one observed count among all plots of Padampur grassland are presented in Appendix II. During the survey period 18 bird species were observed only once. Appendix II also displays the habitat for which each of these species was sighted in comparison to their preferred habitat.

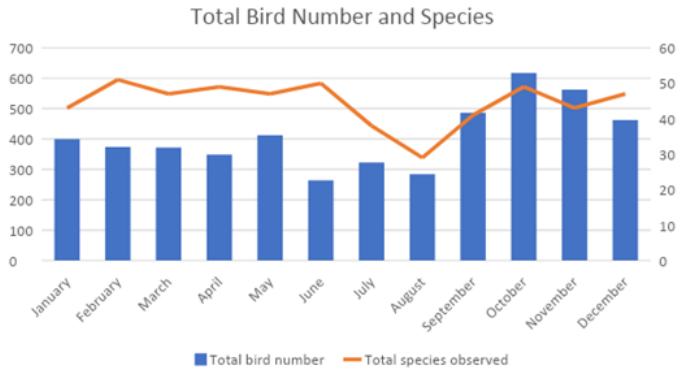

Figure 3: Total bird number and species observed in different months of the year.

The highest count of birds (total bird number) recorded was in October with 617 individuals. The average count of birds per month across the study was 409 birds per month. Of the 118 bird species recorded in Padampur, 86 were resident, 13 were summer visitors, 18 were winter visitors and 1 was a monsoon visitor (Figure 4)

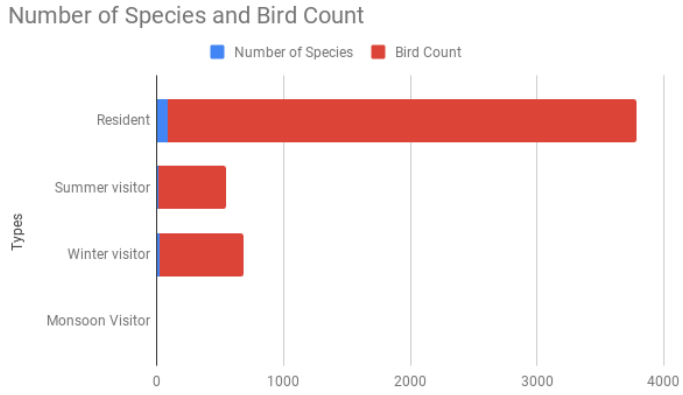

Figure 4: Resident, Summer, Winter and Monsoon Visitor Bird species and their counts.

Results from accumulated surveys revealed the maximum number of bird species (n=75) within winter and autumn, while bird counts were higher in autumn (n=1665). However, in the rainy season, bird species (n=73) and their individuals (n=871) were observed to be low. Forty-one bird species were recorded within scattered trees across all the plots (Supplementary).

3.4. Species Abundance and Richness:

The species richness for all survey plots resulted in a cumulated abundance of 118 (Appendix IV) and a mean species richness of 44.5 (7.01). The bootstrap prediction model resulted in 118 (8.99) and a mean of 490.5 (64.27).

3.5. Rarefaction Curve Analysis:

Rarefaction curves for species richness were calculated and plotted for all surveyed plots revealing Plots 7, 4, 8, and 5 to contain the highest average species richness (Figure 5). Accumulation units were the months surveyed for all plots, approximately to 11 months of surveying, richness appeared to stabilize across all plots.

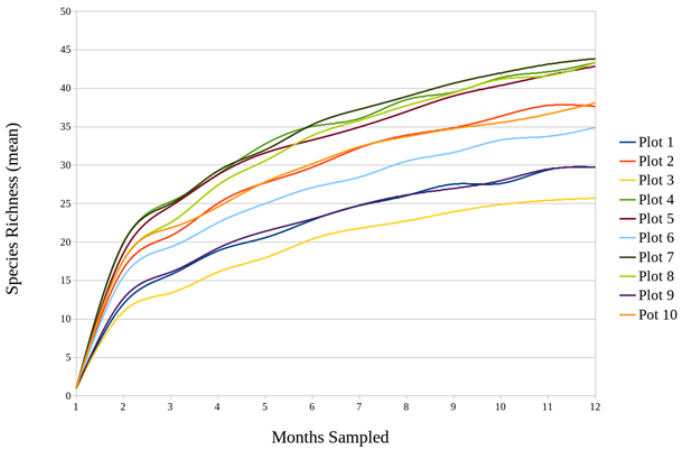

Figure 5: Rarefaction curves of all plots with months surveyed as sampling unit.

3.6. Species Abundance:

The Fisher log series model for abundance resulted in an average of 43 species across plots and an abundance of alpha =13.77 (Appendix IV). The Preston's log-normal model resulted in a species mean of 43 and an average abundance of 10.19 individuals per species (Figure 6).

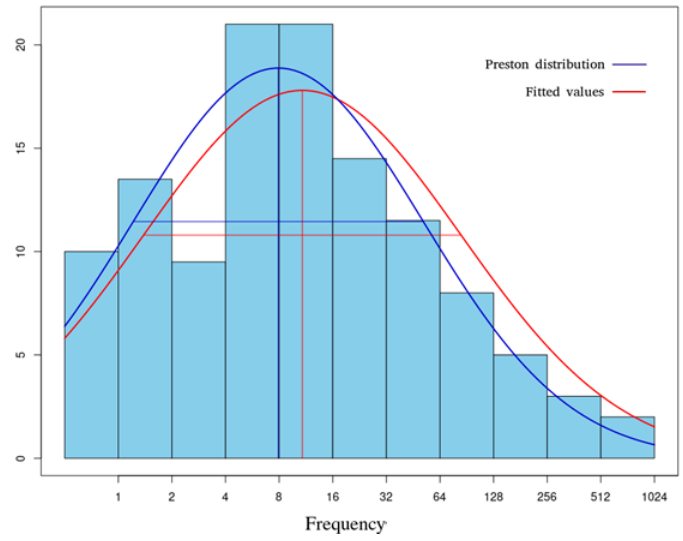

Figure 6: Average species abundance and frequencies across plots Preston lognormal plot with y-axis species abundance and x-axis as frequency. Results from preston model: species mean = 43, width = 1.80, S0 = 10.19.

3.7. Species diversity:

Among the 10 sampled plots in Padampur, plots 4 and 5 resulted in slightly higher values of species diversity while plot 10 resulted in relatively lower values of species diversity (Table 3). Plot 10 resulted in a relatively low diversity index value (1-D = 0.8803, H' = 2.5958, J = 0.678) to other plots (Table 2).

Table 2. Count rates of all species across plot number.

Variable	β	SE	exp(β)	Lower Bound	Upper Bound
Plot 1	0.60**	0.21	1.81	1.21	2.73
Plot 2	0.41	0.23	1.50	0.96	2.35
Plot 3	0.13	0.26	1.13	0.68	1.88
Plot 4	0.72**	0.24	2.06	1.28	3.30
Plot 5	0.30	0.24	1.35	0.84	2.17
Plot 6	0.34	0.23	1.40	0.89	2.20
Plot 7	0.77***	0.23	2.15	1.387	3.38
Plot 8	0.60**	0.23	1.82	1.17	2.84
Plot 9	0.63*	0.25	1.87	1.16	3.04
Plot 10	0.66**	0.23	1.94	1.23	3.07
Elephant back	0.66***	0.04	1.05	1.03	1.06

Random Effects

Groups	Variance	SE	exp(β)	LowerBound	UpperBound
Family:Species	0.87	0.94	2.55	2.14	3.16

Note: β-Unstandarized coefficient; SE-Standard error;expo(β)-Exponentiated regression coefficient. '***' $p < 0.001$, '**' $p < 0.01$, '*' $p < 0.05$.

3.8. Occupancy Rates of CNP

3.8.1. Bird occupancy rates across plots:

The regression analysis of the total bird count (occupancy) rate within plots resulted in significant differences between seven plots (Table 2). Plot 7 contained the highest count rate across species ($\beta = 0.77(0.23)$, $p < 0.001$) where plots 2, 3, and 6 resulted in no significant difference in occupancy. The use of elephant back appeared to be a significant positive predictor for count rates across plots ($\beta = 0.66(0.04)$, $p < 0.001$).

Table 3. Bird species diversity in Padampur Grassland of CNP, Nepal.

Species Diversity Indices	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10
Simpson's index (1-D)	0.91	0.94	0.90	0.95	0.95	0.93	0.91	0.94	0.91	0.88
Shannon's Index (H')	2.87	3.20	2.80	3.36	3.25	2.96	3.04	3.22	2.76	2.60
Jacob's Equitability (J)	0.79	0.84	0.80	0.85	0.86	0.78	0.77	0.81	0.77	0.68

3.8.2. Seasonal Occupancy of all Species:

The negative binomial regression model for counts withregar to season included the variation between species (nested within family) and plot location as a random effect. The results from Table

4 revealed that using elephant back for surveying had insignificant effect on the count rate of all bird species across seasons (Elephant back p = 0.278). Comparing the count rates of all betas, the winter season had the highest coefficient (0.49 (0.07), p < 0.0001) following autumn, summer and the rainy season, thus supporting results from Figure 4. Comparing between seasons, the winter season is shown to have .06 times more counts than in autumn. Continuing the comparison of seasons, we see that the autumn season is likely to have 0.10 times more counts than summer and the summer season 0.13 times more counts than the rainy season. Plot location had little effect on the seasonal count rate (Var = 0.005 (0.07)) whereas more variability was expectedly seen across species (Var = 0.15 (0.38)).

Table 4. Results for Total Bird Count Truncated Negative Binomial Regression.

Variable	β	SE	exp(β)	Lower Bound	Upper Bound
Intercept	1.54*	0.08	4.68	4.00	5.47
Winter	0.49*	0.07	1.62	1.41	1.87
Autumn	0.44*	0.13	1.56	1.22	1.99
Summer	0.38*	0.08	1.46	1.26	1.70
Rainy	0.28*	0.07	1.33	1.15	1.53
Elephant back	0.14	0.13	1.15	0.90	1.47

Random Effects

Groups	Variance	SE	exp(β)	LowerBound	UpperBound
Family:Species	0.150	0.387	1.53	1.33	1.98
Plot Number	0.005	0.070	1.13	1.05	1.35

Note: β-Unstandardized coefficient; SE-Standard error; exp(β)-Exponentiated regression coefficient. Log Likelihood: 1167, '*' p < 0.001, Elephant back p = 0.278, (df = 436); AIC: 2351; BIC: 2388.

Comparison of monthly occupancy displayed in Table 5 revealed that September had the highest rate of counts when including variation of species and plot location (β = 0.24(0.04)). The highest coefficients in the model were predominantly from the winter and autumn season which support the results in Table 4. However, the month with the lowest count rate was in November (β = 0.04(0.01)). The months within the rainy and the summer season were relatively lower than autumn and winter which did not reach over 0.18 except for the month of May (β = 0.22 (0.04)).

Table 5. Monthly Variation of Occupancy Rates.

Variable	β	SE	exp(β)	Lower Bound	Upper Bound
Intercept	1.46	0.09	2.53	2.14	2.99
January	0.16	0.05	1.17	1.06	1.29
February	0.22	0.04	1.24	1.15	1.33
March	0.15	0.05	1.16	1.06	1.29
April	0.12	0.05	1.12	1.02	1.24
May	0.22	0.04	1.24	1.16	1.34
June	0.18	0.04	1.19	1.10	1.29
July	0.13	0.04	1.13	1.02	1.08

Continued Table 5.

Variable	β	SE	exp(β)	Lower Bound	Upper Bound
August	0.17	0.05	1.18	1.08	1.29
September	0.24	0.04	1.27	1.18	1.37
October	0.16	0.06	1.17	1.04	1.33
November	0.04	0.01	1.04	1.02	1.06
December	0.21	0.04	1.23	1.14	1.35

Random Effects

Groups	Variance	SE	exp(β)	LowerBound	UpperBound
Family:Species	0.18	0.43	1.53	1.32	1.90
Plot	0.01	0.11	1.12	1.04	1.35

Note: β-Unstandardized coefficient; SE-Standard error; exp(β)- Exponentiated regression coefficient. Log Likelihood: 1136, (df = 422); AIC-2304; BIC- 2369. All betas had $p < 0.05$.

Thorough observation of habitat selection across bird species is crucial for comprehension of their life patterns, history, adaptation, or behavior, which ultimately is useful in conservation and management of these species (Hussain and Sultana, 2013). With the execution of avian count surveys and statistical modeling, this paper attempted to have a more comprehensive understanding of the species diversity, richness, abundance and occupancy within the mosaics of CNP.

3.9. Species Richness and Abundance Across Plots:

Bird species richness is influenced by both agricultural and rural abandonment in human dominated landscapes where agricultural practices favor bird richness more than rural abandonment (Salaverri et al., 2018). For example, the red-vented bulbul and red-whiskered bulbul (Pycnonotus jocosus) are mostly observed in tall grasses for basking and eating seeds in winter (Grimmett et al., 2016). These species had higher species richness predominantly in plots with tallgrass vegetation such as plot 7 (Table 1, Supplemental). Close inspection of generalist bird species such as the red-vented bulbul (Pycnonotus cafer) showed relatively higher species abundance in plot 10 (Appendix I) which contained savanna habitat (Table 1). In CNP, forest birds have been reported to use broad-leafed and mixed forests extensively (CNP, 2013). For instance, this study observed the highest richness of tree bird species within research Plots 5, 8, 9 and 10 (supplementary material). These plots represent the assemblage of diverse grassland vegetation with mixed-broad leafed trees.

Community structure has also shown to vary with distance to forest and habitat size of low grasslands; therefore, grasslands may provide mosaics of habitat for only a limited number of species (Baral, 2001). For instance, although most generalists dwell in forest edges close to grassland, specialists have been shown to prefer open grassland sites (Baral, 2001). In essence, our results are consistent with Baral (2001) who reports that grassland specialists in the CNP prefer tallgrass wetlands at forest edges (Table 2, supplemental). According to the rarefaction curves for each plot, Plots 4, 5, 7, and 8, predominantly consisting of tallgrass prairie, resulted in the highest species richness (Figure 5). Moreover, after reaching approximately 12 months of sampling, these four plots accumulated a species richness above 43. This estimate is also the result of both the Fisher-log and Preston log-normal models for average species abundance (Figure 6). This supports previous studies that report vegetation patches as preferred habitat for bird species; these mosaics

may therefore contribute to the richness in complex bird communities (Anderson 1979; Kirk and Hobson 2001). For example, Plot 4 contained wet meadow with the presence of Phragmites karka, Saccharum spontaneum, S. munja, and S. bengelense (Table 1). Having one of the highest species richness and occupancy estimates, this plot would be worth further investigation of contributing factors including habitat (Figure 5). Additionally, study plots that contained mixed vegetation mosaics within wetland habitat also appeared to have higher overall occupancy rates compared to other plots (Table 1). The plots with the highest detection rates within this study included plots 4, 7, and 8 (Table 2). Not only did these plots contain the highest species richness, but also possessed predominantly ecotone habitat i.e. wetlands, grassland and scattered trees (Baral, 2001).

3.10. Seasonal Richness and Occupancy Rates:

Low seasonal variation of count rates within the park highlights that overall occupancy of avian species is relatively consistent throughout the year with relatively higher rates during the winter and autumn seasons (Table 4). On review of the seasonal species richness, it appears there are some consistencies with research conducted in the highland region. For example, Sultana Hussain (2012) and Katuwal et al. (2016) reports comparatively high richness during post-monsoon season in the highlands. This paper similarly observes high species richness within the same season but within a geographically different region (Figure 3). According to previous observations in CNP, summer visitors prefer grassland and forested areas (Inskipp et al., 2016). For example, within our study plots, three species: black headed munia (*Lonchura Malacca*), green bee eater (*Merops orientalis*) and cotton pygmy-goose(*Nettapus coromandelianus*) were only observed during the rainy season (Supplemental). Although these bird species have been reported outside the study site during pre-monsoon and post monsoon season, they have a breeding season that commonly aligns with the rainy season (Grimmett et al, 2016). Moreover, the cotton pygmy-goose, a small waterfowl found in water bodies with aquatic vegetation, are usually observed in pairs or groups; they roost and nest on riparian vegetation while their breeding season also coincides with the rainy season (Birdlife International, 2012).

3.11. Species diversity:

In our research site, we found insignificant species diversity and evenness between plots for all indices (Table 3). However, a study carried out by Adhikari et al. (2019) between January and December, 2017 on threatened bird species of CNP (Block A: Khagendra Malli, Kathar, Sauraha to Old Padampur) resulted in the Simpson diversity index (1-D) = 0.7518, Shannon diversity (H = 1.689) and Jacob equitability (J = 0.7337). These diversity outcomes were comparatively low though not significantly different ($p > 0.05$) corresponding with our study plots, Simpson diversity index (1-D) = 0.922, Shannon diversity (H) = 3.006 and Jacob equitability (J) = 0.795. This shows the bird species diversity in Padampur grassland has reduced along the course of time. This could be due to inadequate grassland and wetland habitat management activities in the park (CNP, 2016). The extent of grassland bird species is determined by various complex factors such as habitat area affects, landscape pattern and composition, and foraging opportunities (Hamer et al., 2006). Previously, the settlement of Padampur lacked endemic tree species; the whole region was occupied with cultivated lands and orchards which were owned and managed by the local people (CNP, 2013). However, after the relocation of Padampur village, the abandoned land was gradually converted into grassland with tree regeneration which ultimately formed potential habitat for resident and migratory bird species (CNP, 2016; BES, 2018).

4 Conclusion

This study observed bird species preferring plots with habitats interspersed with mosaics of tallgrass prairie, shrubby grassland, savanna and marshy grassland. Our regression analyses show relatively consistent seasonal detection of avian species across plots with insignificant to positive effect of using elephant back. This paper encourages this type of survey method when conducting avian point counts. The rarefaction curves for all plots reveal that surveys conducted over at least eleven months will improve detection of reliable richness estimates. Moreover, the diversity indices did not significantly differ between the plots but shows improved diversity when compared to previous studies. Therefore, conservation efforts should consider these estimates when implementing initiatives. Conclusively, Padampur, a post human-settlement grassland, may present opportunities to improve avian species richness and diversity in Nepal. We recommend concerned authority to prioritize and give continuity to bird conservation and their habitat management throughout the year. For this, managing grasslands alongside the wetlands is crucial to maintaining and promoting avian diversity in CNP.

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Conflict of interests

The authors declare that there are no conflict of interest

Data Accessibility

Pathak, Abhinaya (2021), Birds of Padampur, Chitwan National Park, Nepal, Dryad, Dataset, https://doi.org/10.5061/dryad.cjsxksn5s

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Appendix I: Habitat use by different bird species in Padampur grassland of CNP.

S.N	Family	English Name	Scientific name	Habitat use		
				Grassland	**Wetland**	**Shrubs**
	Phasianidae (Pheasants, partridges)					
1		Black Francolin	*Francolinus franconlinus*	Yes	No	Yes
2		Red Junglefowl	*Gallus gallus*	Yes	No	Yes
3		Indian Peafowl	*Pavo cristatus*	Yes	No	Yes
	Anatidae (Ducks, geese)					
4		Lesser Whistling-duck	*Dendrocygna javanica*	Yes	Yes	No
5		Ruddy Shelduck	*Tadorna ferruginea*	Yes	Yes	No
6		Gadwall	*Anus strepera*	Yes	Yes	No
7		Mallard	*Anas platyrhynchos*	Yes	Yes	No
8		Red-crested Pochard	*Rhodonessa rufina*	Yes	Yes	No
9		Cotton Pygmy-goose	*Nettapus coromandelianus*	Yes	Yes	No
	Picidae (Woodpeckers)					
10		Streak-throated Woodpecker	*Picus xanthopygaeus*	No	No	Yes
11		Fulvous-breasted Woodpecker	*Dendrocopos macei*	No	No	Yes
12		Greater Yellownape	*Picus flavinucha*	No	No	Yes
	Picidae (Woodpeckers)					
13		Blue-throated Barbet	*Megalaima asiatica*	No	No	Yes
14		Lineated Barbet	*Megalaima lineate*	No	No	Yes
	Bucerotidae (Hornbills)					
15		Oriental Pied Hornbill	*Anthracoceros albirostris*	No	No	Yes
	Upupidae (Hoopoe)					
16		Common Hoopoe	*Upupa epops*	Yes	yes	Yes
	Coraciidae (Rollers)					
17		Indian Roller	*Coracias benghalensis*	No	No	Yes
18		Dollarbird	*Eurystomus orientalis*	No	No	Yes
	Alcedinidae (Kingfishers)					
19		White-throated Kingfisher	*Halcyon smyrnensis*	Yes	Yes	Yes
20		Pied Kingfisher	*Ceryle rudis*	No	Yes	No
21		Common Kingfisher	*Alcedo atthis*	Yes	Yes	Yes

	Meropidae (Bee-eaters)					
22		Chestnut-headed Bee-eater	*Merops leschenaultia*	Yes	No	Yes
23		Green Bee-eater	*Merops orientalis*	Yes	No	Yes
24		Blue-tailed Bee-eater	*Merops philippinus*	Yes	Yes	Yes
	Cuculidae (Cuckoos)					
25		Pied Cuckoo	*Clamator jacobinus*	Yes	No	No
26		Common Hawk Cuckoo	*Hierococcyx varius*	No	No	Yes
27		Drongo Cuckoo	*Surniculus lugubris*	No	No	Yes
28		Indian Cuckoo	*Cuculus micropterus*	No	No	Yes
29		Greater Coucal	*Centropus sinensis*	Yes	Yes	No
30		Lesser Coucal	*Centropus bengalensis*	Yes	Yes	No
	Psittacidae (Parrots)					
31		Alexandrine Parakeet	*Psittacula eupatria*	No	No	Yes
32		Plum-headed Parakeet	*Psittacula cyanocephala*	No	No	Yes
33		Rose-ringed Parakeet	*Psittacula krameri*	No	No	Yes
	Accipitridae (Hawks, eagles)					
34		Grey-headed Fish Eagle	*Ichthyophaga ichthyaetus*	No	yes	No
35		Black-shouldered Kite	*Elanus caeruleus*	Yes	yes	Yes
36		Shikra	*Acipiter badius*	Yes	No	Yes
	Falconidae (Falcons)					
37		Collared Falconet	*Microhierax caerulescens*	No	No	Yes
	Anhingidae (Darters)					
38		Darter	*Anhinga melanogaster*	Yes	Yes	No
	Columbidae (Pigeons, doves)					
39		Spotted Dove	*Streptopelia chinensis*	No	No	Yes
40		Red Collared Dove	*Streptopelia tranquebarica*	No	No	Yes
41		Eurasian Collared Dove	*Streptopelia decaocto*	No	No	Yes
42		Orange-breasted Green Pigeon	*Treron bicinctus*	No	No	Yes
	Rallidae (Rails, gallinules, coots)					
43		Brown Crake	*Amaurornis akool*	Yes	yes	No
44		White- breasted Waterhen	*Amaurornis phoenicurus*	Yes	yes	No
45		Watercock	*Gallicrex cinerea*	No	Yes	No

46		Common Moorhen	*Gallinula chloropus*	Yes	yes	No
	Scolopacidae (Sandpipers, snipes)					
47		Common Snipe	*Gallinago gallinago*	Yes	yes	No
48		Green Sandpiper	*Tringa ochropus*	Yes	yes	No
49		Common Greenshank	*Tringa nebularia*	Yes	Yes	No
	Jacanidae (Jacanas)					
50		Bronze-winged Jacana	*Metopidius indicus*	Yes	Yes	No
	Charadriidae (Plovers)					
51		Red wattled Lapwing	*Venellus indicus*	Yes	Yes	No
	Ardeidae (Herons)					
52		Indian Pond Heron	*Ardeola grayii*	Yes	Yes	No
53		Cinnamon Bittern	*Ixobrychus cinnamomeus*	Yes	Yes	No
54		Yellow Bittern	*Ixobrychus sinensis*	Yes	Yes	No
55		Purple Heron	*Ardea purpurea*	Yes	Yes	No
56		Black-crowned Night Heron	*Nycticorax nycticorax*	Yes	Yes	No
57		Great Egret	*Ardea alba*	Yes	Yes	No
58		Intermediate Egret	*Mesophoyx intermedia*	Yes	Yes	No
59		Little Egret	*Egretta garzetta*	Yes	Yes	No
60		Grey Heron	*Ardea cinerea*	Yes	Yes	No
	Ciconiidae (Storks)					
61		Asian Woolly-necked Stork	*Ciconia episcopus*	Yes	Yes	No
62		Lesser Adjutant	*Leptoptilos javanicus*	Yes	Yes	No
63		Asian Openbill	*Anastomus oscitans*	Yes	Yes	No
	Dicruridae (Drongos)					
64		Black Drongo	Dicrurus macrocercus	Yes	Yes	Yes
	Monarchidae (Monarchs)					
65		Asian paradise-flycatcher	*Terpsiphone paradise*	No	No	Yes
	Laniidae (Shrikes)					
66		Long-tailed Shrike	*Lanius schach*	Yes	No	No
	Artamidae (Wood swallows)					
67		Ashy Woodswallow	*Artamus fuscus*	No	No	Yes
	Oriolidae (Orioles)					
68		Eurasian Golden Oriole	*Oriolus oriolus*	No	No	Yes
69		Black-hooded Oriole	*Oriolus xanthornus*	No	No	Yes
	Campephagidae (Cuckoo-shrikes)					
70		Large Cuckooshrike	*Coracina macei*	No	No	Yes

	Rhipiduridae (Fantails)					
71		White-browed Fantail	*Rhipidura aureola*	Yes	No	Yes
	Corvidae (Crows)					
72		Large-billed Crow	*Corvus macrorhynchos*	Yes	No	Yes
73		Rufous Treepie	*Dendrocitta vagabunda*	No	No	Yes
	Muscicapidae (Chats and Old World flycatchers)					
74		Ultamarine Flycatcher	*Ficedula superciliaries*	No	No	Yes
75		Siberian Rubythroat	*Luscinia calliope*	Yes	No	No
76		Bluethroat	*Luscinia svecica*	Yes	No	No
77		White-tailed Rubythroat	*Luscinia pectoralis*	Yes	No	No
78		Oriental Magpie Robin	*Copsychus saularis*	Yes	No	Yes
79		Common Stonechat	*Saxicola torquata*	Yes	No	No
80		Pied Bushchat	*Saxicola caprata*	Yes	No	No
	Sturnidae (Starlings)					
81		Jungle Myna	*Acridothers fuscus*	Yes	Yes	Yes
82		Chestnut-tailed Starling	*Sturnus malabaricus*	Yes	Yes	Yes
83		Asian Pied Starling	*Strunus contra*	Yes	yes	No
84		Hill Myna	*Gracula religiosa*	No	No	Yes
	Paridae (Tits)					
85		Great Tit	*Parus major*	No	No	Yes
	Hirundinidae (Swallows and martins)					
86		Plain Martin	*Riparia paludicola*	Yes	yes	No
87		Barn Swallow	*Hirundo rustica*	Yes	yes	No
	Pycnonotidae (Bulbuls)					
88		Red-vented Bulbul	*Pycnonotus cafer*	Yes	No	Yes
89		Red-whiskered Bulbul	*Pycnonotus jocosus*	Yes	No	Yes
	Cisticolidae (Cisticolas)					
90		Ashy Prinia	*Prinia socialis*	Yes	No	No
91		Yellow-bellied Prinia	*Prinia flaviventris*	Yes	yes	No
92		Grey-breasted Prinia	*Prinia hodgsonii*	Yes	No	No
93		Plain Prinia	*Prinia inornata*	Yes	No	No
	Sylviidae (Old World warblers)					
94		Common Tailorbird	*Orthotomus sutorius*	No	No	Yes
95		Smoky Warbler	*Phylloscoppus fuligiventer*	Yes	Yes	No

96		Greenish Wrabler	*Phylloscopus trochiloides*	No	No	Yes
97		Chesnut-crowned Bush Warbler	*Cettia major*	Yes	No	No
98		Bristiled Grassbird	*Chaetornis striatus*	Yes	No	No
99		Rufous-rumped Grassbird	*Graminicola bengalensis*	Yes	No	No
	Timaliidae (Babblers)					
100		Rufous-capped Babbler	*Stachyris ruficeps*	No	No	Yes
101		Chesnut-capped Babbler	*Timalia pileata*	Yes	Yes	No
102		Striated Babbler	*Turdoides earlei*	Yes	No	No
103		Slender-billed Babbler	*Turdoides longirostris*	Yes	No	No
104		Jungle Babbaler	*Turdoides striatus*	Yes	No	Yes
105		Yellow-eyed Babbler	*Chrysomma sinense*	Yes	No	Yes
	Alaudidae (Larks)					
106		Rufous-winged Bushlark	*Mirafra assamica*	Yes	No	No
	Passeridae (Sparrows)					
107		Chestnut-shouldered Petronia	*Petronia xanthocollis*	Yes	No	Yes
	Motacillidae (Wagtails and Pipits)					
108		Richard's Pipit	*Anthus richardi*	Yes	Yes	No
109		Tree Pipit	*Anthus trivialis*	No	No	Yes
110		Rosy Pipit	*Anthus roseatus*	Yes	yes	No
111		Citrine Wagtail	*Motacilla citreola*	Yes	Yes	No
112		White Wagtail	*Motacilla alba*	Yes	Yes	No
	Ploceidae (Weavers)					
113		Black-breasted Weaver	*Ploceus benghalensis*	Yes	yes	No
114		Baya Weaver	*Ploceus philippinus*	Yes	yes	Yes
	Estrildidae (Munias)					
115		Scaly-breasted Munia	*Lonchura punctulata*	Yes	No	No
116		Red Avadavat	*Amandava amandava*	Yes	No	No
117		Black-headed Munia	*Lonchura Malacca*	Yes	No	No
	Fringillidae (Finches)					
118		Common Rosefinch	*Carpodacus erythrinus*	Yes	No	No

Appendix II: Birds Resulting in One Observed Count

S. N	Species	Plot	Month	Sighted Habitat	Preferred habitat
1	*Anus strepera*	4	December	Small lakes and marshes.	Commonly found in the rivers, particularly Rapti and Narayani.
2	*Rhodonessa Rufina*	4	November	Small freshwater lakes and marshes.	Commonly seen in Rapti and Narayani rivers
3	*Merops orientalis*	1	June	Grassland	Open areas with scattered trees.
4	*Clamator jacobinus*	7	October	Grassland	Resides in dense forest habitat.
5	*Dendrocopos macei*	9	October	Grassland	Commonly found in forest edges and open forest.
6	*Picus flavinucha*	10	November	Grassland	Fairly common in broadleaved forest and its edges.
7	*Megalaima lineata*	10	January	Grassland	Commonly found in Sal forest and well-wooded areas.
8	*Ichthyophaga ichthyaetus*	6	January	Small lakes and marshes	Close to water bodies
9	*Microhierax caerulescens*	6	December	Grassland	Forest edges and broadleaved tropical forests.
10	*Tringa nebularia*	4	September	Marshy grassland	Sighted on the edge of slow flowing rivers.
11	*Terpsiphone paradisi*	10	October	Grassland	Found in forested areas in the CNP.

12	*Ficedula superciliaris*	5	March	Grassland	Found in common forest areas.
13	*Orthotomus sutorius*	10	March	Grassland	Common sightings in bushes, gardens and cultivation edges.
14	*Chaetornis striatus***	6	June	Grassland	Found in short grass with scattered bushes.
15	*Phylloscopus trochiloides*	8	December	Grassland	Commonly found in well-wooded areas.
16	*Petronia xanthocollis**	10	February	Grassland	Found in open dry forest.
17	*Lonchura malacca*	8	August	Grassland	Sacchharum species is an original grassland habitat of this species.
18	*Carpodacus erythrinus*	8	November	Grassland	Fairly common in open scattered bushes and scrubs.

* =uncommon species, **=globally threatened species,

Appendix III:

All species diversity indices across plots resulted in insignificant differences. A Shapiro-test was run to verify normal distribution ($p>0.05$). A one-way ANOVA was run to compare index values between the sites (Simpson's index ($p>0.05$), Shannon's Index ($p>0.05$) and Jacob's Equitability ($p>0.05$).

Diversity Indices	**Estimate**	**SE**	**t-value**	**p-value**
Simpson	-42.34	43.07	-0.983	0.354
Shannon	-4.177	4.038	-1.034	0.331
Jacob	-36.08	16.20	-2.227	0.0566

Appendix IV

Fishers log model results (species richness)

Model Output	**Observed Values**	**Bootstrap**
Cumulated Richness	118	118 (8.99)
Mean Richness	44.5 (7.01)	490.5 (64.27)

Preston's Log-Normal Model (species abundances)

Octaves	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Observed	5.5	9.0	9.0	7.0	5.5	6.0	1.0
Fitted	6.57	9.46	10.04	7.84	4.51	1.91	0.60

richness=43, mode= 1.69, width = 1.81, S0=10.19