USE AND EFFECTIVENESS OF WILDLIFE CROSSINGS IN NEPAL

Results from the Wildlife Underpasses Built along Narayanghat – Mugling Road in Barandabhar Corridor Forest

2019

Hariyo Ban Program

USAID FROM THE AMERICAN PEOPLE

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Published by
WWF Nepal, Hariyo Ban Program
PO Box: 7660
Baluwatar, Kathmandu, Nepal
T: +977 1 4434820, F: +977 1 4438458
info@wwfnepal.org, www.wwfnepal.org

Prepared by
Dr. Kanchan Thapa
Sabita Malla
Prasan Karmacharya

Contributors
Dr. Shant Raj Jnawali, Santosh Mani Nepal, Gokarna Jung Thapa, Pramod Neupane, Samundra Subba, Saroj Koirala

Disclaimer
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ABBREVIATIONS AND ACRONYMS

AADT	Average Annual Daily Traffic
BaNP	Banke National Park
BCF	Barandabhar Corridor Forest
BNP	Bardia National Park
CHAL	Chitwan Annapurna Landscape
CNP	Chitwan National Park
DNPWC	Department of National Parks and Wildlife Conservation
DoFSC	Department of Forests and Soil Conservation
DoR	Department of Roads
EIA	Environmental Impact Assessment
GDP	Gross Domestic Product
GoN	Government of Nepal
IUCN	International Union for Conservation of Nature
km	Kilometer
MoPIT	Ministry of Physical Infrastructure and Transport
PCU	Passenger Car Unit
PNP	Parsa National Park
ShNP	Shuklaphanta National Park
TAL	Terai Arc Landscape
USAID	United States Agency for International Development
USD	United States Dollar
VWC	Vehicle Wildlife Collision
WWF	World Wildlife Fund Inc.

FOREWORD

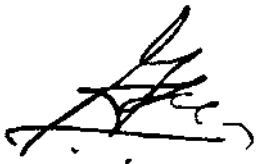
Nepal envisions to achieve Sustainable Development Goals (SDGs) by 2030 which will be backed up by its motivation to graduate to Middle Income Country. To align with the SDG goals, Nepal seeks more investment in Infrastructure Development and use those resources to ameliorate existing infrastructures and develop new ones to meet the national demand.

Major existing highways are being upgraded from two lanes to four lanes, while more new roads are being constructed at both national and local level. Construction of North-South trade routes, electrified East-West railway lines, large irrigation canals and transmission lines are under planning process to improve the overall infrastructures of the country with a vision to achieve rapid economic growth and improve living standards of people. With such massive investment on large infrastructures it's impacts on overall biodiversity and wildlife in particular will be perilous if appropriate mitigation measures are not adopted.

Sustainable and wildlife-friendly roads are imperative to conserve country's natural wealth and cultural heritage. Mitigation measures such as underpass and overpass have proven to be very successful intervention around the world to minimize adverse impacts of linear infrastructures traversing through core protected areas and critical wildlife corridors. Such mitigating measure not only supports safe wildlife movement across linear infrastructures but is also very crucial for human safety.

Department of Roads (DoR) constructed Nepal's first wildlife crossing underpasses at Aaptari and Ramnagar of Narayanghat-Muglin Road section while WWF Nepal, Hariyo Ban Program supported in assessing its effectiveness. This report is a result of seasonal monitoring over a period of one-year and presents species type, timing, and pattern of use of those underpasses by wild animals. I hope this report will encourage developers and planners to include dedicated crossing structures at critical forest where linear infrastructure passes through. WWF Nepal is committed to contribute for the development of Sustainable Green Infrastructure in Nepal.

I would like to thank DoR for its support and coordination and Division Forest Office, Chitwan, for their engagement throughout the assessment. I would also like to thank United States Agency for International Development (USAID) for funding this study under the Hariyo Ban Program, and the consortium partners for their participation.



Dr. Ghana S. Gurung
Country Representative
WWF Nepal

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EXECUTIVE SUMMARY

The increasing trend of wildlife mortality due to road accidents are a growing concern in Nepal. This trend is severe along the highways that traverse protected areas and corridor forests. This study examines the use and effectiveness of newly built underpasses in Narayanghat-Mugling road that bisect the northern section of Barandabhar Corridor Forest (BCF). BCF is the only remaining forest strip in Chitwan that provides north-south forest connectivity facilitating gene flow between Chitwan National Park (CNP) in south and Annapurna Conservation Area in the northern Mahabharat range of Chitwan Annapurna Landscape. With gradual recognition for wildlife crossing structures as a measure to mitigate the impacts of roads on wildlife, Department of Roads (DoR) have constructed four underpasses at Aptari and Ramnagar areas of Narayanghat-Mugling road.

Wildlife use of the four underpasses at Aaptari and Ramnagar areas were monitored using remote camera traps. A total of 14 cameras were placed at both ends of the underpasses for one month each in summer, monsoon and winter seasons to observe seasonal movement of wildlife. Highest wildlife movement was recorded in winter season (52.15%) followed by monsoon (26.6%) and least usage was recorded in summer (21.2%). We recorded a total of fifteen species of which thirteen were reported using underpasses. Overall wildlife crossings were dominated by medium size animals (61.06%) followed by small size (28.3%). The least number of crossings were made by large mammals (10%). This study provides photographic evidences on the use of four underpasses by different wildlife species and recommend measures to prevent wildlife-vehicle collision leading to ecological and financial ramification.

Provision of wildlife crossing structures are very essential for all linear infrastructure projects traversing through critical forest, incorporating designs based on the international practice and available guidelines in all planned projects.

Keywords: *conservation, highway, infrastructure, mammals, underpasses, wildlife crossings, wildlife mortality*

INTRODUCTION

1

Nepal, with a vision of graduating to a developing country prioritizing its economic prosperity. To fulfill its vision, Government of Nepal (GoN) has given high precedence for development of large infrastructures including highways, hydro-power dams, high tension lines, airports, irrigation canals and industries that are considered vital for contributing to national GDP growth. The study conducted by UN-ESCAP and Nepal Planning Commission estimates that Nepal needs the infrastructure investment of least 8 to 12 percent of GDP until 2020 to adequately develop its infrastructures. Transport infrastructure sector alone shows that between present investment of NRs 44 billion ~ (USD 440 million) against an estimate of NRs. 370 billion ~ (USD 3.7 billion) the ratio is eight-fold (UN-ESCAP/National Planning Commission, 2017). While large infrastructures remain imperative for country's economic development, the environmental impact can be significant and is of growing concern. These can affect environment and wildlife in many ways, like habitat loss and fragmentation, disturbances/edge effect, barriers to movement and dispersal; vehicle-wildlife collision (VWC) causing injuries and casualties to wildlife, human safety, and property. Wildlife mortality due to road kills are in an increasing trend in Nepal particularly in areas where highways bisects National Parks and corridor forests. A total of 133 animal casualties due to road accident have been recorded in a single fiscal year in 2017 (DNPWC, 2017).

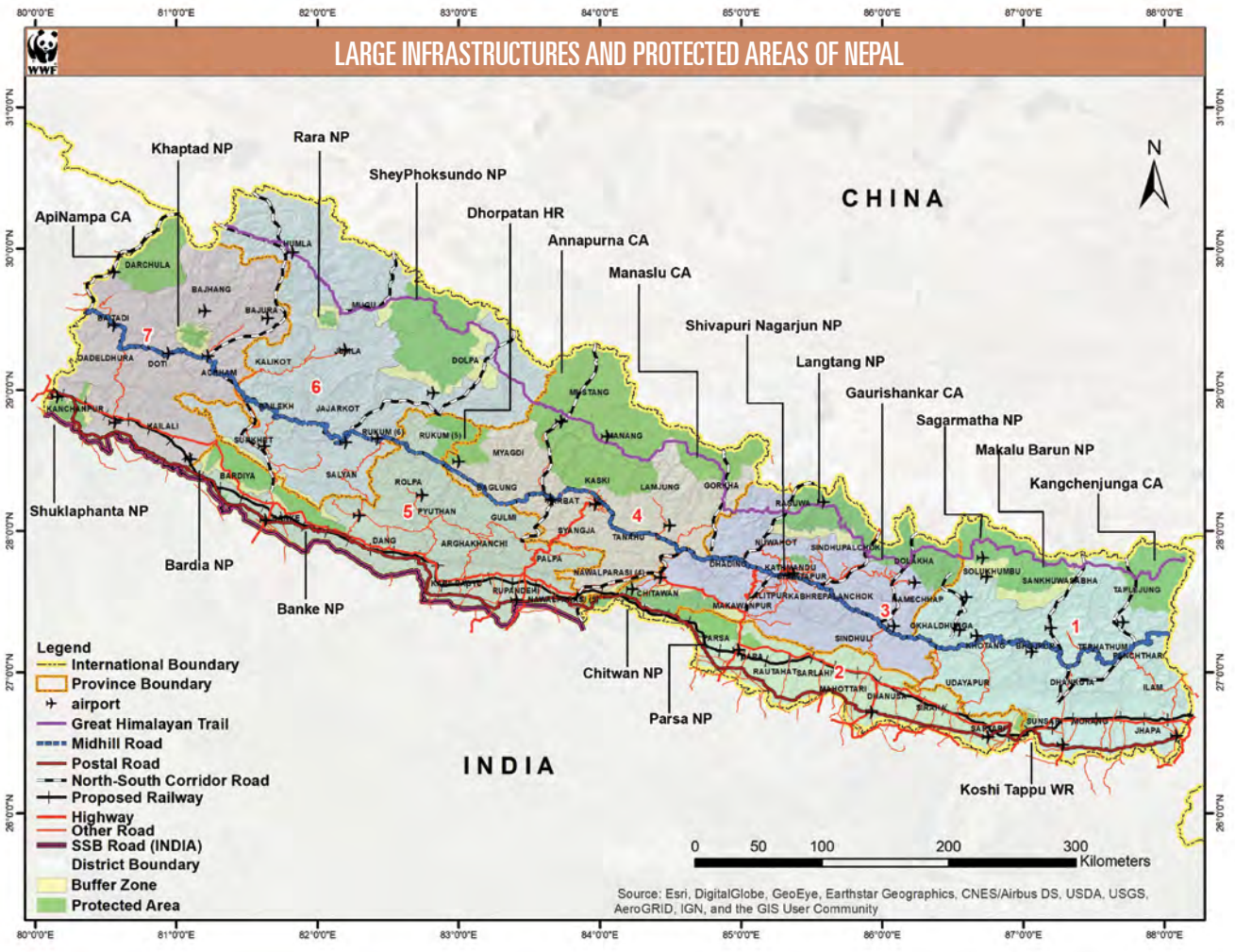
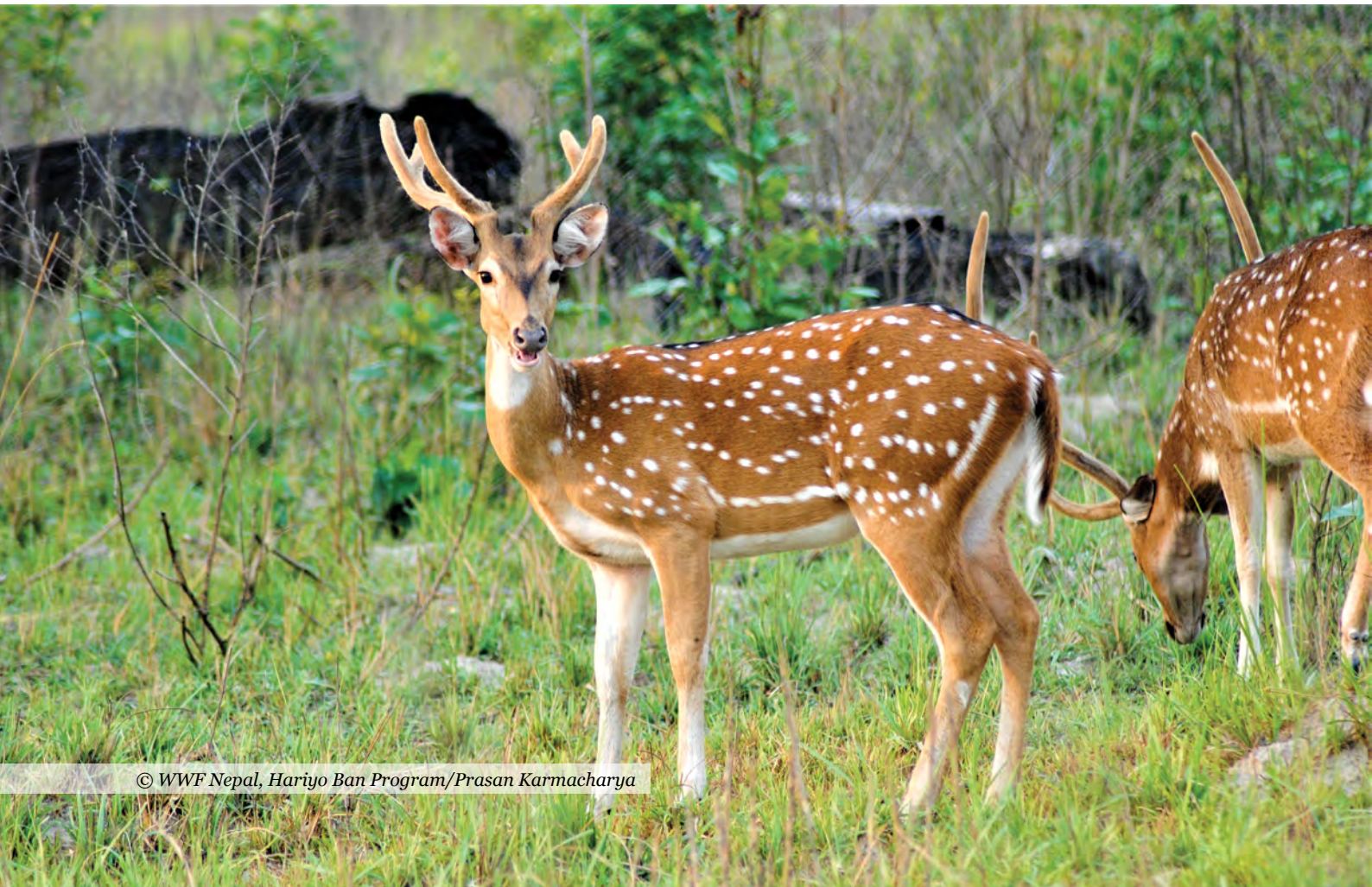


Figure 1: Map Showing Large Infrastructures and Protected Areas of Nepal

Impact of roads on diverse wildlife species is likely to worsen given mitigation measures are not put in place along the planned extension of the East-West Mahendra highway that bisects the 271 km of important wildlife habitats in Parsa National Park (PNP), Chitwan National Park (CNP), Banke National Park (BaNP), Bardia National Park (BNP), Shuklaphanta National Park (ShNP), their buffer zones and other forest areas including corridor forests (Figure 1). East-West Postal highway that runs along Nepal-India border bisecting 122 km of Kamdi, Khata, Karnali, Basanta and Laljhadi-Mohana corridor forests will also have similar impact on wildlife and their critical habitats.

With priority of GoN to expand and upgrade transportation facilities, Ministry of Physical Infrastructure and Transport (MoPIT) through DoR is planning to expand major highways of the country to a minimum of four lane. Recently, DoR has expanded and upgraded Narayanghat-Mugling Road section to Asian highway standards for road safety and environmental sustainability. This road section traverses through dense forest of Barandabhar corridor forest (BCF), lower stretch of Seti corridor forest that extends along the lower Trishuli and Seti-Madi rivers to link Annapurna Conservation Area (CA) in the northern Mahabharat range with Chitwan National Park (NP) and further south with Valmiki Tiger Reserve in India (GoN, 2016). Narayanghat-Mugling section road (33.27 km) was upgraded with the financial support from World Bank connects important business centers (Mugling and Narayanghat) with average annual daily traffic (AADT) in Passenger Car Unit (PCU) of 15150 (GoN, 2016). With gradual recognition for wildlife crossing structures as a measure to mitigate the impacts of roads on wildlife, DoR took initiatives to construct four underpasses in most potential wildlife crossing points based on Environmental Impact Assessment (EIA) report and stakeholder consultation within the stretch of 12 km of BCF.

These are the first underpasses targeted to facilitate safe movement of wildlife and prevent vehicular wildlife Collison. This study was conducted to understand status of wildlife use and effectiveness of these underpasses and share the results to all concerned stakeholders including policy makers, infrastructure developers, conservation partners and donor agencies so that provisions for wildlife friendly under passes or over passes are made mandatory while upgrading the existing roads and building new ones in future.



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MATERIALS AND METHOD 2

STUDY AREA

The BCF (27°34' to 27°40'N and 84°21' to 84°28'E) covers an area of 107 km² in Chitwan district and has high ecological significance as it is the only remaining strip of forest that connects Annapurna CA in north with Chitwan NP and further south with Valmiki Tiger Reserve in India. (Bhattarai & Basnet 2004, Kandel, 2012). Also, BCF serves as a climate refugia providing shelter for wildlife during high floods in the East Rapti River.

BCF is bisected by 4 km stretch of East West Highway-Mahendra Highway between Tikauli and area. The narrow strip of forest is also traversed by a blacktopped single lane road north of Mahendra highway. The forest south of highway (approx. 57 km²) is the buffer zone of Chitwan NP whereas part of the forest north of highway (approx. 20.9 km²) is designated as Protected Forest and falls under the jurisdiction of Province 3 Forest Division. BCF comprises of 102 km² forests, 4.4 km² non-forest area and 0.01 km² wooded land (DFRS, 2015). BCF borders with Khagedi river in the east, agricultural land as well as settlements in the west, Chitwan NP in the south and contiguous forest area in the north. Important wetland in BCF include Bishazari Lake, a Ramsar site, Gaida Lake and Dominated with sal (*Shorea robusta*) forest. The corridor forest is exceptionally rich in biodiversity with 33 species of mammals, 328 species of birds, 37 species of fishes, 16 species of butterflies, and 31 species of herpetofauna and 199 species of plants, (Lamichhane et al. 2016). The mammals documented also included Tiger (*Panthera tigris*), Common leopard (*Pathera pardus*), Sambar (*Cervus unicolor*), Sloth bear (*Melursus ursinus*), rhinoceros (*Rhinoceros unicornis*), Elephant (*Elephas maximus*). The area has a sub-tropical climate with average annual temperatures of 25°C, but it can reach up to ≥ 40°C during the summer. The monsoon season is between June and September and the average annual rainfall is 2,000 mm (Bhattarai, 2003).

Figure 2: Study area showing BCF and north south connectivity

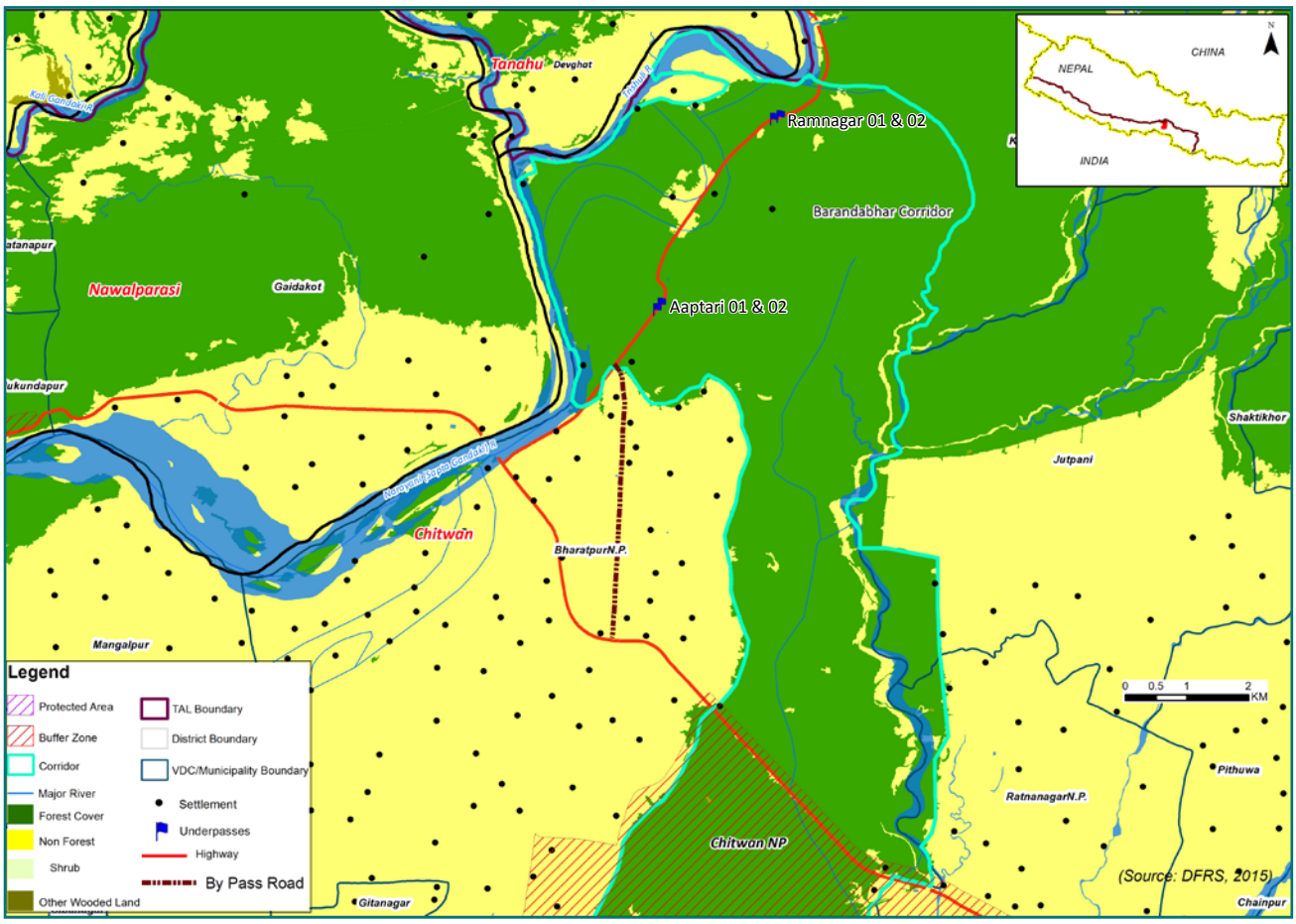

Figure 3: Map showing Barandabhar corridor and Underpasses location

DoR has constructed 4 underpasses at Aaptari and Ramnagar area within the stretch of about 12 km of BCF in the Narayanghat - Mugling Road section. The first 2 underpasses are constructed at Chainage 3+500, 1.2 km north of Aaptari intersection and other two underpasses are constructed at Chainage 7+500, 1.6 km south of Ramnagar town, the distance between two adjoining underpasses is about 50 m. All four underpasses have similar structural and landscape attributes with slight variation in openings with respect to visibility (Fig. 4, 5, 6). The details of each of the underpasses (Aaptari 01 and 02, Ramnagar 01 and 02) is provided in *Annex* - 1.

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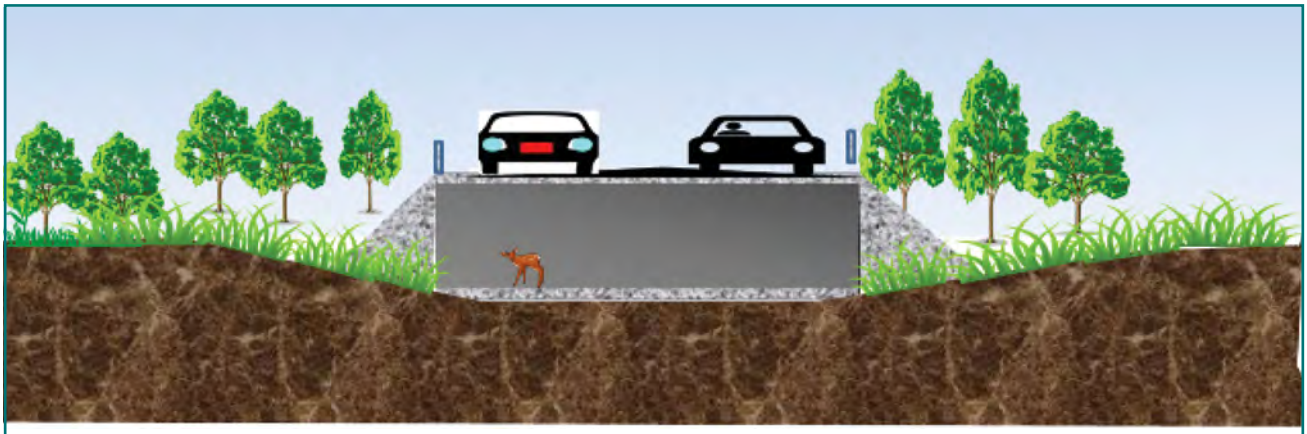

Figure 4: Longitudinal Section View of the Underpass (Source: DoR)

Figure 5: Cross Section View of the Underpass (Source: DoR)

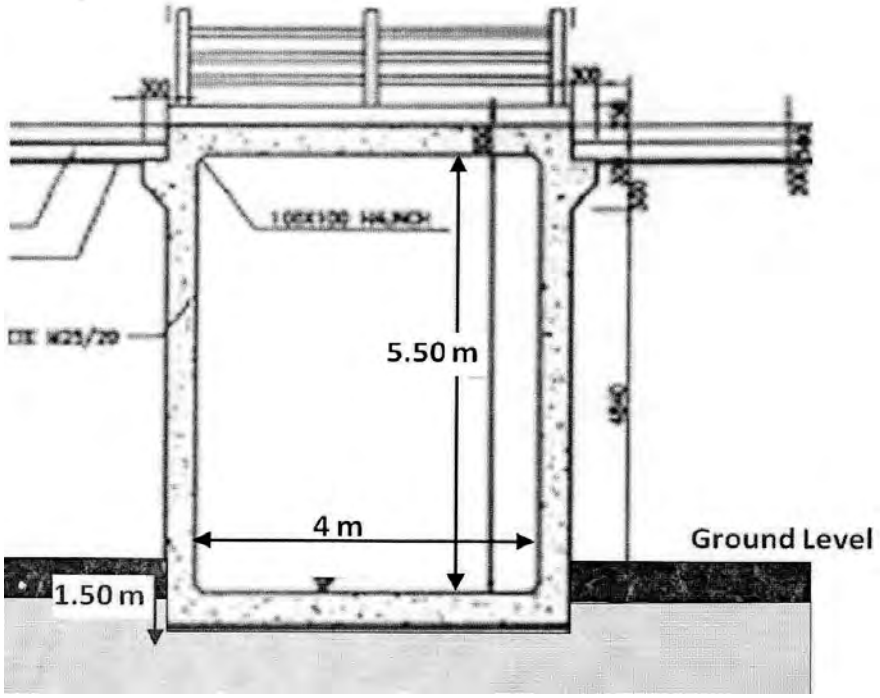

Figure 6: Cross Section View of Underpass (Source: DoR)

2.2 FIELD METHODS

The study was conducted from August 2017 to June 2018 spanning across three different seasons monsoon (23rd August - 23rd September), winter (17th January - 18th February) and summer (8th May - 7th June). To detect and record underpass use by wildlife, 14 remote cameras (4 Cuddeback Attack and 10 Cuddeback X-change color) were deployed at both ends of the underpasses including one additional set of cameras in the nearby forest. Height of the cameras were maintained at 70 cm to capture wildlife species of all sizes (small, medium and large) reported from the study area. Each camera trap in underpass was given a unique code (Aap 01 and Aap 02 and Ram 01 and Ram 02) for cameras near Aaptari and Ramnagar, respectively) for data sorting and management. Trap period was set for a maximum of 30 days in each of the monitoring season. All the camera traps were operational 24 hours a day, with 30 second interval between each independent capture. Camera traps were checked and data were downloaded every day to prevent possible losses due to theft.

2.3 DATA ANALYSIS

All the images obtained from the camera traps were analyzed using software ReNamer Lite ver 6.9 (den4b Team, 2018) and BR's Exifextracter ver 0.19.16 Beta. Total number of independent detections were calculated as a measure of the quality of underpass as sensed by wildlife. Animal detections were considered independent if the time between consecutive photographs of the same species was taken at an interval of more than 30 minutes (O'Brien et al. 2003). Microsoft Excel 2010 and SPSS (IBM SPSS Statistics ver. 20) was used to generate appropriate illustrations and test the significance of different data outcomes amongst underpasses, seasons and animal size classes that used underpasses. For all analyses, differences were considered statistically significant at 95 % confidence interval (Chi square test). Crossing rate was calculated as percentage of individual detection divided by total number of detections of all species in all underpasses.

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RESULTS 3

SUCCESSFUL WILDLIFE CROSSINGS IN UNDERPASSES STUDIED

Altogether, 668 photographs in 607 independent detections were recorded from four underpasses, of which 93 % (n = 621) comprised of 15 mammal species and 4 species of birds, and 7 % (n = 47) domestic cattle (Table 1).

Even though avifauna are not targeted species of the study, Peafowl that usually subsists on the ground were captured crossing the underpass (Table 2).

Of the total 607 independent detections, highest successful animal crossings were recorded from Ramnagar 01 (n = 238) followed by Aaptari 02 (n = 131), Aaptari 01 (n = 130)

Table 1: Mammals recorded in underpasses at Aaptari and Ramnagar area of Narayanghat-Mugling road

S. N	Species name	Zoological name	IUCN Category	Size class
1	Asian palm civet	*Paradoxurus hermaphroditus*	LC	Small
2	Barking deer	*Muntiacus muntjak*	LC	Medium
3	Spotted deer*	*Axis axis*	LC	Medium
4	Common leopard	*Panthera pardus*	VU	Large
5	Crab eating mongoose	*Herpestes urva*	LC	Small
6	Indian crested porcupine	*Hystrix indica*	LC	Small
7	Indian grey mongoose	*Herpestes edwardsii*	LC	Small
8	Jungle cat	*Felis chaus*	LC	Small
9	Leopard cat	*Prionailurus bengalensis*	LC	Small
10	Rhesus macaque	*Macaca mulatta*	LC	Medium
11	Sambar Deer*	*Rusa unicolor*	VU	Large
12	Small Indian civet	*Viverricula indica*	LC	Small
13	Indian grey langur*	*Semnopithecus hector*	LC	Medium
14	Wild boar	*Sus scrofa*	LC	Medium
15	Yellow throated marten	*Martes flavigula*	LC	Small

*Note: * denotes species recorded near the underpasses but avoided it*

Table 2: Birds species recorded in underpasses at Aaptari and Ramnagar area of Narayanghat-Mugling road

S. N	Species name	Zoological name	IUCN Category
1	Peafowl*	*Pavo cristatus*	LC
2	Black kite	*Milvus migrans*	LC
3	Yellow billed blue- magpie	*Urocissa flavirostris*	LC
4	Large billed crow	*Corvus macrorhynchos*	LC

*Note: * denotes species that crossed the underpass*

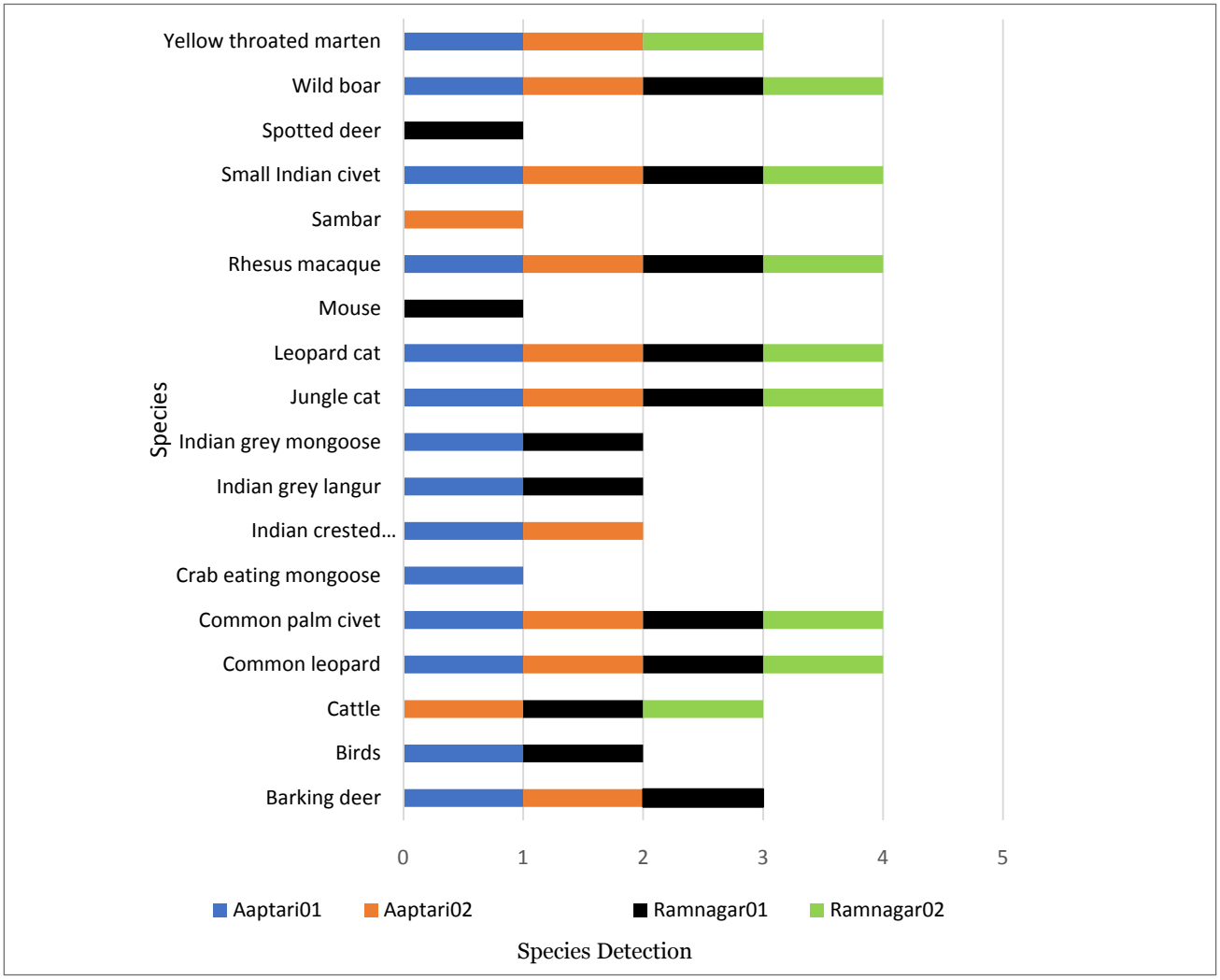

Figure 7: Wildlife detection in four underpasses

and the lowest record was from Ramnagar 02 (n = 108) (Fig. 7). The overall use of underpass was significantly different ($\chi^2 = 2564.18$, df = 3, $p < 0.05$) between the underpasses. Details on species rate of capture are provided in *Annex* 2.

However, the number of species using underpasses was higher for Aaptari 01 (n=14) followed by Ramnagar 01 (n = 13), Aaptari 02 (n = 12) and Ramnagar 02 (n=9).

USE OF UNDERPASSES BY SPECIES AND THEIR BODY SIZE

Wild boar used the underpasses most frequently with highest crossing rate of 40.03%. The underpass uses of other species, such as rodents, spotted deer, crab eating mongoose, spotted deer ranged from less than 1% to 10.28% for common leopard (Fig. 8). Sambar deer, Spotted deer and Indian grey langur were detected with 20 images captured near the underpasses but avoided to use for crossing.

Of the four species of birds (Peafowl, Black kite, Yellow billed blue-magpie and Large billed crow), peafowl used underpass only once. Remaining three species of birds did not cross but spent significant time feeding on the animal waste dumped at the underpass (Fig. 8). Domestic cattle used the underpasses less frequently with only 7.7% of the total animal crossings recorded from underpasses.

The use of underpass between species was varied significantly ($\chi^2 = 252.56$, df = 17, $p < 0.05$).

The overall wildlife crossings were dominated by medium (61.06%) and small sized animals (28.3%). The least number of crossings were made by large mammals (10%).

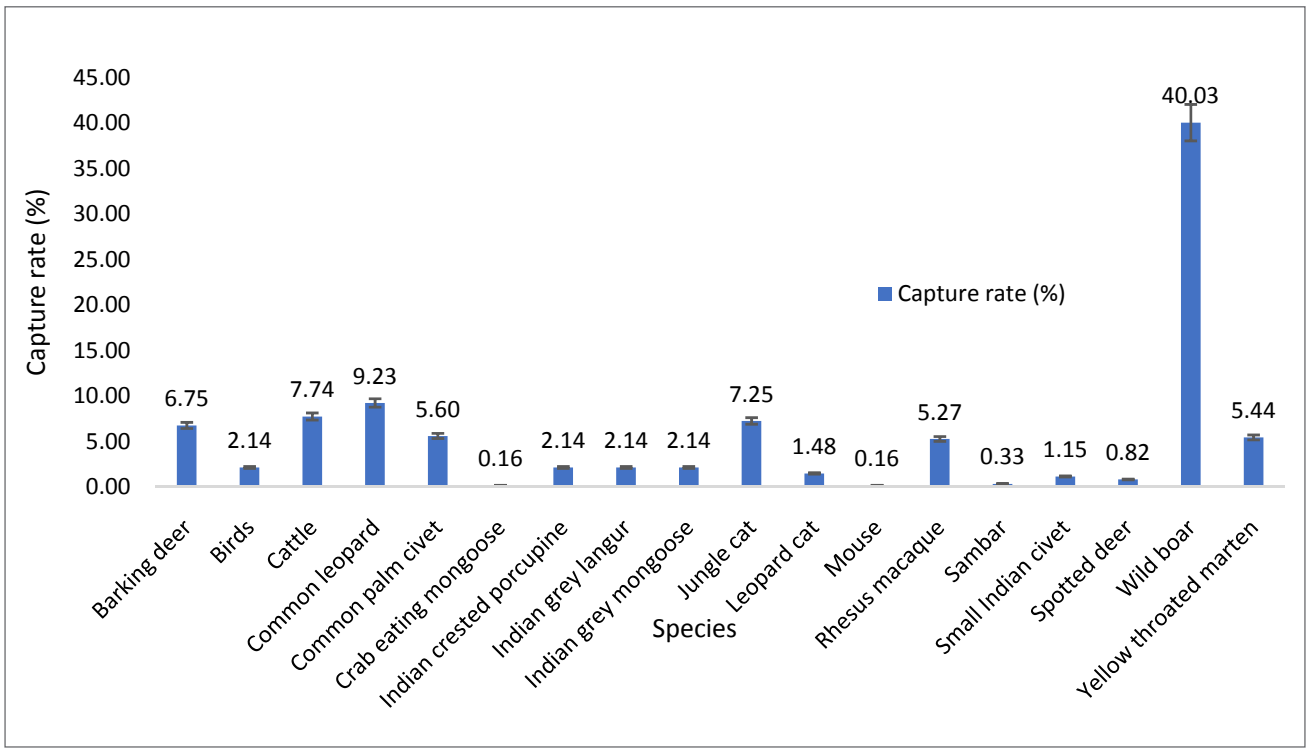

Figure 8: Detection rate of species in underpasses

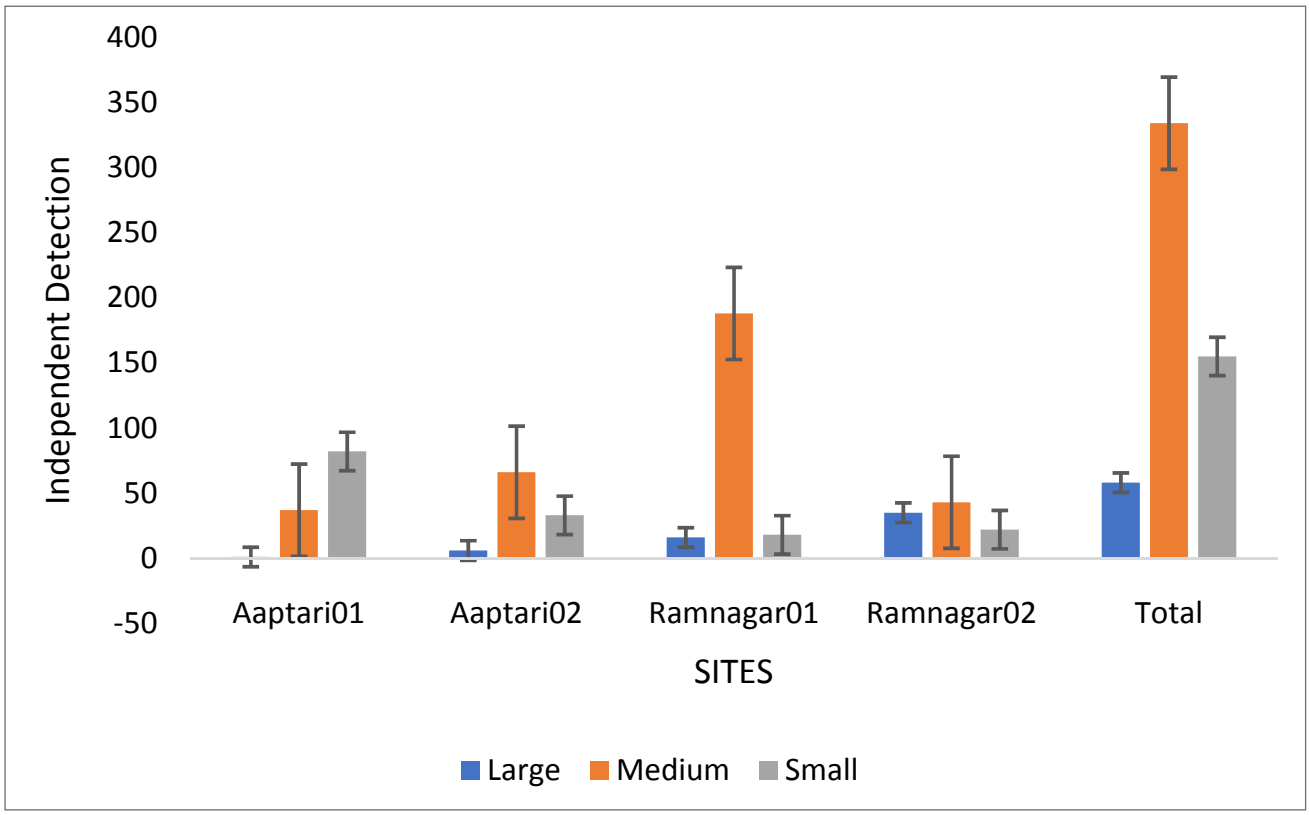

Figure 9: Use of different underpasses by large, medium and small body size animals

However, this trend was not consistent in site specific underpasses (Fig. 9)

Common leopard was the only felid species detected in all four underpasses with 60 images from 24 independent detections. This accounted for 4 individual common leopards using the underpasses (Both flanks image-1; Left flank only-3 and Right flank only-2). The site wise crossing of common leopard was highest in Ramnagar 02 (n = 12) followed by Ramnagar 01 (n = 8), Aaptari 02 (n = 3) and Aaptari 01 (n = 1).

SEASONAL USE OF UNDERPASSES

The seasonal use of underpasses was highest (52.15%) in winter followed by monsoon (26.6%) whereas the least (21.2%) usage was recorded in summer. The site wise seasonal use of underpasses didn't follow the similar pattern. It varied between the sites with higher animal crossings in winter season in Ramnagar 01 (n = 169) and Aaptari 02 (n = 68), whereas higher animal crossings occurred in monsoon in Aaptari 02 (n = 48) and Ramnagar 02 (n = 42) (Fig. 10).

Seasonal use of the underpasses was significantly different (χ^2 = 102.69, df = 2, p< 0.05) with higher usage in winter as compared to summer and monsoon. There was also significant variation with the usage of underpasses between two sites: Ramnagar and Aaptari both with respect to seasonal usage (χ^2 = 102.69, df = 2, p< 0.05) and animal size classes (χ^2= 104.81, df = 2, p< 0.05).

IMPACT OF DISTURBANCES ON WILDLIFE CROSSINGS

Wildlife active period in underpasses was considered as an index to measure the impact of disturbances on wildlife crossings. Disturbance here indicates noise of vehicle movement, vibration, human trespassing, and openness perceived as threat which could have implication on wildlife movement. Animals captured in camera traps were categorized as diurnal, crepuscular and nocturnal based on their observed and established behavioral pattern. The independent detection of the species was plotted against 24 hours period to understand if human disturbance and or noise had an impact on their movement pattern. Wildlife crossing by diurnal species were recorded to spread beyond the diurnal time period suggesting possible compromise by wildlife to avoid human disturbances (Fig. 11).

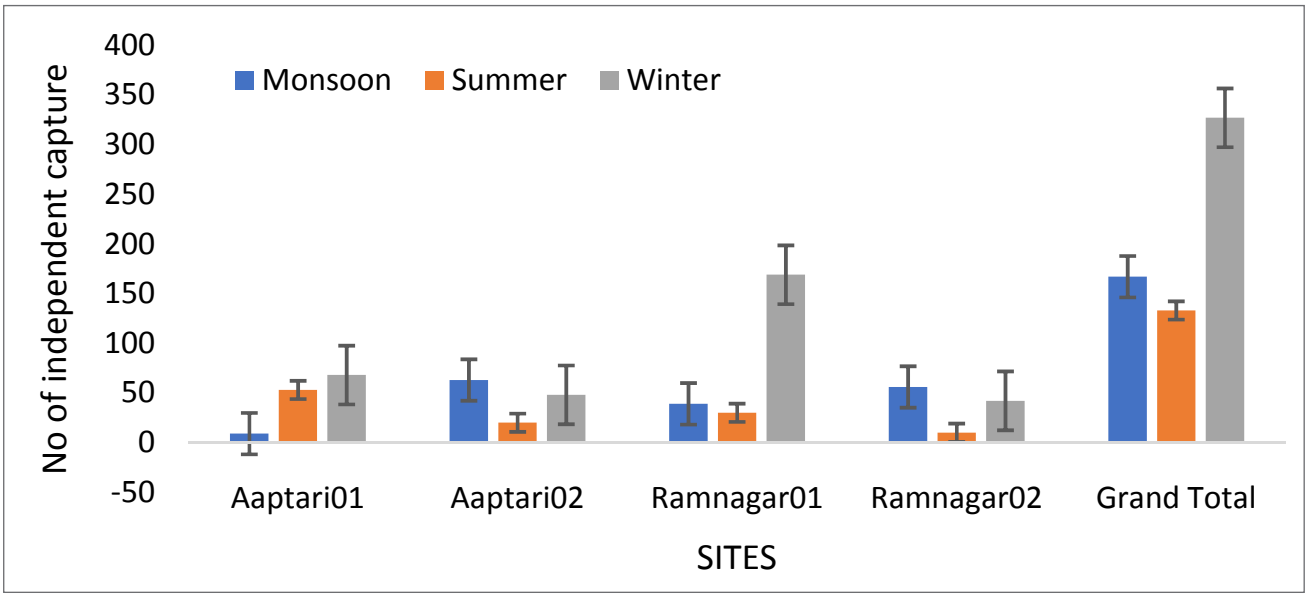

Figure 10: Seasonal use of underpasses

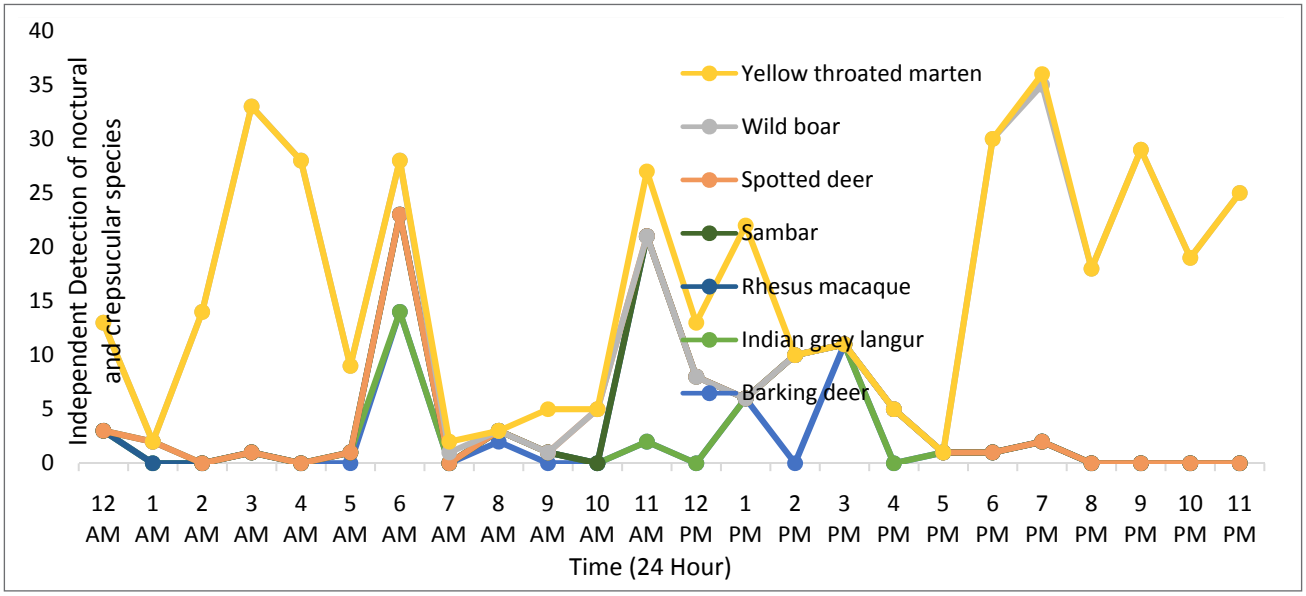

Figure 11: Activity pattern of the diurnal species

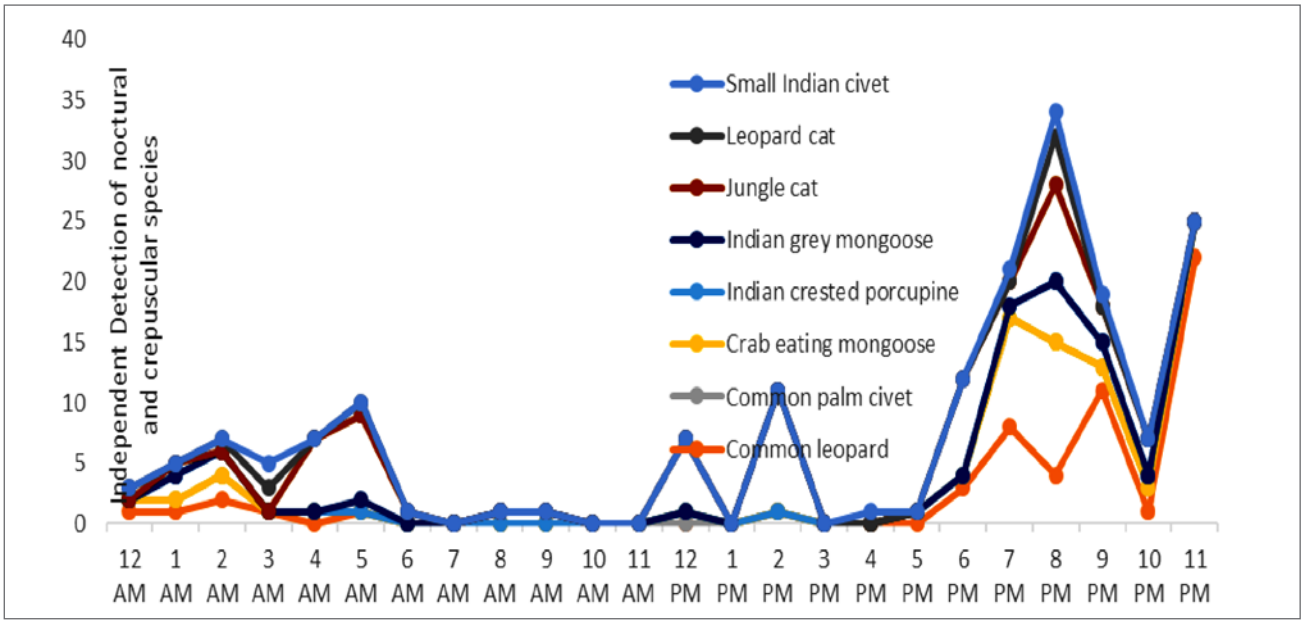

Figure 12: Activity pattern of the nocturnal and crepuscular species

Similarly, activity pattern of nocturnal and crepuscular species followed regular routine. However, Small Indian civet used the underpasses during the day time too (Fig. 12). This pattern indicates lesser disturbance during night time compared to day time.

4 DISCUSSION AND CONSERVATION IMPLICATIONS

The effectiveness of an underpass depends upon several variables including dimensions (height and width), proximity to natural wildlife corridors, noise levels, substrate, vegetative cover, moisture, light, temperature and human disturbances (Jackson and Griffin 2000). As the four underpasses constructed had similar structural and landscape attributes, there wasn't much scope for testing the effectiveness with respect to structural design. None-the-less, we found significant differences in the use of underpasses at Aaptari and Ramnagar areas though each underpass was within the range of 50 m (Aaptari 01 and Aaptari 02) and (Ramnagar 01 and Ramnagar 02). Ramnagar 01 provided highest permeability (40%) largely owing to the vegetation cover, good drainage system and better visibility. In contrary, Ramnagar 02 contributed for only 18% of the total animal crossing, probably due to the poor drainage system and site used for dumping solid wastes by road side hoteliers in Ramnagar.

In Aaptari 01, there was heap of earthen mass at north-western end of underpass causing obstruction for animals to navigate safe way out of underpass. In Aaptari 02, slope gradient at north-western end of the underpass was higher compared to the south-eastern end also hindering visibility. Both of these, underpasses contributed to only 21% of animal crossings. Hence, we recommend correcting these attributes to facilitate easy movement of wildlife by leveling the substrate, removing the earthen mass for visibility, providing proper drainage system and promoting vegetation cover. Moreover, waste dumping and human interference near underpass area shall be controlled and monitored to possible extent.

The animal crossings in the underpasses were dominated by small to medium sized mammals. The past studies (Kandel, 2012; Aryal 2012) have also documented presence of sloth bears (*Melursus Ursinus*), Tigers (*Panthera tigris tigris*) and One-horned rhinoceros (*Rhinoceros unicornis*) in areas where these underpasses have been constructed from the northern BCF but did not document the usage of underpasses by these species. The study by CNP reported eleven tigers from BCF (Annual Report-2074/75-CNP, 2018) of which 2 were exclusively captured from north of highway whereas the 4 tigers had the home range extended both to the north and south of highway. In case of sambar deer, it is possible that they are either reluctant to use underpasses or are in extremely low density in the area to be using the existing animal crossings.

Similarly, the shift in activity pattern of diurnal species can compromise their ecological, behavioral and dietary needs leading to detrimental impacts in species viability in long run. These findings also highlight the importance for considering the ecological attributes during the construction phase. Additionally, to achieve the maximum usage of these wildlife crossings, natural vegetation of appropriate species and size should be maintained in and around animal crossing structures, existing game trails need to be identified prior to the roadway construction for the placement of crossing structure where possible. Also, the construction of guiding fence to the crossing structure would enhance the use of crossing structures for a wide variety of species.

As these underpasses are first initiatives of wildlife friendly infrastructures development, this assessment is a novel study of its kind. As there are several ongoing and planned linear infrastructure projects that will traverse through critical forest area, provision of appropriate mitigating structures at appropriate location is must for maintaining ecological balance and harmony between human and wildlife. Results from this assessment has given positive vibes to conservationist and developers towards need of mitigating structures and future consideration on design and other associated factors.

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CONCLUSION 5

This study provides ample of evidences of frequent wildlife crossings in underpasses dominated by medium and small sized mammals. The study concludes that wildlife of different species is using the underpasses more frequently in winter season comparatively when the water availability in nearby areas was scarce and must move towards water abundant areas. These mitigating structures do not only support safe passage for wild animals but also substantiate for domestic animal and human safety. Thus, all the available records confirm use of existing underpasses as potential mitigative measures for preventing vehicular-wildlife collision in high vehicular density road and use of camera trap as a viable and robust technique to evaluate an effectiveness of underpass built for wildlife. Provision of wildlife crossing structures are very essential for all linear infrastructure projects traversing through critical forest, incorporating designs based on the international practice and available guidelines in all planned projects seems imperative in future. Use of camera trap for evaluate an effectiveness of wildlife underpass and design used in existing study seems to be viable option for its replication in similar setting elsewhere.

The overall wildlife crossing dominated by small and medium sized animal contributing to around 90 % of total detections concludes underpasses of this dimensions are generally good for small to medium sized animal. However, the study could not comment on the proportion with change on dimension of mitigation structure. Long-term monitoring is required to know wildlife behavior with respect to human disturbance and other associated factors. Few Recommendations for future study are:

a) Monitoring for comparative study of wild species occurrence beyond underpass area along highway section of the corridor.
b) Understanding noise levels and human disturbance to wildlife usage could be meticulously studied like knowing the daily traffic, local human activity and correlating with the temporal movement pattern.
c) Proper documentation of road kills along the road section for further comparative study.

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ANNEXES

ANNEX 1: SITE DESCRIPTION OF EACH UNDERPASSES

1. Aaptari 1 (AaP 01):

South Eastern End

North Western End

Location & Surroundings	This underpass is located around 1.2 km south west of Aaptari Junction and 1.5 km north-east of Ramnagar. River Narayani is around 1.7 km far to its North-West.
GPS Coordinate	27°43'7.86"N 84°26'50.16"E
Elevation	261 msl
Vegetation	The vegetation cover on both the sides of underpass is dense with few trees felled for construction activities. The forest is Sal dominated with the major species being *Shorea robusta*, *Terminaia tomentosa, Anogessius latifolaia* and *Mallotus philippinensis*
Slope grade	The substrate level at one end is plain and sloppy at the other end with gradient higher at North-western section. The difference of 8 feet exists between ground surface level of the underpass and natural surface level. Moreover, the earthen mass at north-western section prevents complete visibility of the other end.
Observation	Solid wastes such as paper, plastic bottles were noticed in and around underpass entrance site during first monitoring season

2. Aaptari 2 (AaP 02)

South Eastern End

North Western End

Location	This underpass is located at a distance of 50m from Aaptari 01. This underpass is also located This underpass is located around 1.2 km south west of Aaptari Junction and 1.5 km north-east of Ramnagar. River Narayani is around 1.7 km far to its North-West.
GPS Coordinate	27°43'9.46"N 84°26'51.54"E
Elevation	264 msl
Vegetation	Landscape features and vegetation is similar to Aaptari 01.
Slope grade	Similar to Aaptari underpass 01, the slope gradient is higher at one end and lower at the other. And natural steam flows underneath from north-west to south-western end.

3. Ramnagar 1 (RAM 01)

Southern End

Northern End

Location	This underpass is located at around 5.1 km from Aaptari Junction and around 1.8 km south-west of Ramnagar settlement. Jugedi is located 1.7 km north-east and Thimura is around 900 meters in its North. Similarly, Narayani River is 500 meters north from this site.
GPS Coordinate	27°44'48.00"N 84°28'10.02"E
Elevation	295 msl
Vegetation	Sal (*Shorea robusta*) is the dominant species with other associated species.
Slope grade	Slope gradient of this underpass is plain from both the end.
Observation	Plenty of wildlife signs (footprints) observed during the reconnaissance survey in the underpass and in surrounding areas.

4. Ramnagar 2 (RAM 02)

Southern End

Northern End

Location	It is located at a distance of 50 m from underpass Ramnagar 01.
GPS Coordinate	27°44'47.29"N 84°28'6.50"E
Elevation	297 masl
Vegetation	The vegetation is dominated by Sal (*Shorea robusta*) forests.
Slope grade	Surface is plain with wide openings.
Observation	The ground surface was water logged during the monsoon season. Also, the solid waste (animal remains, bottles, plastics were dumped in the site.

ANNEX 2: DETAILS OF SPECIES CAPTURED IN THE UNDERPASSES AND THE SPECIES RATE OF CAPTURE

Species name	Aaptario1	Aaptario2	Ramnagaro1	Ramnagaro2	Grand Total	Capture rate (%)
Barking deer	2	39			41	6.75
Birds	10		3		13	2.14
Cattle		26	13	8	47	7.74
Common leopard	1	4	16	35	56	9.23
Common palm civet	17	13	1	3	34	5.60
Crab eating mongoose	1				1	0.16
Indian crested porcupine	12	1			13	2.14
Indian grey langur	11		2		13	2.14
Indian grey mongoose	11		2		13	2.14
Jungle cat	12	8	11	13	44	7.25
Leopard cat	3	1	2	3	9	1.48
Mouse			1		1	0.16
Rhesus macaque	14	6	3	9	32	5.27
Sambar deer		2			2	0.33
Small Indian civet	2	3	1	1	7	1.15
Spotted deer			5		5	0.82
Wild boar	10	21	178	34	243	40.03
Yellow throated marten	24	7		2	33	5.44
Grand Total	**130**	**131**	**238**	**108**	**607**	**100**

ANNEX 3: PHOTOGRAPHS OF THE SPECIES DETECTED IN UNDERPASSES

(** denotes species that didn't use underpass for crossing)

Barking deer

Common leopard

Asian Palm Civet

Indian crested porcupine

*Indian grey langur ***

Indian grey mongoose

Jungle cat

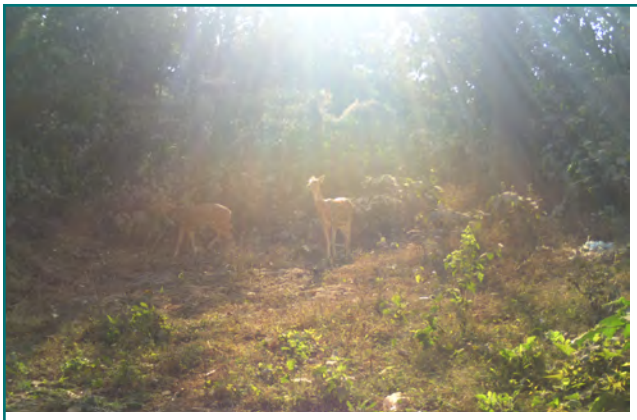
Leopard cat

*Unknown rodent species***

Rhesus macaque

*Sambar deer***

Small Indian civet



Spotted deer **

Wild boar

Yellow throated marten

Peacock

Black kite and Large billed crow **

Yellow billed blue magpie **

Domestic cattle

WWF NEPAL, HARIYO BAN PROGRAM
PO Box: 7660 Baluwatar, Kathmandu, Nepal
T: +977 1 4434820
F: +977 1 4438458
Email: hariyobanprogram@wwfnepal.org
Website: www.wwfnepal.org/hariyobanprogram

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