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Road wildlife ecology research in China

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Abstract

This paper comprehensively summarizes the research advancing the impact of highways on wildlife and the countermeasures used in China. By the end of 2011, the total length of highways and expressways in China was 4.1 million and 85,000 kilometers, respectively, and both are listed as the second longest road systems in the world. Wildlife biodiversity in China is listed as the eighth highest in the world, and thus the conflict between wildlife biodiversity and road systems has increased in recent years. In China, road mortality levels, wildlife road effect zones, wildlife migration and behavior differed between pre- and post-road construction activity. Road networks resulted in the fragmentation of wildlife habitat in multiple different regions in China. In response to this, countermeasures have consisted of route re-selection, locating suitable areas for wildlife crossing construction, and erecting wildlife warning signs along the roadside to alert drivers. However, such basic research efforts and recommendations have only recently begun in China, compared to western developed countries. As a result, the recommended countermeasures were often absent during road construction practices that were monitored in this study. We provide three major recommendations from our research findings in road wildlife ecology in China: 1.) develop and initiate basic studies in road wildlife research in China; 2.) develop multidisciplinary collaborations and co-operations during highway construction; and 3.) establish and strengthen international exchange and collaborations with western developed countries to advance the issue of road-wildlife ecology in China.

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Key words: road mortality; road effect zone; habitat fragmentation; road ecology

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1. Introduction

In China, studies on the interactions between roads and wildlife have only emerged relatively recently. This paper reviews current research progress in the field of road-wildlife ecology, and aims to raise public awareness of this issue to strengthen wildlife conservation during highway construction, and promote current research advancing road-wildlife ecology interactions in China.

2. Impacts of road construction on wildlife

At present, research into the impacts of roads on wildlife has mostly been carried out in Changbai Mountain (Jilin Province) and Qinghai-Tibet highway/railway (Qinghai Province, Tibet) regions. The impacts, protective measures and key wildlife species impacted are presented in Table 1.

Table 1 Road-wildlife ecology studies in China

Area, highway/railway	Province	Impact/protective measures	Class of wildlife impacted	Key Wildlife species impacted
Changbai Mountain	Jilin	Road mortality, road effect zone/ wildlife crossing structure monitoring	Amphibian, reptile, bird, mammal	Roe deer, wild boar, Siberian Chipmunk, Chinese Brown Frog, Oriental Fire-bellied Toad, Asiatic Toad, Siberian Weasel
Tibet-Qinghai Highway/railway	Tibet, Qinghai	Wildlife crossing structure monitoring; road effect zone; migration; genetic diversity studies	Mammal	Tibetan antelope , Tibetan gazelle, Kiang
Kalamaili Nature Reserve	Xinjiang	Road mortality	Mammal	Przewalski's Wild horse
Zoige wetland Nature Reserve	Sichuan	Road mortality, road effect zone	Amphibian, reptile, mammal, bird	Plateau brown frog, Tibetan frog
Xishuangbanna Nature Reserve, Simao-Xiaomengyang Expressway, Yunnan	Yunnan	Wildlife crossing structure monitoring	Mammal	Asian elephant
Three Paralled Rivers of Yunnan Protected Areas	Yunnan	Road effect zone, behavioral impacts	Bird	Black-necked crane
Qinling Panda Reserve	Shanxi	Habitat fragmentation	Mammal	Giant panda
Niubeiliang Nature Reserve	Shanxi	Migration	Mammal	Takin

2.1. Road Mortalities

Studies investigating the mortality impacts of roads on wildlife are very limited in China. To date, there are only three cases of research in this field:

1) Research funded by WWF investigated the impact of roads on wildlife along the G213 in the Zoige Wetland region in September, 2006, which demonstrated that amphibian mortality was 4.13 ind/km (n=29), which was lower than on provincial roads and county roads (39.6 ind/km) (Gu et al., 2011)；
2) In Kalamaili Nature Reserve, five Przewalski's Wild horse mortalities were reported as a result of car collisions from August to October, 2007, along G215. Horses were observed to cross sections of this highway frequently for water access (Zhang et al., 2008);
3) Our current research has found that 3475 wildlife mortalities, from a total of 63 species, were attributed to road collisions from 2009 to 2012 along the Ring Changbai Mountain Scenic Highway. Among these mortalities, amphibians were the most affected taxa (86.21 % of reported road mortalities, followed by mammals (5.70 %), birds (5.24 %), and reptiles (2.85 %)).

2.2. Road Effect Zone

Wildlife behavior avoidance of highways forms road effect zones. The concept of road effect zones has become a topic of global interest (Forman et al., 2000). Research has recently advised that more comprehensive investigations need to be carried out on road effect zones in China. (Ding et al., 2008)

Along the Tibet-Qinghai highway and railway, the density of Kiang along the 0-500 m zone perpendicular to the highway was significantly lower than densities in the 1001-2000 m and 2001-3000 m zones. However, the density of Tibetan antelope and Tibetan gazelle in the 0-500 m zone perpendicular to the highway was significantly higher than densities in the 1001-2000m and 2001-3000 m zones. This may be attributed to a barrier effect causing this phenomenon (Yin et al., 2007).

Along the highway in the Zoige wetland region, the use rate of habitat by amphibians during their breeding season is low, and this pattern of habitat use is also reported for some bird species. While species abundance does not appear to have been impacted, road effect zones of the Black-lipped pika was 400 m along the G213 during highway construction (Dai et al., 2006).

Our current research measured the road effect zone for some species in the Changbai Mountain and Three Paralled Rivers of the Yunnan Protected Areas, and found that the road effect zone of the Siberian weasel was approximately 50 m (Wang et al., 2010). Along the Napahai wetland highway, the road effect zone of 17 bird species was variable, with the Black-necked crane having the largest zone of 151 m (Wang et al., 2011).

2.3. Migration and Behavioral Responses

In 2001 and 2002, during the Tibet to Qinghai Railway construction period, researchers found that busy highway traffic, human disturbance, construction activity and areas of bare land all prolonged the migration time of antelope, with some individuals failing to cross the highway. The Tibetan antelope, Tibetan gazelle, and Kiang all adapted to highway and railway construction through adjustments to their movement behavior, including higher crossing incidences during lower traffic volume, utilizing the wildlife underpass associated with the railway construction, and in 2006, researchers found 2952 antelopes migrating east, of which 98.17 % crossed the railway by using the wildlife underpasses (Qiu, et al., 2004; Xia et al., 2005; Yin et al., 2006; Yang and Xia., 2008).

Where the G210 highway cuts through the Niubeiliang Nature Reserve, Takin crossed the highway only 8.53 % (7 times) of their total road crossing activity. Of the factors impacting road crossing by wildlife, including

landform, vegetation, cars, travel and business facilities, operation cars had the highest impact on road use by wildlife (Ma, 2007a; 2007b).

We monitored wildlife road crossings on the Ring Changbai Mountain Scenic highway in winter of 2008, and found that nine species crossed the highway, the activity of which was largely concentrated on the K10-45, specifically on the K20-40 (Wang, et al., 2009).

2.4. Habitat Fragmentation

Yangtai highway construction and operation is likely to result in considerable fragmentation of the giant panda's habitat in the Qinling Mountain. Lanyu expressway and railway construction should further heighten the barrier effect for the giant panda between Qingmuchuan and Caojiahe Nature Reserve in Qinling Mountain (Zeng et al., 2009a; 2009b). Before road network construction occurred in the Qinling Mountain region, the area of suitable habitat amounted to 1561 km^2 for the giant panda, and the area of marginally suitable habitat was 1499 km^2. The corresponding panda density in this region was approximately 240 individuals. Following road network construction, suitable habitat was reduced by 30 % to 1093 km^2, while marginally suitable and unsuitable habitat have increased by 17 % and 1 %, respectively. Panda population size was reduced to 217 individuals (Fan et al., 2011).

We found the road density in Changbai Mountain Nature Reserve to be 0.254 km/km^2. At present, 90 % of the total road is paved road, while the mileage of road increased from 210 km in the 1980s to more than 400 km presently, which will continue to be a potential threat to the habitat integrity of the Nature Reserve.

2.5. Other Important Impacts

The barrier effect presented by the Qinghai-Tibet highway has impacted the genetic interactions between plateau pikas that inhabit the two sides of the highway, resulting in some genetic differentiation between these two populations (Zhou et al., 2006).

3. Protection of wildlife during highway construction

3.1. Route Selection

In China, generally, route selecting should aim to avoid Nature Reserve and wildlife habitat areas. For example, before the Simao-Xiaomengyang expressway construction in Xishuangbanna, researchers investigated populations of endangered species along the roadside, to assist the Department of Transportation (DOT) in Yunnan in selecting the best possible route to avoid habitat degradation used by endangered wildlife (Song et al., 2005).

3.2. Wildlife Crossing Structures/Wildlife Bridges

When highways are required to pass through wildlife habitat, a common method to reduce the resulting impacts on wildlife are to improve the ratio of bridges and tunnels to the highway, in order to mitigate the barrier effect and habitat fragmentation on wildlife.

Monitoring wildlife crossing structures and their frequency of use is also important, where monitoring wildlife crossing behavior on the Qinghai-Tibet railway is the first research in China to do so (Yang and Xia, 2008).

Through monitoring 33 underpasses from 2004 to 2007, researchers found that antelope used underpasses more frequently over time, with shortening wandering and vigilance patterns over time (Kong, 2009; Li, 2008). Tibetan gazelle and Kiang also reportedly used the underpasses (Zhang et al., 2009).

Concerning the monitoring of highway wildlife crossing structures, the first study to investigate this occurred at the Simao-Xiaomengyang expressway underpass, to monitor Asian Elephant passage from September 2005 to September 2006. Research found that elephants crossed the constructed highway corridor 28 times pre-highway construction, and 23 times post-highway construction; with the rate of use of the underpass being 44.4 % (Pan et al., 2009).

We interviewed residents along the S303 cut through road in Wolong Nature Reserve, which assisted us in providing the principle and methodology for locating wildlife crossing structure placement (Wang et al., 2007).

Ring Changbai Mountain Scenic highway is the first scenic highway in the Jilin Province which has been nominated by DOT of China, which began to operate in Oct 2009. We monitored the rate of wildlife use of bridges and culverts, and found that six middle and large size species used these structures, used at a rate of 88 % and 44.2 % for bridges and culverts, respectively (Wang et al.,2013).

3.3. Warning Signs

At present, wildlife protection warning signs have been erected along the Ring Changbai Mountain Scenic Highway and the Qinghai-Tibet highway, but no current data is available assessing the potential effectiveness of these warning signs. The evaluation of the importance of warning signs in raising public awareness and reducing wildlife road mortalities remains a fruitful area of research in China.

4. The limitations of road-wildlife ecology studies in China

4.1. Lack of Basic Research

Road wildlife ecology research is a very recent field of study in China, including aspects of road mortality, temporal and spatial characters of wildlife crossing highways, road effect zones for wildlife, monitoring wildlife crossing structures, wildlife crossing structure locations, effects of road networks on wildlife populations, and genetic impacts on populations as a result of road barrier effects, etc.

4.2. Lack of Wildlife Protective Measures along Highways in China

Due to a lack of basic studies of wildlife-road ecology in China, DOT has encountered considerable difficulties in evaluating the effectiveness of protective measures during highway construction. Many structures classified as “wildlife crossing structures” have the primary purpose of drainage and human crossing areas, thereby acting as secondary measures for wildlife crossings.

5. The advantage of road-wildlife ecology studies in China

China is listed as one of the most species diverse countries in the world. China contains 13.39 % of the world’s mammal species, 14.25 % of bird species, 5.97 % of reptile species, 7.08 % of amphibian species, 17.53 % of fish species and 5.5 % of insect species (Ma et al., 2010).

The mileage of highways and expressways in China is rated as the second largest in the world, at 4.1 million km and 85,000 km, respectively (Li, 2012). Most highways span ecologically sensitive areas of western China. In two years, this mileage will likely exceed USA to become the largest road mileage in the world.

According to the Environmental Impact Assessment of national expressway networks, 18 biodiversity hotspot areas will likely be impacted by expressway network among 22 biodiversity hotspot areas in China (Research on the National Forestry Nature Reserve System Plan), and 27 endangered species will likely be impacted among 38 top endangered species in China. Almost half of China's wildlife species are endemic - these include many archaic and distinctive evolutionary lines, such as the giant panda (Liu et al., 2003).

6. Future recommendations

6.1. Initiating Basic Studies in Road-wildlife Ecology in China

We recommend such actions as conducting basic research studies throughout all stages of highway construction in China, in order to establish and provide a scientific baseline and policy support for protective management measures, including sustaining habitat management and connectivity during highway planning stages; identifying sites for wildlife crossing structures (corridors) during highway design; reducing short- and long-term disturbance to wildlife habitat; monitoring the efficiency of protective measures; and adaptive management strategies to improve management efforts.

6.2. Developing Multidisciplinary Cooperation during Highway Construction

From highway planning to operation deployment, engineers to wildlife biologists to landscape architects should strive to cooperatively work together in order to provide the most effective highway design scheme for a more sustainable use at the human-wildlife interface.

6.3. Strengthening International Exchange and Collaborations with Western Developed Countries in the study and Advancement of Road-wildlife Ecology in China

At present, the USA, Canada and multiple European countries have invested considerable research and mitigation strategies to address the issues of road wildlife ecology. Some notable examples include the US 93 reconstruction project on the Flathead Indian Reservation in northwest Montana, representing one of the most extensive wildlife-sensitive highway design efforts to occur in the United States. The Trans-Canada Highway, which runs through Banff National Park, was constructed and regularly monitored for over- and underpass use in Canada, where resulting reports and publications from these projects should be used as important guidelines for future road wildlife ecology projects in China.

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References

Dai Q, Yuan Z P, Zhang J D, et al. (2006). Effects of alpine wetland road and road construction on habitat using of small mammals and birds. *Biodiversity Science*. 14(2):121-127

Ding H, Jin Y H, Cui J G, et al. (2008). Review on ranges of ecological road-effect zones. *Journal of Zhejiang Forestry Colloge.* 25(6):810-816

Fan J T, Li J S, Quan Z J, et al. (2011). Impact of road construction on giant panda's habitat and its carrying capacity in Qinling Mountains. *Acta Ecologica Sinica*. 31:145-149

Forman R T T, Deblinger R D.(2000). The ecological Road-effect zone of a Massachusetts (U.S.A.) Suburban Highway. *Conservation Biology*, 14(1):36-46

Gu H J, Dai Q, Wang Q, et al. Factors contributing to amphibian road mortality in a wetland. 2011. *Current Zoology*. 57(6):768-774

Kong F. (2009). Monitoring behavior of Wildlife crossing underpass. Master's Dissertation. *Northwest University*.

Li S L. Speech on 2012 national traffic and transportation Meeting [EB/OL]. (2012-01-05)[2012-07-18]. http://wenku.baidu.com/view/b8c8787c168884868762d6d2.html

Li Y Z, Zhou T J, Jiang H B. (2008). Utilization effect of wildlife passages in Golmud-Lhasa Section of Qinghai-Tibet Railway. *China Railway Science*.29 (4):127-131

Liu J G, Ouyang Z Y, Pimm S L, et al. (2003). Protecting China's Biodiversity. *Science*. 300:1240-1241

Ma J Z, Zong C. (2010). Conservation and Management of Wildlife resources in China. *Science&Technology Review*. 26(14):36-39

Ma Y T, Tian L H, Zeng Z G, et al. (2007a).Influence of road G210 on the diffusion by golden takin between east and west in niubeiliang nature reserve(Ⅰ)-diffusion characteristics of golden takin on both side of road G210. *Journal of Shanxi Normal University (Natural Science Edition). 35(Sup.)*: 104-107

Ma Y T, Tian L H, Wu X T, et al. (2007b). Influence of road G210 on the diffusion by golden takin between east and west in niubeiliang nature reserve(Ⅱ)-The changing of floating vehicle of road G210. *Journal of Shanxi Normal University (Natural Science Edition) 35*, sup: 108-111

Pan W J, Lin L, Luo A D, et al. (2009). Corridor use by Asian elephant. *Integrative zoology*. 4: 220-231

Qiu L, Feng Z J. (2004). Effects of traffic during daytime and other human activities on the migration of Tibetan Antelope along the Qinghai-Tibet highway, Qinghai-Tibet Plateau. *Acta Zoologica Sinica.* 50(4):669-674

Song F C, Tian W P, Zhao Q Q, et al. (2005). Environment Impact and Engineering Measures for the Si-Xiao Expressway Construction in Tropical Rain Forest Area. *Journal of China & Foreign Highway*. 22(9):175-178

Wang Y, Li H F, Cui P, et al. (2007). A study on Wildlife Passage along highway in Wolong National Nature Reserve. *Highway*. 1:99-104

Wang Y, Piao Z J, Kong Y P, et al. (2009).Primary investigation of wildlife crossing Ring Changbai Mountain Scenic Highway. *Transportation Construction&Management*. 9:117-121

Wang Y, Piao Z J, Li Q L, et al. (2010). Research on Yellow Weasels' Roadside activities along Changbaishan Mountain Tourist Highway in Jilin Province. *Sichuan Journal of Zoology*. 29(2):166-169

Wang Y, Li Q L, Guan L, et al. (2011). Effect of Traffic Noise around Napahai Wetland Highway on Birds. *Chinese Journal of Zoology*. 46(6):65-72

Wang Y, Piao Z J, Guan L, et al. (2013). Influence of Ring Changbai Mountain Scenic Highway on wildlife. *Chinese Journal of Ecology*. 32(2): 425-435

Xia L, Yang Q S, Li Z C, et al. (2005). Disturbance of Transportation Facilities to Seasonal Migration of Tibetan Antelopes in Hoh-Xil National Nature Reserve. *Sichuan Journal of Zoology*. 24(2):147-151

Yang Q S, Xia L. (2008). Tibetan wildlife is getting used to the railway. *Nature*. 452:810-811

Yin B F, Huai H Y, Zhang Y L, et al. (2006). Influence of Qinghai-Tibetan railway and highway on wild animal's activity. *Acta Ecologica Sinica*. 26(12):3917-3923

Yin B F, Yu Z Y, Yang S M, et al. (2007).Effects of Qinghai-Tibetan highway on the activities of Pantholops hodgsoni, Procaprapic-ticaudata and Equus kiang. *Chinese Journal of Ecology*. 26(6):810-816.

Zeng Z G, Li J S, Yan W B, et al. (2009a). Impact of the Lanzhou-Chongqing Highway and Railway on the movement of Giant Pandas and their habitat protection. *Sichuan Journal of Zoology*. 28(5):641-646

Zeng Z G, Li J S, Yan W B, et al. (2009b). Impact of Yangxian-Taibai Highway on the movement of Giant Panda in the Qinling Mountains and its habitat protection. *Journal of Northwest Forestry University*. 24(6):88-93

Zhang F, Hu D F, Chen J L, et al. (2008).Safe passage for wild horse. *Great nature*. 3:14-16

Zhang H F, Feng T, Ji M Z, et al. (2009). Monitoring wildlife using small bridges of Qinghai-Tibet railway. *Biology Magazine*. 44(10):8-10

Zhou L, Yin B F, Yang S M, et al. (2006). Effects of Qinghai-Tibet highway on genetic differentiation of plateau pika(*Ochotona curzoniae*). *Acta Ecologica Sinica.* 26(11):3572-3577