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Behavioural Responses of the Passerine Birds to the Environmental Variables in Central Punjab, Pakistan

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ABSTRACT

Present paper discusses the effects of altered temperatures due to the environmental stressors on the four passerines in varied habitats of Central Punjab, Pakistan. In the worldwide ecosystems, the biodiversity has been seriously jeopardized with uncertain ecological changes as of the inconsistent faunal shifts and their changed behaviour. The study was conducted in the selected habitats of Central Punjab (Pakistan) to elicit the responses of three climate variables viz. temperature, precipitation and relative humidity on the four passerines (house sparrow *Passer domesticus*, rosy starling *Pastor roseus*, tree sparrow *Tachycineta bicolor* and brown shrike *Lanius cristatus*). Of the four major habitats viz., Faisalabad, Toba Tek Singh, Sheikhupura and Khanewal, further three sub-habitats were randomly selected in the present investigations. This whole region is agriculturally diversified and comprises a sufficiently large proportion of the productive landscapes. Elevated temperatures significantly impacted the loud bird calls (0.006** and 0.003**) in the diurnal hours; however, its effects on the short flights for the tree sparrow remained significant, and for the other three species, noise effects were more or less fairly low. Seemingly, the precipitation influences generally were non-significant for the short flights of house sparrow and brown shrike in and around their roosts. Considering the climate effects of temperature, precipitation, and relative humidity, it was evident that temperature imposed more serious implications on all the four designated birds as determined by the generalized linear mixed model (GLMM), while precipitation, which remained lower during the study period, apart from some cases, hardly impacted on the swift behaviour displays of birds; nonetheless, relative humidity was also an important factor to reduce smooth efficiencies of bird behavioural displays in this study. Overall, the climate uncertainties remained significant for the four designated birds, and their likely impacts owing to unwanted man-made activities on humans for diverse ecosystems. Therefore, it is highly significant to utilize the present resources with the incorporation of ecosystem-friendly measures to maintain and prolong the environment sustainability.

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Authors' Contribution
MY conducted experiments and wrote the manuscript. HAK conceived the idea and supervised the research work. ZUA conducted the research, and edited and proofread the manuscript. SM compiled the data.

Key words
Climate variables, Passerines, Biodiversity, Ecosystems

INTRODUCTION

Bird roosting provides the high levels of altruism to increase competition for the available resources in the worldwide ecosystems (Socolar *et al*., 2017; Capilla-Lasheras *et al*., 2021). Intraspecific competition is responsible for the fitness and also that of the adaptive values to the birds in the wake of enhanced predatory influences (Harel *et al*., 2017; Lapiedra *et al*., 2021). Thus, the weather attributes are considered the main factor to impact the avifauna to adapt ecological conditions accordingly to affect their phenology, roosting characteristics with their intrinsic and extrinsic factors to cause shifts in bird populations (O'Mahony, 2015). The diversity of birds and other wild animals is threatened by these changing trends (Toussaint *et al*., 2019). Furthermore, the possibility in their recent population decline due to climate conditions is also caused by the anthropogenic and vulnerable ecosystems (Roy *et al*., 2022). As reported by (Reif and Vermouzek, 2019), several farmland birds also have decreased in view of weather uncertainties among varied habitats.

Movement patterns of birds remain predominantly limited for space and time in different localities for their rural and urban environments; nonetheless enforce their random sequential and non-sequential migrations (Moller and Fiedler, 2010; Robinson *et al*., 2010). The sparrows

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are largely considered the communal type for such habitats. Due to weather changes, such behaviour appears to be more non-consecutive (82%) in their metropolitans and only (18%) regards to the rural habitats (Robinson *et al*., 2005). Moreover, the sparrow's roost sustainability in various ecosystems based on foraging and feeding schedules has also been altered to significantly reduce their roosting and feeding proportions (Beaugeard *et al*., 2019; Mahesh and Lanka, 2021; Ramos-Elvira *et al*., 2023).

The rosy starling (*Pastor roseus*), a migratory bird of Europe, seems to be well adapted to the Asian region. Generally, its expansive population forages in suitable environments, therefore, acts like the bio-indicator of environmental fluctuations (Ali *et al*., 2018). The starling due to its instinct and sensitivity to manage the variabilities of climate for its respective roosts provides better adaptations to enhance its ecological fitness. Nonetheless, for various birds, such environmental suitability has been adversely impacted by the present trends of increased temperature, precipitation and relative humidity with the changed behavioural characteristics (Coomes and Derryberry, 2021; Sauve *et al*., 2021; Yasin *et al*., 2021).

Global warming and allied factors are considered critical to cause swift decline in bird population status from the favourable environments (Cunningham *et al*., 2021; Schmaljohann *et al*., 2022; Nelson *et al*., 2023). The region of Central Punjab, Pakistan is largely regarded as the main agricultural site to predominantly suffice (30%) the country's food requirements (Khan *et al*., 2013). Therefore, main stream of agriculture relies on productive commercial crops in Punjab province to provide food and economic incentives to the fairly large populations (Iftikhar *et al*., 2019). Logically, in this region there seems no food limitations to variety of vertebrate pests as of the birds throughout the year. The majority of birds, therefore, have wide feeding niche and cause serious depredations and economic losses in the unprotected conditions. Present study was, therefore, performed to evaluate the effects of three climate variables *viz*., temperature, precipitation and relative humidity, on the four designated passerines in four major habitats of their differential behaviour patterns.

MATERIALS AND METHODS

Present study on assessments of behaviour in four passerines as influenced by the three weather variables *viz*., temperature, precipitation and relative humidity lasted for 28 months in the cultivations of Central Punjab, Pakistan. The first phase lasted from January to April 2017. The existing food crops here were wheat (*Triticum aestivum*), maize (*Zea mays*), barley (*Hordeum vulgare*), sugarcane (*Saccharum officinarium*), rice (*Oryza sativa*), sorghum (*Sorghum bicolor*), millet (*Pennisetum glaucum*), cotton (*Gossypium hirsutum*), graminoid and leguminoid fodders. The predominant fruits were citrus (*Citrus reticulata*), mango (*Mangifera indica*), dates (*Phoenix dactylifera*), guava (*Psidium guajava*), watermelon (*Citrullus lanatus*), and also the jaman (*Eugenia jambolana*).

Three crops *viz*. wheat, maize, and barley were sampled for the roost composition and the population abundance of the four passerine species. Observations were conducted continuously per week with assistance of field workers to obtain the accurate data at all the sub-habitats of the four main habitats of Central Punjab. The four passerines *viz*. house sparrow, rosy starling, tree sparrow, and brown shrike, as influenced by three climate variables (temperature, relative humidity and precipitation) were assessed through field surveys with effect from October 2017 and September 2019 in the day-long observations (0600 through 1800 h) without hiatus. Each observation comprised 30-min time intervals.

Study sites

The Punjab province is considered major agricultural contributor of Pakistan and, therefore, useful source to the economy of the Punjab, Pakistan, contributes largely to Pakistan's agricultural sector and plays a significant part in Pakistan's economy (Rahman, 2015; Rehman *et al*., 2015). Occurrence of canal irrigation system with three main irrigation canals viz., Jhang, Gogera, and Rakh which were developed before the sub-continent partition to promote agriculture here, remain the invaluable water resource for crops with various water tributaries It is also regarded as one of the largest irrigation systems in Asia (Khan *et al*., 2013). Weather wise, the Punjab province is differentiated in four seasons *viz*. hot (summer) from May through July, fall (August through October), winter (November through January), and spring (February through April) with differential temperatures (Khattak and Khalil, 2015). Observations were conducted in the three randomly selected four main districts *viz*. Faisalabad, Toba Tek Singh, Khanewal, and Sheikhupura to ascertain the different behaviour displays of the four designated birds in response to three of the climate variables.

Experimental observations

In the outset for first four months, observations were conducted to assess the population abundance of the four birds regarding the four major roosts in study sites. Three sub-habitats from the four main habitats were randomly selected by simple randomized selection (SRS) wherein roost composition, bird population, and climate impacts were evaluated for the four species.

Observations on weather impacts

Impacts of climate variables viz., temperature, rainfall and relative humidity were recorded from October 2017 through September 2019 in all the designated locations of study area. Behavioural displays *viz*. the active and passive foraging, intra and inter-species tussles, mobbing, short flights, and that of calls were examined to adjudge the effects of weather variables on the designated birds which were considered as the biological indicators. Observations were recorded on non-consecutive and consecutive bird shifts for their respective roosts in all the major study sites. Weekly field visits were recorded respective sites were determined with the sensitive weather stations (WS-2320 CE-MISOL), to depict the altered temperature and relative humidity, nonetheless, the rainfall was measured using the rain gauge (228L). Day-long observations were recorded from 0600 through 1800 h to adjudge the varying bird behaviour were extended throughout the study duration. Differential behaviour displays viz. short flights, mobbing, calls notes, intra and inter species tussles, roost and nest defense and bird chases were recorded precisely.

Ironically, the bird mobs occurred sporadically due to their accumulation in sufficient numbers together with loud noise to aware the other marauding and roosting birds on the approach of predator bird to successfully circumvent the possible threat. Regular incidences of intra and inter tussles also happened in good numbers in their breeding season (spring) and comprised the conflicts and scuffles with either the same or different territorial birds and in pair bond formation in nest behaviour. Defense for the nests with other competitors was also customary in the breeding phase, and that of the roost protection remained throughout the year regardless of their seasonal movements. Increased bird movement patterns from one habitat to the other regularly occurred in the relatively higher temperature tolerant periods.

Statistical analysis

Data of the present study were statistically analyzed with the R-software with the incorporation of logistic, poisson regression, the generalized linear and generalized linear mixed models for the data analyses and interpretation results.

RESULTS

Bird calls

It was apparent that the bird calls were also impacted by the temperature. The incidence of loud noise became considerably reduced in the considerably high temperatures. Implication of the GLMM evinced that bird calls were increasingly low during the daylight conditions for their different roosts ($p<0.006$** and 0.003**) for the tree sparrow and brown shrike. Nonetheless, both the house sparrow and rosy starling were more seriously affected in elevated temperatures (decreased calls), with their slopes being -2.17 and -1.96 (Table I). Ironically, more call notes were emitted between temperature ranges 20 and 25^{o}C, considered as optimal for all birds. Impact of rainfall however remained negligible with hardly any correlation with the ecological variables negative, and palpable ecological factors; however, the effect of relative humidity was sort of mixed on all the four designated birds (Fig. 1A).

Table I. Impacts of three environment variables on the calls emitted of the four passerine birds in study locations of Central Punjab, Pakistan.

Behaviour	Fixed factors	Species	Slope	S.E.	t-value	p-value
Calls	Temperature	*Passer domesticus*	-1.88	± 1.02	-1.83	0.10
		Pastor roseus	-2.87	±1.46	-1.96	0.06
		Tachycineta bicolor	-2.76	± 0.86	-3.17	0.006**
		Lanius cristatus	-3.16	±0.87	-3.63	0.003 **
	Precipitation	*Passer domesticus*	2.97	±46.78	0.06	0.94
		Pastor roseus	7.27	± 6.46	1.12	0.26
		Tachycineta bicolor	28.65	±24.13	1.18	0.23
		Lanius cristatus	2.99	± 15.89	0.18	0.85
	Humidity	*Passer domesticus*	-2.17	± 0.70	-3.06	0.005**
		Pastor roseus	-1.96	±0.74	-2.65	0.01*
		Tachycineta bicolor	-0.73	±0.48	-1.50	0.14
		Lanius cristatus	-1.09	± 0.56	-1.91	0.06

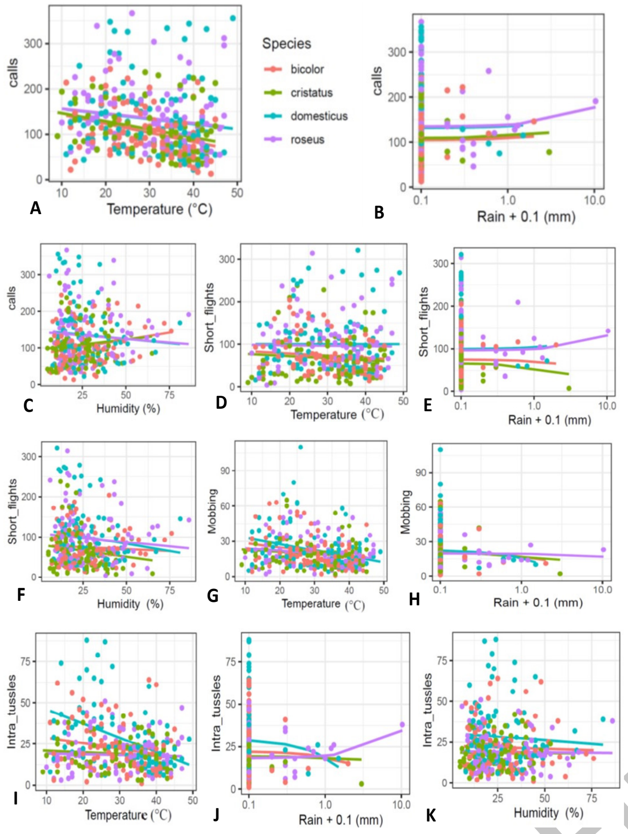

Fig. 1. Effect of temperature on bird calls with more impairments on the *Tachycineta bicolor* and *Lanius cristatus* (A). Least impacts of rainfall on the birds (B). Relative humidity significant effects on *P. domesticus* and *P. roseus* bird call notes. Influence of temperature on short flight of birds (C). Impact of perception on the short flights with +0.1 mm log-transformation (D). Effect of humidity on the birds' short flights (E). Effect of temp. on mobbing on all four bird's species (F). Non-significant effect of rainfall on the birds (G). Effect of temp. on intra tussles on the four bird species (H). Precipitation effects recorded for the intra tussles on *P. roseus* (I). Effect of humidity on intra tussles (J).

Short flights of birds are important roost characteristic of all birds. It enables them to make cursory survey around the roosts for foraging and search for any of the predators to harm themselves or fledglings. It was evident for the present study that higher temperature influenced the short flights of tree sparrow, while it hardly affected three other selected species *viz.* house sparrow, rosy starling and also brown shrike. The analyses using the GLMM model indicated that there was negative relationship with the birds. Therefore, an increase of single degree temperature reduced the mean short flight for the house sparrow (-0.59), whereas for the rosy starling (-1.25), for the *T. bicolor* (-2.08) and 0.71 for brown shrike, respectively. Ironically, the temperature between 25 to 30^{o}C proved ecologically friendly for their respective roosts (Fig. 1B). The rainfall in present findings remained fairly passive with little impact variable. Nonetheless, its undesirable influence was evinced on the house sparrow and also on brown shrike with reduced flights (Fig. 1C). Moreover, the relative humidity impacted its reverse impacts for the four sampled birds in all study sites on their slope patterns -1.79, -1.27, -1.12 and -1.80, respectively (Fig. 1D).

Mobbing behaviour

Elevated temperature exerted significant effect for the mobbing patterns for the Tree sparrow while that of rainfall provided no significant effect (Fig. 1E, F). Therefore, impact of temperature remained statistically non-significant for the bird mobbing on house sparrow, tree sparrow and also on brown shrike (0.24, 0.51 and 0.32), respectively.

Intra-tussles

Increased temperature in the diurnal conditions imposed rational effects for the intra-tussles for the brown shrike (0.04*); however, rainfall was non-significant regarding two remaining birds except for the rosy starling, it was significant (0.004**). The GLMM also showed that house sparrow, tree sparrow and brown shrike were largely impacted as there was rise in temperature of 1^{o}C, with their respective slopes of 0.64, 0.38 and 0.35. Yet again, the optimal temperature to conduct customary activities ranged for all birds from 25°C to 30°C (Fig. 1H).

Incidentally, the effects of low intensity rainfall remained yet again negligible effects on the designated birds for the stipulated habitats of all major habitats in study localities of Central Punjab. Relative humidity influenced passively on the behaviour of birds apart from that on the tree swallows, while relative humidity slopes were -0.17 (house sparrow), -0.36 brown shrike and that for the tree sparrow, it was recorded to be -0.11 which suggested that for every percentage increase of 0.17 relative humidity, predominantly of the selected birds became sluggish in their movement patterns (Fig. 1I).

DISCUSSION

Present findings clearly reported that all the four selected birds of the randomly chosen three sub-habitats in the four major habitats of Central Punjab, Pakistan indicated multiple altered behaviour displays due to weather variables. Of the three main climate factors under consideration in the study *viz.* temperature, relative humidity and rainfall, undeniably temperature was the major driver and, therefore, influenced invariably all the four designated birds at the varied locations with several undesirable changes to the bird behaviour. Its impact was evident regarding the overall behavioural displays viz. the reduced calls in their roosts, passive foraging, minimum short flights, mobbing patterns and also the intra and inter-bird tussles which were evinced in their breeding season. The other two weather variables also impacted their behavioural performances at different habitats; nonetheless, could not exercise the similar alterations among them as compared to the temperature (Table I; Fig. 1I, J).

It would be significant to suggest that the delayed activities of the four species perhaps in their longer outlooks would migrate either non-consecutively and consecutively to the more suitable environment for the better survival value than staying at their existing habitats with more vulnerable climate changes. Similar findings have also been reported by (Miller *et al*., 2016). Considering the bird calls as their roost characteristic with their other displays within relatively short distance occurred in good proportions at the start of the day, time when they made exits from their roosts after the long nocturnal hiatus for foraging. At the outset, the calls were loud and cogent; however, in wake of increasing temperatures particularly during the hot summer seasons, the calls became feeble as influenced by stronger temperature effects. Moreover, their movements apparently were of more magnitude during the summer and fall seasons in the late afternoon periods due to the less warm temperatures. Several findings have reported that a certain connectivity occurs between bird displays and the external temperature. Gradual increase of temperature for more than three decades in varying annual seasons at various worldwide habitats affect their incubation success and fledglings success. Numerous studies within species have shown a link between incubation behaviour and air temperature (Van de Ven *et al*., 2020; Batool *et al*., 2023).

Bird migration is also related to varied weather variables. Generally, tolerance limits and levels exhibited by birds cannot account for their survival at their roost points, therefore, enforce direct and indirect patterns of roost away movements directed towards more fitting environment (Haest *et al*., 2019; Horton *et al*., 2020). Precipitation also proved harmless to inhibit the mobbing patterns in their diurnal hours as its frequency of occurrence in the report period was of fairly lowered intensity and to cause substantial impairments to the four selected birds in varying roosting sites hazards except for their rare slope effects. Mobbing, undoubtedly attracts wide range of birds mainly their conspecifics for either at single habitat or different localities which mostly relies on predatory threats (Dutour *et al*., 2016; Cunha *et al*., 2017). Therefore, the interference with environment remains pivotal factor to trigger the weather variabilities for the worldwide ecosystems and produces numerous undesirable modifications to seriously jeopardize ecological sustainability.

CONCLUSION

Avian diversity indicates close relationships with man among the varied ecosystems of the world. As majority of the birds also account for the environmental bioindicators for the swift ecological conditions. Of various weather factors to inhibit the optimal performance of birds, temperature is considered a significant driver to incorporate undesirable changes to the bird populations. It also impacts their routine type of foraging, roosting and breeding profiles. Such altered changes can prove hazardous to the surviving abilities of various birds and lead to loss of bird diversity in any region. Therefore, it addresses the obligations to maximally reduce the human-environment interplay which not only proves mayhem to the birds but also to the humans to jeopardize the environment sustainability.

DECLARATIONS

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Ethical statement

It is certified that the research was conducted by following the protocols set forth by the ethical committee of the University of Agriculture, Faisalabad.

Statement of conflict of interest

The authors have declared no conflict of interest.

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