

ABUNDANCE AND OCCUPANCY OF BLUE BULL IN RUPANDEHI, NEPAL



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special paper Ecology and Environment

Submitted to:
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May, 2023

DECLARATION

I, hereby declare that the work prescribed in this thesis entitled "ABUNDANCE AND OCCUPANCY OF BLUE BULL IN RUPANDEHI, NEPAL" has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by references to the author(s) or institution(s).

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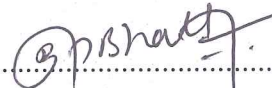
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RECOMMENDATION

This is to recommend that the thesis entitled “**ABUNDANCE AND OCCUPANCY OF BLUE BULL IN RUPANDEHI, NEPAL**” has been carried out by Miss Prabina Dhakal for the partial fulfilment Master’s Degree of Science in Zoology with special paper Ecology and Environment. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institution.

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LETTER OF APPROVAL

On the recommendation of supervisor Dr. Bishnu Prasad Bhattarai, Assistant Professor, Central Department of Zoology, Tribhuvan University, this thesis is submitted by Ms. Prabina Dhakal entitled “**ABUNDANCE AND OCCUPANCY OF BLUE BULL IN RUPANDEHI, NEPAL**” is approved by for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for the master’s degree of Science in Zoology with special paper Ecology and Environment.

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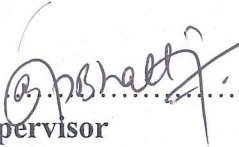
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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Ms. Prabina Dhakal entitled “**ABUNDANCE AND OCCUPANCY OF BLUE BULL RUPANDEHI, NEPAL**” has been accepted as a partial fulfillment for the requirements of master’s degree of science in Zoology with special Ecology and Environment.

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LIST OF ABBREVIATIONS

AIC	Akaike Information Criterion
CDZ	Central Department of Zoology
CI	Class Interval
GPS	Global Positioning system
HCBF	Haryana Cattle Breeding Farm
HD	Human Disturbance
IUCN	International Union for Conservation of Nature
KM	Kilometer
KTWR	Koshi Tappu Wildlife Reserve
LDTA	Lumbini Development Trust Area
SE	Standard Error
Sq	Square
Sp	Species
Wgt	Weight

ABSTRACT

Blue bull is the largest Asian antelope and is commonly called as 'Nilgai' or 'Ghodagadha'. This is the first research on occupancy carried out in Rupandehi districts. This research helps to identify the blue bull condition in Nepal by determining the factors affecting detection probability in different habitat. In order to estimate blue bull detection probability, 44 grid cells out of 363 grid cells were covered in the March, 2023. Single species, single season models was used to make assumptions factor affecting detection probability. A total number of 344 individuals of blue bull were recorded. Bishnupura has a record of the highest population whereas Saupharsatikar has the least population. During the survey, blue bull was often recorded in herds or groups. A total of 32 groups of blue bull were recorded whereas the highest number of group size were recorded in Bishnupura. The reason behind this might be the least human disturbance in the forest. The naïve occupancy estimate in Rupandehi was 0.6136. Forest was the most influenced habitat covariates supported by the agriculture land whereas waterbodies was least supported habitat. The model average with estimates detection probability rate of 0.8947 with S.E of 0.0498, 95% C.I 0.7510-0.9599 in forest while in water bodies estimates least detection probability rate of 0.7 with S.E of 0.0947, 95% C.I 0.5436-0.9097. Data on their abundance and detection probability may serves as a baseline for future studies and expected to aid in blue bull conservation planning in a systematic way.

1. INTRODUCTION

1.1 Background

Blue bull (*Boselaphus tragocamelus*) (Pallas, 1778) is Asia's largest antelope. Female and juvenile blue bull are orange in color while the adult male has bluish grey coat. Both sexes have a common mane on the neck and develop a tuft of long hair on the throat. Males are larger as compare to the females with the average weight of an adult being about 200 kg (Nowak and Walker, 1999). Blue bull is generally shy and noticeable from very far (Schaller, 2009). It is the only species of the genus *Boselaphus*, a sexually dimorphic ungulate with a huge stature and distinctive coloring (Leslie, 2008).

It is known to be endemic to India, Pakistan and Nepal, whereas extinct from Bangladesh. They have been introduced in southern Texas in 1924 (Leslie, 2008), Mexico, South Africa, and Italy. (Baumgardt et al. 2023) recorded that the population in Texas is nearly 37,000. Hence, they are called exotic in Texas.

Herds of blue bull often vary in social structure, and they are various types of herds: those with young calves, those with calves and bachelor groups, female with younger calves and once these calves are older, they join larger herd and their yearling calves. And when males mature, they join all male herd until it is time breed (Sankar and Goyal, 2004).

The ecosystems in Nepal vary in altitude, and around 23% of area is covered by protected areas. However, these protected areas are not evenly distributed to cover all ecological zones, as pointed out by (Shrestha et al. 2010). Blue bull referred to is present in various protected areas located in the Terai region, the southern plain of Nepal. It is predominantly found in Koshi Tappu Wildlife Reserve (KTWR) situated in the eastern region, Parsa National Park in the central region, and Bardia National Park & Shuklaphanta National Park located in the western region of Nepal, as stated by (Khanal et al. 2018). The species has also been observed in Kapilvastu and Rupandehi beyond Protected Area.

This species has been classified to have 'Least Concern' status on the IUCN Red List of Threatened Species (IUCN 2022). While in Nepal, compared to other countries, it is vulnerable and one of the biggest problems (Jnawali et al. 2011).

Dinerstein (1979), found that blue bull in Nepal show a preference in sub-climax habitat with vegetation in middle successional stages. They favored the savannah/grassland habitat compare to the other associations, particularly during the hot-dry season, when 86 % of the observation were made in this habitat type. Aryal (2007) while carrying out research in Rupandehi district it is observed that they mostly utilize riverine and community forests, plains, grasslands and agricultural field. Jnawali et al. (2011) found that the majority of blue bull were outside the protected area of Nepal and their distribution was maximum in Sal *Shorea robusta* dominated forest followed by grassland. Similar research carried out in Bardiya revealed that blue bull distribution was more in Sal *Shorea robusta* and Sisoo *Dalbergia sissoo* dominated forests where both sites were connected with Orahi River (Koirala et al. 2020).

Occupancy modeling was first introduced by (MacKenzie et al. 2002) in which, occupancy (denoted by the Greek symbol ψ , Ψ) is defined as the probability of species presence. It is considered to be similar as a mark capture-recapture model for a closed population as replication is used to estimate detection and probability of occurrence. Binary data is recorded for detection/non-detection at each site and additional modeling of occupancy can also be investigated by including covariate information for ψ (at the site-level) and p (detection).

These models are applied in order to peruse population trends and understand ecological interactions. Large mammal occupancy estimation was based on a single-season single-species model (Thapa et al. 2017). This model is required for detection and non-detection species (MacKenzie et al., 2002).

1.2 Rationale

In Rupandehi, the abundance of blue bull is experienced in increasing number so farmers have applied mitigation methods for reducing the crop raiding and tramping by herds of blue bull (Khanal et al. 2018). As mentioned earlier, blue bull numbers have been recorded in this study area previously, but occupancy research have not been conducted on the blue bull. The information is needed to reveal the abundance of the blue bull, and to assess the effect of covariates on the habitat of blue bull. The abundance of blue bulls observed in the study area provides information about the number of individuals of this species. The findings will be useful and crucial for policy managers to conserve blue bull population systematically.

1.3 Objectives of the Study

1.3.1. General Objective

- i. The main objective of this research was to know the abundance and understand the occupancy of blue bull in Rupandehi district, Nepal.

1.3.2. Specific Objectives

The specific objectives of this research were to:

- i. Estimate the abundance of blue bull in the study area.
- ii. Assess the factors affecting detection probability of blue bull

2. LITERATURE REVIEW

2.1 Abundance and distribution

They have been introduced in southern Texas in 1924 (Leslie, 2008), Mexico, South Africa, and Italy. The blue bull was introduced to Texas in the 1920s to 1930s. As of 2008, the feral population in Texas is nearly 37,000 (Baumgardt et al., 2023). Blue bull has since expanded, occupying the southern counties of Texas and northern states of Mexico (i.e., Tamaulipas, Nuevo Leon, Coahuila, and Sonora) (Wang et al., 2006), with population estimates ranging from 36 000 to over 70 000 individuals (Baumgardt et al., 2023; Traweek & Welch, 1992)

Burt (1943) was the first who define the concept of home-range as “that area traversed by an individual in its normal activities of food gathering, mating, and caring for young ones. Occasional probing sallies outside the area should not be considered part of the home range”. With advancement in technology, the home-range estimators use telemetry data which provides a vast amount of literature on the home ranges of most animals (Powell & Mitchell, 2012). Assuming that home-range behavior is the result of natural selection shaping decision-making processes to improve the contributions of spatially scattered resources to fitness (Powell & Mitchell, 2012).

The research conducted in Gujrat groups of blue bull have a mean size 14.2 which is slightly greater than overall mean size 14.2, which is also greater than average mean group size 8.41 and herd between 31 individual which is largest herds (Vaghela et al., 2020).

Blue bull stays for long time in fixed area which was found to be up to 8km² (Vaghela et al., 2020). In southern Texas the home ranges of blue bull in 5,680hacter with area 4.3km² (0.6–8.1 km²).

Khan et al. (1996) reported mean group size of Nilgai as 2.2, with high seasonal variability in group sizes. In the study area the average of group size was found 8.41+ 8.26 individuals per group.

Thirty-one blue bull was found in a single herd and least herd was a single individual was recorded in Gujrat in 2015-2016 (Vaghela et al., 2020)

During the survey of population of blue bull, it was recorded that 73.07% recorded in forest followed by 23.07% in grasslands and 2.88% in agricultural land and single individual recorded in wetland. 15.53% of individual of blue bull were observed in both single and in pair, while 68.93% in group's more than two individuals. The density of blue bull was 0.0037km². (Gajera et al., 2014)

The number of Nilgai in this area Dumraon, India (HCBF) is estimated to about 550 and total Nilgai reported 407. overall sex ratio was found 14.25% male, 38.57% female, 9.58% semi adult male, 20.15% semi adult female, and 18.46% calves (Prasad et al., 2020).

The research conducted in Rupandehi along Tinau River it was found that group size of animals ranged from 3–12 individuals while the average group size was estimated five animals per group (Aryal et al., 2016).

A total of 303 individual blue bull were counted in Lumbini, where 90 blue bulls were adult male, 111 adult females, 102 adult females and 102 were calves. Male to female sex ratio was 81:100 (Khanal et al., 2017) They were mostly found in open grassland and is not represented in zoos as well as privately geographically (Leslie, 2008). Blue bull presence in this area Dumraon, India (HCBF) is estimated to have 550 residents, while the total blue bull population was 407. According to Prasad et al. (2020), the overall sex ratio was 14.25% male, 38.57% female, 9.58% semi-adult male, 20.15% semi-adult female, and 18.46% calves. They used ponds for drinking and fed on plants that the pond water was sustained. They consumed the principal sources from edges and woody patches associated with root plowed area (Sheffield, 1983)

In Southern Texas, during the winter season, they were mainly observed on shrub lands and woodlands; while they adapted on the agricultural field and areas like short bushes and scattered trees and now it has been found in a common field and near the human settlement areas (Granger, 2021; Prasad et al., 2021).

Blue bull mostly prefers grassland, scrub forests, and they usually avoid the dense forests and were observed mostly in day in the cultivated land, meadow pasture and timberland areas. (Sathapathy et al., 2017).

The study conducted by (Prasad et al. 2021) reports revealed at its habitat loss, deforestation and developmental work like industrialization and urbanization has been driving and forced Nilgai into the crop fields and human dwellings in search of food in taming condition. The populations of Nilgai increase in agricultural area due to lacks of predators (Devanda & Jayashankar, 2021)

Blue bull is most closely associated with croplands as compares to other ungulates indigenous to Karnali-Bardiya and this was due to the cultivated plants such as rice, mustard, and lentils which provides nutrients, and they are mostly recorded from October through January. In Karnali-Bardiya and other areas outside protected area they never go four km far from the border with agricultural (Dinerstein, 1979)

Only 14.27%, or 3204.35 km², of Nepal's total appropriate habitat 22,462.57 km² falls under the management system for protected areas, whereas 85.73% (19,257.16 km²) is situated outside of it. Out of all management systems, it was discovered that the Koshi Tappu Wildlife Reserve buffer zone had the greatest percentage of acceptable land (100%), followed by the Shukhlaphanta Buffer Zone (94%), Chitwan National Park (91%), and Shukhlaphanta National Park (89%) (Dhami et al. 2023).

Forest covers over 70% of the habitat utilized by blue bulls in the Lumbini area of Central Lowland Nepal, followed by grassland. (Aryal, 2007). In addition, blue bulls were found in cultivated areas in the Rupandehi area of central lowlands, Nepal, showing their tolerance to habitation (Khanal et al. 2018)

Pellet count is an indirect census method used to estimate the density of an animal population from the dropping of ground (Lioy et al. 2015). It is considered as a well-suited method in the lowland Terai Nepal in the winter and early part of the dry season. It is one of the dependent indicator based on direct sightings because pellets reflects habitat use over long time period than direct sighting because the actual time of sighting may be restricted latter (Thapa, 2003). This method helps to remove biasedness as direct sighting may create biasedness because most of the time animal might move from one place to another as they sense the people movement or sometime animals used to hide in the grass or tree or due to their size they may not be visible(Thapa, 2003) . The pellet of blue bull in color is blackish brown in color which is round in shape with pointed on the top which is larger than spotted deer (Karki, 2009).

2.2 Occupancy Models

Occupancy was first introduced by (MacKenzie et al. 2002) in which, occupancy (denoted by the Greek symbol ψ , Ψ) is defined as the probability of species presence. The main focus was to estimate the fraction of the sites that are actually occupied by the species. It is similar to mark capture-recapture model for a closed population as replication is used to estimate detection and probability of occurrence. This was proposed by a likelihood-based model for estimating site occupancy rates when detection probabilities are binary data is recorded for detection/non-detection at each site and additional modeling of occupancy can also be investigated by including covariate information for ψ (at the site-level) and p (detection). The occupancy estimation method has lately gained popularity for tracking the status and distribution of a wide range of vertebrate taxa while accounting for detection likelihood (Wan et al. 2009, Thorn et al. 2011).

Numerous species monitoring programs across the world have effectively used detection/non-detection surveys in site occupancy models. Evaluation of possible Northern Spotted Owl territories in Northern California is one example of such research (MacKenzie et al. 2003), in the purpose of monitoring the Mahoenui giant weta population, a threatened insect in New Zealand, site occupancy is being evaluated (MacKenzie 2003). Many researches in monitoring mammalian species are broadly based on detection/nondetection survey such as habitat occupancy of Asian small-clawed otter (Perinchery et al. 2011), estimating Brown Hyaenas occupancy and abundance (Thorn et al. 2011), site occupancy and relative abundance of four-horned antelope (Krishna et al. 2008), estimating occupancy of ghoral and erow (Bhattacharya et al. 2012) etc. Few researches that have been included detection/ non detection survey technique for occupancy modeling in the country include occupancy and abundance of Tigers and their prey in the Terai Arc Landscape, Nepal (Karki 2011), occupancy estimation of Tiger and Leopard in Banke National Park, Nepal (Thapa 2012), and assessing the influence of prey depletion and human disturbance on tiger occupancy in Nepal 8 (Barber-Meyer et al. 2013).

Different researchers carried out the occupancy of blue bull in different regions of Nepal. Thapa et al. (2017) studied the occupancy of multiple species including blue bull at Laljhadi-Mohana wildlife corridor. Therefore, depending on the previous literature and research work, this study aims to fill the gap of abundance of blue bull. Till date, inadequate research has been conducted regarding occupancy of blue bull in Rupandehi district so this study aims to study not only abundance but the occupancy of blue bull in Rupandehi.

3. METHODS AND MATERIALS

3.1. Study Area

The study was conducted in the Nepal's Rupandehi District, which spans 1360 km². The Rupandehi District is located 100–1229 meters above sea level. Six municipalities and ten village development committees comprise up the Rupandehi. Rupandehi population was 1,121,957 according to CBS (2021). Rupandehi District cover 1360 km² in which agricultural land consists of 946.6km², following by forests 263.31km², built up area 71.15km², water cover 23.79 km² and barren 0.65km² (KC et al. 2021)

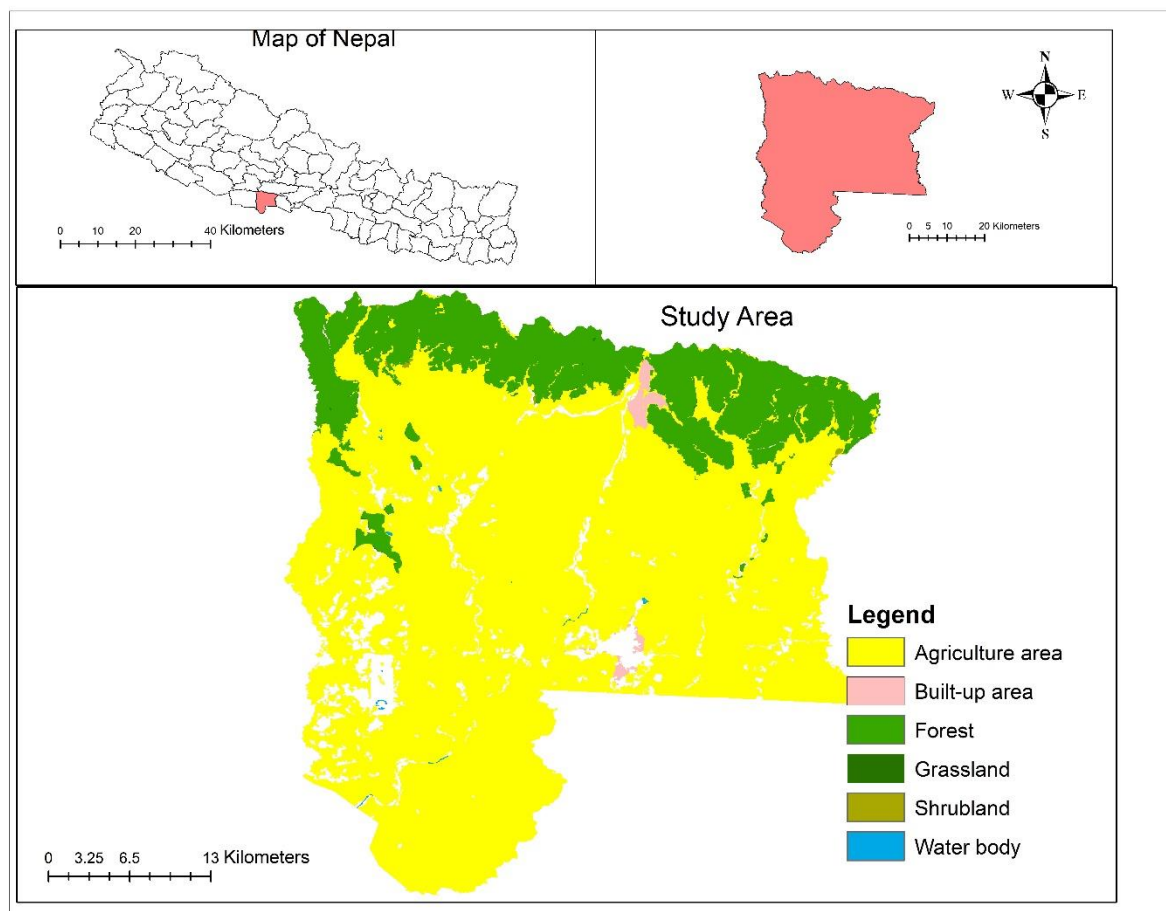


Figure 1. Map of the study area (Rupandehi district)

3.2 Data collection methods

3.2.1 Abundance estimation

Abundance estimation of blue bull was done by direct observation and count method. Blue bull was searched by walking through the transect length of 1 km through the habitat Bisht (2012). The presence of blue bull pellets provides the aid to find out the animal's spot. Major habitat forest, grassland, cultivated land were taken as the potential blue bull habitat. GPS was used for recording the location of animals and pellets during study period.

3.2.2 Sex composition

Blue bull sex was distinguished by direct observation through the body characteristics as described by (Sankar and Goyal, 2004).

1. Calves

Both young male and female are tawny in color. They always stay around their mothers. (Figure 4)

2. Adults

Both male and female blue bull can be distinguished on the basics of their body size.

- Females

Females have larger head, longer snout and back. They are yellow brown in color (Figure 3)

- Males

Males have larger horns and longer snout. Males was maximum noticed in solitary or in completely isolation after being fully mature. They are dark-grey blue color with black leg (Figure 2)



Figure 2. Male blue bull in Lumbini Area



Figure 3. Female blue bull in Farmland



Figure 4. Calves blue bull in Lumbini Area

3.2.3 Habitat use

During the field study, the habitat used by blue bull were recorded wherever blue bull or signs such as pellet were recorded. Blue bull was frequently observed in the forests which are especially dominated by Sal Forest *Shorea robusta*, grasslands covered by cogon grass *Imperata cylindrica*, dubo grass *Cynodon dactylon* and kush grass *Desmostachya bipinnata*. Agricultural lands were mostly cultivated by wheat field, chickpeas field and tomato fields mostly. Binoculars were used to observe the blue bull from a distance. Vegetation as well as the grass consumed by blue bull were identified as well as the grass used for resting purposes is also identified.

3.2.4 Identification of covariates

Covariates were identified through literature and information during preliminary survey. Measurable habitat covariates were selected as covariates that reflected the habitat types, water bodies, covariates that indicated the ecological and human disturbance. A total of four covariates were generated. The habitat was differentiated into forests, agriculture land, grassland, water bodies. Signs of fire, tree cutting, and livestock grazing were used to infer the human disturbance.

3.2.5 Sampling designs

The Rupandehi district comprised of approximately 1360 sq. km in which the whole district has been selected at first. The study was conducted by using square size 2km x 2km grid cells in order to check out the factors affecting the detection probability of blue bull through the co-variates forest, agriculture land, grassland, water bodies, human disturbance. ArcMap 10.8 tools were used to overlay 2km x 2km geographical grid cells on the study area. The area has been overlaid with 363 grid cells with 2km x 2km grid since no information regarding this exact home-range was documented, so a safe estimate of 1 sq. km was assumed. (Figure 2)

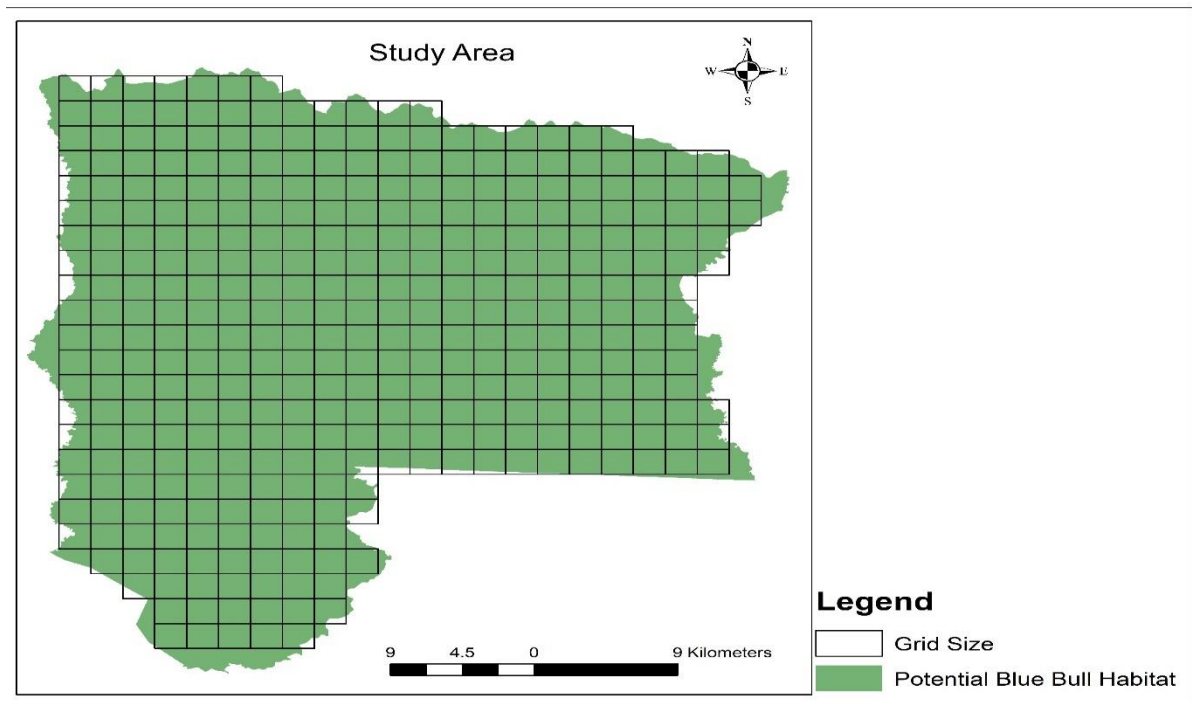


Figure 5. Survey grid of Rupandehi District

3.2.6 Occupancy survey

The survey was conducted in the area where there is a higher probability of detection of blue bull either direct or indirect observation in each grid during the month of March 2023. Existing forests, animal trails, agricultural land meadow, grasslands, tracks along the side of the grid were walked in 1 km length transect for the direct and indirect sign. After the direct or indirect sign found they were recorded through GPS and number of blue bull observed through direct observation were also counted and recorded according to their categories: male, female, and calves.

Table 1. Description of ecological and human disturbances covariates hypothesized to influence the site use (Ψ) and detection probability (p) of blue bull.

Co-variates	Expected influence on site	Supporting citation
Forests	Positive effect on blue bull	(Karanth et al., 2004; Harihar & Pandav, 2012)
Grassland	Positive effect on blue bull	(Chanchani et al., 2014)
Human Disturbances	Negative effect on blue bull abundance because it can increase competition for livestock forage and indirectly human disturb blue bull	(Chanchani et al., 2014; Harihar & Pandav, 2012; Karanth et al., 2004)

3.3 Data analysis

All the collected information were categorized and tabulated according to the objectives of the study. Data were manually processed in excel sheet and analyzed in descriptive way as well as PRESENCE version 2.13.46 software is used.

3.3.1 Group size

The group size was calculated by the method described by (Bisht, 2012). Total number of blue bulls observed during study period were divided by a total number of groups observed.

3.3.2 Detection Probability estimation

Symbol “1” is used for the detection of blue bull either by direct or indirect method and “0” for non-detection of blue bull for recording the detection histories in each site (Hines, 2006). PRESENCE version 2.13.46 single season analysis model was used to analyze field data (Hines, 2006).

The likelihood that a grid was occupied by the species and the calculation of the detection probability (p) and occupancy (Ψ) using likelihood functions were generated using the detection histories and covariates data entered into the Program PRESENCE (version 2.13.46) (MacKenzie et al., 2002). The modeling program PRESENCE was used for detection (p) probabilities of blue bull interest (v. 2.13.46) (Hines, 2006). This software uses logistic regression to estimate the probability of a site occupied by species. This model clarifies all models with an Akaike's information criterion AIC value less than 2 were regarded as equivalent models (Burnham & Anderson, 2004). However, these models averaged the detection probability and related standard errors. The relative impact of each covariate was inferred using the site used estimation of that covariate in the top models. This was caused by the fact that a single "best" model could not possibly include all of the variables influencing the likelihood of occupancy or the detection of a species (Bailey et al., 2004). $-2\log\text{likeli}$ is a relative measure of how well the model fits the data, using the least parameters (Rathore, 2017). The proportion of sites where the species was detected at least once is referred as naïve occupancy (Rathore, 2017)

To evaluate the impact of various covariates on detection probability where the overall site usage probability, a total of seven models were created.

1. $\Psi(\cdot), p(\cdot)$, occupancy constant with detection probability constant
2. $\Psi(\cdot), p(\text{forest})$, occupancy constant with detection probability influenced in forest
3. $\Psi(\cdot), p(\text{Forest} + \text{Human Disturbance})$, occupancy constant with detection probability influenced in forest by human disturbance (3 types)
4. $\Psi(\cdot), p(\text{Water bodies})$, occupancy constant with detection probability influenced by waterbodies
5. $\Psi(\cdot), p(\text{Agriculture land})$, occupancy constant with detection probability influenced by cultivated land
6. $\Psi(\cdot), p(\text{Grassland})$, occupancy constant with detection probability influenced by grassland
7. $\Psi(\cdot), p(\text{Agriculture land} + \text{People Presence})$, occupancy constant with detection probability influenced in Agriculture land by People Presence

4. RESULTS

4.1 Abundance and group size of blue bull

Males up to seventeen individuals were observed in the herd, while few of them were found solitary. Sometimes, Males and females were found in single group. During the research 32 herd/group of blue were observed, group size ranging from 1 to 31 individuals the average group size was found to be 10.75 animals per group. The largest herd was recorded with 31 individuals at Bishnupura village (Table 4)

A total of 344 individuals blue bull were recorded in the study area. Among them, Bishnupura was recorded with highest blue bull individuals (134) whereas Saupharsatikal was with only one male blue bull. (Figure 7). The highest number of blue bull were recorded in the forests dominated by sal and in the agricultural field they were recorded mostly in wheat field. 238 blue bull were recorded in the forests, 64 in agricultural land and 42 in grasslands.

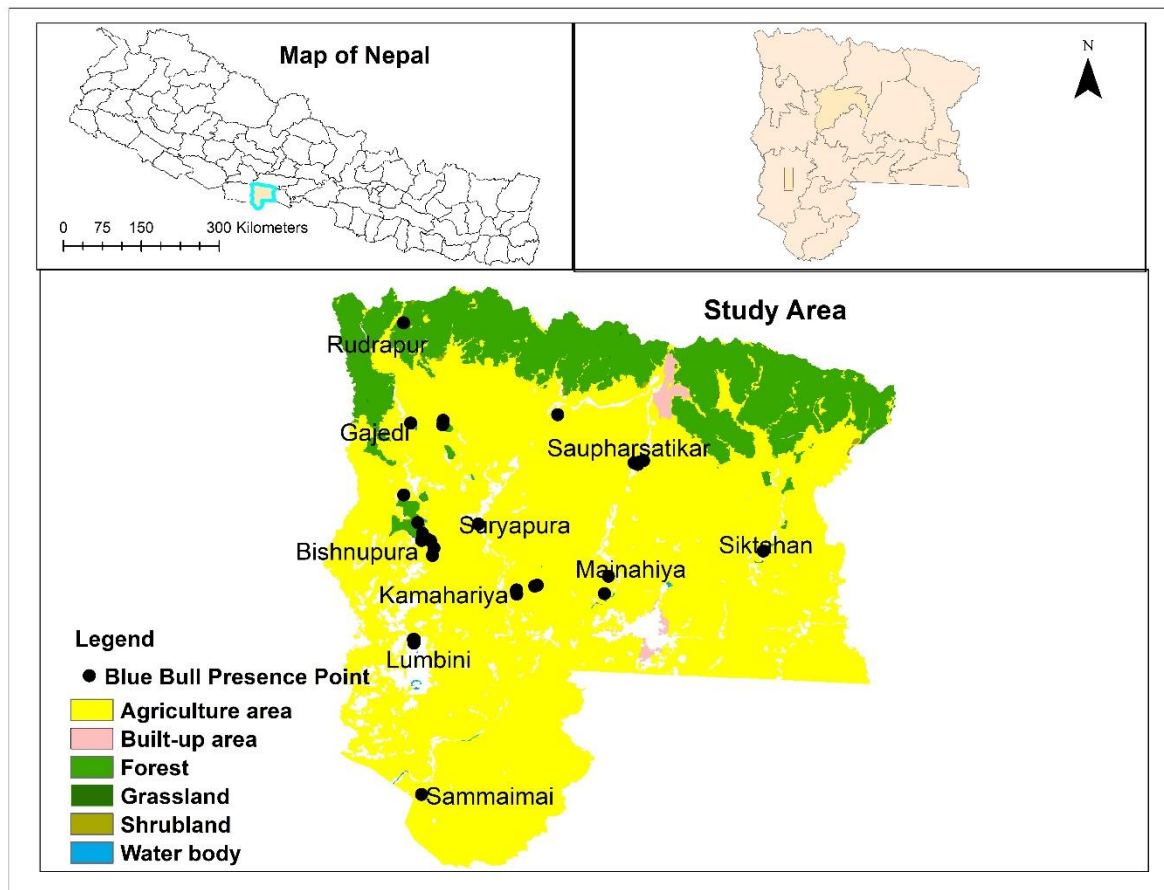


Figure 6. Map showing presence point of blue bull within Rupandehi District

Table 2. Group/herd composition of blue bull in sampled area.

S.N.	Study area	Male	Female	Calves	Total	Herd/Group
1	Saupharsatikar	1			1	1
2	Anandaban	9	14	5	28	3
3	Gajedi		8	5	13	2
4	Dahargaun	4			4	1
5	Lumbini	14	7	6	27	3
6	Gaidahwa	7	5	2	14	2
7	Mainahiya		5	3	8	1
8	Sammarimai		1	2	3	1
9	Siktahan	7	13	8	28	1
10	Suryapura	8	7	3	18	1
11	Baksad	3	5	4	11	1
12	Rudrapur	2	4		6	1
13	Kamahariya	2	19	3	24	2
14	Dayanagar	10	5		15	3
15	Deupar	6	3	1	10	1
16	Bishnupura	55	48	31	134	8
	Total	127	144	73	344	32

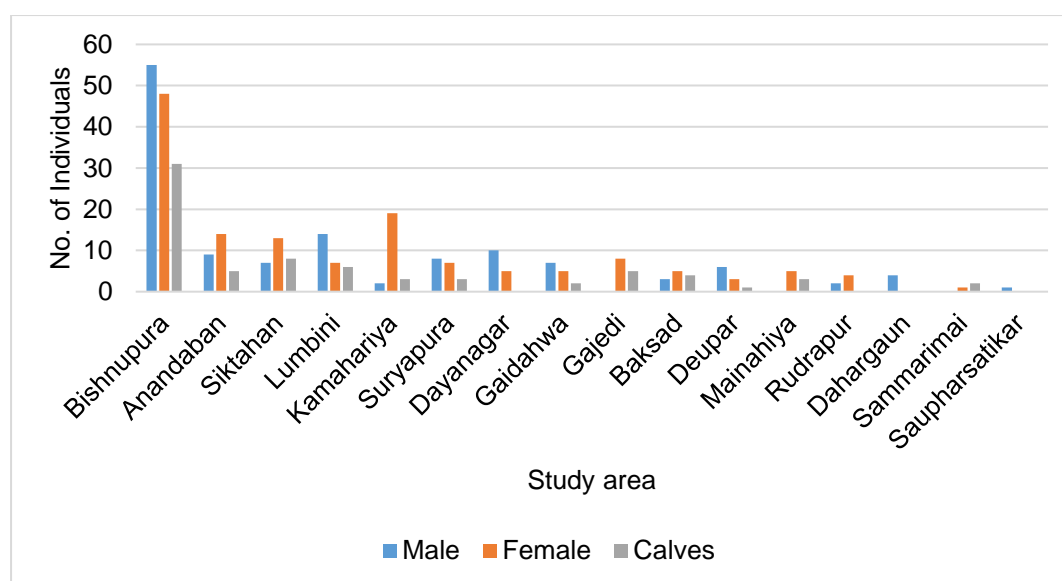


Figure 7. Population of blue bull on the basics of study area.

4.2 Occupancy of blue bull in Rupandehi District

A total of 88 trails each of 1 km length across each grid cells were surveyed. The naïve occupancy estimate was 0.6136, out of 44 grids only 27 grids showed the blue bull signs which may be either direct or indirect signs. Direct sighting of blue bull was recorded in 23 grids, while pellet was recorded as indirect sign in all 27 grids as blue bull presence. Most of the evidences were recorded in the forests following by agricultural land.

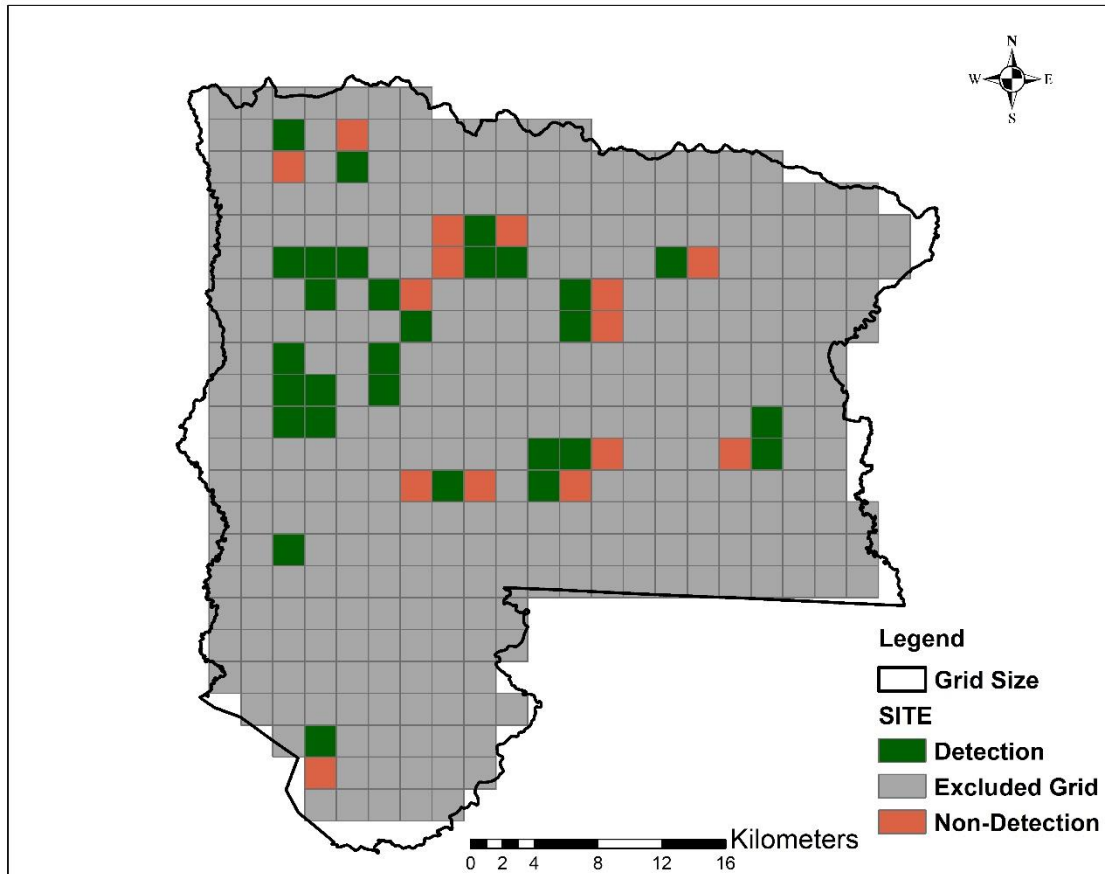


Figure 8. Map of study area finding detection and non-detection of blue bull.

4.3. Detection probability estimation

Different covariates have different influences on the habitat of blue bull. Summary model showed that only forest with human disturbances (three types) having ($\Delta AIC < 2$) shows the best models which greatly influenced the detection probability of blue bull. The magnitude and direction of influence on ecological and anthropogenic variable on site use patterns shows the different where among all the model forest with human disturbance, forests and agricultural land shows the suitable habitat, while agricultural land with the presence of people was the least supporting habitat for the blue bull (Table 3).

For forests, it was reported that it has a strong positive covariate on detection probability in blue bull with estimates detection probability rate of 0.8947 with S.E of 0.0498, 95% C.I 0.7510-0.9599, while waterbodies show the least supporting covariates in detection probability with estimates detection probability rate of 0.7 with S.E of 0.0947, 95% C.I 0.5436-0.9097 (Table 4)

Table 3. Summary model for factor affecting the detection probability of Blue bull in Rupandehi districts, giving Δ AIC is Akaike Information Criteria to top ranked model, AIC wgt is model weight, No. of parameters (k).

Model	AIC	Delta AIC (Δ AIC)	AICwgt	Model likelihood	No. of parameter (k)	- 2*LogLike
$\Psi(\cdot), p(\text{forest+ Human Distrubance})$	80.67	0	0.9528	1	7	66.67
$\Psi(\cdot), p(\text{forest})$	88.67	6.01	0.0472	0.0495	3	80.68
$\Psi(\cdot), p(\cdot)$	106.61	25.94	0	0	2	101.61
$\Psi(\cdot), p(\text{agriculture land})$	107.67	27	0	0	3	101.67
$\Psi(\cdot), p(\text{water bodies})$	107.83	27.16	0	0	3	101.83
$\Psi(\cdot), p(\text{grassland})$	108.05	27.38	0	0	3	102.05
$\Psi(\cdot), p(\text{agriculture land + Human Presence})$	108.32	27.65	0	0	4	102.32

Table 4. Covariates influencing detection of blue bull in the habitat ranked by beta coefficient estimates and associated standard errors with 95% class interval. SE is the associated standard error for estimates.

Covariates	β -coefficient	SE	95% Class Interval
Forest	0.8947	0.0498	0.7510-0.9599
Agriculture land	0.8774	0.0663	0.6812-0.9599
Grassland	0.8	0.0763	0.6111-0.9106
Waterbodies	0.776	0.0947	0.5436-0.9097

5. DISCUSSION

The findings of this study revealed that different habitat showed different occupancy of blue-bull, and their abundance in study area.

Forty-one individuals of blue bull in Lumbini were recorded by Aryal (2007) whereas Ghosai (2007) recorded 17 blue bull individuals in the same area. 40 blue bull individuals along Tinau River Forest was recorded by Aryal et al. (2016). During this field visit, 344 blue bull individuals were recorded which shows the increasing population of blue bull in Rupandehi as compared to 303 blue bull individuals in Rupandehi district (Khanal et al., 2018). The reason might be the migrating blue bull herds from India to Nepal or vice versa due to open border between Nepal and India (Khanal et al., 2018).

In Chilia, Khanal et al. (2018) recorded 12 individuals of blue bull but during field visit, individuals as well as their indirect sign were not recorded whereas in Bishnupura, highest blue bull individuals seventy-one were observed similar to this study. According to local people perception wild boar might be the reason for not recording blue bull either by direct or indirect sign in the field.

The major habitat of blue bull was recorded in open grassland with small patches of shrub areas and Khair/Sisoo forest which is different to the study where blue bull were observed mostly in sal forest (Bisht, 2012).

Aryal et al. (2016) found that group size of animals ranged from 3–12 individuals with mean group size was estimated five animals per group, similar to this study revealed that groups with 1-31 individuals with mean group size 10.75 animals per group which is in increasing condition. The reason might be the increasing number of populations in Rupandehi District.

Singh (1995) reported male blue were often solitary or male herds which is similar to the study where male blue bull were recorded mostly solitary or herds of two to seventeen individuals male blue bull. Vaghela et al. (2020) discovered that the group's size varied between agricultural and forested areas and it remained smaller in agricultural land as compared to the forest which is similar to this study.

Forest with human disturbance shows the best proportion of occupancy used by blue bull in this study among the other habitat which is also supported by (Lamichhane et al. 2020) where 70% of the forest area is occupied by blue bull. Pandey et al. (2022) also recorded similar findings. From the study of (Karki et al. 2012) in Bardia-Katarniyaghat forest corridor of western Nepal, the blue bull was distributed only in sal dominated forest (67%). The size of blue bull in forest area was found to be larger which is similar to the study conducted by (Vaghela et al. 2020). The abundance of blue bull was also recorded in forest in Arid Region of Kachchh, Gujarat, India (Gajera et al. 2014).

Bisht (2012) reported that blue bull utilized mostly *Shorea robusta* forest with grass patches as compared to other habitat which is similar to the study as forest provides shelter, cover from the sunlight during the day, as well as different grasses such as cogon grass provides food for blue bull.

Dinerstein (1979) concluded that 86% of the blue bull favored the grassland. The ground layer in lumbini was mainly covered by types of grass such as cogon grass and dubo grass, which bear similarity to the grassland found in the area of my research (Aryal, 2007). Similar type of grassland area was recorded to occupy by blue bull (Pandey et al. 2022). Similarly, in Bardia-Katarniyaghat forest corridor of western Nepal, 33% of blue bull was found to be distributed in grassland. But study conducted by Lamichhane et al. (2020) shows that blue bulls were less observed in grassland patches of park area. In this study, positive relationship was obtained between blue bull and grassland habitat and grassland is not differentiated into tall grassland and short grassland.

In agricultural areas, blue bull will feed throughout the night in open fields and retreat to the cover of forests during the day (Leslie, 2008). Pandey et al. (2022) found that habitat covered by blue bull is (16.9%) in Lumbini. Thapa et al. (2017) showed positive association between blue bull and distance to cultivated areas supporting this study.

Even though the blue bull site used were observed in cultivated land, but due to many agricultural practices such as fencing a wire, scarecrow, frequent encounter of human in agricultural land, shouting, hitting with stick, stone, lightening a fire, microbial fermented fish deterrent can be the reason for less site use in the agricultural field (Aryal et al. 2016; Gajera et al. 2014; Kushwaha, 2022). The blue bull habitat occupancy shows the less detection probability towards the cultivated land due to disturbance Thapa et al. (2017), which is similar to this study.

After flood in Doda river in 2007, the human activities in forest were recorded such as tree cut on the edge of forest which might be the anthropogenic disturbance (Thapa et al. 2017) supporting this study. During the rainy season, there was a significant risk of the Blue Bulls, including the calves, being carried away and experiencing unexpected death (Aryal et al., 2016) similar to the study as detection of Blue Bulls near water bodies was notably low, indicating that they were avoiding these areas due to the increased likelihood of flood-related deaths.

In Koshi Tappu Wildlife Reserve, livestock grazing was a serious issue for blue bull, since they share the same grazing grounds and reserve ground for grazing by livestock causes the biggest threats to blue bulls Mallik (2019), which is similar to the study as reported that livestock and blue bull sharing the same grazing ground.

(Aryal 2007) reported that Blue Bull's habitat is declining and it appears that this case in the Lumbini area is similar to the study where numerous construction projects have been reported in the area around Lumbini which might be the reason for declining the population of blue bull in Lumbini. The locals use a variety of techniques to prevent blue bull from grazing on their crops, including scarecrows, electric fences, and physical obstacles, which is similar to the study used for preventing crop raiding (Khanal et al., 2018)

Khanal et al. (2018) reported that blue bull was found consuming rice, wheat, maize, mustard and chickpea which is similar to the study where blue bull were observed consuming wheat, chickpeas, lentils, potato, cauliflower in our study. It has raised the negative interaction and perception of people towards blue bull.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The presence of large number of individuals and the pellet groups suggests that Rupandehi districts is good habitat for the Blue Bull. Among all habitat types in Rupandehi District, forest provides the suitable habitat for Blue Bull and highest number of blue bulls were recorded in forests. Among all the study area, Bishnupura comprises suitable habitats for Blue Bull where 134 individuals blue bull was recorded.

The results revealed the proportion of area occupied by blue bull in Rupandehi during March. The study was based on single season single species model (MacKenzie et al. 2002) using both sign survey and direct observation. The grids gave a naïve estimate of 0.6136. Seven sets of models were created occupancy estimation among which the detection probability of the species was positively correlated with human disturbances like sign of fire, grass cutting, livestock grazing and least correlated with agricultural land in the presence of people. This study estimates detection probability from the optimal range of 0.54-0.96 in study area. The summed model weight indicated that the forest habitat type was the most suitable habitat for blue bull use.

6.2 Recommendations

- The present study was carried out in single season with limited sites. A multi season analysis need to be carried out to calculate the effect of covariates through the year.

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Appendix I. List of Photographs



Photo 1. Pellet drop of blue bull in forest



Photo 2. Pellet of Blue bull in Grassland habitat



Photo 3. Herd of Blue bull spotted in wheat land in sammarimai



Photo 4. Herd of Blue bull spotted in wheat field in kamahariya



Photo 5. Herd of Female and Juvenile Blue bull spotted in Bishnupura



Photo 6. Herd of Blue bull spotted in Forest of Bishnupura