WILDLIFE CROSSINGS ALONG THE RING CHANGBAI MOUNTAIN SCENIC HIGHWAY, CHINA

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ABSTRACT

China State Forestry Administration is in the process of restoring Siberian tiger (Panthera tigris altaica) habitat in the Changbai Mountain National Nature Reserve. The 84 km long Changbai Mountain scenic Ring highway encircles and bisects the nature reserve. Although, traffic flow is under 100 vehicles per day in winter, the highway is being upgraded to a paved surface. With the expected increasing traffic flow, increased wildlife vehicle collisions and barrier effects are likely. In order to identify wildlife crossing zones and future protective measurement, we carried out 10 wildlife highway crossing surveys during the winter in 2008-2009. Each survey took place two or three days after the last snow event. We drove along the highway at a low speed (about 20–30 km/h) and stopped to identify wildlife tracks crossing the highway. We concluded wildlife crossed based on seeing wildlife's tracks on both sides of the highway. For each 5km section, we recorded highway crossings of all small-mid sized and large mammals and one large protected bird species, the hazel grouse (Bonasa bonasia) and noted snow depth and the dominant vegetation type. We detected 12 mammal species and 1 avifauna species crossing the highway 502 times. The smallest of mammal was the Eurasian red squirrel (Sciurus vulgaris). The most common species which crossed was the Siberian weasel (Mustela sibirica) (169) and Manchurian hare (Lepus mandschuricus) (100). Large mammals detected included the wild boar (Sus scrofe) (64) and brown bear (Ursus arctos) (1). The average number of wildlife crossings per five km was 29.5. We found species richness and crossing frequency was higher in sections with broad leaf forest compared to sections with white birch secondary forest significantly. Snow depth was negatively related to species richness and crossing frequency, but was not significant. We concluded that wildlife crossing opportunities would serve most wildlife and likely tiger in sections with natural broad leaf forest. We recommended disturbance of broad leaf forest be minimized during construction and strict protection be established for broad leaf forests around Changbai Mountain National Nature Reserve.

INTRODUCTION

There were lots of studies regarding the impact of road construction on wildlife among Europe, north American, Australia, including negative effects consisted of road killing (Patten et cl.,2008; Grilo et al.,2009; Baskaran et al.,2010), avoiding effect (Forman, et al.,2000), crossing behavior (Hoeven, et al.,2009), migration barriers (Shepard et al.,2008), habitat degradation (Ortega et al.,1999), habitat fragment (Thiel et al.,1985), gene loss (Lesbarreres et al.,2003), and also considering positive effects consisted of habitat creation (Meunier et al.,2000) and mobility enhanced (Laursen 1981).

The studies regarding the impact of road construction on wildlife in China include road construction impacts on Tibetan antelope across Qinghai-Tibet highway or railway (Qiu et al., 2004; Yin et al., 2006), wildlife conservation covered by Asian elephants' passages construction and monitoring along Simao-Xiaomengyang expressway in Yunnan (Pan et al.,...
2009) and wildlife’s passage monitoring among Qinghai-Xizang railway (Yang et al., 2008). China is one of the richest biological resource countries in the world, ranked 8th in global wildlife biodiversity (Ma et al., 2008). China’s road network with 3984 thousand kilometer spread by the year 2010, ranking 2nd in the world, especially freeway with 74 kilometers length, also ranking 2nd in the world, presumably will exceed USA by the end of 2012 (web of Ministry of transport of the people’s Republic of China). It’s urgent and significant for China to carry out the studies regarding impact of highway on wildlife (Wang et al., 2010). The pattern of wildlife across road, including species, frequency, location, time, is vital to wildlife passage setting, but there are few studies for wildlife across road continuous monitoring in China, therefore, lacking of theoretical basis about wildlife passage design.

Road constructions are carried dramatically for tourism and economic development in Changbai Mountain area (Jilin Daily, 2010). It should be considered for road impact on wildlife, Because Changbai Mountain rich in wildlife resource and used to be the main habitat for Siberian tiger historically (Li et al., 1990). Recently, international organizations (such as WWF, WCS) combined Chinese government carried out some studies about Siberian tiger passage constructions, habitat restoration in and around nature reserve, and tigers’ preys monitoring (Li et al., 2010). It is significantly providing reasonable protective measures and strategies through studies and surveys on pattern of wildlife across road and relationship between wildlife and environment.

1. AREA

1.1 Changbai Mountain National Nature Reserve

Changbai Moutain National Nature Reserve is located in Southeast of Jilin province, across Antu County of Yanbian Korean Autonomous Prefecture and Fusong County and Changbai County of Hunjiang Area, adjacent to North Korea. The nature reserve lay between E127°42'55"-128°16'48" and N 41°41'49"-42°51'18", covering an area of 196,465 hectares. This area has a monsoon continental mountainous climate, with long and cold winter, and short summer warm and humid. Annual average temperature is about 2-5℃, with almost 2300 sunshine hours per year, and frost-free period of 100 days. Changbai Mountain is one of East Asia’s largest volcanic areas, consisted of volcanic lava tectonic geomorphology, water landscapes, glaciers, and periglacial landforms. Changbai Mountain Reserve is one of the Man and Biosphere reserve areas, and China’s richest biodiversity area. There are 2,277 plants species and 25 species of national important conserving plants, mainly including Korean pine (Pinus konialiensis), Mongolian scotch pine (P. syluesris), Yellow pineapple (Phellodendrion amurense) and etc. More than 1,225 wildlife species are active in the region, 59 species of which are national key protected species, mainly including National 1st Class Protected Wildlife sable (Martes zibellina), and roe deer(Capreolus pygargus), yellow weasel (Mustela sibirica) etc. Additionally, National 1st Class Protected Wildlife Siberian tiger appeared in the area historically (Li et al., 1990).

1.2 Ring Changbai Mountain Scenic Highway

Although, traffic volume of Changbai Mountain scenic highway is less 100 vehicles per day in winter, yet it has been upgraded to a paved surface. Recently a rapid increase in traffic flow on the highway has been observed, increased wildlife-vehicle collisions and barrier effects are likely. Ring Changbai Mountain scenic highway improvement project began in late 2007, mainly circled Changbai Mountain Nature Reserve, covering existing forest road. The road starts from Erdaobaihe Town, Antu County of Yanbian Korean Autonomous Prefecture, and goes till Manjiang Town, Baishan City. The total length of the highway is 84.132km, with about 21km (K10-K31) section overlapped the edge of nature reserve and 6km (K31-K37) section bisected experimental zone of Changbai Mountain Nature Reserve. Secondary road standard was carried out along this highway, with a design speed 60 km/h, and subgrade width of almost 10m (Fig. 1).

Many ginseng fields, mixed human activities area, are distributed among Ring Changbai Mountain scenic highway (K0-K10). Forestry agency planted many tree seedlings, mainly of spruce, along the roadside, and put rat poison in order to combat the destruction of rodents in the area every year. White birch secondary forest distributed along K37-K84 section, sometimes suffered from mosaiced in ginseng fields, and contributing to human disturbance partly. As K0-K10 section, Forestry agency put rat poison preventing the destruction of rodents.
2. METHODOLOGY

2.1 Field Survey

Line transects of low speed cars (20-30km/h) combined pedestrian (Alexander, 2000) were taken for recording footprints, feces, and tracks of food residue from wildlife across road. We concluded wildlife crossing based on seeing wildlife’s tracks on both sides of the highway. Setting 5km intervals along the road, for recording wildlife across road species, frequency, location and environment characters consisting of maximum snow depth and vegetation types (divided into broad leaf forest, and white birch secondary forest), meanwhile we used the camera to make photos and used GPS to record the geographic position. We recorded highway crossings of all small-mid sized and large mammals and one large protected bird species, the hazel grouse (*Bonasa bonasia*). Surveys were conducted in November and December 2008, November and December 2009, January to March 2010, with 10 surveys in total are conducted, and
each survey lasted about 2 days. Each survey takes place two or three days after the last snow event. We recorded most mammals active along Ring Changbai Mountain scenic highway, as ungulates including roe, wild boar, red deer and other small mammals. Only hazel grouses’ entities and footprints were recorded, as the only one bird species.

2.2 Data Analysis

Normal distribution of data was tested by K-S method, and variances about species and frequency among various sections were tested by One-way ANOVA. Homogeneity among variance, data was compared by LSD method, otherwise Tamhane method was used. Interrelation among species, frequency and snow depth, was analyzed by Spearman correlation analysis. The differences about species and frequency in various vegetation types was discriminate by T-test. All above analysis was carried out in SPSS 16.0.

3. RESULTS

3.1 Wildlife Species, Frequency and Locations Across Ring Changbai Mountain Scenic Highway

There were 502 records including 13 wildlife species recorded in10 surveys of which 3 surveys during November and December 2008 and 7 surveys during November 2009 to March 2010. All species found were protected species, 2 wildlife species were listed in National First-class Protected Wildlife, 4 wildlife species were listed in National Second-class Protected Wildlife, 6 wildlife species were listed in Terrestrial Wildlife List of Beneficial or Important in Economy and Science, and 1 wildlife species was listed in IUCN LIST. The most frequently observed species crossing road is Siberian weasel (Mustela sibirica) (169 times), followed by Manchurian hare (Lepus mandschuricus) (100 times), Wild Boar (Sus scrofe) (64 times), Squirrels (Sciurus vulgaris) (57 times), Roe Deer (Capreolus capreolus) (50 times), and Yellow-throated marten (Charronia flavignula) (34 times). The crossing frequency of these species accounts for 94.42% of all (table 1). The average number of wildlife crossings per five km was 29.5.

<table>
<thead>
<tr>
<th>Species</th>
<th>Scientific name</th>
<th>Class</th>
<th>Order</th>
<th>Family</th>
<th>Protection level</th>
<th>Crossing frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Himalayan weasel</td>
<td>Mustela sibirica</td>
<td>Mammalia</td>
<td>Carnivora</td>
<td>Mustelidae</td>
<td>*</td>
<td>169</td>
</tr>
<tr>
<td>Manchurian hare</td>
<td>Lepus mandschuricus</td>
<td>Mammalia</td>
<td>Lagomorpha</td>
<td>Leporidae</td>
<td>*</td>
<td>100</td>
</tr>
<tr>
<td>Wild bore</td>
<td>Sus scrofe</td>
<td>Mammalia</td>
<td>Artiodactyla</td>
<td>Suidae</td>
<td>*</td>
<td>64</td>
</tr>
<tr>
<td>Squirrels</td>
<td>Sciurus vulgaris</td>
<td>Mammalia</td>
<td>Rodent</td>
<td>Sciuridae</td>
<td>*</td>
<td>57</td>
</tr>
<tr>
<td>Roe deer</td>
<td>Capreolus capreolus</td>
<td>Mammalia</td>
<td>Artiodactyla</td>
<td>Cervidae</td>
<td>*</td>
<td>50</td>
</tr>
<tr>
<td>Yellow-throated marten</td>
<td>Charronia flavignula</td>
<td>Mammalia</td>
<td>Carnivora</td>
<td>Mustelidae</td>
<td>II</td>
<td>34</td>
</tr>
<tr>
<td>Hazel Grouse</td>
<td>Bonasa bonasia</td>
<td>Avian</td>
<td>Galliformes</td>
<td>Tetraonidae</td>
<td>II</td>
<td>5</td>
</tr>
<tr>
<td>Sable</td>
<td>Martes zibellina</td>
<td>Mammalia</td>
<td>Carnivora</td>
<td>Mustelidae</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>Red deer</td>
<td>Cervus laphus</td>
<td>Mammalia</td>
<td>Artiodactyla</td>
<td>Cervidae</td>
<td>II</td>
<td>5</td>
</tr>
<tr>
<td>Least weasel</td>
<td>Mustela nivalis</td>
<td>Mammalia</td>
<td>Carnivora</td>
<td>Mustelidae</td>
<td>*</td>
<td>2</td>
</tr>
<tr>
<td>Sika deer</td>
<td>Cervus nippon</td>
<td>Mammalia</td>
<td>Artiodactyla</td>
<td>Cervidae</td>
<td>I</td>
<td>10</td>
</tr>
<tr>
<td>Brown bear</td>
<td>Ursus arctos</td>
<td>Mammalia</td>
<td>Carnivora</td>
<td>Ursidae</td>
<td>II</td>
<td>1</td>
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<tr>
<td>Wild cat</td>
<td>Felis silvestris</td>
<td>Mammalia</td>
<td>Carnivora</td>
<td>Felidae</td>
<td>&amp;</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: “I” represents National First-class protected wildlife; “II” represents National Second-class protected wildlife; “*” represents Terrestrial Wildlife List of Beneficial or Important in Economy and Science; “&” presents IUCN Mammals Redbook, 2009 ver 3.1.

We analyzed whether there are any differences between species richness and frequency in various sections by One Way ANOVA. Results were showed in Figure 2 and 3. Data were analyzed and tested using K-S normal distribution among 17 sections for species richness. Section K60-65 and section K80-85 were neglected as data of these two sections were abnormal. Section K0-5 was also neglected as data of this section was too few to analyze. LSD test was
also performed. Significant differences ($F = 2.706$, $df=13, P=0.002$) was observed among species richness of other 14 sections. The variance of 14 group data was homogeneity ($P=0.217$) by Levene variance homogeneity test, and species richness of section K10-15 was higher than section K15-20 and K35-80 significantly, and species richness of section K20-35 was higher section K45-80 significantly.

Data were analyzed and tested using K-S normal distribution among 17 sections for crossing frequency. Section K80-85 was neglected as data was abnormal. Section K0-5 was also neglected as data was too few to analyze. Significant differences were observed among different crossing frequencies in different sections through One-Way ANOVA test. The variance of these data was heterogeneity by Levene variance homogeneity test. In contrast, the difference was not significant by Tamhane method.
3.2 Factors

3.2.1 Snow depth

Species richness and crossing frequency of various sections showed abnormal distribution by K-S normal test, and their correlation was analyzed by Spearman correlation analysis. There was no significant correlation found neither between species richness and snow depth \( R = -0.170, P = 0.123, N = 84 \), nor between crossing frequency and snow depth \( R = -0.191, P = 0.083, N = 84 \). Therefore, Snow depth was negatively related to species richness and crossing frequency, but was not significant.

3.2.2 Vegetation

The vegetation along Ring Changbai Mountain scenic highway was classified as natural broad-leaved forest (K10-40) and white birch secondary forest for other sections. Wildlife species richness showed normal distribution by K-S normal test, and significant differences was observed between the vegetation types \( t = 3.662, df = 15, p = 0.002 \). Crossing frequency also showed normal distribution, and differences was significant \( t = 4.366, df = 5.789, p = 0.005 \) between the vegetation types.

Therefore, both species richness and crossing frequency was significantly higher in sections with broad leaf forest compared to sections with white birch secondary forest.

4. DISCUSSION

In the study, we analyzed preliminarily characters of wildlife crossing along Ring Changbai Mountain scenic highway as affected by vegetation type, snow depth, human activities and others aspects. There are 24 wildlife species in roadside (200m range area) accounting for 47.06% of mammals species in Changbai Mountain National Nature Reserve (Piao et al., 2011). In this study, we recorded 12 mammals species crossing highway, accounting for 50% mammals species of roadside and 23.53% mammals species of nature reserve. Thus, it revealed that wildlife were active in roadside area. We should pay more attention to wildlife crossing highway and take measurement to reducing road kill (Friends of Nature, 2009).

The differences of species richness were significant among various sections. Species richness of section (K10-35) was higher than others, and crossing frequency of section (K10-35, especially in K10-15 and K20-35) was higher than others. These results suggested location of wildlife activities were relatively regular, which sections were adjacent to and bisecting nature reserve. More wildlife passages should be provided among these sensitive sections to facilitate routes for wildlife across road. This result is consistent with other relevant researches (Wang et al., 2009). Wildlife passages must coincide with wildlife historical migration routes before it can be effective (Pan et al., 2009).

The elevation of Ring Changbai Mountain scenic highway varies from 707.86m to 1089.74m, and average altitude is about 901.43m. Previous studies show that with the increase of snow depth the frequency of wildlife across road decreased. When snow depth reaches 50cm or more, it affects deer and wild boar feeding activity and movement, making predation of medium or small mustelidae wildlife more difficult because of small rodents activity below snow cover. Red deer, roe deer and other ungulates would walk as short as possible, consuming less energy for more food (Zhou et al., 2006). In this study, there was negative correlation between snow depth and species richness or crossing frequency, but not significantly. This result may be caused by small snow fall during survey period. Most of the wildlife active in roadside area was herbivores and carnivores, snow depth had impact on the foraging behavior of Mustelidae wildlife. Our study showed that wildlife activity frequency decreased with increasing snow in higher elevation section.

Species richness and crossing frequency differed significantly among sections within a various vegetation class, which in natural broad-leaved forest was notably higher than those in birch forest, and it suggested various vegetation around road area was various attractive on wildlife. Wildlife distribution density varied with vegetation. Li et al. (1981) surveyed rodent density in Changbai Mountain area, with 2.64 rodents per day per clip in secondary birch while 4.08 rodents per day per clip in broad-leaved and pine forest respectively. According to result of our survey in 2006, rodent density was 76.8 per ha in conifer forest while the density was only 16.8 per ha in white birch secondary forest. In this study, sections in natural broad-leaved forest distributed belong to nature reserve, so there were few human disturbances. And sections in white birch secondary forest were due to harvesting, and not belonging to nature reserve; frequent human activities disturbed wildlife habitat and behavior. Some studies (Hoeven, et al.,2009) showed human disturbance had impact on wildlife migration. Therefore, we thought there is significant relationship between roadside vegetation types, human disturbance and crossing highway activity. In future, we should minimize interference to natural broad-leaved forest during road construction among Changbai Mountain area.
This study was only primary carried out through macro analysis, which analysis should be combined with GIS technology, infrared camera, sand tracking and other technologies in order to have a systematically survey from studies were carried out specifying on the micro and macro perspective. It was greatly encourage and further studies were carried out specifying on the location, types and usage monitoring about wildlife passage for scientific construction and wildlife passages maintenance.

**BIOGRAPHICAL SKETCHES**

**Dr. Yun Wang** is an assistant professor pursuing road ecology study in China Academy of Transportation Sciences (CATS). He holds a Dr Degree from China Academy of Sciences in road landscape and ecological protection. He has 6 years’ experience in road ecology in China. In 2005, he translated the famous textbook “road ecology: science and solution” into Chinese and in 2009, he and other ecologist and transportation engineers cooperative published “road ecology in China”, and in 2010, he make endeavor to successfully promote CATS to invite Richard T.T. Forman to visit CATS. Now his interesting is focusing mainly on the interactions of roads and wildlife, landscape fragmentation and road ecology. He has published more than 10 peer-reviewed articles in road ecology.

**Professor Zhengji Piao** is a local wildlife ecologist in Changbai Mountain area, he has about 40 years’ experience in biodiversity investigation and protection in Changbai Mountain Nature Reserve, and now he is the consultant expert of CATS.

**Lei Guan** has his Mater degree from Beijing Normal University in 2009, and now is doing research about wildlife protection during highway construction.

**Haifeng Li** got his Ph.D from Melbourne University in Australia in 2000, and in 2005 he guided Dr. Yun Wang to translate the famous textbook “road ecology: science and solution” into Chinese and in 2009, he and other ecologist and transportation engineers cooperative published “road ecology in China”. In 2005, as a central principal he and other scientists constructed the first environmental protection and landscape aesthetics pilot project “Chuanzhusi to Jiuzaigou scenic highway in Sichuan Province” in China.

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Providing Connectivity across Roads for Tree-Dwelling Mammals

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Abstract

Linear clearings for roads can impact on populations of forest tree-dwelling mammals by fragmenting populations of canopy species that will not move at ground level. In contrast, arboreal fauna willing to cross roads at ground level may suffer road mortality. Therefore adequate conservation of tree-dwelling species requires provision of safe means of crossing roads. We examined mortality and fragmentation impacts of roads and highways for a group of rain forest arboreal mammals living in the uplands of north Queensland, Australia. Several of these species are rare or threatened under State nature conservation legislation. We also investigated whether these mammals will use inexpensive rope canopy bridges above roads and a highway.

Barrier impacts of highways were examined through spotlighting and radio-tracking at night. Individuals of several rain forest ringtail possum species were radio-tracked at two sites with abundances determined using spotlighting data. Rain forest ringtail possums treated highways as a home range boundary which they were not prepared to cross in normal movements.

A community database of sightings of the more mobile Lumholtz’s tree-kangaroo, for which road mortality is considered a threat, was interrogated for factors influencing roadkill sites. Factors influencing road mortality in a fragmented landscape included the presence of remnant rain forest and proximity to creeks with riparian vegetation. Areas requiring connectivity across roads were identified.

At four sites, three rope bridge designs were trialed, including a single rope, rope ladder-like bridges and rope tunnel-shaped bridges. Use was determined using direct observations by spotlighting, faecal pellet collection, hair samples and infrared-triggered cameras and video cameras. Nine mammal species were recorded using canopy bridges, including the three rare rain forest ringtail possums that were our target species. Over 50 crossings above a 15 m-wide tourist road were observed on an elevated ladder-like bridge. Occasional use of longer (approximately 40 m) rope bridges by four species was demonstrated, although further monitoring is required. Although tree-kangaroo hair was sampled from the end of one bridge, this species did not appear to make use of the structures. However, other possum and rodent species that suffer road mortality impacts were observed using the rope canopy bridges.

Our observations suggest that canopy bridges can assist rare arboreal mammals to cross roads through rain forest, thereby reducing both the risk of road-kill and the potential for subpopulation isolation. Further research is required to ascertain the level of benefit afforded by canopy bridges for arboreal mammal populations. However, it is likely that rope canopy bridges will have broad application globally for a wide range of arboreal mammal species. These structures are relatively inexpensive and can be erected using the assistance of community groups, making them extremely cost-effective.
A SYNOPSIS OF THE CASE STUDY: TARGETING ECOLOGICAL INVESTIGATIONS TO PRIORITIZE MANAGEMENT FOR REDUCING VEHICLE-CAUSED BUTTERFLY MORTALITY

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ABSTRACT

Roads that bisect habitat can decrease population size due to animal-vehicle collisions or interruption of key life history events. Along the Oregon coast, a highway divides primary breeding from nectaring habitat of the Oregon silverspot butterfly (*Speyeria zerene hippolyta*), a federally listed species. We could not directly evaluate the management options for reducing vehicle-caused deaths of silverspots; therefore, to prioritize management, we studied relevant ecology. We sampled behavior in road and surrounding meadow plots and sampled flowers along the verge. Silverspots did not prefer the road for basking or flying, suggesting management to increase wind or shading in the road should not be considered further. They crossed the road where the verge had more flowering plants, and most crossings were concentrated in specific areas. Hence, we recommend vegetation management and barriers that increase flight height. Reduction of traffic speed when road temperature is just over the threshold temperature correlated with flight, also may reduce butterfly-vehicle collisions. This approach of gathering targeted ecological information was effective for prioritizing management options and should be useful across taxa and habitats. Such effective, quick, and inexpensive approaches are needed to identify how to respond to road impacts, especially given greater urbanization and climate change.

SYNOPSIS OF THE CASE STUDY

Animals frequently encounter roads that cross their habitat, which can affect animal behavior (e.g., movement) and result in population-level consequences (e.g., Shine et al. 2004). Population-level effects include mortality from animal-vehicle collisions (e.g., Hels & Buchwald 2001) and barrier effects through road avoidance or habitat fragmentation (e.g., Keller & Largiadèr 2003; Epps et al, 2005, McGregor et al. 2008), as well as other causes. Mitigation techniques to prevent animals from crossing roadways and to provide safer access to habitat patches across roads have rarely been developed and tested for small or flying organisms. Several management approaches, however, have successfully reduced collisions between flying animals and vehicles. Both visual and physical barriers effectively kept flying organisms off the road. Poles discourage royal terns (*Sterna maxima*) from flying low over a Florida bridge (Bard et al. 2002). Managing vegetation has also been used for birds (Orlowski 2008). In another approach, speed reduction signs were used for the endangered Hine’s emerald dragonfly (*Somatochlora hineana*), milkweed butterfly, and Alkali bee (*Nomia melanderi*) to increase the success of evasive maneuvering for insects (Soluk & Moss 2003; Bissonette et al. 2007).

Due to expense and scale, it is prohibitive to install and test multiple management options. Therefore, to provide managers with sufficient information to prioritize options, we used an approach of identifying rapidly assessable ecological questions that could help inform the usefulness of the different management options under consideration. We present a case study of this approach for a threatened butterfly that is thought to be negatively affected by a road through its habitat, the Oregon silverspot butterfly (*Speyeria zerene hippolyta*; hereafter OSB).

At the Rock Creek - Big Creek (RC-BC) site, the focus of this study, Highway 101 severs habitat connectivity between ideal oviposition locations on the west side of the highway and the primary nectaring and roosting sites on the east side (P. Hammond unpublished data). Several potential management measures had been proposed to reduce butterfly mortality from vehicles: manipulating wind or shade of the road corridor such as with earthen berm removal; barrier installation; vehicle speed reduction using environmentally triggered, flashing speed-reduction-signs; and vegetation manipulation. Because these management scenarios were not yet in play, we could not directly test them. Rather, we gathered data on the behavioral ecology of OSBs and the environmental conditions of the road compared to surrounding habitat to determine which management measures would have the greatest potential for effectiveness. To
inform management options, we examined six questions about environmental conditions across habitats or microhabitats and how these correlated with OSB presence.

The study was conducted south of Waldport, from the mouth of Rock Creek south to 200 m beyond Big Creek, along the Oregon central coast in a salt spray meadow that is intersected by a north-south segment of Highway 101. This site is home to one of the five remaining OSB populations, as it provides the requisite meadows with the larval food plant Viola adunca (early blue violet), nectar plants, and forest fringe areas to roost. The site has been managed for V. adunca since 1985 with mowing events to control non-native grasses and woody species (Hammond 1994).

Within the study area, a 1.2 km section of Highway 101 was divided into sixteen 75m x 8m plots. Each plot was divided into 5 marked 15m x 8m subplots. Each road plot was paired with a plot of the same dimensions in the surrounding meadow. Surveys were conducted 17 August-19 September 2009, spanning peak flight, on road and meadow plots. We performed instantaneous scan sampling and all occurrence surveys and, for approximately 60 min per day, opportunistically recorded all sightings of OSBs in the road. Instantaneous scan sampling determined patterns of OSB presence and evaluated activity levels in the road plots relative to the surrounding habitat. We systematically surveyed each component subplot, until a whole plot was scanned, then repeated the survey. Upon completing ten replicate surveys of a road or meadow plot, we surveyed its paired plot using the same protocol. We recorded date, time, wind speed, temperature, and humidity using a Kestrel 4500 Pocket Weather Tracker. At the instant of each scan, we counted the number of butterflies engaged in any of following seven behaviors (described by Arnold 1988).

The all occurrence survey, recording all OSB activity for 15-minute intervals, documented OSB activities in the road. We observed each road plot four times throughout the season. For every OSB sighting in the road, we recorded the same variables included in scan surveys plus flight direction, flight height, and if a collision occurred.

Number of flowering plants was quantified for 15 road subplots. Five randomly selected subplots were sampled within 1m of the road within each of 3 levels of OSB crossing (none, low, medium). We counted every flowering plant detected at each of the 100 points in a divided square meter frame placed at six randomly located sampling areas in each 1m x15m subplot.

One confirmed account of an OSB-vehicle collision, during the seasonal peak of OSB flight. Another dead OSB was found on the walkway at the north end of the Big Creek Bridge (R Miller unpublished observation). Nine instances of likely OSB-vehicle collisions (apparent mortality) could not be confirmed because in each case the vehicle was moving away from the observer so its grill could not be examined. The road and verge were inspected soon after the vehicle passed but no OSBs were found. Therefore, between 1.0% and 10.5% of the 95 observed road crossings yielded mortality.

OSB presence was more than three times higher in meadow than road plots. Four behaviors were observed in the road: basking, nectaring, flying, and interactive. OSBs rarely basked (three times) or nectared (once) in the road while these were common behaviors in the meadow. The predominant behavior was flying.

Both temperature and humidity were correlated with OSB presence. More OSBs were sighted at warmer temperatures and lower humidity. Wind was not correlated with OSB presence in this study. No difference was detected between OSB presence in the road-cut subplots versus subplots to the immediate north and south, although the road-cut subplots were warmer and had lower wind speeds than in the subplots immediately adjacent to the north and south.

OSB presence in the road was positively related to flowering plants along the roadside. More OSBs were found in the road subplots that had more flowering plants adjacent to them. Five main locations of OSB road crossing, encompassing about half the plots, were apparent within the project area. OSB height of flight (relative to the road surface) among all the road plots mostly occurred within heights affected by vehicles and their turbulence. A majority of OSBs flew directly across the road without lingering. A third of the remaining 40 continued to fly along the road but eventually returned to their road corridor entry points.

Our data on the behavioral and spatial ecology of the OSB at Rock Creek-Big Creek suggest that this threatened butterfly is likely at risk from vehicle collisions but that several management options could reduce this risk. A high proportion of the total OSB observations occurred on the road during scan surveys. During this study, one instance of vehicle-caused mortality was confirmed, nine apparent mortalities occurred (10%) for which vehicle-caused mortality was likely but death could not be verified, and one dead OSB was found along the roadside. We used the study findings on the ecology of these butterflies to rank the effectiveness of management options at reducing the risk of butterfly mortality due to vehicle-butterfly collisions.
Vegetation manipulation has been established as high priority as it offers a benefit at an assumed relatively low, albeit on-going, cost. Based on our data showing more OSBs entered road plots that contained higher densities of flowering plants than plots with fewer flowers, we recommend the verge be cleared of flowering plants, especially during the season of OSB flight. Also, the timing of verge mowing could be coordinated with meadow mowings so the verge does not have greater flowering plant diversity or more patches of flowering plants than the meadow. In addition, we recommend increasing nectar and larval food plants in meadows away from the road, and adding hedgerow or forest fringe for shelter, to meadows on both sides of Highway 101 so butterflies do not have to cross the road to access resources.

Barriers are likely to be successful, but at a greater cost than vegetation manipulation. Hedgerows serve as a strong barrier to Fender’s blue butterflies (*Icaricia icarioides fenderi*) along a two-lane, paved road in Oregon, with only 1.2% of butterflies flying over them (Severns 2008). Fences, netting, guardrails with vertical extensions, and/or concrete (temporary or permanent) structures in key locations could manipulate movement of OSBs, ideally keeping them in meadows longer or forcing them to fly higher over the road and vehicle turbulence than they otherwise would, while allowing access to all habitats. Four lines of evidence suggest this management would be effective. First, butterflies were not seeking the road to use as a habitat, except for nectaring on the verge. They basked less in the road and spent much less time in the road than the surrounding habitat. Second, height of flight above the road was low and typically depended on the height of vegetation or land on either side of the road. Third, OSBs tended to follow the most direct route across the road. Fourth, five road segments (across seven plots) accounted for the majority of OSB crossings, suggesting that strategic placement of relatively narrow barriers could be effective. It may be necessary to extend the length of barriers beyond prioritized plot locations to prevent circumvention of the barriers, such as with fences for ungulates (Clevenger et al. 2001). OSBs were observed following edges and flying into the road once they approached a break in the hedge.

The other management options under consideration are given low priority, as for installing an environmentally triggered flashing speed reduction sign, or removed from the list of options. Uncertain effectiveness, inconvenience to travelers, and high cost may hinder feasibility of the speed reduction sign. The removal and addition of earthen berms and other manipulations of the wind or temperature of the road were eliminated as management options because no sheltering effect or preferential basking of OSBs was detected in the road-cut or elsewhere on the road, despite lower wind speed and higher temperature in the road cut and higher temperature of the road than meadow. Although the mean wind speeds are different from the road-cut subplots to the adjoining subplots, this area does not necessarily represent a shelter from wind as air is funneled through the road-cut independent of prevailing wind direction (Zielin 2010) and vehicles create air movement independent of wind.

Determining which management measures should be pursued to minimize the impact of roads on the surrounding animal community is not always straight-forward. We evaluated potential management techniques to determine which should be pursued further by gathering information on the behavioral ecology of our target organism. We found using ecological observations with management options in mind was an effective technique for prioritizing management options and identifying what related future research is most needed. Vegetation manipulation and barrier installation were designated high priority to reduce vehicle-caused mortality to OSBs, whereas manipulating the wind or sun in the road, including the removal of earthen berms in the road-cut area, appears unjustified, as no sheltering effect and no preferential basking were detected. This approach is likely to be effective for other taxa as well. Because roads are already having large effects on some populations and likely will have more as organisms move in response to climate change, such effective, quick, and inexpensive approaches are needed to identify how best to respond.

**BIOGRAPHICAL SKETCHES**

Sara Zielin conducted this study in partial fulfillment of her Master’s degree in Environmental Management at Portland State University. She now is a field biologist with Northwest Wildlife Consultants in Hood River, Oregon.

Catherine de Rivera is an assistant professor in Environmental Science & Management at Portland State University. Her research examines how behavior and habitat connectivity combine with other biotic interactions and abiotic factors to affect the local to geographic distribution of species and the composition of biological communities. Her research is largely concerned with three overarching and inter-related themes: 1) Investigating anthropogenic, biotic (especially behavioral), and abiotic factors that limit abundance, geographic distribution, and habitat connectivity; 2) Quantifying the effects of the addition or removal of invasive species to recipient communities; and 3) Developing and testing approaches to managing populations and communities. She teaches courses in Road Ecology, The Ecology and Management of Biological Invasions, and Communicating Science, among others.

Winston P. Smith is a Principal Research Scientist, University of Alaska-Fairbanks, with 33 years of experience studying habitat relations and demography of imperiled/sensitive species; ecological advisor to the Columbian White-tailed Deer.
Recovery Team (25 yrs); retired Research Wildlife Biologist with the Pacific Northwest Research Station; wildlife viability expert on the Interdisciplinary Team of PNW scientists for the revision of the 1997 Tongass Land Management Plan; Associate Editor of the Journal of Mammalogy; author of 84 peer-reviewed articles and 18 peer-edited technical publications; and member of the Distinguished Graduate Student Registry, Department of Fisheries and Wildlife, Oregon State University. Current research focuses on influences of landscape composition and structure on functional connectivity and meta-population viability and roads as barriers and ecological traps.

Sandra Jacobson (USDA Forest Service, Pacific Southwest Research Station) is a wildlife biologist who provides technical expertise and training nationally in transportation ecology. She is an invited charter member of the National Academy of Science–Transportation Research Board Committee on Ecology and Transportation; served on the expert panel for the Congressionally-mandated report on animal/vehicle collisions; was an invited transportation task force member for the Western Governors' Association Initiative on Wildlife Movement and Crucial Habitat; is a Steering Committee member for the International Conference on Ecology and Transportation; and served as a member of the Technical Advisory Committee for the international ARC Wildlife Crossings Design Competition. A frequent conference speaker on road ecology, she developed and teaches the credited course called Innovative Approaches to Wildlife and Highway Interactions. She developed and edits the recently renovated Wildlife Crossings Toolkit website.

REFERENCES


INFRASTRUCTURE OBSTRUCTION PROFILING: A METHOD TO ANALYSE ECOLOGICAL BARRIERS FORMED BY TRANSPORT INFRASTRUCTURE

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ABSTRACT

Environmental fragmentation and habitat reduction are among the most widespread factors that cause biodiversity loss. Transportation infrastructure is the principal element that determines and exacerbates such conditions. The infrastructure system is a barrier to movement for most non-flying terrestrial animals because of obstacles like guard rails, new-jerseys, walls, enclosures and vehicular traffic. Each obstacle creates a different degree of occlusion which acts on the various species in different ways. The present study proposes a methodological approach to compare the technical characteristics of roads with their impact on wildlife movement. The analytical procedure is called “Infrastructure Obstruction Profiling” (IOP). It is presented as a longitudinal diagram of the transportation infrastructure along which the degree of interference is expressed in consideration of the entity and the typology of obstacles that are present. The data obtained could support studies of environmental evaluations and inform mitigation measures to reduce habitat fragmentation.

INTRODUCTION

Fragmentation of landscapes caused by road networks of all types is increasing globally. Negative effects are compounded by urban residential areas, as well as commercial and industrial areas scattered along rural roads (Jaarsma 1997). The main adverse effects on ecosystems caused by roads include chemical and noise pollution, invasion of exotic species, declining adjacent area quality and habitat loss, wildlife mortality, environmental fragmentation and reduced ecological connectivity (Jaarsma and van Langvelde 1997).

Road accidents involving wildlife are an important consideration in transport infrastructure design. In Europe, over 500,000 ungulate-vehicle collisions (stags, roe deer, fallow deer and wild boars) have caused about 300 human fatalities, 30,000 human injuries and 1 billion Euro in material damage (Dinetti 2000). In Italy, this type of road accident accounts for approximately 2% of the total and, according to ISTAT (National Central Statistical Institute) data, between 1995 and 2000 there have been over 2,000 animal-vehicle collisions, of which, 76 caused human fatalities.

When roads cross or are adjacent to ecological networks (Noss 1991; Sabo et al. 1996; Bennet 1999) the disturbance caused to wildlife populations is particularly significant as their movement along natural corridors is hindered by the presence of anthropogenic barriers.

Of the European countries, Italy has the least experience and sensitivity towards “road ecology” (Forman et al. 2002) already well-established in northern Europe and the USA since the seventies and eighties (van Gelder 1973; Leedly 1975; Erickson et al. 1978; Wilkins and Schmidly 1980; Ballon 1985; Camby and Maizeret 1985; Schultz 1985; Der Bundesminister Für Verkehr 1987; Podloucky 1989).

The aim of this paper is to introduce a technical tool, called “Infrastructure Obstruction Profiling” (IOP) to quantify fragmentation effects that existing or planned roads have on wildlife within the framework of the “road effect zone” (Forman and Deblinger 2000; Coffin 2007). This tool may help reduce the costs of mitigation significantly, particularly in the design phase. IOP makes it possible to analyse the ecosystem fragmentation caused by a project, allowing us to make technical changes on a case-by-case basis, thereby limiting the “barrier” effect that the road has on the movement of target species.

IOP is aimed at road projects as a tool to support Environmental Impact Assessments and Environmental Incidence Assessments as required by European Directives 85/337/EC of 27th June 1985 and Habitat 92/43/EEC. Examples on existing roads described in this paper are taken from experience gained in central Italy in study areas in the regions of...
Umbria and Abruzzo, where infrastructure causes severe territory fragmentation for species (see Fig. 1 and 2) of conservation interest.

![Figure 1](image1.png)

**Figure 1.** Roads without physical barriers in which it is possible to have many accidents between vehicles and animals.

![Figure 2](image2.png)

**Figure 2.** A multiple barrier formed by railway, high-speed railway and highway

**METHODS**

Roads vary considerably in relation to local geography and the landform of the territory. Some roads are completely isolated from the surrounding context. Fencing or geological protection nets can form an insurmountable barrier for most terrestrial tetrapods and macroinvertebrates. In this case, which generally concerns motorways, some railways and many roads on potentially unstable landforms, the adjacent habitats are highly fragmented (the extent of fragmentation depends on the height of fencing, as well as the form and size of nets). In these cases, the fragmentation impact on habitats is severe, but the virtually inaccessible road also reduces the accidental killing of wildlife by vehicles to a minimum. If the road is not fenced off then the different circumstances summed up in Fig. 3 may occur.
Figure 3. Technical types of road sections

The special cases b2 and c2 do not essentially cause fragmentation, even though, in the b2 case, the height of the road from the ground may hinder crossing by some species. In other cases, ecological connection between habitats crossed by infrastructure is certainly affected, but not interrupted in theory. This is particularly true in case a, while in the other cases there may be a change or reduction in connectivity depending on the landform profile of transverse sections. The obstruction caused by infrastructure is all the more significant when the road section c becomes “canyon-like”, lying at the bottom of deeply excavated areas, or when types c and d are on extremely steep natural landforms. In the latter case, escarpments and embankments are either very high and steep or replaced by supporting walls, thus creating an obstruction of biotic flows similar to that caused by fencing as described earlier.

If sections a, b, c and d have a profile that is not too exaggerated, they can be crossed by all terrestrial species and then the real problem becomes the disturbance caused by vehicle traffic. If traffic flow is very high, then both the continued usage of the carriageway and side effects such as noise, pollution and lighting will create a condition of significant obstruction, thus almost entirely deterring wildlife from crossing (Rhe and Seitz 1990; Findlay and Bourdages 2000).

At a road section used for measurement, if traffic flow is equal to n vehicles/h, the time during which the section is transit-free will be:

\[ \Delta t = \frac{1}{n} \]

The probability of successful road crossing by terrestrial wildlife therefore depends on average speed of movement of animals of various species, road width and length, and width of travelling vehicles and their average speed, if \( \Delta t \) remains constant (Romano 2002; Battisti and Romano 2007). These considerations show the possibility of developing a very detailed biological obstruction coefficient for vehicle traffic involving the use of numerous variables.

However, the key data required is currently scarce in Italian Territorial Information Systems and extremely difficult to process, even if we want to produce ad hoc data for individual projects, given that traffic flows on road sections differ considerably depending on the season or time of the day or night.

To reduce fragmentation caused by existing infrastructure when road-crossing interference due to traffic is significant, we need to carry out works. In the case of sections a, c and d this is extremely difficult both technically and financially,
as it requires ecoducts or culverts. In these cases, works are generally inadvisable, unless it is necessary for a species of great conservation interest. Important examples may be found in the Netherlands, Canada, Switzerland, Germany, Hungary and Norway (Bekker and Iuell 2004; Dinetti 2004; Trocmé 2006); these involve actual bridges that cross roads, equipped with vegetation on the extrados in order to create multiple and parallel ecosystem strips for the movement of various animal species from one side of the road to the other.

In the b1 case, projects involving culverts are feasible (Velasco et al. 1992; Yanes et al. 1995; Rosell and Velasco 1999) with the inclusion of connecting elements and longitudinal “inducements” that may be used by some species of meso- or micro-mammals, amphibians and reptiles (Malcevschi et al. 1996; Dinetti 2000; Merrow 2007). In some cases, it is however possible to exploit the culverts already in place for the channelling of water (Fig. 4), but useful for reducing the road barrier effect for many species of fauna. We can increase their use by local wildlife by improving the substrate and implementing measures to re-naturalise the passageway.

Figure 4. Some culverts built for hydraulic aims

Although, as mentioned previously, high traffic flows create almost insurmountable barriers, very low traffic flows, especially those relating to road sections with a minimum obstruction, such as those of type a, are certainly not harmless. Low traffic flows entail a low disturbance level, creating conditions of apparent peacefulness in the area adjacent to the roadway and therefore do not deter wildlife crossing and frequenting the road area, thus increasing the probability of accidental wildlife-vehicle collisions, compared to more heavily trafficked roads (Scoccianti 2006).

Road mortality data, i.e. systematically classified data on animal-vehicle collisions, are not widespread, especially in Italy. This information is not easy to prepare and requires long periods of observation and data collection. However, if available, it provides a valid support to the analysis of critical road sections (Smith 2004). In the case of road and railway projects, this highlights the need for adequate information on ecosystems regarding the habitats, behaviour and mobility of resident species in the areas which will be crossed (Ferroni et al. 2006; Clevenger and Waltho, 2005).

The greatest barriers to wildlife mobility coincide with multiple infrastructural belts, where there are motorways, railway lines and ordinary roads. In fact, the motorway alone, like railway tracks, causes total physical obstruction of the environmental connections of the territory (Romano 2000). This is due to continuous lateral fencing which prevents accidental or intentional entry of persons and animals (see Fig. 5).

Figure 5. Different typologies of road side barriers
In these circumstances, crossing points exist only when motorways or railway lines run in tunnels or viaducts, at least for animals of a given size. For this reason, a survey of infrastructure is a key element of an analysis of territorial continuity and in seeking potential ecological corridors. In the case of very long tunnels, the infrastructure in question does not cause any disturbance, not even noise, other than at the entrance and exit. In the case of viaducts and bridges on the other hand, especially along motorways where traffic occurs over 24 hours, although crossing is possible, noise and vibrations disturb wildlife movement. The extent and effects of this disturbance may be assessed only on a case-by-case basis, according to the linear expanse of the construction, its height from the ground and the general characteristics (Spellerberg 1998). Some experiences in the Netherlands have shown that certain ungulates do not get closer than 500-600 metres from motorways, but also that there have been significant losses in bird populations within 100-metre strips at the sides of roads (ANPA 1997; Reijnen et al. 1995).

However, even if there are some longitudinal discontinuities of infrastructural barriers, we must also consider that, as in most parts of Italy, infrastructural belts are often associated with residential, or more often commercial and industrial buildings, in varying degrees of density. These form additional barriers and cause concentrated disturbances, even during the night (e.g. property fencing, lighting, noise and localised traffic).

A high level of ecological obstruction is generally attributed to territorial sectors in these situations where opportunities to intervene are scarce. In-depth analysis of these contexts may instead lead to the identification of some plots of land - generally small - where potential micro-permeability for some species may be identified and restored by adopting limited re-naturalization measures.

RESULTS

As described above, IOP is a technical tool that highlights barriers, such as roads and railways, which hinder crossing by terrestrial vertebrates. It serves as a link between the strictly technical characteristics of road infrastructure and its interaction with the surrounding environment. The implementation process involves an initial phase to assess the obstruction caused by the road throughout its longitudinal expanse, regardless of current and future vehicle traffic volume. IOP is a longitudinal diagram of the road axis showing the different types of barriers and their technical parameters along the sides of the carriageway. There can be different sorts of barriers along roads ranging from simple escarpments, supporting or containment walls, fencing, to new jersey road separators, guardrails and anti-noise barriers; each type of barrier leads to different degrees of obstruction which affect terrestrial wildlife to a varying extents, depending on the ability or inability of animals to cross infrastructural section i considered by overcoming lateral barriers. It is only too clear that this ability is tied to the "performance" levels of animals of different species (speed, agility, leaping height and climbing skills); an obstacle that may be easily overcome by one species may be insurmountable for another. For example, a three-metre high, broad-mesh fence may be insurmountable for a large mammal, but will not block the passage of a reptile at all.

The first piece of structural information on the road provided by IOP is tied to the landform of the territory and is the altitude profile. Then, the actual side barriers broken down by type and geometry (height and length) are listed. Further elements registered in IOP concern the cross-section of the road and its relation to the natural landform of the ground (i.e. level, embankment, cut and fill, cutting, terraced) (see Fig. 3).

This structural analysis is followed by a functional analysis to measure the degree of obstruction of barriers for the species present in the ecosystems surrounding the road infrastructure. Given that IOP is an important tool for the study of ecological networks, the set of reference species will be those identified as target species, picked from among "umbrella" or "focal" species (Lambeck 1997; Andelman and Fagan 2001).

For every species considered, the opportunity of crossing road section i is assessed; this implies overcoming the most occlusive lateral barrier among those present on both sides of the carriageway. The information on the degree of agility of species in overcoming the different types of barriers is obtained using expert-based procedures (Table 1) by consulting experts of the various species in question who can provide information on their probability of crossing the various obstacles considered (Romano et al., 2008; Ciabò et al. 2009) in the geographical areas in which the studies are conducted. IOP is represented in a diagram of Figures 6 and 7: Fig. 6 shows an Infrastructure Obstruction Profile (IOP) implemented along the n. 3 national road (Flaminia) in Umbria region in which have been indicated four obstruction levels in relation with 5 target species. On Fig. 7 we have another IOP implemented along the n. 17 national road (Abruzzese and Appulo-Sannitico Apennine) in Abruzzo region. In this case have been indicated six obstruction levels in relation with 10 target species.

On Fig. 8 it possible to see a map with symbols explaining the levels of species-specific obstruction by position for the target species considered in the IOP of Figure 6.
Table 1. Expert based table about degree of agility of species in overcoming the different types of barriers

<table>
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<tr>
<th>Target species</th>
<th>Barriers</th>
<th>( h &lt; 0.7 \text{ m} )</th>
<th>( 0.7 \text{ m} \leq h &lt;1.5 \text{ m} )</th>
<th>( 1.5 \text{ m} \leq h &lt;2 \text{ m} )</th>
<th>( 2 \text{ m} \leq h &lt; 3 \text{ m} )</th>
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Figure 6. IOP implemented along the n. 3 national road (Flaminia) in Umbria region.
Figure 7. Another IOP implemented along the n. 17 national road in Abruzzo region.

Figure 8. Map schemes of six obstruction levels (indicated by different size of lines) for the target species considered in the IOP of Figure 6.
CONCLUSIONS

IOP can be used in many ways in infrastructure design and planning processes. Firstly, it is a flexible tool to gain information on the permeability of an area crossed by infrastructure, as it provides data that may be used at different levels:

- broad scale, by indicating the areas with the highest probability of wildlife passage;
- local scale and detailed level, by indicating if and where infrastructure can be crossed.

This helps optimise the planning of ecological networks and, at the same time, identify places – even small ones – where one can intervene by implementing mitigation projects.

It is important to stress that the data acquired through IOP should be supplemented by other additional information, in the case of projects concerning new roads or works to mitigate existing infrastructure. In the first case, it is essential to fit the new infrastructure in the territorial-environmental setting where it will be erected, by surveying and modelling the changes that it will bring about to the existing road system and the local ecosystem. In this case, it is useful to conduct interference analysis by applying thematic indices, such as infrastructure density and the infrastructure-related fragmentation index (Romano 2000).

In the case of studies on existing road networks, instead, it is important to have data, collected using systematic and planned methods, on the various impacts produced by infrastructure, especially those tied to traffic flows, such as pollution curves, sound propagation functions, in addition to the number and species of animals killed in collisions with vehicles. Besides the yearly average values of the aforementioned indices, it would be important to have data broken down per month, day and sample hour and season in order to relate them effectively with the phenology of the species, and also taking into account that the behaviour of a wild species towards barriers is not always the same in all the geographical areas of their range.

As is only too evident, this data is hardly easy to collect and requires significant financial investment by organisations, as well as adequate extension of study and data collection time. The availability of information systems of the sort described herein would help enrich the database accompanying IOP significantly, thus making it possible to standardise it in a simple way, and include it among the means used to inform road or railway projects and in the assessment systems of such infrastructure (especially EIS).

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