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Spatiotemporal Status of Wildlife-Vehicle Collisions in Banke National Park, Nepal

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Abstract

Wildlife-road kill is the death of wildlife resulting from collision with a moving vehicle. In protected areas, roads have a significant impact on natural environment including health of ecosystems. The most obvious direct effect of these impacts is evidenced by animal mortality on the road. Wildlife-road kill does not occur randomly along roads but are spatially clustered area because wildlife movements tend to be associated with specific habitats, terrain, and adjacent land use types. In an effort to understand these environmental factors and animal susceptible to road kill, this study was conducted in Banke National Park (BaNP), where frequent road accidents occur along East-West (EW) highway. Last 8 (2015-2022) years recorded road kill data (N=402) by BaNP office were used for this study, spatial and temporal data were generated from this data. Total 70.56 km length of EW highway that passes from park was further divided into 141 segments in ArcMap containing each segment of 500 m length. Presence absence of road kill was obtained from spatial join between segments and road kill data. Environmental factors; road curvature, crown cover, land use, distance from settlement, forest type, straightness of road, topography and distance from water source that affect patterns of road kill data were recorded in each segment in field survey. Descriptive statistics, *chi-square* test and binary logistic regression model were used for data analysis. Wild boar (90), Spotted deer (54) Rhesus monkey (48), Jackal (40) and other mammals were susceptible to wildlife vehicle collision. WVC pattern was recorded in clustering in some locations but was independent to season and time. Total 6 WVC hotspots were identified namely; H_1: Shivakhola, H_2: Khairi, H_3: Muguwa, H_4: Obhari, H_5: Samshergunj and H_6: Pragatinagar for WVC. Land use, canopy cover and distance from settlement are statistically significance with WVC. Distance from water, straightness of road, road curvature, topography of site and forest type were not important in wildlife vehicle collision. Hence more signposts (about laws and the speed limit of the road and also about biodiversity conservation) should be installed to control WVCs.

Keywords: Wildlife • Hotspots • National park • Biodiversity • Environmental

Introduction

The death of wildlife as a result of a collision with a moving vehicle is referred to as wildlife road kill. It happens because wildlife and people driving vehicles are on the road at the same time and cannot predict each other's behavior [1]. Wildlife is present on roads for many reasons and becomes a victim of road-kill due to a various factor. When there is little food or water available elsewhere, animals are drawn to grass and water in roadside ditches. Roads are also used as open spaces for socializing and access to new territories for young people dispersing [2]. Animals are frequently present on roads for crossing to the other side [3]. They are able to cross roads in order to gain access to crops, pasture, water, or territories [4]. Roads have a significant impact on the natural environment in protected areas Trombulak and Frissell including ecosystem health, the most visible direct effect of these impacts is animal mortality on the road [5].

Highways through wildlife refuges are an encroachment that harms wildlife and their habitats. The consequences include habitat loss and fragmentation Carr and Fahrig, influenced wild animal distribution patterns Newmark et al., movement Baskaran and Boominathan, breeding density Reijnen and Foppen, heterozygosis, genetic polymorphism Reh and Seitz and directly by vehicle collisions resulting in death [6]. Highways have been shown to have a negative impact on wildlife and their habitats [7].

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Roads of all sizes appear to act as a filter for animals' natural movement [8]. Large-bodied animals with large home ranges or species that disperse widely have been most frequently encountered by roads and are thus the most affected [9]. Large-bodied animals with large home ranges or species that disperse widely have been most frequently encountered in roads and thus have suffered the most [10]. Wildlife movements are linked to specific habitats, terrain, and adjacent land use types. Thus, landscape spatial patterns are expected to play a significant role in determining locations with a higher probability of being involved in an animal-vehicle collision than other locations.

Highways intersect many protected areas in Nepal, the number of WVC could be underestimated due to absent of systematic monitoring of road kill data. Over the last several decades, the negative effects of roads on wildlife populations have become all too common Trombulak and Frissell and reducing road mortality is a top priority for many environmental and wildlife management organizations.

Statement of the problem

Frequent wildlife-related road accidents along the East-West highway, which passes through several protected areas, have jeopardized conservation efforts, in which the country has made significant strides in recent years. Banke National Park is more susceptible to Wildlife Vehicle accidents or Collisions (WVC) because the highway surrounds the park and animals wander near the highway. Within the national park, there is 70.56 km of East-West highway and 32 km of Ratna Highway.

WVCs pose a serious danger to animals on the road. It was estimated that these collisions killed wildlife. As a result, to reduce the number of WVC on roads, mitigation measures must be planned. Banke national park is one of Nepal's newest protected areas. As a result, there is insufficient research on the various aspects of wildlife conservation and challenges. WVC is one that has not been evaluated in Banke national park. As a result, in the coming days, the study will be critical for analyzing the status of WVC and its control measures for biodiversity conservation.

Materials and Methods

This research was carried out in Banke National Park (BaNP), which is located in western Nepal. It's between 81° 39'29" and 82°12'19" east longitude and 27°58'13" and 28° 21'26" north latitude. The park's total area is 550 square kilometers, with a buffer zone of 343 square kilometers. It is linked to a transboundary landscape that connects to India's Suhelwa Wildlife Sanctuary through national and community forests to the south. It is linked to Nepal's Bardia National Park to the west and India's Katerniaghat Wildlife Sanctuary *via* the Khata Corridor, national forests, and community forests. Banke National Park is an important part of the Terai Arc Landscape (TAL), which provides tigers with additional habitat. So, the primary goal of establishing this park was to conserve wild tigers (endangered wildlife species). It is home to 124 plant species, 34 mammals, over 300 birds, 24 reptiles, 7 amphibians, and 58 fish. Natural forest coverage is primarily made up of Sal, Karma, Khair, and Sissoo. The main focus of this research was the east-west highway that runs through the protected area. This research is being conducted along a 70.56 km stretch of road in Banke national park, stretching from Shivakhola East to Kohalpur West (Figure 1).

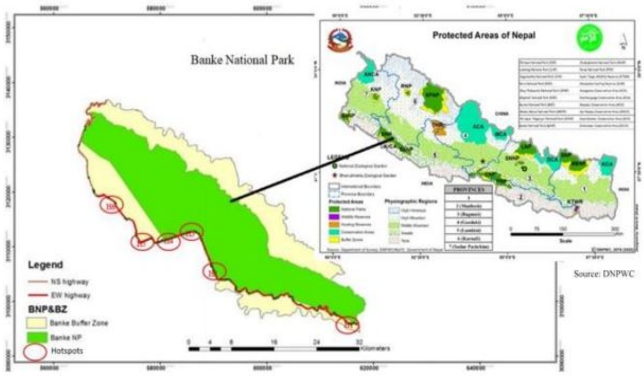

Figure 1. Map showing study area.

Data collection

Both primary as well as secondary data were collected for this study using various tools and techniques. Preliminary field visit was conducted to the study site to know the physical and social condition of the study area for rapport building. The goal of the study was to determine the spatial variation in wildlife road-kill along the road stretch, segments were required. The East-West highway runs through Banke national park for 70.56 kilometers. This entire stretch of road was divided into 500 m sections. Banke NP thus had a total of 141 segments. Initially, the portions or starting and ending points of each of the 500 m segments of road that intersect in Banke national park were identified and GPS-marked. Road-kill incidents were recorded within an appropriate distance from the center of the road on both sides Banke NP routes. In each of the segments defined above, a complete road survey was conducted every four days (total 22 surveys in 90 days) for three months to record and monitor the actual status of the road-kill. The survey was conducted from 1st of October to 30th of December in 2022. During this time period, 29 WVC were recorded. The survey was conducted on a motorcycle travelling at a slow speed of 4 km/h hour. When a WVC incident was detected, additional incident information such as GPS location, the width of the road, road curvature, forest type, land use and so on are recorded as predictor variables and used in analyzing the spatial pattern of road-kill. The survey was conducted just after sunrise in the morning, assuming that most roadkill occurs at night and that the carcass will be visible in the early morning. The GPS location of the carcasses has been immediately recorded in the field to map the precise location of roadkill and evaluate its distance from the forest using Arc GIS. The observer also observed and recorded the vegetation cover in the nearby forest from the location of roadkill. Table 1 contains detailed information about the data measured. To learn about key informants' perspectives on wildlife roadkill in the area, an unstructured questionnaire interview was conducted. The key informants included stakeholders from Obhari headquarters, army personnel at highway checkpoints, assistant conservation officers, Rangers, and office staff from various posts. Official records of Banke NP on the roadkill, records of the traffic check-posts in the highway, newspapers, were reviewed to know the previous occurrence (2015-2022) Eight years of roadkill on the particular roads of Banke. Whenever available, descriptive information of each of the road-kill accident obtained from secondary sources were obtained or was asked from national park office. This descriptive information includes location, time, and date of the incident, species, and age of the wild animal killed or injured, and weather condition.

Data analysis: Descriptive statistics

Descriptive statics was used for presenting available road kill data and for general description of presence absence data in segment. Different bar diagram, pie chart was used.

Chi square test

The *Chi square* test was used to investigate the relationship between the presence of road kill and other factors such that road curvature, forest type, topography, distance from settlement, and use, crown cover, straightness of road, distance from water source etc. The lower P value ($P<0.05$) and high *chi square* value indicates that some association between the variables is present. The *chi-square* test statistic is computed as:

$\chi^2=\sum(\text{Observed-Expected})^2/\text{Expected})$

Where the square of the differences in predicted and observed values within every cell divided by the anticipated value is added across all cells in the table.

Logistic model

Logistic model was used for to check how the probability of road accident was affected by other one or more explanatory variables *i.e.*, categorical environmental variables (road curvature, crown cover, forest types, straightness of road and distance of water sources from road) in this study.

The statistical model for the logistic regression is: $\text{Log } P/(1-P)=\beta_0+\beta_1X_1+\beta_2X_2+\ldots\beta_nX_n$

Where P is a binomial proportion and $X_1,X_2,\ldots,X_n$ are the explanatory variable. The parameters of the logistic model are $\beta_0,\beta_1,\beta_2,\ldots,\beta_n$.

GIS mapping: We used a kernel density method to identify roadkill hotspots in Banke national park [11]. Kernel density estimates areas of high and low intensity by measuring the dispersion pattern of locations of interest within a given area. ArcGIS spatial analyst tool ARC GIS 10.8 was used to generate kernel densities with raster colors showing areas of high and low intensity of roadkill, *i.e.* hotspots.

Species susceptible for road kill

A total of 402 individual wildlife were killed in road accidents in the last 8 years (2015 to 2022). Throughout the study period, a total of 90.05% of mammals, 7.96% of reptiles, and 1.99% of birds were recorded being killed in vehicular accidents that can be categorized into 21 species of mammals, 4 species of birds and 4 species of reptiles. Among them golden monitor lizard, Indian rock python, leopard cat and four horned antelopes are the protected species listed by DNPWC. The IUCN Red List the golden monitor lizard as endangered, while the four-horned antelope, leopard cat, and sambar are listed as vulnerable (Table 1). Wild boar, spotted deer, monkeys and jackal were the main susceptible species to road accidents.

S. n.	Species	Year									Susceptibiliy to road kills
		2015	2016	2017	2018	2019	2020	2021	2022	Total	
1	Wild boar	15	15	28	8	4	9	7	4	90	
2	Spotted deer	4	7	13	9	8	3	4	6	54	
3	Rhesus monkey	0	10	6	5	3	5	12	7	48	
4	Jackal	4	3	6	6	6	6	2	7	40	
5	Porcupine	0	2	6	2	3	2	1	2	18	
6	Barking deer	1	I	2	0	3	2	3	4	16	
7	Civet	0	3	2	3	2	1	4	0	15	
8	Four horned antelope	1	I	1	4	1	2	1	I	12	
9	Wild cat	0	I	3	2	4	1	0	I	12	

10	Golden monitor lizard	0	0	7	0	2	0	0	2	11
11	Flying squirrel	2	0	0	1	3	0	2	3	11
12	Other species	3	7	14	13	9	5	10	14	75
	Total	30	50	88	53	48	36	46	51	402

Note: WVCs recorded more than 10 times were kept in descendingorder in Table 1.

Table 1. Number of species killed by road accident (2015-2022).

Due to their ecological nature, wild boar, spotted deer and barking deer were identified as more vulnerable wildlife species for road accidents. Herbivorous in nature, they prefer open edge areas such as settlement areas and grassland areas. On either side of the road, there are some open spaces and good food resources. This may make wild boar, spotted deer, spotted deer, and barking deer more vulnerable to road accidents. In general, agricultural products such as maize and potatoes attracted wild boar. Adolph and Porter states that reptiles' activity is more related to temperature oscillations and their use of road surface as a thermoregulatory source so that's its number is less compared to mammals and more related to the season. Roadkill also occurs in mammals and birds when they use roads as dispersal corridors Getz et al., or food sources [12]. So, mammals were more susceptible to road kill.

Spatial and temporal pattern of road kill spatial pattern of road kill

Out of 402 road kill locations, the highest number of road accidents (n=81, 20.15%) was recorded in the Khairi area from 2015 to 2022. It was followed by the Muguwa area with (n=66, 16.42%) accidents, Obhari (n=43, 10.70%) accidents, Samshergunj (n=36, 8.96%), Shivakhola n=23 (5.72%), and Pragatinagar recorded total 22 (5.47%) road accidents during study period. The spatial pattern of road kills suggested that the western part of the park *i.e.*, the Kohalpur sites recorded higher number of road accidents than eastern part. Eastern part had encountered less road kill (Figure 2).

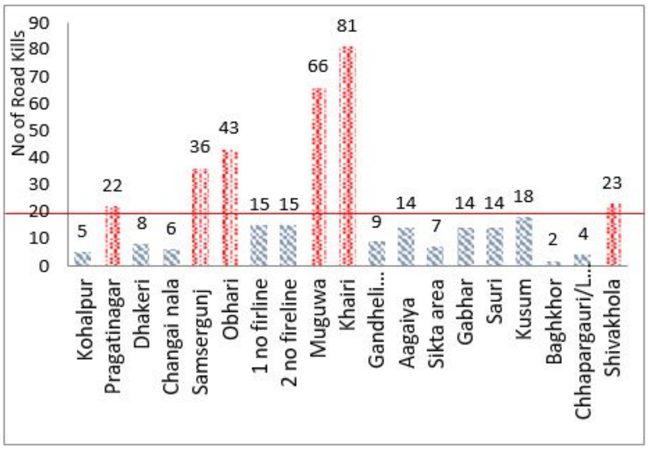

Figure 2. Spatial pattern of road kills.

The spatial pattern of occurrence of road-kill events Banke NP shows that highest WVCs are noticed in Shivakhola, Khairi, Muguwa, Obhari, Samshergunj and Pragatinagar area. In this pattern, more animal was killed in linked forest area. This is because mainly mammals were moved from one part to another in search of food. So that they became more susceptible to road accidents.

This study also showed that more animals were killed far from water sources. This might because all the water sources are seasonal so animals move from various location in search of food and water. So, they become susceptible to road accidents. Similarly, the study done by Sharma in Barandabhar Corridor Forest, Chitwan has similar findings that shows the road-kill events is concentrated in the Tikauli section near Sichai gate due to tendency of wildlife to cross the road food and water. These particular sites have more road-kill consistently across four years. These areas are more inter intersected by forest area which may be the reason for wild animals to pass through the routes in search of food and water. The study done by Lala et al. in Tsavo Conservation Area in Southern Kenya reported that the spatial distribution of roadkill was not associated with the closeness to permanent and seasonal rivers.

Results and Discussion

Temporal pattern of road kill

Season wise distribution of road kill data: Of the total of 402 road kill data 26% were occurred in the Spring season (Mar-May), 24% of road kill were occurred in summer (Jun-Aug) and 25% found in both autumn (Sept-Nov) and winter (Dec-Feb) season (Figure 3). Generally, it was noticed that average road kill was higher in the spring season. But, the *chi-square* goodness of fit test, gives there is no difference in season and occurrence of road accidents (χ^2=0.607, df=3, p=0.895). That means road accidents has no significance relation with change with seasons.

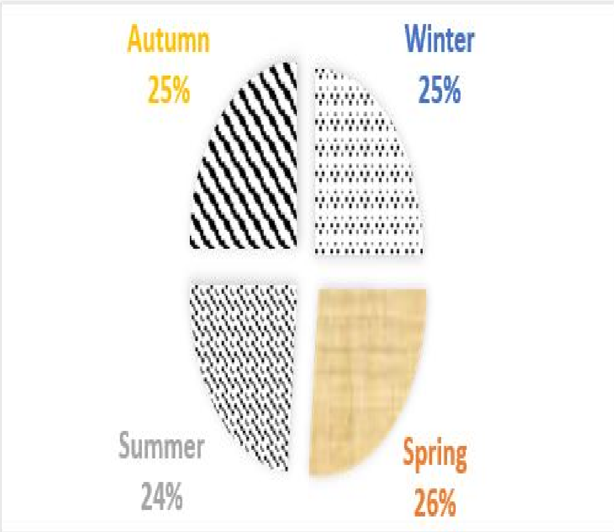

Figure 3. Season wise distribution of road kills data.

Mainly, mammals were killed by road accidents in this study. They used the road as a dispersal corridor or as a food source. So that they were independent of the season compared to reptiles. Reptiles generally used the road as a thermoregulatory source so they depend on the season. In the spring and winter seasons, there is a scarcity of food and water sources inside the core area hence animals were forced to move towards the Southern part of the road in search of water. During the crossing of the road, they were more likely to be killed by vehicles, which may be the main cause of increased wildlife kill in this season.

Banke national park's road-kill patterns were consistent across seasons. All seasons are risky because water sources inside the core forest are not very durable and generally dry in a short period of time, attracting them to nearby water resources where such rivers intersect the road segments. Another cause of road-kill could be a lack of food and visibility along the roadside. Similar Lala et al. explained that in the Tsavo Ecosystem, Kenya too there is no relation of vehicular accident with season since the wet season, there is typical surface water dispersed for most areas of the park and ranches; most wildlife does not rely on different seasons and permanent rivers. Mammals would therefore tend to move more in new places because there is palatable vegetation and water that is evenly distributed. But these findings contradict with the findings of da Rosa and Bager who studied the seasonality and habitat types that affect road-kill of neo-tropical birds in southern Brazil that birds frequently dwell in areas near vegetation and water supply throughout the year, which means that the number of road-killed species each season has equal chances of road kill in the area where the vegetation and water resources are insufficient for the species.

Day time wise distribution of road kill data: The highest number of wildlife vehicle accidents were recorded in the morning time 4 AM to 10 AM, 32% of total road kill, which was followed by night time 10 PM to 4 AM (28%). Evening time 4 PM to 10 PM (24%) and slightest in the daytime 10 AM to 4 PM (16%) (Figure 4). The goodness of fit test shows there's statistically significance relation between time and event of street mischances (χ^2=23.095, df=3, p-value (0.00039)<0.05.

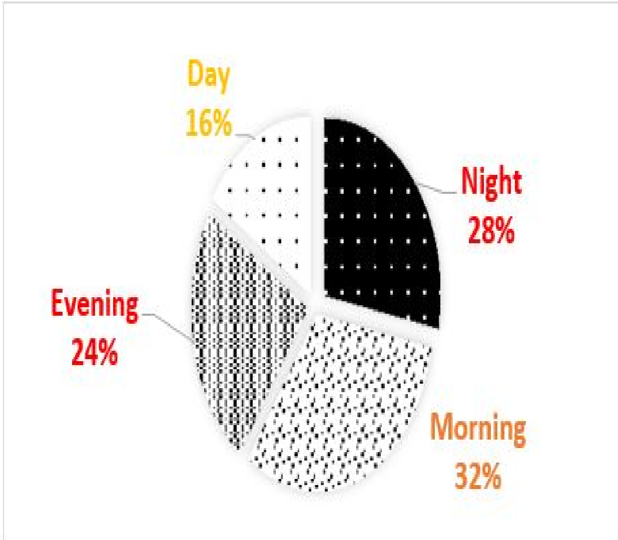

Figure 4. Day time wise distribution of road kill data.

The chi-square test between time and wildlife kill by vehicles in Banke national park shows that there is significant relation between time and wildlife vehicle collision (p-value<0.05) with five wild animals only: Wild boar, rhesus monkey, porcupine, small Indian civet and golden monitor lizard except these five animals none of them have any relation with time and vehicle accident (Table 2).

Porcupine, small Indian civet and wild boar are nocturnal, golden monitor lizard rhesus monkey diurnal other are either diurnal or nocturnal or also crepuscular.

The events of higher road kill were found in morning and night time. It is basically due to behavioral characteristics wildlife as most of the wildlife are active during down and dusk. Wild boar is active at night though spotted deer, barking deer, and four-horned antelope are active in the morning and evening time therefore the record of WVC is recorded round the clock in BaNP [13]. The nocturnal behavior of badgers, wild boars, and certain amphibians has frequently resulted in these species road mortalities being concentrated during the evenings [14]. Animal behavior, environmental factor and other factors all have an impact on the number of wild animals killed on the road.

S. n.	Species	Numbers	*Chi-square* value	P value
1	Wild boar	90	12.489	0.005883

2	Spotted deer	54	4.815	0.185856
3	Rhesus monkey	48	21.167	0.000097
4	Jackal	40	4.4	0.221385
5	Porcupine	18	13.556	0.003576
6	Barking deer	16	5.5	0.138639
7	Small Indian civet	15	24.733	0.000018
8	Four horned antelope	12	3.333	0.343076
9	Wild cat	12	0.667	0.880937
10	Golden monitor lizard	11	10.455	0.015069
11	Red giant flying squirrel	11	5.364	0.147003

Table 2. Species wise temporal (hour wise) pattern of road-kills.

Distribution map of road kill hotspot in BaNP

Total 6 hotspots were identified namely; H_1: Shivakhola, H_2: Khairi, H_3: Muguwa, H_4: Obhari H_5: Samshergunj. and H_6: Pragatinagar. The dispersion of accidents along the highway was not uniform, according to a spatial analysis of road kill data. Although wildlife road kill takes place all over the highway, a highly clustering pattern was observed in some locations that were considered road kill hotspots (Figure 5).

Figure 5. Distribution of road kill hotspots.

The majority of hotspots were located near bodies of water (Khola area), indicating that water resources accounted for the majority of traffic accidents in BaNP. There is a place called Curiya in the northern portion of the road stretch, although there aren't many water sources there. Wild animals came to cross the EW highway for water because the Rapti River was running in the southern section of the region.

The risk zones along the highway were identified using Kernel Density Estimation (KDE) and classified as low, medium, high, and very high-risk zones, as shown in Figure 6. The color yellow, green, blue, and red in the figure represent the various risk zones, which are classified as low, medium, high, and very high. Although the road-kill incidents may have occurred throughout the route but mainly, the collision area clustered in the same section. Distribution of road-kill event throughout the survey route has not been found uniform as shown in Figure 6.

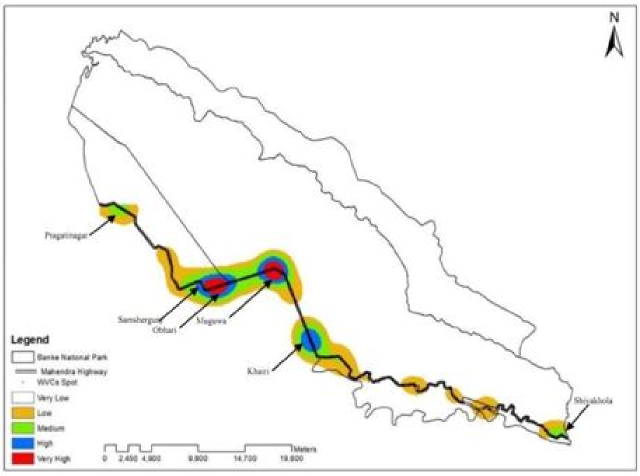

Figure 6. Predicted wildlife road-kill hotspots in banke NP.

Factors that affecting road accidents description of different environmental factor

The 70.56 km EW highway passes through BaNP was divided into 141 segments, each of which is 500 meters long. ArcMap was used to record the presence or absence of road kill in each segment. During the field visit, other environmental variables of these segments were also recorded. Some variations are described below:

Road curvature: The highest number (n=61) of road accident recorded in straight road segments. Nearly 50% of accidents in straight road was taken in curve road (n=32). Road curvature is an important factor for road accident for wildlife. The study noted that the WVC will be changed if road curvature will be change. In test of independence, value of χ^2=3.941, df=1, p-value (0.047)<0.05 suggesting road accidents has significant relation with structure of the road.

The study in landscape and traffic factor affecting animal road mortality Kinmen island, Taiwan by Lin and management also explain similar result. It concluded that due to limited vision at hard edges and narrow road width, both drivers and animals have an insufficient response time. increasing the risk of collision (Figure 7).

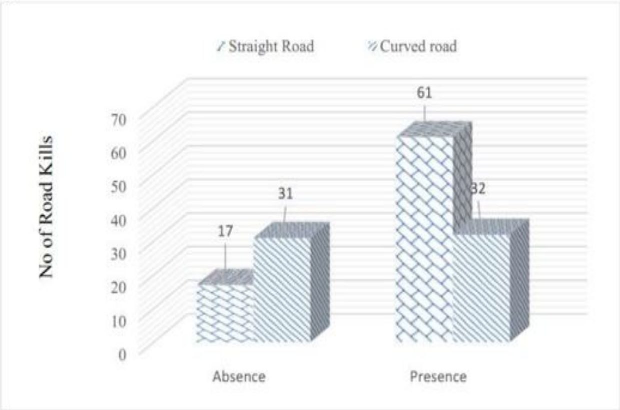

Figure 7. Presence absence of road kill on road.

Crown cover: The highest number WVC was recorded in the segment with crown cover less than 25% and higher than 75% (n=31). The least WVC was recorded in the segment with canopy cover between 50-75%. Segment with crown cover less than 25% was common near settlement and water source areas (Figure 8). Wildlife flocked to that location in search of food or water which leads more wildlife and road kill in that area. However, segment with crown cover greater than 75%was primarily found in the Muguwa to Obhari range, *i.e.*, the park's core area. Drivers drove at excessive speeds because the road was straight and forested. Wild animals were killed as a result while crossing the road. In the *chi-square* test of independence, the value of χ^2=1.129, df=3, p-value (0.770)>0.05. showed that there is no association between road accident occurred and the crown cover of the segment. This study yields similar results to the study conducted in East Africa inside the Tarangire-Manyara ecosystem of Tanzania, which shows the WVC are occurred if there is change in percentage of crown cover.

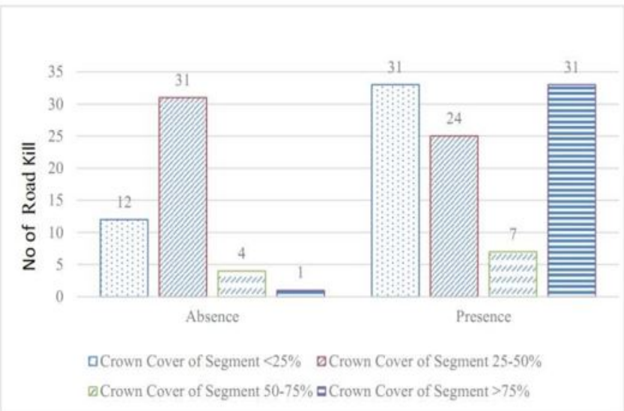

Figure 8. Presence absence of road kill on crown cover %.

Land use: Land use near roadsides such as forest areas, and settlement area is also an important factor in road accidents for wildlife That means WVC may occur at any site, but forests and settlements do not affect it. Because another factor as the speed of the vehicle was higher in the forest area compared to the settlement area. The speed of the vehicle was directly related to WVC. But, in the test of independence, the value of χ^2=0.141, df=1, p-value (0.708)>0.05 showed that there is not significant relation between WVC and land use (Figure 9).

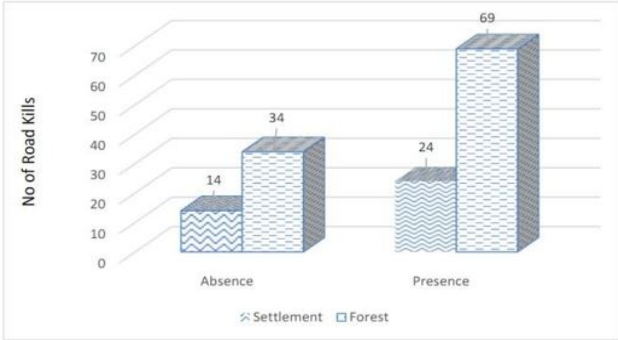

Figure 9. Presence absence of road kill on land use.

Human settlement along the road segments also reduced the likelihood of wildlife road-kills. Higher percentage of human settlement along the road segments is correlated with lesser number of road-kill incidents. The animals have high sensitivity to human presence and avoid roads, so road-kill numbers are low along these segments. This finding is similar with that of Fahrig et al. who reviewed effects of roads on animal abundance in Europe and North America where the area near human settlements are less likely to have road-kills.

Distance from settlement: Vehicle speed differs between settlement and forest areas. In the study higher number (n=37) of WVC was taken more than 1000 m far from human settlements. However, a *chi-square* test of independence result of χ^2=0.211, df=3, p-value (0.976)>0.05 revealed that there is no statistically significant difference between the frequency of WVC and the distance from the settlement (Figure 10).

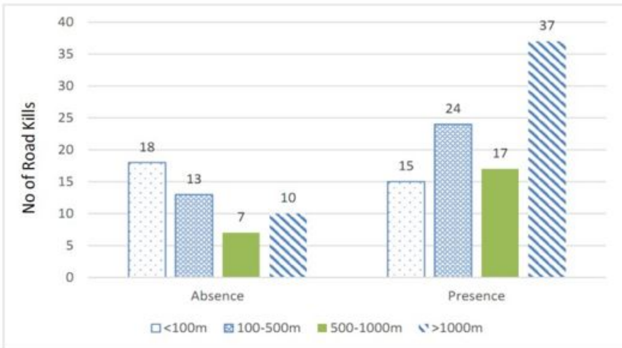

Figure 10. Presence absence of road kill on distance from settlement.

These findings were in line with those obtained by Sharma in two road sections, namely the Aaptari-Jugedi sections and the Tikauli jungle section, which revealed no association between distance from settlement and road kill. Another study conducted on Kinmen Island, Taiwan, yielded similar results. However, there is also the possibility that near towns wildlife has been already depleted, and therefore, this pattern would reflect the numerical availability of animals in areas near and far away from towns.

Forest types: The highest number of WVC (n=45) was recorded in Sal forest followed by mixed forest (n=38). The riverine forest type possesses fewer numbers (n=10) (Figure 11).

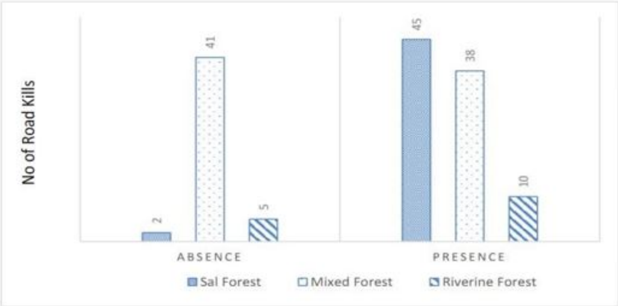

Figure 11. Presence absence of road kill on forest type.

The majority of road kill was recorded in the Sal forest, specifically in the core area from Muguwa to the Obhari site. The leading cause of traffic accidents was vehicle speed. Since the most mixed forest was found near the settlement area, that type of forest had a second higher number of road kills. In the *chi-square* test of independence, the value of χ^2=1.785, df=2, p-value (0.410)>0.05 showed that there is no statistically significant difference between WVC occurring with forest type (Sal forest, mixed forest, riverine forest). This is because all forest type has different species diversity so the possibility of WVC is no change with forest type. According to the study, mixed habitat had the highest number of accidents than holm oak forests, and broom brushes had the lowest number of accidents.

Straightness of road: The straightness of the road is also a factor in wildlife road accidents. The highest number was found in straightness greater than 1000 m in Figure 12 and the lowest in areas where the road straightness was less than 100 m because straight roads had a higher number of WVC because vehicle speed is directly related to straight road. In general, drivers drive faster on straight roads than on curves, so wildlife cannot cross the road quickly due to the high speed. As a result, there were traffic accidents. In the *chi-square* test of independence, a value of χ^2=9.871, df=3, and p value (0.606)>0.05 indicated that there is no association between the occurrence of a road accident and the straightness of road

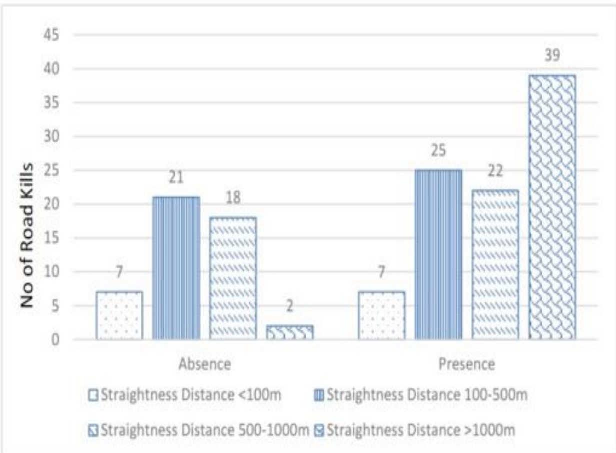

Figure 12. Presence absence of road kill on straightness of road.

This finding is similar to the findings of Cuyckens et al. which was carried on three protected areas in the Ecuadorian Andes, and shows that the more straight the road, the greater the change in animal mortality [16]. The primary cause of this road death is excessive speed.

Topography: Topography also has an impact on wildlife road accidents. The more level the road surface, the more accidents occur. The topography (plains and undulations) has an impact on road accidents. The study recorded 78 WVCs out of 99 in plain road segment than undulated road segments. However, in the *chi-square* test of independence, the value of χ^2=2.070, df=1, p value (0.150)>0.05 indicated that there is statistically no relation between road accidents and topography [17]. According to our findings, more WVCs were recorded in plain road segments. The WVC will be change if the topography of the road changes. Smoother and more level roads segments have more WVCs than other segments. A similar result was found by Ciolan et al., namely that smooth roads are more likely to kill animals than rough ones (Figure 13).

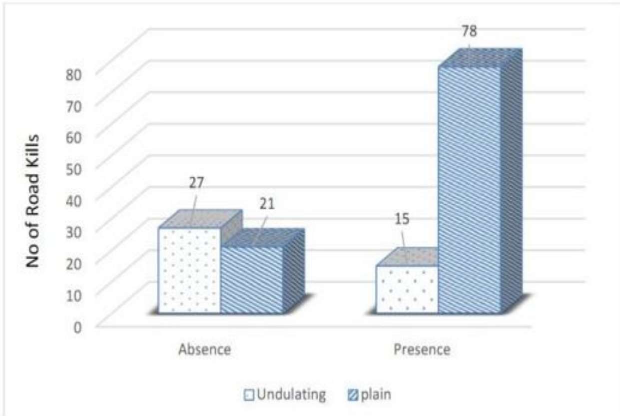

Figure 13. Presence absence of road kills on topography of site.

Distance from water source: Distance from a water source is another important factor in wildlife road accidents. The highest number of WVC was recorded in water source distances greater than 1000 m (n=38), and lowest in areas where the distance between the water source and the house is less than 500-1000 m (22). In the *chi-square* test of independence, a value of, χ^2=2.923, df=2, p value (0.232)>0.05 indicated that there is no statistical significant difference between the location of the WVC and the distance to the water source (Figure 14).

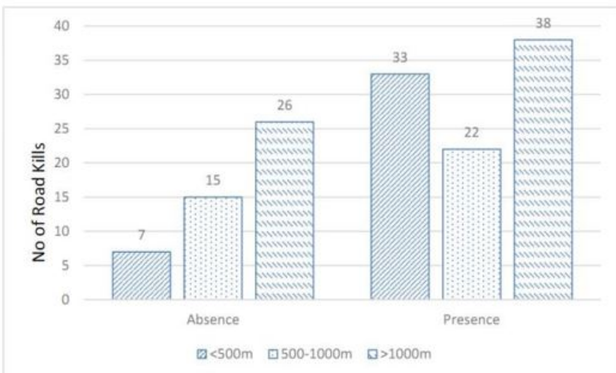

Figure 14. Presence absence of road kill on distance from water source.

According to this study, the number of WVCs is higher near water sources. This is most likely because many species of wildlife, including wild ungulates, are drawn to areas near a water source or river. WVC victims are animals crossing the road in search of water [18]. This finding is supported by a study conducted in Rhode Island, USA, by Hallisey et al. where the majority of the roadkill was found on the road near water sources. Another study performed in Northern Portugal discovered a link between the presence of water bodies or the configuration of water bodies and wildlife mortality by road accidents. Langen et al. found similar results in his study conducted in New York State, USA, where wildlife road mortalities occurred on sections of roads that are directly adjacent.

Binary logistic model

Eight environmental variables (road curvature, crown cover percentage, forest type, distance from water source, topography of site, straightness of road, distance from settlement and land use) showed a relationship with the wild animal road kill positively or negatively. These variables were used in the binary logistic model. It was discovered that the distance from settlement, land use and crown cover significantly impact the likelihood of wildlife road kills (Table 3). So, to order to effectively conserve or reduce road kill. More signposts (about laws and the speed limit of the road and also about biodiversity conservation) should be installed to control WVCs [19].

Covariates	Coef (B)	Odds Ratio Exp (B)	95% C.I.	p-value
Road curvature				
Straight		1		
Curve	-0.870	0.419	0.159-1.106	0.079
Crown cover percentage				
More than 75%		1		0.210
Between 50-75%	0.864	2.373	0.441-12.778	0.314
Between 25-50%	0.797	2.218	0.768-6.405	0.141
Less than 25%	1.275	3.577	1.091-11.725	0.035
Land use				
Forest		1		
Settlement	-0.384	0.681	0.260-1.784	0.434
Distance from settlement				
500-1000 m		1		0.059
100-500 m	1.340	3.819	1.005-14.515	0.049
More than 1000 m	1.758	5.800	1.548-21.735	0.009
<100 m	1.055	2.871	0.944-8.725	0.063
Forest type				
Sal forest		1		0.265
Riverine forest	1.381	3.981	0.740-21.400	0.107
Mixed forest	0.449	1.567	0.548-4.475	0.402
Straightness of road				
Between 100-500 m		1		0.904
Less than 100 m	-0.008	0.992	0.151-6.496	0.994
Between 500-1000 m	0.372	1.451	0.429-4.906	0.549
More than 1000 m	0.063	1.065	0.332-3.413	0.916
Topography of site				
Plain		1		
Undulate	-0.074	0.928	0.366-2.351	0.875
Distance from water				

More than 1000 m		1		0.889
Metween 500-1000 m	-0.257	0.773	0.262-2.280	0.641
Less than 500 m	-0.220	0.802	0.226-2.848	0.733
Constant	-0.967	0.380		0.241

Table 3. Significant factor for road kill by binary logistic model.

In comparison to the odds of a straight road segment, the odds of a curve road segment are 58% lower and statistically insignificant (p-value (0.079)>0.05). WVC considers road curvature to be statistically insignificant. In comparison to the odds of crown coverage greater than 75%, the odds of crown coverage less than 25% are 3.57 times higher for WVC and statistically significant (p-value (0.035) 0.05). The odds of forest segment WVC are 32% lower than the odds of settlement and are statistically insignificant (p-value (0.432)>0.05).

The odds of distance from a settlement 100-500 m are 3.8 times greater, and the odds of distance from a settlement more than 1000 m are 5.8 times greater, and they are statistically significant. WVCs increase with distance from settlement. Sal forest has 3.98 times more odds than riverine forest, but the difference is not statistically significant.

The odds of an undulating road segment are 7% lower than the odds of a straight road segment and statistically insignificant (p-value (0.875)>0.05).

Distances greater than 1000 m from water have a higher chance than distances less than 500 m and greater than 500-1000 m. It has no statistical significance. The seasonal dwindling of water sources is to blame. WVC is 38% likely on Banke National Park Highway. Land use, canopy cover, and distance from settlement all have a positive impact on WVC [20].

This study contributes to the growing literature on wildlife-vehicle collisions. First of all, these findings can be helpful to protected area managers by giving them information on where wildlife-friendly infrastructures like underpasses and overpasses should be constructed, and where water holes should be made. Our result showed that proper management interventions should be done in the segments with low visibility. Wildlife roadkill could be reduced if drivers were educated in road awareness and could anticipate the behavior of wildlife near roads and understand what they could do to avoid the collision.

Conclusion

Mammal species were more susceptible compared to reptile and birds for WVC. Wild boar, spotted deer, wolf, porcupine, and rhesus monkey are more susceptible for WVCs compared to other species. Roadkill can have occurred any season and any time *i.e.*, independent of time and season. Except for some species like rhesus monkey, golden monitor lizard, porcupine, barking deer and civet which are killed in a particular period of time. Road kill pattern shows that species are not uniformly distributed to the road and but found clustering pattern. Distance from settlement, land use and crown cover were directly correlated to occurrences of road kill whereas forest type, distance from water, road curvature, straightness of road and forest type doesn't correlate to occurrence of road kill.

The study and its finding suggested; management of road side vegetation need to be done to improve the visibility, identified hotspots need be prioritized for wildlife friendly infrastructures and related interventions. In addition, siting of such infrastructures should be based on site specific data of road-kills of particular taxa of fauna., The vehicles that travel through this park should monitor and track by their speed limit by providing time card system.

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