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Monitoring wildlife crossing structures along highways in Changbai Mountain, China

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ABSTRACT

In China, the construction and monitoring of wildlife crossing structures is uncommon. Mountainous area occupies two-thirds area of China. A lot of tunnels (similar to overpasses in developed countries), bridges, and culverts (similar to underpasses) are constructed along highways. In general, these structures are multifunctional, including wildlife migration. However, studies on monitoring these potential crossing structures are almost vacant. Taking two highways in Changbai Mountain area as case studies, infra-red camera trapping and snow tracking were used to investigate the efficiency of tunnels, bridges and culverts on the highways. A total of 13 medium and large-sized wildlife species crossed highway through tunnels, bridges and culverts. One third of species were Chinese national protective species, and almost all species were present within 500 m from Ring Changbai Mountain Scenic highway used bridges and culverts to cross this highway. The tunnel along the expressway (length = 1000 m) and the bridges along the highway (width > 8 m) have been important passages for ungulates, Eurasian red squirrels (*Sciurus vulgaris*), yellow throated martens (*Martes flavigula*) and sables (*Martes zibellina*). Different species preferred to different types of structures, although most species preferred to bridges and tunnels. We suggest that short fences should be set around the bridges and culverts to guide animals to cross the passages, especially for ungulates. Monitoring programs of uses of crossing structures by wildlife should be conducted for at least 2 months to catch most species activity.

1. Introduction

The impact of roads on wildlife has been recognized widely in Europe, North America and Australia. The primary negative impacts include (1) road mortality (Glista et al., 2009; Baskaran and Boominathan, 2010; Wang et al., 2013a; Kušta et al., 2014a,b), (2) changes in wildlife migratory routes caused by roads and vehicles (Hoeven et al., 2009; Neumann et al., 2012), (3) barrier effects that restrict wildlife activity and gene flow (Gerlach and Musolf, 2000; Shepard et al., 2008), (4) changes in roadside environment (Ascensao et al., 2012), (5) deteriorate and fragmentation of wildlife habitats (Ortega and Capen, 1999; T.A. Li et al., 2010; Z.X. Li et al., 2010). Some positive effects including creating roadside habitat for some species (Meunier et al., 2000), and serving as corridors that may improve the move ability of some species (Laursen, 1981).

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The main measures to mitigate these negative impacts include locating the suitable road network planning (Rhodes et al., 2014), and building different types of wildlife crossing structures, commonly, which consist of overpasses and underpasses, with long-term monitoring programs (Iuell et al., 2003; Ng et al., 2004; Grilo et al., 2008; Olsson et al., 2008; Ford et al., 2009). The first comprehensive and systematic manual for design and evaluation of wildlife crossing structure was published by Federal Highway Administration of USA in 2011 (Clevenger and Huijser, 2011). Globally, although presently almost all studies prove that wildlife crossing structures contribute to the movement of wildlife along roads and improve the stability of wildlife population, the study on monitoring of wildlife crossing structures is limited (Glista et al., 2009), particularly in developing countries.

In China, presently only 3 studies focus on monitoring wildlife crossing structures. The first is to monitor wildlife crossing structures along Qinghai-Tibet Railway by the video cameras and observation (Xia et al., 2007). The second is to monitor Asian Elephant underpass along Simao-Xiaomengyang expressway in Yunnan Province by track transecting, rural surveys and direct monitoring (Pan et al., 2009), and the third is to monitor underpass along Ring Changbai Mountain Scenic highway by snow tracking (Wang et al., 2013b). As one of the richest biodiversity countries in the world, China has many endemic wildlife species (Liu et al., 2003). Presently, road construction is spreading over the wide west areas, which is sensitive and fragile, it is urgent to initiate the construction and monitoring of wildlife crossing structures (Kong et al., 2013).

Changbai Mountain Nature Reserve, a member of the International Man and Biosphere Reserve Network, is rich in fauna resource, and is the main habitat for Amur Tiger (*Panthera tigris altaica*) historically (Piao et al., 2011). Local Department of Transportation (DOT) plans to accelerate the construction of road network in the future. It is important to study the impacts of road construction on wildlife during highway construction and provide the protective measures. Recent years, Chinese government plans to restore the Amur Tiger passage/corridor in Changbai Mountain area, and restore the habitat inside and around Changbai Mountain Nature Reserve (Z.X. Li et al., 2010). Therefore, the tunnels and bridges and culverts along the highway and the expressway in Changbai Mountain Area are extreme important passages to wildlife movements.

Infra-red camera trapping technology has been used successfully to monitor many species of elusive animals in remote areas (Samejima et al., 2012; Wang et al., 2014). The advantages of the technology include self-contained systems operating unattended for extended periods of time that are capable of 24 h a day monitoring and recording high resolution photos. Infra-red cameras are especially valuable for monitoring species of wildlife which are highly sensitive to human presence. It is regarded as a method superior to sand beds for long-term monitoring, because of its low labor cost and high reliability (Ford et al., 2009). In addition, photographs of wildlife taken during monitoring studies have the advantage of generating more interest in wildlife to public (Ford et al., 2009; Clevenger and Huijser, 2011). Using infra-red camera trapping technology to monitor the wildlife crossing structures in Changbai Mountain area is in vacant, so we will use this method to monitor the uses of crossing structures by wildlife.

The aim of this study is twofold: (1) to determine what species uses wildlife crossing structures to cross the highway, the frequency, and time of crossings; (2) to investigate species specific preference of crossing structures. This is the first study to monitor wildlife movements through a tunnel along expressway using infra-red camera surveillance technology in China.

2. Materials and methods

2.1. Research area

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 196465 ha. The study area experiences a monsoon continental mountainous climate, with long, cold winter and short, warm and humid summer. 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 member of the International Man and Biosphere Reserve Network, and is one of the richest biodiversity regions in China. There are more than 1225 fauna species in the region, with 59 species declared as national key protected species, mainly including the sable (*Martes zibellina*), Siberian roe deer (*Capreolus pygargus*), and Siberian weasel (*Mustela sibirica*). Additionally, the Amur tiger historically inhabited this area (Chen et al., 2010).

The main wildlife species occur along roadside areas in and around Changbai Mountain Nature Reserve are Siberian roe deer, Siberian weasel, Manchurian hare (*Lepus mandschuricus*), wild boar (*Sus scrofa*), Eurasian red squirrel (*Sciurus vulgaris*), sable, red deer (*Cervus elaphus*), Asian badger (*Meles leucurus*), Amur hedgehog (*Erinaceus amurensis*), and others rodent species (Piao and Shen, 2009). Manchurian hare is nocturnal, same as sable which the home range can be 5–10 km^2. Asian badger is nocturnal, and is active mainly in spring, summer and autumn, and hibernates in winter. Wild boar, red deer, and sika deer (*Cervus nippon*) exhibit seasonal movements between high elevation in summer and bottom of valley in winter. Siberian roe deer mainly act in dawn and sunset (Piao et al., 2013).

The JiYan expressway is a fenced, four-lane expressway, which began operation in September 2008. The expressway bisects two National Nature Reserves: the Changbai Mountain Nature Reserve and Wangqing Nature Reserve. Wildlife crossing structures along the expressway are vital to maintain wildlife movements between the two reserves. The 1000 m length

Xiaqinggou Tunnel was constructed to connect the two nature reserves. The main vegetation is Mongolian oak secondary forest.

The improvement project for Ring Changbai Mountain Scenic highway was completed in October, 2009. The project was 84 km long, with about 21 km (Km10–Km31) located around the edge of the Changbai Mountain Nature Reserve, and about 6 km (Km31–Km37) transecting the reserve. The highway is a second class highway based on Chinese national highway standards. The width of the roadbed is 10 m and the speed limit is 60 km/h. There are 8 medium and large-sized bridges (width > 30 m), 16 small bridges (width > 8 m) and 190 culverts (width > 1.5 m, height > 1 m, or diameter > 1 m) located along the highway.

2.2. Using infra-red camera trapping technology along Jiyan expressway

Two principles determine the range of time period to monitor wildlife by infra-red cameras. Firstly, snow season (November to April) is not good for locating cameras, due to low temperature and heavy snow, which may affect operation of cameras. Secondly, as habitat on the top of the tunnel is not belonging to the Nature Reserve, we avoided installing cameras in July, August and September because of high activity of livestock. In 2011 and 2012, basically we located those cameras according to these two principles. However, in 2013, we thought may be the livestock and wildlife can co-exist, so we kept on locating those cameras from April to December. Therefore, Infra-red cameras were set from 16th September to 15th December, 2011; from 10th May to 26th July, 2012; and from 30th April to 11th December, 2013.

The Xiaqinggou Tunnel is approximately 1000 m length. Eight cameras were set at equal distances apart (Fig. 1). To increase the potential of detecting wildlife, cameras were installed near known locations of animal sign. The cameras were attached on the trees at a height approximately 0.5 m to take photos of medium and large-sized species of wildlife. The camera lens was oriented toward the north to avoid direct sunlight triggering the cameras. The field of view in front of each camera was cleared of vegetation to provide unobstructed photos. Where cameras were obscured by tree falls caused by snow accumulations, the cameras were relocated to other sites. The operational configurations of the cameras were standardized for: time (year, month, date, hour, minute, second), mode (camera), interval (1 s), sensor lever (normal). The cameras were inspected about every 2 months. Photos were retrieved from memory cards and batteries were changed. All information (including wildlife English name, scientific name, location, number of photos, and time) was collected and recorded in a Microsoft Excel spreadsheet (Samejima et al., 2012; Liu et al., 2013; Wang et al., 2014).

2.3. Using snow tracking technology along Ring Changbai Mountain Scenic highway in winter

In the Changbai Mountain Area, winter extends from November to April. Our primary investigation activities occurred during this period. From November, 2009 to December, 2014, after snow events lasting 2 days, we checked the bridges and culverts to record species richness and crossing frequencies. Due to time constraints during the monitoring study, we were not able to check all underpasses along the 84 km highway after each 2 day snow event. As a result, we were not able to calculate the absolute number of crossing at each structure, nor distinguish potential multiple crossing by an individual wildlife at each structure. We focused only on the relative frequency of different species using the structures. Snow track identification was based on "*The mammals of Changbai Mountain*" and "*Guideline of recognizing tracks of wildlife in Far East area*"(Li, 2008; Piao et al., 2013). Over the course of the study, we carried investigations on 60 separate dates.

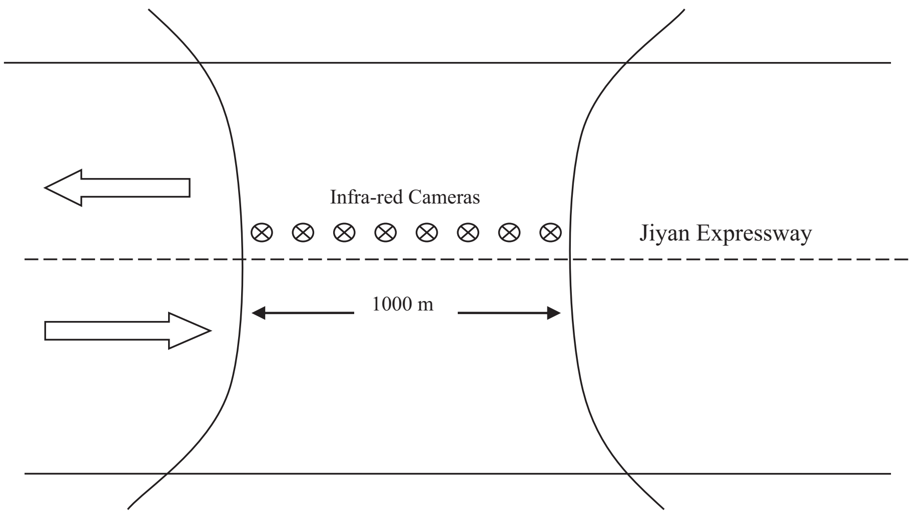

Fig. 1. Map of locations of 8 infra-red cameras in the Xiaqinggou Tunnel along Jiyan expressway.

During our monitoring of the wildlife crossing structures, we also established 5 transects perpendicular to Ring Changbai Mountain Scenic Highway. The 1 km long, 500 m wide transects were located at Km15, Km20, Km25, Km32 and Km50. We determined the locations of the 5 transects on the basis of the distance to the Nature Reserve and sign of wildlife activity. Along each transect we recorded species richness and sign abundance (number of animals sign), and evidence of roadside wildlife activity.

2.4. Data analysis

2.4.1. Use of tunnel

Eight Infra-red cameras operated 386 days with 2330 camera days in the field. Only medium and large-sized mammals, and large birds, were identified. A large number of small animals were extremely difficult to identify accurately in the photos, so we did not attempt to do so. Among all photos, we selected the independent photographs (IP), which were defined as (1) photos of different individuals of the same or different species; (2) photos of individuals of the same species taken more than 0.5 h apart; or (3) nonconsecutive photos of individuals of the same species (Samejima et al., 2012; Liu et al., 2013; Wang et al., 2014).

(1) RAI = A*i*/N $*$ 100 (RAI-relative abundance index, Ai-number of IP of species *i*, N-number of IP of total species).
(2) MRAI = Mi/N $*$ 100, MRAI-Monthly relative abundance index, Mi-number of IP of Month *i*, N-number of IP of total months).
(3) NRAI = D*i*/N*i* $*$ 100, NRAI-Night time relative abundance index, D*i*-night time number of IP of species *i*, Ni-number of IP of Species *i*. (20:00–6:00 night time).

The density of monitored species can affect the frequency of use of wildlife crossing structures. Generally, if the density of the monitored species is high, then the RAI-relative abundance index of these species should be high too. Because the studies about population density of wildlife in Changbai mountain area are very few, we only collected information of some species from literature, including: yellow throated marten (0.60 individual/km^2); sable (0.38 individual/m^2); wild boar (1.51 ± 0.19 individual/km^2); Siberian roe deer (1.08 individual/km^2); red deer (0.033 individual/km^2) (Piao et al., 2013). Sika deer was not be found since 1980, and small population was reintroduced in Changbai Mountain Nature Reserve several years before (Piao and Shen, 2009).

We suspect the RAI of wild boars and Siberian roe deer are likely high. Furthermore, the two species migrate from bottom of valley in winter to the high elevation of mountain in summer. Therefore, the top of tunnel is probably the part of their migratory route. By our estimate, all mammals lived along Ring Changbai Mountain Scenic highway can cross the highway by medium and large-sized bridges and small bridges, while only part of species can use the culverts to cross the roads. We used the Spearman correlation to test the relationship between MRAI of wildlife and livestock.

2.4.2. Use of bridge and culvert

We calculated RCR = F*i*/T $*$ 100 (RCR-Relative crossing rate, F*i*-Frequency of crossing of species i, T-frequency of crossing of total species) for all bridges and culverts. We used the Chi-Square test to compare RCR between bridges and culverts.

3. Results

3.1. Use of tunnel

The number of IP was 220 (wildlife: 121, livestock: 99). Eleven medium and large-sized species of wildlife used the tunnel to cross expressway. Among of these species, one species was the listed national First-class protective species—sable, three species were the listed national Second-class protective species-yellow throated marten, hazel grouse (*Bonasa bonasia*) and unidentified owl (there are 9 owl species in Changbai Mountain area, it's difficult for us to identify the specific species in night only by photos), and 7 species were the listed "Terrestrial Wildlife List of Beneficial or Important in Economy and Science" (Piao et al., 2013)- Siberian roe deer, wild boar, Manchurian hare, Asian badger, Siberian weasel, least weasel (*Mustela nivalis*) and Eurasian red squirrel (Table 1).

Siberian roe deer used the tunnel most often according to the RAI (relative abundance index, 39.55%); following by wild boar (17.16%) and Manchurian hare (15.67%). The other species were rarely detected in the tunnel given that their RAI were very small (Fig. 2). The MRAI (Monthly relative abundance index) of October (22.39%), May (21.64), September (17.16) were highest, which occupied 61.19% of total. This suggested that wildlife used the tunnel more often in autumn and spring. The relationship between MRAI of wildlife and livestock was negative, although not significant (Spearman correlation, $r = -0.108$, $p = 0.818$) (Fig. 3).

Based on the NRAI (Night time relative abundance index), wild boar and yellow-throated marten were more active during day time while Manchurian hare and hazel grouse were nocturnal. The NRAI(Night time relative abundance index) ranking were following: Manchurian hare (95.24%), hazel grouse (70.00%), Siberian roe deer (58.49%), Asian badger (57.14), wild boar (34.78%), yellow-throated marten (0,Fig. 4).

Table 1
Wildlife using crossing structures on Ring Changbai Mountain Scenic highway and Jiyan expressway.

Taxa	Chinese name	English name	Scientific name	Protective level	Type of crossing structures
Birds	鸮	Owl		II	T
	雉鸡	Common pheasant	*Phasianus colchicus*	*	C, B
	花尾榛鸡	Hazel grouse	*Tetrastes bonasia*	II	T, B
Mammals	东北兔	Manchurian hare	*Lepus mandschuricus*	*	T, C, B
	獾	Asian badger	*Meles leucurus*	*	T
	黄鼬	Siberian weasel	*Mustela sibirica*	*	T, C, B
	银鼠(伶鼬)	Least weasel	*Mustela nivalis*	*	T, C, B
	狍	Siberian roe deer	*Capreolus pygargus*	*	T, B
	青鼬	Yellow-Throated marten	*Martes flavigula*	II	T, C, B
	松鼠	Eurasian red squirrel	*Sciurus vulgaris*	*	T, C, B
	野猪	Wild boar	*Sus scrofa*	*	T, B
	紫貂	Sable	*Martes zibellina*	I	T, C
	银狐	Silver fox	*Vulpes vulpes*		C
	Total	13			

Notes: "I" represents National First-class protective wildlife; "II" represents National Second-class protective wildlife; "*" represents Terrestrial Wildlife List of Beneficial or Important in Economy and Science; "T" represents Tunnel, "C" represents Culvert, "B" represents bridge.

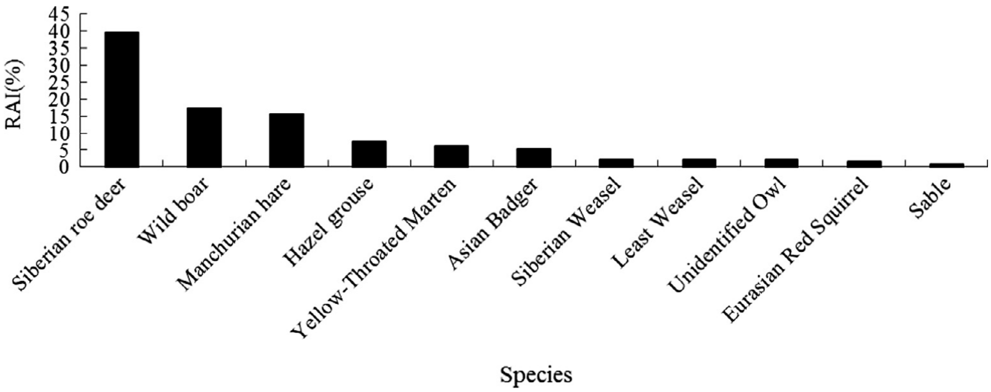

Fig. 2. Relative abundance index-RAI in Tunnel.

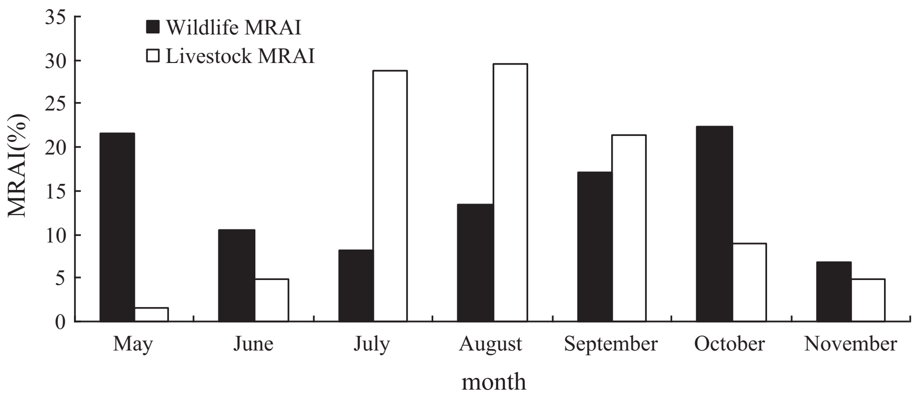

Fig. 3. Wildlife monthly relative abundance index-MRAI in tunnel.

On the basis of the relationship curve between camera days and cumulative number of species, most of species (72.7%) were not detected until 50 days after installing cameras (Fig. 5).

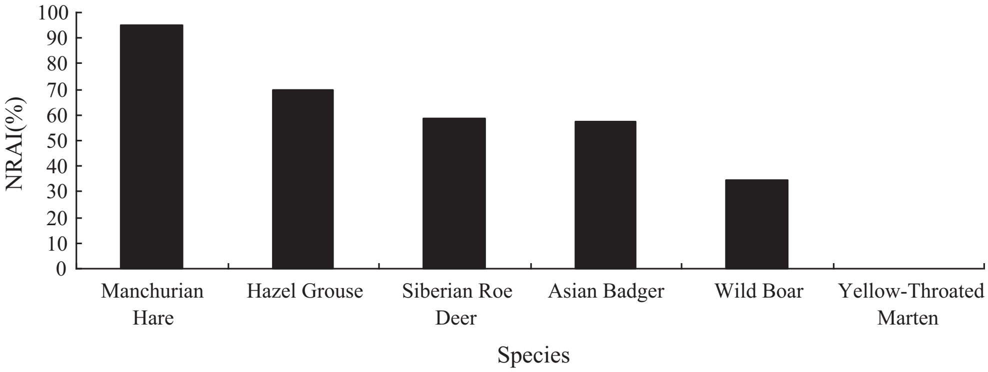

Fig. 4. Night time relative abundance index-NRAI of different species.

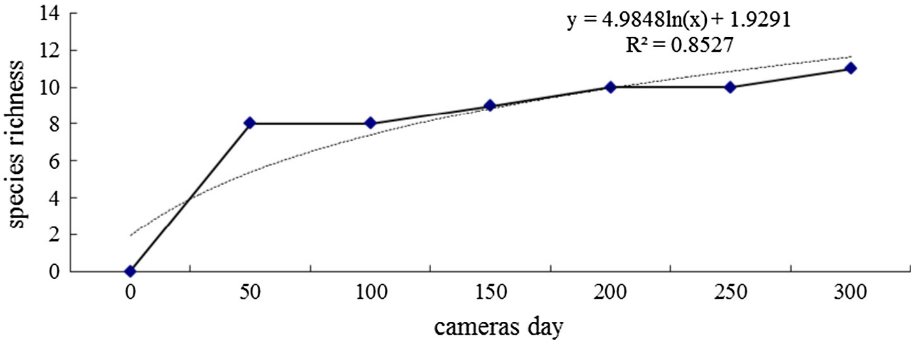

Fig. 5. Relationship curve between camera days and cumulative number of species.

3.2. Use of bridges and culverts

Thirteen medium and large sized wildlife were recorded within 500 m from roads range, including 5 species of carnivore: yellow throat marten (*Martes flavigula*), sable, least weasel (*Mustela nivalis*), Sebiran weasel and silver fox; and four species of ungulate: sika deer (*Cervus Nippon)*, red deer, Siberian roe deer and wild boar. The signs of all species were ranking following: Siberian roe deer (23.14%), Siberian weasel (22.08%), wild boar (18.04%), sable (11.34%), Eurasian red squirrel (10.84%), Manchurian hare (4.39%), yellow throat marten (4.08%), red deer (2.17%), least weasel (1.43%), hazel grouse (1.41%), Sika deer (0.71%), silver fox (0.26%) and common pheasant (0.15%).

Eleven medium and large-sized of wildlife used bridges and culverts to cross the highway, including one national First-class protective species: sable, two national Second-class protective species: yellow throated marten and hazel grouse.

Different species preferred different types of crossing structures. Siberian weasels preferred culverts ($\chi^2 = 11.560$, df = 1, p = 0.001); yellow throated martens and Eurasian red squirrels both preferred bridges ($\chi^2 = 38.440$, df = 1, p < 0.001; $\chi^2 = 31.360$, df = 1, p < 0.001); Manchurian hares has no identified preference ($\chi 2 = 1.440$, df = 1, p = 0.230). Siberian roe deer and wild boars only used bridges to cross the highway (Fig. 7).

The sign of Siberian weasels was list second, and it crossed the structures through all monitoring years (6 years), so the crossing rate was highest, 86.47% (Fig. 6). Compared with Siberian weasels, although the signs of Siberian roe deer, wild boars, sables, Eurasian red squirrels were abundant, the crossing rate were small (5.56%, Fig. 6). Eurasian red squirrels crossed the structures in 4 years among 6 years, and Siberian roe deer and sables began to use the structures only in recent 3 years, and wild boars began to use the structures only in recent 2 years (Table 2).

4. Discussion

By long-term monitoring use of crossing structures by wildlife, we found that the tunnels, bridges, and culverts have become important passages for wildlife, even though these structures were originally built for non-wildlife purposes, such as water drainage, crosswalk for livestock and local residents (Ng et al., 2004; Mata et al., 2008). The RAI of Siberian roe deer and wild boar are highest in the tunnel and both species used bridges to cross the highway, so we should construct more tunnel passages and bridges to benefit both species to cross the highway. As ungulates densities are a critical determinant of habitat quality for Amur Tiger (*Panthera tigris altaica*) in Changbai Mountain area (Zhang and Ma, 2010). To assist in recov-

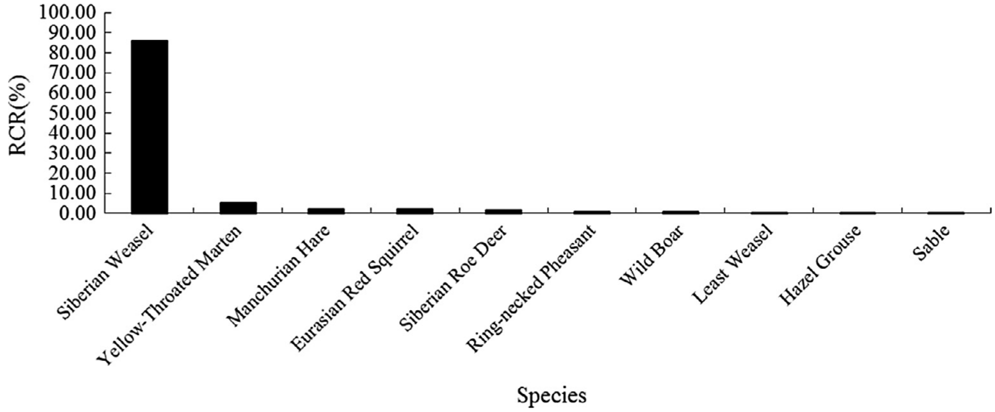

Fig. 6. RAI of wildlife using bridge and culvert in winter along Ring Changbai Mountain Scenic highway.

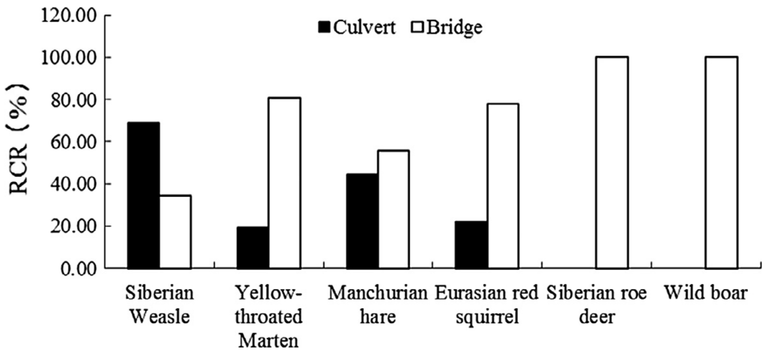

Fig. 7. Wildlife selective tendency to bridge and culvert.

Table 2
Wildlife emerged within 500 m from the highway and used bridges and culverts to cross the highway in winter from 2009 to 2014.

Series Number	Wildlife emerge in roadside 500 m	2009	2010	2011	2012	2013	2014
1	Manchurian hare	●	●		●	●	
2	Siberian weasel	●	●	●	●	●	●
3	Least weasel	●	●				
4	Eurasian red squirrel	●	●		●	●	
5	Ring-necked pheasant	●	●				
6	Yellow- throated marten		●	●	●	●	
7	Siberian roe deer				●	●	●
8	Sable				●		●
9	Hazel grouse						●
10	Wild boar					●	
11	Red deer						
12	Sika deer*						
13	Silver fox *						●
	Sum	5	6	2	6	7	4

(Notes: "●" represents species using underpass; "*" represents Sika Deer only emerged in 2009, 2010 and 2014; *Silver fox only emerged in 2013, Sika deer and Silver fox both are reintroduce into wild land by human).

ery of ungulates, several countermeasures are provided, such as continuation and strengthening of the existing ban on hunting in Changbai Mountain area, ungulate monitoring programs, selective reintroduction of prey species into core areas of Tiger Conservation to facilitate recovery, negative impacts of new roads on tigers must be considered and mitigation measures must be included in the planning process to preserve the connectivity of habitat of Tigers and their prey (Z.X. Li et al., 2010). Ungulates also play a vital role in control vegetation during forest succession progress (Piao et al., 2011). Consequently, tunnel passages and bridges should be strictly protected during and after highway construction. Tunnels, culverts, and bridges have all been used by Mustelid. The RCR of Siberian weasels were highest on bridges and in culverts. This species appears to be active along roadsides, with a 50 m range (Wang et al., 2010). Since few road killed specimens were recorded, it appears the impact of highways on Mustelid is slight. It is apparent that Mustelid have adapted to these crossing structures. Sable is one of the typical species inhabiting in Taiga forest regions, which are far away from artificial disturbance (Zhang and Ma, 2000). Since sable used tunnels to cross expressways, we believe the tunnel is also important for Sable. In 2014, sables began to use the culverts to cross the highway, so by estimate, sable is probably becoming to adapt to the culverts with the time elapse.

A substantial number of researchers have identified the positive relation between the size of wildlife crossing structures and rate of use by wildlife (Yanes et al., 1995; Ng et al., 2004; Mata et al., 2005). Species such as Siberian roe deer and wild boar prefer wide crossing structures (Mata et al., 2005, 2008). We also found both of two species only using tunnels and bridges. However, Siberian weasels preferred to cross the highway using culverts in our study. Of the 13 medium and large-sized wildlife found distributed along the within 500 m of the roadside of the Ring Changbai Mountain Scenic highway, 11 species was found using bridges or culverts to cross highways in winter. Only two species have not used the bridges or culverts. First is red deer, which are very sparsely distributed in the Changbai Mountain Nature Reserve and even close to local extinct state (Piao and Shen, 2009), and, to date, none have been found to use crossing structures. Second is sika deer that was reintroduced into the area several years before. The number of tracks of sika deer was very few and only recorded n roadside in 2009, 2010 and 2014. According to our field investigation, sika deer often crossed the highway directly on the road and not by the bridge or culverts. Isolated underpasses without fencing or with very short fences have used by large mammals and inclusion of wildlife fencing may improve the use of individual underpasses (Huijser et al., 2016). Therefore, if the intent is to improve the use of bridges by sika deer, we should locate fences around the bridges.

Both sika deer and silver foxes were reintroduced into the area. It appears these reintroduced species have difficulty adapting to wild environment. During our field investigations, we often found these species feed the rubbish along the highway and four foxes were killed by vehicles along the Ring Changbai Mountain Scenic Highway in 2014. Surrounding environment can have impacts on the rate of using crossing structures by wildlife. The presence of habitat around crossing structures and minimize human disturbance will improve the rate of use of crossing structures (Rodriguez et al., 1996; Clevenger and Waltho, 2000; Wang et al., 2013b). During our monitoring period, from July to September, we found a considerable number of livestock at the tunnel. Concurrently, relatively few photos of wildlife were recorded. Consequently, we suggest human disturbance in the tunnel should be controlled to improve the utility of the wildlife passages.

In the view of wildlife using the tunnel, MRAI was highest in October, May and September (62%), likely because of the phenology of Mongolian oak, an important food resource for wild boars and roe deer which were the majority of the species recorded during this period. In Changbai Mountain, the seeds of Mongolian oak grow and fall in September, although are buried by snow through the winter, the seeds reemerge on the ground and are available for wildlife again in May after snow melting in April. While wild boars and yellow-throated martens tend to be active during the day, Manchurian hares, hazel grouses, Siberian roe deer, Asian badgers are active at night (or dawn and sunset). This phenomenon is probably related to the foraging, breeding, and migration characteristics of each species and their response to artificial disturbances.

The relationship curve between cumulative species richness and camera days shows 72.7% of species (8 species among 11 species) can be found within a 50 day period. Therefore, we suggest monitoring programs of uses of crossing structures by wildlife should be conducted for at least 2 months, ideally from September to November, to catch most species activity in the Changbai Mountain Area. From the perspective of use of the bridges and culverts, 5 species were recorded in 2009, and only 6 species were found in 2012. However, after 2012, Siberian roe deer, sables and wild boars were found to begin using the crossing structures. Given the high variability of use of culverts and bridges by wildlife monitoring programs should be conducted on an ongoing and permanent basis. Furthermore, it is difficult to prove the effectiveness of crossing structures solely based on the species of wildlife found using the structures. The effectiveness of wildlife crossing structures should be based on maintaining the long-term viability of wildlife populations and promote sufficient genetic variation in wildlife populations to ensure ongoing genetic robustness (Forman et al., 2003; Clevenger and Sawaya, 2010). For example, wildlife crossing structures located along the Trans-Canada highway in Banff National Park allowed sufficient gene flow to prevent genetic isolation of grizzly bears (*Ursus arctos*) and black bears (Sawaya et al., 2014).

Our study proved infra-red camera trapping technology is a good method to use for monitoring wildlife in a forest environment. The technique should be applied to wildlife monitoring in other similar environments in east-north China. The snow tracking is a good method to use in snowy areas in the winter, as it can measure the crossings and activities of wildlife clearly, in a fashion similar to sand beds in non-snowy conditions (Bellis et al., 2013).

5. Conclusion

In Changbai Mountain area, the multifunctional bridges and culverts have been used by most species of wildlife found within 500 m of the roadside in winter. The tunnel along expressway (length = 1000 m) and bridges along highway (width > 8 m) have been important passage for wildlife, although different species preferred to different types of structures. Infra-red camera trapping technology is advised to monitor the tunnel in the Changbai Mountain Area, and the monitoring should be conducted for at least 2 months to catch most species activity. We suggest that tunnels and bridges should be locate much more along roads or railway projects in Changbai Mountain area in the future to benefit to wildlife movements. With the increasing of traffic volume on Changbai Mountain roads, we suggest that short fences should be set around the bridges and culverts to guide species to cross the passages. In the future, the long-term viability of the wildlife populations found adjacent to the highway should be evaluated based on DNA technology and molecular genetics.

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