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Role of the Riparian Corridor in Conserving Avian Diversity in Intensively Farmed Regions: Evidence from Punjab's Beas River Region

S. Kumar and T.K. Kler

Department of Zoology, Punjab Agricultural University, Ludhiana-141 004, India
E-mail: 810sachinkumar@gmail.com

Abstract: This study examined avian diversity along the Beas River in Punjab, India from April 2019 to March 2021. Three locations were sampled, each divided into agricultural fields, riparian zones, and wetlands. Bird diversity was assessed using point counts and diversity indices. Hierarchical multiple regression revealed habitat type significantly influenced avian ecological indices. Riparian zones consistently showed the highest species richness (51.8-80.1), evenness (0.934-0.946), and Shannon-Wiener diversity (3.677-4.113) compared to agricultural fields and wetlands. Agricultural fields exhibited moderate diversity (3.576-3.889), while wetlands showed lower diversity (2.945-3.609). The Simpson index was highest in riparian zones (0.968-0.980), followed by agricultural fields (0.965-0.974) and wetlands (0.934-0.960). Habitat type explained 45.0%, 40.0%, 45.6%, and 53.9% of the variance in species richness, evenness, Shannon-Wiener diversity, and Simpson index, respectively. Results highlight the importance of preserving riparian zones and wetlands in intensively farmed regions to support diverse bird communities. Despite narrow widths, riparian habitats along the Beas River maintain rich avian diversity, emphasizing their conservation value. Findings underscore the crucial role of habitat type in shaping avian communities and inform strategies for sustainable bird conservation in agricultural landscapes.

Keywords: River Beas, Riparian, Avian, Diversity, Richness, Sustainability

Rivers and their riparian areas play crucial roles in supporting avian diversity (Dallimer et al 2012, Keten et al 2020). They help to regulate the temperature of aquatic habitats, provide woody debris, and create green spaces that enhance landscapes. Beyond these functions, riparian zones act as ecological corridors that connect otherwise isolated habitat patches, including farmland, home gardens, and parks (Bryant 2006). These corridors offer essential food and cover for bird species and serve as colonization and dispersal routes, facilitating the movement of birds from riparian areas to adjacent green spaces (Litteral and Shochat 2017). The width of riparian buffers positively influences bird species richness and abundance, highlighting the significance of maintaining suitable buffer widths for avian habitats. However, extensive agricultural activities in landscapes globally have led to the loss and fragmentation of natural vegetation. This phenomenon is also applicable to riparian ecosystems, where agricultural practices have simplified their structure, resulting in substantial consequences for wildlife diversity (Kontsiotis et al 2019).

Agricultural and urbanization growth has adversely affected the ecology and environment of rivers (Rafie and Kumar 2020, Kumar et al 2023). Agriculture alone has an effect on 87% of the globally threatened bird species. Ecologists have two schools of thought to maintain a balance between landuse and wildlife, i.e., by sparing specific land for wildlife and intensifying production on existing agricultural land or sharing land with wildlife with less intensive agricultural practices (Green et al 2005, Law and Wilson 2015). Sustainable avian diversity can be observed in undisturbed natural areas (Moura et al 2013); however, this is not possible in intensive agricultural farming regions such as Punjab, India. Punjab boasts an impressive gross cropping area (GCA) of 98.5%, (Gulati et al 2021). Such a high level of agricultural development poses significant challenges for biodiversity conservation. However, in the face of this scenario, there is still potential to leverage the natural spaces available within the state, such as areas along rivers (Kumar 2021, Kumar and Kler 2021), canals (Kaur 2018), wetlands (Kumar 2021) and village ponds (Sidhu et al 2022). To harness these spaces effectively for conservation, preliminary studies are essential to gain a deeper understanding of the diversity and ecology of these ecosystems. Punjab, with its prevalent intensive agricultural practices, offers an ideal setting for investigating the role of these natural spaces in avian conservation. The substantial stretch of the Beas River traverses this intensive agricultural region, resulting in the continuous encroachment of the river's boundaries and the narrowing of the riparian zone between the river and agricultural areas (Kumar and Kler (2021). These unique conditions along the Beas River present an exceptional opportunity to study avian diversity within the complex interplay of agricultural, riparian, and wetland habitats, as the ecotone between these three habitats is exceptionally narrow (Kumar 2021). The current study explores avian diversity in the Beas River Conservation Reserve, Punjab, focusing on agricultural, riparian, and wetland regions.

MATERIAL AND METHODS

The study was conducted at three locations along the Beas River, i.e., at the entrance of the river in Punjab state (T1-T) Talwara (31.949 latitude 75.900 long), at the middle of the river in Punjab (T2-B) Beas (31.505 latitude 75.298 long) and before the river merged into Satluj (T3-H) (31.211 latitude, 75.046 long) at Harike (Ramsar Wetland from April 2019–March 2021).Each location was further divided into three sub habitat strata types, i.e., agricultural fields, riparian zones and wetlands along rivers. The stratified random sampling method was used to cover approximately 15 km (5 km× 3 locations) of the total stretch of the river. The point-count method (Verner, 1985) was implemented during the study period. Each sampling consisted of 10 random points with an interval of straight-line distance of at least 500 m between two random sampling points. Each point was counted for 6 minutes within 4 hours after sunrise at each sampling point (Shiu and Lee 2003). The locations under study were visited every fortnightly during the study period. To minimize disturbance to the birds, observations were recorded using binoculars (10×50) and a camera (Nikon D 7200 with a 200-500 mm lens). The study was intended for hierarchical multiple regression analysis; therefore, the experiment was devised to include independent variables, dependent variables, and control variables (Tu et al 2020).

Independent variables: The landscape habitat was divided into three main categories for the purpose of this study:

Agricultural areas located alongside the river: Farmers predominantly engaged in rice-wheat crop rotation along the river, with maize serving as a secondary crop in certain regions. Typically, the chosen fields extend up to 800 meters perpendicularly from the river's edge. Generally, the agricultural fields had very few trees, but if any trees were present, any bird species observed on the trees were included in the overall sampling data.

Riparian zones of the river: These zones were considered the interfaces between the agricultural land and the river. They encompassed a variety of habitats, ranging from sandy banks to lush vegetation consisting of grasses, shrubs, and tall trees. As an agricultural-dominated state, the riparian zone experiences encroachment for agricultural purposes and experiences continuous stress. Therefore, the riparian zone of the river was fragmented and very narrow (<20 mt wide); at some places, such locations were excluded from the study. On average, the width of the riparian habitat under study ranged between 21 and 70 meter.

Wetlands along the river: These wetlands that formed naturally along the riverbanks were supplied with water from the river as well as rainfall. The size of the wetlands varied, ranging from 100 to 500 m^2. A total of 16 wetlands were studied, seven of which were perennial (present throughout the year), while the rest were seasonal (existing only during monsoon periods).

Dependent variables: Species richness, evenness Simpson index and Shannon-Wiener index were selected as dependent variables as they are important components used to measure species diversity in different habitats (Pyron 2010, Harisha and Hosetti 2009, Xu et al 2011, Lembrechts et al 2018) therefore, the combination of all four parameters was used for inclusive information about diversity and habitat health (Tu et al2020). All indices were calculated using the Vegan-2019 package in the statistical software R (version 1.2.5033) (Kumar et al 2023) (Table 1).

Control variables: The precipitation, wind speed, maximum temperature and temperature were downloaded from WorldClim.com Version 4 of the CRU TS monthly high-resolution gridded multivariate climate dataset along the river

Table 1. Diversity, Evenness, Richness, and Simpson indices of sub habitats along the Beas River

Habitat	Location	Diversity	Evenness	Richness	Simpson Index
Agriculture fields	T1	3.889	0.937	64.583	0.974
	T2	3.576	0.933	46.417	0.965
	T3	3.786	0.920	61.667	0.970
Riparian	T1	4.113	0.942	80.083	0.980
	T2	3.677	0.934	51.833	0.968
	T3	4.073	0.946	75.333	0.979
Wetland	T1	3.415	0.910	48.333	0.953
	T2	2.945	0.923	25.167	0.934
	T3	3.609	0.899	58.083	0.960

T1 -Talwara, T2 -Beas and T3-Harike

and subsequently averaged on a monthly basis (Harris et al 2020).

Data analysis: The single river was taken as a single identity during the study period; therefore, climatic variables were taken throughout the length of the river; however, due to human resource limitations, the avian diversity data were taken only from three locations. Similarly, the data recorded from all three locations were also clustered and averaged for the study period. The data were analyzed using the hierarchical multiple regression method to determine the associations between the habitat types and avian ecological indices. The independent variables were assigned as dummy variables, and wetland areas were taken as constant intercepts for comparative analysis with agricultural and riparian zones for all indices. The same process was performed for each hierarchical multiple regression analysis, with the Shannon–Wiener diversity index, species evenness, species richness and Simpson index taken as the dependent variables. Hierarchical multiple regression analysis was conducted to assess the relationship between independent and dependent variables. Results included R^2 and adjusted R^2 for model fit, B values indicating the specific effect of each independent variable, and beta (β) values representing standardized coefficients. The analysis followed procedures outlined by Tu et al (2020) and was analyzed using SPSS version 16.0.

RESULTS AND DISCUSSION

Species richness: Among the three sub habitats, the riparian zones had the highest avian richness (Table 1). Riparian areas support high levels of species diversity, with bird communities shifting toward urban dwelling species due to human modification (Melanie et al 2017). The results of model one for species richness via hierarchical multiple regression indicated a variance of R= 0.450 and R^2=0.230 with an adjusted R^2 = 0.164, which was significantly different from zero. Model 02 was created using independent variables. The R^2 value changed to 0.671, and ΔR^2 = 0.450, indicating a reasonable level of increase in prediction and significant variance can be explained in the dependent variable (richness) on the basis of the independent variables. Simultaneously, a significant change in R^2 of 0.450 inferred that the independent variables had a significant effect on enhancing the model efficiency and helps to compensate for the optimistic bias of R^2 (Miles 2014). The adjusted R^2 for the model was 0.411, indicating the goodness of fit of Model 02. The control variables had no significant contribution at the individual level other than wind speed. The dummy variables used included agricultural and riparian habitats in the intercept, with wetlands taken as constants for comparison. Similarly, compared with those of the constant wetland richness, the B values were 13.771 ($\pm$ 3.782, β=0.312) and 25.299 ($\pm$ 3.782, β=0.573) for agricultural and riparian zone richness, respectively (Table 2). This signifies that the agricultural fields and riparian zones have significantly greater species diversity than the avian diversity available in wetland pockets present along the river. Avian richness varied notably across habitats, with riparian zones harboring the most species, influenced by urban-dwelling species adapting to human-modified environments. Contrary to expectations, agricultural fields also exhibited high species richness, likely due to their proximity to riparian and wetland ecosystems.

Species evenness: This was measured by Pielou's evenness index, reflects the equitability of species distributions in an avian community. Typically, evenness is inversely related to species dominance. In this study distinct patterns in species composition and dominance. In agricultural fields, a total of 110 species were recorded. Among these, the dominant species, listed in descending order of abundance, were rock pigeon, rose-ringed parakeet, bank myna, cattle egret, house crow, plain martin, house sparrow, baya weaver, common myna, plain prinia, ashy prinia, rufous-fronted prinia, red-wattled lapwing, green bee-eater, and paddy field pipit. Moving to riparian zones, where 164 species were documented, a different set of dominant species emerged. These included jungle babbler, yellow-legged green pigeon, house sparrow, red-vented bulbul, common babbler, house crow, plum-headed parakeet, black-headed munia, common myna, scaly-breasted munia, bank myna, laughing dove, alpine swift, black kite, and oriental magpie robin. In wetland areas, with a total of 149 species observed, the dominant species comprised common coot, indian spot-billed duck, purple swamphen, common moorhen, common teal, common pochard, cattle egret, bar-headed goose, little egret, greylag goose, black-winged stilt, northern shoveler, white-breasted waterhen, gadwall, and little cormorant. These highlight the varied ecological dynamics across different habitats, with each exhibiting its unique assemblage of dominant species. Evenness in agricultural fields, riparian zones, and wetlands along the Beas River indicated relatively high evenness in agricultural fields but exhibited some variability, ranging from 0.920 to 0.937. This suggested a relatively balanced distribution of bird species, with no single species dominating the ecosystem. The diverse array of associated resources in agricultural fields likely supports a fairly even distribution of avian species (Hossain and Aditya 2016). The presence of complex edge habitats, such as small trees along field edges, can lead to higher avian abundance within fields and increased avian-mediated pest control services (Kross et al 2016). The riparian zones had higher evenness values (ranging from 0.934 to 0.946), indicating a more equitable distribution of avian species. Lind et al (2019) reported that a 144-meter buffer zone is required to preserve bird diversity in agricultural riparian areas. However, the riparian zone was fragmented and narrower at many locations along the river in the present study. Nevertheless, the overall study of the region has shown that if the riparian zone along the entire length of the river is conserved, this can contribute to the state's efforts to conserve the overall avian diversity of the region. Wetlands exhibited lower evenness values (0.899 to 0.923), suggesting that there might be some species that dominate these ecosystems. Wetlands often have specialized requirements, and water-dependent species may dominate these areas, leading to slightly lower evenness (Mitsch and Gosselink 2000).

Species evenness was taken as another dependent variable along with the control variables in Model one; here, the variance was R=0.203, R^2 = 0.041, with F (5,102) = 0.873. However, after the incorporation of the independent variables in Model 02, the variance increased to R= 0.633 and ΔR^2=0.400, with an adjusted R^2 = 0.359. Such a high change in R^2 indicates that the independent variable, i.e., type of habitat, strongly influences the even distribution of species and had a significantly strong effect on enhancing model efficiency. The control variables had no significant contribution at the individual level, whereas the habitat variables (independent) had a significantly high variance. The B values were 0.020 ($\pm$ 0.004, β=0.450) and 0.030 ($\pm$ 0.004, β=0.681) for agriculture and riparian zone richness, respectively, in comparison to wetland evenness, which was taken as a constant. In essence, this hierarchical regression model demonstrated that the type of habitat is a key driver of species evenness in avian communities, with agricultural fields and riparian zones significantly enhancing evenness in comparison to wetlands. These findings have implications for habitat management and conservation efforts to promote balanced avian communities in the Beas River region.

Simpson index: Simpson index in agricultural fields (0.965 to 0.974) suggested a relatively balanced avian community, where no single species dominated the ecosystem, which was consistent with the results of the evenness data (Table 1). The riparian zones had higher Simpson indices (0.979 to 0.980), indicating a more even distribution of species and lower dominance of particular species. Due to the high number of some migratory species, wetlands exhibit a lower Simpson index (0.934 to 0.960), suggesting that certain species may be more dominant in these habitats. The variance of R= 0.450 and R^2=0.230 with an adjusted R^2 = 0.164 was recorded for the dependent variable. Model 02 was created using independent variables, and the variance increase R^2=0.734, ΔR^2 = 0.539 infers that the variables present in Model 02 can explain the variance with higher accuracy for the Simpson index. An increase in ΔR^2 =0.539 and an adjusted R^2=507 infers that the model can explain 50.7% of the variance. The control variables had no significant contribution at the individual level. The independent dummy variables had a significant contribution, wetland area was taken as a constant that infers that agriculture and riparian space provided 2.1 and 2.7 points more of a contribution to variance than wetland area (Table 2).

In agricultural fields, the Simpson index suggests a relatively balanced avian community, while riparian zones exhibit a higher Simpson index, indicating a more even distribution of species and reduced dominance of particular species. In contrast, the wetlands displayed a lower Simpson index, hinting at the dominance of certain species, likely influenced by the presence of numerous migratory birds. The model considering independent variables significantly improved the accuracy of the Simpson index, explaining 50.7% of the variance. The control variables had no individual-level significance agriculture and riparian zones contributed significantly more to the variance than did wetlands (Table 2).

Avian diversity in agricultural fields is moderate to high (3.576 to 3.889). The agricultural fields under study have a wheat–rice cropping pattern throughout their length and avian diversity influenced by various factors, such as water level, flooding period, rice plant structure and size, and pesticide use (Ibáñez et al 2010). Intermediate water levels (10-20 cm) promote the highest bird density and diversity in rice fields during the growing season (Stafford et al 2010). Early flooding and late drying also favor waterbird density

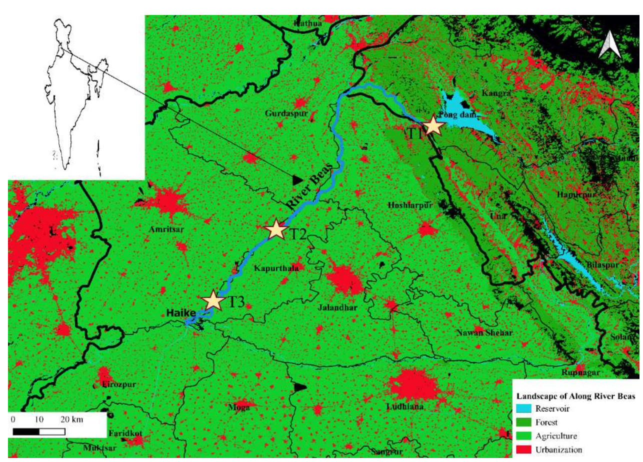

Fig. 1. Landscape along the Beas River

Table 2. Effect of landscape habitat type on the diversity index along the Beas River

Model 02	R (Species Richness)			E (Species Evenness)			D (Shannon–Wiener diversity index)			S (Simpson index)		
	B	Std. Error	B	B	Std. Error	β	B	Std. Error	β	B	Std. Error	β
Constant	51.971**	20.87		0.910**	0.022		122.12**	48.92		0.958**	0.016	
Control variables												
Elevation	0.061	0.021	0.205	0.000*	0.000	0.107	0.001*	0.000	0.177	0.000	0.000	0.134
Temp Max	-1.543	1.237	-0.490	0.000	0.000	-0.082	-0.28	0.023	-0.429	-0.001	0.001	-0.420
Temp Min	0.521	1.220	0.187	0.000	0.000	-0.104	0.0.10	0.023	0.168	0.001	0.001	0.215
Precipitation	-0.057	0.034	-0.259	0.000	0.000	-0.011	-0.001	0.001	-0.236	0.000	0.000	-0.239
Wind	15.230*	7.332	0.179	0.004	0.008	0.053	0.242	0.137	0.139	0.009	0.006	0.120
Independent variables												
Wetland							Constant					
Agriculture	13.771**	3.782	0.312	0.020**	0.004	0.450	13.482**	3.764	0.305	0.021**	0.003	0.558
Riparian	25.299**	3.782	0.573	0.030**	0.004	0.681	25.009**	3.764	0.567	0.027**	0.003	0.19
R^2		0.671**			0.633**			0.675**			0.734**	
ΔR^2		0.450			0.400			0.456			0.539	
Adjusted R^2		0.411			0.359			0.418			0.507	

* P < 0.05; **P < 0.001

and diversity, as well as the stopover of migrating species (Ladha et al 2007). All the factors discussed above, namely, water levels, cropping patterns, the vicinity of the riparian zone and the river, were present in the area of study and might have resulted in the rich avian diversity. The riparian zones exhibited the highest avian diversity among the three sub habitats, with diversity values ranging from 3.677 to 4.113. Riparian areas serve as crucial transition zones between terrestrial and aquatic ecosystems, offering a wide range of resources for avian species. These areas provide water availability, subsidies, and complex habitat structures that support diverse bird populations (Xiang et al 2016). These zones often contain abundant vegetation, water bodies, and a variety of microhabitats that attract diverse avian communities (Naiman et al 2005). The wetlands were studied and exhibited comparatively lower avian diversity (2.945 to 3.609).

The Shannon–Wiener diversity index was taken as the third dependent variable with the same set of control and independent variables. The variance recorded was, R^2 = 0.154 with an adjusted R^2= 0.112, However, the variance increased to R= 0.675 and with an adjusted R^2 = 0.418. A high change in R^2 indicates the significance of independent variables, i.e., type of habitat. Simultaneously, a significant change in the ΔR^2 of 0.456 imply that the independent variables significantly contributed to the diversity index to enhance model efficiency. The elevation variable had some significant effect on diversity, whereas the other control variables did not significantly contribute to diversity at the individual level. The independent variable agriculture was more related to diversity enhancement, with a B value of 13.482 ($\pm$ 3.764, β=0.305), and to the Riparian zone, with a B value of 25.009 ($\pm$ 0.3.764, β=0.567), than was wetland (Table 2).

CONCLUSION

The study highlights the critical role of habitat type in shaping avian diversity along the Beas River, with riparian areas and wetlands being particularly important. Habitat type emerged as the primary factor influencing bird communities, while climatic variables showed less significant impact. This aligns with some previous research, though other studies have found climate to be influential. Agricultural, riparian, and wetland habitats each supported distinct levels of bird species richness and evenness. The riparian zones consistently harbored the richest avian communities, even where these zones were narrow. Agricultural areas, while hosting fewer bird species overall, still provided important ecosystem services through occasional bird use. The study emphasizes the importance of preserving riparian zones and wetlands within intensively farmed landscapes. Smaller wetlands, often overlooked and played significant role in supporting bird diversity, especially for migratory species. The legal protection of rivers and riparian zones, as exemplified by the Beas River Conservation Reserve, contributes positively to wildlife conservation efforts. In conclusion, the research underscores the need to prioritize the preservation of riparian areas and wetlands alongside agricultural regions to maintain avian diversity. This approach can establish a sustainable model for bird conservation in intensively farmed landscapes. The findings highlight the importance of understanding the interplay between various ecological factors and bird communities for effective conservation strategies.

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