Research Project

BROWN BEAR VEHICLE COLLISIONS IN WESTERN CARPATHIAN MOUNTAINS, SLOVAKIA

Silvia Janská

Research Project submitted in partial fulfilment of the Master of Science course in Wild Animal Biology, University of London, 2010

TABLE OF CONTENTS

Statement of Contribution

The author and Robin Rigg from Slovak Wildlife Society have developed the idea behind this research project. The author was responsible for all data collection, analyses (with guidance from Kim Stevens, The Royal Veterinary College) and interpretation, and has written up the project.

Front cover photographs were obtained from the archive of Tatras National Park (TANAP) and the State Nature Conservancy of the Slovak Republic (Štátna ochrana prírody).

Acknowledgments

I would like to thank Tony Sainsbury and Michael Waters for their guidance and support throughout the year.

My particular gratitude goes to my two supervisors, Kim Stevens and Robin Rigg, for their enthusiasm and support throughout my research project.

I would like to say a big thank you to my father and mother for their help and patience. Without them, Mrs. Stevens and Mr. Rigg this project would not have been feasible.

I would like to show my appreciation to the State Nature Conservancy of the Slovak Republic (Štátna ochrana prírody) for providing all of the records on bear-vehicle collisions in Slovakia for the past ten years.

Nominated Journal

Ursus
(http://www.bearbiology.com/ursus/ursinstr.html)

Grant Proposal

BROWN BEAR VEHICLE COLLISIONS IN WESTERN CARPATHIAN MOUNTAINS, SLOVAKIA

Silvia Janská

Grant Proposal submitted in partial fulfilment of the Master of Science course in Wild Animal Biology, University of London, 2010

MSc WAB / WAH GRANT APPLICATION FORM

Institute of Zoology
LIVING CONSERVATION

PROJECT REG CODE

This form must be completed and submitted to the MSc Course Administrator (rlloyd@rvc.ac.uk) by **Monday 12th April 2010**. In the case of projects involving live animals, this must be AT LEAST three months before the start of the project. Please refer to the document 'Guidance Notes – MSc Grant Application Form' for details.

01. Title of Project

Brown bear *(Ursus arctos)* vehicle collisions in the Western Carpathian mountains of Slovakia; spatial analysis and identification of risk factors.

02. Project Aims

AIMS (max 40 words):

The aim of the project is to test the hypothesis that brown bear-vehicle collisions in the Western Carpathian mountains of Slovakia are associated with a) food source attracting bears to travel routes, b) disturbance of bear movement corridors, c) low visibility for vehicle drivers due to the structure of the travel routes and vegetation density, d) overpopulation of bears.

Specific objectives include:

(1) to visualize and explore the spatial pattern of brown bear-vehicle collisions in the Slovakian Western Carpathian mountains;

(2) to identify ursine and anthropogenic factors significantly associated with bear-vehicle collisions.

03. Applicant contact details

NAME: Silvia Janska

EMAIL: sjanska@rvc.ac.uk

04. Supervisor

SUPERVISOR: Mrs. Kim Stevens
EMAIL: kstevens@rvc.ac.uk

SUPERVISOR 2: Mr. Robin Rigg
EMAIL: info@slovakwildlife.org

INTERNAL SUPERVISOR (if principle supervisor is non-ZSL or RVC):

05. Location of project

Study Area: The Western Carpathian mountains, containing over 90% of the Slovak bear population, will form the study area for the project; the Eastern Carpathians will be excluded (Figure 1)[1].The Western Carpathians cover approximately 13,000km^2, the region is mountainous and elevations range from 0 to 2655 m. The mountain ranges in the area are Veľká Fatra, Malá Fatra, Nízke Tatry, Západné Tatry, Vysoké Tatry, Oravská Magura, Belianske Tatry, and Slovenské Rudohorie. Bear distribution is linked to forest cover[1].

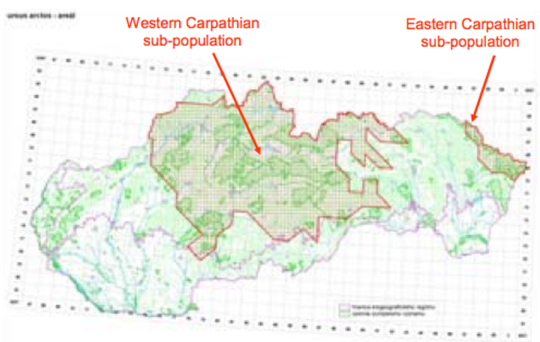

Figure 1: Bear distribution in Slovakia; shown are the two sub-populations.

06. Research Costs

This section should include a detailed breakdown of equipment, consumables, travel and accommodation costs.

Application	Approximate Cost (GBP)
Transport London-Bratislava-London (air travel + train travel)	**200**,-
Transport within the survey area	**150**,- (ca. 1500km; GBP 1 / 1 liter petrol; consumption 10 l/100km; 15x10)
Accommodation	**150**,- (20 nights free, 15 nights x GBP 10)
GPS equipment	**185**,-
Consumables (stationary, food…)	**180**,-
Total	**865**,-

07. Funding sources identified

Approx. GBP 700 RVC MSc course

08. Project Abstract (maximum 250 words)

In the second half of the 20th century, the number of brown bears (*Ursus arctos*) in the Slovakian Carpathian mountains increased rapidly from 20 to 30 individuals to the current 800 to 900 individuals[(2)]. As a result human-bear conflict has increased. However, there is no published evidence of 'overpopulation' of bears in this region due to the limited scientific research[(1)]. Bear – vehicle collisions are one of the main sources of humans – bear contact. Apart from 'regulation shooting' (n=418), bear-vehicle collisions (n=48) accounted for the highest mortality of bears between 1994-2006[(1)]. The presence of anthropogenic factors that may attract bears, such as food sources related to human activity, have been shown to be associated with bear-vehicle collision sites[(3)]. Moreover, the average annual growth rate of bear population is 4.5% per year[(2)]. Therefore, additional scientific research data are critical features for successful management of bears, but if human-bear conflict cannot be adequately alleviated, public support for bear conservation risks being undermined. A better understanding of the factors that increase the risk of bear-vehicle collisions may facilitate the development of management recommendations to improve acceptance of bears by decreasing the number of human-bear conflicts. The aim of the project is to test the hypothesis that brown bear-vehicle collisions in the Western Carpathian mountains of Slovakia are associated with a) the presence of food sources, b) disturbance of bear movement corridors, (c) low visibility due to the structure of the travel routes and vegetation density, d) overpopulation of bears.

09. Case for Support

This section should describe the background to the project, the motivation for the proposed research, the hypothesis to be tested (if applicable), SMART objectives (specific, measurable, achievable, realistic and time-limited) and justification for the resources sought and references.

1. Motivation for research

The brown bear is the largest and the most numerous carnivore in Slovakia. The recovery of the numbers of this species was most certainly noticed by both experts and the public, resulting in numerous articles in the popular press and wildlife magazines. However, high quality scientific papers are scarce, there is little research using modern methods and little participation of Slovak wildlife researchers in international initiatives. Consequently, little is known about bears in Slovakia and this may prove detrimental as the population of bears is growing. Therefore this project aims to enrich this subject with analysing one area of human – bear conflict, the bear – vehicle collisions.

Specific objectives include:

(1) to visualize and explore the spatial pattern of brown bear-vehicle collisions in the Slovakian Western Carpathian mountains;

(2) to identify ursine and anthropogenic factors significantly associated with bear vehicle collisions.

1.1. Background to the project:

i. **Introduction.** Over 95% of the European brown bear (*Ursus arctos*) population in Western Carpathian mountains is located in Slovakia. This population has grown substantially since the 1930s, when there were only 20 to 60 individuals, to approximately 5 bears/100km^2 (reaching 11 bears/km^2 in some mountain ranges) in 2009[(2)]. Expert estimates and game statistics suggest that the current population size is between 770 and 870 individuals occupying a total area of 16,500 km^2. The observed annual growth rate is 4.5% per year and is still increasing[(2)]. The habitat in Slovakia is somewhat fragmented, consequently some mountain ranges have higher bear densities while the lower lying areas have lower bear densities; human activity is most intensive between these areas. Some authors believe that the presence of bears in these areas is undesirable on the grounds of economic and human safety reasons[(7)]. However, there have been no reported cases of people being killed by a bears in the Slovak Carpathians ever since the population started recovering in late 1900s. In addition, although people have been injured, the number of injuries has decreased from an average of nine people per year between 1985 and 1987, to a current average of four instances per year[(2)].

ii. **Research background.** The most apposite series of scientific research has been reported in Croatia, Slovenia and the USA. In the mid 1900s it was suggested that the increasing availability of human food and garbage resulted in a change in bear behaviour and a subsequent increase in bear-related human injures. Between the 1930s and 1960s most injuries in Yellowstone National Park, USA occurred along roadsides where bears were attracted by human food and garbage. A management programme (focusing on removing food-conditioned bears from roadside and developed areas, prohibiting feeding and installing bear-proof garbage bins) changed the statistics drastically from an average of 48 to 6.4 people injured per year. However, the majority of these injuries still occur along roadsides(4). A similar scenario occurred at the Denali National Park, USA, where incidents of bears obtaining anthropogenic food decreased by 96% after a management plan was implemented(5). As portrayed by the research at Yellowstone and Denali National Parks, identification of factors such as food source is important in developing appropriate management plans to minimize the number of bear-related human injuries.

Bear mortality resulting from vehicle collisions seems to be a worldwide problem. In Croatia bear-vehicle collision mortality equalled 19% (42 out of 217 bears) (1986-1995), in Slovenia collision mortality 15% (58 out of 350-450 bears) (1997-2002), and in Slovakia 7.7% (45 out if 584 bears) (1994-2002). The proportion of bear mortalities resulting from vehicle collisions in Slovenia and Slovakia is substantially less than that of Croatia, which may be because the data represents a shorter time period; however, this may be negated as the frequency of bears killed due to vehicle collisions has been increasing(1). Research in Slovakia showed that an increased risk of bear mortalities resulting from vehicle collision was associated with a) an increase in the size of the bear population, b) geographical expansion of the bear population, c) increased habituation of bears to the presence of humans and d) increased density and volume of vehicles.

Scientific research data are critical features for the successful management of bears, but if human-bear conflict cannot be adequately alleviated, public support for bear conservation risks being undermined. A better understanding of the factors that increase the risk of bear-vehicle collisions may facilitate the development of management recommendations to improve acceptance of bears by decreasing the number of human-bear conflicts.

The aim of the project is to test the hypothesis that brown bear-vehicle collisions in the Western Carpathian mountains of Slovakia are associated with a) the presence of food sources, b) disturbance of bear movement corridors, (c) low visibility due to the structure of the travel routes and vegetation density, d) overpopulation of bears.

Specific objectives include:
(1) to visualize and explore the spatial pattern of brown bear-vehicle collisions in the Slovakian Western Carpathian mountains;
(2) to identify ursine and anthropogenic factors significantly associated with these collisions.

References

1. Rigg R, Adamec M. Status, ecology ad management of the brown bear (Ursus Arctos) in Slovakia. 2007;
2. Rigg R, Adamec M. Conservation and management of the brown bear (Ursus acrtos) in the Western Carpathians [Internet]. Prague, Czech Republic: Slovak Wildlife Society & State Nature Conservancy of the Slovak Republic; 2009. Available from: http://www.eccb2009.org/
3. Huber D, Kusak J, Frkovic A. Traffic kills of brown bears in Gorski Kotar, Croatia. Ursus. 1995;10:167-171.
4. Gunther K, Hoekstra H. Bear-inflicted human injuries in Yellowstone National Park, 1970-1994. Ursus. 1995;10:377-384.
5. Schirokauer D, Boyd H. Bear-human conflict management in Denali National Park and Preserve, 1982-94. Ursus. 1995;10:395-403.
6. Taberlet P, Bouvet J. Mitochondrial DNA Polymorphism, Phylogeography, and Conservation Genetics of the Brown Bear Ursus arctos in Europe. Proceedings of the Royal Society of London. Series B: Biological Sciences. 1994 Mar 22;255(1344):195-200.
7. Hell P. (2003). Current problems of the co-existence of man and bear in the Slovak Carpathians and options for their solution. In: The integrated solution to the problem of nuisance bears (*Ursus arctos*). Rigg R. and Baleková K. eds. Conference proceedings, Nová Sedlica, Slovakia 11-12.4.2002

10. Project Methodology/ Project Plan

This section should describe briefly the methodologies involved in the project. However, it should aim to provide sufficient detail to allow adequate assessment of scientific, conservation, ethical, welfare and public relations implications of the work. Also include your proposed statistical analyses.

2. Methods to be used

2.1. Study Area: The Western Carpathian mountains, containing over 90% of the Slovak bear population, will form the study area for the project; the Eastern Carpathians will be excluded (Figure 1). The Western Carpathians cover 13,000km^2, the region is mountainous and elevations range from 0 to 2655 m. The mountain ranges in the area are Veľká Fatra, Malá Fatra, Nízke Tatry, Západné Tatry, Vysoké Tatry, Oravská Magura, Belianske Tatry, and Slovenské Rudohorie. Bear distribution is linked to forest cover(1).

2.2. Study population and study design: The study population comprises of West Carpathian brown bear (*Ursus arctos*) sub-population. There is no evidence of genetic differences between the two sub-populations in Slovakia (West Carpathian and East Carpatian)(1). On a larger scale, European brown bears may be divided into either the Western or Eastern lineage; the mitochondrial DNA of the two lineages differs by more than 7% (7). All bears in Slovakia belong to the Eastern lineage(1). The present study will include bears of all ages and both sexes.

This will be a retrospective case-control study. Cases will be all sites that have experienced bear-vehicle collisions between 1997 and 2010. For each known collision site a non-collision site (control) will be selected along the same road/railway. Due to time restrains and for practical reasons, a non-collision site will be selected by moving 200 m down the road away from a known collision site.

2.3. Data Collection: A bear-vehicle collision is defined as an instance when a moving vehicle collides with a bear. Records of bear-vehicle mortalities ranging from 1997 to 2010 will be obtained from Statna Ochrana Prirody ('National Protection of Environment') in Bansky Bystrica, Slovakia and include location of collision site, date and season of collision, type of vehicle involved in collision (car/train) and demographic data on the bear.

2.4. Statistical and Spatial Analysis

i. **Visualisation and exploration of collision sites:** Exact collision sites will be visited and georeferenced. Point locations of the collisions will be mapped using ArcGIS 9.3 and kernel–smoothing used to produce a map showing density of collisions (number of collisions per square kilometre).

ii. **Identification of risk factors associated with collisions:** Data regarding anthropogenic factors that are potentially associated with collisions will be recorded. These include:

   a. Local food attractants present along the road or railway such as garbage, grain spills from trains, presence of fruit-bearing vegetation (blueberries, apples, pears) and food-source fields (corn)
   b. Speed limit at the site of collision
   c. Bear movement corridors that have been cut by a traffic lines
   d. Longitudinal and perpendicular visibility on the road/railway. Longitudinal visibility will be assessed by identifying curves in the road/railroad; perpendicular visibility by vegetation cover.

   Ursine factors that may increase the risk of collisions include overpopulation and therefore dispersal of bears further away from forest areas.

   Descriptive statistics for the risk factors will be obtained using SPSS version 17.

   As case and control sites are matched on location, conditional logistic regression will be used to identify risk factors associated with being a collision site. STATA version 10 will be used to perform the regression analysis.

   A 5 square kilometre grid will be placed over the study area and frequency of collisions per 5 km2 determined. Linear regression will be used to identify factors associated with frequency of collisions per 5 km2 STATA version 10 will be used to perform the linear regression.

11. According to the criteria below, is this a conservation project?: Yes: ☒ No: ☐

CRITERA:

Interventions with the explicit intention of:

- managing wildlife or assisting in wildlife management (including baseline monitoring, wildlife health, conservation breeding and reintroduction).
- changing human attitudes / behaviour for the purpose of conservation.
- influencing biodiversity related policy.

12. Additional Information

Continent:

☐ Global
☐ Africa
☐ Americas
☐ Antarctica
☐ Asia
☒ Europe
☐ Oceania
☐ Not Applicable

Global ZSL Programmes: (if applicable)

☐ Business & Biodiversity
☐ Conservation breeding and reintroductions
☐ EDGE
☐ Indicators & Assessments
☐ Marine & Freshwater
☐ Wildlife Health

Conservation Activity:

☐ Surveys and monitoring
☒ Research
☐ Planning and policy
☐ Conservation breeding and reintroduction
☐ Communication (education and awareness, CEPA)
☐ Law enforcement in situ
☐ Law enforcement ex situ

☐ Capacity building and training
☐ Conflict resolution
☐ Economic incentives

If your project includes field activity, what is the primary country?:

Sovakia

What type of habitat?:

☒ Temperate Forest
☐ Tropical Dry Forest
☐ Tropical Wet Forest
☐ Grasslands
☐ Tundra
☐ Deserts
☐ Marine
☐ Freshwater
☐ Global
☐ Not Applicable

Further information on field location:

Western Carpathian mountains of Slovakia covering a range of 13,000km^2. The region is mountainous and elevations range from 0 to 2655 m.

If the project has a taxon focus, what is the primary taxon (common name)?:

Ursus arctos

Additional species (common names):

Does this project directly impact…	**Live animals?:**	☐ Yes	☒ No
	Humans?:	☐ Yes	☒ No

This section covers HEALTH AND SAFETY and other STATUTORY requirements.

13. Date of Project Risk Assessment AND Date of COSHH Assessment.

To be carried out before this form is submitted. Contact Marie Knudsen (Health & Safety Administrator) for advice.

RISK Assessment date: COSHH Assessment date:

14. Health & Safety risks identified

(e.g fieldwork, lab work, lone working, animal handling, sample handling etc)

15. Does the project involve the import of samples? Yes: ☐ No: ☒

If yes, what type of samples?
Tissue: ☐
Blood: ☐
DNA/RNA: ☐
Faeces: ☐
Other:

Give brief details of how samples will be handled:

Does this require an import licence (DEFRA, CITES etc)? Yes: ☐ No: ☐

If yes, give details:

16. Does the project involve recombinant organisms? Yes: ☐ No: ☒

Is a new ACGM assessment required? Yes: ☐ No: ☐

Staff member responsible for training:

17. Does the project involve ionising radiation? Yes: ☐ No: ☒

Staff will require dosimetry monitoring. Please contact RPS before work begins.

Staff member responsible for training:

18. Does the project require specific computer software? Yes: ☒ No: ☐

If yes, is the software…
Purchased: ☐
Shareware: ☒
Freeware: ☐

Has this been registered with the ITC Office? Yes: ☒ Give date: 26 March 2010

19. Does the project involve the use of live animals? Yes: ☐ No: ☒

If yes, which species?

How many animals will be involved?

Are these animals listed as threatened? Yes: ☐ No: ☐

If yes, define category of threat (i.e. if listed by IUCN or nationally, define list and give details):

20. Where will the project be carried out?

NOTE: Ensure that animal accomodation is available.

Nuffield Building:	☐	**WZ:**	☐
Wellcome Building:	☐	**London Zoo:**	☐
RVC Camden:	☒	**RVC Hawkshead:**	☐
Other:	☒		

Field: UK (give details):
Overseas (give details): Slovakia

21. Will live animals be imported? **Yes:** ☐ **No:** ☒

NOTE: Appropriate accommodation to satisfy rabies and other quarantine regulations must be available.

If yes, give details of permits and licences required (e.g CITES) and reference numbers where appropriate:

22. Does the project involve any of the following?

NOTE: Section 10 (Methodology) should be used to give specific details (for example, technique or agent used for euthanasia or physical restraint).

Behavioural observations: ☐
Marking or radio-tracking: ☐
Manipulation of litters/clutches: ☐

Post mortem sample collection: ☐
Sampling from live animals: ☐
Euthanasia: ☐

Physical restraint: ☐
Sedation/chemical restraint: ☐
Anaesthesia: ☐
Surgery: ☐

Temporary or Permanent isolation: ☐

Other:

23. If taking samples from live animals, define the nature of the sample.

Blood: ☐	Urine: ☐	Feathers: ☐
Tissue: ☐	Hair: ☐	
Faeces: ☐	Scales: ☐	

Other:

Is an additional licence required for sample collection (e.g CITES, English Nature)?

Comments:

NOTE: Relevant comments might for example include reference to the fact that samples are a bi-product of a management procedure such as ear tagging, OR that only shed feathers are collected, OR that faeces are collected after a tracked animal has moved away.

24. Please list any procedures likely to cause pain and/or distress to the animals.

N/A

25. Please list any other relevant issues.

NOTE: Relevant issues might include taking bat wing punches just prior to hibernation, OR that a particular type of marking might have behavioural consequences, OR that individual animals would only be sampled once during a given period.

N/A

26. Who will carry out the work (if not the Applicant, please specify)?

The Applicant – Silvia Janska

27. Will a Home Office Project Licence be required? **Yes:** ☐ **No:** ☒

If in doubt about the need for a Home Office licence, please contact Andy Hartley (andy.hartley@zsl.org) for advice.

If yes, give details (PPL and PIL reference numbers):

Will Licensed work be carried out by the Project Leader (if not, please specify)?

Will any staff training be required? Yes: ☐ No: ☐

If yes, how will that training be carried out?

APPROVAL - FIRST STAGE

To be completed by the Secretary of the Ethics Committee and Head of IoZ

Does the project proposal require further consideration by the ZSL Ethics Committee?

Yes: ☐ No: ☐

01. Secretary of Ethics Committee :____________________ **Date** :__________

02. Director of IoZ :____________________ **Date** :__________

FOR OFFICE USE:
Ethics Approval Form Submitted: __________
Approved by the Ethics Committee? Yes: ☐ No: ☐

Have the policy and PR implications for IoZ and ZSL been fully considered? Yes: ☐ No: ☐

Are there any issues to be noted, considered or further discussed with the PR Dept.? Yes: ☐ No: ☐

If yes, give details:

03. Director of IoZ :______________________________ **Date** :__________

APPROVAL - FINAL STAGE

To be signed in order of listing

04. Safety Advisor :______________________________ **Date** :__________

05. Project Supervisor :______________________________ **Date** :__________

06. Course Co-Director :______________________________ **Date** :__________

07. Course Co-Director :______________________________ **Date** :__________

08. Head of PID at the RVC:______________________________ **Date** :__________

09. Director of IoZ :______________________________ **Date** :__________

STATUS: **FILED:**

Scientific Paper

BROWN BEAR VEHICLE COLLISIONS IN WESTERN CARPATHIAN MOUNTAINS, SLOVAKIA

Silvia Janská

Project Supervisors: Kim Stevens and Robin Rigg

Format in accordance with the "instructions to authors" of the journal Ursus.

Scientific Paper submitted in partial fulfilment of the Master of Science course in Wild Animal Biology, University of London, 2010

BROWN BEAR VEHICLE COLLISIONS IN WESTERN CARPATHIAN MOUNTAINS, SLOVAKIA

SILVIA JANSKÁ, The Royal Veterinary College, Royal College Street, London NW1 0TU, United Kingdom, email: sjanska@rvc.ac.uk

KIM STEVENS, The Royal Veterinary College, Hawkshead Lane, North Mymms, Hatfield, Hertfordshire AL9 7TA, United Kingdom, email: KStevens@rvc.ac.uk

ROBIN RIGG, P.O. Box 72, Belanská 574/6, 033 01 Liptovský Hrádok, Slovak Republic, email: info@slovakwildlife.org

Abstract: Over 95% of Slovakia's brown bear (*Ursus arctos*) population is found in the Western Carpathian Mountains. Besides regulation shooting, collision with vehicles causes the highest mortality of bears in Slovakia. At least 47 bears have collided with vehicles in this region between 2000 and 2010. Previous research suggests biocorridors are often cut by traffic lines. The aim of the present research is to test the hypothesis that bear-vehicle collisions are associated with a) the presence of food sources, b) disturbance of biocorridors, (c) low visibility due to the structure of the travel routes and vegetation density. Matched-pair case-control study was performed. The population of bears involved in collisions was investigated. Spatial distribution of collisions was visualized using ArcGIS. Anthropogenic factors significantly associated with collision sites (n = 47) compared to non-collision sites (n = 47) along roads and railways were identified. Out of the 47 collisions, 66% (n = 31) involved a car, 32% (n = 15) a train and 2% (n = 1) a bus. Of the years studied, 2002 had the highest proportion of collisions (23%) and most accidents occurred in June, October and September. Most accidents involved male bears up to the age of 3 years. Multivariable conditional logistic regression showed a strong association between collision sites and the presence of a forest and an agricultural field ($p < 0.05$). These factors are approximately eleven times more likely to be present at a collision site compared to a non-collision site (OD 11.19, 95% CI 0.94 – 133.04). When developing measures and prioritizing locations to decrease the number of bear-vehicle collisions, the presence of both a forest and an agricultural field should be considered. Provisional mitigation measures proposed are continuous electrical fence in high-risk collision regions and use of the chemical repellents.

Key words: *Ursus arctos*, brown bear, Slovakia, Western Carpathian Mountains, vehicle collisions, risk factors, ArcGIS

The Western Carpathian Mountains form an important habitat for brown bears (*Ursus arctos*) in Central Europe. Even during a period of excessive harvest up to the early 1930s, the bear population persisted in this mountain range while going extinct elsewhere (Janik 1997). The bear range in the Western Carpathian Mountains in Slovakia is approximately 13,000 km^2 and over 95% of Slovakia's brown bears are found here (Janik 1997; Minďáš et al. 2006). Much of the area is covered by coniferous and mixed coniferous-deciduous forest, which is the optimal ecological condition for brown bears (Nováková & Hanzl 1970). Here, bears are usually found at altitudes between 700 and 1,250m

(Compiled by C. Servheen, H. Herrero and B. Peyton and the IUCN/SSC Bear and Polar Bear Specialist Groups 1999).

The number of bears in Slovak Carpathian Mountains has grown substantially since 1932 when contemporary authors reported there to be less than 100 individuals (Žuffa 1932). By the late 1960s, questionnaire research reported 334 bears (Randik 1971). Currently, the number of bears in Slovakia is considered to be between 700 and 900 individuals (Rigg & Adamec 2007). Hunters' estimates are 1500 individuals. However this statistic is obtained on the basis of observation, leading to the error of duplicate counts of animals that move between different forestry areas. The mean density is 5 bears/100 km^2, reaching 11 bears/100 km^2 in some areas, and the annual growth rate since 1932 has averaged 4.5% per year (Robin Rigg & Michal Adamec 2009) (Figure1). During the communist period, bear hunting managers considered 300 – 500 individuals in a 12,000 km^2 range to be a 'tolerable number' of bears in Slovakia while an 'optimal number' was said to be 350-400 bears, which would be equivalent to an average density of 2.5-4.2 bears/100km^2 (R. Rigg & M. Adamec 2007). Hell (2003) suggested that the 'optimal number' of bears in Slovakia would be 3-5 individuals per 100km^2. Although the population now seems to have exceeded these parameters, the number of bear-caused injuries to people appears to have decreased from an average of nine people per year between 1985 and 1987 to a current average of four per year (Robin Rigg & Michal Adamec 2009). There have been no reported cases of people being killed by bears in the Slovak Carpathians since the population started recovering in 1930s.

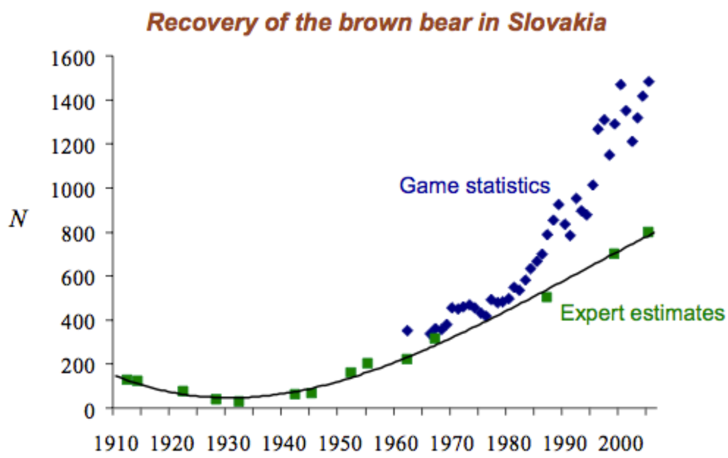

Figure 1: Estimated brown bear population growth in Slovakia between 1910 and 2005 (Rigg & Adamec 2009).

Besides ‘regulation shooting’, which removes approximately 4% of the population per year, collision with vehicles causes the highest mortality of brown bears in Slovakia. A series of studies conducted by Rigg and Adamec (2007) provide insight into some aspects of bear-vehicle collisions in Slovakia:

1. Between 1994 and 2006, 3.5 bears were killed on average per year as a result of colliding with a vehicle.
2. Road vehicles account for about 70% of these collisions, while 30% of collisions involve trains.
3. The majority of the collisions seem to occur between August and November, with a peak in October.
4. Of all bears killed, 75% weighed up to 110kg.
5. There was no significant difference between the number of males and females killed.
6. 57% of bears killed were under the age of 3 years suggesting that cubs and subadults are particularly susceptible to vehicle collisions.

However, other possible risk factors associated with bear-vehicle collisions were not investigated.

Bear mortality resulting from vehicle collisions seems to be a worldwide problem. The most apposite series of scientific research has been reported in Croatia, Slovenia and the USA. Frequently, increased availability of human food and garbage appears to result in a change in bear behaviour leading to an increased number of bear-related human injuries. During the mid 1900s in Yellowstone National Park, USA, most injuries occurred along roadsides where human food and garbage served as an attractant for bears (Gunther & Hoekstra 1995). Consequently, a management programme was implemented which focused on removing food-conditioned bears from roadside and developed areas, prohibiting feeding and installing bear-proof garbage bins. As a result the number of people injured per year decreased from an average of 48 to 6.4. However, the majority of these injuries continued to occur along roadsides (Gunther & Hoekstra 1995). A similar scenario occurred at the Denali National Park, USA, where instances of bears obtaining anthropogenic food decreased by 96% after a management plan was launched (Schirokauer & Boyd 1995). As portrayed by the research at Yellowstone and Denali National Parks, identification of risk factors such as food source is important in developing appropriate management plans in order to minimize bear-human conflict.

In Croatia bear-vehicle collision mortality equalled 19% (42 out of 217 bears) (1986-1995), in Slovenia collision-caused mortality was 15% (58 out of 350-450 bears) (1997-2002), and in Slovakia mortality was 7.7% (45 out if 584 bears) (1994-2002). Although the reduced mortality in Slovakia may be because the data represent a shorter time period, this may be negated as the frequency of bears killed due to vehicle collisions has been increasing (R. Rigg & M. Adamec 2007).

Research in Slovenia showed that an increased risk of bear mortalities resulting from vehicle collision was associated with a) an increase in the size of the bear population, b) geographical expansion of the bear population, c) increased habituation of bears to the presence of humans and d) increased density and volume of vehicles (Jerina et al. 2005).

Scientific research data are critical features for the successful management of bears, and if human-bear conflict cannot be adequately alleviated, public support for bear conservation may be undermined. Now that bear-vehicle collisions and subsequent bear mortality has increased, while still being insignificant up to the late 20th century, it is ever so more important to gain a better understanding of the factors that increase the risk of bear-vehicle collisions, which may then facilitate the development of management recommendations to improve acceptance of bears by decreasing this type of human-bear conflicts (Kalaš 2010).

The aim of the present research is to test the hypothesis that brown bear-vehicle collisions in the Western Carpathian Mountains of Slovakia are associated with a) the presence of food sources, b) disturbance of bear movement corridors, (c) low visibility due to the structure of the travel routes and vegetation density.

Specific objectives include:

1. to describe the population of bears involved in collisions;
2. to visualize and explore the spatial pattern of brown bear-vehicle collisions in the Slovakian Western Carpathian Mountains;
3. to identify anthropogenic factors significantly associated with these collisions.

STUDY DESIGN, STUDY POPULATION AND STUDY AREA

A retrospective matched case-control study was performed to investigate the given objectives. A case was defined as a site where a bear-vehicle collision occurred between 2000 and July 2010. A control was defined as a site 1 km away from the collision site. It was assumed that this would be a site where no collision has occurred in the past 10 years. This was mostly the case, however, some control sites also happened to be a collision site. This is further explained in the discussion.

The study population comprised of Western Carpathian brown bear (*Ursus arctos*) sub-population. There is no evidence of genetic differences between the two sub-populations in Slovakia (West Carpathian and East Carpathian), although on the larger scale the European brown bear may fall under either Western or Eastern lineage on the basis of mitochondrial DNA (R. Rigg & M. Adamec 2007).

The Western Carpathian Mountains of Slovakia, where 95% of Slovak bear population lives in a range of approximately 13,000km^2, form the study area for this research. Due to time constraints, the Eastern Carpathians were excluded from this study. The Western Carpathian mountain ranges include Veľká Fatra, Malá Fatra, Nízke Tatry, Západné Tatry, Vysoké Tatry, Oravská Magura, Belianske Tatry, and Slovenské Rudohorie (Rigg & Adamec 2007). The elevation of the mountain ranges where bears can be found most often varies between 700m and 1,250m (Compiled by C. Servheen, H. Herrero and B. Peyton and the IUCN/SSC Bear and Polar Bear Specialist Groups 1999). Coniferous and mixed coniferous-deciduous forest covers these mountains (Nováková & Hanzl 1970; Minďáš et al. 2006). Bears are commonly found in beech-fir, beech-fir-spruce and spruce forests of Slovakia. Forest cover forms c. 40% of the total territory of Slovakia.

METHODS

Data Collection

All records of traffic-killed bears are archived by the State Nature Conservancy of the Slovak Republic (Štátna ochrana prírody). Records of bear-vehicle collisions in Malá Fatra National Park were obtained from M. Kalaš (pers. communication, June 2010). The records obtained for this research covered the period 2000 to 2010. The records included an approximate description of the site (some of the more recent records included global positioning system (GPS) coordinates), date of collision, age and sex of the bear if determined, the type of vehicle involved (car/bus/train), size measurements of the bear (weight, height, body length, tail length, ear length, head length, length and width of font and hind paws, hair length at withers and on the back, quality, color and density of coat), and the name of the person present at the investigation. These individuals, corresponding to different national parks, were contacted and meetings arranged. Where possible, they identified the collision site in the field; otherwise the location was identified on a map. 85% of the collision sites between years 2000 and 2010 were visited, GPS coordinates recorded and data regarding risk factors recorded. Due to some collision records received at a later date and National Park representatives knowing the precise location of the collision sites being on holidays, it was not possible to visit all of the collision sites. For consistence and reduction of bias, the same researcher visited all sites. Each collision site (n = 47) was paired with a non-collision site (n = 47), which served as the control. Each non-collision site was 1 km away from its paired collision site as this was the approximate average distance after which the terrain would change. Risk factors investigated, as visible from the collision/non-collision site, included the presence of an agricultural field, a meadow, a forest and water source. The presence of a tunnel or a wall was recorded if it was within 200 m of the collision/non-collision site. The presence of biocorridors was recorded; these were identified according to the biocorridors established by the Landscape system of ecological stability in Slovakia (Územný systém ekologickej stability, SR) (Finďo et al. 2007). Longitudinal visibility was determined based on curves in the road or railway. If the visibility was less then 100 m it was recorded as low visibility. Perpendicular visibility was based on the presence of vegetation and rocks and recorded if they obstructed vision within 100m. The speed limit was also recorded. Train speed limits were obtained from Slovak railways 'ŽSR' official website (Železnice Slovenskej Republiky 2008). For each non-collision site, data regarding anthropogenic risk factors were collected.

Statistical And Spatial Analysis

Statistical analysis.— Descriptive statistics were obtained for the study population using SPSS version 17.0 for Windows (SPSS Inc., Chicago, Illinois, USA). As case and control sites were matched on location conditional logistic regression was used for both the univariable and multivariable analysis to identify risk factors associated with the collision site. An automated backwards stepwise procedure was used to fit the multivariable model. STATA/SE 9.0 for Windows (StataCorp LP, College Station, Texas, USA) was used for these analysis.

Spatial analysis.— Point locations of the collision sites were mapped using ArcGIS 9.3 (ESRI Inc., California, USA) and kernel-smoothing using bandwidth of 0.17 was used to produce a map showing density of collisions.

RESULTS

Description of the Study Population and Collision Sites

Forty-seven bear-vehicle collisions were reported in Slovakia between 2000 and 2010; 66% (n = 31) involved a car, 32 % (n = 15) a train and 2% (n = 1) a bus. The bear was not necessarily killed as a result of the accident.

Yearly distribution of vehicle-bear collisions in Slovakia between 2000 and 2010 is shown in Figure 2. The highest number of collisions in one year (23%, n = 11) occurred in 2002, with 6 involving a train and 5 involving a road vehicle. In the past ten years, at least two bears per year collided with a vehicle (4.3% in 2003, 2007 and 2010) except in 2001, when no collisions were recorded.

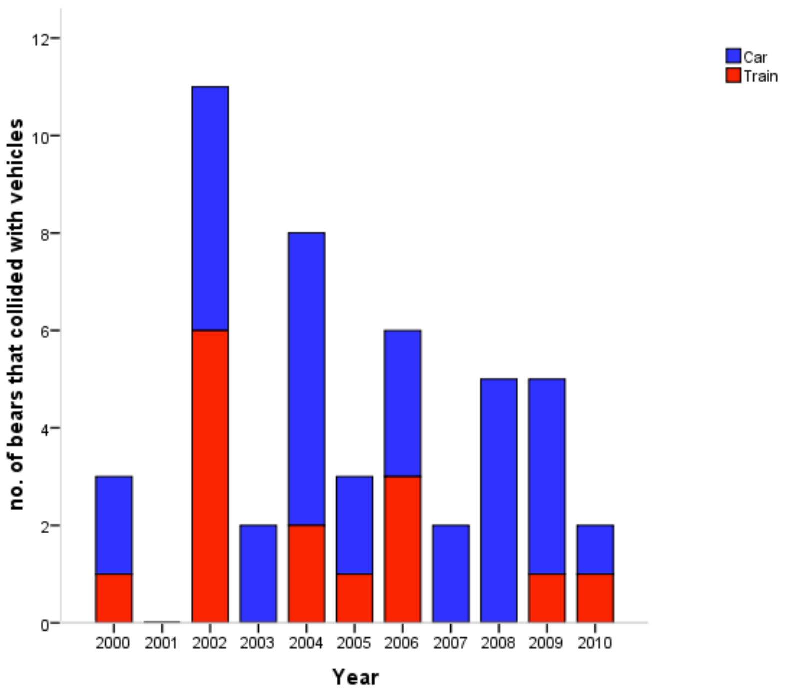

Figure 2: Yearly distribution of vehicle-bear collisions between 2000 and 2010.

The monthly distribution of vehicle-bear collisions in Slovakia between 2000 and 2010 is shown in Figure 3. Most collisions (17%, n = 8) occur in June, September and October. Only one collision occurred in each of April, July and December. For eight collisions, the month was not recorded.

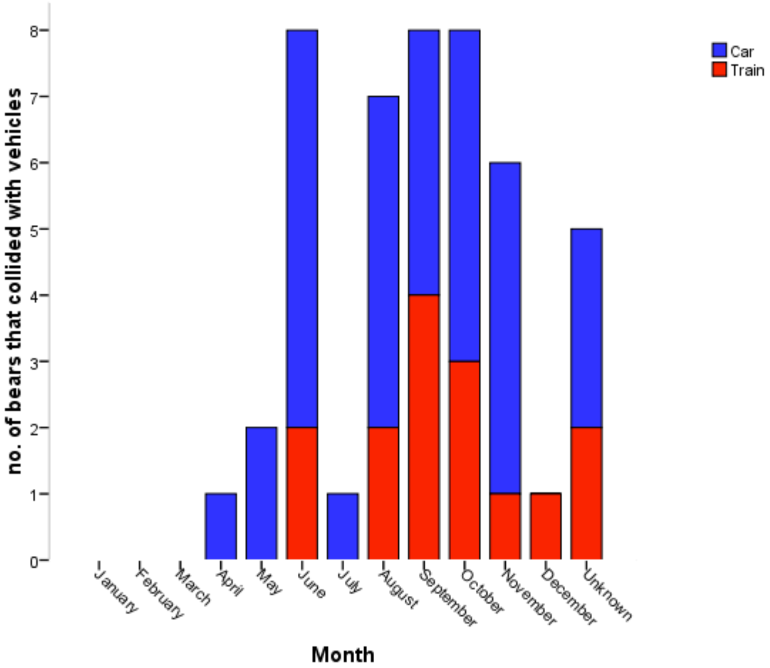

Figure 3: Monthly distribution of vehicle-bear collisions between 2000 and 2010.

The proportions of female bears, male bears and bears of unknown gender that collided with vehicles in Slovakia between 2000 and 2010 are shown in Figure 4: 44% of bears were males, 28% were females and 28% unknown.

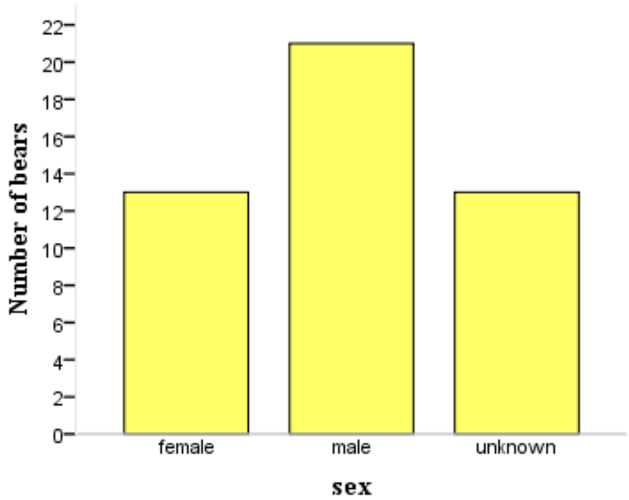

Figure 4: Proportion of female bears, male bears and bears of unknown gender that collided with vehicles between 2000 and 2010.

The proportions of subadults (≤3 years), adults (>4 years) and bears of unknown age that collided with vehicles in Slovakia between 2000 and 2010 are shown in Figure 5. 30% of collisions involved subadults, 25% involved adults and 45% were of unknown age.

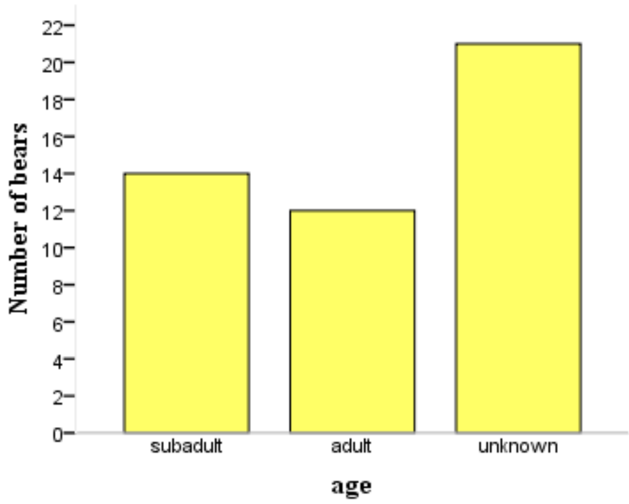

Figure 5: Proportion of subadults (≤3 years), adults (>4 years) and bears of unknown age that collided with vehicles between 2000 and 2010.

Summary statistics for collision and non-collision sites for the variables under consideration are listed in Table 1. Over 70% of collisions occurred in the vicinity of a forest (n = 33). In descending order, the factors at the collision sites with occurrence percentages ranging between 50% and 10% included speed limit 90km/h, agricultural field, movement corridor, water, longitudinal visibility, meadow, speed limit 70km/h, wall and speed limit of 100km/h, and tunnel and perpendicular visibility. In descending order, the factors present less then 10% of the time included speed limit of 40km/h, speed limit of 130km/h, speed limit 60km/h, and speed limits of 75 km/h, 80km/h and 120km/h all with the same percentage. Similarly, the highest and the only percentage above 50 for the non-collision sites was the presence of a forest, 57.4% (n = 27). In descending order, factors at non-collision sites with occurrence percentages ranging between 50% and 10% included water, movement corridor, speed limit 90km/h, agricultural field, speed limit of 60km/h, meadow and speed limit of 70km/h and longitudinal visibility with the same percentage. Factors with occurrence less then 10% included speed limit of 40km/h, speed limit of 130km/h, tunnel, and wall, speed limits of 75km/h, 80km/h and 120km/h.

Table 1: Frequency and percentages of collision and non-collision sites associated with various anthropogenic risk factors.

Anthropogenic risk factors		Collision Site (n (%))	Non-collision Site (n (%))
Agricultural field		18 (38.3)	12 (25.5)
Meadow		11 (23.4)	7 (14.9)
Water		17 (36.2)	18 (38.3)
Speed limit	40	4 (8.5)	4 (8.5)
(km/h)	60	2 (4.3)	9 (19.1)
	70	7 (14.9)	7 (14.9)
	75	1 (2.1)	1 (2.1)
	80	1 (2.1)	1 (2.1)
	90	22 (46.8)	15 (31.9)
	100	6 (12.8)	6 (12.8)
	120	1 (2.1)	1 (2.1)
	130	3 (6.4)	3 (6.4)
Forest		33 (70.2)	27 (57.4)
Movement Corridor		18 (38.3)	17 (36.2)
Visibility (Longitudinal)		12 (25.5)	7 (14.9)
Visibility (Perpendicular)		5 (10.6)	0 (0)
Tunnel		5 (10.6)	2 (4.3)
Wall		6 (12.8)	1 (2.1)

Spatial Distribution of Collision Sites

The spatial distribution of the collisions is depicted in Figure 6 and shows that the collisions occured in the central Slovakia. Most car collisions occured towards the north of this region while most train collisions seemed to occur more towards the south. Furthermore, there are two main clusters of car and train collisions seen on the North-East side of the collision region.

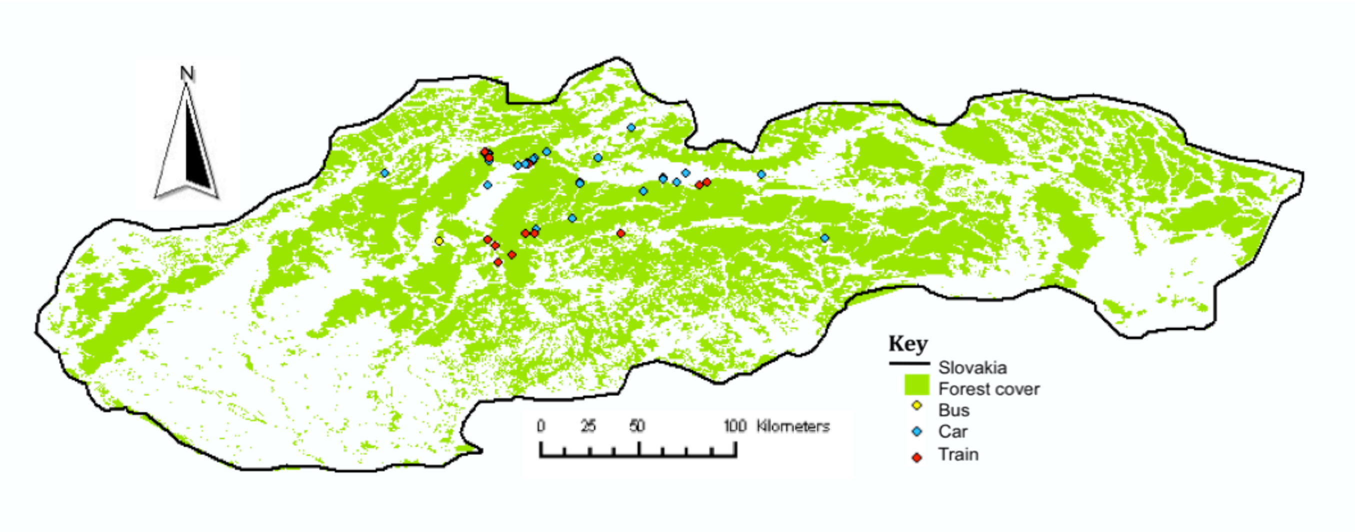

Figure 6: Point map showing the distribution of 47 bear-vehicle collisions in Slovakia between 2000 and 2010 (geographic coordinate system: WGS84).

A kernel smoothed map of bear-vehicle collision densities in Slovakia between 2000 and 2010 is presented in Figure 7. This map identifies two main regions in central Slovakia as high-risk regions. More specifically these regions are between cities/towns: (a) Žilina – Vrútky and (b) Turany – Ratkovo. Both of these regions fall within the jurisdiction of Malá Fatra National Park.

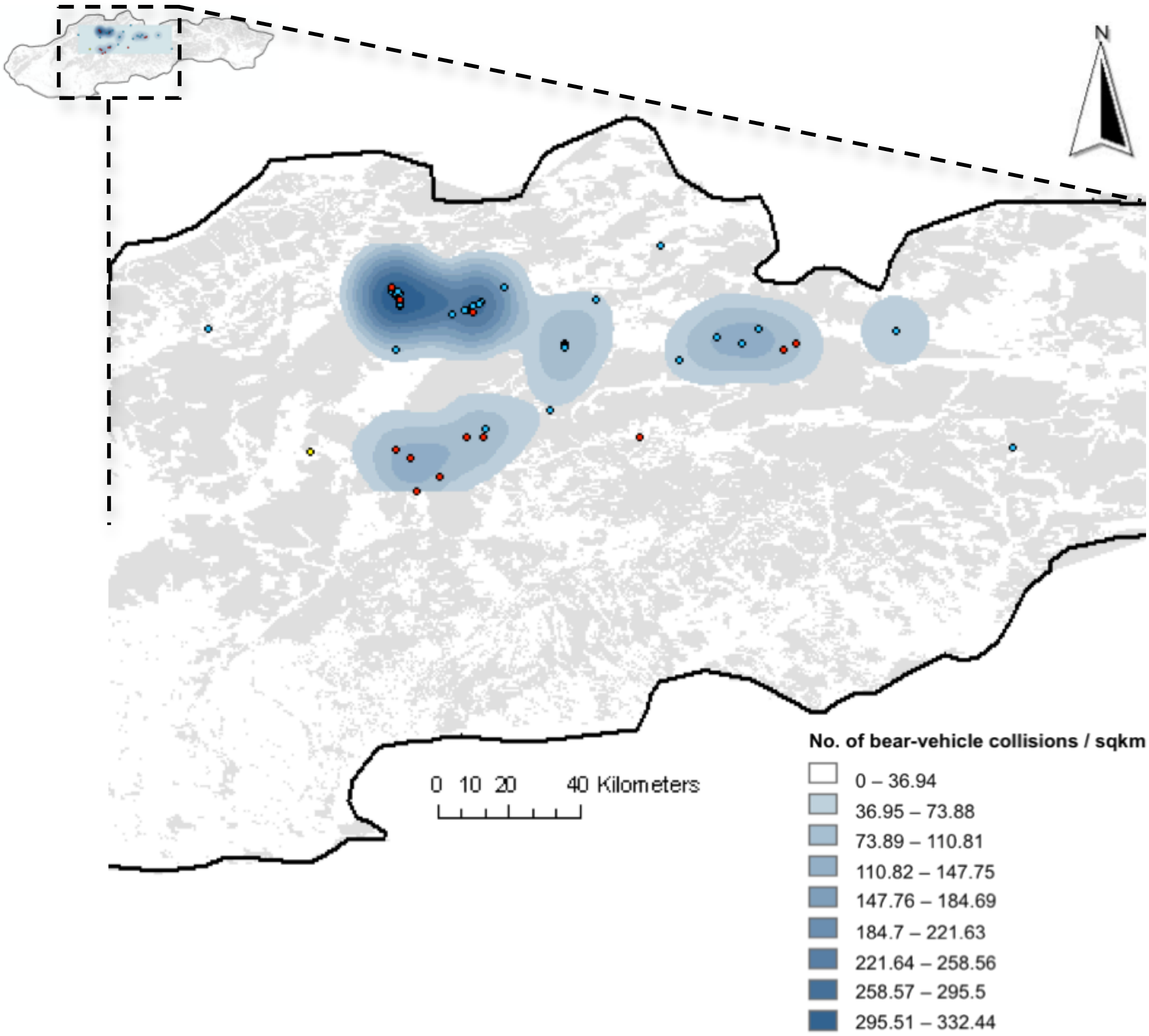

Figure 7: Kernel smoothed map representation of 47 bear-vehicle collision densities in Slovakia between 2000 and 2010 (geographic coordinate system: WGS84).

Identification of Risk Factors Between Collision and Non-collision Sites

Univariable conditional logistic regression showed no significant difference between collision and non-collision sites for any of the variables under consideration (Table 2). However, three risk factors approached significance: presence of an agricultural field ($p = 0.069$), presence of a forest ($p = 0.069$) and presence of a wall ($p = 0.097$).

Table 2: Results of the univariable conditional logistic regression used to identify anthropogenic variables associated with a collision site.

Univariable Conditional Logistic Regression			
Variable	**Odds Ratio**	**95% Confidence Interval**	**p-value**
Agricultural Field	7.00	0.86 – 56.89	0.069
Forest	7.00	0.86 – 56.89	0.069
Wall	6.00	0.72 – 49.84	0.097
Meadow	5.00	0.58 – 42.8	0.142
Visibility (Longitudinal)	2.70	0.71 – 10.05	0.147
Tunnel	4.00	0.45 – 35.79	0.215

The results of the multivariable conditional logistic regression showed that bear-vehicle collisions were significantly associated with the presence of an agricultural field and the presence of a forest; these variables are about eleven times more likely to be present at a collision site compared to a non-collision site (OD 11.19, 95% CI 0.94 – 133.04).

Table 3: Results of the multivariable conditional logistic regression used to identify anthropogenic variables associated with a collision site.

Multivariable Conditional Logistic Regression			
Variable	**Odds Ratio**	**95% Confidence Interval**	**p-value**
Agricultural Field	11.19	0.94 – 133.04	0.056
Forest	11.19	0.94 – 133.04	0.056

DISUCUSSION

Description of the Study Population and Collision Sites

Forty-seven bear-vehicle collisions were reported in Slovakia between 2000 and 2010. 68% of these collisions occurred on a road and 32% on a railway. Similarly, in Slovenia, more collisions occurred on roads (57%) than on railways (43%) (Kaczensky et al. 2003). Furthermore, some of the bears were recorded traveling along railway tracks rather then just crossing over them, which possibly increases the chances of collision. The results from the present study and Slovenia are in contrast to the number of bears killed on roads (30%) and railways (70%) in Croatia (Huber et al. 1995). Similarly in Montana, a railway was responsible for higher mortality than an adjacent highway (Waller & Servheen 2005). The reason suggested was that the bears learned to cross the highway at night, when there is less traffic, whereas rail traffic is higher at night, and so after crossing the highway successfully, the bear would then be hit by a train. In Slovakia, however, there is no highway in the regions where bear-train collisions occurred and all of the road traffic has to pass through the only road present, which is closer to the forest, from which the bears might be descending, than the railway. However, highway construction is planned for this region.

Year 2002 marked the highest number of bear-vehicle collisions in Slovakia as well as Slovenia. During this year, 11 bears collided with vehicles in Slovakia, and 15 bears in Slovenia, while in 1997 for example, only 8 bear collisions occurred in Slovakia and 5 in Slovenia (Jerina et al. 2005; R. Rigg & M. Adamec 2007).

On a monthly scale, most vehicle-bear collisions occurred in June, September and October. Rigg & Adamec (2007) also reported September and October for highest number of collisions in Slovakia between 1994 and 2006. During these months when the summer is at its end, there is a decrease of natural food sources at higher elevations and bears may be more tempted to venture towards villages in search of food. In British Columbia, bears are responsible for approximately 3% of all collisions and most of them occur during September and October (B.C. Ministry of Transportation 2004). In Croatia the peaks of bear-vehicle collisions were in May and October (Huber et al. 1995).

Of all bears killed, 44% were male, 28% female and 28% unknown. Reasons for the inability to identify the gender of the bear include it being hit with such a force that only pieces remained, or it being hit, running away and decomposing by the time it was found. Slovenia also recorded that most of the bears hit by vehicles were males (77% males, 18% females and 5% unknown) (Kaczensky et al. 2003). A possible explanation for more male collisions compared to female may be their more intensified movement as they search for territory. In comparison, in Croatia more females suffered vehicle collisions (45% females, 36% and 19% unknown), while data from Slovakia during the period 1997 to 2005 show no difference between sexes: 14 males and 12 females were killed (Huber et al. 1995; Rigg & Adamec 2007).

In the present study, most collisions occurred with young bears under the age of 3 years; six of them were yearlings. However, the age of a large number of bears was not recorded (45%). Similarly to problems identifying the gender, this may be because bear remains were either not intact or had already decayed when examined. Data on bear-collisions in Slovakia between 1997 and 2005 recorded 14 bear mortalities, 57% being bears up to the age of 3 years, of which six out of eight were cubs in their first year of life (Rigg & Adamec 2007). Likewise in Croatia, the majority (63%) of bears that collided with vehicles were subadults (up to 3 years old) (Huber et al. 1995). In the European populations of brown bears, maternal care usually extends for 18 months (Guillermo Palomero et al. 1997). It is therefore likely that the majority of the subadults killed are young cubs that only recently left their mother.

In the current study, 70% of collisions occurred in the vicinity of a forest, where roads and railways are at lower altitudes and closer to villages. Keeping in mind that most of the collisions took place during

September and October, this is a second study that shows a movement of bears away from the forest during these months. In the Polish Carpathians it was detected that in September and October brown bears leave their main foraging sites and move closer to orchards in valleys (Gula et al. 1995).

The spatial analysis (Figure 5) shows that most collisions occur in central and northern areas of Slovak Carpathian mountain ranges.

Identification of Risk Factors Between Collision and Non-collision Sites

There was no significant difference detected between collision and non-collision sites for any of the risk factors investigated. However, it is likely that significance would have been reached if the sample size of collision sites was larger. Secondly, the 1km distance between a collision site and its matched non-collision site may have been too short, because in the two areas of high collision risk, the supposedly non-collision site fell on a collision site. For consistency, this ‘non-collision’ site was kept and analyzed as such. However, if collision risk was to be analyzed again in Malá Fatra, the stretch of road at each high-risk site should be considered as one site. This would make the stretch of road between Žilina – Vrútky approximately 10km long and Turany – Ratkovo, 5km long.

However the presence of a forest, agricultural field and a wall approached significance. This is most relevant to the two high-risk collision stretches of road identified. Both of these stretches (two different sections of E50) transect a biocorridor, as established by the Landscape system of ecological stability in Slovakia (Územný systém ekologickej stability, SR) (Finďo et al. 2007). In Slovakia, a biocorridor is defined as “an adjacent set of ecosystems which connects biocentres and allows the migration and exchange of genetic information between wildlife and its communities connected to interactive elements” and a biocentrum is “an ecosystem or a group of ecosystems that create permanent conditions of reproduction, refuge and feeding of wildlife and for conservation and natural development of their communities” (Jongman et al. 2002). In the present study, the presence of a biocorridor was not found to be significant, but as discussed above, this may be due to the non-collision sites falling under the collision sites. Both of the transected biocorridors are connected to one of the largest biocentres in Slovakia, the Malá Fatra Mountains, ie forest, a factor that was nearly statistically significant ($p = 0.069$).

Furthermore, while there is forest on one side of the road, the Turany – Ratkovo collision stretch has a corn agricultural field on the other side; another factor which approached significance. This field has been there for a minimum of 10 years (pers. observation), thus it is safe to assume this was a possible attractant for the brown bears during the years for which data are collected in this study. Furthermore, northwards from this collision stretch of road the road starts running parallel with a railway and a canal, making it difficult for a bear to pass this way (Figure 8); and southwards of the collision stretch is a town.

Figure 8: The canal – railway – road layout northeast of Turany – Ratkovo collision road stretch.

The Žilina – Vrútky collision stretch has a forest on both sides of the road, but it additionally has a retaining wall on one the side of the road in a number of segments (Figure 9). The presence of a wall was a variable, which also approached significance in the present study. This side of the road also has chain-linked fencing (Figure 10). This fence may be an attempt to prevent wildlife from accessing the road, however the fence is discontinuous with numerous segments where animals are free to pass. In fact, it is likely that the presence of this fence creates bottlenecks that encourage the animals to pass through, leading straight to the road. It would be interesting to see the statistics of bear-vehicle collisions at this road stretch if this fencing was repaired in such a way that it would create one long continuous fence; this would probably have to be a minimum of 10km long as this is the approximate length of the collision stretch. Taking it a step further, it may be beneficial to apply electrical fencing, because a simple chain-linked fence could be easily broken by a large animal.

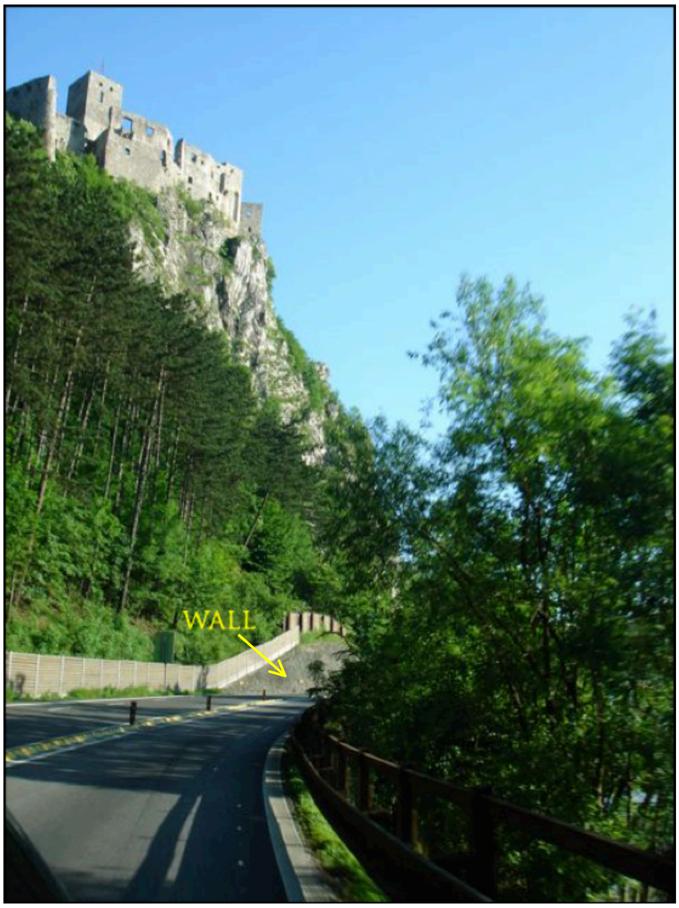

Figure 9: One of the segments on the Žilina – Vrútky collision stretch with a wall running along side it.

Figure 10: A segment of chain-linked fencing alongside the Žilina – Vrútky collision stretch.

Besides fences, chemical repellents are socially acceptable and non-lethal management tools for crop control against wildlife. They are successfully used against deer and even bears in certain areas. Repellents work on the basis of fear, conditioned avoidance and taste (Trent 2001). It is an option to use repellents on the agricultural fields in question.

CONCLUSION

In conclusion, findings from this study suggest a significant interaction between collision sites and the presence of an agricultural field and a forest; however if either a forest or an agricultural field is present on its own, it has no association with a collision site. None of the other anthropogenic factors demonstrated significance. When developing measures and prioritizing locations to decrease bear-vehicle collisions, the presence of both forest cover and an agricultural fielding close proximity should be considered. Provisional mitigation measures proposed are continuous electrical fence in high-risk collision regions and use of the chemical repellents.

ACKNOWLEGMENTS

Particular thanks to K. Stevens and R. Rigg for supervision during this research. Also thanks to M. Adamec (State Nature Conservancy of the Slovak Republic [Štátna ochrana prírody]), M. Kalaš (NP Malá Fatra), V. Slobodník (CHKO Ponitrie), I. Pavlišin (CHKO Kysuce), V. Kacerová (TANAP), J. Kicko (NAPANT), J. Žiak (NP Veľká Fatra), L. Paule & D. Krajmerová & M. Holbová (Faculty of Forestry, Technical University in Zvolen), S. Finďo & M. Skuban (National Forest Centre – Forest Research Institute Zvolen) and S. Ondruš (NP Nízke Tatry) for contribution during data collection.

LITERATURE CITED

BC Ministry of Transportation, 2004. Wildlife accident reporting and mitigation in British Columbia: Special annual report. Available at: http://www.th.gov.bc.ca/Publications/eng_publications/environment/references/WARS/WARS_1983-2002/WARS_AR2002_113004W_6-10.pdf.

Compiled by C. Servheen, H. Herrero and B. Peyton and the IUCN/SSC Bear and Polar Bear Specialist Groups, 1999. *Bears: Status Survey and Conservation Action Plan*, IUCN. Available at: http://www.iucn.org/about/work/programmes/species/publications___technical_documents/publications/species_actions_plans/ [Accessed March 17, 2010].

Finďo, S., Skuban, M. & Koreň, M., 2007. *Brown Bear Corridors in Slovakia* 1st ed., Slovakia: Carpathian Wildlife Society.

Gula, R., Frankowiak, W. & Perzanowski, K., 1995. Current status and conservation needs of brown bears in the Polish Carpathians. *Ursus*, 10, 81-86.

Gunther, K. & Hoekstra, H., 1995. Bear-inflicted human injuries in Yellowstone National Park, 1970-1994. *Ursus*, 10, 377-384.

Huber, D., Kusak, J. & Frkovic, A., 1995. Traffic kills of brown bears in Gorski Kotar, Croatia. *Ursus*, 10, 167-171.

Janik, M., 1997. Biogeography, Demography and Management of Ursus arctos in the Western Carpathians. *Bears: Their Biology and Management*, 9, 125-128.

Jerina, K. et al., 2005. Transportation-related mortality of brown bears in Slovenia. In Trentino, Italy.

Jongman, R. et al., 2002. *Ecological corridors in land use planning and development policies*, Council of Europe.

Kaczensky, P. et al., 2003. The impact of high speed, high volume traffic axes on brown bears in Slovenia. *Biological Conservation*, 111(2), 191-204.

Kalaš, M., 2010: Regulácia medvedej populácie v širšej oblasti NP Malá Fatra. In: *Naše poľovníctvo*, 2010, č.3, s. 26 - 27

Kalaš, M., 2010: Regulácia medvedej populácie v širšej oblasti NP Malá Fatra (2). In: *Naše poľovníctvo*, 2010, č.5, s. 12 - 13

Minďáš, J. et al., 2006. Lesy Slovenska. (Forests of Slovakia). In Zvolen: Národné lesnícke centrum, p. 222 pp.

Nováková, E. & Hanzl, R., 1970. Rys a medvid hnidy patri jen do nikterych kulturnich lesu. *Myslivost*, 6:128-129(7:161).

Palomero, G. et al., 1997. Ecology and Behavior of 3 Wild Orphaned Brown Bear Cubs in Spain. *Bears: Their Biology and Management*, 9, 85-90.

Randik, A., Razsirenie a ochrana medveda hnedego (Ursus arctos) v C□eskoslovensku. *Československ. Ochr. Prirody*, 11, 231-256.

Rigg, R. & Adamec, M., 2007. Status, ecology ad management of the brown bear (Ursus Arctos) in Slovakia.

Rigg, R. & Adamec, M., 2009. Conservation and management of the brown bear (Ursus acrtos) in the Western Carpathians. In Prague, Czech Republic: Slovak Wildlife Society & State Nature Conservancy of the Slovak Republic. Available at: http://www.eccb2009.org/.

Schirokauer, D. & Boyd, H., 1995. Bear-human conflict management in Denali National Park and Preserve, 1982-94. *Ursus*, 10, 395-403.

Trent, A., 2001. Comparison of Commercial Deer Repellents. Available at: http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1568&context=icwdm_usdanwrc.

Waller, J. & Servheen, C., 2005. Effects of transportation infrastructure on grizzly bears in northwestern Montana. *Journal of Wildlife Management*, 69(3), 985-1000.

Železnice Slovenskej Republiky, 2008. Trate a TTP. Available at: http://www.zsr.sk/slovensky/zeleznicna-dopravna-cesta/marketing/trate/trate-a-ttp.html?page_id=925 [Accessed October 8, 2010].

Žuffa, A., 1932. Tatranska zverina. *Lovec*, 4:20.