Avifaunal diversity in disturbed and undisturbed winter forests of Gogona Forest Management Unit, Wangdue Phodrang

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Abstract
Bhutan lies in the Eastern Himalayan eco-region and is identified as part of the 10th global biodiversity hotspot. The baseline data for bird conservation on species richness, abundance, and diversity of avian in Forest Management Units (FMUs) are, however, inadequate because of a conservation focus on rare and endangered species. The objectives of this study were to compare the avian richness, abundance, and diversity to analyze the effect of vegetation parameters on avian species diversity and composition in disturbed and undisturbed habitats in GFMU in one winter season. The Open Width Point Count method was used to sample birds along the established transects. Quadrates 20 m x 20 m were used to sample vegetation, with 30 quadrates in each habitat type. A total of 71 avian species belonging to 28 families were recorded. A higher avian diversity (H' = 2.95), species richness (S = 22) and abundance (n = 1150) were observed in the undisturbed habitat than disturbed habitat (H' = 2.85), (S = 15), and (n = 809). Moreover, correlation of vegetation parameters such as canopy cover and shrub cover with avian diversity and avian composition revealed a medium association in undisturbed habitat. Further, there was a statistically significant difference between the disturbed and undisturbed habitats on avian diversity and composition, signifying that both the habitats are vital for avian conservation. A long-term study is needed to indicate variations in species composition and diversity caused by the existence of migrants, by breeding, and by effects of the other season in both the habitats.

Keywords: Avian diversity, disturbed habitat, species composition, undisturbed habitat.

Introduction

Avifaunal are the most popular life forms compared to other species on the planet, and their biodiversity leads to a richness of life and beauty (Joshi and Shrivastava, 2013) and even act as bio-indicators of the health of the ecosystem (Acharya *et al*., 2011). Understanding bird species diversity and abundance in disturbed and undisturbed forest are crucial for the conservation of birds in mountain ecosystems (Acharya *et al*., 2011). According to Ghasemi (2015), avian species are signified as living records of choices for evaluating the effect of forest logging. Also, birds are vastly responsive to changes due to certain ecological processes, displaying a wide range of responsiveness to habitat alteration and disturbance (Ghasemi *et al*., 2012). They are particularly helpful as indicator species of change in the overall condition of the forest ecosystem (Kampichler *et al*., 2014), which is pricey to determine directly (Kumar and Kumar, 2008). According to Tozer *et al*. (2010), human activities like extraction of forest products affect forest structure and composition, which lead ultimately to a decrease in avian diversity. Logging activity has a direct impact to the structure of habitats used by avian species and changes in species composition of trees and decrease in canopy coverage affect avian diversity (Laiolo *et al*., 2003). In addition, forest logging practices have created large areas of juvenile forests missing the composition and structural elements needed by some avian species (Díaz *et al*., 2005) but providing habitats for certain other avian species.

In Bhutan, the extensive range of forest cover depicts the representative of rich biodiversity that harbors 84% of the breeding birds in the Himalayan countries. It also includes 57% of globally threatened birds and 90% of restricted-range birds (Inskipp *et al*., 1999). According to Wangdi (2017), a recent sighting of a Yellow-eyed babbler in the Royal Manas National Park (RMNP) has now increased the avian species count in Bhutan to 719. Out of 719 species of birds, 14 species are globally threatened and 10 falls within the restricted range (Information and Communication Services [ICS], 2012). However, Bhutan lacks baseline information on diversity and abundance of avian species in relation to disturbed and undisturbed forests. Bhutan has made great efforts by declaring 51% of its land under protected area (Department of Forest and Park Services, 2015). Nevertheless, in order to meet the timber needs of the country, the Department of Forest and Park Services (DoFPS) established 19 Forest Management Units (FMUs) for sustainable harvesting of timber (DoFPS, 2015). These FMUs will have greater impact on balancing avian species diversity and its composition within the FMU (GFMU 2015).

As per the Forest Management Plan (FMP) 2005-2015 of Gogona Forest Management Unit (GFMU), only 40 avian species had been recorded in the GFMU during the first general inventory in 2000-2001(GFMU 2015-2024). No studies have been conducted regarding species richness, abundance, and diversity of avian within the FMU. This study is aimed to investigate avian species richness, abundance, and diversity and to analyze the effect of vegetation parameters on avian species diversity and composition in disturbed and undisturbed habitats in GFMU.

Materials and Methods

Study area

Gogona Forest Management Unit (GFMU), which has a total area of 8080 ha, is located in Gangtey Gewog under WangduePhodrang Dzongkhag. It has an elevation ranging from 2648 to 4197 meters above sea level (GFMP, 2015-2024). It lies between the latitudes 27°22’2” N to 27°28’2” North and longitudes 90° 3’ 1” East. The FMU encompasses diverse plant species and is dominated by *Abiesdensa, Tsugadumosa*, *Piceaspinulosa,* and the understory is profusely covered by rhododendron species (GFMP, 2015-2024).

The study on avian diversity was carried out in two blocks, Gangkha with 2940 ha and Dakaysa with 3090 ha covering a total area of 6030 ha of productive forest (Figure 1). Forest in Dakaysa block is particularly conserved to meet the future demand of the country, so no extraction of forest produce is carried out so far and is considered as undisturbed habitat. Whereas, Gangkha block is considered as disturbed habitat as most of the timber extractions are carried out in this block by using heavy machinery to fulfill the needs of people and the country.

Avian sampling

The open width point count method developed by Bibby *et al*. (2000) was used to sample birds along predetermined transects (Forest road and Natural trail) in disturbed

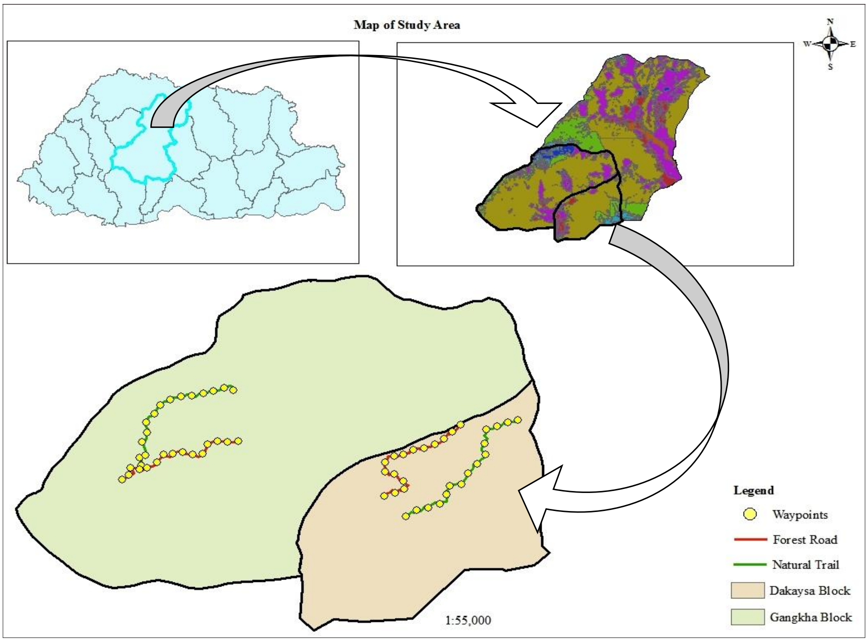

Figure 1: Study Map of disturbed and undisturbed habitats under Wangduephodrang Dzongkhag.

and undisturbed habitats. Sampling points were established at a uniform distance of 200 meters (m) between the plots using GPS (10 m) to minimize measurement error. An existing forest road and natural trails were used as transects in both habitats in both the blocks. Each transect was three kilometers (km) in length, with 15 sampling plots in each transect. Thus, each habitat type (disturbed and undisturbed) had 30 sample points on 6 km of transects. All 60 points were sampled each month, for a total of 120 samples (point counts) in December 2016 and February 2017. The avian counting was done for six hours in a day; 06:00 to 09:00 hours in the morning and 15:00 to 18:00 hours in the afternoon. For every point station, 10 minutes were spent to record all the birds in the area seen and identified through photographic guides (Grimmet *et al*. 2011 & 2013).

Vegetation sampling

In order to check the composition and the structure of the vegetation, following predetermined transects in both disturbed and undisturbed forest was carried out. A quadrate of 20 m x 20 m was laid out at every point within a 20 m radius from the center of the plot, where bird sampling was carried. The trees and shrubs above diameter at breast height (DBH-1.3 m) were measured. Undergrowth and ground cover that were less than 1.3 m in height were not considered in this study to avoid confusion since the study was conducted in one winter season and the ground was covered in snow. Vegetation parameters were considered to assess their relationship with Avian Species Composition (ASC) and Avian Species Diversity (ASD); Plant Diversity (PD); Plant Species Abundance (PSA); Basal Area (BA); Stem Density (SD); Shrub Cover (SC) and Canopy Cover (CC). The parameters mentioned above were recorded in 60 sampling plots in two habitats.

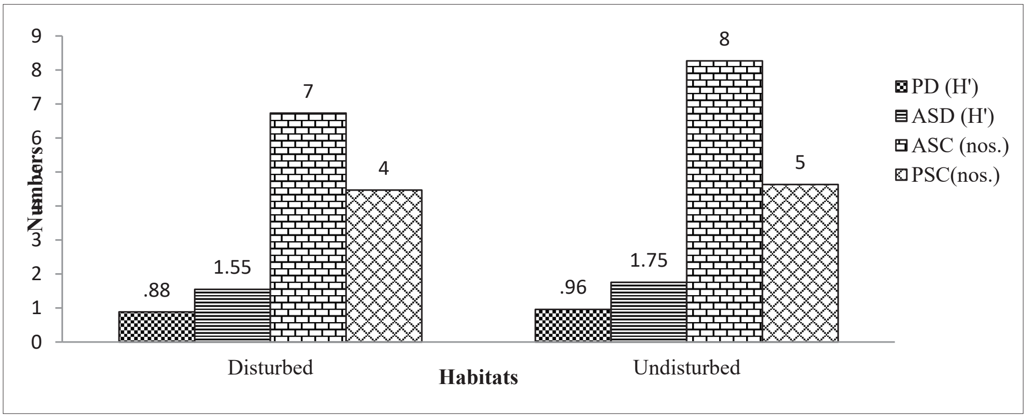

Figure 2: Relationship between PD, PSC, ASC, and ASD in two habitat types

Data analysis

Data were analyzed using Microsoft Excel 2010 and SPSS (Statistical Package for Social Science, version 23.0). The Geographic Information System (GIS) software Arc GIS10.2.2 was used for the production of maps. Shannon-Wiener Diversity Index formula (*$H'=-\sum_{i=1}^{N} pi \ln pi$, Where P_i = Number of individual of one species/Total number of all individual. Where, $P_i = n_i/N$, n_i = the number of individuals in species i, the abundance of species, N = total number of individuals in all species; S = the number of species which is also called species richness; P_i =the relative abundance of each species, or proportion)* was used in both plant and avian species diversity at the plot (transect) level.

Inferential and descriptive statistics were used to analyze quantitative data on avian diversity. Correlation was performed to determine the relationship between the habitats on avian species composition and diversity in the disturbed and undisturbed forests. In order to analyze the influence of vegetation parameters on avian species composition and diversity, Mann-Whitney Test were performed after performing the data normality test. The result was reported by presenting the probability (*p* values) of the null hypothesis being true at a significance level α = .05.

Result

Plant diversity in the combined quadrants (Shannon-Wiener diversity index) varied from a minimum of 0.04 to maximum of 1.58 and plant species richness (trees and shrubs) varied from the minimum of two species to the maximum of nine species per quadrant in the two habitats of GFMU. The lowest plant composition was recorded in plot number 44 and the highest composition was recorded in plot number 57 in the undisturbed habitat. The highest mean ASC, PSC, ASD, and PD in disturbed and undisturbed habitats are represented in (Figure 2).

Overall, our survey in undisturbed habitat revealed significant associations between plant diversity and avian diversity (r_s=0.36, p = 0.051) probably because PD and ASD depend on each other.

In disturbed habitat, associations between PD and ASC, PSC, and ASD, and PSC and ASC were not significant (r_s= -0.19, p = 0.304), (r_s= -0.05, p = 0.780), (r_s= -0.15, p =0.433). Similarly, a correlation analysis performed for undisturbed habitat also revealed statistically

Table 1: Spearman Correlation (r_s) test indicating relationship between vegetation parameters, ASR & ASD in disturbed habitat. [Avian Species Composition (ASC), Avian Species Diversity (ASD): Plant Diversity (PD); Plant Species Abundance (PSA); Basal Area (BA); Stem Density (SD); Shrub Cover (SC) and Canopy Cover (CC).]

	PD	**ASD**	**Alt**	**ASR**	**ASC**	**PSC**	**BA**	**SD**	**CC%**	**SC%**
PD	1.00	.36	-.04	.07	-.19	.34	.06	.36*	.45*	-.05
ASD		1.00	.05	.83**	.54**	-.05	-.29	-.23	.18	.05
Alt			1.00	-.01	-.00	-.71**	.30	.04	.38*	.98**
ASR				1.00	.73**	-.19	-.37*	-.34	-.05	.02
ASC					1.00	-.15	-.37*	-.41*	-.24	.05
PSC						1.00	-.18	.23	-.13	-.73**
BA							1.00	.57**	.16	.29
SD								1.00	.25	.04
CC%									1.00	.34
SC%										1.00

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 2: Spearman Correlation (r_s) test indicating relationship between vegetation parameters, ASR & ASD in undisturbed habitat. [Avian Species Composition (ASC), Avian Species Diversity (ASD): Plant Diversity (PD); Plant Species Abundance (PSA); Basal Area (BA); Stem Density (SD); Shrub Cover (SC) and Canopy Cover (CC).]

	PD	ASD	Alt	ASR	ASC	PSC	BA	SD	CC%	SC%
PD	1.00	.27	.60**	.35	.39*	.88**	.02	-.03	.31	.67**
ASD		1.00	.24	.78**	.59**	.18	-.11	.21	.46*	.43*
Alt			1.00	.59**	.29	.57**	-.28	.09	.40*	.59**
ASR				1.00	.81**	.34	-.11	-.01	.48**	.59**
ASC					1.00	.47**	.00	-.10	.43*	.69**
PSC						1.00	-.04	-.09	.25	.57**
BA							1.00	.32	.00	.12
SD								1.00	.08	-.04
CC%									1.00	.67**
SC%										1.00

*. Correlation is significant at the 0.01 level (2-tailed).
**. Correlation is significant at the 0.05 level (2-tailed).

non-significant relationship between PD and ASD (r_s= 0.27, p = 0.157), and PSC and ASD (r_s= 0.18, p = 0.352).It was also revealed non-significant associations among PD and ASC; PSC and ASC; PD and ASD in undisturbed habitat (r_s= 0.39*, p = 0.033), (r_s= 0.47**, p = 0.008) and (r_s= 0.35**, p = 0.006).

Vegetation parameters: Their relationship with avian species composition and diversity

In total, 51 species of trees and shrubs were recorded in the study area. The PD at each plot with uniform distance of 200 m varied irregularly from 0.04 to 1.58 species (*M* = 0.92, *SD* = 0.36). PSC varied a minimum of two to a maximum of nine species (*M* = 4.55, *SD* = 1.53). Similarly, BA varied from 0.50 to 40.98 m^2/ha (*M* = 16.07, *SD* = 7.63). Stem density (SD) varied from 125 to 1150 stems per hectare (*M* = 509.58, *SD* = 216.83). Likewise, SC varied from 0 to 88 % (*M* = 39.15, *SD* = 18.78) and CC varied from <25 to >75 %. The PSC recorded in disturbed habitat was 31 species and 20 species in the undisturbed habitat. The relationship between the vegetation parameters, ASC and ASD in disturbed and undisturbed habitat are shown in Table 1 and Table 2, respectively.

Effect of stem density on avian species richness and diversity

The stem density (SD) varied from 125 to 1150 stems per hectare with the mean density of 600 stems per hectare as shown (Table 2). The correlation analysis showed the negatively significant relationship between SD and ASC in disturbed habitat (r_s= -0.41*, p =0.023). No relationship was found between SD and ASD (r_s= -0.23, p = 0.220). The SD was found to have non-significant association with ASC (r_s= -0.10, p = 0.583) and an inverse non-significant association between SD and ASD (r_s= 0.21, p = 0.265) in undisturbed habitat.

Table 3: Relationship between SD, mean ASC and ASD

	SD	ASD	ASC
Disturbed	382	1.55	7
Undisturbed	638	1.75	8

The correlation analysis showed a negatively significant relationship between stem density and bird species composition in disturbed habitat. It was found that SD increases while ASC decreases and vice-versa in this particular habitat. This concludes that more extraction of forest resources from a habitat can hamper the ASC in that particular habitat.

Comparison of avian species between disturbed and undisturbed habitat

A total of 71 avian species belonging to 28 families were recorded from all point count stations in two habitats of GFMU. Out of 28 families recorded, *Muscicapidae* was represented by the most species (9) followed by *Corvidae* (7) and the least was *Upupidae* (1). Fewer bird species were observed in the disturbed forest (n = 45) than in the undisturbed forest (n = 68). The Avian Species Richness (ASR) observed in the two habitats varied from a minimum of five to a maximum of 11 species with an average of nine species per habitat. Undisturbed habitat had higher mean Avian Species Diversity (ASD) and Avian Species Abundance (ASA) (Table 4). The differences in ASD and ASA could be due to the short study duration (one winter season).

Table 4: Difference in mean ASD, ASR and ASA between the two habitat types

Habitat Type	Disturbed	Undisturbed
ASD (H')	2.85	2.95
ASR (S)	15	22
ASA (No.)	809	1155

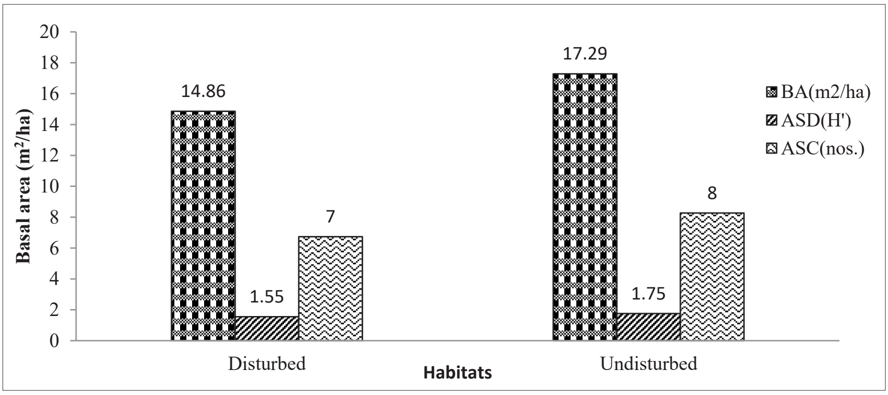

Figure 3: Relationship between BA, mean ASC, and ASD

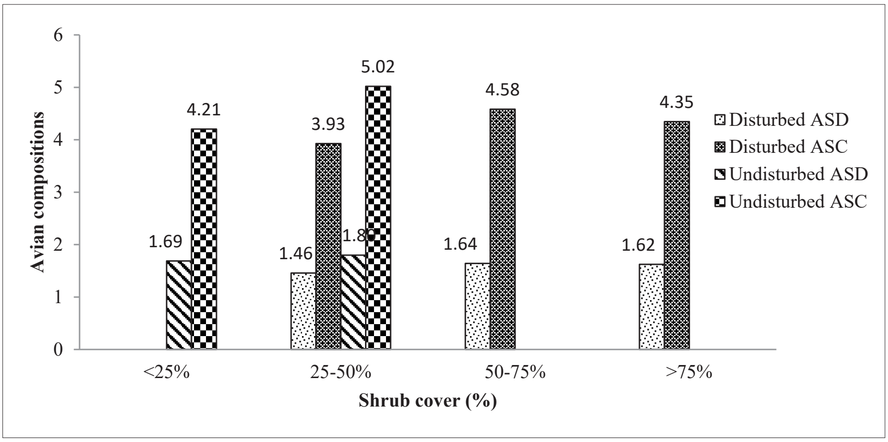

Figure 4: Relationship between SC, mean ASC, and ASD

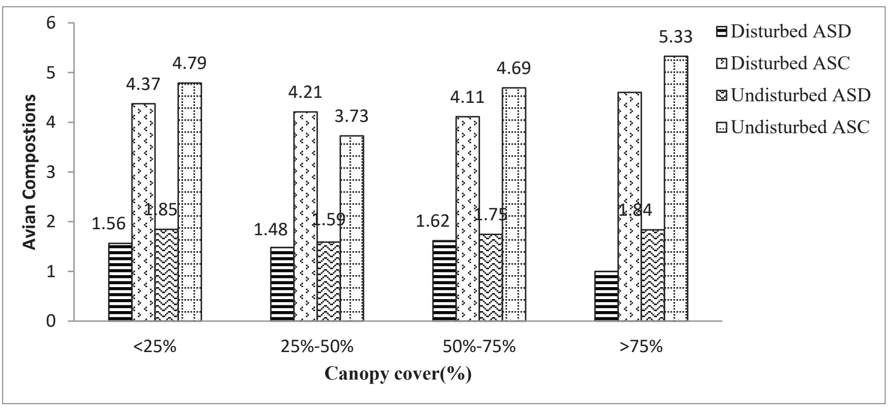

Figure 5: Relationship between CC, mean ASC, and ASD

The results indicate that ASD, ASR, and Avian Species Abundance (ASA) are extensively higher in an undisturbed habitat than a disturbed habitat.

Effect of the basal area on avian species richness and diversity

Basal area (BA) varied from 0.50 m^2 per hectare to 40.98 m^2 per hectare in both the habitats with a mean of 16.07 m^2 per hectare (n = 60). The highest BA was recorded in the undisturbed forest with 17.29 m per hectare and the lowest in the disturbed forest with 14.86 m^2 per hectare (Figure 3).

The BA shows both negative correlations with ASD and ASC for both the habitats, though it is non-significant. The correlation analysis between BA, ASD, and ASC in disturbed habitat showed non-significant association (r_s= -0.29, p = 0.125) and showed significant association (r_s= -0.37, p = 0.042) respectively. Similarly, undisturbed habitat revealed non-significant relationship between BA, ASD and ASC (r_s= -0.11, p = 0.551) and (r_s= 0.00, p = 0.995) respectively.

Effect of shrub cover on avian species composition and diversity

The shrub cover (SC) varied from a minimum of zero to a maximum of 88%, with a mean cover of 39.15% in the study area (Figure 4).

The correlation analysis between SC, ASC, and ASD in disturbed habitat shows a non-significant association (r_s = .05, p = .778) and (r_s = .05, p = .795), respectively. Whereas, in undisturbed habitat, SC showed strong significant association with ASC and ASD (r_s= .69**, p = .001) and (r_s = .43*, p = .017) respectively. The shrub cover was found to have a negatively non-significant correlation with avian species diversity and avian species composition (r_s= -.08, p = .542) and (r_s= -.01, p = .944) respectively, as compared between both habitats (Table 4)

Effect of canopy cover on avian species richness and diversity

The Canopy Cover (CC) of the study area varied from a minimum of 5% to a maximum of 90% with a mean cover of 46.58%. The highest canopy cover was recorded in the undisturbed forest with 90% and the least in disturbed forest mixed with agriculture field and settlement with 5% (**Figure 5**).

The correlation analysis showed non-significant relationship between Canopy Cover (CC) and ASC (r_s = -0.24, p = 0.197) and ASD (r_s = 0.18, p = 0.351) in disturbed forest. Whereas, in undisturbed forest, CC was significantly associated with ASC and ASD (r_s = 0.43*, p = 0.017) (r_s = 0.46*, p = 0.022) respectively.

Discussion

According to Bopearachchi and Wickramasinghe (2015), vegetation composition, structure and microclimate variables are some of the other factors that affect the distribution and diversity of the avian species (Zakaria and Rajpar, 2013). Our finding correlates with findings of Khanaposhtani *et al.* (2012), that ASR and ASA are significantly higher in undisturbed habitat than in disturbed habitat in the GFMU.

The reason could be that large trees benefit birds by offering nesting sites for crater nesters and abundant resources in bark, dead woody tissues, and in the dense epiphytic layer that covers most of the tall branches for birds such as arthropods (Diaz *et al*., 2005). Sheldon *et al*. (2010) also found that it is easier to get an abundant source of food in high stand density as compared to low stand density. Moreover, a forest with thick and taller undergrowth essentially upheld various and rich flying creature groups (Laiolo, 2004). In addition, a closed canopy gap in an undisturbed forest increases the nesting site for some upper story avian (Powell and Steidl, 2000) as some prefer nesting in closed canopy to hide from predators (Alderton, 2008).

On the other hand, the disturbed habitat was found with lower ASD, ASR, and ASA. A prominent reason for this might be due to the use of heavy machinery for extraction of timbers and other logging activities in the habitat, creating an unpleasant foraging environment for the birds. The diminished habitat in vegetative areas is likely to be due to food scarcity and subsequently reduced and inappropriate breeding areas. Avian-species diversity naturally falls with increasing disturbance, partly for the reasons mentioned above (Francl and Schnell, 2002). This finding was consistent with Chaves *et al*. (2012) who also found that forest logging causes habitat disintegration and reduces nutrient availability leading to a change in the structure, composition of the forest, and microclimate, and thus affecting avian diversity. A study by Díaz *et al*. (2005) concluded that the forest logging practices created large areas of juvenile forests missing the composition and structural elements needed by some avian species. This was supported by Laiolo (2004) who found that the forests avifaunal are sensitive to overexploitation of their habitats; species diversity was significantly lower in the heavily disturbed forest. This similarity is probably an effect of the comparable degree of disturbance, availability of food sources, and forest vegetation at each of the study sites. According to Sethy *et al*. (2015), the variation in species diversity and species composition in a disturbed habitat may be due to the influx of visitors, vehicles, and local people and the lack of food.

The non-significant association finding (Figure 2) of this study is in contrast with the findings of Acharya *et al*. (2011), who found that ASC, ASD, PSC, and PD were positively and strongly associated with plant species richness in disturbed habitat. The finding of this study agrees with Joshi *et al*. (2012) who observed a significant correlation between plant species composition and avian species diversity with (r = .95), and the study conducted by Acharya *et al*. (2011) also found that the bird species richness and diversity to be positively and strongly interrelated with plant species richness. This difference could be due to diverse strata composition and more breeding sites for avian nesting. The results are probably a consequence of the differences in the level of disturbance between the two habitats. This finding is in line with findings of Wimalasekara and Wickramasinghe (2014) and Marsden (1998), who stated ASD, ASR and ASA are significantly higher in the undisturbed forest as compared to disturbed forest. The result of Dawson *et al.* (2011) also stated that the highest avian diversity based on the Shannon-Wiener index was observed in undisturbed habitat.

Waterhouse *et al*. (2002), in his short study duration on a similar topic, also perceived that the avian species composition and diversity did not differ significantly between different habitats due to similar vegetation. The higher avian diversity in an undisturbed forested area is also accorded to a greater diversity of plant species composition. Sethy *et al*. (2015) pointed out that bird abundance and its diversity rise with an increase in sufficient food accessibility. The higher abundance of birds in undisturbed habitat could be due to the composition of the vegetation that forms the main element of their habitat.

The findings in Figure 3 show that both avian species richness and avian species diversity were independent of basal area. It is in contrast with findings of Acharya *et al*. (2011), who stated that there is a strong correlation between avian species richness with shrub density, plant species composition, and basal area of the trees. Diaz *et al.* (2004) support a similar finding, that there is a strong influence of local forest stand structure on avian species richness and abundance, mainly for large-tree users and terrestrial understory birds. While, Willson and Comet (1996) found that the habitat heterogeneity and productivity are strongly correlated with avian species diversity and abundance at various geographical scales.

Sekercioglu (2002) reported having a significant correlation between forest stand structure and avian species richness. The independence of avian species on the basal area might be the seasonal shifts in habitat use by forest bird species that increased their use of forested habitat during the breeding season (Bowen *et al*., 2007). The association between basal area and avian species composition and diversity was not significant and this result could be attributed to the study period being just one winter season.

The findings of this study is also in contrast with the findings of Acharya *et al*. (2011) onavian species richness and diversity being positively and strongly correlated with habitat variables such as shrub cover, plant species composition, and basal area of the trees. It is also in contrast with the findings of Diaz (2005) that showed diverse undergrowth of shrub layer encouraged higher avian species richness and abundance. Moreover, Ghosh *et al*. (2011) also found that there was a general shift to lower foraging heights during winter, mainly to adjust with changes in habitat composition and reduced food availability.

On another hand, in undisturbed habitat, the Spearman Correlation (SC) correlation analysis (Table 1 and 2) showed a significantly strong positive association with ASC and ASD. This finding is in line with the findings of Batary *et al*. (2014) where avian diversity including ground-breeding birds increased in numbers where a higher percentage of shrub cover exists. This was because higher percentages of shrub cover can provide better food supply and shelter for the birds. The same finding was supported by Daiz *et al*. (2004) as they too found that higher avian diversity was connected with greater availability of canopy developing trees with different shrub undergrowth. According to Batary *et al*. (2014), avian richness, abundance, and diversity were higher at forest edges where different habitats shrub adjoined with mature forest stand. So, SC influenced the ASD and ASC in undisturbed habitat because it provides good food source for the avian species that depend on the undergrowth.

The correlation analysis (Figure 5) in disturbed habitat showed a non-significant association between CC, ASC, and ASD. This finding is in line with the findings of Chettri *et al*. (2001) whose study found that both avian species richness and diversity were higher in an open canopy condition as compared to closed canopy forest even though the differences were statistically non-significant. This finding state that CC does not have much implication on the species composition;

diversity shows an inverse relation with CC. Schneider *et al.* (2012) have also shared a similar finding that the decrease in canopy cover confronts birds with a higher degree of edge habitats and the negative effects linked to diversity.

On the contrary, in undisturbed forest, CC showed a positive significant association with ASC and ASD. This finding is in line with findings of Chettri *et al*. (2005) and Laiolo (2003) where it was reported that forest with dense and taller undergrowth significantly supported diverse and rich avian community compared to heavily utilized forest stand with poor undergrowth. Daiz *et al*. (2005) also found that bird density was higher with greater availability of canopy emergent trees with various undergrowth shrubs. At the stand scale, results of Khanaposhtani *et al*. (2012) also revealed that avian abundance and richness are strongly associated with the complexity of vegetation structure. Closed canopy forests with relatively undisturbed habitat showed significant variation in habitat attributes, suggesting the complexity of habitat structure. Since the study was conducted during the non-breeding season, the relationship between canopy cover, avian species composition and diversity revealed a significant relationship in disturbed habitat.

The correlation analysis (Table 3) showed a negatively significant relationship between stem density and bird species composition in disturbed habitat. The reason is that when SD increases, ASC decreases and vice-versa in that particular habitat as more extraction of forest resources from the habitat can hamper the ASC in that particular habitat. This finding is in line with the findings of Acharya *et al*. (2011) who reported that there is a strong correlation between avian species richness with stem density, plant species composition and basal area of the trees. Sompud *et al*. (2016) reported similar findings, where the avian species increase with stems density.

Further, Willson and Comet, (1996) also supported that; habitat heterogeneity and productivity were strongly correlated with avian species diversity and abundance at various geographical scales. However, the finding is in contrast with the findings of Bowen *et al*. (2007), who observed a seasonal shift in habitat use with the increased use of forested habitat during the breeding season.

Conclusion

The study on avifaunal diversity in two habitats of Gogona Forest Management Unit found that there is not much difference in Avian Species Diversity (ASD) between the two habitat types. However, undisturbed habitat has a slightly higher avian richness and abundance as compared to disturbed habitat. It could be due to a single season data from a short study period of one winter month, which might have overlooked avian species diversity and species composition, providing poorer results. Similar studies with longer field research periods would yield better results in the future. A year-long (all four seasons) period to study the diversity of avifaunal in the FMU might generate reliable and representative avian diversity data for the FMU. Biotic and abiotic factors are the main determinants for avifauna diversity within the current FMU beside vegetation parameters. Biotic factors alone cannot conclude the overall ecology of avian fauna within the FMU. So, abiotic factor should be considered in future in order to understand the long-term population ecology of the avifauna within the FMU.

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2. First record of the Hawkmoth *Theretra lycetus* (Cramer, 1775) (Sphinidae: Macroglossinae) from Bhutan
3. First Record of Common Goldeneye *Bucephala clangula* for Bhutan

Whiskered Tern *Chlidonias hybrid*: first record for Bhutan and many more.

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3. First Record of Common Goldeneye *Bucephala clangula* for Bhutan, 2019.
4. Butterfly Visitors to Two invasive Plants in the Indian and Bhutanese Himalaya, 2020,
5. New Herpetofaunal Records from the Kingdom of Bhutan Obtained through Citizen Science, 2020,

6. Predation by the Wolf snake *Lycodon aulicus (Linnaeus, 1758) on the House Gecko Hemidactylus frenatus* Dumeril & Bibron, 1836 in Tsirang District, Kingdom of Bhutan, 2021.
7. First confirmed record of Caecilians (Amphibia: Gymnophiona) from the Himalayan Kingdom of Bhutan,2021.