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Caption: Stripe-backed Weasel *Mustela strigidorsa*. Medium—digital, Software—procreate, Device—iPad + Apple pencil © Dhanush Shetty.



Habitat use and conservation threats to Wild Water Buffalo *Bubalus arnee* (Mammalia: Artiodactyla: Bovidae) in Koshi Tappu Wildlife Reserve, Nepal

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Abstract: Wild Water Buffalo (WWB) *Bubalus arnee* is an endangered species and a protected animal in Nepal. The remaining WWB population is located in Koshi Tappu Wildlife Reserve (KTWR), and it appears to have low viability under prevailing conditions. We assessed the habitat use and conservation threats to wild water buffalo in KTWR. For habitat analysis the quadrant method was used. Eighty-four quadrants of 25 m² for trees, 168 quadrants of 10m² for shrubs and 336 quadrants of 1 m² for herbs were laid out in the study area. Ivlev's electivity index (IV) was calculated to assess the use of different habitat components. The important Value Index (IVI) was used for vegetation assessment. A relative threat ranking method was used to assess conservation threats for wild buffalo and their habitats. Wild buffalo mostly preferred habitats with distance to water resources less than 500 m (IV= 0.4), less than 25 % crown coverage (IV= 0.39) and more than 75 % ground coverage (IV= 0.42). The trees species *Phyllanthus emblica*, *Acacia catechu*, shrub species *Mimosa pudica* and the herb species *Brachiaria distachya*, *Vetiveria zizanioides*, *Imperata cylindrica*, and *Saccharum spontaneum* were preferred by WWB in the study area. Among the different plant categories, we found that *Acacia catechu* was the most preferred tree species (IVI= 156.95), *Mimosa pudica* the most preferred shrub species (IVI= 58.68), and *Imperata cylindrica* the most preferred herb species (IVI= 64.73). Major conservation threats perceived by local stakeholders for wild buffaloes were overgrazing by cattle and genetic swamping through crossbreeding with domestic buffalo. Therefore, conservation of grass species through control of grazing, and prevention of cross breeding are measures supported by this study. Additionally, site-specific conservation strategies should be adopted, based on identified threats in the study area.

Keywords: Crossbreeding, endangered, genetic swamping, important value index, Ivlev's electivity index, quadrats.

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INTRODUCTION

Nepal has two zoogeographic regions: Palearctic and Oriental, and is known for faunal diversity including 212 species of mammals (Baral & Shah 2008; Jnawali et al. 2011; Amin et al. 2018), including 49 threatened species. The Wild Water Buffalo *Bubalus arnee* (WWB), also called Wild Asian Buffalo (Image 1) is a large bovine native to southern and southeastern Asia (Dahmer 1978), which primarily occurs in tropical, subtropical forest, and swampy grasslands (Thapa et al. 2020). It is legally protected in India, Nepal, Cambodia, Myanmar, Thailand, and Bhutan (Groves 1981). This species is categorized as 'Endangered' mammal species on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Kaul et al. 2019) and in Appendix III of the Convention on International Trade in Endangered Species of wild fauna and flora (CITES) (CITES 2017). It is one of the protected mammals included in Nepal's National Parks and Wildlife Conservation Act, 1973 (GoN 1973).

WWB is a large powerful animal that weighs between 800–1,200 kg, with horn span of around 2 m (Aryal et al. 2011). Home ranges are 1.7–10 km² (Nowak 1999). Generally, males are able to breed after 18 months while females are able after 3 years. The pregnant female undergoes a gestation period of 12 months and gives birth to a single calf at a time, with a minimum birth interval of about 2 years (Shrestha 1997). In the wild, WWB can live up to 25 years, and in captivity up to 29 years (Roth 2004). They are social animals and typically form herds of 10–20 individuals, with herds of up to 100 having been witnessed (Heinen 1993). Being intensely reliant on water and investing significant time wallowing in puddles or rivers, they are frequently sighted in swamps and marshes, grasslands, and riverine forests (Roth 2004). WWB usually prefer marshy floodplains with towering elephant grass (e.g., *Saccharum* and *Phragmites*) and scrubby wooded forests of *Bombax*, *Dalbergia*, and *Acacia* (Sah 1997). Additionally, open short grasslands, forests and agriculture fields provide good shelter (Adhikari 1999).

In Nepal, Koshi Tappu Wildlife Reserve (KTWR), established in 1976, shelters the last enduring population of WWB, consisting of 498 individuals (DNPWC 2021). With the aim to establish a second sub-population of WWB, 15 individuals were translocated and kept in an enclosure in Chitwan National Park in January 2017, but their viability is not yet ensured (Shah et al. 2017). Thus conserving WWB in KTWR is a serious issue that is getting more critical every year. The species and their habitat

have been mainly threatened by human interference, including illegal hunting, habitat fragmentation, and degradation (Heinen & Kandel 2006; Kafle et al. 2020). Besides, there is also the severe problem of crossbreeding with domestic buffalo (Khatri et al. 2012), consequently losing the genetic diversity of the species (Kaul et al. 2019). There is only about 0.8 km² area per individual WWB in the reserve, which is inadequate to sustain a thriving buffalo population (Aryal et al. 2011).

Apart from habitat-use information, it is essential for conservationists to find out the threat status of an ecological community (Nicholson et al. 2009; Joshi et al. 2020) to plan and implement conservation activities effectively. The threat ranking method used by WWF in the Standards of Project and Program Management shows the degree to which each direct threat affects the biodiversity target at a given site (WWF 2007). In this study, a similar technique was employed, which consisted of recognizing a set of standards and applying them to direct risks in order to develop a conservation action plan by focusing on the areas where they are most needed. To our knowledge, very limited studies have been conducted particularly on the habitat use and threats of WWB in the study area, so this study attempts to fulfill such information gap that can help the conservationists, planners, and reserve managers to implement the required conservation measures for such threatened and isolated species.

MATERIALS AND METHODS

Study area

The KTWR extends from 86.916–87.0830 E to 26.566–26.7510 N and is located in Eastern Nepal's Saptari, Sunsari, and Udaypur districts, on the alluvial flood plains of the Sapta Koshi River (Figure 1). It covers a total core area of 175 km² with an additional buffer zone of about 173 km² surrounding the reserve, declared in 2004. Recognizing the reserve's significance, it was assigned as a wetland of global significance and included in the Ramsar list on 17 December 1987 (IUCN 1990). The reserve is mostly comprised of riverine grasslands (56%), sand & gravel deposits (22%), agricultural field (5%), forest land (1%), river & stream (10%), marshes & swamps (6%), and lake & pond (0.01%) (Chettri et al. 2013). It is listed as an important bird area where 490 species of birds have been recorded (Shrestha & Pantha 2018). Natural predators of WWB such as Leopard *Panthera pardus*, Dhole *Cuon alpinus*, Tiger *Panthera tigris*, were wiped out from KTWR for at the last 40 years

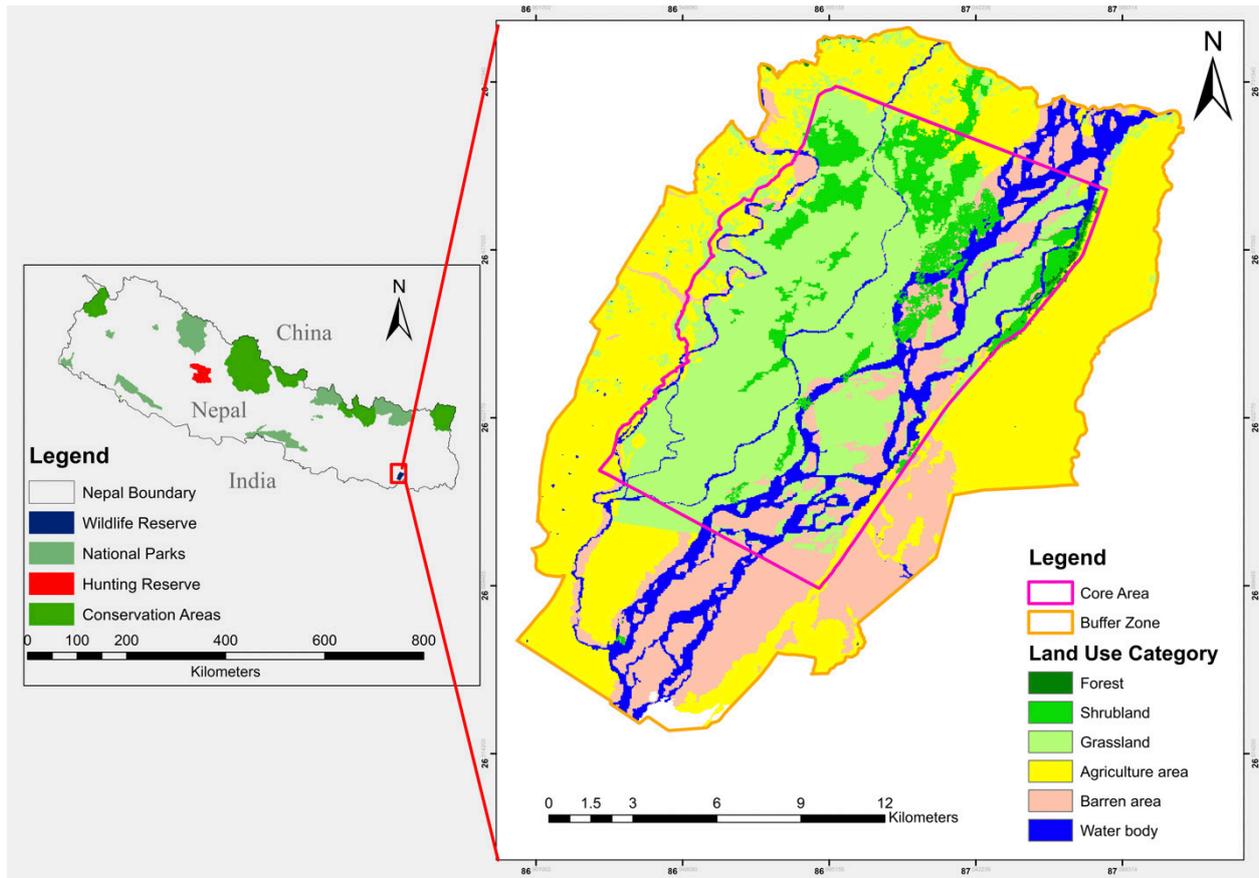


Figure 1. Map of the study area (Koshi Tappu Wildlife Reserve, Nepal).



Image 1. Wild Water Buffalo *Bubalus arnee* sighted in KTWR. © Reeta Khulal.

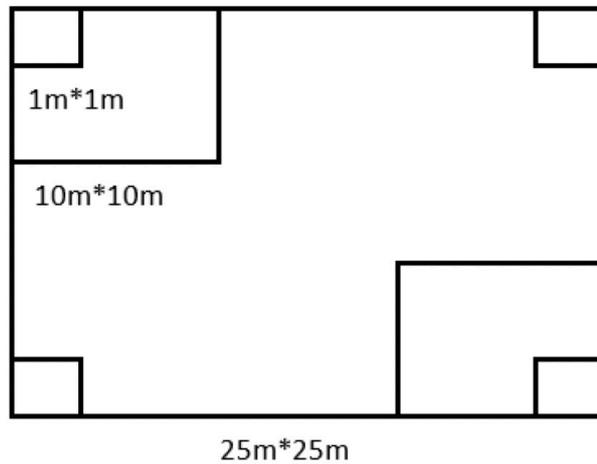


Figure 2. Layout of quadrant in the study area.

(Heinen & Paudel 2015). The climate of the reserve is the tropical monsoonal type and the monsoon season, which runs from mid-June to late September, accounts for 80–85 percentage of total rainfall. The average monthly temperature ranges between 15.7 °C and 29.2 °C and the average annual rainfall range from 1,300 mm to 2,050 mm with higher humidity that remains throughout the year.

Data collection

We conducted the field study between December 2019 and January 2020. In the initial phase, all the potential sites of WWB, in consultation with the experienced park staff and warden, were surveyed for evidence such as droppings, exudation of sap, crushed tissues, fresh clipping, and direct sighting during the active periods of dawn and dusk (Heinen & Singh 2001). Then, a random sampling method was adopted to identify different attributes of habitat associated with WWB. Both Habitat Use plots “U” and Availability plots “A” were established on those sites. In each location where the indirect evidence (droppings, hair, pugmarks, bedding sites, and horns) of the WWB were observed; the habitat use plot was established within a distance of 50 m (Neupane et al. 2021). Different habitat attributes from each plot such as ground cover, crown cover, and distance to water source were noted. Further, Availability plots were established within 100 m distance from the Use plots in random direction (Neupane et al. 2021). Similar habitat attributes were noted in each availability plot as noted in use plots. If any signs of the WWB were observed in availability plots, the availability plots were renamed as use plots. Vegetation analysis was conducted on both the availability and use plots.

Eighty-four quadrants each of size 25 x 25 m for trees; 168 nested quadrants of 10 x 10 m for shrubs and 336 nested quadrants of 1x 1 m for herbs were laid out randomly on those selected sites (Figure 2). Within each quadrant, all the trees were counted and their diameter at breast height (DBH), and heights were assessed using diameter tape and clinometers respectively. Similarly, the species composition and percentage cover of shrubs and herbs and their respective frequencies were noted.

Threat assessment was done by direct field observation and through interviews with the local people, local experts, and reserve authorities in the study area. These interviewees were conducted with different local stakeholders who have been residing there for more than 20 years and are familiar with the WWB and their habitats, following a similar method used in the previous studies (Chhetri et al. 2020; Neupane et al. 2020). Literature reviews were also conducted to gather information on various facets of each threat. Interviews were taken with conservation officers, political pioneers, and heads of the metropolitan wards to investigate their insight and perspectives on the existing threats to WWB and their habitats. We assigned the scope, severity, urgency, and irreversibility ratings of each threat component, and based on the information gained from these methods, we ranked the threats using the relative threat ranking method.

Data analysis

The habitat utilization of WWB was analyzed using Ivlev’s electivity index (IV), whose value ranges in between +1 to -1. The positive value of IV indicates habitat utilization and negative value indicates habitat avoidance and finally, zero value indicate random utilization of the habitat (Ivlev 1961). The (IV) value was calculated using following formula.

$$IV = (U \% - A \%) / (U \% + A \%)$$
 (Ivlev 1961; Yonzon & Hunter 1989; Neupane et al. 2021).

Percentage of crown cover as well as ground cover was divided into four categories that include 0–25 %, 26–50 %, 51–75 %, and 76–100 %. Vegetation analysis and calculations was done according to the methods suggested by Zobel et al. (1987) with the formula mentioned below.

$$\text{Density of species A} = \frac{\text{Number of individual of A species in all quadrates} \times 100\%}{\text{Total number of quadrates studied} \times \text{Size of quadrate taken}}$$

$$\text{Relative density of species A} = \frac{\text{Density of species A occurred} \times 100\%}{\text{Sum of all density}}$$

Table 1. Interpretations of criteria and associated rankings used to prioritize each threat (adapted from TNC 2007; WWF 2007; NHWAP 2015).

Criteria and rankings	Definition
Scope	The geographical extent of impact on the biological target that can be fairly foreseen within 10 years under existing conditions
Very high	The threat is expected to be pervasive in its scope, influencing the target over all or most (71–100%) of its occurrence/population.
High	The threat is expected to be widespread in its scope, influencing the target over (31–70%) of its occurrence/population
Medium	The threat is expected to be restricted in its scope, influencing the target over (11–30%) of its occurrence/population
Low	The threat is expected to be very narrow in its scope, influencing the target over a less part (1–10%) of its occurrence/population
Severity	The degree of damage to biological target that may be realistically predicted within 50 years under existing conditions.
Very high	The threat is expected to eliminate or degrade the target or minimize its population by 71–100% within 10 years or 3 generations, within the scope
High	The threat is expected to seriously degrade the target or minimize its population by 31–70% within 10 years or 3 generations, within the scope
Medium	The threat is expected to moderately degrade the target or minimize its population by 11–30% within 10 years or 3 generations, within the scope
Low	The threat is expected to slightly degrade the target or minimize its population by 1–10% within 10 years or 3 generations, within the scope
Urgency	This attribute is used to measure the certainty and time frame over which the threat's effects will be seen.
Very high	The impacts of the threat are noticeable already and there is an urgency to take action to cope with the issue within a year.
High	The impacts of the threat are likely to emerge and the issue are predicted during the upcoming 1–10 years.
Medium	The impacts of the threat are likely to emerge and the issue are predicted within the upcoming 10–25 years.
Low	The impacts of the threat are unlikely to occur and the issue are predicted in about 25 years from now
Irreversibility	The extent to which the impacts of a stressor can be reversed
Very high	The threat's impact cannot be reverted and it is doubtful that the target can be recovered, and/or it would take 100 years to attain this
High	The threat's impact can technically be reverted and the target is likely to be recovered, but it is not feasible practically and/or it may take long period i.e., 21–100 years to achieve this
Medium	The threat's impact can be reverted and the target is likely to be recovered with a sensible commitment of resources and/or within 6–20 years
Low	The threat's impact is quickly reversible and the target may be easily recovered at a reasonable cost and/or within 0–5 years

$$\text{Frequency of species A} = \frac{\text{No of quadrates in which species A occurred} \times 100\%}{\text{Total number of quadrates studied}}$$

$$\text{Relative frequency of species A} = \frac{\text{Frequency of species A occurred} \times 100\%}{\text{Sum of total frequencies}}$$

$$\text{Basal area} = \frac{\pi d^2}{4}$$

$$\text{Relative coverage (RC)} = \frac{\text{Coverage of a species} \times 100\%}{\text{Total coverage of all species}}$$

$$\text{Relative basal area of species A (RBA)} = \frac{\text{Basal area of species} \times 100\%}{\text{Total basal area of all species}}$$

In the community structure, importance value index (IVI) provides the general significance of every species and calculated as mentioned in equations (I) and (II).

$$\text{IVI} = \text{RF} + \text{RD} + \text{RC (for herbs and shrubs)} \dots\dots\dots \text{(I)}$$

$$\text{IVI} = \text{RF} + \text{RD} + \text{RBA (for trees)} \dots\dots\dots \text{(II)}$$

Threat assessment

A relative threat ranking method was followed in order to assess the conservation threats (TNC 2007; WWF 2007) and four scales of classification - scope, severity, urgency, and irreversibility (permanence) (Table 1) (NHWAP 2015) were used to identify and prioritize the major existing issues based on the collected data. Those four threat criteria were assigned to each of the identified issues and ranked with the highest rank equal to the number of total threats.

From these different fields, 10 types of major threats were identified and ranked as threats with the value of rank ranging from 1 to 10, where the value 10 implies very high with serious effect, and value 1 implies very low with least effect, respectively. These values are categorized under a 4-point scale for analysis and categorized as Very High (VH), High (H), Medium (M), and Low (L).



RESULTS

HABITAT UTILIZATION

Distance from water sources: WWB mostly utilized the distance less than 500 m (IV= 0.40), and randomly used distance more than 2000 m (IV= 0) from the water source. It is observed that as distance from water source increases, WWB avoided the use of the area (Figure 3).

Crown cover: WWB highly preferred the area with crown cover of 0–25% (IV= 0.39) followed by 26–50% (IV= 0.13) and avoided 51–75 % (IV= -0.1), and closed crown cover of 76–100% (IV= -0.25) (Figure 4).

Ground cover: WWB highly utilized the area with 76–100% (IV= 0.42) ground cover followed by 0–25% (IV= 0.36), and 51–75% (IV= 0.17), and randomly used the area with 25–50% ground cover (IV= 0) (Figure 5).

Vegetation Analysis

In total, we recorded nine major species of trees, nine shrub species, and 50 species of herbs in our study area. Out of nine major tree species, *Acacia catechu* possessed the highest IVI. Besides, six of them were preferred by

WWB whereas two of them were randomly used and one species was completely avoided. Among the nine major species of shrub, *Mimosa pudica* possessed the highest IVI among them, which was also the only preferred shrub species of WWB. Similarly, *Ziziphus mauritiana* and *Cascabela thevetia* were randomly used while other shrub species were avoided by WWB. Six of the 50 herb species commonly documented in the research region were preferred by WWB where *Imperata cylindrica* shared the highest IVI followed by *Saccharum spontaneum*, *Phragmites karka* and *Cynodon dactylon* as shown in Table 2.

Threats assessment

Among the 10 identified threats to WWB, overgrazing by domestic cattle and crossbreeding between domestic and WWB were ranked as the most severe threats in the study area. Similarly, invasion by weeds, disease and parasites, flooding and intensive utilization of forest resources were ranked as the high threats. Other threats with their ranked results are mentioned in Table 3.

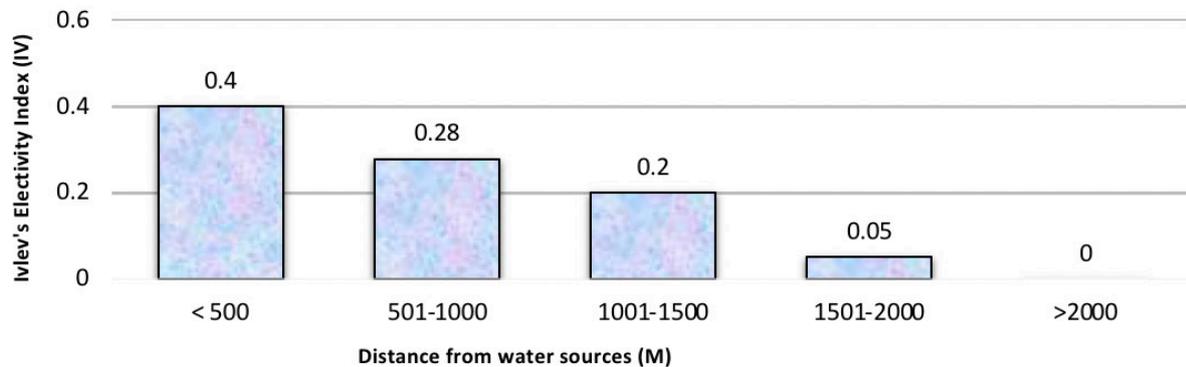


Figure 3. IV values with respect to distance from water sources.

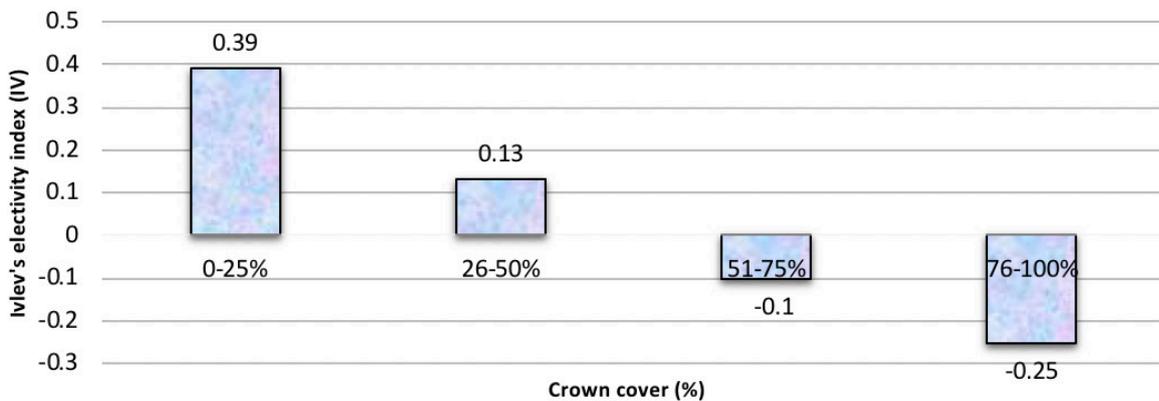


Figure 4. IV values with respect to percentage of crown cover

Table 2. Most abundant tree, shrub, and herb species with IV and IVI values.

	Species	Local Name	Family	Life form	IV	IVI	Preference
1	<i>Acacia catechu</i>	Khair	Fabaceae	Tree	0.34	94.85	Preferred
2	<i>Dalbergia sissoo</i>	Sissoo	Fabaceae	Tree	0	36.02	Random use
3	<i>Trewia nudiflora</i>	Gutel	Euphorbiaceae	Tree	-0.25	26.32	Avoided
4	<i>Bombax ceiba</i>	Simal	Malvaceae	Tree	0.18	21.97	Preferred
5	<i>Streblus asper</i>	Bedula	Moraceae	Tree	0.25	9.91	Preferred
6	<i>Phyllanthus emblica</i>	Amala	Phyllanthaceae	Tree	0.42	8.81	Preferred
7	<i>Albizia chinensis</i>	Kalo siris	Fabaceae	Tree	0.17	5.35	Preferred
8	<i>Mangifera indica</i>	Aanp	Anacardiaceae	Tree	0	2.89	Random use
9	<i>Syzygium cumini</i>	Jamun	Myrtaceae	Tree	0.29	2.88	Preferred
10	Others	-	-	Tree		91	-
11	<i>Mimosa pudica</i>	Shy plant	Fabaceae	Shrub	0.43	58.68	Preferred
12	<i>Chromoleana odorata</i>	Ban Masha	Asteraceae	Shrub	-0.95	42.25	Avoided
13	<i>Lantana camara</i>	Banmara	Verbenaceae	Shrub	-1.0	24.36	Avoided
14	<i>Calotropis procera</i>	Aank	Apocynaceae	Shrub	-1.0	19.35	Avoided
15	<i>Ziziphus mauritiana</i>	Bayer	Rhamnaceae	Shrub	0	18.18	Random used
16	<i>Xanthium strumarium</i>	-	Asteraceae	Shrub	-0.17	15.64	Avoided
17	<i>Jatropha curcas</i>	Sajiwani	Euphorbiaceae	Shrub	-0.31	13.58	Avoided
18	<i>Datura metel</i>	Dhaturo	Solanaceae	Shrub	-0.42	12.89	Avoided
19	<i>Cascabela thevetia</i>	Yellow oleander	Apocynaceae	Shrub	0	8.1895	Random used
20	Others	-	-	Shrub		86.873	Preferred
21	<i>Imperata cylindrica</i>	Siru	Poaceae	Herb	0.56	64.73	Preferred
22	<i>Saccharum spontaneum</i>	Kash	Poaceae	Herb	0.49	61.47	Preferred
23	<i>Phragmites karka</i>	Narkat	Poaceae	Herb	0.31	44.55	Preferred
24	<i>Cynodon dactylon</i>	Dubo	Poaceae	Herb	0.65	34.46	Preferred
25	<i>Brachiaria distachya</i>	Bansho ghas	Poaceae	Herb	0.90	21.97	Preferred
26	<i>Vetiveria zizanioides</i>	Kus	Poaceae	Herb	0.82	16.31	Preferred
27	Others	-	-	Herb		56.50	-

Table 3. Relative ranking of the most severe threats.

	Threats	Scope	Severity	Urgency	Irreversibility	Total	Threat Classification
1	Overgrazing	10	9	10	8	37	Very high
2	Crossbreeding between domestic and Wild Water Buffalo	9	8	9	9	35	Very high
3	Flooding	8	7	7	8	30	High
4	Invasion by weeds	7	8	7	6	28	High
5	Intensive utilization of the forest resources	6	6	7	6	25	High
6	Disease and parasite	5	5	4	7	21	High
7	Road traffic accident	4	4	4	5	17	Medium
8	Hunting and poaching	2	3	3	3	11	Medium
9	Poisoning	2	2	2	1	7	Low
10	Electrocution	1	2	1	1	5	Low
	Total	54	54	54	54	216	

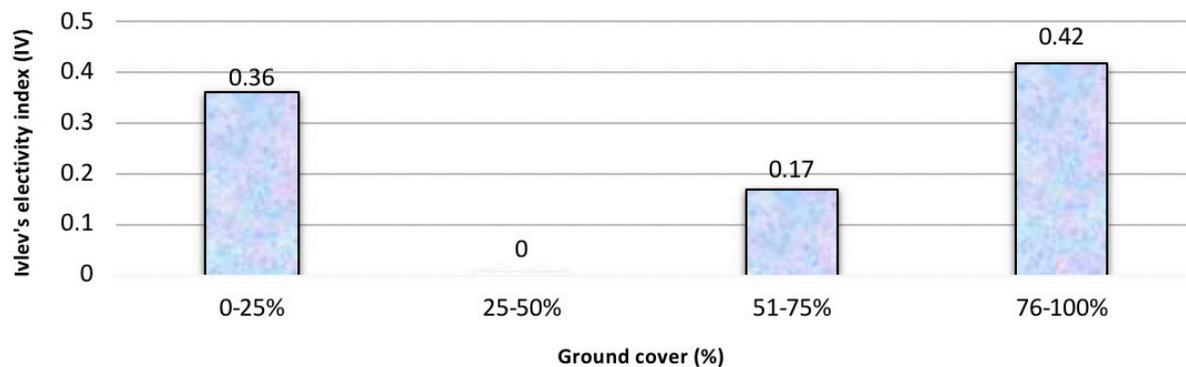


Figure 5. IV values with respect to percentage of ground cover.

DISCUSSION

Our study showed that WWB preferred the area within the distance of 500 m from the river and the habitat use got decreased with increasing distance from those sources. This might be because WWB require continuous supply of water for wallowing. Supporting this fact, Singh (2015) have reported that WWB home range size extends up to 3.9 miles² that mainly consist of water bodies, grazing area and resting sheds. Similarly, the study carried out by Dahmer (1978) indicated that the visibility of WWB is seen less frequent in the dense vegetation. Our study also showed that WWB mostly used the area with crown cover of only 0–25 % and avoided the area with crown cover more than 50 %. This might be because the dense crown cover does not permit the entry of light that is necessary for the growth of ground cover and necessitates greater alertness to the predators. Likewise, we observed that WWB mostly preferred the ground cover of 76–100%. This preference is obvious because WWB is a chief grazer (Ram & Sharma 2011) and selects area with dense ground cover to fulfill the dietary requirements.

With regard to types of vegetation, a study conducted in Thailand revealed that *Saccharum arundinaceum* and *S. spontaneum* were preferred by WWB (Bolton 1975). Likewise, a study carried out by Lama (2013) in KTWR showed that *Imperata cylindrica*, *Cynodon dactylon*, and *Saccharum spontaneum* were preferred by WWB, similar to the findings of our study. This might be because the KTWR is dominated by the above-mentioned species as shown by their IVI values. Parihar et al. (1986) showed that *Dalbergia sissoo*, *Acacia catechu* and *Bombax ceiba* were the preferred tree species in Kanha National Park and Lama (2013) mentioned that WWB preferred *Acacia-Dalbergia* associated forest in KTWR. However, our study shows that *Phyllanthus emblica* and *Acacia catechu* were

the most preferred tree species while *Dalbergia sissoo* was randomly used. Majority of the shrub species were avoided by WWB in our study. Siwakoti (2009) identified these species as invasive species in KTWR, which are regarded as problematic species by Aryal et al. (2011).

WWB face serious threats in KTWR (Heinen & Kandel 2006). Our study demonstrated that open grazing and crossbreeding with domestic buffalo are the critical threats to WWB survival in KTWR. To settle the problem of over grazing, conservation managers had adopted a few strategies in the past like culling buffaloes of domestic origin with the permission from DNPWC in 2001, evacuation of domestic cattle from the park between 2004–2005 and 2010 through a sweeping method (DNPWC 2020). However, these strategies were ineffective. Livestock farming is a traditional mode of subsistence for many people in buffer zone. There are few public lands left outside for grazing, so there is no alternative to use of the reserve as a land for grazing and bringing their livestock into the reserve for sharing food with the wild animals. Hence, providing incentives to the local farmer to initiate stall-feeding might help to control over grazing inside the park.

The small size of the reserve and higher number of livestock inside it is leading to problems of both in-breeding of WWB and cross-breeding with domestic buffalo. Low genetic variation among WWB groups is linked to the practices of local farmers, who crossbreed domestic females with wild males (Heinen 2001). Flamand et al. (2003) conducted genetic analysis to validate that the reserve consists of pure wild stock, and found that three genetically identifiable populations of buffalo were present in the KTWR: wild, domestic and backcrossed. A study carried by Aryal et al. (2011) supports our findings in that they identified livestock grazing inside the KTWR as serious threat to WWB and their foraging plant species. Adhikari (2006) also

reported overgrazing as major threat, as extensive grazing retards plant regeneration. Similarly, Khatri et al. (2012) and (KTWR 2018) reported crossbreeding as the major threat in KTWR similar to our study. Further, our study shows that existing threats like flooding, invasion by weeds, intensive forest resource extraction, disease and parasite are of high level, which is supported by several studies. Aryal et al. (2011) stated flooding as the significant threat in KTWR, which is similar to our finding. Flash floods during monsoons also have a high chance of impacting WWB, especially calves.

Similar to our findings, Khatri et al. (2012) reported invasive weeds as serious threat to native vegetation, including species preferred by WWB. Weeds like *Lantana camera*, *Chromolaena odorta* cover most of the study area and are invading forest areas and grasslands of the reserve, which is leading to loss of food and destruction of habitat. Similar to our study, Aryal et al. (2011) noted that over-harvesting and uncontrolled use of reserve resources are the major threats, where the local community enter the reserve in unauthorized manner and accumulate grass and other forest product (Heinen & Kandel 2006). Food preferred by WWB, such as *Imperata cylindrica*, *Saccharum spontaneum*, *Typha elephantina*, and *Cynodon dactylon*, are used by local people for fodder, firewood and making mats, brooms and baskets. Similar to our study, transfer of disease and parasite from domestic cattle to WWB is also regarded among the major threats (Aryal et al. 2011; Heinen & Paudel 2015) since there is close overlap of WWB and domestic livestock, the high density particularly of latter, and the small and localized nature of WWB population.

Several strategies have been developed to conserve the endangered population of the WWB of KTWR in joint efforts by the Government of Nepal with other stakeholders using the habitat. In order to minimize conflicts between local people and the reserve, an area of 173.5 km² adjoining to KTWR was set up in 2004 as a buffer zone which is the innovational strategy for participatory conservation (Khatri et al. 2012). Further, the management plan of KTWR approved in 2010 is now revised as the management plan (2018–2022) with the vision to manage ecological integrity and to conserve biological diversity of the reserve (KTWR 2018). Likewise, with the assistance of Conservation and Sustainable Use of Wetlands in Nepal (CSUWN) project, various livelihood and conservation interventions have been adopted particularly to prevent movement of domestic buffalo population into KTWR (Khatri et al. 2012). In addition, there is legal provision by KTWR office over the gathering of forest products like; fuelwood, fodder and grass in

seasonal basis with the aim to reduce illegal collection (Khatri et al. 2010). Further, to provide sufficient forage and wallowing locations to guarantee the vitality and ecological integrity of WWB population, the WWB Conservation Action Plan for Nepal has emphasized to expand the habitat of KTWR (DNPWC 2020). Likewise, in every two years, KTWR undertakes a census of wild buffalo to analyze their population dynamics (Khadka 2018).

CONCLUSION

This study concluded that WWB mostly preferred the habitats within the distance of 500 m from the water sources, crown cover less than 25 % and ground cover more than 75 %. *Imperata cylindrica*, *Cynodon dactylon*, and *Saccharum spontaneum* were the most preferred grass species whereas *Phyllanthus emblica* and *Acacia catechu* were the most preferred tree species. However, majority of the shrub species, which have weed characteristics, were avoided. Overgrazing and cross breeding with domestic buffalo were the critical surviving threats to WWB in KTWR. As the last remaining population of WWB is experiencing several threats, different conservation interventions are required to secure the wild population. Our study recommends for strict prohibition of the livestock grazing inside the park, conservation of grass species such as *Imperata cylindrica*, *Saccharum spontaneum*, and *Typha elephantina* should be encouraged and effective management plan for controlling the spread of invasive plant species such as *Chromolaena odorata*, *Eupatorium adenophorum*, *Lantana camara*, and *Mikania micrantha* should be carried out immediately. Additionally, there is an urgent need to establish veterinary clinic, animal orphanages and proper service of rescue to control vulnerability of wild animals by flood and spreading of communicable diseases.

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