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The response of bird communities to forest loss in the district Swat Khyber Pakhtunkhwa, Pakistan

Atta Ullah[1]*, Khurshaid Khan[1] & Nehafta Bibi[2]

[1]Department of Zoology Abdul Wali Khan University Mardan - Pakistan
[2]Government Girls Degree College Mansehra - Pakistan

*corresponding author: attakhan_154@yahoo.com

AU 0000-0003-1901-8422

Abstract - This study examines how avifauna reacts to the loss of forest cover in Swat Khyber Pakhtunkhwa, Pakistan. Birds play a key role in the ecosystem, but in disturbed areas their roles may be limited due to the changes of their natural habitats. We sampled birds in disturbed and undisturbed sites using a fixed radius point counting method. It was revealed that the species richness and abundance of bird species varied significantly between disturbed and undisturbed sites, and that this difference was related to the disturbance indices measured. The results showed that in total, 85 species of birds from 38 families were observed in the 16 sampling sites. Ardeidae (14 species, n = 178) had the greatest abundance and species richness. Twenty of the 85 locally abundant bird species (23.5%) responded significantly to the disturbance regime, resulting in changes in bird species composition. Five vegetation structure variables, including two that were substantially changed by disturbance, were found to be significantly correlated with bird species composition. All changes in bird species composition caused by disturbances are due to changes in vegetation structure. The loss of forest cover, on the other hand, has a negative effect on the diversity of frugivorous and particularly insectivorous species. Our study demonstrated the widespread effect of forest loss on bird communities in one of the most important hotspots for bird conservation and shows that many vulnerable species require extensive forest cover to persist.

Keywords: Birds composition, diversity, vegetation structure, forest loss, Pakistan

INTRODUCTION

Humans have caused irreversible alterations in the world's ecosystems. The demand for food and other resources by the planet's 7.6 billion people puts immense pressure on the planet's land and aquatic habitats (McConkey 2020). As the world's population grew, so did the resources required to support it. Agricultural productivity has increased in parallel with humanity's population rise throughout history. Unfortunately, the more the population, the more land is necessary for crop cultivation and animal farming. With a present global population of 7 billion people, agriculture accounts for 37 % surface on the planet (12 % crops and 25 % livestock) (Brain & Anderson 2020). The size, expansion, and resource demands of the human population are currently the most important agents of change in much of biodiversity. With rising population and wealth-driven per capita consumption, demand for fuel, food, and fibers is on the rise (Grooten & Almond

2018). Wild animal populations have declined by an estimated 50 to 60 % on average during the last 40 years (Stein et al., 2018).

In the last three decades, humans have had a major impact at some different ecological scales, including the landscape one (Karanth & DeFries 2010). For instance, in developing countries natural land is often converted for the purpose of agricultural expansion and urbanization (LeBlois et al., 2017). Since a large number of species have unique habitat requirements for breeding and other life activities, they are sensitive to human-caused disturbances (MacGregor-Fors et al., 2009). Bird abundance and diversity in disturbed habitats have declined. In North America, these declines have been more severe and common than those of species associated with less frequently disturbed habitats such as mature or closed-canopy forests (Brawn et al., 2001). The loss of animals from seemingly healthy wooded ecosystems can have serious immediate and long-term consequences. This is partly owing to the disturbance that these losses have on the key interactions that keep these ecosystems functioning. (McConkey 2020). However, it is unknown which attribute of habitat change influences the various components of bird diversity (Hill & Hamer 2004). However, since the current literature reports fragmented and sometime contradictory findings, the responses of bird communities to various disturbed environments (e.g., crop fields, grazing lands, and urban settlements) are not completely understood. Crop fields, for example, do not often have more diverse and complex bird assemblages than grazing lands (e.g. Morris 2000).

We studied the diversity, abundance and species composition of bird communities in the Swat district, a mountainous region of Pakistan, while characterizing the vegetation structure with respect to the attributes of trees, understory vegetation (consisting of shrubs and trees) and herbaceous soil layers. Our aims were: (i) to identify what changes in forest vegetation structure mediate changes in avifauna; (ii) to understand how disturbances caused by forest loss affect bird diversity and composition.

MATERIALS AND METHODS

Study area

The research was carried out from March 2019 to June 2020 in the Swat district, a mountainous area of Khyber Pakhtunkhwa province in Pakistan, which consists of numerous valleys with scrub and/or coniferous forests on the upper slopes and alpine pastures on the ridges (Fig. 1). The district is situated between 34 ° -40 ′ and 35 ° N latitude and 72 ′ to 74 ° -6′E longitude, with altitude ranging from 500 to 6500 m above sea level. Total area is about 5337 square kilometers. The average annual temperature is 19.3 °C, with an average annual precipitation of 894 mm. Annual deforestation rates in the district's various zones are 1.86 % (Scrub Forest Zone), 1.28 % (Agro-Forest Zone), and 0.80 % (Pine Forest Zone). Agriculture has expanded mostly at the expense of forest lands, with only minor accounts of afforestation between 1968 and 2007. A decline in forests and a rise in agriculture and built-up areas were found in the spatial and temporal database used to measure overall trends in changes in landscape structure (Qasim et al., 2011). The study area was chosen based on the following characteristics. First, the area has the highest cover of temperate coniferous forest, which, as previously mentioned, is under threat of deforestation. Second, despite having important commercial forest resources, Swat is one of the poorest regions in Pakistan.

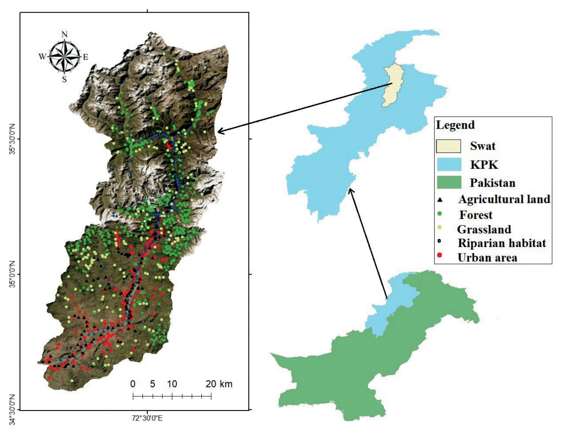

Figure 1. Map of district Swat Khyber Pakhtunkhwa, Pakistan showing administrative details and site of the study area.

Birds and habitat survey

We compared resident avifaunal diversity and composition (as well as forest vegetation structure) between sites facing a high pressure of forest loss and those that are better protected and currently face little or no pressure (hence referred to as “disturbed” and “undisturbed sites,”, respectively). Sixteen study sites along a gradient of disturbance were selected, based on detailed discussions with park staff and village peoples in addition to our visual assessments of human use over 6 years. We counted birds twice a month in each of the 16 sites between March 2019 and June 2020. A fixed radius point counting method was used to count the birds (Shankar 2003). Within a 10-minute span, three observers reported all the birds they heard or saw within a 10-meter radius. Using 8×40 binoculars and field identification guidelines (Bebby et al., 2000). Migrant birds in flight were exclude and were not recorded. According to their feeding habits, the birds were divided into eight groups: Omnivorous, insectivorous, carnivorous, Granivorous, Frugivorous, Piscivorous, Scavengers and Nectarivorous. Moreover, we characterize the vegetation at each site with respect to 12 separate variables that refer to the structure of trees, shrubs, and herbs, as well as underground vegetation. We measured the following variables: percent canopy cover, forest density, number of tree species, basal area of trees, average height of trees, density of shrubs, number of shrub species, percent area covered by shrubs, average height of shrubs, grass density (using a densimeter), percent of field area covered with grass and percent of bare ground area. In each site, each of the 12 measured vegetation composition variables was averaged over two circular plots. This was the average value used in all subsequent analysis for each of the 16 sample sites (see Tab. 1 and 2). With the aid of an instantaneous densitometer, we measured canopy cover as the presence or absence of overhead vegetation at every 10-m interval with two mutually perpendicular diameters within each 10-m-radius circular plot. The number of points where overhead vegetation was registered determined the canopy cover quantitative ratio for that plot. Samples of plants collected in each site were identified in the herbaria at the Department of Botany, Abdul Wali Khan University Mardan Pakistan.

Data analysis

Bird abundance, cumulative species richness and Shannon-Wiener diversity index (Faria et al., 2007) were calculated for each surveyed site, and compared between disturbed and undisturbed sites using non-parametric Kruskal–Wallis tests for difference in means (Sokal & Rohlf 1981). Each of the 12 studied structural attributes of vegetation was compared between disturbed and undisturbed sites using non-parametric Kruskal–Wallis tests of difference to investigate the effects of disturbance on specific attributes of forest structure. To compare the plant composition of disturbed and undisturbed sites, Kruskal – Wallis tests were used. The impact of various vegetative structural changes as well as disturbance indices on the composition of bird populations, including those that were not observed to be significantly different between disturbed and disturbed locations, were studied using Mantel's tests. Partially Mantel test were used to examine the cumulative impact of disruptions and changes in vegetation structure on the composition of bird populations (McCune et al., 2002). Partial Mantel’s test calculates the association between two distance matrices while taking into account a third. We used partial Mantel’s tests to explore the association between (1) overall bird species composition with vegetation structure while accounting for disturbance index and (2) overall bird species composition with disturbance index while accounting for vegetation structure

RESULTS

Bird composition

At the 16 sampling sites, we found 1,193 individual birds belonging to 85 specie and 38 families (Appendix 1). The most abundant and diverse families

Table 1. Values of structural variables related to the trees and scrubs forest for 16 sites. CDF: Coniferous dominated forest, SF: Scrubs Forest.

Site	% canopy cover	No of trees	No of trees species	Basal area of trees	Average height of trees
CDF					
C1	12.345	12	6	0.54	6.452
C2	29.456	21	4	0.78	7
C3	8.267	24	5	0.43	5.435
C4	13.333	18	4	0.93	10.128
C5	72.543	52	8	1.4	8.333
C6	74.768	47	6	1.8	5.771
C7	87.233	70	10	2.6	11.324
C8	89.711	44	9	2.3	13.777
SF					
S1	11.67	12.00	9.00	0.32	3.53
S2	1.33	8.00	2.00	0.52	3.67
S3	2.78	13.00	5.00	0.21	3.55
S4	11.67	14.00	7.00	2.07	5.25
S5	3.17	6.00	10.00	0.39	5.07
S6	11.67	13.00	9.00	0.68	3.33
S7	40.43	14.00	8.00	1.73	6.18
S8	52.33	11.00	8.00	1.18	8.24

Table 2. Values of structural variables associated with the forest understory. CDF: Coniferous dominated forest, SF: Scrubs Forest.

Sites	Shrub abundance	Shrub sp no	% of ground area covered by shrub	Average height of shrub	Herb sp no	% of ground area covered by herbs	% of ground area which were bare
CDF							
C1	12.00	2.00	10.47	103.53	6.00	23.24	55.71
C2	20.00	6.00	18.37	116.36	5.00	17.28	85.71
C3	38.00	10.00	52.65	137.21	4.00	17.26	70.33
C4	5.00	4.00	6.67	113.87	2.00	14.77	84.86
C5	3.00	2.00	1.87	106.53	9.00	37.37	40.63
C6	42.00	10.00	50.66	143.65	2.00	9.15	87.83
C7	40.00	8.00	14.27	122.45	7.00	20.21	60.68
C8	45.00	8.00	72.59	118.93	1.00	8.30	76.21
SF							
S1	21.00	5.00	22.33	112.67	5.00	23.93	61.67
S2	79.00	3.00	24.89	104.79	6.00	30.67	60.45
S3	68.00	7.00	12.42	120.89	9.00	26.58	68.68
S4	20.00	3.00	26.65	123.09	8.00	33.77	45.25
S5	37.00	8.00	37.91	135.34	9.00	24.68	54.81
S6	23.00	5.00	27.66	112.34	7.00	12.66	72.71
S7	82.00	6.00	33.78	102.72	4.00	30.82	33.63
S8	7.00	3.00	6.71	104.00	3.00	30.54	67.19

were Ardeidae (14 species, n = 178), Columbidae (11 species, n = 134), and Phasianidae (5 species, n = 99). *Passer domesticus* (n = 117), *Passer rutilans* (n = 88), and *Coturnix coromandelica* (n = 30) were the most abundant species, with only three individuals reported for each of the five species (*Sturnus vulgaris, Trochalopteron lineatum, Ploceus philippinus, Phaethon aethereus, Psittacula krameri*). These birds were also seen in landscapes with a dense canopy. Species like *Alectoris chukar, Francolinus francolinus*, and *Coturnix coromandelica*, on the other hand, were commonly seen in habitats with varying levels of vegetation cover.

The majority of species described are omnivorous (24), followed by insectivorous (20), carnivores (18), granivorous (9), and frugivorous (7). The bird species diversity in the forested land was distinct from that of other ecosystems. The variations in guild composition between open-canopy areas (agricultural land, grassland, urban environment, riparian habitat) and closed-canopy areas (forest) revealed that agricultural land was a transition zone between forest and grassland, making it the second most common habitat for bird nesting, foraging, and breeding after forests. Species that were not present in bird communities in different habitats allow comparisons of habitat function. Omnivores and insectivores dominate the species composition in general. Since the other trophic guilds were underrepresented (Fig. 2), they were excluded from the analysis.

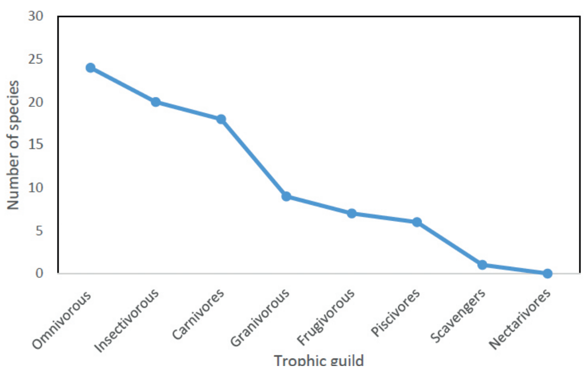

Figure 2. Number of species according to trophic guild.

The effect of declining forest cover on the bird population

Fig. 3 compare the total bird abundance, number of species reported, and bird diversity in disturbed and undisturbed areas. The Shannon - Wiener diversity index of birds was higher in undisturbed areas (3.315) than in disturbed sites (3.142). According to Kruskal–Wallis tests, the abundance of birds at disturbed and undisturbed sites differs significantly (χ^2= 8.7432, P = 0.0031, d.f. = 1) see appendix 2. However, in comparison to disturbed sites, the bird diversity index calculated by Shannon - Wiener diversity index was not significantly higher in undisturbed sites (χ^2= 0.9794, P = 0.3224, d.f. = 1). The species-level analysis contained 85 species in all. Just four species showed a significant preference for disturbed sites (Tab. 3). Sixteen species, on the other hand, shows a significant preference for undisturbed sites. There was no significant selection for any disturbance regime in the remaining 65 species.

The effect of disturbance on vegetation's structural characteristics

The vegetation structural attributes for the 16 sites are listed in (Tab. 1 and 2). The Kruskal–Wallis tests were used to analyze the effect of disruption on the structural characteristics of plants, and the findings are shown in (Tab. 3). In addition to undisturbed sites, percentage canopy cover, basal area of trees, and average height of trees were significantly lower in disturbed sites (percentage canopy cover 2 = 12.3, P = 0.0001, basal area of trees 2 = 5.4, P = 0.012, average height of trees 2 = 7.56, P = 0.010). There were no significant differences in tree density or tree species diversity between disturbed and undisturbed sites (Tab. 4). No significant differences in the structural characteristics of the understory shrub layer or herbaceous ground layer assessed between disturbed and undisturbed areas.

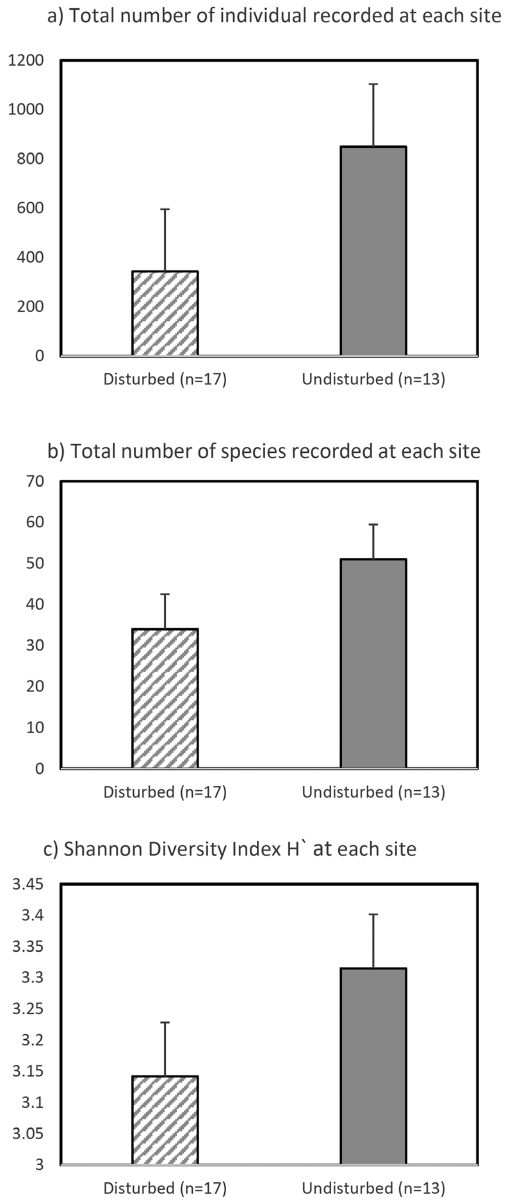

Figure 3. Abundance (a), species richness (b) and Shannon diversity (c) of birds in disturbed (n = 17) and undisturbed (n = 13) sites in the study area. The bar plots depict mean ± SEM.

Table 3. Results of a comparison of disturbed (n = 7) and undisturbed (n = 9) sites for bird indicator species. D = disturbed sites; U = undisturbed sites. Only those species with significant indication value (P < 0.05) are shown.

Scientific name	**Preferred disturbance regime**	**Indication value**	**P-value**
Chalcophaps indica	U	90.2	0.0003
Columba rupestris	U	51.4	0.02
Coracias garrulus	U	48.3	0.02
Upupa epops	U	72	0.001
Alectoris chukar	U	67	0.001
Francolinus francolinus	U	42.2	0.02
Francolinus pondicerianus	U	66.2	0.001
Turnix suscitator	U	87	0.0003
Gallicrex cinerea	U	89.4	0.0003
Pericrocotus erythropygius	D	27.4	0.05
Trochalopteron lineatum	D	22.4	0.05
Emberiza stewarti	D	19	0.05
Copsychus saularis	U	54.3	0.02
Parus cinereus	U	77	0.001
Chloris spinoides	U	93	0.0003
Certhia himalayana	U	44.3	0.02
Motacilla cinerea	D	25.3	0.05
Corvus corone	U	62.3	0.001
Pelecanus crispus	U	67	0.001
Psittacula cyanocephala	U	96.1	0.0003

Table 4. Results of Kruskal–Wallis tests for assessing differences in vegetation structure between disturbed (n = 7) and undisturbed sites (n = 9). *Significant at 0.1%, **Significant at 1%, ***Significant at 5%.

Variable	Habitats	χ^2	P-value
% canopy cover	U	12.3*	0.0001
Tree density	U	2.04	0.137
No. of tree spp	U	0.80	0.400
Basal area of trees	U	5.4**	0.012
Average height of trees	U	7.56***	0.010
Density of shrub	U	1.03	0.310
No. of shrub species	D	0.06	0.666
% area covered by shrubs	U	0.005	0.760
Average height of shrubs	D	0.36	0.444
Herbs density	D	1.4	0.235
% of ground area covered with grass	D	1.87	0.165
% of ground area that were bare	U	0.20	0.600

Table 5. Results of simple Mantel's tests for the effect of vegetation structural variables on bird species composition across 16 sites in district Swat. *Significant at 0.1%.

Variable	R statistic	P-value
% canopy cover	0.450*	0.0001
Tree density	0.335*	0.001
No. of tree spp	0.082	0.195
Tree basal area	0.015	0.365
Average height of trees	0.435*	0.0001
Shrub density	0.016	0.300
No. of shrub species	0.072	0.177
% of ground area covered by shrubs	0.002	0.440
Average height of shrubs	0.040	0.408
Herbs density	0.181*	0.008
% of ground area covered by grass	0.162*	0.006
% of ground area that were bare	0.077	0.140

Effects of vegetation structure on the composition of bird species

The composition of bird species is highly significant compared to percentage canopy cover, tree density, and average tree height, according to simple Mantel tests for the effects of single variables on bird species composition. Grass cover has a direct impact on the composition of bird species (Tab. 5).

Combined model: the impact of disturbance and vegetation structure on the composition of bird species

With the disturbance indices taken into account, partial Mantel tests for correlation between bird species composition and vegetation structure yielded a correlation coefficient of 0.176, which was significant at P = 0.040. (Tab. 6). The partial Mantel's test for bird species composition and disturbance indices, which took vegetation structure into account, yielded a R of 0.058, which was not significant (P = 0.221; Tab. 6). These findings indicate that, in addition to disturbance impacts, vegetation structure has a residual effect on bird species composition, but not vice versa. This means that changes in vegetation structure are to contribute for all of the impact of disturbances on bird species composition. There were no external disturbance effects on the composition of bird species, other than those caused by the vegetation

Table 6. Results of partial Mantel's tests for the effect of vegetation structural variables and disturbance index (DI) on bird species composition across 16 sites in district Swat. ***Significant at 5%.

Variable	R statistic	P-value
Vegetation structure by keeping DI constant	0.176***	0.040
DI by keeping vegetation structure constant	0.058	0.221

DISCUSSION

We reported that forest loss at the habitat scale resulted in significant changes in the bird populations that live in the anthropological lands of Swat, Khyber Pakhtunkhwa, Pakistan. Changes in three important structural variables (percentage canopy cover, basal area of trees, and average height of trees) associated to trees were induced by disturbance, and these changes, in turn, caused changes in bird species composition. However, Mantel tests revealed that, in addition to the effects of forest loss, vegetation structure had a substantial impact on the composition of bird species. Loss of forest-specific birds in the disturbed sites is doubtful by the existence of bird species typical of scrub forest, disturbed or open habitat (Petit and Petit, 2003), and seems to follow trends close to the squalor of natural forests caused by deforestation and agricultural expansion in general (Thiollay 1999).

The current study represents a significant addition to our quantitative knowledge of ecological impacts of forest use in Swat, Khyber Pakhtunkhwa, Pakistan, one of the regions most affected by such 'chronic' extraction. There are two strong trends in land use change: From 1968 to 2007, there was a rise in deforestation and changes in land cover types, especially declines in forest area (70.9%) and increases in cultivation (202.6%) and built-up area (216.1%) (Qasim et al., 2011). The results pointed to the need for a few designated areas where a wide range of faunal diversity can be preserved. The pattern of biodiversity in the study region was mostly affected by land use/cover shifts, provided that species abundance was poor in areas such as deforestation, forestry, and grazing fields were strong. The loss of forest has resulted in a significant decrease in the number of species of frugivorous and insectivorous birds. The IUCN classifies the *Grus antigone* and *Streptopelia turtur* in the current study as "Vulnerable" indicating that its population trend is declining and its population size is also very small that is threatened with extinction in the near future unless the circumstances that are threatening its survival and reproduction improve (see appendix 1). Regardless of their ecological characteristics, frugivorous and insectivorous birds have extinction threshold values that are representative of all forest specialists (Morante 2015). In the district of Swat, canopy cover, basal area of trees, and tree height all decreased significantly along the observed disturbance gradient. The significant correlation of many bird species to vegetation structure variables supports this conclusion. The insectivorous guild includes all the species found to be vulnerable to habitat loss. The variety of frugivorous bird species and their foraging activity (Moegenburg & Levey 2003) and habitat preference (Levey 1988), for example, is linked to the abundance of fruiting plants, but the response to disturbance of fruiting and flowering plants is not clear. At all, canopy structure is perhaps the only variable that is only indirectly significant, since it correlates with other, more important parameters including food supply. Insectivorous birds are of critical interest in conservation strategies because they are particularly vulnerable to habitat destruction and change in a variety of tropical areas (Johns 1991). According to our study insectivorous birds are affected by habitat change and deforestation. Insectivorous birds can need specific canopy structures and microclimatic conditions that are only possible in natural patch mosaics found in forests, which are altered by activities such as deforestation, conversion to plantations, fuelwood production, and livestock grazing. However, some bird species are affected by vegetation disturbance, some species have higher densities in disturbed areas than in protected areas. Our results are consistent with those of Canaday (1996). This explains that although bird species composition changes significantly as a result of disturbance, overall species richness and abundance are unaffected. A small proportion of the bird fauna was found to be vulnerable to habitat degradation in the study. Our knowledge of the Swat avifauna, however, suggests that our findings may be conservative. Deforestation has been found to have positive relationships with population density, agricultural productivity, corruption, public policies, governance quality, and trade openness, making these factors drivers of deforestation in developing regions (LeBlois et al., 2017). This, in turn, can have an impact on wildlife species. In this respect, Brazil is an important instance because it is a potential candidate for agricultural intensification (favorable climate, large productive land area), is a major exporter, has outstanding biodiversity to begin with, and also confronts political volatility (Zalles et al., 2019).

The trends identified in this study must be seen in the context of the long history of exploitation of forests in various forms in district Swat. Important coniferous forests have been significantly reduced, often resulting in land degradation. Many species in the study area were classified near to threatened (NT) by IUCN as *Ephippiorhynchus asiaticus, Gyps himalayensis, Anhinga melanogaster, Pelecanus philippensis, Pelecanus crispus* and *Phoenicopterus minor* (see ESM1). As a result, the current trend is alarming and requires more policy action to protect remaining forest resources that would otherwise face a similar fate (Qasim et al., 2011). As a result, we assume our study is most representative of the impact of recent disturbances (35-40 years) on forested land in Pakistan's Swat district.

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