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Cover: Coromandal Sacred Langur *Semnopithecus priam* - made with acrylic paint. © P. Kritika.

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COMMUNICATION

Seasonal variation and habitat role in distribution and activity patterns of Red-wattled Lapwing *Vanellus indicus* (Boddaert, 1783) (Aves: Charadriiformes: Charadriidae) in Udaipur, Rajasthan, India

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Abstract: Red-wattled Lapwings *Vanellus indicus* are resident waders in Asia. They usually inhabit areas close to water and are mainly insectivorous. Their principal habitats are grasslands, wetlands, arable lands, gardens and open forests. These highly active and vocal birds are known for their wide range of distraction displays. A field investigation of distribution across different seasons and diverse habitats in Udaipur, Rajasthan was conducted from 2019 to 2021. Populations of lapwings varied significantly among locations, with the largest documented at Fateh Sagar Lake and the lowest at Rang Sagar Lake. Both habitat types and seasons (summer, monsoon and winter) had significant effects on lapwing distribution. Wetlands were the most preferred habitat at ten major study locations, and the monsoon was found to be the most favored season. Bird activity patterns did not exhibit significant variation with seasons, with locomotion, vigilance, feeding and maintenance being the most performed activities.

Keywords: Behavioral activities, habitat preference, lapwings, seasonal effect, vigilance.

Abbreviations: MLSU—Mohanlal Sukhadia University | RCA—Rajasthan College of Agriculture

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Author contributions: SG carried out research work on Red-wattled lapwings under the supervision of Prof. Kanan Saxena. All the photographs and data were collected by him. He performed statistical analyses of data and wrote the manuscript. KS laid out the concept and framework of the research work. The interpretation of results was carried out by her. The manuscript was written under her guidance.

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INTRODUCTION

Red-wattled Lapwings *Vanellus indicus* are resident waders that usually inhabit areas close to water. They are widely distributed throughout Asia, having been reported from India, Iran, Iraq, Kuwait, Oman, Syrian Arab Republic, Turkey, United Arab Emirates, Bangladesh, Bhutan, Cambodia, China, Indonesia, Israel, Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, Pakistan, Singapore, Sri Lanka, Thailand, and Vietnam (Ali & Ripley 2001; Wiersma & Kirwan 2020; BirdLife International 2023). This species is found in lowlands up to 1,800 m in Sri Lanka, and to at least 2,300 m in the Himalaya. The principal habitats of lapwings are grasslands, wetlands, arable lands, gardens, and open forests (Wiersma & Kirwan 2019). The global population is estimated to be about 50,000 to 60,000 individuals (BirdLife International 2023). The IUCN Red List of Threatened Species classifies Red-wattled Lapwing as 'Least Concern', and it is listed under Schedule IV of the Indian Wildlife Protection Act, 1972.

The literature on the population structure and distribution of Red-wattled Lapwing is limited, and a proper assessment of populations is lacking, probably due to a perceived absence of immediate threats to the species. However, some reports do indicate threats to lapwing populations and habitats. Karakas (2016) recorded 20–30 breeding pairs in Turkey, and reported that the construction of dams posed a threat to the habitats of this species causing population decline and moderate range expansion in search of suitable habitats. Gupta & Kaushik (2011) highlighted habitat destruction and threats to lapwings in Kurukshetra, Haryana.

Red-wattled Lapwings are highly active and vocal birds that are known for their wide range of distraction displays (Kalsi & Khera 1987). These birds are mainly insectivorous but also are known to feed on food grains (Babi 1987), molluscs (Madhava & Botejue 2011) and fishes (Greeshma & Jayson 2019). Studies on the seasonal variations as well as variations in the daily activity patterns with breeding and non-breeding periods have not been reported earlier.

Udaipur city offers unique habitat diversity such as mountain ranges, elevated plateaus, green plains, forests, rivers, and wetlands which explains the choice of this city as the field for study. The presence of ample natural resources such as food and water make the city a perfect haven for bird species such as Red-wattled Lapwings. Thus, the study was conducted to provide baseline information regarding the distribution pattern, habitat preference, and activity patterns of Red-wattled Lapwing at 10 major locations covering diverse habitats of Udaipur city.

MATERIALS AND METHODS

Study area

The field survey was carried out in different areas of Udaipur City (24.585° N and 73.712° E), southern Rajasthan, India between 01 September 2019 to 30 September 2021. The study was conducted during the three main seasons viz. summer (March to June), monsoon (July to September), and winter (October to February). Diverse habitats of Red-wattled Lapwings, such as wetlands, grasslands, open fields, river banks, islands, and gardens were selected for the assessment. The sampling sites were randomly chosen and their GPS (global positioning system) coordinates were determined using Garmin eTrex 20x (Appendix 1, Image 1a) for documenting the distribution pattern of Red-wattled Lapwings. The Red-wattled Lapwings were recorded in wetlands (Lake Fateh Sagar, Lake Pichola, Rang Sagar Lake, Goverdhan Sagar Lake, and Ayad River), crop-fields (farms near Fateh Sagar Lake, Ayad River, and agricultural lands in Rajasthan College of Agriculture (RCA) and Mohanlal Sukhadia University (MLSU) campuses), grasslands (inside MLSU, areas around Fateh Sagar Lake, Goverdhan Sagar Lake, Ayad River, and Sajjangarh Biological Park), urban parks (Sukhadia Memorial Park and Gulab Bagh), protected areas (Sajjangarh Biological Park and Gulab Bagh), institutional green spaces (MLSU and RCA campuses) and constructed buildings, roads, and footpaths (areas around Fateh Sagar Lake, Pichola Lake, Rang Sagar Lake, Goverdhan Sagar Lake, MLSU, and Ayad River) as shown in Image 1b.

Population monitoring

The population survey was carried out by adopting the point count method (Bibby et al. 2000). A total of 288 vantage points (maintained 200 m between two sites) spanning a total area of 37.5 km^2. We spent 5 min at each site and then started documentation of the lapwings without disturbing them. Birds were recorded using binoculars (Nikon Aculon A211 8 x 42) as well as auditory detections (using RecForge II app on a smartphone) within a range of 30 m at each site. Flying birds were not recorded. To analyze the correlation between the influence of season and habitat preference, the number of birds recorded during the first week of the month were selected for each season, viz.: January for

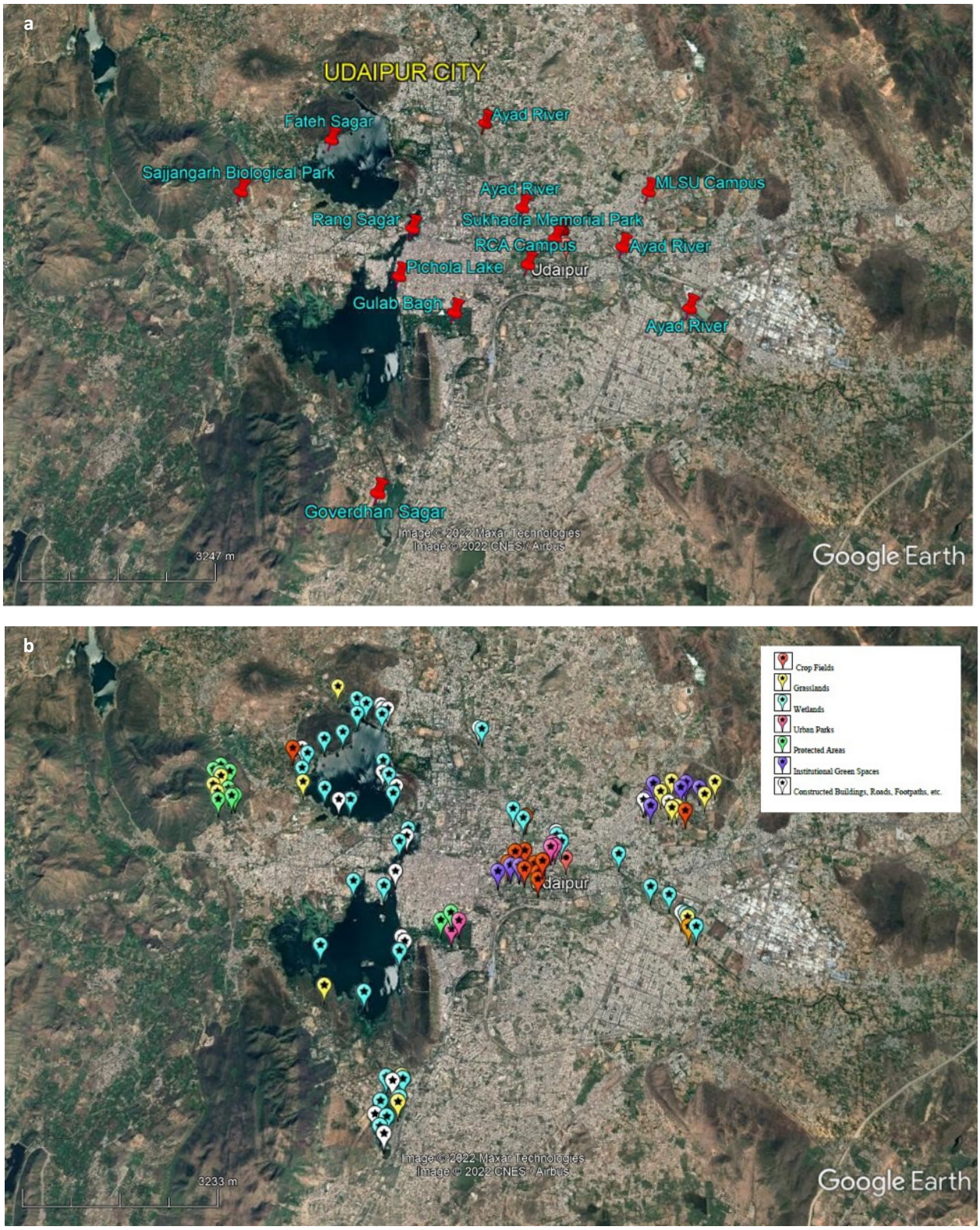

Image 1. a—Satellite map of selected sampling sites in Udaipur city for population survey of Red-wattled Lapwing | b—Satellite map showing diverse habitat areas of Red-wattled Lapwings at the study sites in Udaipur city.

winter, June for summer, and September for monsoon (Chaudhury & Koli 2018).

Activity pattern sampling

Focal sampling and scan sampling techniques (Altmann 1974) were employed to observe the activity patterns of lapwings daily between 0700–1000 h, 1200–1300 h, and 1600–1800 h during different seasons. About 6–8 pairs of birds were randomly selected from diverse habitats. The behaviour was recorded and observed using binoculars at a distance of 15 m to avoid disturbance. Each bird was observed at 5 min time intervals.

The activity patterns of selected birds were recorded for 480 hours during the entire study time. The following activity patterns of Red-wattled Lapwings were observed during the investigation: (i) locomotion, (ii) maintenance, (iii) feeding, (iv) vigilance, (v) vocalizations, (vi) displays, (vii) inactivity, (viii) social interaction, and (ix) miscellaneous activities. Since the birds were not tagged, there was a possibility of recording the activity of birds more than once. However, the probability of deviation in data due to the error gets reduced because the same bird was not recorded more than once during the time of scanning. To ensure that the same bird was not observed more than once during the scanning time, observations were made only of birds that were present throughout the observation time. The activity of a bird that flew away or towards the selected site during a particular observation time was not recorded. Moreover, each bird was observed only for 5 min during every observation cycle and and if birds are presumed to alter their activities with specific factors such as breeding or non-breeding seasons and time, then according to Maruyama et al. 2010, the spotting of same individual more than once doesn't imply strong pseudo-replication.

Statistical analyses

The statistical analyses were carried out using GraphPad Prism and Microsoft Excel software. Two-way analysis of variance (ANOVA) was used to test the significance of the population status of Red-wattled Lapwings in different months (Factor 1) at various sampling sites (Factor 2). Similarly, the numbers of lapwings in diverse habitats (Factor 1) during different seasons (Factor 2) were also tested using the two-way ANOVA method. Mann-Whitney U test and two-way ANOVA were used to study the activities of the birds across different months. A comparative analysis of activities between breeding and the non-breeding season was also performed by carrying out Mann-Whitney U test and multiple-t tests. Further, the activities at various periods during breeding and non-breeding season were also analyzed by two-way ANOVA. Data were computed at a probability level of 5% and were used as the minimal criteria of significance.

Table 1. Population status of *Vanellus indicus* during study periods 2019–2020 and 2020–2021 from all study sites of Udaipur City.

	Sites	2019–2020											2020–2021										
		Sep 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Jun 20	Jul 20	Aug 20	Mean ± SD	Oct 20	Nov 20	Dec 20	Jan 21	Feb 21	Mar 21	Jun 21	Jul 21	Aug 21	Sep 21	Mean ± SD
1.	Fateh Sagar	33	31	24	23	22	24	58	60	68	72	41.5 ± 20.45	43	31	28	29	32	52	66	74	68	56	61.7 ± 14.22
2.	Rang Sagar	2	0	2	2	0	2	6	6	8	4	3.2 ± 2.70	3	1	0	2	2	4	4	8	6	4	3.6 ± 2.50
3.	Pichola Lake	32	22	21	19	20	22	48	57	60	64	36.5 ± 18.62	30	22	21	23	23	36	48	50	54	39	37.9 ± 16.32
4.	Ayad River	18	16	18	17	15	18	28	42	48	52	27.2 ± 14.53	22	19	18	18	17	24	32	48	46	24	26.8 ± 11.52
5.	Goverdhan Sagar Lake	21	12	12	10	10	12	22	28	34	38	19.9 ± 10.44	14	8	8	7	8	12	18	26	31	16	15.4 ± 8.53
6.	RCA Campus	10	10	12	12	10	11	30	27	32	28	18.2 ± 9.92	8	10	8	8	10	14	19	24	20	14	13.5 ± 5.76
7.	MLSU Campus	21	24	22	20	22	20	47	43	48	56	32.3 ± 14.34	23	22	20	20	20	28	42	46	44	26	30.1 ± 11.28
8.	Sajjangarh Park	15	16	16	14	14	16	39	52	58	46	28.6 ± 17.98	17	14	16	15	16	30	37	32	34	25	23.9 ± 9.10
9.	Sukhadia Memorial Park	6	3	4	4	3	3	5	8	6	8	5 ± 1.94	2	0	1	0	2	4	6	4	6	5	3 ± 2.31
10.	Gulab Bagh	14	10	8	9	8	8	12	22	26	28	14.5 ± 7.85	16	12	12	8	10	16	22	30	38	27	19.1 ± 9.85

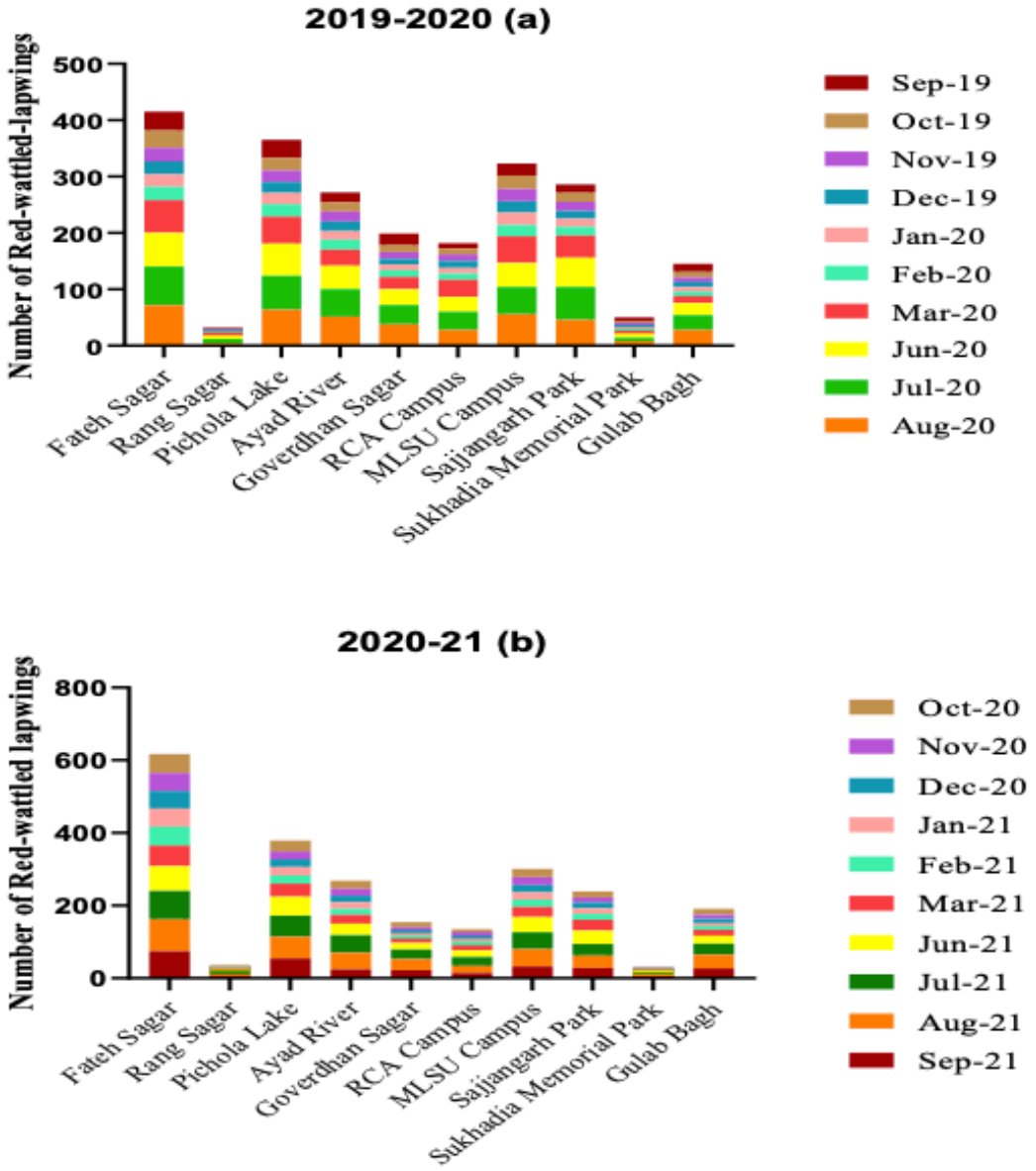

Figure 1. Population status of Red-wattled Lapwings at different locations of Udaipur City in various months during the study periods: a—2019–2020 | b—2020–2021.

RESULTS

During the current study, 2269 (Mean value = 226.9) Red-wattled Lapwings were observed in the period from September 2019 to August 2020, while 2350 (Mean value = 235) lapwings were recorded during the period between October 2020 and September 2021.

Maximum population of Red-wattled Lapwing was found at Lake Fateh Sagar (41.5 ± 20.45) and minimum at Rang Sagar Lake (3.2 ± 2.7) during the observation period from 2019 to 2020. The statistical analysis of data presented in Table 1 revealed that the variation of the population at diverse locations ($F = 32.37$; $p < 0.0001$; $df = 9$) was slightly more significant than that with different months ($F = 26.02$; $p < 0.0001$; $df = 8$). The highest population was recorded in August 2020 (39.60 ± 22.72) while the lowest was in January 2020 (12.4 ± 7.63) (Figure 1a).

During the study period from 2020 to 2021, the highest population occurred at Fateh Sagar (61.70 ± 14.22) while the lowest population was found at Sukhadia Memorial Park (3.00 ± 2.31) (Figure 1b). On performing ANOVA for Table 1, the result showed that the population varied highly significantly at various sites ($F = 105.30$; $p < 0.0001$; $df = 9$) compared to different months ($F = 26.71$; $p < 0.0001$; $df = 9$). The highest

population was observed in August 2021 (37.70 ± 24.91) while the least was in January 2021 (15.10 ± 14.45).

Combining the results of both years, the highest population was found at Lake Fateh Sagar (51.47 ± 14.28) and the lowest at Rang Sagar Lake (3.4 ± 0.28).

Further, the varied habitats and seasons on the population status of Red-wattled Lapwings were also analyzed (Figure 2). The Red-wattled Lapwings existed in diverse habitats (Image 2). It was found that the nature of the habitat produced a highly significant impact on the population ($F = 67.62$; $p < 0.0001$; $df = 6$). The highest population occurred in wetlands (50 ± 13.34) followed by crop fields (21.33 ± 9.85), protected areas encompassing scrub forests and shrubland (20 ± 7.82), grasslands (18.83 ± 9.35), institutional green spaces (18.33 ± 8.11), urban parks or gardens (15.83 ± 7.49) and constructed buildings, footpaths & roads (11.5 ± 3.39) (Table 2). Although the wetland was the most preferred habitat, the lowest numbers of lapwings were recorded at Rang Sagar Lake. This may be due to the indiscriminate dumping of garbage and sewage in the lake as well as excessive human disturbances near this wetland. Conversely, the presence of these birds near human habitation such as urban parks and constructed buildings indicates that these birds have adapted well to the anthropogenic pressure.

Further, variation of the population across different habitats in diverse seasons also showed significance ($F = 33.92$; $p < 0.0001$; $df = 8$). The overall highest population of lapwings in various seasons was recorded in monsoon (33.14 ± 1.11) followed by summer (19.86 ± 1.21) and winter (14.57 ± 0.61) during the study periods (Table 2). On the contrary, the number of individuals was higher in the wetlands in the summer season.

The activity patterns of Red-wattled Lapwings studied during the periods 2019–2020 and 2020–2021 did not show any significant variation by performing Mann Whitney U-test ($U = 39$; $p = 0.9314$). A two-way ANOVA revealed that the percentage of each activity varied highly significantly across different months ($F = 218.4$; $p < 0.0001$; $df = 8$) but the percentage of all activities in a particular month did not vary considerably ($F = 0.0072$; $p > 0.9999$; $df = 8$) in 2019–2020 (Table 3). For the 2020–2021 study period, again the percentage of each activity varied significantly across different months ($F = 182.6$; $p < 0.0001$; $df = 8$) but the percentage of all activities in a particular month showed insignificant variation ($F = 0.0019$; $p > 0.9999$; $df = 8$) (Table 3).

The analysis of activity patterns during the breeding and non-breeding season showed that there were no

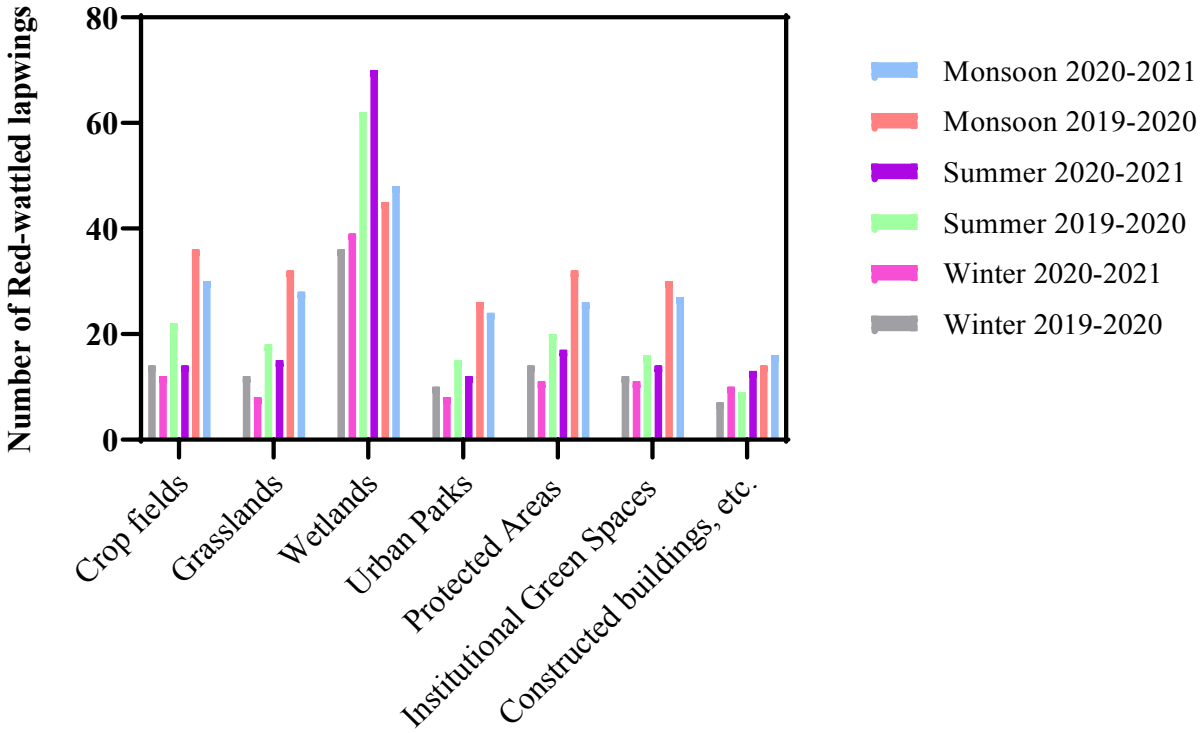

Figure 2. Population distribution of Red-wattled Lapwings across various habitats in Udaipur City during winter, summer, and monsoon seasons in 2019–2020 and 2020–2021.

Image 2. Red-wattled Lapwings thriving across different habitats in Udaipur City: a—Crop-field | b—Grassland | c—Wetland (Lake) | d—Wetland (River) | e—Protected area | f—Urban Park | g—Institutional green spaces | h—University Campus' fountain area | i—Embankment | j—Footpath | k—Building's rooftop| l—Vacant site | m—Roadside. © Sahil Gupta.

Table 2. Population distribution of *Vanellus indicus* across different habitats of Udaipur City in various seasons during 2019–2021.

	Habitats	Winter Season		Summer Season		Monsoon Season		Total	
		2019–2020	2020–2021	2019–2020	2020–2021	2019–2020	2020–2021	2019–2020	2020–2021
1.	Crop fields	14	12	22	14	36	30	72	56
2.	Grasslands	12	8	18	15	32	28	62	51
3.	Wetlands	36	39	62	70	45	48	143	157
4.	Urban Parks (Gardens)	10	8	15	12	26	24	51	44
5.	Protected Areas (Scrub Forests and shrubland)	14	11	20	17	32	26	66	54
6.	Institutional Green Spaces	12	11	16	14	30	27	58	52
7.	Constructed buildings, roads, footpaths, etc.	7	10	9	13	14	16	30	39
Total individuals in different seasons		105	99	162	155	215	199	482	453

Table 3. Activities of Red-wattled Lapwings during different months in the periods 2019–2020 and 2020–2021.

	Activity	Relative Percentage of Activities (2019-2020)										Relative Percentage of Activities (2020-2021)									
		Sep 19	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	Aug 20	Mean ± SD	Oct 20	Nov 20	Dec 20	Jan 21	Feb 21	Jun 21	Jul 21	Aug 21	Sep 21	Mean ± SD
1	Locomotion	18.19	21.68	22.08	22.01	23.21	21.72	17.64	16.82	16.74	20.01 ± 2.59	21.13	22.78	22.11	23.27	21.12	15.01	16.54	16.65	16.98	19.51 ± 3.17
2	Foraging	12.86	15.12	15.19	15.08	15.23	15.7	10.93	12.97	12.82	13.99 ± 1.64	15.07	15.29	15.38	15.98	15.11	12.06	11.91	10.94	11.77	13.72 ± 1.98
3	Vigilance	32.28	31.03	30.45	30.23	29.08	30.8	40.87	41.05	40.24	34.00 ± 5.11	30.83	30.96	29.5	30.32	30.98	42.07	40.44	41.95	40.89	35.33 ± 5.74
4	Maintenance	15.84	15.28	15.81	15.88	16.32	15.43	13.24	12.06	12.12	14.66 ± 1.70	16.12	15.68	16.18	15.48	15.29	13.08	12.96	12.95	12.56	14.48 ± 1.54
5	Defense	1.17	1.19	1.08	1.26	0.98	1.14	1.98	2.04	1.27	1.34 ± 0.39	1.16	1.17	1.21	1.15	0.99	2.01	2.06	1.9	1.48	1.46 ± 0.42
6	Vocalization	2.38	1.95	2.05	1.99	1.66	1.72	2.6	2.66	2.42	2.16 ± 0.37	1.92	2.12	1.96	1.79	1.71	2.75	2.85	2.93	2.08	2.23 ± 0.48
7	Social interactions	0.73	0.63	0.67	0.68	0.7	0.82	0.72	0.66	0.74	0.70 ± 0.05	0.69	0.68	0.65	0.72	0.68	0.69	0.67	0.7	0.71	0.69 ± 0.02
8	Inactivity	11.67	9.68	10.02	9.78	10.06	10.72	8.88	8.62	10.33	9.97 ± 0.92	9.82	9.27	9.87	9.23	10.91	9.23	9.38	9.14	11.19	9.78 ± 0.77
9	Miscellaneous	4.88	3.44	2.65	3.17	2.76	3.67	3.14	3.12	3.32	3.35 ± 0.65	3.26	2.05	3.14	3.06	3.21	3.1	3.19	2.84	2.34	2.91 ± 0.43

significant differences in the behaviours during both seasons (Figure 3) (Mann Whitney U = 40; p >0.9999). During the breeding season, vigilance (40.31%), locomotion (16.89%), maintenance (12.73%), and foraging (12.22%) were the main activities followed by inactivity (9.72%), miscellaneous activities (3.14%), vocalization (2.14%), defense (2.07%), and social interactions (0.78%) (Table 4). A two-way ANOVA at different periods of the day revealed that each activity varied significantly at different times during the breeding season (F = 194.5; p <0.0001; df = 8) but there was no major difference in all activities performed in a particular period (F = 2.29; p = 0.0712; df = 5) (Table 4, Figure 4a).

The major activities of Red-wattled Lapwing during the non-breeding season were vigilance (30.66%) followed by locomotion (21.21%), feeding (16.17), maintenance (15.19%), and other activities such as inactivity (10.02%), miscellaneous (2.74%), defense (1.36%), vocalizations (1.94%), and social interactions (0.71%) (Table 4). Multiple t-tests for activities in breeding and non-breeding seasons revealed that significant differences exist in vigilance (t ratio = 5.571; p = 0.000182; df = 10; q-value = 0.000645) and defense (t ratio = 6.587; p = 0.000062; df = 10; q-value = 0.000437) (Table 4). In the non-breeding season, each activity at different periods of the day (F = 230.6; p <0.0001; df = 8), as well as activities performed in a particular period (F = 2.29; p = 0.0712; df = 5), showed noteworthy variation, the former being far more significant than the latter (Table 4, Figure 4b).

Overall, the results show that amongst all the

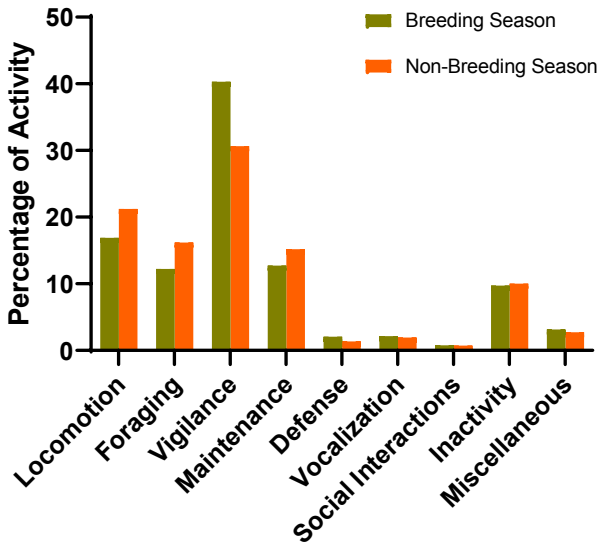

Figure 3. Percentage of activities of Red-wattled Lapwings across breeding and non-breeding seasons.

activities displayed during the study period, the Red-wattled Lapwing showed the highest level of vigilance activity (alert posture/crouched in alert, neck usually extended forward with upright posture and horizontal bill) throughout the months of breeding as well as non-breeding seasons. Locomotion (walking, running, and flying) was the second most performed activity. Feeding (foraging- foraging-stop-run-peck, foot stirring as well as prey handling) and maintenance (preening, bathing, scratching, stretching, grooming legs with bill, and shaking the plumage) were the next most important activities. It was found that during the non-breeding season, the birds were less vigilant and spent more time feeding, especially during morning and late afternoon.

Red-wattled Lapwings were often observed standing still or resting during the study schedule. It was more prominent during the evening hour (1700–1800 h). Miscellaneous activities such as disheveling of feathers, tail shaking, stomping the ground, head lowering, spreading wings, and defecating were also demonstrated by Red-wattled Lapwing during the investigation.

The defense strategies adopted by Red-wattled Lapwing included distraction displays like injury feigning, crouched run, false brooding, false feeding, aggression and mobbing, escape behaviour, and swooping. The lapwings showed defense behaviour and uttered loud alarm calls more during the breeding season (March to September) to protect their nests and young ones from predators.

Red wattled-Lapwings were also spotted interacting among themselves as well as found in association with birds like Cattle Egret *Bubulcus ibis*, Little Cormorant *Microcarbo niger*, Red-naped Ibis *Pseudibis papillosa*, Painted Stork *Mycteria leucocephala*, Asian Openbill Stork *Anastomus oscitans*, Little Grebe *Tachybaptus ruficollis*, and mammals like cattle. The lapwings were frequently seen roosting with birds like cormorants and alerting other bird species by making alarm calls. Two intra- and one inter-specific conflicts were observed. The intra-specific conflicts were for territory and mate while the interspecific fight with Cattle Egret *Bubulcus ibis* was for food. We observed that when predators like crows or dogs were sighted, lapwings showed active defense behaviour, especially during the breeding season. We also documented that during the non-breeding season, a foraging lapwing was not found to be scared in the presence of a dog who was at less than 1 m. Our observations revealed that when humans were at 5 m or less, the Red-wattled Lapwings were often observed uttering loud calls, running, and on approaching closer, the birds often flew away. Thus, a diverse range of behaviour of Red-wattled Lapwings was observed during our study.

DISCUSSIONS

Population Studies on Red-wattled Lapwings

The overall highest population was found at Fateh Sagar Lake while the lowest was recorded at Rang Sagar Lake, which could probably be ascribed to several factors such as high level of human disturbance, indiscriminate dumping of garbage and poor sewage management of Rang Sagar Lake (Pillai 2000) rendering it one of the most polluted lakes of Udaipur city and unsuitable habitat for lapwings. The breeding season of Red-wattled Lapwing extends from March to August (Kumar et al. 2005). The occurrence of the highest number of Red-wattled Lapwings in August and the lowest number of lapwings in January is probably because August and January coincide with the breeding and non-breeding seasons of these birds, respectively.

Red-wattled Lapwings usually prefer open areas near water resources (Wiersma & Kirwan 2019). In our surveys the birds were found over a wide range of open habitats such as croplands, grasslands, wetlands, protected areas, institutional green spaces, constructed buildings, roads, footpaths, etc. which corroborate with earlier observations (Ali 1996; del Hoyo et al. 1996; Ali & Ripley 2001; Narwade et al. 2010; Sethi et al. 2011; Muralidhar & Barve 2013). The habitat preference of lapwings reveals that the proximity of water and food

Table 4. Percentage of activities of Red-wattled Lapwings at a different period of the day during the breeding and non-breeding seasons.

	Activity	Period of day (hours) during Breeding Season						Total Percentage	Period of day (hours) during Non-Breeding Season						Total Percentage
		0701–0800	0801–0900	0901–1000	1201–1300	1601–1700	1701–1800		0701–0800	0801-0900	0901-1000	1201-1300	1601-1700	1701-1800	
1	Locomotion	3.52	3.69	3.21	2.04	2.23	2.2	16.89	3.56	3.8	3.95	3.12	3.74	3.04	21.21
2	Foraging	2.06	2.62	2.29	1.46	2.16	1.63	12.22	2.16	3.24	3.47	2.1	2.98	2.12	16.17
3	Vigilance	6.72	7.14	7.03	6.38	6.93	6.11	40.31	4.93	5.52	5.68	4.44	5.57	4.52	30.66
4	Maintenance	1.37	2.64	2.66	2.76	1.78	1.52	12.73	2.38	2.68	2.78	2.42	2.56	2.37	15.19
5	Defense	0.37	0.39	0.36	0.32	0.35	0.28	2.07	0.2	0.22	0.25	0.24	0.21	0.24	1.36
6	Vocalization	0.38	0.37	0.35	0.29	0.36	0.39	2.14	0.33	0.35	0.34	0.31	0.32	0.29	1.94
7	Social interactions	0.09	0.11	0.23	0.17	0.1	0.08	0.78	0.08	0.14	0.17	0.15	0.11	0.06	0.71
8	Inactivity	1.62	1.42	1.39	1.73	1.67	1.89	9.72	1.69	1.49	1.45	1.72	1.64	2.03	10.02
9	Miscellaneous	0.5	0.57	0.59	0.48	0.56	0.46	3.14	0.46	0.48	0.49	0.44	0.45	0.42	2.74

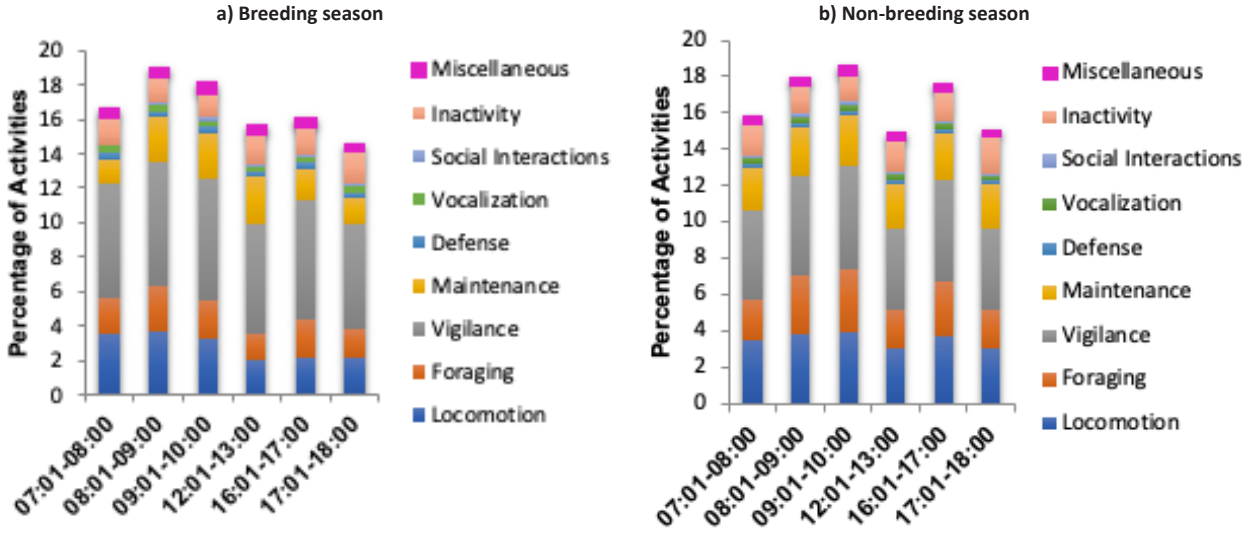

Figure 4. Percentage of activities of Red-wattled Lapwings at different hours of the day during: a—breeding season | b—non-breeding season.

resources, as well as the level of disturbance, play key factors in deciding the dwelling sites of these birds. This correlates with previous studies on shorebirds, waders, and other terrestrial birds (Smith et al. 2007; Verma & Murmu 2015). Further, the presence of these birds near human habitations such as urban parks and construction sites confirms that these birds have adapted very well to anthropogenic pressures.

The effect of seasonal variation on the distribution of Red-wattled Lapwings across different habitats of Udaipur City reveals that the monsoon season is the most favorable season for these birds followed by summer and winter. The highest population of birds during monsoon could be attributed to the abundance of food (in the form of insects) and water (Delgado & Moreira 2010; Franca et al. 2020). Red-wattled Lapwings are also known to feed on food grains (Babi 1987). Therefore, the high population of Red-wattled Lapwings in croplands during the monsoon could be attributed to the presence of harvest of maize and sorghum (Jat et al. 2004; Lin 2005). Also, during monsoon, growth of wild grass and vegetation increases across different habitats like protected areas, grasslands, institutional green spaces, urban parks or gardens, along roads, and empty plots, thus providing shelter along with insects as food to lapwings.

The wetlands were the most preferred sites during all seasons. However, unlike other habitats where the lapwings' population was higher during monsoon, at wetlands the trend was reversed, the population was lesser than that in summer. This is because during monsoon due to rain, the water level increases

thereby flooding the islands of wetlands (Kushlan 1981; Chaudhury & Koli 2018). So, during monsoon, the Red-wattled Lapwings were mainly encountered on the embankment of the wetlands and not on the islands. The highest population of lapwings was recorded at the wetlands during summer (breeding season) because the shallow wetlands serve as breeding as well as feeding grounds for these birds. The most preferred site of lapwings during winter was also shallow wetlands, this is perhaps due to decreased water level, the wetland serves as feeding as well as social interactions grounds for the birds (Chaudhury &Koli 2018).

Activity Patterns

The investigation of the activity pattern of Red-wattled Lapwings in the present study revealed that a major part of their routine includes vigilance, locomotion, feeding and maintenance. Similar prominence of the above-mentioned activities has also been noted in other species of lapwings such as the Southern Lapwing *Vanellus chilenesis* (Maruyama et al. 2010) and River Lapwing *Vanellus duvaucelii* (Mishra et al. 2018). This confirms the active and vigilant nature of lapwings. During the study, it was observed that lapwings were vigilant during both breeding and non-breeding seasons and different periods from morning to evening. The percentage of vigilance was higher in the breeding season than in the non-breeding season. This could be due to the ground/shallow feeding as well as ground-nesting nature of the bird, which requires constant vigil against any predator or other risk factors for their enhanced survival (Lendrem 1986; Walters 1990).

Locomotion was the second most recorded activity. Locomotion is an important activity of birds that helps them to move from one place to another in search of food, water, shelter, nesting sites, and even as defense (escape) to move away from potential threats.

Feeding and maintenance were the next most visible activities of Red-wattled Lapwings. Maintenance is an imperative activity that contributes to the fitness of birds and keeps away parasites (Bush & Clayton 2018). This is perhaps because as reported in certain birds, ritualized preening has become part of courtship displays performed during breeding (Howe 1975) while in some birds, the preening oil is used to attract mates (Johansson & Jones 2007; Hirao et al. 2009).

The other behaviours displayed by Red-wattled Lapwings included defense, vocalization, social interactions, inactivity, and miscellaneous activities. Inactivity (sleeping, standing, or resting) provides them rest and helps in conserving energy (Maruyama et al. 2010).

The birds of the Charadriidae family including Red-wattled Lapwings are known for their characteristic defense strategies and vocalizations (Kalsi & Khera 1987; Walters 1990; Mishra & Kumar 2022). Vocalizations are an important part and parcel of their day-to-day activities. Though calls are less prominent than vigilance, feeding, locomotion, and maintenance activities these are quite an important mode of communication in lapwings.

CONCLUSION

The study suggests that Red-wattled Lapwings thrive across different habitats in Udaipur city throughout all seasons, with monsoon being the most favoured season. The primary habitats of these birds were found to be wetlands due to the presence of ample food and water resources. However, the lowest occurrence of lapwings in Rang Sagar Lake indicates that high level of disturbance and water pollution are anthropogenically induced threats to these birds. The study also revealed that breeding and non-breeding seasons did not produce a significant impact on the activity patterns of lapwings. Moreover, these birds are highly vigilant and vocal and display a broad range of activity patterns including feeding, locomotion, maintenance, defense, social interactions, resting, and other miscellaneous activities which supports their survival.

Overall, it can be ascertained from the present study that the availability of wide-ranging habitats, abundant supply of food and water, and highly active defense techniques of Red-wattled Lapwings have helped these birds to adapt to the growing anthropogenic pressure and there is no immediate threat to the population of Red-wattled Lapwings in Udaipur city. However, habitat destruction through pollution and ever-increasing human activities can cause a decline in their population in the future. The following measures may be helpful to conserve habitats of Red-wattled Lapwing:

1. Carrying out extensive population surveys of Red-wattled Lapwings.
2. Satellite monitoring of birds' habitats to keep track of factors that may be a threat to their survival.
3. A strict ban should be imposed on the discharge of untreated industrial effluents, sewage, microplastics, medical waste, and garbage in wetlands.
4. The use of motor boats that cause oil spillage must be prohibited.
5. Restricting vehicles and night tourism around

lakes and protected areas.

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Appendix I. GPS coordinates of major study sites.

	Main Sites/Locations	Habitats	GPS Coordinates
1.	Fateh Sagar	Wetland, crop-fields, grasslands and constructed buildings, roads and footpaths	24.601°N, 73.674°E
2.	Rang Sagar	Wetland and constructed buildings, roads and footpaths	24.584°N, 73.679° E
3.	Pichola Lake	Wetland and constructed buildings, roads and footpaths	24.572°N, 73.678°E
4.	Ayad River	Wetland, crop-fields, grasslands and constructed buildings, roads and footpaths	24.606°N, 73.696°E
5.	Goverdhan Sagar	Wetland, grasslands and constructed buildings, roads and footpaths	24.543°N, 73.683°E
6.	RCA Campus	Crop-fields and institutional green spaces	24.580°N, 73.702°E
7.	MLSU Campus	Institutional green spaces, crop-fields, grasslands and constructed buildings, roads and footpaths	24.594°N, 73.731°E
8.	Sajjangarh Biological Park	Protected areas and grasslands	24.591°N, 73.652°E
9.	Sukhadia Memorial Park	Urban Park	24.585°N, 73.709°E
10.	Gulab Bagh	Protected areas and urban park	24.572°N, 73.692°E

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