Journal of the Korean Association of Geographic Information Studies, 19(3) 2016, pp. 89-101 ISSN 1226-9719(Print)
http://dx.doi.org/10.11108/kagis.2016.19.3.089 ISSN 2287-6952(Online)

How Do Landscape and Road Barriers Affect Road Crossing of Multihabitat Mammals

Ye-Seul BYUN[1] · Ji-No KWON[1] · Jeong-Hwan KIM[1]
Moon-Hyun SHIN[1] · Sang-Don LEE[2※]

경관과 도로침입 방어막이 범서식지 포유류종의 도로 횡단에 미치는 영향 분석

변예슬[1] · 권진오[1] · 김정환[1] · 신문현[1] · 이상돈[2※]

ABSTRACT

This study examined spatial disposition of wildlife highway mortality using road-kill GIS database and Naver panoramic 360 degree views to find out which habitat and road variables most influenced road-kill numbers for each mammal species and how the landscape and road elements are connected on highway. Road-kills on Yeongdong(YD) and Jungbu highway(JB) generally tended to be higher in natural barren, grassland and cropland due to its value of preferred habitats of nocturnal and multihabitat species like water deer(*Hydropotes inermis argyropus*), raccoon(*Nyctereutes procyonoides*) and hare(*Lepus coreanus*). Land cover in YD showed no difference between species (p=0.165) while JB did by species (p=0.001). This may be explained by disparate landscape between mountain and urban or the fact that YD in long term operation might have enabled consistent crossing pattern compared to JB experiencing continuous extension works which may in turn have deviated the road crossing. Although road-kill prevention effect of local topography alone was appreciable, compared to less significant or ineffective fence and guardrail, gentle slope declining in a direction to the road turned out to offset the preventive effect of juxtaposed fence. Furthermore, green patches on road near intersection were deemed a visual stepping stone facilitating wildlife attempted crossing and local roads juxtaposed with a highway were especially left defenceless to road-kill without road barriers.

KEYWORDS : Road-Kill, Mammal, Land Cover, Fence, Slope

2016년 7월 29일 접수 Received on July 29, 2016 / 2016년 9월 2일 수정 Revised on September 2, 2016 / 2016년 9월 22일 심사완료 Accepted on September 22, 2016
1 Division of Forest Restoration, National Institute of Forest Science 국립산림과학원 산림복원연구과
2 Ecological Restoration Engineering Lab, Ewha Womans University 이화여자대학교 생태복원공학연구실
※ Corresponding Author E-mail : lsd@ewha.ac.kr

요 약

본 연구에서는 로드킬 GIS 데이터와 네이버 거리뷰를 이용하여 토지피복과 도로침입 방어막이 포유류 로드킬에 주는 영향을 분석하고 야생동물의 도로 횡단을 가능하게 하는 이웃 경관과 도로 변수 간의 상호작용을 검증하였다. 야행성이며 다중 서식지를 이용하는 일반종인 고라니, 너구리, 멧토끼의 로드킬은 섭식, 번식을 위해 선호하는 서식지를 중심으로 영동과 중부 고속도로 인근 나지, 초지, 습지에서 다발하는 것으로 나타났다. 개통된 지 오래된 노선인 영동에서는 종 간 토지피복의 차이가 없던 것(p=0.165)으로, 신규 개통 후 지속적인 연장공사가 이루어졌던 중부는 차이가 유의했던 것(p=0.001)으로 나타났는데, 이는 산악지대인 영동선과 도심화 지대인 중부선 간 경관 유형의 차이 혹은 개통일과 야생동물의 주변 서식지 적응도 및 연장공사 빈도수의 차이에서 비롯된 결과로 추정된다. 야생동물 도로 횡단 방지 효과가 미미하거나 없는 것으로 나타난 펜스 및 가드레일과 달리, 절 · 성토면의 방지 효과는 유의한 것으로 나타났으나, 도움닫기를 위한 경사면으로 연출될 경우 병치된 펜스효과를 상쇄시키는 것으로 나타났다. 또한 교차로 인근에서 고속도로와 병치되는 국도 혹은 지방도의 경우 펜스 및 성토면이 부재한 사례가 많아 로드킬 발생의 취약 지점으로 나타나며, 특히 교차로의 초지 패치는 고속도로 양 옆 경관 패치와 이어지는 시각적 징검다리 역할을 함으로써 도로를 건너려는 동물들에게 시각적 은폐기능을 제공하고, 이는 교차로 인근에서의 높은 로드킬 발생율로 설명되어진다.

주요어 : 로드킬, 포유류, 토지피복, 펜스, 경사

Introduction

Wild animal is a dynamic landscape element and must be recognized as one component part of landscape configuration. The accidents of animal collision with vehicles on the roadway can thus be understood within the text of interaction of landscape components, that is how the landscape patterns affect animal' s attempted crossings. Analyzing specific land cover adjacent to road-kill points has long been focus of road-kill studies. Choi and Park(2006a) calculated road-kill occurrence density per ㎢ of each land cover using GIS and Song *et al.*(2011) have traced amphibian road-kill aggregations for 3 years on highway with SPSS frequency analysis and One-way ANOVA. Glista *et al.*(2007) divided each survey route into 100×200m sections and examined the spatial distribution of road mortality event by vertebrate taxonomic categories using GIS and stepwise regression analysis. Many of ecological research on habitat selection and home range of species also have been linked to the studies of road impact and road-kill(Min and Han, 2010; Choi *et al.*, 2012; Seok and Lee, 2015). Apart from land cover type, as the major causes of road-kill D'Amico *et al.*(2015) collected data on the components of phenology of vertebrate such as rainfall and temperature along with tracking species' life history such as breeding and habitat preference and then used generalized linear model (GLM), a binominal distribution and logit link function of SAS for analysis.

Studies of road-kill can adjoin in the project of establishing ecological network and inventorying local bioresources so that it can play a role as an integral part of the holistic ecological restoration plan. Connecting national ecological range axes within Baekdu-daegan mountain system is one of the huge restoration work for the road-caused habitat fragmentation in Korea (Ministry of Environment, 2004; Korea Forest Service, 2014). Korea Forest Service(2007) indicates that establishing wildlife crossing structure or fence at fragmented patch must be followed by the precedent research on relationship between animal movement and neighboring environmental factors.

While many of road-kill studies have focused on specific elements or habitat patch, this study explained how the landscape and road elements are connected on highway and interacts each other. Along with analysis on land cover type and efficacy of each road barriers, the hypothesis of this study that local topography and road barrier facilities have interaction effect each other and the green patches on highway influence animal' s attempted crossing was tested.

Methods

1. Study Area and Data Collection

Among major 30 highways in Korea, a 48.72㎞ section of the Yeongdong highway (No.50)(YD) and a 60㎞ section of Jungbu highway(No.35)(JB) traversing horizontal and vertical axes each in Korean peninsular were selected for spatial analysis(FIGURE 1). YD is a third and JB is a fifth highway having high average traffic volume(Korea Expressway Corporation, 2011) at which a high risk of wildlife mortality on roads is expected. YD survey routes encompass a mixture of forested and agricultural land use whilst JB traverses urban and built-up areas of Daejeon and Jinju city, Geumsan county. Considering that mortality can vary according to a number of lanes by species (Clevenger *et al*., 2003) the two-lane sections of YD and JB were selected as a survey route.

Road-kill data inventoried from January 2007 to December 2012(unpublished data) was provided from Korea Expressway Corporation(KEC). The road-kill survey data was collected by KEC patrols in a way to record road-killed species, highway, date, traffic direction and a brach office of KEC in charge of managing the area.

2. Land Cover Variables Analysis

1) Analysis Process

A total of 888 road-kill cases (8 identified species) were collected within the selected survey route of YD(48.72㎞) and JB(60㎞) and based on the result of total mammal road-kill occurrence, Korean water deer(*Hydropotes inermis argyropus*), Raccoon dog(*Nyctereutes procyonoides*) and Korean hare(*Lepus coreanus*), the three most frequently killed mammals within the selected sections of both highways (TABLE 1), were chosen for the analysis.

The analysis scope of road-adherent land cover(㎡) is set in consideration of home range of Korean water deer which made up the majority of road-kill on both highways. Although the actual home range varies by season and population density the surrounding terrain within 500m from either side of the survey routes(herein after 500ST) was extracted according to the research on home range of Korean water deer(Park and Lee, 2013; Choi and Park, 2006b; Kim and Lee, 2011; Kim et al., 2011).

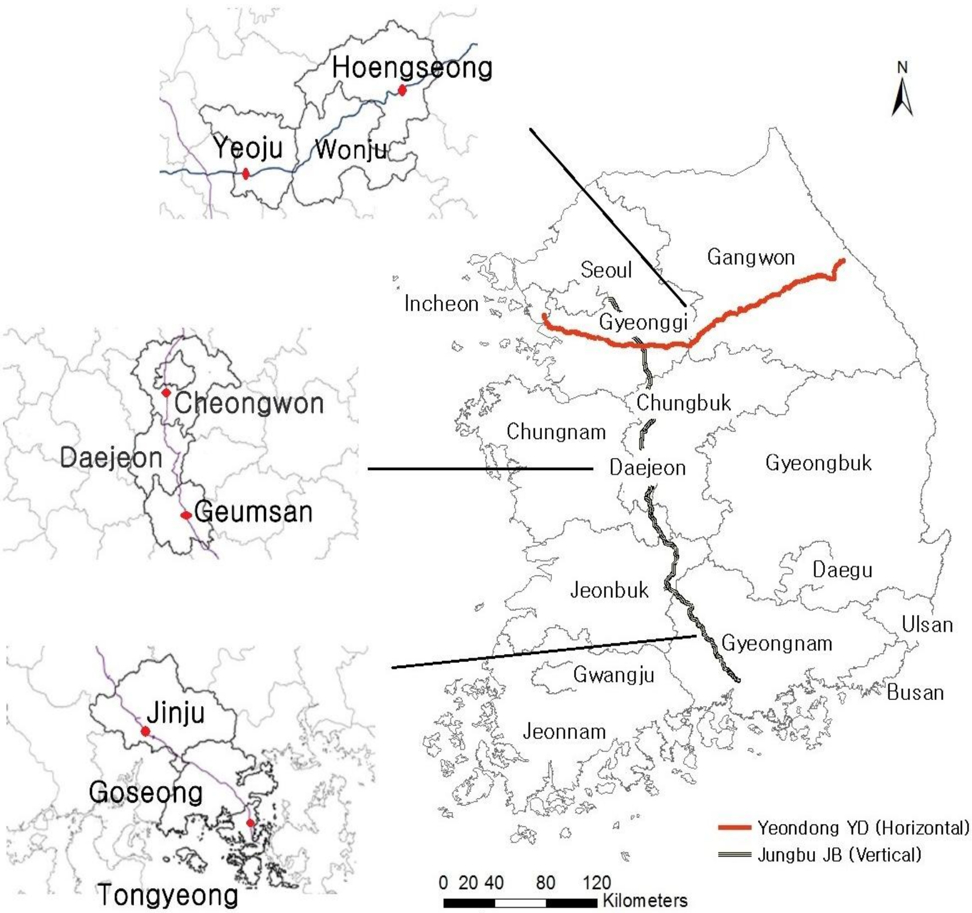

FIGURE 1. Location of study area and roads sectioned for mammal road-kill analysis

TABLE 1. Frequency of mammal road-kill in YD and JB (2007-2012)

Common name	Scientific name	N (% of total kills) YD (101.28~150km)	N (% of total kills) JB (21.1~59.1km, 189~211km)
Korean Water Deer (고라니)	*Hydropotes inermis argyropus*	499 (56.2%)	215 (24.2%)
Raccoon Dog (너구리)	*Nyctereutes procyonoides*	65 (7.3%)	40 (4.5%)
Korean Hare (멧토끼)	*Lepus coreanus*	29 (3.2%)	14 (1.5%)
Leopard Cat (삵)	*Prionailurus bengalensis*	1	8
Korean Yellow Weasel (족제비)	*Mustela sibirica coreanus*	1	4
Eurasian Badger (오소리)	*Meles meles*	3	4
Wild Boar (멧돼지)	*Sus scrofa*	2	1
Roe Deer (노루)	*Capreolus capreolus*	2	0

22 types of mid-level land cover (1:25,000) classified by Ministry of Environment was recategorized into 10 types using Merge tool of GIS(TABLE 2).

50m-Buffer was created around each land cover polygon within 500ST, meaning that immediate vicinity of each accident point (Choi and Park, 2006a). Considering forest polygons take up the largest portion of total land cover, relative density rate of each land cover polygon should be taken into consideration.

Multipoints of road-kill can lastly be counted within the 50m Buffer of each land cover polygon by Intersect tool to calculate road-kill frequency per ㎢(FIGURE 2).

2) Weight Cases

Cross tabulation analysis(SPSS Inc., ver.17.0) was used to determine whether the land cover type of road-kill is statistically independent with species type or if it is associated. Monte Carlo simulation was selected, for YD and JB each have more than 20% of the cells having expected counts less than 5 (23.3% and 40.9% cells for YD and JB).

The intersected land cover is not represented evenly, proportion adjustment was needed; for example, in YD we weighted down forest cover (㎢) from 71.41% to 10% having the highest average size by assigning case weights of 0.14 to forest cover and 0.87% of pasture cover was weighted up to 10% as well by using weights of 11.49. When weighting is in effect, the size of weighted forest dominated landscape around the road can be equal to the size of pasture landscape. Weighted road-kill frequency of each species on YD and JB was determined through

TABLE 2. Reclassified land cover classes

Mid-level classification (1:25,000)	Newly defined land cover
Low/High intensity residential	Residential
Industrial	Urban and developed
Commercial	
Recreational	
Transportational	
Public utilities	
Small grains	Rice paddy field
Row crops	Cropland
Vinyl greenhouse	Vinyl greenhouse & orchard
Orchards	
Other agricultural land	
Deciduous forest land	Forest
Coniferous forest land	
Mixed forest land	
Semi-natural vegetation	Grassland
Herbaceous planted/cultivated	
Forested wetland	Wetland
Non-forested wetland	
Bare rock/sand/clay	Barren
Quarries, mines	
Streams, canals, lakes	Water
Bays and estuaries	

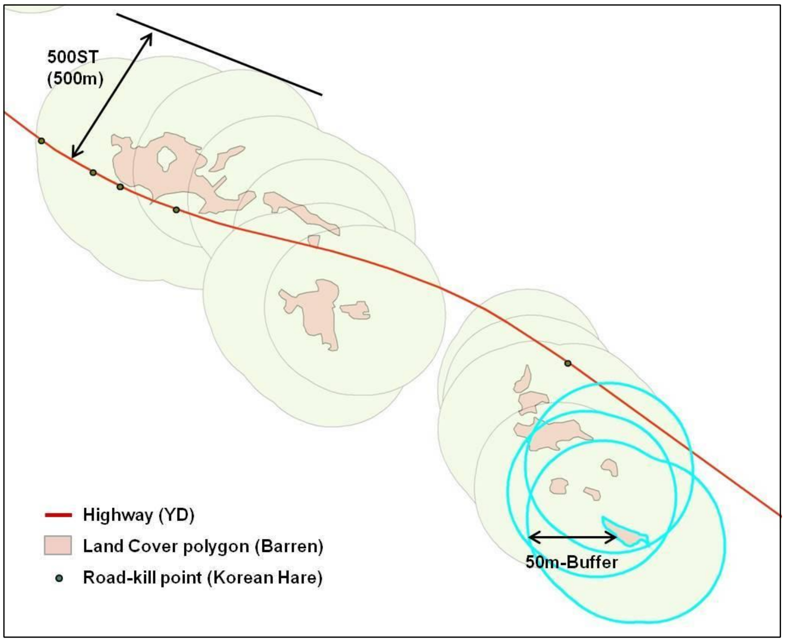

FIGURE 2. Calculation of road-kill frequency per ㎢

the following formula:

$$wf_{ik} = \frac{of_{ik}}{m_k} \times \frac{1}{N} \qquad (1)$$

wf_{ik}: Weighted road-kill frequency of species i in k type land cover
m_k: km^2 of k type land cover
of_{ik}: Observed road-kill frequency of species i in k type land cover (Number of species i road-kill observation that actually made in land cover type k)
N: Number of categorized land cover type

3. Road Variables Analysis

Korean water deer was selected solely for road variable impact analysis on account of its heavy casualty and capability of jumping above fence. Fishnet tool was used to construct 100m×300m sampling unit in YD and 300m×100m sampling unit in JB to identify sections with higher number of road-kill point (sections with more than 2 points)(FIGURE 3) based on a synthesis of field observations and panoramic 360 degree views provided by Naver Geori View, Flight View and Daum Road View. Each sampling unit is described with three road-related factors; fence, guardrail and roadside topography. These identification works are for spotting the road variables having the open section deemed to have wild animals cross the highway. Based on a study which has investigated the role of highway fence gate influencing mammal road-kills(Song *et al.*, 2011) a section with gate opening was considered a non-fenced section, and rock-fall prevention structure or noise barrier were considered a fence in this

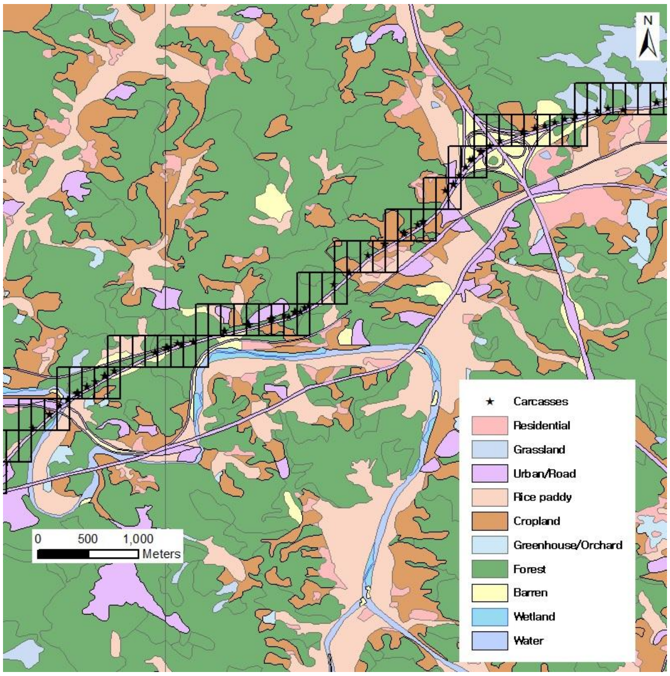

FIGURE 3. Yeongdong highway(YD) and road-kills covered by fishnet grid(2007-2012)

study. The study also counted the number of road-kill accidents near the highway intersection.

Results

1. Land Cover Analysis

The result suggested that the land cover-specific attributes of road-kill sites have no difference among species in YD (p=0.165) and over half of the accident points congregate in barren(41.6% for water deer, 40.8% for raccoon, 35.9% for hare) and grassland(14.3% for water deer, 12.1% for raccoon, 17.7% for hare) (TABLE 3). Representing land cover type differently among species(p=0.001), JB showed spatial pattern of road-kill mostly in wetland, barren, cropland and grassland as well(TABLE 4).

The grassland patches created on highway section near junction or intersection recorded a total of 44 casualties out of 414(10.6%) in YD and 31 casualties out of 162(19.1%) in JB.

2. Road Variable Analysis

There was a tendency for mammal road-kill to occur less frequently in road sections being installed with steep highway embankment, fence(1.5~1.7m) had little effect and guardrail(single rail) had no significant deterring effect(FIGURE 4).

Lying with a steep highway embankment or cut slope, fence did not seem to play a big role in road-kill prevention on account of deterring effect of topography(ⓐ, FIGURE 5). Fencing with gentle slope

TABLE 3. Weighted road-kill frequency and surrounding patch in YD(2007-2012)

Land cover (㎢ within 500ST) \ Species	*Hydropotes inermis argyropus*		*Nyctereutes procyonoides*		*Lepus coreanus*	
	of	*wf* (%)	*of*	*wf* (%)	*of*	*wf* (%)
Barren(2.15㎢)	183	8.51 (41.6)	20	0.93 (40.8)	6	0.28 (35.9)
Grassland(2.18㎢)	64	2.94 (14.3)	6	0.28 (12.1)	3	0.14 (17.7)
Cropland(14.77㎢)	286	1.94 (9.5)	35	0.24 (10.4)	10	0.07 (8.7)
Wetland(2.18㎢)	19	0.87 (4.3)	2	0.09 (4.0)	0	0
Vinyl greenhouse & orchard(1.27㎢)	24	1.89 (9.2)	2	0.16 (6.9)	1	0.08 (10.1)
Rice paddy(35.84㎢)	425	1.19 (5.8)	38	0.11 (4.6)	26	0.07 (9.3)
Urban(3.29㎢)	35	1.06 (5.2)	4	0.12 (5.3)	1	0.03 (3.9)
Residential(3.31㎢)	42	1.27 (6.2)	9	0.27 (11.9)	3	0.09 (11.7)
Forest(179.05㎢)	563	0.31 (1.5)	84	0.05 (2.1)	37	0.02 (2.7)
Water(6.72㎢)	34	0.51 (2.5)	3	0.04 (2.0)	0	0

* Monte Carlo sig. (p value) = 0.165 of: Observed frequency wf: Weighted frequency

TABLE 4. Weighted road-kill frequency and surrounding patch in JB(2007-2012)

Land cover (㎢ within 500ST) \ Species	*Hydropotes inermis argyropus*		*Nyctereutes procyonoides*		*Lepus coreanus*	
	of	*wf* (%)	*of*	*wf* (%)	*of*	*wf* (%)
Barren(10.85㎢)	97	0.89 (20.9)	12	0.11 (12)	4	0.04 (12.5)
Grassland(6.72㎢)	79	1.18 (27.4)	10	0.15 (16.1)	3	0.04 (15.1)
Cropland (24.47㎢)	118	0.40 (11.2)	19	0.08 (8.4)	9	0.04 (12.5)
Wetland (1.12㎢)	6	0.54 (12.5)	4	0.36 (38.7)	1	0.09 (30.2)
Vinyl greenhouse & orchard (0.96㎢)	38	0.29 (6.9)	5	0.04 (4.2)	8	0.06 (20.9)
Rice paddy (41.97㎢)	100	0.24 (5.6)	15	0.04 (3.9)	8	0.02 (6.5)
Urban (5.97㎢)	12	0.20 (4.7)	3	0.05 (5.5)	0	0
Residential (14.11㎢)	21	0.15 (3.5)	6	0.04 (4.6)	0	0
Forest (218.8㎢)	225	0.10 (2.4)	44	0.02 (2.2)	15	0.01 (2.3)
Water (7.44㎢)	16	0.22 (5.0)	3	0.04 (4.4)	0	0

* Monte Carlo sig. (p value) = 0.001 of: Observed frequency wf: Weighted frequency

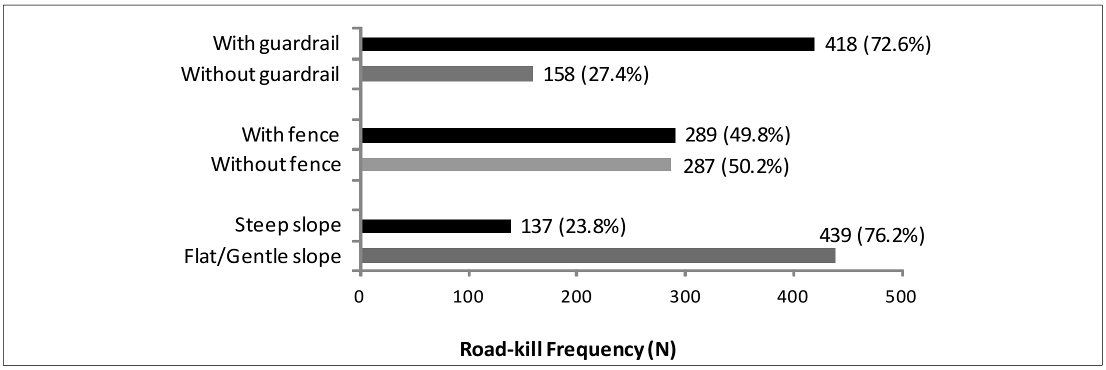

FIGURE 4. Road-kill prevention effectiveness of each road variable in YD and JB(2007-2012)

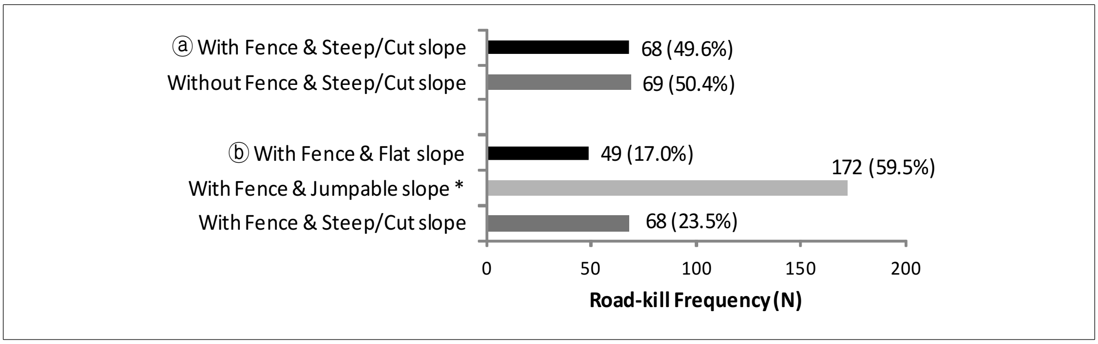

FIGURE 5. Interaction effect of each road variable in YD and JB(2007–2012)
* Jumpable slope means traversable topography not being capable of deterring ⓐ effectiveness test of the steep or cut slope on wildlife crossing ⓑ hypothesis test determining if topography decreases fence effectiveness

where animals can traverse had a 3 times more likely to have mortality than did flat slope with fence(ⓑ, FIGURE 5).

Conclusion and Discussion

Road–kills on both highways generally tended to be higher in the preferred habitats of nocturnal and generalist species like raccoons, hare and water deer and these animals are often attracted to cropland, grassland and natural barren areas such as river basin and sea coast for foraging and dispersing. The results are in agreement with findings of previous road–kill associated land cover studies (Min and Han, 2010; Choi and Park, 2006a). Unlike the spatial consistency of road–kill in YD's mountainous area, fragmented patches and various constraints within JB's urban and developed area can play a role influencing animal's convoluted movements, thus resulting in a different road–kill pattern by species in a varied land cover type. This assumption supported other study that revealed leopard cat(*Prionailurus bengalensis*) uses various land cover patches due to residential distribution (Choi *et al*., 2012). Another explanation has to do with different opening date of the two lanes. YD started its first operation in 1971 and did JB in 1999, 2000 and 2005 for each part of the survey route. Wildlife could be less adjusted than YD to the altered habitats near the road by the continuous extension works of JB through 1999 to 2005 while YD which has been in operation over 40 years could enhance consistency in animal's appearance pattern onto the road. One study(Ministry of Environment, 2007) described bushes or wild herbaceous plants can play a role of a hide for the animal's attempted crossing.

A topography turned out to work best for road kill prevention compared to fence of 1.5~1.7m height and single line guardrail. Low prevention efficacy of guardrails and fences seems due to its jumpable height for medium to large sized mammals. Though Ministry of Land, Instruction and Transport (2010) states that installation of fences for mammal species is to be 1.2~1.5m, US federal government demonstrated that ungulates like deer, elk, moose can easily jump over the fence of 1m(4.0~4.2") above the ground(Paige, 2012). On the other hands, Song *et al.* (2011) indicated a fence of 1.0m height without an entrance gate is as more effective as a fence of 1.5m height with a gate. As Paige (2012) states that slope increases barrier effect of fence, fencing can work effectively if set next to the slope increasing in the road direction and with closed or well-managed entrance gate of the same height of the fences. The patent on a double layered barrier (Gwon *et al.*, 2014) which was designed to limit access of artiodactyla to protect crops implies discouraging ungulates from jumping over 1~1.5m fence by stepping humps would be necessary. On that note, the interaction effect between fence and slope along the road is noteworthy as well in that fences may become even more jumpable when juxtaposed with gentle or moderate slopes decreasing in the road direction.

Some part of the roadside in the study area may have been equipped later with fence or rockfall prevention structure after data collection (2007-2012), which might have rendered the analysis of road variables (2014) somewhat inaccurate or disparate from the result of the other studies on fence design.

Given that quite a number of road-kill occurred near junction and intersection, the greenery patches on intersection may have played a role as a visual stepping stone connected with neighboring landscape, thus leading attempted crossing of wild animals. Unlike a specialist species, a generalist species can cross the road for the purpose of using lands at both sides of road as they are able to adapt to a wide variety of environments and forage various types of resources. Multihabitat vertebrates may make a daily use of different habitats (Forman, 1995) and the movement of animals along roadsides is enhanced by the high degree of connectivity of roadside habitats (Forman *et al.*, 2003). Junction and intersection generally have good landscape connectivity across both sides of road, which eventually can facilitate wildlife crossing onto the road.

This study concluded that installation of fence or management of steep slope or embankment primarily near grassland, barren, cropland and wetlands should be an important consideration when planning the road construction or extension work. Furthermore, since most of the local roads next to interchange showed not being equipped with fence, fence or other type of road barriers at an appropriate height can be installed.

The road sections with steep slopes, unless it functions as a rockfall prevention system or a noise barrier, can best work alone in cost effective way but also be adjoined with highway mitigation fencing for best preventive effect if fence is adjusted to impassible height for medium -large sized mammals.

The collected road-kill samples are assumed to be underestimates of the numbers of observations actually made as people scavenge carcasses, some animals have traits of moving and dying outside of road or carcasses even degrade by the food chain(Ministry of Environment, 2007). The time gap between examining road facilities with Naver Geori View(updated as of March 2014) and recording road-kill data (2007-2012) may implies certain level of inaccuracy even if most spatial characteristics have remained stable across time. The observer's subjective view on intrinsic road-kill risk in the open part of the road facilities when viewing the panorama with Naver Geori View also may influence the analysis. Due to the wild animals' traveling distance before reaching a point of collision, the accident locations of road appearance in the analysis somewhat involve distortion as well.

Some studies on urban planning emphasize integrated approach involving road and land use(Kim and Jun, 2014) and pay attention to building green network and wildlife passage as the important factor to be considered when utilizing urban green space (Lee *et al*., 2014). As Choi et al. (2014) suggests the necessity of forming an integrated GIS-based climate-environment database, future research of road-kill can be designed to structure road-kill database based on integrated road and land cover data within the urban green space to secure wildlife movement and driver's safety. Future research of road-kill can be designed to structure road-kill database based on integrated road and land cover data within the urban green space to secure wildlife movement and safety of driver.

Acknowledgement

The road-kill data (unpublished data) used in this study was obtained from Korea Expressway Corporation. KAGIS

REFERENCES

Choi, T.Y., H.S. Kwon, D.G. Woo and J.H. Park. 2012. Habitat selection and management of the lopard cat(*Prionailurus bengalensis*) in a rural area of Korea. Korean Journal of Environment and Ecology 26(3):322- 332 (최태영, 권혁수, 우동걸, 박종화. 2012. 농촌지역 삵 *Prionailurus bengalensis*의 서식지 선택과 관리방안. 한국환경생태학회지 26(3):322-332).

Choi, T.Y. and J.H. Park. 2006a. The effects of land use on the frequency of mammal road-kills in Korea. Journal of the Korean Institute of Landscape Architecture 34(5):52-58 (최태영, 박종화. 2006a. 토지이용유형에 따른 포유류 로드킬 발생 특성. 한국조경학회지 34(5):52-58).

Choi, T.Y. and J.H. Park. 2006b. Home-range of raccoon dog *Nyctereutes procyonoides* living in the rural area of Korea. Journal of Ecology and Environment 29(3):259-263 (최태영, 박종화. 2006b. 농촌지역 너구리 *Nyctereutes procyonoides* 행동권. 한국생태학회지 29(3):259-263).

Choi, Y.K, K.H. Kim, C.Y. Lee. 2014. Development of an integrated DB management system for GIS-based client/ server data sharing in climate and environment fields. Journal of the Korean Association of Geographic Information Studies 17(2):32-43 (GIS기반의 기후·환경분야 자료 공유를 위한 Client/Server 방식의 통합 DB관리 시스템 개발. 2014. 최용국, 김계현, 이철용. 한국지리정보학회지 17(2):32-43).

Clevenger, A.P., B. Chruszcz and K.E. Gunson. 2003. Spatial patterns and factors influencing small vertebrates fauna road-kill aggregation. Biological Conservation 109(1):15-26.

D' Amico, M., J. Román, L. de los Reyes and E. Revilla. 2015. Vertebrate road-kill patterns in mediterranean habitats: who, when and where. Biological Conservation 191(2015):234-242.

Daum Road View (다음 로드뷰). http://map.daum.net.

Forman, R.T.T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press, Cambridge, UK, p.388.

Forman, R.T.T., D. Sperling, J.A. Bissonette, A.P. Clevenger, C.D. Cutshall, V.H. Dale, L. Fahrig, R. France, C.R. Goldman, K. Heanue, J.A. Jones, F.J. Swanson, T. Turrentine and T.C. Winter. 2003. Road ecology: science and solutions. Island Press, Washington DC, USA, p.98.

Glista, D.J., T.L. Devault and J.A. Dewoody. 2007. Vertebrate road mortality predominantly impacts amphibians. Herpetological Conservation and Biology 3(1):77-87.

Gwon, J.N. S.W. Bae, J.H. Lim 2014. Apparatus of preventing artiodactyla's damage and the method of preventing artiodactyla's infringement (application number: 10-2014-0083658) (권진오, 배상원, 임주훈. 묘목 및 농작물의 우제목 피해 방지 장치 및 우제목의 침입 방지 방법 출원번호 10-2014-0083658).

Kim, B.J., D.H. Oh, S.H. Chun and S.D. Lee. 2011. Distribution, density, and habitat use of the Korean water deer (hydropotes inermis argyropus) in Korea. Landscape and Ecological Engineering 7(2): 291-297.

Kim, B.J. and S.D. Lee. 2011. Home range study of the Korean water deer(hydropotes inermis argyropus) using radio and GPS tracking in South Korea: comparison of daily and seasonal habitat use pattern. Journal of Ecology and Environment 34(4):365-370.

Kim, H.Y., C.M. Jun. 2014. Classification analysis of road network-based land use considering spatial structure. Journal of the Korean Association of Geographic Information Studies 17(1): 24-34 (김혜영, 전철민. 2014. 공간구조를 고려한 도로망 기반 토지이용의 분류분석. 한국지리정보학회지 17(1):24-34).

Korea Expressway Corporation (KEC). 2011. Traffic volume statistics of expressway. http://www.ex.co.kr/site/com/pageProcess.do (한국도로공사. 2011. 고속도로 교통량 통계).

Korea Forest Service. 2007. A study on habitat fragmentation in Baekdudaegan and restoration strategy. p.193 (산림청. 2007. 백두대간 훼손실태조사 및 복원방안. 193쪽).

Korea Forest Service. 2014. A study on changes in natural resource of Baekdudaegan and management strategy. pp.583-585 (산림청. 2014. 백두대간 자원실태변화조사 및 관리방안 연구. 583-585쪽).

Lee, W.S., S.G. Jung, K.H. Park, J.H. You. 2014. An integrated assessment of green environment on urban space. Journal of the Korean Association of Geographic Information Studies 17(2):15-31 (이우성, 정성관, 박경훈, 유주한. 2014. 도시공간의 통합적 녹지환경 평가. 한국지리정보학회지 17(2): 15-31).

Min, J.H., G.S. Han. 2010. A study on the characteristics of road-kills in the Odaesan National Park. Korean Journal of Environment and Ecology 24(1):46-53 (민지홍, 한갑수. 2010. 오대산국립공원의 야생동물 로드킬 특성. 한국환경생태학회지 24(1):46-53).

Ministry of Environment. 2004. A study on habitat fragmentation in Baekdudaegan II. pp.118-120 (환경부. 2004. 백두대간 훼손실태 조사 연구 II. 118-120쪽).

Ministry of Environment. 2007. Development of road type-specific and animal species-specific management techniques according to analysis of the degree of fragmentation of wildlife habitats by roads, and of causal factors behind road-kills p.84, 166, 179, 180, 193, 204, 215, 225 (환경부. 2007. 도로의 야생동물 서식지 단절 정도의 분석과 road-kill의 원인 분석에 따른 도로유형별 · 동물종별 관리기법 개발. 84, 166, 179, 180, 193, 204, 215, 225쪽).

Ministry of Land, Instruction and Transport, Ministry of Environment. 2010. A guide on environment-friendly road construction p.26 (국토교통부, 환경부. 2010. 환경친화적인 도로건설 지침. 26쪽).

Naver Geori View. http://map.naver.com (네이버 거리뷰, 네이버 항공뷰).

Paige, C. 2012. A landowner's guide to wildlife friendly fences. Second edition. Private Land Technical Assistance Program, Montana Fish, Wildlife & Parks, Helena, MT. p.10.

Park, H.M. and S.D. Lee. 2013. Habitat use pattern of Korean water deer based on the land coverage map. Journal of Wetlands Research 15(4):567-572 (박효민, 이상돈. 2013. 토지피복도를 이용한 고라니의 서식지이용분석. 한국습지학회 15(4):567-572).

Seok, S.M. and J.Y. Lee, 2015. A study on the correlation between road-kill hotspot and habitat patches. Journal of Environmental Impact Assessement 24(3):233-243 (석상묵, 이지영. 2015. 야생동물 서식지 패치와 로드킬 핫스팟의 상관관계 연구. 환경영향평가 24(3):233-243).

Song, J.S., K.J. Lee, K.S. Ki and I.Y. Jun. 2011. The efficiency and improvement of the highway wild-life fences for decrease of mammals road-kill -in case of Manjong~Hongchun section on Jungang Highway-. Korean Journal of Environment and Ecology 25(5):649- 657 (송정석, 이경재, 기경석, 전익요. 2011. 포유류 로드킬 저감을 위한 고속도로 유도울타리 효율성 및 개선방안 연구. 한국환경생태학회지 25(5):649-657).

KAGIS