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Population status, habitat preference and distribution of Bristled Grassbird *Chaetornis striata* in Bangladesh

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Summary

The little-known Bristled Grassbird *Chaetornis striata* is thought to be declining due to the loss of grassland habitats throughout its range, and is currently classified as globally 'Vulnerable'. In order to investigate the current status and possible causes of the presumed decline, we assessed population density of Bristled Grassbird in Padma and Jamuna river systems of Bangladesh. The study was conducted during the breeding seasons of the Bristled Grassbird in April and May in 2016–2019, using distance sampling and habitat suitability modelling. We also examined habitat preferences and responses to environmental changes based on vegetation structure and habitat modifications at point count locations. We detected a total of 39 birds with a mean group size of 1.44 individuals. We estimated 4.52 (95% CI: 2.65–7.73) individuals per km^2 with an encounter rate of 1.48 detections per point count station and 341.15 birds within the study area. Our habitat suitability model projected a total of 167.41 km^2 of suitable habitat and a total of 756.7 birds in floodplain grasslands of Padma and Jamuna river systems. The Bristled Grassbird was positively associated with grass height and grass density with 92.31% of 39 detections at *Saccharum spontaneum* dominated grasslands. We did not find a significant effect on Bristled Grassbird detections with increasing human activities, although the detection rate decreased linearly with increasing agricultural intervention and grass harvesting. These findings indicate that the Bristled Grassbird is more widely distributed throughout Bangladesh, and may be less vulnerable to grassland modifications, than previously thought.

Introduction

Grasslands are one of the most threatened ecosystems in the world, under increasing pressure from various human activities and especially vulnerable to conversion into agricultural lands. Moreover, grasslands are one of the least protected biomes globally with only 4.5% of the temperate grasslands, savannas, and shrublands are under the protected area system (Brooks *et al.* 2004) and much less in Asia (BirdLife International 2001). This has resulted in the loss of numerous grassland dependent species (White *et al.* 2000, Ceballos *et al.* 2010, Haddad *et al.* 2015) including the 'Critically Endangered' Bengal Florican *Houbaropsis bengalensis* and other bustards in Asia (Collar *et al.* 2017). It is believed that one of the silent victims of the depleting grassland ecosystems of Asia (BirdLife International 2001) is the Bristled Grassbird *Chaetornis striata.* This South Asian endemic is thought to be undergoing a rapid population decline due to the loss of dense floodplain grassland habitats, and is listed as globally 'Vulnerable' (BirdLife International 2019). The species is likely to face severe threats in the near future, as floodplain grasslands continue to be converted and degraded throughout its range in Bangladesh, India, Nepal, and Pakistan (del Hoyo *et al.* 2006, Baral *et al.* 2013, BirdLife International 2019, Collar *et al.* 2017). The current global population of the Bristled Grassbird is estimated to be 3,500–15,000 individuals, although population size is difficult to assess because the species often remains undetected owing to its secretive behaviour during the non-breeding season, and therefore it is likely to be overlooked outside its breeding seasons and known areas (Singh and Buckingham 2015, Baral *et al.* 2013, BirdLife International 2019).

In Bangladesh, the species was listed as formerly resident with only two records from the grasslands of Dhaka and Khulna Divisions in late 19th and mid 20th centuries (Siddiqui *et al.* 2008). It was rediscovered after more than 100 years at Tanguar Haor in north-east Bangladesh in April 2014 (Haque and Tareq 2014) and is currently listed as nationally 'Endangered' (IUCN Bangladesh 2015). Subsequent visits to this seasonal freshwater wetland during the breeding

season have resulted in regular records including documentation of nesting activity (Khan *et al.* 2015, S. U. Chowdhury pers. obs. 2018). Between 2014 and 2016, the Bristled Grassbird was regularly seen and photographed in April–May by local birdwatchers in riverine floodplain grasslands along the Padma river in Rajshahi (12 records) and Dhaka (one record) Divisions (Khan *et al.* 2015, Chowdhury 2016, BirdLife International 2019). The increasing number of active birdwatchers in Bangladesh aided by digital photography (Thompson *et al.* 2014) and mobile phone sound recorders to document observations, as well as regular visits to the riverine grassland sites during the breeding season and availability of online references (e.g. xeno-canto, eBird) to identify Bristled Grassbird by its call may explain the recent growth in the number of sightings.

The Bristled Grassbird is a little-known species with only a few targeted studies (Baral *et al.* 2013, Singh and Buckingham 2015) and opportunistic observations (Heath and Thorns 1989, Arya 2010, Haque and Tareq 2014, Khan *et al.* 2015, Krishnan 2021). Data on its population decline, information on ecology, population, distribution, local movement, and response to environmental changes remains scanty (Singh and Buckingham 2015, BirdLife International 2019, Krishnan 2021). However, in order to construct long-term conservation and management strategies for threatened species, detailed understanding of these aspects is necessary, especially the way anthropogenic actions affect a species and how it responds to these perturbations (McKinney 1997, Woodroffe and Ginsberg 1998, Purvis *et al.* 2000, Clavel *et al.* 2011).

In this study, we investigated the breeding population density of the Bristled Grassbird and estimated its population size in Bangladesh for the first time. We also identified key habitat characteristics during breeding and developed a habitat suitability model in order to target future survey and conservation efforts. Furthermore, we sought to determine how the Bristled Grassbird is responding to landscape modification arising from anthropogenic activities in riverine floodplain grasslands of Bangladesh and discuss the significance of our results for the conservation and management of this species.

Methods

Study area

Our study took place on the floodplain grasslands along the Padma and Jamuna rivers, the largest river systems in Bangladesh. The Jamuna River is 205 km long with an average width of 10 km (range 3–18 km), it is the main channel of the Brahmaputra river when it flows south out of India into Bangladesh. The 4–8 km wide and 120 km long Padma river is the downstream section of the Ganges (Islam 2016). The alluvial channels and floodplains of both rivers are highly productive for agriculture and fisheries due to their dynamic hydrological system and nutrient-rich sediments that are annually deposited in the adjacent floodplains (Smith *et al.* 1998, Ashworth *et al.* 2000). These floodplains support early successional tall grasses dominated by *Saccharum spontaneum* (Peet *et al.* 1999, Wegge *et al.* 2006).

Point counts

We conducted point counts at 51 locations spread across 10 sites along the Padma and Jamuna rivers of Bangladesh (Figure 1). These sites were systematically spaced across the two river systems, depending on accessibility, local logistics and availability of

resources. Point counts were established across sites within the Upper and Lower Padma river (20 km apart) and the Jamuna river (85 km apart). As the survey sites were identified, point count stations were randomly spaced 500 m apart by placing the first point count station at a random starting point at a minimum 250 m from the edge of the river. Point count stations falling within habitats known to be unsuitable (disturbed grassland areas; Baral *et al.* 2013, Singh and Buckingham 2015, Krishnan 2021) were not excluded from point counts in order to determine habitat preference of Bristled Grassbird in riverine floodplain grasslands.

Bristled Grassbirds were counted during 10-min point counts after a 3-min settling down period upon arrival at a point count station. All counts were conducted between 05h45 and 14h00. We recorded all Bristled Grassbirds detected visually and acoustically within a radius of 250 m around the point count stations. We used a handheld GPS device to record location details of each point count station. Distances between the observer and Bristled Grassbirds were measured using a rangefinder and in some cases by a measuring tape. Each point count station was visited once over the whole three-year period between early April and early May in 2017–2019. The date of the counts can be a critical detection covariate due to change in behaviour of the target species as the breeding season progresses (Cornils *et al.* 2015, Buckland *et al.* 2016). The Bristled Grassbird is highly active during the early stage of the breeding season when the males perform breeding courtship displays by flying and calling and females respond (Baral *et al.* 2013, Singh and Buckingham 2015, Krishnan 2021). Courtship behaviour declines over the course of the breeding season, thus affecting the detection probability (Buckland *et al.* 2005, Thomas *et al.* 2010). We therefore conducted the surveys starting in the first week of April and ending in the first week of May.

Habitat variables and vegetation cover

Based on previous work on this (Singh and Buckingham 2015, Baral *et al.* 2013, Khan *et al.* 2015, Krishnan 2021) and related species such as the Striated Grassbird *Megalurus palustris* (Madge 2020), we recorded geographical and habitat variables that are known to influence Bristled Grassbird occurrence and abundance. Habitat variables such as distance to waterbodies (river, pool), bare sand, and human activities (agricultural interventions, livestock grazing, fire and grass harvesting) were recorded at each point count station.

Data were collected from three broad vegetation categories (grasses, shrubs, and trees), based on previous knowledge of the Bristled Grassbird's ecology (Baral *et al.* 2013, Khan *et al.* 2015, Singh and Buckingham 2015). To determine the structure of the grassland vegetation, square quadrats were established at the centre of all point count stations (Rotenberry and Wiens 1980, Klimeš 2003, Winter *et al.* 2005). Species, density (number of shoots per quadrat) and average height of each grass (1m x 1m quadrats), shrub (5m x 5m quadrats) and tree (25m x 25m quadrats) were recorded (Erdelen 1984, Winter *et al.* 2005, Godínez-Alvarez *et al.* 2009, Singh and Buckingham 2015). All species at each quadrat were identified using a field guide (Hossain 2017), the number and height of each vegetation type was carefully recorded, and height was determined using measuring tapes. Percentage cover of each vegetation type was visually estimated using 1m x 1m quadrats for grasses, 5m x 5m for shrubs and 25m x 25m for trees (canopy cover) and categorized in different
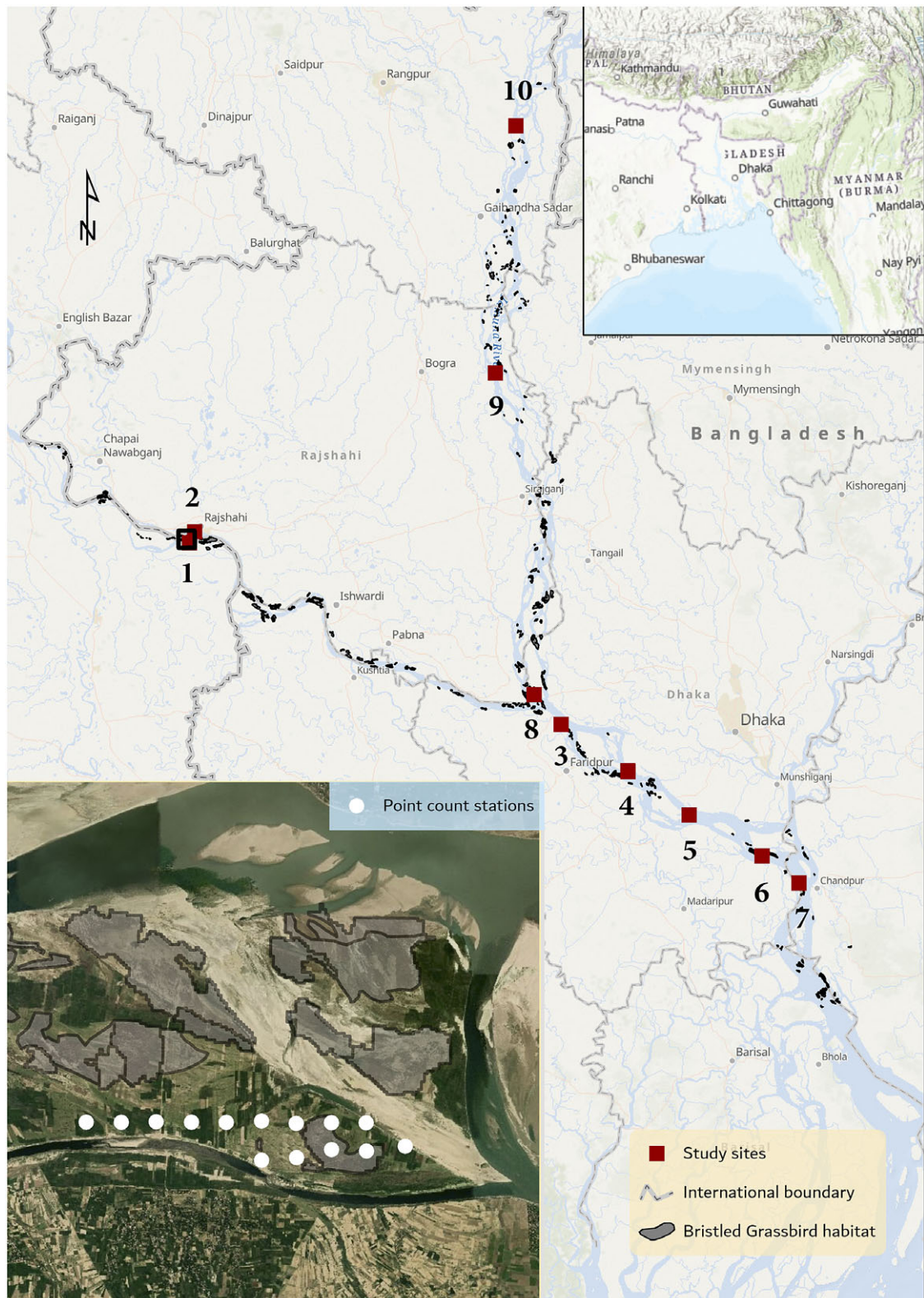
Figure 1. Projected potential distribution (black areas) of Bristled Grassbird in the Padma and Jamuna river systems in Bangladesh based on habitat suitability model (ISO Cluster classification), study sites (red squares) and point count stations of site 1 (white circles). Further details of each location are given in Table 1.

percentage bands (1 = 0–25% cover, 2 = 25–50%, 3 = 50–75% and 4 = 75–100%), following guidelines outlined in Bråkenhielm and Qinghong (1995), Klimeš (2003) and Singh and Buckingham (2015).

Habitat suitability model and extrapolation of population size

We used unsupervised ISO Cluster classification in ENVI 5.3 (Congalton and Green 2008, Phillips *et al.* 2009) to determine distribution and area of potential grassland habitats for the Bristled Grassbird along the Padma and Jamuna river floodplains. A total of 30 points of Bristled Grassbird presence locations were used for ground truthing land cover classification (Gottschalk *et al.* 2005, Long *et al.* 2008). This provided us with data on the area of total suitable habitat for Bristled Grassbird along Padma and Jamuna river systems. We then used this estimate of total area of suitable habitat and data on Bristled Grassbird density in our study area to estimate the total population size of the entire floodplain grasslands along the Padma and Jamuna river systems (Lauver *et al.* 2002, Nikolakaki 2004, Long *et al.* 2008).

Threat assessment

We identified various factors that may have a direct or indirect effect on Bristled Grassbird and its habitats. We recorded ecological attributes of habitat fragmentation in a circle of 250 m radius around each point count station. We visually estimated alteration of grassland habitat through livestock grazing (presence or signs of livestock), grass harvesting by locals, agricultural interventions, and fire to clear grassland habitats.

Statistical analysis

We used distance sampling to estimate Bristled Grassbird density within our study areas, as distance sampling is a simple, effective, and widely used approach to estimate densities of biological populations in defined areas (Buckland *et al.* 2001, 2016, Cornils *et al.* 2015). We used perpendicular distances between the Bristled Grassbird and point count stations in the 'Distance' package in R

statistical software (R Development Core Team 2016) to determine density of Bristled Grassbird at each site and total population of Bristled Grassbird within our study area. We started the analysis with a truncation of the data at a distance of 100 m from the point count stations and less than 5% detections were beyond 100 m (Cornils *et al.* 2015, Buckland *et al.* 2001). We used three models in the 'Distance' package of R software, these were (i) half-normal with simple polynomial adjustment, (ii) uniform with cosine adjustment, and (iii) hazard-rate with simple polynomial adjustment (Buckland *et al.* 2001, Thomas *et al.* 2010). We used Akaike information criterion (AIC), AIC_C weights and visual evaluation of quantile-quantile plots to select the model that best fit our data as these are widely used and a simple approach to determine the most suitable model (Buckland *et al.* 2005, 2016, Thomas *et al.* 2010).

To evaluate the effects of habitat variables, vegetation cover and human activities on the presence of Bristled Grassbird, we fitted generalised liner models (GLMs) in which presence/absence of Bristled Grassbird in a point count station was the binary dependent variable with binomial error distribution and logit link.

Results

Distribution, population density and estimate

Bristled Grassbird was present at all surveyed sites, providing evidence of its occurrence throughout riverine floodplain grasslands of the Padma and Jamuna river systems (Figure 1). A total of 39 individuals were recorded during distance sampling between 2017 and 2019 with mean group size of 1.44 birds and encounter rate of 1.48 birds per point count station. Bristled Grassbirds were detected 27 times, at a distance of up to 102 m. Birds were usually (86.04%) detected perched on tall grasses but also circling overhead while calling. After excluding six (13.95%) detections of aerial birds and truncation at 100 m (which excluded only one observation), 27 detections were used for distance sampling analysis (Figure 2).

Hazard rate detection function
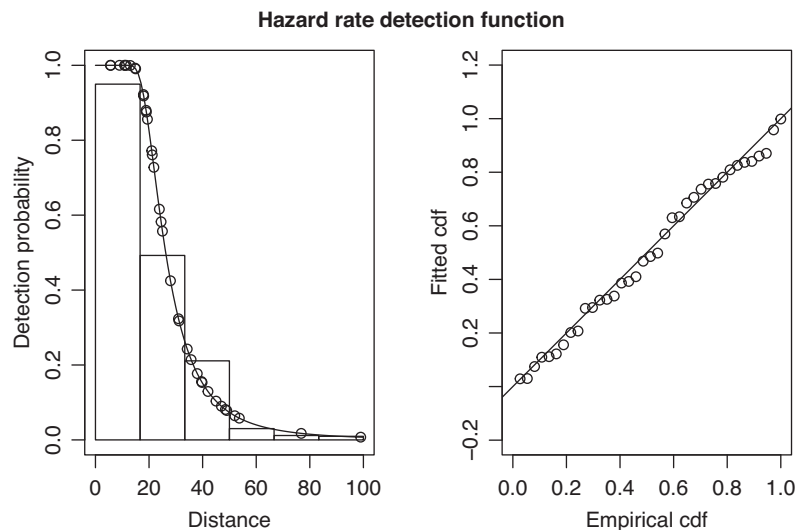

Figure 2. Histogram (left column) of detection distances for point count surveys with corresponding fit to model predicting the detection probability with increasing distance from the point count stations using a truncation at 100 m distance. The detection curve, corresponding QQ-plot (right column) with goodness of fit test results are predicted by Hazard-rate key function model.

Table 1. Bristled Grassbird survey sites, area, number of point count (PC) stations and GPS coordinates of each site.

Site ID	Site Name	River Name	Area (km^2)	No of PC stations	Coordinates
1	Rajshahi Majher Dia	Upper Padma	1.96	14	24.327589, 88.570800
2	Rajshahi Shimla	Upper Padma	0.15	3	24.362367, 88.588794
3	Aricha	Lower Padma	1.10	6	23.747247, 89.814367
4	Moinot	Lower Padma	0.85	6	23.599583, 90.035319
5	Mawa	Lower Padma	0.45	3	23.457892, 90.238011
6	Naria	Lower Padma	0.39	2	23.326466, 90.478986
7	Shakhipur	Lower Padma	0.41	2	23.239386, 90.600279
8	Pabna	Jamuna	1.09	6	23.840532, 89.725428
9	Bogura	Jamuna	0.37	3	24.839508, 89.615260
10	Kurigram	Jamuna	1.20	6	25.603896, 89.701858

Table 2. Results of distance sampling of three different models used to estimate density (individual/km^2) of Bristled Grassbird along large rivers of Bangladesh, with Akaike information criterion (AIC) values, AIC_C weights of each model, encounter rate (ER) per point count station, standard error (SE), coefficient of variation (CV), 95% confidence interval (CI) and degrees of freedom (df).

Candidate Models	AIC	AIC_C weight	P	Density (95% CI)	ER	SE	CV	df	N (95% CI)
Hazard-rate key function	314.55	0.46	0.10	4.52 (2.65–7.73)	1.48	1.22	0.26	39.98	341.15 (184.10–536.76)
Uniform key function	314.95	0.37	0.11	4.37 (3.08–6.20)	1.48	0.76	0.17	42.54	329.49 (213.80–430.89)
Half-normal key function	316.64	0.16	0.09	5.16 (3.38–7.87)	1.48	1.09	0.21	42.24	388.70 (235.46–547.95)

The model with the lowest AIC value (Table 2) using Hazard-rate key function was identified as the best-fit model. The model estimated 4.52 (95% CI: 2.65–7.73) individuals per km^2 with an encounter rate of 1.48 detections per point count station and population estimate of 341.15 (95% CI: 184.10–536.76) birds within the study area.

Results of an unsupervised ISO Cluster classification model estimated a total of 167.41 km^2 of suitable habitat for Bristled Grassbird along the Padma and Jamuna river systems (Figure 1). Therefore, a mean of 756.7 (CI: 443–1,294) Bristled Grassbirds are estimated to occur in grasslands of the Padma and Jamuna river systems.

Habitat preference

We recorded a total of five grass, seven shrub and six tree species in our 51 vegetation plots (Table S1 in the online supplementary material). Almost all (92.31%) of the 39 detections were in *Saccharum spontaneum*-dominated grasslands ($\chi^2 = 52.51$, df = 1, $P < 0.001$) and only 7.39% were detected at *Tamarix dioica*-dominated vegetation. Logistic regression for effects on the presence of the Bristled Grassbird indicated a significant positive effect ($r^2 = 0.52$, $F = 11.46$, $P < 0.001$) of grass height and density (Table 3), where Bristled Grassbird mainly occurred in locations with tall grass (1.35 ± 0.35 m; $n = 27$) and high grass density (86.96 ± 72.49) (Figure 3), compared to short (0.48 ± 0.33 m; $n = 24$) and low grass density (13.83 ± 11.40) at locations without the species. Similarly, Bristled Grassbird detection rate was negatively associated with tree density, tree height and shrub density (Table 3). Four habitat variables including distances from sand, river, water, and

human did not show a significant effect ($r^2 = 0.04$, $F = 0.22$, $P = 0.92$) on Bristled Grassbird detections (Table 3).

Effect of human disturbance

Human activities such as agriculture, grass harvesting, livestock grazing, and fire did not show a significant effect on Bristled Grassbird detections (Figure 4). However, detection rate decreased linearly with increasing agricultural intervention ($\chi^2 = 24.66$, df = 28, $P = 0.64$) and grass harvesting ($\chi^2 = 24.30$, df = 24, $P = 0.44$), but moderately with increasing grazing ($\chi^2 = 15.41$, df = 20, $P = 0.67$) and fire ($\chi^2 = 0.79$, df = 2, $P = 0.75$).

Discussion

Density and population estimate

Our study demonstrates that the Padma and Jamuna floodplain grasslands with 4.52 (95% CI: 2.65–7.73) birds per km^2 support a moderate density and potentially a significant part of the Bristled Grassbird's global population, considering the availability of vast tracts of *Saccharum spontaneum*-dominated floodplain grasslands along both large rivers of Bangladesh (Sarker *at al.* 2003). In comparison, in Chitwan National Park in Nepal, 60 Bristled Grassbirds were recorded during a survey in March–May 2010 and density was estimated as 54 (± 15 95% CI) individuals per km^2 (Singh and Buckingham 2015), indicating a significantly lower population density in Bangladesh. Singh and Buckingham (2015) determined density of Bristled Grassbird per km^2 by dividing number of birds recorded at each sample point (75-m radius at
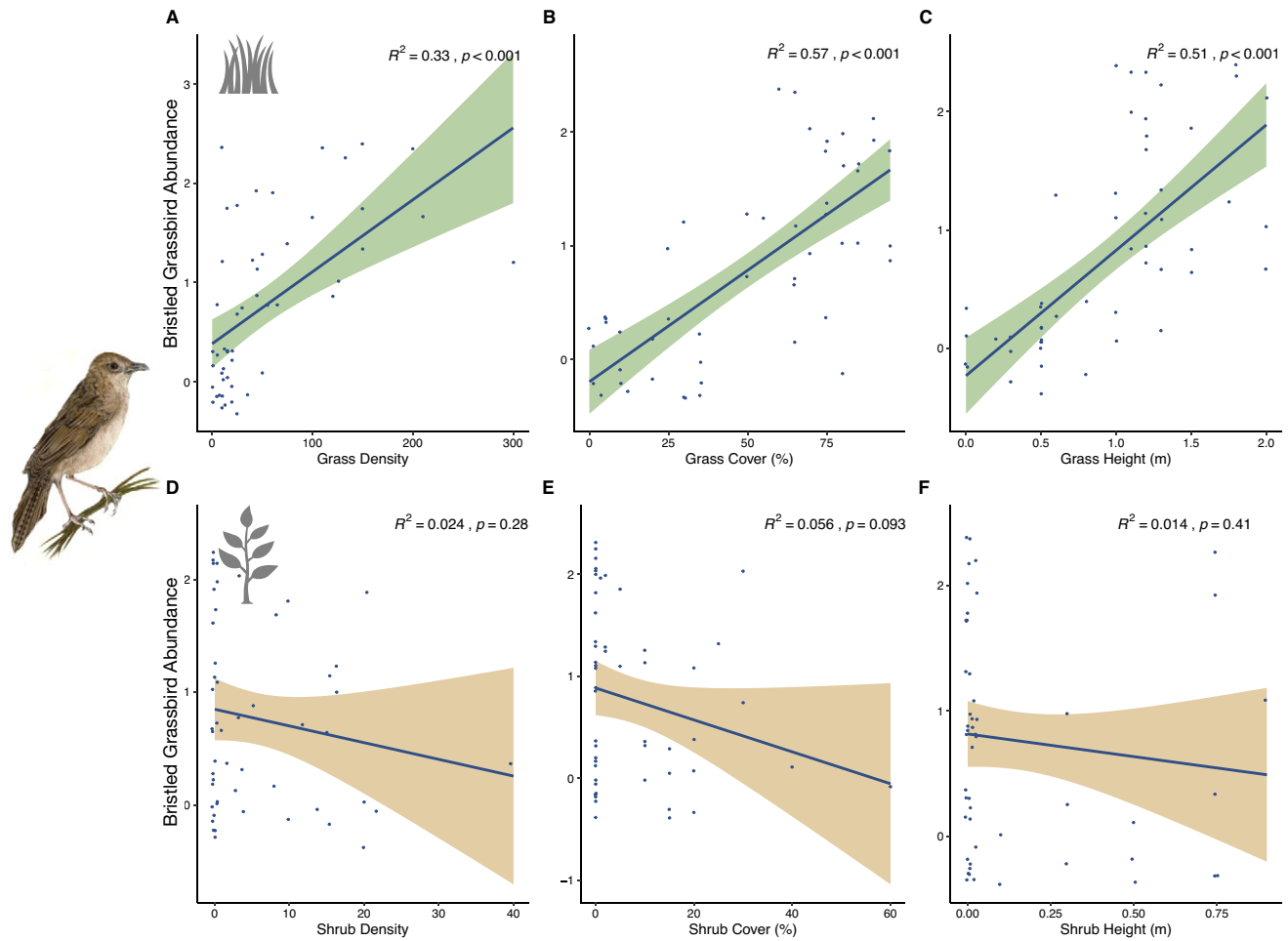
Figure 3. Linear regression indicating significant positive correlations between Bristled Grassbird abundance and grass density (A), grass cover (B) and grass height (C), and weak relationship with shrub density (D), cover (E) and height (F).

Table 3. Results of Generalised Liner Models (GLMs) testing for the effect of habitat variables, vegetation height, vegetation density and human activities on presence of Bristled Grassbird during breeding season across all sites of the study area. Significant effects are indicated in bold.

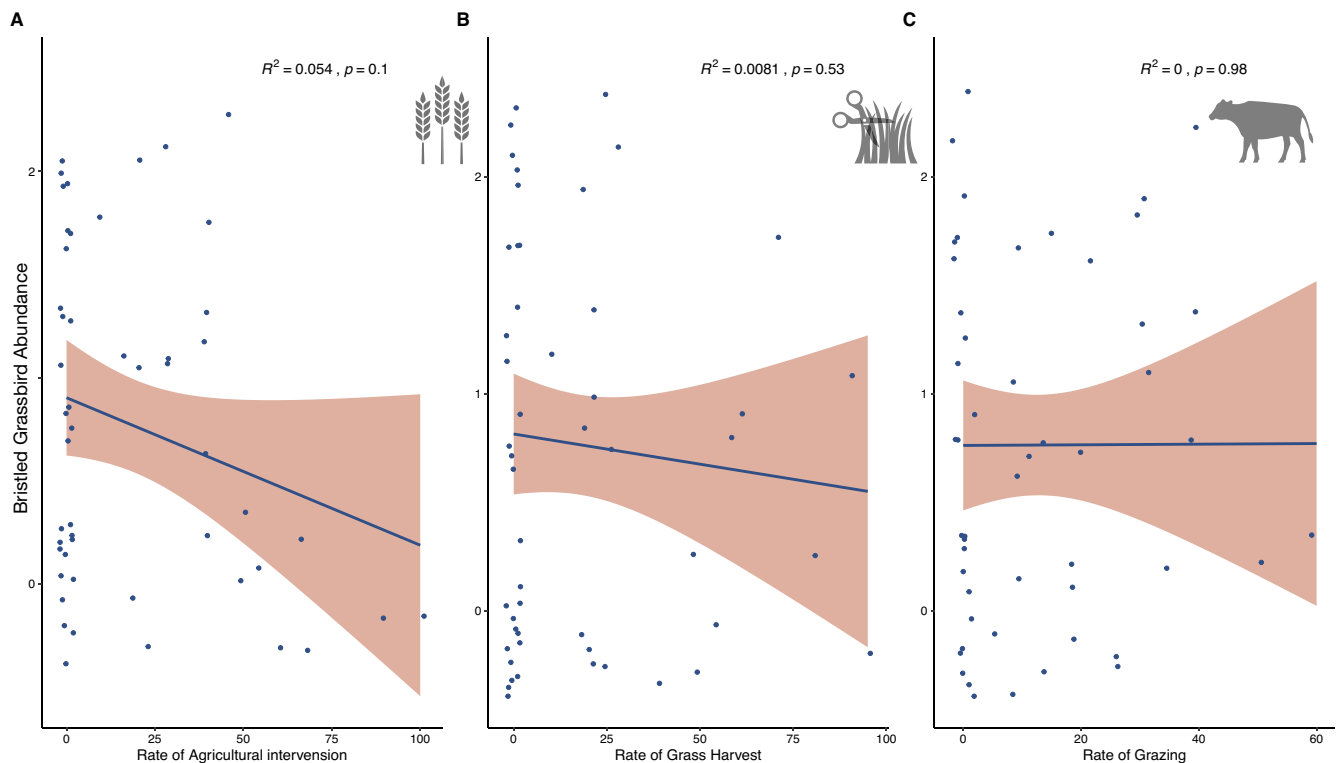| Model term	Parameter Estimate	SE	z value	Pr (>|z|)
Habitat variables				
Distance to sand	−0.000369	0.001474	−0.251	0.8020
Distance to river	−0.000401	0.000532	−0.754	0.4507
Distance to water	0.000453	0.001157	0.392	0.6954
Distance to human	0.003590	0.002000	1.795	0.0727
Vegetation height				
Grass height	**8.1687**	**2.4004**	**3.403**	**0.000666**
Shrub height	−1.6430	1.9510	−0.842	0.399704
Tree height	−0.3801	0.4529	−0.839	0.401310
Vegetation density				
Grass density	**0.085262**	**0.027452**	**3.106**	**0.00190**
Shrub density	0.003941	0.051006	0.077	0.93841
Tree density	−0.012014	0.066414	−0.181	0.85645

Figure 4. Linear regression showing effect of agricultural interventions (A), grass harvesting (B) and livestock grazing (C) on the abundance of Bristled Grassbird at point count stations.

intervals of 200 m) and an area of sample plot that denoted wide confidence limits.

This high density in Nepal could be because of unadjusted estimates and possible positive bias resulting from call playbacks, which led nearby Bristled Grassbirds into the counting plots that were rather small with short intervals between them (Thompson 2002, Buckland *et al.* 2005). Baral *et al.* (2013) estimated 10 birds per km², which is $81.84 \pm 33.34\%$ lower than 54 ± 15 birds km² (Singh and Buckingham 2015), although both studies used playback methods (but line transects instead of point counts) to estimate density of Bristled Grassbird. Therefore, these largely dissimilar population estimates of Bristled Grassbirds from Nepal may be incomparable to our results from Bangladesh since different methods were used to compute densities.

The unsupervised ISO Cluster classification model predicted that high quality grassland habitat is still found in the Padma and Jamuna river systems. This habitat suitability map provides the first insight into the spatial patterning of potential suitable Bristled Grassbird habitats across the entire extent of Padma and Jamuna riverine grassland systems. It is likely that the Bristled Grassbird may occur in riverine grasslands along other rivers of Bangladesh during breeding and further surveys are needed to verify this prediction.

Based on the assessment of known records throughout its range and studies in Nepal (Baral *et al.* 2013, Singh and Buckingham 2015), the current population estimate by BirdLife International is 2,500–9,999 mature individuals (BirdLife International 2019). In that estimate, populations of riverine systems of Bangladesh had not been included since there were only a few records prior to this study. Therefore, considering this new population estimate for Bangladesh, the global population of Bristled Grassbird should be

higher than 2,500–9,999 with 443–1,294 mature individuals in the Padma and Jamuna river systems of Bangladesh alone.

Habitat preference and tolerance

In Nepal, Bristled Grassbird preferred *Saccharum spontaneum*-dominated and often lightly grazed grasslands, that are similar (Figure 3) to Bangladesh (Baral *et al.* 2013, Singh and Buckingham 2015). The species showed a negative correlation with trees in Nepal (Singh and Buckingham 2015), however in the Rajshahi region of Bangladesh, grassbirds occurred in short (1.3 m) *Tamarix dioica*-dominated grassland as well. Broadly, the habitat preference of Bristled Grassbird appears to be similar amongst all range countries (BirdLife International 2019)

As described earlier (del Hoyo *et al.* 2006, Baral *et al.* 2013, BirdLife International 2019), our study clearly showed that the occurrence of Bristled Grassbird is restricted to grasslands with tall grasses. However, our results also indicate that the Bristled Grassbird is more tolerant to human presence and habitat modifications than previously thought. We found that 66.66% detections ($n = 39$) were within 250 m of human presence with an average distance of 194.56 m (SD = 174.25, SE = 27.28) from humans. Moreover, we found presence of Bristled Grassbird in plots with agricultural interventions (59.25%, $n = 27$), grazing by domestic cattle (55.55%, $n = 27$) and grass harvesting by local people (44.44%, $n = 27$), suggesting that the species may be less vulnerable to grassland modifications and can tolerate low to moderate human disturbance (Figure 4). Studies in Nepal (Baral *et al.* 2013, Singh and Buckingham 2015) took place within protected areas, the effect of human-made disturbance and interventions on Bristled Grassbird's occurrence was not fully investigated.

Distribution in Bangladesh

Bristled Grassbird was rediscovered in north-east Bangladesh in April 2014 at Tanguar Haor (seasonal freshwater wetland). After the rediscovery, we could trace only 13 records along Upper Padma river (Khan *et al.* 2015, Chowdhury 2016, BirdLife International 2019). Our surveys confirm its occurrence in the Lower Padma and throughout Jamuna river for the first time. Previous records and our findings indicate that the Bristled Grassbird is more widely distributed throughout Bangladesh and has been overlooked due to lack of visits by birdwatchers and researchers during the breeding season in its preferred habitats (tall grasses near water) across riverine and grasslands in freshwater wetland (Khan *et al.* 2015, S. U. Chowdhury pers. obs. 2016, BirdLife International 2019).

Breeding behaviour

At all survey locations we detected courtship display by males from the second week of April. The males were seen flying around the grassland, circling and calling. Bristled Grassbirds were seen carrying nesting materials on 15 occasions in Rajshahi, Moinot, Mawa, Pabna, Bogura and Kurigram (Table 1). Opportunistically, we found two nests on 20 April 2019 at Pabna (Table 1) when Bristled Grassbirds were seen carrying nesting materials and subsequently followed to locate the nests. Both nests were under construction and were found in 1.2 m and 1 m tall *Saccharum spontaneum* stands, positioned 1 m and 0.5 m above ground. Nests were located near to the river (60 m and 38.4 m) and 1.23 km apart. Nests were small (width: 6 cm and 7 cm), globe-shaped structure built with dry *Saccharum spontaneum* grass, with an entrance near the top but slightly sloping to the side. Our nests match the description provided in Khan *et al.* (2015), although the authors found the nest in *Imperata* grass, not *Saccharum spontaneum*.

Threats

The major threats to this species and riverine floodplain grassland appear to be habitat conversion as a result of agricultural interventions (45.09%, $n = 51$), grazing (52.95%) and grass cutting (43.13%). Detection rate of Bristled Grassbirds sharply decreased with increasing agriculture and grass harvesting but no decline in plots with grazing (Figure 4). Agricultural encroachment appears to be more severe in Bangladesh than Nepal, possibly because Bristled Grassbird mainly occurs inside protected areas in Nepal (Baral *et al.* 2013, Singh and Buckingham 2015). Other threats such as drainage, sand mining, commercial forestry plantations and irrigation projects (BirdLife International 2019) do not pose a significant threat to the species in riverine floodplain grasslands of Bangladesh. A number of factors that may have affected the floodplain grasslands and riverine ecosystems have occurred due to the construction of dams, bridges, and embankments (Chowdhury *et al.* 2014).

Conservation implications

Given the possible ongoing decline of Bristled Grassbird throughout its range (BirdLife International 2019), Bangladesh appears to be an important country, especially because of vast tracts of suitable riverine grassland habitats that potentially support a substantial number of the Bristled Grassbird's global population. Riverine habitats are possibly the most neglected ecosystems in terms of conservation efforts in Bangladesh (Chowdhury *et al.* 2014, IUCN Bangladesh 2015). However riverine wetlands, waters and floodplain grasslands support 22 avian species of global concern including the 'Critically Endangered' Yellow-breasted Bunting *Emberiza aureola* (S. U. Chowdhury pers. obs. 2020) and Baer's Pochard *Aythya baeri*, 'Endangered' Black-bellied Tern *Sterna acuticauda* and Steppe Eagle *Aquila nipalensis*, eight 'Vulnerable' and 11 other 'Near Threatened' birds (Siddiqui *et al.* 2008, Chowdhury *et al.* 2014).

None of the Bristled Grassbird sites or any riverine floodplain grassland and associated habitat is currently protected in Bangladesh. However, the authors submitted three possible protected areas proposals across the Padma and Jamuna river systems to the Bangladesh Forest Department under the Ministry of Environment, Forest and Climate Change. These potential protected areas include 2,522 ha near Kushtia district and 947 ha near Rajshahi city along Padma river, and 7,082 ha along Jamuna river from Sirajganj district to Kazipur sub-district. For long-term conservation of riverine grassland birds of Bangladesh, these protected areas should be immediately established and conservation management including prevention of agricultural encroachment, grass cutting, and livestock grazing should be implemented.

Our study represents the most complete report on the distribution, habitat use, population and density of Bristled Grassbird in Bangladesh. However, various important aspects of its natural history and ecology such as breeding biology, migration, non-breeding habitat use, and response to rainfall patters are still largely unknown. We recommend further surveys in riverine habitats across smaller rivers throughout Bangladesh and long-term studies to fully understand Bristled Grassbird's natural history and movement. Our findings also illustrate that there are vast tracts of riverine grassland habitats along large rivers of Bangladesh and point out that grassland ecosystems are highly neglected in terms of conservation actions in South Asia including Bangladesh. Only 4.61% of the terrestrial ecosystem of Bangladesh is protected, which is considerably lower than the target set by Aichi target 11 (Woodley *et al.* 2012). Bangladesh is one of the densely populated countries in the world with an extremely high demand for land, and where unoccupied land without infrastructure is scarce (Streatfield and Karar 2008, Hasan *et al.* 2017). Hence, protecting these yet unoccupied grassland ecosystems offer an excellent opportunity for the government of Bangladesh to meet Aichi target 11 and Sustainable Development Goal (SDG) 15 'Life on Land' (Rahman 2021). We therefore urge rapid and immediate designation of grassland protected areas in Bangladesh, which do not exist in the current protected area network.

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