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Cover: Illuminating the cruelty of Pangolin trade in India for the purpose of black magic, for the sanctity of protection. Using an animal's shell, ripping its armor against the world to protect oneself. When does one become the evil they are trying to ward off? — Acrylic on wood. © Maya Santhanakrishnan.

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ARTICLE

Waterhole utilization pattern of mammals in Jigme Singye Wangchuck National Park, Bhutan

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Abstract: Most studies on waterholes come from arid and semi-arid countries where water availability for wildlife is limited. Bhutan is a country with rich running water sources. Less is known about the waterhole usage by wildlife in the country. The present study aimed to understand the importance and usage pattern of waterholes by mammals in the protected areas of Bhutan. Thirty waterholes in Jigme Singye Wangchuck National Park, Bhutan were monitored for dry and wet seasons. A generalized linear model was used to assess the impact of various waterhole parameters on mammal usage of the waterholes. Seven out of 12 parameters studied showed a significant impact on waterhole visitation by mammalian species. When water availability and salinity showed a positive impact on waterhole visits by mammals, distance from agricultural land, altitude, herb density, canopy cover, and livestock presence showed a negative impact. The study shows that even in the presence of major running water sources, waterholes are well utilized by mammals independent of seasons with ungulates being the most frequent visitors in the waterholes. This shows the importance of waterholes in protected areas of the country for better management of wildlife.

Keywords: Camera-trapping, negative binomial regression, species-environment relationship, waterholes.

Abbreviations: DO—dissolved oxygen | GBH—girth at breast height | JSWNP—Jigme Singye Wangchuck National Park | SMART—spatial monitoring and reporting tool | TDS—total dissolved solids.

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Author contributions: AKS—data collection, data analysis and paper writing; UD—principal supervisor, guidance in research methodology and manuscript preparation. KS—co-supervisor and provided guidance throughout the research work; MMG—Guidance in data analysis.

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INTRODUCTION

Bhutan is the only country that is entirely part of the eastern Himalayan hotspot known for its rich biodiversity and extensive forest cover (Banerjee & Bandopadhyay 2016; Nepal 2022). With a land area of <0.0075% of the world's surface, Bhutan is home to 1.99% of the world's mammal species, 7.07% of its bird species, and 4.29% of its butterfly species (Nepal 2022). The country places great emphasis on environmental protection and management through policies such as Gross National Happiness (Thinley & Hartz-Karp 2019). According to Lham et al. (2019), the effective management of the country's protected areas is limited due to gaps in monitoring and research data. Various scientific studies have been conducted in Bhutan on wildlife management, including human-wildlife interaction and climate change (Penjor et al. 2021; Yeshey et al. 2023). No major studies have been done on the water-related aspect of wildlife management in the country (Lham et al. 2019).

Wildlife water development is an effective and appropriate wildlife management tool, especially during the dry seasons (Rosenstock et al. 2004). The provision of sufficient water in the protected areas is considered a key managerial intervention (Hayward & Hayward 2012). The linkages between forests, water, and wildlife create a mosaic that benefits both wildlife and communities living in the forest (Warrington et al. 2017). The seasonal availability of water in the water sources can impact the individual species even in their habitat selection (Najafi et al. 2019). The non-uniform distribution of water resources can even affect the overconsumption of vegetation in an area and thereby the vegetative degradation in the forest (Dzinotizei et al. 2017). Waterholes are one of the major sources of water for wildlife, especially in arid and semi-arid ecosystems (Sirot et al. 2016). The importance of waterholes in supporting wildlife, especially during dry seasons, is well-documented in the context of other ecosystems too (Vaughan & Weis 1999).

More than a water source, the waterholes are utilized by wildlife as a foraging ground, hunting ground, and mineral sources (Adams et al. 2003; Davidson et al. 2013; Pin et al. 2020). Wildlife preference for waterholes may depend on various factors such as physical, chemical, geographical, and ecological factors. These factors must be properly studied and understood for the proper management of these waterholes. The present study tries to understand the importance of waterholes in Bhutan, a country with one of the highest per capita water resource availability of 94,500 m^3/capita/year (Tariq et al. 2021) and also to understand how water quality (salinity, dissolved oxygen, total dissolved solids), anthropogenic disturbances (distance from road, distance from agricultural land, distance from settlements, presence of livestock), vegetation (herb density, shrub density and canopy cover), geophysical factors (elevation and presence of other waterholes) and availability of water in the waterhole are related to the selection of waterholes by the mammal species in Jigme Singye Wangchuck National Park, Bhutan.

MATERIAL AND METHODS

Study Area

The study was conducted in Jigme Singye Wangchuck National Park, formerly known as Black Mountain National Park (JSWNP, 27.017 to 27.483 latitude and 90.067 to 90.683 longitude) in central Bhutan. With an area of 1,730 km^2, JSWNP is the third largest national park in Bhutan. It covers five political districts (Sarpang, Trongsa, Tsirang, Wangdue Phodrang and Zhemgang) with elevation differences ranging 250–4,925 m (Department of Forests and Park Services, Ministry of Agriculture and Forests, Bhutan 2021). The south-west monsoon contributes most of the annual rainfall in the region from June to September. JSWNP connects Jigme Dorji National Park (JDNP) with Wangchuck Centennial National Park (WCNP) in the north and Royal Manas National Park (RMNS) with Phibsoo Wildlife Sanctuary (PWS) in the south through biological corridors, making JSWNP biologically diverse (Tshewang & Letro 2018). The national park supports 876 species of plants, 55 species of mammals, 323 species of birds, 376 species of butterflies, 42 species of herpetofauna, and 16 species of fishes (Tshewang & Letro 2018; JSWNP 2021). The park also supports 10–15% of Bhutan's total tiger population in its cool and warm broadleaved forests (Wang & Macdonald 2006). Thirty natural waterholes, all of similar size, were monitored over a six-month period from March 2023 to August 2023 across four ranges (Taksha, Langthel, Tingtibi, and Nabji) of the national park (Figure 1). Most of these waterholes are fed by springs, while a few were sourced from rainwater.

Data Collection

The study attempted to conduct a homogeneous sampling effort of 30 days for 30 camera stations. Because the camera trap in station three was turned off within 20 days due to high animal activity and the distorted camera trap in station 17, these two camera

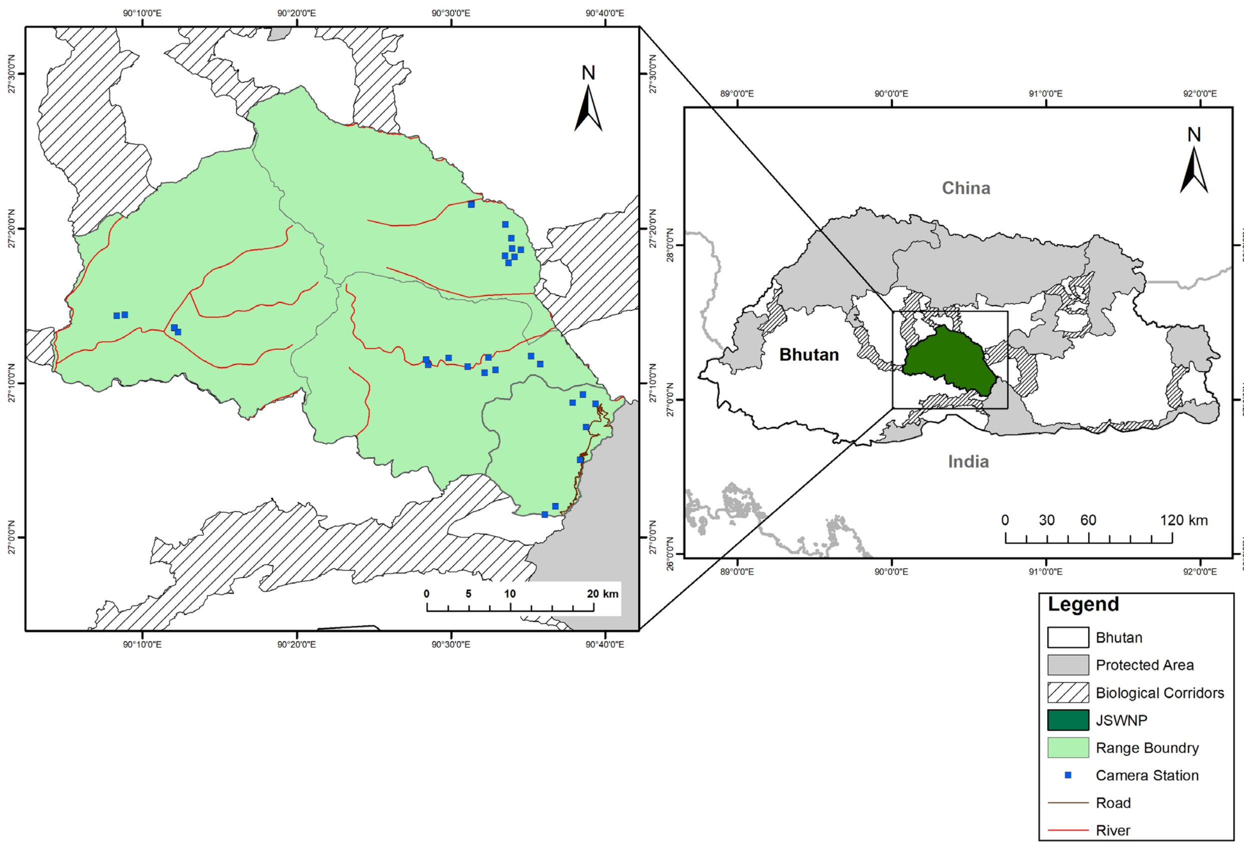

Figure 1. Map showing Jigme Singye Wangchuck National Park, Bhutan, different ranges, rivers, roads, and the camera station (waterhole that were monitored for the following research).

stations were avoided. Twenty-eight camera traps for 60 days in two seasons resulting in 1,680 trapping days. RECONYX Hyperfire II camera traps were used for the study. The cameras were oriented in such a way that water availability in the waterhole was evident in the captured images. To capture all mammal species visiting the waterhole and to avoid distractions from ground vegetation, the cameras were mounted at a height of 50 cm to 1 m above the ground level (Meek et al. 2014). Data was collected in two seasons, dry season (March–April 2023) and wet season (July–August 2023).

The time delay of each camera trap was 3 min and the delay between each image was 30 s . Of the images recorded by the camera traps, only those images from which the animal species can be identified properly were analyzed. The image of the same species within 30 minutes from the same waterhole was considered the same individual, therefore such images were not considered for analysis (Pin et al. 2020). It is not necessarily that the image captured shows animals drinking at the time of observation, even their proximity near to the waterhole was be considered as drinking behavior (Hayward & Hayward 2012).

Water quality parameters of each waterhole were recorded twice in each season. The parameters such as salinity, dissolved oxygen (DO) and total dissolved solids (TDS) of the water samples were tested and recorded. Hanna Edge HI2002-02 and Microprocessor COND-TDS-SAL-Meter LT-51 were used to test the following parameters. Parameters such as salinity and TDS were tested within 24 h of sampling and DO was tested in the field. The availability of water in the waterhole during the study period and the presence of livestock in the waterhole were also recorded using the camera trap images.

Additionally, vegetation assessment was carried out from three vegetation plots around each waterhole. The plots were taken in three directions (0° north, 120° south-east, and 240° south-west) 100 m from the waterhole, considering the waterhole as the center point. All tree species within a 12.62 m radius that had a GBH greater than 10 cm were recorded. Square plots of 5 x 5 m and 1 x 1 m were used to assess shrub and herb species, respectively, inside the same circular plot. The number of stumps was counted for both herb and shrub species. The canopy cover around the waterhole was recorded using Canopeo software (Patrignani & Ochsner 2015). Anthropogenic disturbance in the waterhole was recorded by measuring the shortest distance of the waterhole to human settlements, agricultural land, and roads. The coordinates of the waterholes and other parameters in the field were recorded using Garmin eTrex 32x. ArcGIS software was used to determine the shortest straight-line distance from anthropogenic disturbance to the waterhole using the recorded coordinates from the field (Environmental Systems Research Institute, Inc. 2016). The presence of other waterholes within 500 m of the studied waterhole was surveyed and recorded. The altitude and slope of the waterhole location were also recorded as geophysical parameters.

Data Analysis

The camera trap images were used as an index of animal visit to the waterhole. For images showing more than one individual, all the individuals were counted separately and recorded. The camera trap images were processed to correct date and time errors in some camera stations, and a species dataset was created using the Camera Trap File Manager software (Panthera). Species richness, evenness and abundance were calculated from the species dataset. For statistical analysis, paired t-test was adopted to assess seasonal differences in waterhole visitation by mammals (Wilkerson 2008).

The collinearity between environmental variables were examined with the variance inflation factor (VIF), using this function from the car package in R (Fox & Weisberg 2018). Variables with VIF >10 were considered to be highly correlated and therefore excluded from future analysis (Montgomery et al. 2012). There was no strong correlation between any environmental variables except salinity and TDS. Therefore, all environmental parameters except TDS were retained (Table 1).

The negative binomial regression model from the MASS package was used to understand the impact of different waterhole parameters on the waterhole visitation rate of mammal species (Ripley 2022). A separate negative binomial regression model was performed for wet and dry seasons using count data of mammalian species to examine their preferences concerning various waterhole parameters, including water quality (salinity and dissolved oxygen), anthropogenic disturbance (presence of livestock, agricultural land, and settlements), vegetation (herb density, shrub density, and canopy cover), geophysical factors (elevation and presence of other waterholes), and water availability.

To understand how different waterhole parameters affect each mammal species in the selection of a waterhole, a separate negative binomial regression model was performed for a select group of the most abundant mammals in the studied waterhole separately for wet and dry seasons. All environmental data were scaled using the scale function in r before performing a negative binomial regression model to avoid bias from variables with different scales. All the statistical analysis were performed using R v. 4.3.2 (R Development Core Team 2023).

RESULTS

Species Richness and Abundance in the waterholes

A total of 3,549 animal visits from 23 different mammal species were recorded over 1,680 trapping days (Table 2). Relatively high species richness was observed in the waterhole during the dry season (M = 4.29) compared to the wet season (M = 3.89). Camera station 13 in the Langthel range showed the highest species richness in both the wet and dry seasons. Ungulate species (*Rusa unicolor, Sus scrofa*, and *Muntiacus vaginalis*) showed higher abundance in the waterhole compared to the other mammal species in both the seasons (Figure 2). *Muntiacus vaginalis* was the only mammal species reported from all 28 waterholes.

Negative Binomial Regression Model

From the separate negative binomial regression

Table 1. Results of multicollinearity between variables showing the variance inflation factor of individual variable in wet and dry season.

Variable	Variance inflation factor (VIF)	
	Dry season	Wet season
Dissolved oxygen	2.44	1.83
Salinity	1.58	1.50
Water availability	4.25	3.01
Distance to river	2.45	2.60
Waterholes within 500 m	1.55	2.21
Altitude	2.56	2.65
Slope	2.02	2.51
Distance to road	4.37	5.08
Distance to agriculture land	2.60	2.10
Distance to settlement	1.66	2.39
Herb density	2.11	2.67
Shrub density	2.03	2.66
Canopy cover	2.50	2.80
Livestock	1.56	2.59

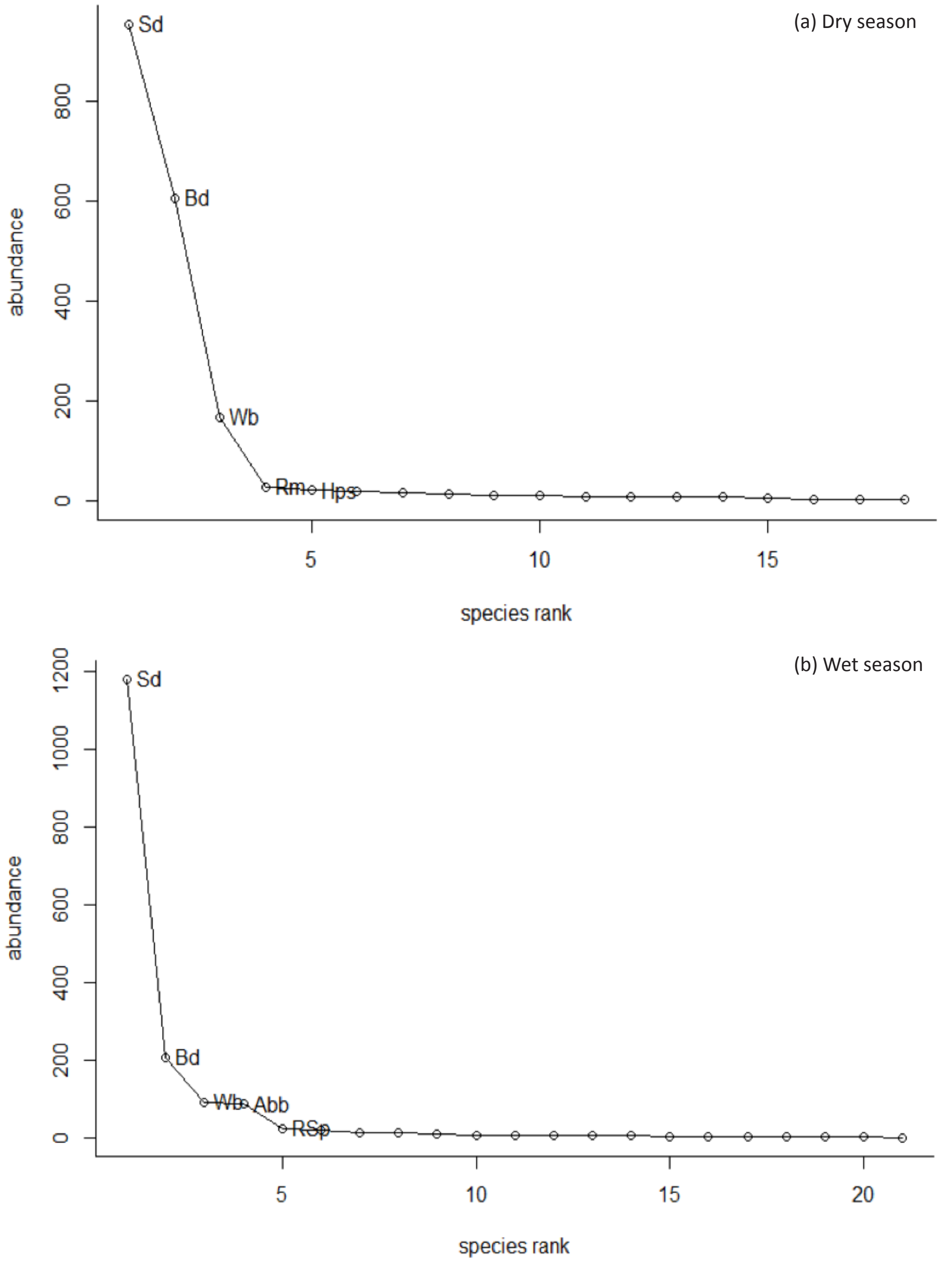

Figure 2. Graph showing species abundance of mammals in waterhole: a—dry season| b—wet season. Sd—*Rusa unicolor* | Bd—*Muntiacus vaginalis* | Wb—*Sus scrofa* | Rms—*Macaca assamensis* | Hps—*Paguma larvata* | Abb—*Ursus thibetanus* | Rsp—*Niviventer* sp.

models for the dry and wet seasons, four waterhole parameters showed a significant impact on the use of waterholes by mammals, including canopy cover (Est. = -0.835, SE = 0.226, p = 0.000) and the presence of livestock (Est. = -0.619, SE = 0.225, p = 0.006) in the dry season. Conversely, in the wet season, more parameters showed significance: shrub density (Est. = -0.493, SE = 0.232, p = 0.03), distance from agricultural land (Est. = -0.548, SE = 0.243, p = 0.02), and altitude (Est. = -0.500, SE = 0.206, p = 0.01). Availability of water, salinity, and canopy cover showed a significant impact on mammal visits both in wet and dry seasons. Salinity, water availability, and the presence of agricultural land showed a positive impact on the animal visit to the waterhole whereas the presence of livestock, altitude, herb density, and canopy cover of the waterhole location showed a negative impact on the waterhole visit of mammal species.

As *Rusa unicolor*, *Sus scrofa*, and *Muntiacus vaginalis* exhibited the highest abundance at the studied waterhole, separate negative binomial regression

Table 2. Mammal species recorded from the waterholes and their seasonal visit.

Species		IUCN Red List	No. of visit	
Common name	Scientific name		Dry season	Wet season
Asian Black Bear	*Ursus thibetanus*	Vulnerable	19	86
Asian Golden Cat	*Catopuma temminckii*	Near Threatened	4	4
Assamese Macaque	*Macaca assamensis*	Near Threatened	27	19
Black Giant Squirrel	*Ratufa bicolor*	Near Threatened	-	2
Clouded Leopard	*Neofelis nebulosa*	Vulnerable	-	1
Dhole	*Cuon alpinus*	Endangered	9	4
Gaur	*Bos gaurus*	Vulnerable	-	12
Gee's Golden Langur	*Trachypithecus geei*	Endangered	2	5
Himalayan Goral	*Naemorhedus goral*	Near Threatened	-	1
Hoary-bellied Squirrel	*Callosciurus pygerythrus*	Least Concern	8	12
Indian Leopard	*Panthera pardus fusca*	Near Threatened	2	6
Mainland Leopard Cat	*Prionailurus bengalensis*	Least Concern	6	1
Mainland Serow	*Capricornis sumatraensis*	Vulnerable	6	-
Malayan Porcupine	*Hystrix brachyura*	Least Concern	9	10
Marbled Cat	*Pardofelis marmorata*	Near Threatened	2	-
Masked Palm Civet	*Paguma larvata*	Least Concern	20	3
Nepal Gray langur	*Semnopithecus schistaceus*	Endangered	15	-
Northern Red Muntjac	*Muntiacus vaginalis*	Least Concern	606	209
Rodent	*Niviventer* sp.	-	-	24
Sambar	*Rusa unicolor*	Vulnerable	959	1185
Small Indian Mongoose	*Urva auropunctata*	Least Concern	14	2
Wild Boar	*Sus scrofa*	Least Concern	167	90
Yellow-throated Marten	*Martes flavigula*	Near Threatened	8	7

Table 3. Summary of negative binomial model for dry season with model average coefficient, standard error (SE), Z- value and significant value expressed as hyper link with the coefficient (Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z-value
Intercept	3.704 ***	0.177	20.955
Dissolved oxygen	-0.117	0.256	-0.456
Salinity	0.427 *	0.205	2.086
Water availability	0.582 *	0.279	2.088
Other waterhole	-0.184	0.208	-0.883
Altitude	-0.130	0.227	-0.575
Agricultural land	0.010	0.226	0.044
Settlements	0.334	0.193	1.737
Herb density	-0.276	0.214	-1.291
Shrub density	-0.230	0.227	-1.012
Crown cover	-0.835 ***	0.226	-3.699
Livestock	-0.619 **	0.225	-2.748

models were conducted for each of these three mammal species across both wet and dry seasons. The negative binomial regression model for *Rusa unicolor* revealed that parameters such as distance from settlements (Est. = 0.95, SE = 0.46, p = 0.039), shrub density (Est. = -1.29, SE = 0.64, p = 0.045), crown cover (Est. = -1.47, SE = 0. 0.48, p = 0.002), and water availability (Est. = 1.37, SE = 0.52, p = 0.008) significantly influenced the visitation rates of *Rusa unicolor* to the waterhole. Notably, shrub density (Est. = 1.15, SE = 0.54, p = 0.034) around the waterhole was found to be the most influential factor for *Sus scrofa*. *Sus scrofa* was found to prefer waterholes with higher shrub density, particularly during the dry season. *Muntiacus vaginalis* showed a significant impact on the waterhole parameters including dissolved oxygen (Est. = -0.62, SE = 0.27, p = 0.022), presence of livestock (Est. = -0.78, SE = 0.32, p = 0.014), and crown cover (Est. = -0.62, SE = 0.25, p = 0.011).

Table 4. Summary of negative binomial model for wet season with model average coefficient, standard error (SE), Z- value and significant value expressed as hyper link with the coefficient (Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z-value
Intercept	3.253 ***	0.177	18.359
Dissolved oxygen	-0.277	0.226	-1.225
Salinity	0.494 *	0.210	2.351
Water availability	0.728 **	0.222	3.279
Other waterhole	-0.224	0.223	-1.003
Altitude	-0.500 *	0.206	-2.424
Distance from agricultural land	-0.548 *	0.243	-2.259
Distance from settlements	0.190	0.193	0.981
Herb density	-0.325	0.219	-1.479
Shrub density	-0.493 *	0.232	-2.123
Crown cover	-0.480 *	0.235	-2.045
Livestock	-0.075	0.229	-0.326

Table 5. Summary of negative binomial model for *Sus scrofa* in the dry season with model average coefficient, standard error (SE), Z- value, and significant value expressed as a hyper link with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	0.99 *	0.41	2.41
Dissolved oxygen	-0.74	0.59	-1.25
Salinity	-0.31	0.49	-0.63
Water availability	0.30	0.62	0.48
Other waterhole	0.04	0.48	0.09
Altitude	0.06	0.53	0.12
Distance from agricultural land	-0.24	0.66	-0.36
Distance from settlements	-0.24	0.50	-0.48
Herb density	0.99	0.71	1.39
Shrub density	1.15 *	0.54	2.11
Crown cover	-0.42	0.50	-0.84
Livestock	-0.71	0.53	-1.33

Table 6. Summary of negative binomial model for *Sus scrofa* in the wet season with model average coefficient, standard error (SE), Z- value, and significant value expressed as hyperlink with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	0.33	0.54	0.61
Dissolved oxygen	-1.05	0.72	-1.47
Salinity	-0.47	0.69	-0.68
Water availability	0.23	0.69	0.34
Other waterhole	0.29	0.66	0.43
Altitude	-0.81	0.71	-1.15
Distance from agricultural land	-0.31	0.77	-0.40
Distance from settlements	0.22	0.67	0.32
Herb density	0.40	0.91	0.44
Shrub density	0.30	0.74	0.41
Crown cover	-0.01	0.65	-0.02
Livestock	0.52	0.65	0.81

Table 7. Summary of negative binomial model for *Rusa unicolor* in dry season with model average coefficient, standard error (SE), Z- value and significant value expressed as hyper link with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	1.85 ***	0.41	4.56
Dissolved oxygen	0.33	0.61	0.55
Salinity	0.49	0.46	1.08
Water availability	0.54	0.64	0.85
Other waterhole	-0.32	0.45	-0.71
Altitude	-0.27	0.52	-0.52
Distance from agricultural land	0.80	0.62	1.29
Distance from settlements	0.95 *	0.46	2.06
Herb density	-0.63	0.67	-0.94
Shrub density	-1.29 *	0.64	-2.00
Crown cover	-1.47 **	0.48	-3.05
Livestock	-0.39	0.52	-0.76

DISCUSSION

This research was a preliminary study to understand the importance and utilization pattern of waterholes by mammals in the protected areas of Bhutan. The results of the study showed a fairly high species richness in the waterhole, recording a total of 23 mammal species from the waterholes studied (Table 2). Ungulate species were the frequent visitors to the waterhole (Figure 2) as their water requirements are relatively high compared to the other mammal species (Najafi et al. 2019). This can also be due to the higher densities of ungulates in general. The result of the paired sample t-test did not show any significant difference in the use of waterholes in the wet and dry seasons, which implies that more than a seasonal watering point, waterholes were utilized by the mammals regardless of the season. The significance of water availability in the waterhole in both seasons also back the following statement. The presence of water in the waterhole must be a concern as 52.7% (n = 16) of the waterholes studied were found to be without water at some point during the data collection, with

Table 8. Summary of negative binomial model for *Rusa unicolor* in wet season with model average coefficient, standard error (SE), Z- value and significant value expressed as hyper link with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	1.85 ***	0.40	4.65
Dissolved oxygen	-0.25	0.48	-0.52
Salinity	0.63	0.49	1.29
Water availability	1.37 **	0.52	2.62
Other waterhole	0.07	0.47	0.15
Altitude	-0.39	0.50	-0.79
Distance from agricultural land	0.07	0.56	0.12
Distance from settlements	0.44	0.50	0.88
Herb density	-0.82	0.68	-1.21
Shrub density	0.11	0.55	0.21
Crown cover	-0.86	0.48	-1.77
Livestock	-0.49	0.53	-0.93

Table 9. Summary of negative binomial model for *Muntiacus vaginalis* in the dry season with model average coefficient, standard error (SE), Z- value, and significant value expressed as hyperlink with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	2.66 ***	0.21	12.98
Dissolved oxygen	-0.03	0.29	-0.10
Salinity	0.36	0.24	1.50
Water availability	0.40	0.31	1.28
Other waterhole	-0.43 .	0.23	-1.85
Altitude	0.30	0.26	1.14
Distance from agricultural land	-0.23	0.32	-0.73
Distance from settlements	0.25	0.24	1.02
Herb density	-0.09	0.34	-0.26
Shrub density	-0.24	0.27	-0.88
Crown cover	-0.62 *	0.25	-2.52
Livestock	-0.78 *	0.32	-2.46

Table 10. Summary of negative binomial model for *Muntiacus vaginalis* in wet season with model average coefficient, standard error (SE), Z- value and significant value expressed as hyper link with the coefficient (Significant codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1).**

	Estimate	SE	z value
(Intercept)	1.34 ***	0.29	4.64
Dissolved oxygen	-0.62 *	0.27	-2.28
Salinity	-0.02	0.26	-0.08
Water availability	0.00	0.28	-0.01
Other waterhole	-0.26	0.27	-0.96
Altitude	-0.36	0.28	-1.27
Distance from agricultural land	-0.47	0.30	-1.53
Distance from settlements	0.41	0.26	1.56
Herb density	0.06	0.38	0.16
Shrub density	0.24	0.30	0.80
Crown cover	0.17	0.27	0.63
Livestock	-0.98	0.99	-0.99

two waterholes being completely dry throughout the dry season. The result of a separate negative binomial regression model performed for the most abundant mammal species (Table 8) also shows the close relationship of *Rusa unicolor* with water availability in the waterhole.

Regarding the water quality parameters of the waterhole, salinity showed a positive impact on the waterhole visit by the mammal species both in the wet and in the dry seasons. One-unit increase in the salinity showed a 53.3% increase in the animal visit in the dry season and a 63.7% in the wet season. Consistent with some previous studies on waterholes, the positive impact of animal visitation on water salinity in JSWNP may be to meet the mineral requirements of mammalian species (Adams et al. 2003). This can be one of the reasons why mammal species tend to prefer waterholes over the freshwater streams in the national park. Whether the waterhole in the national park is used by the mammals as an alternative source to meet their mineral requirements is still a question as the presence of the salt licks around the waterhole was not considered as one of the variables for the following study, which merits further research in the following topic.

The presence of livestock has been reported from the 13 of the waterholes monitored which had a significant negative impact on the waterhole visit of the mammal species, especially during the dry season (Table 3). *Muntiacus vaginalis* also exhibited a negative impact on the presence of livestock in waterholes (Table 9), particularly during the dry season when livestock activity is high in the forest areas of Bhutan (Buffum et al. 2009). Many studies showed the implications of sharing the same water source by wildlife and livestock, especially when it comes to the spreading of disease from livestock to wildlife species which shows a higher potential in stagnant water sources like waterhole (Cowie et al. 2016). Ungulate species as well as the livestock were camera-trapped defecating in the waterholes having high use pressure. The forest department needs to give much importance to the following situation in the protected areas of the country. In the wet season, there was no significant effect observed on the presence of livestock on the mammals (Table 4). Further research needs to be conducted for a better understanding of the following situation in the country.

The proximity of agricultural land to waterholes was found to have a significant positive impact on waterhole visitation rates by mammal species during the wet season. This positive impact was not observed during the dry season. The presence of farmers engaged in agricultural activities during the dry season may account for the non-significant effect during this period, particularly as the major agricultural activity in my study area is the cultivation of black cardamom, which involves significant fieldwork that occurs only two to three times a year. The negative binomial regression model for *Sus scrofa* indicated a strong association between *Sus scrofa* and waterholes characterized by higher shrub density (Table 5). In contrast, other mammals tended to prefer waterhole locations with lower shrub density. Most shrub species recorded around the waterholes monitored were non-palatable species. The dense shrub cover can limit visibility and potentially increasing predation risk (Sutherland et al. 2018). *Sus scrofa* preferred these bushy habitats to take advantage of the concealment they provide, which could help them minimize predation risk. In contrast, larger ungulate species may avoid waterholes with dense shrub patches due to their need for greater visibility to detect predators.

CONCLUSION

The following study shows that even in the presence of major running water sources, mammals tend to prefer waterholes for their water requirements. The results show that salinity may be the reason why the mammals prefer waterholes over the running water source in the national park. In addition to salinity, waterhole parameters including distance from agricultural land, altitude, herb density, canopy cover, livestock presence, and water availability also significantly impacted the waterhole visit by the mammal species. More importance needs to be given to the waterhole management practices in JSWNP. Currently, reliable data on the distribution of waterholes in the national park is lacking. The SMART (Spatial Monitoring and Reporting Tool) patrolling data of the waterhole also seems to be unreliable, which was the major challenge faced during the initial stages of research data collection (Wildlife Conservation Society). The preparation of accurate data base on waterhole distribution and water availability throughout the year will help in the better management of waterholes in the national park. This can also support future research on waterholes in the national park. Since salinity and water availability in the waterhole seem to be the most influential parameters for mammals regardless of seasons, it is recommended that more importance be given to waterholes with continuous water availability and presence of salinity when it comes to future waterhole management practice in the country. Stagnant water sources such as waterholes shared by livestock and wildlife, can be a medium for the spread of disease from livestock to wildlife. Therefore, the forest department needs to consider the presence of livestock in the waterhole to avoid further impacts. In the following context, the presence of disease-causing pathogens and antibiotic-resistant bacteria (AMR) in waterholes is the subject of further research.

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