Usage of Man-Made Underpass by Wildlife: A Case Study of Narayanghat-Muglin Road Section

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Abstract: Natural areas are increasingly fragmented and degraded globally due to increasing anthropogenic pressure. Linear infrastructures such as roads, railways, canals, and transmission lines are major causes for such fragmentation resulting in population isolation, habitat connectivity loss, and gene pool shrinkage. Various mitigation measures are adopted to minimize such effects. The first such mitigation measure (an underpass) has been constructed along the Narayanghat – Ramnagar, and Ramnagar – Jugedi section of the Narayanghat-Muglinroad (section connecting two national highways; Prithvi and Mahendra highway). The effectiveness of these underpasses was assessed using a camera trap picture of wildlife movement during March and April 2019. Key informant interviews (n=14) were also carried out to understand the abundance of recorded species in the local forest. With 37 trap nights of sampling effort, seven mammalian species were recorded and among them, wild boar was found with the highest independent images (35). A total of 31 independent images (70.4 %) captured during the night hours showed that manmade underpasses were used more during the night. Confirmation of usages of these underpasses supports the study to indicate the necessities of underpasses while constructing roads that pass and traverse the wildlife habitat.

Keywords: *Barandabhar corridor, camera trapping, wildlife usage, underpass, temporal pattern*

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Introduction

Globally, natural areas and wildlife habitats are increasingly fragmented and degraded due to increasing anthropogenic pressure to meet the escalating human needs. Linear infrastructures such as roads, railways, canals, and transmission lines are major causes of such fragmentation. Roads are the main form of development, transecting vast areas of the earth's surface, negatively affecting ecosystems and associated wildlife (Forman and Alexander 1998; Coffin 2007). Effects of roads include increased wildlife mortality rates, as collision with vehicles are among the most obvious, and in some cases, primary causes of mortality for large vertebrates (Coffin 2007). The less obvious but very influential impact of roads on ecosystems is habitat fragmentation (Blakenhol and waits 2009). Road networks fragment landscapes and populations by impeding wildlife movement with physical barriers (Donázar et al. 2018) and restriction on movements can reduce migration, dispersal, and opportunities for mating, leading to population subdivision and genetic differentiation (Andren 2013). The expansion of road networks and the increase in traffic have emerged in recent years as key threats to the conservation of biodiversity (Donázar et al. 2018). As connectivity between major blocks of habitat is a keystone of modern conservation planning (Longcore et al. 2018), wildlife crossing structures are now being designed and incorporated during road constructions in many places in the world (Wang 2014). These wildlife-friendly crossing structures permit safe movement of wildlife across barriers providing connectivity and reducing wildlife-vehicle collision (Clevenger et al. 2001; Riley et al. 2014).

Nepal is one of the least developed countries with a high priority of infrastructure development such as highway, hydropower, high tension lines, and airports for the economic growth of the country. While highways are considered to be the mainstay of the country's development, environmental impacts can be significant and of growing concern. In the Terai of Nepal, protected areas are like islands and small-sized area due to infrastructure development and human settlement, which can restrict the movement of large vertebrates.

In recent years, a landscape-level conservation approach has been initiated to mitigate the negative impacts of habitat fragmentation by connecting the remaining natural areas through corridors and connectivity (Anderson and Jenkins 2006). Terai Arc Landscape (TAL) in Nepal and India is one such landscape. The Barandabhar Corridor Forest (BCF) is one of the major corridors within TAL, Nepal. The BCF, which connects Chitwan National Park (CNP) & Mahabharat mountain range, serves as a wildlife corridor for some animals and alternative habitat for others (Liviaitis et al. 1996). Though the importance of this forest strip is immense, the BCF is fragmented mainly by highways. East-West highway and Narayanghat- Muglin road section has fragmented the wildlife habitat in BCF, leading to the collision of wild animals with high speeding vehicles. The Narayanghat-Muglin road section links two major highways; East-west (Mahendra) Highway and Prithwi Highway. This road section connects people from major districts of Nepal such as Chitwan, Kathamandu, and Kaski which are inhabited by a higher number of human populations and so this highway is exceedingly used.

A large part of the Nepalese highways bisects the forest patches, increasing the chances of vehicles- wildlife collision (VWC) especially in the patches with high vehicular pressure. In a single year (2016/2017), a total of 133 animal casualties were recorded due to road accidents (DNPWC 2017). With the soaring effects of habitat fragmentation and vehicle- wildlife collision, wildlife crossing structures are now getting gradual recognition as a measure to mitigate these impacts. The Department of Roads (DoR) constructed 4 underpasses in early 2018 in Aaptari and Ramnagar area of Narayangadh-Muglin road in BCF. Near the underpass, 1.3 km of a mesh wire fence was constructed along the road to guide the wildlife towards the underpass (Rimal 2018). Understanding the functionality of these underpasses plays a crucial role in the construction of crossing structures in other parts of the forest. Thus, this research was carried out to understand the effectiveness of the manmade underpass using camera traps in terms of species composition and the temporal use pattern.

Materials and methods

Study Area

The Barandabhar Corridor Forest (BCF) in Chitwan district of Nepal is located at 27°34′ to 27°40′ N latitude and 84°21′ 84°28′ E longitude, covering an area of 107 km^2 (Aryal et al. 2012; Kandel 2012). It is an important wildlife corridor connecting Chitwan National Park (CNP) and Mahabharat foothills in Nepal's inner Terai (Bhattarai 2003; Bhattarai and Basnet 2004). The exceptionally biodiversity-rich BCF also provides an extended habitat for wildlife specially Rhinoceros during the periodic flood in the Rapti river (Kandel 2012). This corridor forest is home for 33 species of mammals, 328 species of birds, 37 species of fishes, 16 species of butterflies, 31 species of herpetofauna, and 199 species of plants (Lamichhane et al. 2016b). Important wetlands such as Bishazari lake (a Ramsar site), Rhino lake, Tiger lake, and Jukedhap lake lie in the BCF. Despite its importance for biodiversity, the forest patch is bisected by two major highways: East-West (Mahendra) highway and Narayanghat- Muglinroad section as shown in Figure 1. The East-West highway primarily fragmented this corridor into two parts. On the south of the East-West highway is the buffer zone of CNP whereas on the north of the highway is a protected forest, which is managed by Division Forest Office, Chitwan. The study was carried out in the underpasses of the Narayanghat- Muglinroad which traverses the northern part of BCF (Figure 2). The forest has monsoon dominated sub-tropical climate. In the Narayanghat-Muglin road section of BCF, the first 2 underpasses were constructed about 1.5 km north of Aaptari and the other two about 2 km north of Ramnagar. The distance between two adjoining underpasses is about 50 meters and all four underpasses have similar structural dimension (4 m width and 5.5 m height) and landscape attributes with Sal (*Shorearobusta*) dominated forest in nearby habitat (WWF 2019).

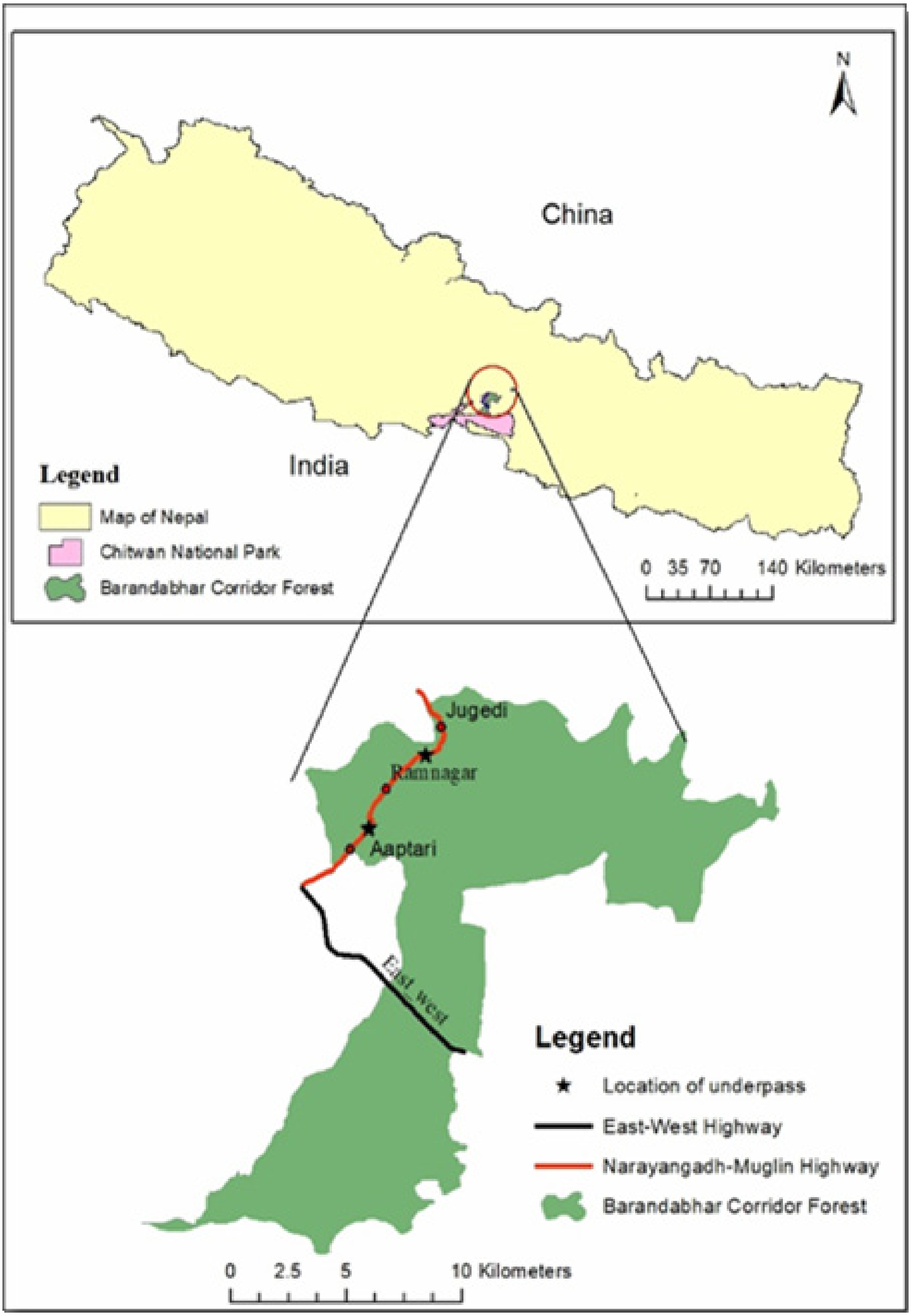

Figure 1: Study area

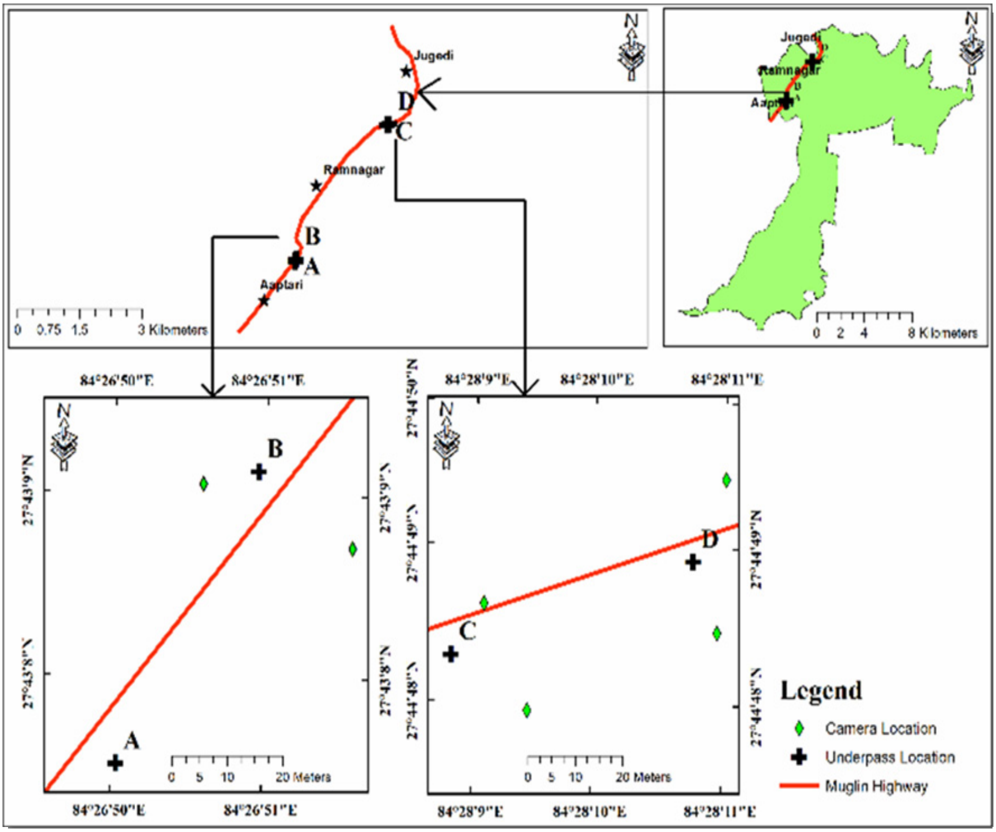

Figure 2: Location of underpasses in Narayanghat-Muglin road

Methods

Camera Trapping

Camera traps are useful in obtaining non-invasive photographic evidence of rare and cryptic wildlife (WWF 2019). In this study, camera traps were used to study the temporal pattern of species detection. A preliminary field visit was conducted in early March 2019 to gain the locality knowledge and condition of the site. Based on the available resources, we randomly selected three underpasses and one underpass was left unequipped. We used a total of 6 Cuddeback camera traps (Xchange IR, model no. 1279), 1 for each side of the selected underpass. One underpass from the Aaptari area and two underpasses from the Ramnagar area were selected randomly and given the name Underpass- B, Underpass-C & Underpass-D respectively (Figure 2). Camera traps were given the ID, for example, B1 & B2, C1 & C2, D1 & D2 for ease in sorting the images while offloading the data.

Camera traps were placed in a corner of the selected underpasses and were fixed throughout the study period. The GPS locations of camera trap stations were recorded along with the habitat characteristics and dimensions of underpasses. A total effort of 37 trap nights was applied during the study between March 2019 and April 2019 (Total 7 trap nights). Seven trap nights were considered assuming that the wildlife activities within 7 days would represent the overall use of underpass by those species within the particular season. Six camera units were used for the first 2 trapping nights but one camera was lost and only 5 camera units were used for the remaining 5 trapping nights. Camera traps were placed at the height of 60 cm above the ground (Lamichhane et al. 2016a) and angled slightly down towards the openings of the underpass to capture the species of all size that attempted to cross the underpass. Camera traps were daily monitored to offload the images.

Key Informant Interview

Key informant interviews are used to access feelings, understanding, and experiences of participants of the case in a study (Michel 1999). In this study, key informant interviews were conducted to understand community people's sighting of the uses of underpass by different wildlife animals, and also to share their knowledge of the available species of wildlife in the study area. A semi-structured interview was conducted with the leaders of the local community, relevant government officials (CNP and Division Forest Office), the staff of Nepal Police, and members of the community forest users' groups Semi-structured interviews provide greater flexibility to respondents to explain the actual situations. A semi-structured questionnaire prepared in advance was used to interview 14 key informants. The interviews conducted in the Nepali language lasted from 15-30 minutes. With the permission from the respondents, the interviews were recorded and later transcribed and translated into the English language for analysis.

Data Analysis

Data from the camera trap were collected and sorted within the file hierarchy of personal computer systems by an underpass, camera, species, and some subjects following (Harris et al. 2010). Photo capture of a species within 30 minutes interval was termed as independent events (Lamichhane et al. 2016a). Only independent images of particular species were counted as valid. To assess the abundance index of a particular species in the area, the capture rate was calculated following Carbone et al (2001).

$$\text{Capture rate} = \left(\frac{\text{No. of independent images}}{\text{Total trap nights}}\right) \times 100$$

$$\text{Trap night per photo} = \frac{\text{Total trap nights}}{\text{Number of independent images}}$$

Temporal Pattern of Species Detection

For temporal pattern, first, we categorized a day into 4 time periods: morning (5 to 9 hours), day (9 to 15 hours as a day), evening (15 to 19 hours), and night (19 to 5 hours). The time stamp of the camera trap images was used to analyze the temporal activity pattern of captured species. Individuals which were captured on both traps traveling in the same direction within a limited time were considered to have crossed the underpass successfully. Descriptive analysis was conducted using Microsoft Excel for collected camera trap data. The materials of the key informant interview were analyzed qualitatively.

Results and Discussion

A total of 567 images were captured by all camera traps during the study period. Out of them, 214 (37.74 %) were animal images, and the remaining 353 (62.26 %) included pictures of humans, cattle, and goats and falsely triggered by camera traps. Seven species of mammals were recorded in the camera traps. Wild boar has the highest number of independent images (n=35) followed by a common leopard (n=3), barking deer (n=2), whereas spotted deer, Asian palm civet, Indian crested porcupine, and yellow-throated marten had only a single independent detection (n=1). The number of independent images, capture rate, and trap nights per photo of particular captured species is shown in Table 1.

Table 1: Detected species along with their independent images and capture rate

SN	Species	Independent Images (I)	Capture rate (I/37) *100	Trap nights per photo
1	Wild boar *(Sus scrofa)*	35	94.59	1
2	Common leopard *(Panthera pardusfusca)*	3	8.10	12
3	Barking deer *(Muntiacusmuntjak)*	2	5.40	19
4	Spotted deer *(Axis axis)*	1	2.70	37
5	Asian palm civet *(Paradoxurus hermaphrodite)*	1	2.70	37
6	Indian crested porcupine *(Hystrixindica)*	1	2.70	37
7	Yellow-throated marten *(Martes flavigula)*	1	2.70	37

Although seven species were detected in cameras close to underpasses, we obtained evidence of two species, i.e. wild boar and common leopard, crossing the underpass successfully. With a total of 18 successful crossings, wild boar had the highest number of crossing events (n=17). The crossings of underpass were high during the night period (n=14), followed by evening (n=2) while day crossing was minimum during morning and daytime (Figure 3).

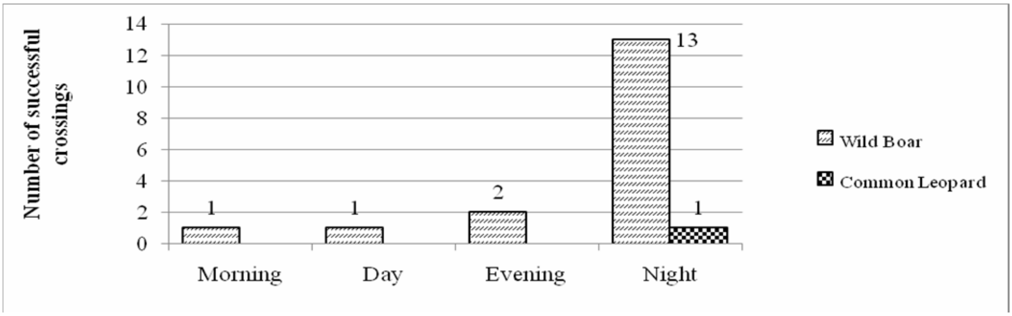

Figure 3: Temporal pattern of successful crossings

The highest number of independent events (70.4 %, n=31) were recorded during the night time.

"The Narayanghat-Muglin road section is the busiest road in Nepal. But the road has low vehicular pressure during the night time in comparison to the day time", explained a Nepal police officer who was working in the particular section of the road. Wildlife activities were seen maximum at night (Figure 4) when human activity was less, which is also comparable with similar findings from the USA (Starr and Mcallister 2014; Patten and Burger 2018).

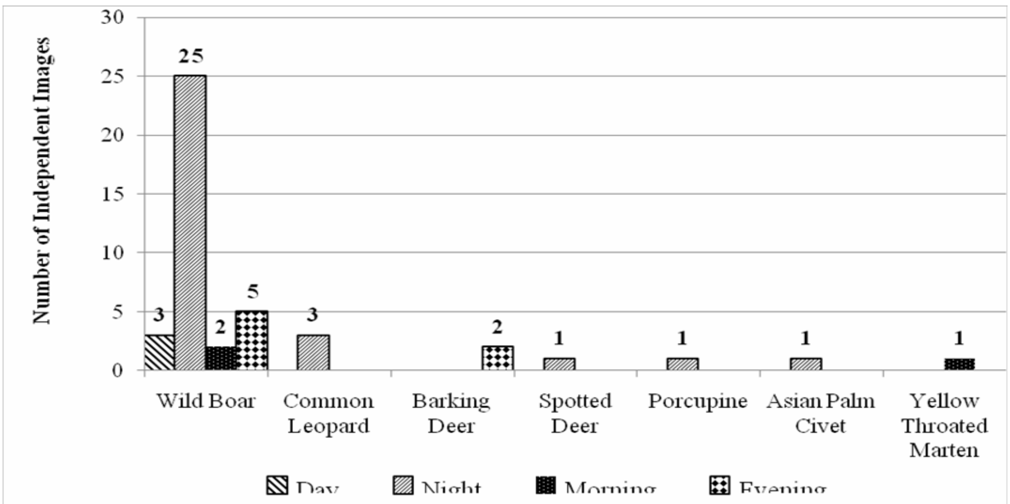

Figure 4: Temporal pattern of species detection

The construction of underpasses in Narayanghat-Muglin highway was completed in the beginning of 2018. Though the parameters such as the time from construction, type of crossing structure & its dimension, and distance from the nearby settlement were similar, the population size of wildlife in the surrounding landscape may have a direct association with passage rates at wildlife crossing structures (Clevenger et al. 2009). This might be one reason for the high detection of wild boar and no detection of one-horned rhinoceros and Bengal tiger, though they were recorded in northern

BCF (Aryal et al. 2012). "Wild animals are using the underpass, which has led to a rapid fall in the number of vehicle-wildlife collisions in Narayanghat-Muglin road section. However, it isn't certain that the dimension of the underpass is suitable for large species such as one-horned rhino", clarified the forest guard of Santanchuli community forest, where the underpass C and D lie.

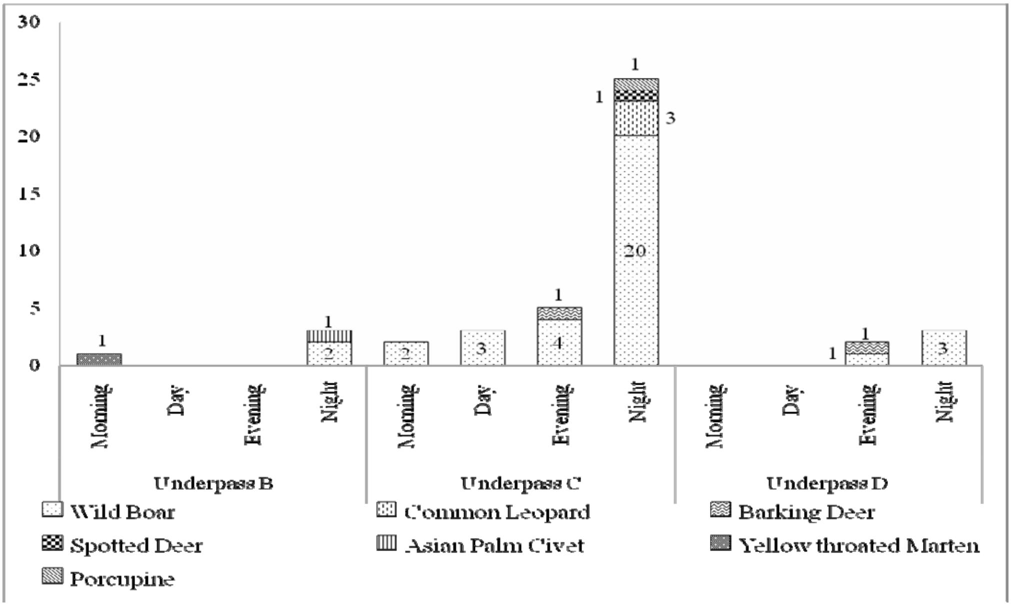

Figure 5: Site wise information of wildlife detection

Among the studied underpasses, the maximum number of species (n=5) and the highest number of independent images (79.54 %) were recorded in underpass C, which is consistent with the findings of WWF (2019). Despite being just 50 m apart, only 11.36 % of independent events were recorded from underpass D (Figure 5).

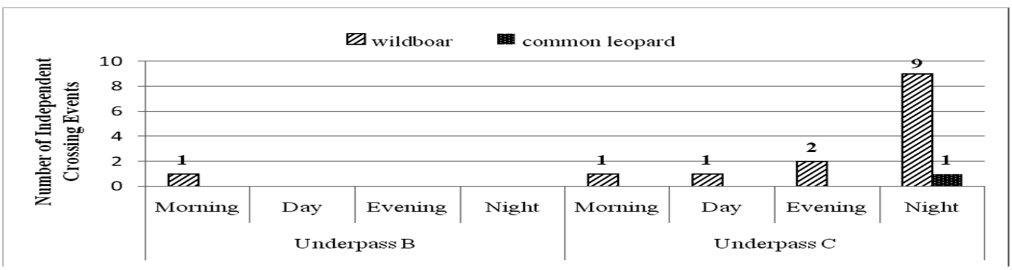

Figure 6: Site wise successful crossing events

Although 2 species—wild boar (n=4) and barking deer (n=1)—were detected in underpass D, they hadn't crossed the underpass successfully (Figure 6). The smaller number of successful crossings in comparison to independent detection in all underpasses might be due to the reluctant behavior of wild animals to use the newly built underpass. This contrary in site-wise result might be due to the preference of wild animals to use existing game trails. This finding highlights the importance of considering ecological attributes during the construction of crossing structures.

Conclusion

The newly constructed underpasses seemed effective, ensuring wildlife movement in Barandabhar Corridor Forest. Confirmation of wild animal movement through underpasses has proven the requirement of underpasses in a feasible road section with busy traffic that traverses the wildlife habitat. The detection of animals was seen maximum during the night period. However, the activity behavior of wild animals and anthropogenic pressure should be studied to conclude the relationship between the usage of an underpass and anthropogenic pressure. Due to the low sample size, usage of underpasses with respect to species composition and size couldn't be assessed. Further, to comprehensively assess the functionality of underpasses, understanding species-wise deaths related to vehicle-wildlife collision in presence and/or absence of underpasses in similar habitats are necessary to address knowledge gaps in developing such mitigation and/or offset measures.

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