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Road mortalities of vertebrate species on Ring Changbai Mountain Scenic Highway, Jilin Province, China

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Abstract. The incidence of wildlife mortality on roads is a widespread phenomenon reported in many countries; despite this, it has received limited attention in China. To address this issue, a field investigation was conducted to assess the magnitude, composition, and temporal patterns of road mortality of native vertebrates on Ring Changbai Mountain Scenic Highway in north-east China from 2009 to 2012. A total of 3.475 vertebrates, belonging to 63 species were recorded as road mortalities. Amphibians were the most abundant taxa recorded (86.21 %), followed by mammals (5.70 %), birds (5.24 %), and reptiles (2.85 %). Regarding the number of species affected by the incidence of road kills, birds were the most affected taxa (31 species), followed by mammals (16 species) and reptiles (10 species), while amphibians were the least affected taxa (6 species). Three vertebrate species that were recorded as road mortalities are under second class protection in China. There were no differences between seasons or months for road mortality or richness for bird and reptile taxa, while significant differences between months were observed for mammals and amphibians. Mammal road mortality was highest in August, most road kills being encountered for the Siberian Chipmunk (*Tamias sibiricus* Laxmann, 1769) mortalities. Amphibian road mortality was highest in June, most road kills being encountered for the Chinese Brown Frog (*Rana chensinensis* David, 1875), Oriental Fire-bellied Toad (*Bombina orientalis* Boulenger, 1890), and Asiatic Toad (*Bufo gargarizans* Cantor, 1842). Each taxonomic group showed no distinct differences in species richness between months. This research recommends creating wildlife crossing structures for amphibians and small-sized mammals to reduce the incidence of road mortalities and adopting traffic management measures to mitigate amphibian mortality especially from April to September, and strictly controlling speed limitations to 60 km/h on this highway.

Key words: road kill, traffic casualties, road ecology, roadside, wildlife mortality.

Introduction

The ecological effects of roads on biological and environmental systems can be complex and extensive (Forman et al. 2003, Mao et al. 2009). Impacts can extend across different distances from the vertical direction of the highway, which can be explained by the "Road-effect zone" proposed by Forman (2000), estimating that 1/5 of the area in USA is directly impacted by road systems (Forman 2000).

By the end of 2010, in China, the total length of the highway network was 4106.400 kilometers, and the total length of the expressway was 84.900 kilometers, which ranks China as the second largest road-surfaced country in the world (Ministry of Transport of China 2012). China has enriched and diverse wildlife resources, with approximately half of China's wildlife being endemic to the region (Liu et al. 2003). The contradiction between large-scale road construction and biodiversity conservation is an obvious and emergent field in China. Therefore, research on road ecology has emerged and developed quickly during recent decades and this has attracted global attention (Mao et al. 2009, Forman et al. 2011)

The impact of roads on wildlife is an important concept in road ecology and has recently attracted considerable attention; animal mortalities are the most apparent and immediate recognizable ecological effect of roads (Gu et al. 2011, Gunson et al. 2012). Wildlife of all size classes can be affected, from insects to large cervids (Trombulak & Frissell 2000). At the global level, wildlife mortalities caused by vehicles has exceeded hunting mortalities, and accounts for the largest human-induced mortalities of terrestrial vertebrates (Forman & Alexander 1998). A vast range of research is now being conducted in this field, focusing on road mortalities in many countries in the world, especially in North America (Clevenger et al. 2003, Sielecki 2010), Europe (Elzanowski et al. 2009, Grilo et al. 2009, Carvalho & Mira 2011, Cicort-Lucaciu et al. 2012, Covaciu-Marcov et al. 2012, Markolt et al. 2012), Australia (Ramp et al. 2006), South America (Coelho et al. 2008), and Asia

(Saeki & Macdonald 2004, Baskaran & Boominathan. 2010).

Few incidents regarding national and international rare and endangered wildlife species injuries or mortalities during vehicle accidents have received recent public attention in China, including incidents of road mortalities of amphibian species on the highway passing through the Zoige wetland National Nature Reserve (Dai 2007), Asian elephant mortalities (*Elephas maximus* Linnaeus, 1758) on the Simao-xiaomengyang motorway section cutting through Xishuangbanna Nature Reserve (Pan et al. 2009), and road collisions of Przewalski's Wild horses (*Equus ferus caballus* Linnaeus, 1758) on roads cutting through Kalamaili Nature Reserve (Zhang et al. 2008). The conflict between wildlife mortality and motorway usage is therefore an obvious and urgent issue for investigating road mortalities of vertebrate species in China (Wang et al. 2010a). There is only a limited number of long-term datasets examining the impact of road mortalities across multiple taxonomic groups in China. This research is the first to examine the impact of road mortalities on vertebrate wildlife over a 2 years investigation on the Ring Changbai Mountain Scenic Highway in the Jilin Province, China.

The aim of this study was to investigate the impact of road mortality on wildlife at the Ring Changbai Mountain Scenic Highway, spanning the composition and temporal patterns of wildlife mortalities. We hypothesize that the impact of road mortality on wildlife composition along the highway varies across seasons, months and taxonomic groups. For testing this hypothesis, the road mortality of four groups of taxa was examined across different seasons and months.

Material and methods

Description of the study site

Changbai Mountain National Nature Reserve is located in the Southeast of the Jilin province, across the Antu County of Yanbian Korean Autonomous Prefecture, Fusong County and Changbai County of Hunjiang Area, adjacent to North Korea. The nature reserve lies between E 127°42′55″-128°16′48″ and N 41°41′49″-42°51′18″, covering a total area of 196.465 hectares. The study area experiences a monsoon continental mountainous climate, with long, cold winters and short, warm and humid summers. Annual average temperature is 2-5 °C, with 2.300 sunshine hours per year, and generally frost-free periods accounting for 100 days. Changbai Mountain is one of the largest volcanic areas of East Asia, with a volcanic lava tectonic geomorphology, water landscapes, glaciers, and periglacial landforms. Changbai Mountain Reserve is a Man and Biosphere Reserve area, and is one of the richest biodiversity regions in China. There are more than 1.225 wildlife species in the region, with 59 species declared as national key protected species, mainly including National 1st Class Protected Wildlife, like the Sable (Martes zibellina Linnaeus, 1758), Siberian Roe Deer (*Capreolus pygargus* Pallas, 1771), and Siberian Weasel (*Mustela sibirica* Pallas, 1773). Additionally, the Siberian tiger (*Panthera tigris altaica* Temminck, 1884) historically inhabited this area (Chen et al. 2010).

In 2007, the Ring Changbai Mountain Scenic Highway was upgraded to a paved surface. With the gradual expected increase in traffic volume, an increased rate of wildlife-vehicle collisions and barrier effects were predicted. This highway mainly circled Changbai Mountain Nature Reserve, and mostly covered an existing forest road. The road starts from Erdaobaihe Town, Antu County of Yanbian Korean Autonomous Prefecture and finishes in Manjiang Town, Baishan City. Total highway length is approximately 84 km, with a 21 km (K10-K31) section overlapping the edge of the Nature Reserve and a 6 km (K31-K37) section bisecting an experimental zone of the Nature Reserve. A standard secondary road was constructed along this highway, with a designated speed limit of 60 km/h, and a subgrade width of 10 m. The research area is presented in Fig. 1.

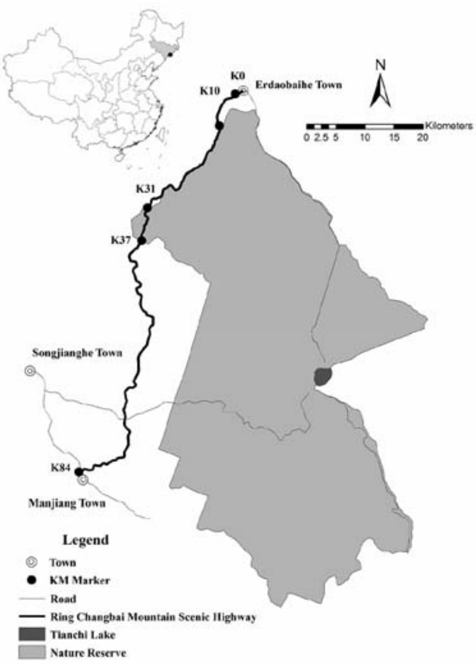


Figure 1. Sketch map of the research area.

Roadkill mortality investigation

Firstly, we carried out an investigation of wildlife mortalities on 7 separate occasions along the highway in 2009, during which a large number of wildlife-vehicle collisions were observed.

In order to figure out the actual number of wildlife species fatalities caused by cars, we decided to carry out regular field investigations, from April 2010 to March 2012, with two investigations conducted at least twice per month, and we selected the beginning, middle or end of the month to investigate wildlife mortalities along the highway. All surveys were conducted by car during daylight hours. We did not survey at night or in inclement weather due to poor visibility. One of the investigators drove the car at a low speed of 30 to 50 km/h, and another investigator observed and recorded any wildlife fatalities along the highway. If mortality was observed on the road, investigators stopped to record the species, number of individuals, and took a photograph; with the study focusing on amphibian, reptile, bird and mammal taxa. We recorded identifiable carcasses that were present on the road but did not consider carcasses hidden in roadside vegetation (following methods of Brenda and Michael, 2008). The length of highway investigated was different in each time period, from 20 km up to 85 km.

Migration intensity and breeding behavior for amphibians is strongly influenced by weather conditions (Hartel et al. 2009). Considering this, we increased the frequency of investigations from April to September during amphibian migration activities according to varying weather conditions. We have specifically done this to coincide with periods of rainfall, during which amphibians migrate between forests and wetlands and the likelihood of road mortalities increases (Wang et al. 2013). Furthermore, actually almost all wildlife is physiologically active from April to September in the Changbai Mountain area.

After recording the above details, each carcass was removed from the road in order to avoid double counting and if unidentified, the carcass was preserved in formalin for later identification.

<u>Data analysis</u>

During some investigation periods we did not locate any wildlife mortalities, so the recorded data was standardized for each recording period (month and season) per every 100 km mortality quantities. Where sample numbers were adequate, a biological difference in number of mortalities by season or month was examined (Smith-Patten & Patten, 2008).

According to the climatic features, seasons were defined as winter (December, January, February), spring (March, April, May), summer (June, July, August), and autumn (September, October, November).

During November to March, the highway is commonly covered by snowfall, where traffic volume may be reduced to 300-500 vehicles daily, and the speed is commonly reduced to < 60 km/h (Wang et al. 2010b). Additionally, amphibian, reptile, and some mammal species hibernate during this time, with many bird species migrating south, thus, lower wildlife mortalities would be expected at this time. In addition, highway maintenance vehicles often remove snow from the highway, thus we disregarded the record and mileage during this time.

The data of species richness and mortality of every group was abnormally distributed (one sample Kolmogorov-Smirnov test, $p < 0.05$). A Kruskal-Wallis H test was used to test the differences in the species richness and mortality among different groups; a Mann-Whitney U test was used to test the differences in the two groups.

The mortality data of all groups (amphibians, reptiles, birds and mammals) in different seasons (spring, summer and autumn) and months (April, May, June, July, August, September and October) was abnormally distributed (one sample Kolmogorov-Smirnov test, $p < 0.05$), so a Kruskal-Wallis H test was used to test the differences in the different seasons and months, and a Mann-Whitney U test was used to test the differences in the two periods among seasons or months.

The data of species richness of all groups (amphibians, reptiles, birds and mammals) across different seasons (spring, summer and autumn) and months (April, May, June, July, August, September and October) was normally distributed (one sample Kolmogorov-Smirnov test, $p > 0.05$), so a one way ANOVA test was used to test the differences in the different seasons and months, a LSD or Tamhane's T2 test was used to test the differences in two periods among seasons or months. For each group, we used Chi-square tests of Nonparametric Tests to determine if there were any differences among mortality or species richness in different months. Exact binomial tests were used to determine if there were significant differences among months.

A value of $p < 0.05$ was considered significantly different for all statistical tests. All statistical calculations were carried out using SPSS 15.0 for Windows software.

We believe that exact practical data and complementary information collected by applying the direct dependent variables method (species richness and mortality) would be useful for management purposes (Arevalo & Newhard 2011).

Results

<u>Magnitude and composition of wildlife mortalities on the highway</u>

From April 2009 to March 2012, we conducted 128 observation periods along the Ring Changbai Mountain Scenic Highway, the investigative samples collected along 7.151 km in total. Almost no road-kill of wildlife was recorded during November, December, January, February and March, so we did not consider this period for further analysis, focusing only on the April to October period, during 2009, 2010 and 2011. We conducted 101 surveys, along a total distance of 5.641 km.

We recorded 3.475 wildlife mortalities belonging to 63 vertebrate species, resulting in 61.6 individuals/100 km during the research period (Table 1). In terms of magnitude, amphibians were the most abundant mortality class (2.996 individuals, 86.21 %), followed by mammals (198, 5.70 %) and birds (182, 5.24 %). Reptiles were least affected by

Table 1. Wildlife road mortalities of species on the Ring Changbai Mountain Scenic highway, China (No- Number of road mortalities recorded).

Taxa	Common name	Scientific name	No
Amphibians	European Tree-Frog	*Hyla arborea* Linnaeus, 1758	35
	Asiatic Toad	*Bufo gargarizans* Cantor, 1842	186
	Oriental Fire-bellied Toad	*Bombina orientalis* Boulenger, 1890	853
	Black-spotted Pond Frog	*Pelophylax igromaculatus* Hallowell, 1861	1
	Chinese Brown Frog	*Rana chensinensis* David, 1875	1826
	Siberian Salamander	*Salamandrella keyserlingii* Dybowski, 1870	95
Reptiles	Mongolia Racerunner	*Eremias argus* Peters, 1869	1
	Steppes Ratsnakes	*Elaphe dione* Pallas, 1773	48
	Japanese Keelback	*Amphiesma vibakari* BOIE,1826	1
	Halys Pit Viper	*Gloydius halys* Pallas, 1776	13
	Red-backed Rat Snake	*Elaphe rufodorsata* Cantor, 1842	2
	Tiger keelback Snake	*Rhabdophis tigrinus* F. Boie, 1826	6
	Adder	*Vipera berus* Linnaeus, 1758	17
	Manchurian Black Water Snake	*Elaphe schrenckii* Strauch, 1873	9
	Unidentified snakes (2 species)		2
Birds	Eye-browed Thrush	*Turdus obscurus* Gmelin, 1789	1
	Pale Thrush	*Turdus pallidus* Gmelin, 1789	2
	White Wagtail	*Motacilla alba* Linnaeus, 1758	5
	Tristram's Bunting	*Emberiza tristrami* Swinhoe, 1870	17
	Pine Bunting	*Emberiza leucocephalos* Gmelin,SG, 1771	1
	Daurian Redstart	*Phoenicurus auroreus* Pallas, 1776	1
	Ural Owl	*Strix uralensis* Pallas, 1771	7
	Long-tailed Rosefinch	*Uragus sibiricus* Pallas, 1773	1
	Long-tailed Tit	*Aegithalos caudatus* Linnaeus, 1758	4
	Chestnut-eared Bunting	*Emberiza fucata* Pallas, 1776	1
	Manchurian Bush- warbler	*Cettia canturians* Swinhoe, 1860	1
	Brown Shrike	*Lanius cristatus* Linnaeus, 1758	1
	Orange-flanked Bush-robin	*Tarsiger cyanurus* Pallas, 1773	4
	Hazel Grouse	*Bonasa bonasia* Linnaeus, 1758	12
	Yellow-throated Bunting	*Emberiza elegans* Temminck, 1835	16
	Grey-backed Thrush	*Turdus hortulorum* Sclater, 1863	18
	Eurasian Bellfinch	*Pyrrhula pyrrhula* Linnaeus, 1758	2
	Gray Wagtail	*Motacilla cinerea* Tunstall, 1771	16
	Cinereous Bunting	*Emberiza cineracea* Brehm, 1855	51
	Barn Swallow	*Hirundo rustica* Linnaeus, 1758	1
	Grey-headed woodpecker	*Picus canus* Gmelin, 1788	1
	Tree Sparrow	*Passer montanus* Linnaeus, 1758	4
	Coal Tit	*Parus ater* Linnaeus, 1758	1
	Common Buzzard	*Buteo buteo* Linnaeus, 1758	1
	Eurasian Nuthatch	*Sitta europaea* Linnaeus, 1758	5
	Rufous Turtle Dove	*Streptopelia orientalis* Latham, 1790	1
	Olive-backed Pipit	*Anthus hodgsoni* Richmond, 1907	1
	Little Grebe	*Podiceps ruficollis* Pallas, 1764	1
	Marsh Tit	*Parus palustris* Linnaeus, 1758	3
	Unidentified birds (2 species)		2
Mammals	Far Eastern Myotis	*Myotis bombinus* Thomas, 1906	1
	Manchurian Hedgehog	*Erinaceus amurensis* Schrenk, 1859	7
	Large Japanese Field Mouse	*Apodemus speciosus* Temminck, 1844	4
	Manchurian Hare	*Lepus mandshuricus* Radde, 1861	8
	Spotted Giant Flying Squirrel	*Petaurista elegans* Müller, 1840	1
	Brown Rat	*Rattus norvegicus* Berkenhout, 1769	1
	Northern Red-backed Vole	*Clethrionomys rutilus* Pallas, 1779	1
	Siberian Chipmunk	*Tamias sibiricus* Laxmann, 1769	143
	Eurasian Badger	*Meles meles* Linnaeus,1758	2
	Siberian Weasel	*Mustela sibirica* Pallas, 1773	1
	Weasel	*Mustela nivalis* Linnaeus, 1766	3
	Siberian Roe Deer	Capreolus pygargus Pallas, 1771	1
	Common Shrew	*Sorex araneus* Linnaeus, 1758	6
	Large Mole	*Mogera robusta* Nehring, 1891	1
	Domestic Cat	*Felis catus* Linnaeus, 1758	1
	Grey Red-backed Vole	*Clethrionomys rufocanus* Sundevall, 1846	17
	Total		3475

vehicular traffic and comprised 2.85 % (99 individuals) of the total mortalities. In terms of the number of species, birds (31 species) were the most abundantly impacted taxa, followed by mammals (16 species), and reptiles (10 species), while amphibians were the taxa with the lowest species richness recorded (6 species).

Four species were most prone to collisions: Chinese Brown Frog (*Rana chensinensis* David 1875, n=1,826), Oriental Fire-bellied Toad (*Bombina orientalis* Boulenger 1890, n =853), Asiatic Toad (*Bufo gargarizans* Cantor 1842, n=186), and Siberian Chipmunk (*Tamias sibiricus* Laxmann 1769, n=143). The total quantity of these four species accounted for 86.56 % (3.008) of all wildlife mortalities along the highway. At present, the influence of road mortalities on the population stability of these four species is unknown, as data collection occurred over a short timeframe. Three species observed as road mortalities are listed under second class protection in China: the Hazel Grouse (*Bonasa bonasia* Linnaeus 1758, n = 12), Ural Owl (*Strix uralensis* Pallas 1771, n = 7), and Common Buzzard (*Buteo buteo* Linnaeus 1758, n = 1) (Fig. 2).

There was a significant difference in mortality numbers among the four taxonomic groups observed (Kruskal-Wallis H test, 8.631, df = 3, p = 0.035, Table 2). Amphibian mortalities were significantly higher than all other taxa ($p < 0.05$), while no differences among the other three taxa were observed ($p > 0.05$). Distinct differences in species richness was found among the four groups (Kruskal-Wallis H test, 16.192, df = 3, P = 0.001, Table 2), with bird species richness being higher than the other taxa ($p < 0.05$), while no differences among the other three taxa was observed ($p > 0.05$).

Temporal distribution of wildlife highway mortalities

Both mortality and species richness showed no significant differences across seasons (Mortality: Kruskal-Wallis H test, 1.885, df = 2, p = 0.390; species richness: One way ANOVA test, $F_{2,9}$= 1.022, p = 0.398, Table 2) or months (Mortality: Kruskal-Wallis H test, 8.279, df = 6, p = 0.218; species richness: One Way ANOVA, $F_{6,21}$ = 1.220, p = 0.335, Table 2).

None of the taxonomic groups showed distinct differences among months in species richness (birds: Chi-Square test, X^2 = 11.78, df = 6, p = 0.067; mammals: X^2 = 6.4, df = 6, p = 0.380; amphibians: X^2 = 2.545, df = 5, p = 0.770; reptiles: X^2 = 2.429, df = 5, p = 0.787; Fig. 3).

Neither bird, nor reptile mortalities showed significant differences among all months (birds: Chi-Square test, X^2 = 8.667, df = 6, p = 0.193, Fig. 3a; reptiles: X^2 = 5.750, df = 5, p = 0.331; Fig. 3b), while significant differences were observed for mammals (X^2 = 18.067, df = 6, p = 0.006; Fig. 3c) and amphibians (X^2 = 74.252, df = 5, p = 0.000; Fig. 3d). The exact binomial tests showed that mammal mortality was higher in August (11.09 ind./100 km) than in any other months (range from 1.13 ind./100 km in May to 6.8 ind/100 km in September) (Fig. 3c), most mortalities occurring in the case of the Siberian Chipmunk (Aug 10.22 ind./100 km, others months range from 0.85 ind./100 km in May to 4.08 ind./100 km in Sep) (Fig. 4a). The exact binomial tests also showed that amphibian mortalities were higher in June (69.23 ind./100 km) than in any other month (range from 10.34 ind./100 km in September to 45.71 ind./100 km in July) (Fig. 3d), most mortalities were encountered for the Chinese Brown Frog, Oriental Fire-bellied Toad, and Asiatic Toad species (Fig. 4 b,c,d).

Discussion

Scientific investigations by the Changbai Mountain Academy of Science reported that 8 amphibian species, 13 reptile species, 193 bird species and 56 mammal species inhabit the Changbai Mountain Nature Reserve (report of monitoring wildlife, unpublished data). Therefore, wildlife road mortality and species richness of amphibians accounted for 75 % of observations from our study in this protected area, reptiles were 76.92 %, birds were 16.06 % and mammals were 28.57 %. Wildlife are prone to road related injuries and mortalities along highways; for example in the Netherlands, 50 % of the Dutch butterfly fauna (80 species) are common highway mortalities (Ministry of Transport 2000). In England, road mortalities occur for 40 % of the 50 mammal species, 20 % of the 200 bird species, 100 % of the 6 reptile species and 83 % of the 6 amphibian species (Way 1977). A rich variety of roadside wildlife mortalities calls for further investigations to protect wildlife diversity in these areas.

The vertebrate mortality observed on the Ring Changbai Mountain Scenic Highway, Jilin Province, China was 61.6 ind./100 km, which was higher in comparison with 8.5 ind./100 km in the

a.) b.) c.) d.)

Figure 2. Wildlife mortalities resulting from vehicle-wildlife collisions on Ring Changbai Mountain Scenic Highway: **a.)** Ural Owl; **b.)** Hazel Grouse; **c.)** Siberian Roe Deer(*Capreolus pygargus* Pallas, 1771) (blood on the paved highway) (China Species Red List – VU); **d.)** Weasel (*Mustela nivalis* Linnaeus, 1766) (China Species Red List – VU).

Table 2. Temporal distribution of mortality and species richness for four taxonomic groups.

Months /seasons	Birds		Mammals		Amphibians		Reptiles	
	Mortality (ind./100km)	Species richness	Mortality (ind./100km)	Species richness	Mortality (ind./100km)	Species richness	Mortality (ind./100km)	Species richness
April	1.18	4	1.18	2	39.48	1	0.00	0
May	3.19	12	1.13	3	10.42	4	0.66	2
Spring	2.35	12	1.15	3	22.57	3	0.38	2
June	4.92	11	2.77	4	69.23	5	2.62	5
July	5.82	14	2.96	6	45.71	4	2.04	5
August	6.30	12	11.09	5	32.17	4	5.65	6
Summer	5.65	22	4.69	7	50.05	6	3.01	7
September	1.22	6	6.80	9	10.34	4	2.31	4
October	1.62	4	4.41	6	0.00	0	1.86	6
Autumn	1.37	10	5.92	10	6.52	4	2.14	8

southern Great Plains highway (Smith-Patten & Patten 2008) and 47 ind./100 km in southern Portugal highway (Grilo et al. 2009) . While this observation is lower than that recorded for tropic forest highways, 72.58 ind./100 km has been recorded in India (Baskaran & Boominathan. 2010) and 408 ind./100 km in Brazil (Coelho et al. 2008). As the taxonomic groups within other research studies were different, as well as survey methods and local population conditions, the interpretation of these comparisons remains difficult (Gu et al. 2011).

Wildlife road mortalities of amphibians were numerous in our study site, and this was also the most abundant wildlife taxa along this highway. The reason for this high number may additionally be attributed to their slow mobility during reduced visibility conditions (Baskaran & Boominathan. 2010, Cicort-Lucaciu et al. 2012), and higher population densities along this highway relative to

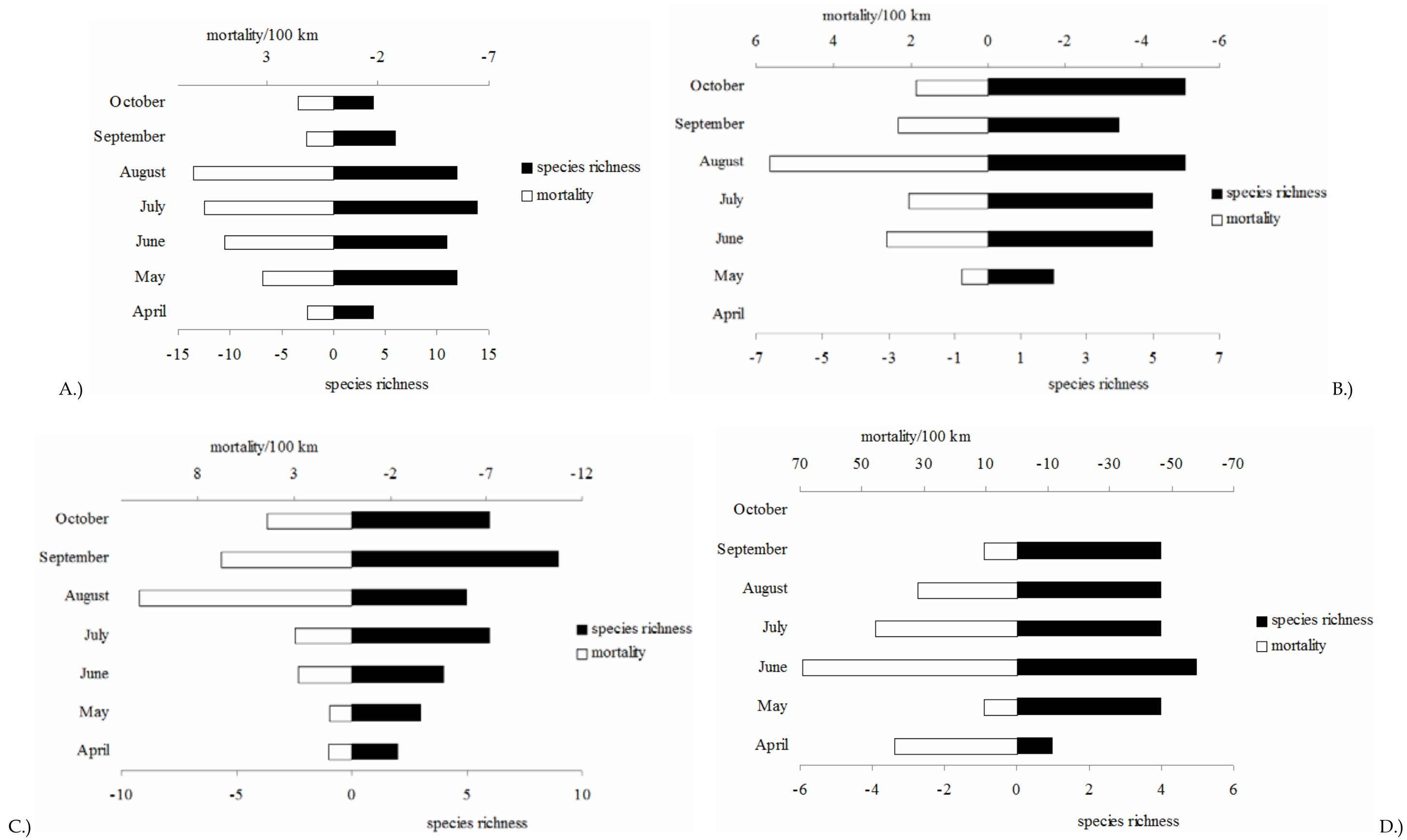
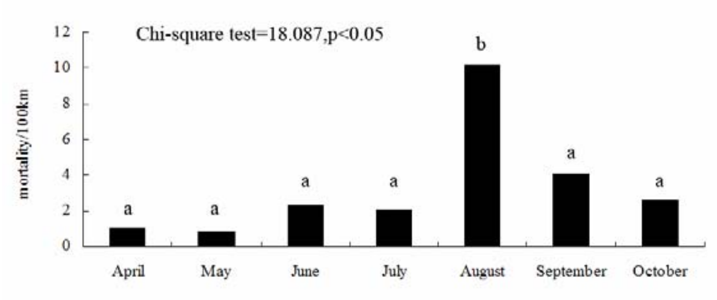
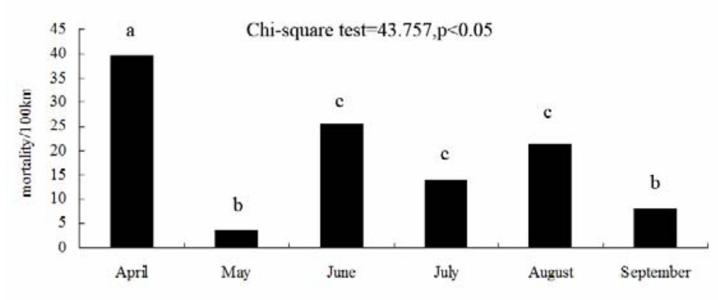


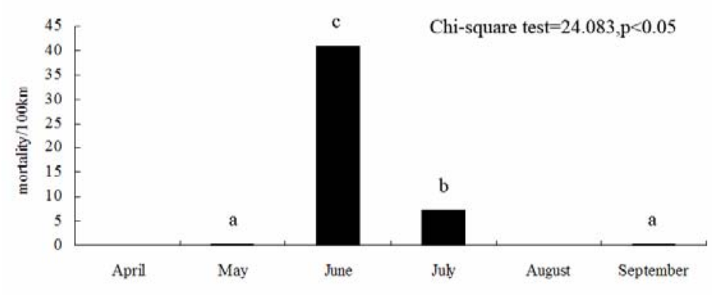
Figure 3. Mortality and species richness in different months for four taxonomic groups (A.- birds, B.- reptiles, C.- mammals, D.- amphibians).



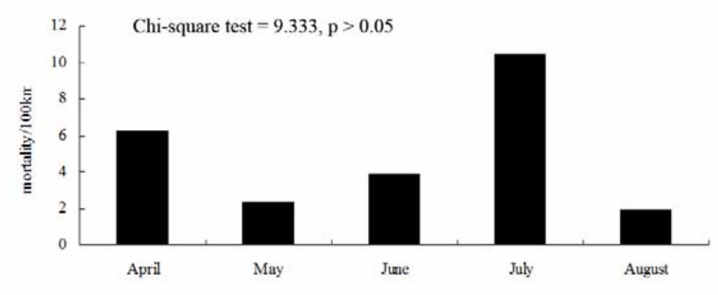
A. - Siberian chipmunk



B. - Chinese Brown Frog



C. - Oriental Fire-bellied Toad



D. - Asiatic toad

Figure 4. Mortality/100 km on different months of four species. Same letters indicate no significant differences ($p > 0.05$) and different letters indicate significant differences ($p < 0.05$) between pairs of months.

other taxa observed in this investigation (Fahrig et al. 1995, Mazerolle et al. 2004, Gu et al. 2011). In addition, the specific life-history (phenological periods) was correlated to the mortality of amphibians (Hartel et al. 2009, Gunson et al. 2012). In the Changbai Mountain area, amphibian migrations mostly occurred from April to September, at the same time the traffic volume in this area increased due to peak tourist activity. Because the migratory route of amphibians is bisected by the highway, high amphibian mortality is currently unavoidable.

Bird species were the most abundant taxa recorded among road mortalities. Vehicle speed is considered a crucial and vital reason leading to vehicle collisions with bird species along highways (Kociolek 2011). Although the official speed-limit is 60 km/h along the Ring Changbai Mountain Scenic highway, our field investigation noticed that more than half of the vehicle speeds approached 80 to 100 km/h during the study. In addition, the three nationally protected species that we observed as road mortalities were all bird species. The Hazel Grouse remains active along the roadside as the species reportedly uses gravel and coarse soil (remaining from road construction) for sand baths. Hazel Grouse are not great flight birds, which increases the probability of injury or mortality by vehicles. The Ural Owl is largely active at night, when traffic volume is lower, although we observed mortalities also for this protected species.

Mammal road mortalities were largely comprised of nocturnal species, while road mortalities of the Siberian chipmunk occurred during the day, mostly in August. This may be attributed to three main reasons: abundance of fruiting seed plants during August, garbage expulsion from vehicles is high during peak tourist seasons, these factors may attract chipmunks to feed along highway, besides, the species is diurnal, therefore its activity period corresponds to higher traffic volume (Piao et al. 2012).

Road mortality can be especially destructive to carnivores that normally have low reproductive rates, low population densities, and large home ranges (Trombulak & Frissel 2000). Similarly, it has been observed that road mortality of the endangered Florida Panther is a major cause of mortality in this species; this phenomenon accounts for 49 % of panther mortalities (Foster & Humphrey 1995). In 2006 in India, an adult tiger and a leopard cub were killed by speeding vehicles in the Tiger Reserve, and the decreasing population density is strongly influenced by such kind of unexpected loss (Baskaran & Boominathan 2010). In the current study, we found at least two carnivore mortalities listed under second class protection in China, and although we were unable to exactly estimate the population density within the Changbai Mountain area, we predict that it is low.

Wildlife road mortalities may be underestimated for several reasons; including unidentified carcasses or removal due to scavenging, decomposition, rain flushing or injured wildlife seeking refuge alongside the highway (Ramp et al. 2006, Coelho et al. 2008, Grilo et al. 2009). Despite these biases, our data allow relative comparisons and provide a representative sample of wildlife road mortalities in northeast China.

Implications for management

This research recommends creating a wildlife crossing structure together with barrier walls for amphibians and small-sized mammals to reduce road mortality (Lucaciu et al. 2012), and adopting traffic management measures to mitigate the amphibian mortality especially from April to September, with special emphasis on rainy days, and strictly controlling compliances with the 60 km/h legal speed limit on this highway. International research indicated that barrier walls and culverts can effectively reduce wildlife mortality of amphibians, reptiles and mammals (Dodd et al. 2004, Bond & Jones 2008). Several researchers provide recommendations of the size of crossing structures and fences (Woltz et al. 2008, Clevenger & Huijser 2011), and recommend temporarily closing roads with gates and signage to reduce wildlife mortality which proved to be highly successful strategies to mitigate wildlife mortalities (Forman et al. 2003). In addition, we advise the investigation into the effectiveness of wildlife crossing structures on sections of the Ring Changbai Mountain Scenic highway to reduce wildlife road mortalities. Similar measures should be examined in other highway areas in an attempt to preserve the connectivity of habitat on both sides of the highway and to reduce the road-barrier effect and habitat fragmentation.

The current speed limit along the Ring Changbai Mountain Scenic Highway is 60 km/h, which we recommend to be strictly implemented in the area of the Nature Reserve to reduce the incidence of wildlife mortalities. We recommend that the Changbai Mountain transportation agency engage in public education activities to raise awareness of the impact of roadside mortalities on wildlife populations. Heightened public awareness of the intrinsic value of wildlife, no matter how common, will assist with the reduction of negative impacts on wildlife (Smith-Patten & Patten 2008). Highways benefit human access to areas that were previously inaccessible, but this comes at a cost of human disturbance of nature that is becoming an increasingly more serious issue (Markolt et al. 2012). The effects of increased population pressure can lead to increased negative influences of roads on wildlife, therefore reasonable human activity management is essential for the protection of wildlife biodiversity in China, and worldwide.

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