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ORIGINAL ARTICLE

Effects of weather on behavioural responses of two warbler (*Phylloscopus*) species in the Great Himalayan National Park Conservation Area

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Abstract
Leaf warblers (*Phylloscopus* F. Boie, 1826) are small, insectivorous passerine birds that prefer trees. Although many songbirds, including warblers, have optimal habitats in the forests of the Western Himalayas, it is unknown how these birds react to the climatic changes. In this study, we examined the foraging and other behaviours of grey-hooded warbler *Phylloscopus xanthoschistos* Gray and Gray, 1847 and Blyth's leaf warbler *Phylloscopus reguloides* (Blyth, 1842) in relation to weather conditions in the Great Himalayan National Park Conservation Area. To investigate this, we statistically evaluated behavioural parameters under different weather situations to see if the behaviour of study species differed with weather. For *P. reguloides*, we identified a significant difference between calling during snowfall and rain (KW $\chi^2 = 11.546$, $P = 0.003$), flying during cloudy and clear skies, grounding during light breeze and high winds, preening and sallying during snowfall and no precipitation, separately. For *P. xanthoschistos*, we found significant difference between the calling and grounding during the rainfall and no rainfall, flying during still air and strong winds and between the rainfall and no rainfall (KW $\chi^2 = 12.289$, $P = 0.002$ for wind pattern and KW $\chi^2 = 9.605$, $P = 0.008$ for precipitation types), preening during clear sky and cloudy sky and during rainfall and no rainfall, sallying during clear sky and partially cloudy sky and during cloudy sky and partially cloudy sky and searching (KW $\chi^2 = 8.095$, $P = 0.017$) during no rainfall and snowfall. This study fills important gaps in the Himalayan songbirds since this study elucidates valuable information on the behavioural aspects of leaf warblers.

Keywords Foraging strategy · *Phylloscopus xanthoschistos* · *Phylloscopus reguloides* · Precipitation · Sky condition · Wind velocity

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Introduction

Leaf warblers (Passeriformes: Phylloscopidae: *Phylloscopus* F. Boie, 1826) are a diverse but morphologically undifferentiated genus of passerine birds (Helbig et al. 1995). The least studied characteristics of warblers are their behavioural responses and feeding adaptations in various altitudes and environmental settings. In addition to elevation, precipitation and wind velocities may influence fly-catching strategies and other activities preferred by birds. Despite the difficulty of recording, quantifying these activities is extremely effective in explaining the structure of the bird community (Hutto 1990; Martin and Thibault 1996). Foraging behaviour can differ depending on the availability and distribution of resources (Ghosh et al. 2011). As a result, identifying and studying the range of foraging manoeuvres is difficult, as some species exhibit consistent and steady foraging manners while others prefer generalized ones in different seasons.

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Feeding activity is significantly higher in the early mornings than in the mid-day and late afternoons, possibly due to radiation heat, mid-day heat stress (Ricklefs and Hainsworth 1968), and decreased metabolic demands, according to studies on the foraging strategies of insectivorous birds (Morton 1967). However, very little is known about the daily foraging habits of free-living birds (Bonter et al. 2013). No two species or groups of species, however, forage in the same way, and no two habitats provide the same foraging opportunities. The foraging methods of leaf gleaners and bark foragers are extremely difficult to quantify in the same way that foliage-foragers are. A forager has preferences over the probability distributions of energetic rewards associated with available resources because natural selection appears to have acted on the preference behaviour of those species confronted with environmental variation.

The Himalayas, with its high topographic variation of landscapes and microclimatic conditions, is home to a diverse range of biodiversity (Chettri et al. 2021) and for conservation of biodiversity, understanding the animal behaviour is critical. Because weather includes actual environmental conditions at any time that may deviate dramatically from the predicted climate for that area, organisms are prepared to respond factitiously to unexpected weather conditions through behavioural changes through hormonal action of the hypothalamo-pituitary-adrenal cortex axis (Wingfield et al. 1983). The behaviour of birds can be affected by climatic conditions such as precipitation, variation in temperature, and cloud cover (Silva et al. 2015). However, the behaviour of Himalayan leaf warblers has received very little attention. Singh and Price (2015) studied latitudinal gradient song complexities of grey-hooded warbler *Phylloscopus xanthoschistos* Gray and Gray 1847 and Blyth's leaf warbler *Phylloscopus reguloides* (Blyth, 1842) in the Himalayas. Chettri et al. (2021) studied foraging strategy and guild structure of Himalayan birds which include *P. xanthoschistos* and *P. reguloides*. We performed this study to understand behavioural differences in grey-hooded warbler and Blyth's leaf warbler between different weather conditions. The findings of this study will lay the groundwork for future passerine research to better understand foraging strategies preferred by Himalayan warblers.

Materials and methods

Study area

We conducted the study in post-winter months of February, March, and April of 2019 in the Great Himalayan National Park Conservation Area (Fig. 1). It is located in the Kullu District of the northern Indian state of Himachal Pradesh, in the western part of the Himalayan Mountains. It is a Natural World Heritage site designated by the United Nations

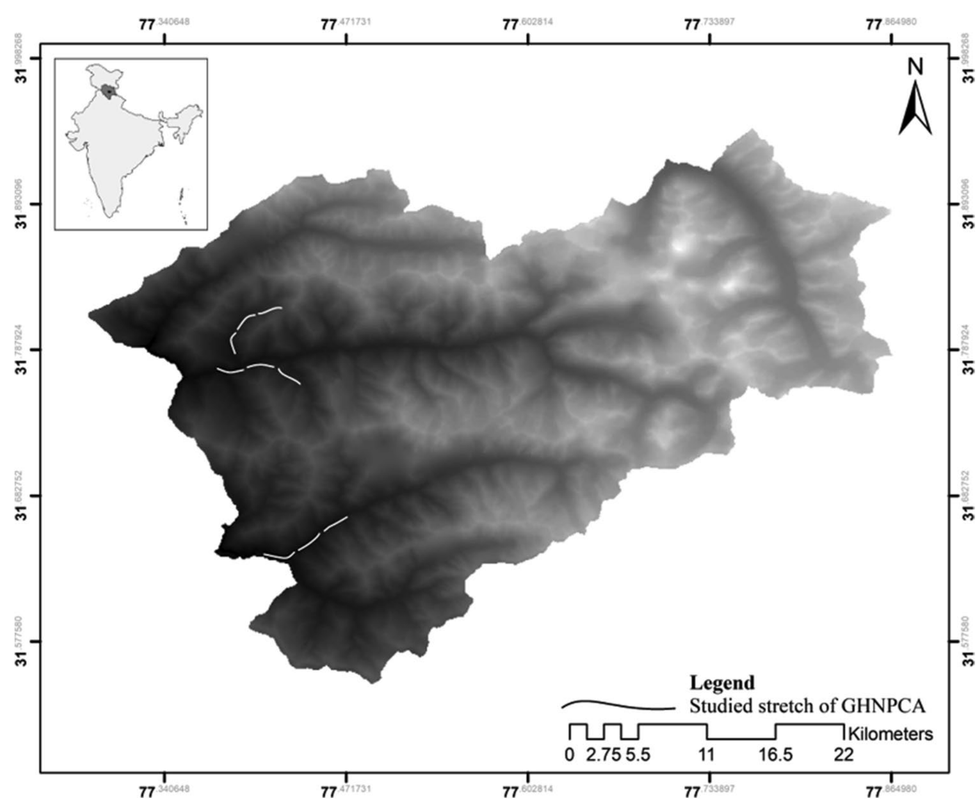

Fig. 1 Location of Tirthan River, Sainj River, and Jiva Nalha in the Great Himalayan National Park Conservation Area (GHNPCA)

Educational, Scientific and Cultural Organization (UNESCO). The park extends from the Himalayan Foothills to the Alpine zone ranging from 1300 to 6000 m of elevational gradient and the area is characterized by temperate broadleaf forests, pine forests, and arid alpine meadows (Singh et al. 2022).

Study design

We chose three locations for data collection: Tirthan Valley, Sainj Valley, and Jiva Nalha. These three areas are nearly parallel (31°38′32.67″N, 77°24′23.09″E to 31°40′51.01″N, 77°32′13.36″E in Tirthan Valley; 31°46′37.85″N, 77°20′48.93″E to 31°44′55.52″N, 77°24′50.78″E in Sainj Valley; and 31°51′8.04″N, 77°16′33.92″E to 31°52′32.14″N, 77°21′35.90″E in Jiva Nalha), have similar altitudinal ranges (1500–3000 m above sea level - asl), and are home to both of the warbler species under study. We divided three areas into three altitudinal zones for data collection: lower (1500–2000 m), mid (2000–2500 m), and upper (2500–3000 m). By using the point count method, we surveyed each zone by plotting a 3-km-long transect with fifteen-point count stations. We chose point census locations at an interval of about 200 m between two points, with a difference of 500 m maintained between two altitudinal zones to reduce the possibility of repeat counts. We performed point count method of recorded birds detected within a radius of 50 m (Wilson et al. 2006; Calladine et al. 2015; Furnas and Callas 2015; Wolff et al. 2018). We conducted survey every day from 08:30 a.m. to 11:30 p.m. Although bird survey work should be started relatively early in the morning, but since our study area is located in the mountainous region, the morning sunlight falls relatively late, so we started bird surveying relatively late. We recorded foraging behaviour along the same transects used for surveying in the evening from early evening (4:00 p.m.) until dusk. We surveyed for 8 days in each zone, for a total of 24 days in one area, and completed the entire survey in 72 days.

Data sampling for foraging behaviour

By observing in field and following Ghosh-Harihar and Price (2013), we recorded ten distinct different activities, namely gleaning (direct dart on the prey), grounding (catching prey and resting on the ground with it), hover picking (when a particular individual hovers and takes prey), interacting (any interactions with individuals of the same or other species), pursuing (when the prey was followed), sallying (flight assisted fly catching in air), searching (searching for prey items), stand picking (when there was no movement of the body), stretch picking (when there was a stretching of the body without use of legs or wings), and others (displays or aggression). We recorded these behaviours by first spotting and identifying an individual bird and then following it. We recorded audio-visuals and later analysed them to reduce the possibility of missing any activity. With various foraging activities, we recorded sky conditions (clear, partially cloudy, and cloudy), precipitation as no rain, rainfall, and snowfall (where drizzle was considered as a rainy day, cloudy day without drizzle or rains was considered as a non-rainy day), and wind velocity (still air: 0 m/s; moderate breeze: > 0–2.5 m/s; and strong winds: 2.5–5 m/s). We measured wind velocity using a Kestrel 5200 professional environmental meter.

Data sampling for other behaviours

While examining active feeding periods, we also recorded four additional observations like calling, preening, sitting, and flying, where the individual was observed until it made foraging movement (Gross and Price 2000). These observations were made with similar sampling design and equipment as used for recording foraging behaviours.

Data analysis

We considered only activities that recorded at least 3 min for analysis. We used non-parametric Kruskal–Wallis rank sum tests (hereafter referred to as KW) followed by post hoc Dunn's test (Dunn 1964) to determine differences in the duration of activities under different environmental conditions (López-Segoviano et al. 2017; Thiebault et al. 2019). We chose the non-parametric Kruskal–Wallis test for data analysis because the presence of null in the data set cannot satisfy the assumptions of parametric tests such as analysis of variance (Aho 2014; Wood et al. 2022). We performed all statistical analysis in R (version 4.0.0) language and environment for statistical computing (R Core Team 2020).

Results

During this study, we counted 1185 individuals of *P. reguloides* and 1002 individuals of *P. xanthoschistos* from the area. We observed *P. reguloides* at elevations ranging from 1500 to 2500 m and *P. xanthoschistos* at elevations ranging from 1700 to 2900 m. We recorded both species from 1700 to 2500 m asl elevation, but we did not find *P. reguloides* below this range and *P. xanthoschistos* is above it (Fig. 2).

Foraging activity of *P. reguloides* and *P. xanthoschistos*

For *Phylloscopus reguloides*, we did not find any significant differences in duration of different foraging activities except for grounding (KW $\chi^2 = 8.223$, $P = 0.016$) and sallying (KW

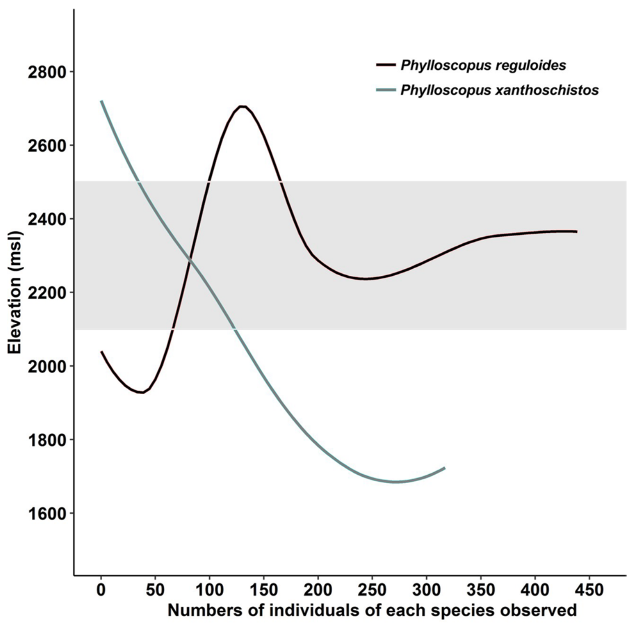

Fig. 2 Trend of elevational distribution of *P. reguloides* and *P. xanthoschistos* in the Great Himalayan National Park Conservation Area. The shaded area represents the elevation at which the maximum numbers of individuals were observed

$\chi^2 = 9.006$, $P = 0.011$). We found a significant difference between the grounding behaviour during moderate breeze and strong winds (Dunn test $z = 2.867$, $P = 0.006$) and sallying during no rainfall and snowfall (Dunn test $z = 2.992$, $P = 0.004$) (Fig. 3).

For *Phylloscopus xanthoschistos*, we did not find any differences in duration of different foraging activities except for grounding (KW $\chi^2 = 8.600$, $P = 0.014$ for precipitation types), sallying (KW $\chi^2 = 9.656$, $P = 0.008$ for sky conditions), and searching (KW $\chi^2 = 8.095$, $P = 0.017$ for precipitation types). We found a significant difference between the sallying behaviour during clear sky and partially cloudy sky (Dunn test $z = 2.498$, $P = 0.019$) and during cloudy sky and partially cloudy sky (Dunn test $z = 2.955$, $P = 0.004$) and searching during no rainfall and snowfall (Dunn test $z = 2.750$, $P = 0.009$) (Fig. 4).

Other recorded activities of *P. reguloides* and *P. xanthoschistos*

A significant difference was observed in duration of different foraging-mediated behaviours of *P. reguloides* like calling (KW $\chi^2 = 11.546$, $P = 0.003$), flying (KW $\chi^2 = 9.301$, $P = 0.009$), and preening (KW $\chi^2 = 11.546$, $P = 0.003$). We found a significant difference between the calling behaviour during the rainfall and the snowfall (Dunn test $z = 2.741$, $P = 0.009$), flying during cloudy and clear sky (Dunn test $z = 3.046$, $P = 0.003$), and preening during no rainfall and snowfall (Dunn test $z = -3.107$, $P = 0.002$) (Fig. 5).

In case of *P. xanthoschistos*, significant difference was observed in duration of different foraging-mediated behaviours like calling (KW $\chi^2 = 12.927$, $P = 0.002$), flying (KW $\chi^2 = 12.289$, $P = 0.002$ for wind pattern and KW $\chi^2 = 9.605$, $P = 0.008$ for precipitation types), and preening (KW $\chi^2 = 10.881$, $P = 0.004$ for sky conditions and KW $\chi^2 = 20.53$, $P < 0.001$ for precipitation types). We found a significant difference between the calling during the rainfall and no rainfall (Dunn test $z = -3.564$, $P = 0.0005$), flying during still air and strong winds (Dunn test $z = 3.227$, $P = 0.002$) and between the rainfall and no rainfall (Dunn test $z = 2.986$, $P = 0.004$), grounding during rainfall and no rainfall (Dunn test $z = 2.736$, $P = 0.009$), preening during clear sky and cloudy sky (Dunn test $z = 3.101$, $P = 0.003$), and during rainfall and no rainfall (Dunn test $z = -4.402$, $P = 0.000$) (Fig. 6).

Discussion

The foraging behaviour of birds is important for resource partitioning (Remešová et al. 2019). For niche complementation or resource partitioning, if the ranges of species overlap, the species who occupy the same fraction of a given resource dimension should differ along other dimensions (Schoener 1974). The behavioural observations recorded in this study may have been influenced by a variety of external factors such as climate, sky, wind, and temperature; the overall survey reveals certain similar pattern in both species. For both species, a significant difference was observed in the duration of other activities like calling, flying, and preening and strict foraging activities like grounding and sallying behaviour but no significant difference was observed in the duration of hover picking, interacting, pursuing, stand picking, and stretch picking. For *P. reguloides*, the precipitation pattern affects calling, preening, and sallying behaviour; sky condition affects flying behaviour; and wind speed affects grounding behaviour. For *P. xanthoschistos*, the precipitation pattern affects other recorded activities like calling, flying and preening behaviour, and grounding (foraging behaviour); sky condition affects preening and sallying; and wind speed affects flying.

This could be due to the fact that these two warblers forage in different microhabitats. *P. xanthoschistos* was observed foraging primarily at lower heights and in undergrowth, whereas *P. reguloides* was observed foraging in the mid-canopies; the differences in behaviours collaborate well with the foraging habitats. Other observations made during the study suggest that these two warblers choose different prey species. *Phylloscopus xanthoschistos* was observed primarily feeding on caterpillars on rhododendrons, whereas *P.*

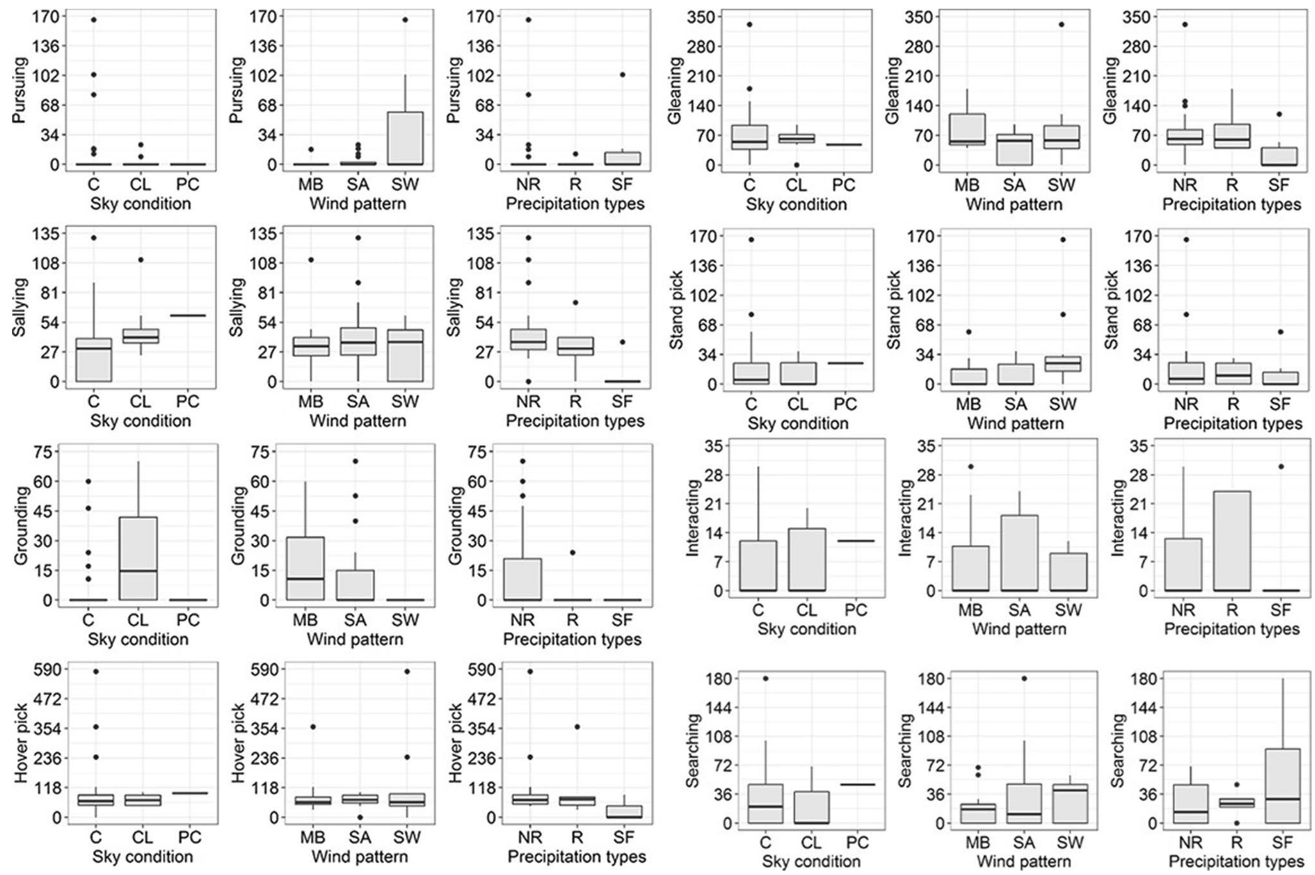

Fig. 3 Box plots depicting the variation in foraging behaviour of Blyth's leaf warbler (*P. reguloides*) under various environmental conditions (C, cloudy; CL, clear sky; PC, partially cloudy; MB, moderate breeze; SA, still air; SW, strong winds; NR, no rain; R, rainfall; SF, snowfall)

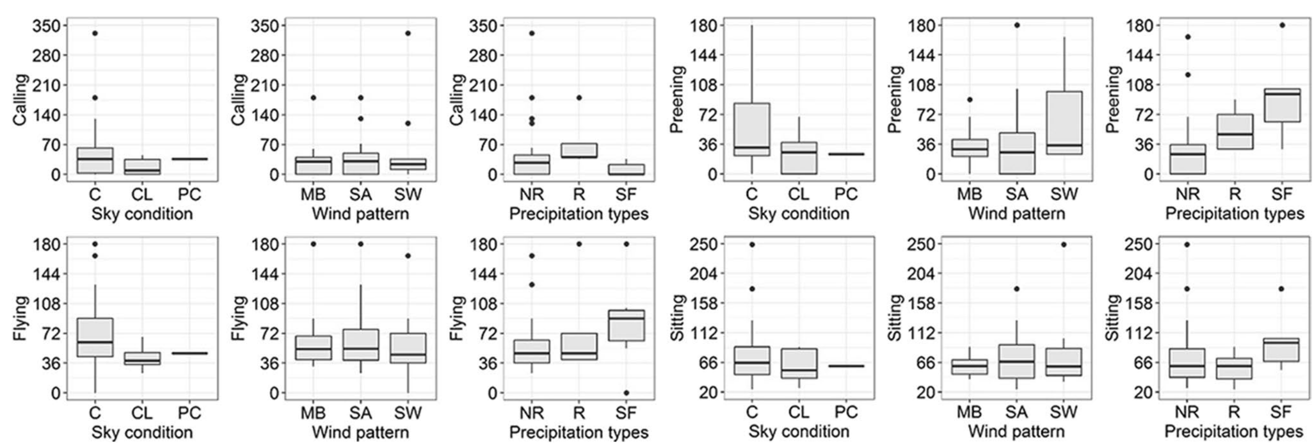

Fig. 4 Box plots depicting the variation in foraging behaviour of grey-hooded warbler (*P. xanthoschistos*) under various environmental conditions (C, cloudy; CL, clear sky; PC, partially cloudy; MB, moderate breeze; SA, still air; SW, strong winds; NR, no rain; R, rainfall; SF, snowfall)

reguloides was found actively preying on spiders on kharsu (*Quercus semicarpifolia*). Food resources can influence spatial variations, habitat selection, and foraging strategies of these species in an indirect way. The observations indicated that *P. reguloides* expends significantly more effort in sallying, especially during snowfall. The calling behaviour observed in both species was obvious during rainy days, as it takes more effort to call when the environment is noisy.

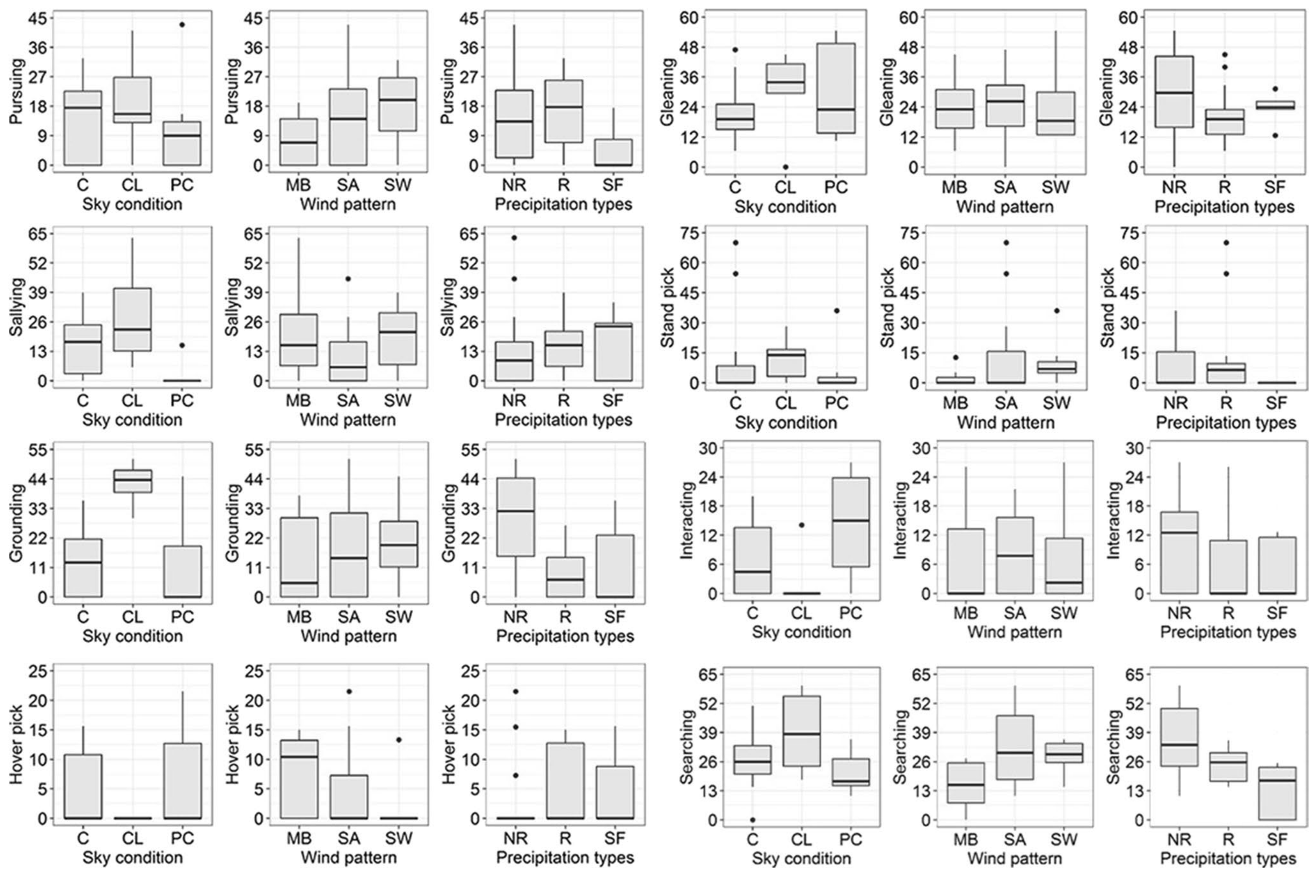

Fig. 5 Box plots depicting the variation in other behaviours of Blyth's leaf warbler (*P. reguloides*) under various environmental conditions (C, cloudy; CL, clear sky; PC, partially cloudy; MB, moderate breeze; SA, still air; SW, strong winds; NR, no rain; R, rainfall; SF, snowfall)

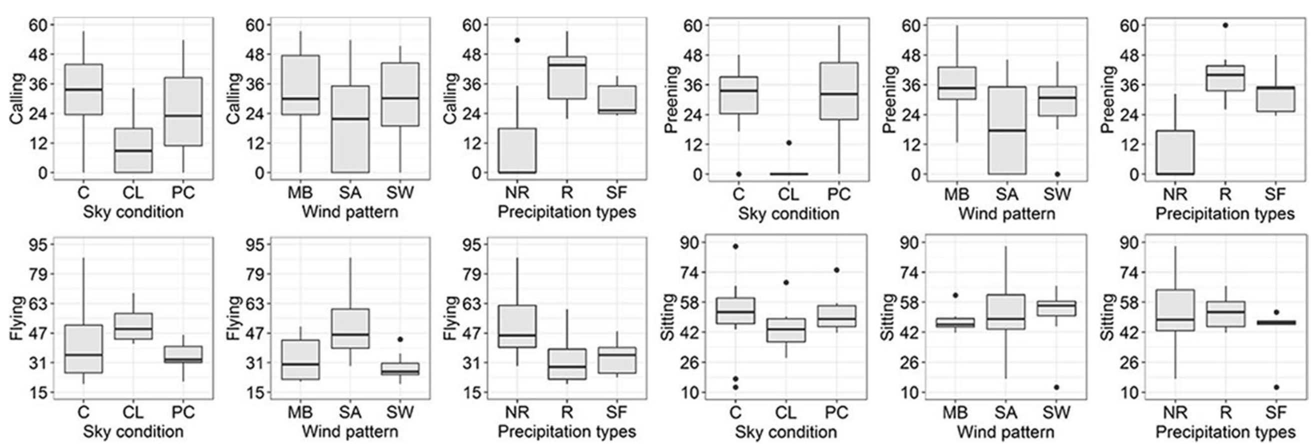

Fig. 6 Box plots depicting the variation in other behaviour of grey-hooded warbler (*P. xanthoschistos*) under various environmental conditions (C, cloudy; CL, clear sky; PC, partially cloudy; MB, moderate breeze; SA, still air; SW, strong winds; NR, no rain; R, rainfall; SF, snowfall)

Flying activity in both species was significantly lower in strong winds than in still air. Higher sample sizes and more observational replicates are required to confirm these conclusions. Pursuing other individuals of the same or different warbler species was observed to be more common in *P. reguloides*, followed by feather ruffling (additional observation). *Phylloscopus reguloides* preferred contact calls but was observed and recorded singing occasionally and was found to use more aerial foraging manoeuvres such as hover picking, gleaning, and sallying, as they primarily foraged near canopies. The abundance of arthropods is influenced by factors such as slope (Tolbert 1975). In the current study, the majority of *P. xanthoschistos* foraging observations were made while feeding on caterpillars on scrubs that were mostly found along the slopes, where there could be increased food availability (including caterpillars) and it could serve as a productive exposure to this species. These differences in foraging strategies between the two species allow them to reach prey with the least amount of effort. The distribution of species within habitats is influenced by morphology, phylogeny, and competition (Forstmeier et al. 2001). We observed that the ashy-throated warbler (*P. maculipennis* Blyth, 1867) was the primary competitor of *P. xanthoschistos*, and the lemon-rumped warbler (*P. chloronotus* Gray, JE and Gray, GR, 1847) was the primary species that competes with *P. reguloides*. The foraging strategies of the species and their competitors are mostly similar, although this aspect was beyond the scope of this study.

While *P. reguloides* was seen foraging in the mid-canopies, *P. xanthoschistos* was seen mostly foraging at lower heights and in undergrowth. Calling may have been the most frequently observed behaviour in *P. reguloides* during rains and snowfall, since it necessitates additional effort to communicate from the middle of canopy than it does in shrubby or open areas. The majority of observations of foraging *P. xanthoschistos* were made in open areas around agricultural fields and bushes, where more insects are likely to skim during strong winds and rainfall, which would have triggered the flying activity. In *P. xanthoschistos*, searching activity may have been more apparent during snowfall because open shrubby patches are less conducive to foraging than canopies during snowfall, which limits the likelihood and amount of time available for foraging.

Knowledge of animal behaviour, particularly resource use patterns in a variety of environmental and weather conditions, is essential for proper conservation and management. However, there is a significant lack of knowledge about Himalayan birds in this regard. In this study, we attempted to comprehend the species-specific foraging behaviour of two leaf warblers in different weather conditions in the Western Himalayas. We recommend that more research be conducted over a longer period of time because this work is solely based on data collected over a 3-month period.

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Author contribution TP conceived the idea, collected data, and wrote original draft. KD analysed the data, designed the figures, and wrote original draft. APS collected data, analysed the data, and designed the figures. VUP supervised the work and edited draft. All authors provided critical feedback and helped to shape the manuscript.

Declarations

Ethics approval Not applicable.

Conflict of interest The authors declare no competing interests.

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