LIFE DINALP BEAR

Population level management and conservation of brown bears in northern Dinaric Mountains and the Alps

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ANALYSIS OF OCCURRENCE OF HUMAN-BEAR CONFLICTS IN SLOVENIA AND NEGHBOURING COUNTRIES

Action A.1: Analysis of the damage cases and bear intervention group interventions, preparation of guidelines for Intervention group protocols

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ABSTRACT

Human-bear conflicts are the single most important threat to long-term conservation of brown bear in Europe. Increasing conflicts and inefficient conflict resolution also increase fear for personal safety among local people and increase loss of their property. Therefore effective conflict resolution is of top priority for bear management and conservation. Good understanding of causes for human-bear conflicts, where and when these conflicts happen and which factors affect their occurrence, is the first step towards conflict resolution. Acquiring knowledge that will provide this understanding was the main goal of this action.

We analysed data on human-bear conflicts that were systematically collected for over 10 years throughout the project area. In the first phase, data was analysed for all four project countries (Austria, Croatia, Italy, Slovenia) to understand the differences among participating countries and how different bear management approaches might affect level of conflicts. In the second phase we performed more detailed temporal and spatial analyses of conflicts in Slovenia to evaluate how various factors affect occurrence of conflicts in time and space. We also mapped spatial distribution of conflicts and identify conflict hot-spots (areas where conflicts are most frequent), which will represent a basis for implementation of further actions within this project.

Results showed high diversity of bear-caused damages in the project area, ranging from damage on livestock, pets, captive game animals, and fish to various damages in agriculture, forestry, equipment and other human property. In the Alpine region the most frequently recorded damage was on domestic animals (mainly sheep and beehives), while in Dinaric region damage was most frequently reported on agriculture (mainly corn and orchards). In all countries the highest costs were connected with damages on domestic animals (sheep and beehives). Overall, the highest amount of damages in the project area was recorded in Slovenia, followed by Italy, Croatia and Austria. If calculated relative to the bear population size, we noted very large differences among the countries with highest damages per bear in Austria, followed by Italy, Slovenia, and Croatia. The most probable reasons for this are differences in bear management and in the historic presence of bears in the region.

Further temporal and spatial analyses for Slovenia indicated that most important factors affecting human-bear conflicts were local bear density (in the 15 km radius), beech masting (annual productivity of beechnuts), presence of anthropogenic food sources (only orchards and supplemental feeding could be evaluated), various landscape characteristics (especially habitat fragmentation) and past experiences in coexisting with bears (historic presence of bears in the area). Results also indicated that other variables, which were not possible to include in the model (e.g. presence of garbage and animals waste, or socially- and politically-related parameters) likely also affect probability for conflicts.

The highest conflict intensity in Slovenia was observed in the north-central part of the Dinaric Mountain range in Slovenia, especially in the arch from Ig through Velike Lašče to Sodražica, Bloke and Lož. This region is characterized by parameters shown to increase probability for human-bear conflicts: strong habitat fragmentation, high bear densities in the southern part, recently colonized areas in the northern part and presence of anthropogenic foods.

Key words: brown bear, *Ursus arctos*, damages, human-bear conflicts, Austria, Croatia, Italy, Slovenia

1 INTRODUCTION

Nowadays, many of the brown bears in Europe live in a human-dominated world. The only possible way for bears to survive and thrive in this landscape is to co-exist with people. But such co-existence often leads to considerable conflicts between people and bears. Today human-bear conflicts are identified as the single most important threat to long-term conservation of species in Europe. Increasing conflicts and inefficient conflict resolution increase fear for personal safety and safety of their property among local people. In turn, their tolerance of bears is decreased, which often results in lethal removal of conflict bears and political pressures to increase bear culling rates. These can strongly impact bear numbers, decreasing the possibilities for long-term population survival. Therefore effective conflict resolution is of top priority for bear conservation.

As the first step to be able to prepare successful management plans and protocols for addressing various human-bear conflicts, conservationists, managers and decision-makers need good understanding of causes for human-bear conflicts, where and when these conflicts happen and which factors affect their occurrence. The same is true for successful implementation of concrete conservation actions within this project. Acquiring knowledge that will provide solid understanding of human-bear conflicts in the project area is the main goal of A1 action and this report.

Results of this action will form the basis for detailed planning and implementation of conflict prevention measures within project activities. Spatial analysis of human-bear conflicts will also serve to pinpoint locations of conflict hot-spots in the project area where conflict resolution is most urgent. These identified conflict hot-spots will become focus of concrete conservation actions C1 and C2. Improved understanding of factors affecting human-bear conflicts will also enable prediction of potential future occurrence of conflicts under various scenarios of bear re-colonization of new areas or planned changes in the landscape (e.g. expansion of potentially conflict land use). Thus bear managers will have opportunity to act proactively, before the conflicts start to appear and it will enable decision-makers to make science-based decisions with predicted outcomes.

To conduct our analyses, we gathered data on various human-bear conflicts that were systematically collected for over 10 years throughout the project area:

1) data on compensations paid for damages caused by brown bears (with type of the object damaged, amount of damage caused and time and geographic location of the damage cases),
2) data on interventions undertaken by the Bear Intervention Groups (type of conflict, actions taken by the group, time and geographic location of the conflict events), and
3) data on recorded bear mortalities including management removals.

These data were analysed in order to provide answers to the following questions:

- Which types of conflicts occur in the project area and what is their relative frequency?
- What is spatial distribution of human-bear conflicts in the project area?
- How does frequency of conflicts change inter-annually?
- What is the effect of local bear densities on frequency and distribution of human-bear conflicts?
- Which other factors (including natural food availability, supplemental feeding of bears, and landscape structure) affect occurrence of human-bear conflicts in the project area?
- How important is the history of human-bear co-existence in the area (whether bears have been present in certain area in the past or not)?
- How does bear management regime (e.g. is bear fully protected or hunted species) influence human-bear conflicts?

2 METHODS

Analysis of occurrence of human-bear conflicts was conducted in two phases at different scales: entire project area, and only in Slovenia.

In the first phase, when conflicts were analysed for all four project countries (Austria, Croatia, Italy, Slovenia), the goal was to understand the differences among participating countries and how different bear management approaches might affect level of conflicts.

In the second phase we performed more detailed analyses of conflicts in Slovenia. Specifically, we analyzed various factors affect occurrence of conflicts in time and space. In this phase we also mapped spatial distribution of conflicts and in this way defined conflict hot-spots (areas where conflicts are most frequent), which will represent a basis for implementation of actions C1 and C2 and other activities within the project in Slovenia.

The reason for the use two-step approach was primarily in differences of data quality among the countries. Lack of sufficient data for other countries but Slovenia did not enable to perform the detailed analysis. This includes data like precise local bear densities and changes of bear numbers in time. Besides, if entire project area was included in the detailed analysis, heterogeneity of explanatory variables would greatly increase. This would likely blur the effects of some of the variables and thus limit our insights into importance of individual variables. However, although the second part of analysis is limited to Slovenia, we believe that many of the results are relevant also for other parts of the project area.

2.1 Description of the data

2.1.1 Human-bear conflicts databases

2.1.1.1 Data on damage cases

<u>Slovenia</u>

The basis for gathering data on damage cases is database of reimbursement claims. Government of Slovenia reimburses each reported damage case proved to be caused by brown bear. Officials of Slovenia Forest Service (SFS) are responsible for field-checking and reporting details on each reported damage case. Data are monthly reported to the head unit of the SFS, which holds and updates official national database, which was used in this report. The data have been gathered since 1994, when reimbursement system started to operate. In the initial period (up to year 1999) not all inhabitants were aware of the system, therefore damage reporting intensity was lower in that period, so only data from 1999-2014 were thus used for temporal analysis of damage cases in Slovenia. Exact locations (coordinates) were not recorded for damage cases prior to year 2003, therefore only data from the period 2003-2014 were used for spatial analyses of damages in Slovenia.

<u>Croatia</u>
Hunting right owners (which were responsible for bear-caused damage compensations in Croatia during the study period) were inspecting damage cases and sending reports about each case to the Ministry of Agriculture. Database with the data of all collected reports was compiled at the Faculty of Veterinary Medicine at University of Zagreb. According to experiences, despite the legal obligation to report damages to the ministry, some hunting right owners did not report damages regularly (they did not want to compensate the damage or they compensated without reporting).

Carinthia, Austria
There is no official common database on damages caused by bear in Carinthia. Database used in this report was compiled from three different sources: a) data deriving from genetic samples taken on damage cases and gathered by University of Veterinary Medicine, b) data gathered through personal communication with individual damage evaluators (damage cases are in most, but not all cases checked by evaluators), and c) information deriving from media reports. Due to non-systematic data collection method we speculate that Carinthian database on damages is less complete (includes lower proportion of actual damage cases) compared to databases of most other countries/regions.

The Autonomous region of Friuli Venezia Giulia, Italy
Official common regional database, used in this report, was provided by the regional biodiversity, forest and hunting department, which primarily collects data for damage compensation purposes. Database thus includes all damage cases over the period considered for which compensation was claimed. Additionally, some (but not all) damage cases when no compensation was asked are included into the database. Proportion of reported vs. actual damage cases may to some degree also depend on competence of the local forest office, which provides field inspection of damage cases, since some local offices are more cooperative with local inhabitants than other.

The Autonomous region of Trento, Italy
Official common regional database, used in this report, was provided by regional wildlife department, which primarily collects data for damage compensation purposes. Members of regional forestry department inspect each reported damage case and promptly provide the data to regional wildlife department. Local inhabitants are well informed about the damage compensation system and report damage cases regularly.

The region of Veneto, Italy
For Veneto region it was not possible to gather any data in time before the completion of this report, thus this region could not be included in any of the analysis.

2.1.1.2 Data on interventions

Slovenia
Slovenian Bear Intervention Group started to operate in 2007 under the competence of the SFS. It consists of four regional teams, which cover entire bear range in Slovenia. When emergency case occurs, inhabitants can call intervention team members directly. Alternatively, they are informed on emergency cases indirectly through emergency call centres, local police stations and hunting clubs. Thus each conflict situation is recorded and dealt by intervention team. Database of intervention cases used in this report was provided by the head unit of the SFS, to whom interventions are monthly reported by the member of the intervention group.

Croatia
Members of intervention team (under Ministry of Agriculture) report intervention cases to Faculty of Veterinary Medicine at University of Zagreb, which prepared the database of all reported cases. Intervention cases when the outcome is a dead bear, when orphaned bear is involved or when human safety or property is endangered are reported regularly. Some other types of intervention cases may not be reported regularly. Probability of intervention case being reported may also depend on attitude of intervention team member involved.

The Autonomous Province of Trento, Italy
Official common regional database on intervention cases is held and was provided by the regional wildlife department. Regional intervention team promptly informs wildlife department on each intervention case. Coordinators of intervention team are available through emergency telephone number 24/7. On each damage case they are informed directly from local inhabitants or through police, firefighters etc.

The Autonomous region of Friuli Venezia Giulia, Italy
In Friuli Venezia Giulia there is an intervention group of experts located by the National Forest Service (Corpo Forestale dello Stato) since the early 1990s – their main task was to control and evaluate damages. Actually the intervention group consists in two teams coordinated at regional level – and they cover the entire region. About 25 people were specially trained even for aversive conditioning measures by experts in the frame of the Life Arctos Project in 2011.
So far there was no need for any activity of the intervention team and the main activity still consist in damage prevention assistance and damage evaluation.

2.1.1.3 Data on traffic collisions

For the purposes of this report, we focused only on consequences that vehicle-bear collisions have for people – primarily damage on a vehicle or injury to the driver (i.e. effects of the collision as perceived for the people involved). We did not evaluate the effects of vehicle-caused mortality on bear population (this is the focus of project reports in Action A4). Therefore we included in this analysis only vehicle collision on roads (including highways), but not collisions on railways. Due to small number (n=4) of vehicle collisions and different approach data gathering in Italy, we did not include this country in the analysis of traffic collisions. In Carinthia, no bear-vehicle collision was ever reported.

Slovenia
SFS collects the data and maintains the database on bear mortality, including bears killed in traffic accidents. All bear mortalities caused by traffic accidents on the roads were used in this report.

Croatia
Each traffic accident where bear was involved and killed is regularly reported to the Ministry of Agriculture and to Faculty of Veterinary Medicine (database was constituted and provided by the latter). All bear mortalities caused by traffic accidents on the roads (railways were excluded) are used in this report.

2.1.2 Data for explanatory variables

2.1.2.1 Number of bears

Variable "number of bears" (i.e. population size) was included in both phases of analysis. For analysis of conflicts in entire project area (i.e. all four countries) we used expert-based estimates of number of bears living in each country, which was based on various monitoring data (for details on methods used to monitor bear population sizes in each of the countries, see Kaczensky et al. 2013). Experts were explicitly asked to take into account when making the estimate also whether certain bear was permanently or regularly present in the country. For example, if there had been two bears occurring in the country, each of them for approximately half a year (the other half being across the border in neighboring country), this would amount to population size estimate of one bear for this country.

For the second phase of analysis (detailed analysis for Slovenia) we used estimates of local bear densities in 1x1 km raster, based on GPS telemetry data, records of bear removals, systematic and opportunistic direct observations and signs of bear presence, and non-invasive genetic samples, available from Jerina et al. (2013). To evaluate on what scale bear densities are most influential for occurrence of conflicts, we tested several buffer zones from 3 to 20 km radius around given location. The results showed the highest explanatory power of the models for 15 km radius. This radius is also biologically meaningful, as it corresponds well to the diameter of the average home range size of bears in Slovenia (Jerina et al. 2012). Therefore we used average bear densities in 15 km buffer zones around each 1 km cell of the study area.

For temporal analysis of conflict occurrence in Slovenia we used reconstruction of bear population dynamics in Slovenia available from Jerina & Krofel (2012). Since in this publication data were available only until 2010, we used the same approach as described therein to reconstruct bear population dynamics also for period after 2010.

2.1.2.2 Beech masting

Beechnuts represent large part of bear diet in Slovenia and are among the most important natural food sources (Kavčič et al. 2015). However, this food source is characterized by extremely high inter-annual variability of its availability, corresponding to the masting intensity that changes from year to year. Lack of natural food could stimulate bears to search more intensively for anthropogenic food sources and consequently conflict rate could increase. We tested in temporal analysis how inter-annual changes in this food source effect conflict probability in Slovenia. We scaled annual masting intensity on a relative scale from 1 to 5 (i.e. from very poor to very rich year; table 1) based on combination of notes from local foresters and biologists (M. Perušek, unpublished data for years 1991-2011; M. Krofel, unpublished data for years 2007-2014) and data on edible dormouse (*Glis glis*) activity, which strongly correlates with beech masting (Kryštufek & Zavodnik 2003 for years 1991-2000; Kryštufek 2007 for years 1999-2005).

Table 1: Relative intensity of beech masting in Dinaric Mountains of Slovenia in 1991-2014. 1 - very poor year, 2 - poor year, 3 - intermediate year, 4 - good year, 5 - very good year.

Year	*Masting intensity*	*Year*	*Masting intensity*
1991	5	2003	4
1992	4	2004	4
1993	2	2005	1
1994	3	2006	1
1995	2	2007	5
1996	1	2008	1
1997	2	2009	2
1998	2	2010	1
1999	3	2011	5
2000	2	2012	2
2001	5	2013	5
2002	1	2014	1

2.1.2.3 Supplemental feeding sites

In Slovenia intensive supplemental feeding of bears is practised, partly with the aim to reduce human-bear conflicts (Kavčič et al. 2015). In spatial analysis we evaluated whether local intensity of supplemental feeding affects occurrence of conflicts. We multiplied the local density of supplemental feeding sites with the amount of food provided annually per site to obtain the amount of supplement food provided for each 1 km^2 cell.

In addition, we also evaluated the use of feeding sites in time. Here, we were not able to test for effects of supplemental feeding on occurrence of conflicts due to possible confounding effects of other factors. But we tested for correlation between the use of supplemental feeding sites and masting of beech, primarily to see if in years of poor natural food availability bears increase use of supplemental food and thus compensate lack of natural food. Data on use of supplemental feeding sites were obtained from systematic bear monitoring conducted at fixed counting sites which are located at the 165 supplemental feeding sites. This monitoring takes place throughout the entire bear range where females with cubs are present. The counting is conducted three times per year (once in spring and twice in autumn) at pre-defined dates on last Friday before full moon, from 6 p.m. until midnight. Since 2003 in total 3,401 bears were recorded during cumulatively 3,465 counting days (Jerina et al. 2013).

2.1.2.4 Bear body mass

Lack of food and resulting hunger could represent an important trigger for bears to search and use anthropogenic food sources and in the process cause conflicts with people. Lack of food should be reflected in the body masses of bears. In temporal analysis we tested to what degree inter-annual changes in body masses of removed bears correspond to changes in conflict rate in Slovenia. We used general additive models to estimate average body mass for each season and bear sex and age. Data of body masses were log transformed in order to achieve normal distribution. For each removed bear we calculated difference (residual) of its body mass from the average body mass of bears removed in the same season and of same age and sex. Then we calculated average value of residuals for each year and thus obtain relative variation of body masses among the years, which we used as year-specific indicator of nutritional status of bears.

2.1.2.5 Other data

As explanatory variables for spatial analysis we included also some potentially important environmental variables, which could be connected with bear space use (e.g. habitat types, habitat fragmentation, distance to roads and human settlements), especially with the availability of natural or anthropogenic food sources (e.g. proportion broadleaf trees in the forest, plant diversity, agriculture land, distance to houses), as well as presence of objects that could potentially be damaged by bears (presence of orchards, gardens, pastures, vicinity of human). For entire list of environmental variables used in the analysis and their description see table 4. For several of the variables, which likely importantly affect occurrence of conflicts (e.g. presence of illegal garbage dumps, local waste management, number and type of livestock, and distribution of beehives, wasp nests and ant hills), it was not possible to include in the analysis due to lack of such data for entire bear range. Some of these parameters however correlate to certain extent with other variables that were included.

2.2 Data analysis

2.2.1 Quantifying conflict intensity

Previous studies on human-bear conflicts focused on analysis of only predominant conflict type or all conflicts were simply summed together. Such approach implicitly assumes that all kinds of problems with bears are equally important. However, various conflict types can be very diverse in respect of how seriously they are perceived by the public. For example, a person being killed in bear attack is incomparable to minimal damage on crops of value <5 €.

Since it would be erroneous to equalize all conflicts that occurred in the project area, when conflict intensity is analyzed, we decided use novel approach in this analysis. We gave relative weights to different conflict types, according to their importance perceived by the public. Because we observed that perception of importance can vary between different countries, we weighted conflict types separately for each of the four project countries.

We grouped different types of human-bear conflicts in 13 categories, based on descriptions available in the databases for each country (see table 2). Then we conducted a questionnaire among bear experts from all participating countries (n=26) to estimate, based on their experiences, relative significance of each conflict category for the local public on continuous equidistant scale from 0 to 100 (i.e. 2 means two-times bigger problem as 1 and 100 means 50-times higher problem than 2). To achieve greater comparability among the countries, in cases when the maximum value given to categories by the local experts was below 100, we proportionally stretched estimated values for all categories so that the maximum value equalled 100.

Table 2: Categorized conflict types with code for each category as it was used for analysis of human-bear conflicts.

CODE	CATEGORY OF HUMAN-BEAR CONFLITS	NOTES/EXAMPLES WHAT BELONGS WITHIN EACH CATEGORY
1	bear damage in hunting and forestry	bear eating supplemental food intended for other wildlife and damage caused on automatic or non-automatic (e.g. wooden) feeders for game animals, including salt-feeders; damage on hunting posts; damage on trees (e.g. peeling tree bark); destroyed cans with oil for lubrication of chainsaws
2	bear attack on humans	cases when bear came in physical contact that resulted in human injury
3	bear damage on silage, grass, hay	damage on grass silage, non-grass silage, silage bales of all kinds, grass, grass turf or hay
4	traffic collisions with bear	traffic collisions on roads and highways (Note: only consequences for people were considered, e.g. damage on a vehicle or injury to the driver)
5	calls to intervention group as a result of bear damages and other types of bear behaviour that can in some people trigger fear or other negative feelings	Note: here only with issue of fear (or other negative feelings) of people who call the intervention group were considered, without the economic consequences of the conflict
6	occurrence of bear near people	occurrence of bear near settlements and human infrastructure (roads, fences for livestock farming facilities, and garbage dumps); confident behavior (habituated to humans) of bears
7	bear damage on beehives/bees	bees and larvae of bees; beehive and other beekeeping equipment; queen bee breeding box

8	bear damage in orchards, vineyards, fruit shrubs	fruit trees and fruit in orchards; grapevine and grapes in vineyards; plantations of blackberries and blueberries
9	bear damage on crops	corn; vegetables; grain; rapeseed oil; garden plants; field crops; harvested crops, including processed and stored crops
10	bear attacks on larger domestic animals	horses; cattle; domestic pigs; donkeys; dogs (hunting, guard and other dogs); we include under domestic animals here also game animals kept and bred in captivity, e.g. captive fallow deer and red deer);
11	bear attack on smaller domestic animals	sheep; goats; rabbits; chickens; common quails; turkeys; ostriches; fish
12	bear damage on buildings and on other human property	barns, including doors, windows etc.; storerooms; hen houses; rabbit houses; feeding box for fish, fishponds; house door and windows; vehicles; dry meat in smokehouse; wooden, electric and other types of fences (e.g. for protection of orchards, fields, livestock…); other buildings/objects/items
13	false attacks of bears on humans	false attack and all kinds of bear behaviour for which people believed that bear attacked them but there was no physical contact between the bear and human

We calculated weights to be given to each conflict category as a median value of importance estimated by the experts in given country (table 3). Median was used due to asymmetrical distribution of received answers. These weights were then used in combination with data on number of recorded conflicts for each category to estimate the weighted conflict intensity (WCI):

$$\mathrm{WCI} = \sum(average\ number\ of\ conflicts\ of\ category\ X\ per\ year * weight\ of\ category\ X)$$

WCI thus quantifies the average intensity of human-bear conflicts in given area or region.

Table 3: Weights for human-bear conflict categories by country – values for Croatia and Austria are scaled so that weight for code 2 is 100. For codes of conflict categories see Table 1. Sample size corresponds to the number of experts responding to the questionnaire.

CODE OF CONFLICTS	*Weight Slovenia (median value)*	*Weight Croatia (scaled median value)*	*Weight Italy (median value)*	*Weight Austria (scaled median value)*
1	2	25,0	5,5	10,5
2	100	100,0	100	100,0
3	10	6,3	5	7,9
4	16	75,0	20	15,8
5	22.5	37,5	10	21,1
6	50	37,5	17,5	36,8
7	30	25,0	10	21,1
8	25	6,3	5	7,9
9	20	6,3	5	5,3
10	35	12,5	17,5	42,1
11	30	12,5	10	26,3
12	25	25,0	20	31,6
13	60	81,3	37,5	57,9
Sample size	*15*	*3*	*4*	*4*

2.2.2 Overall analysis for the entire project area

2.2.2.1 Damage analysis

We grouped damages into four main types: domestic animals, crops and orchards, objects, and other (see tables 5-8 and figures 1 and 2). For each country and category we calculated an average of absolute and relative annual frequencies of damage cases. For each damage type we also estimated the average annual amount of money paid, and average price paid per damage case (see tables 5 and 7-9, and figures 1 and 2). Carinthia (Austria) is the exception because for this region cost is known only for 14 damages in period 2011-2014[1]. To make data more comparable among the countries and to test for potential effects of management regime, we also calculated average annual number of damage cases per bear and average annual amount of cost per bear (table 9, figure 3). We also assessed temporal dynamics of occurrence of damages for each country/region (figure 4).

2.2.2.2 Spatial distribution of human-bear conflicts

We calculated weighted conflict intensity (WCI; see chapter 2.2.1) values for:
- damages (i.e. average of annual sums of weighted damage cases),
- interventions (i.e. average of annual sums of weighted interventions),
- road accidents (i.e. average of annual sums of weighted road accident cases), and
- overall WCI (i.e. average of annual sums of weighted all human-bear conflicts).

These conflict indices were calculated for each km^2 in the project area and are thus indicators of conflict intensity for specific locations. Overall WCI was calculated only for Slovenia, Croatia and Trentino[2], where all conflict types (damages, interventions, road accidents) can be taken into account. WCI for interventions was calculated only for Slovenia, Croatia and Trentino (there were no reported interventions in Austria and Friuli). Conflict index for road accidents was calculated only for Slovenia and Croatia (see chapter 2.1.1.3).

We used Point Statistics ArcMap tool to map WCI and calculated for each 1 km^2 raster cell the floating averages of mean WCI values within the radius of three raster cells. Results are shown on figures 5-8.

2.3.2 Detailed analysis for Slovenia

2.2.2.3 Temporal analysis

We analyzed changes in time for registered damages in Slovenia in the period 1999-2014 (figure 9), and their relation with other focal parameters. We excluded damage data from 1994-1998, because several people were not yet aware of the new reimbursement system in the first few years after its implementation in 1994. Thus substantial part of the damages was likely not reported before 1999 and would undesirably affect the results of the analysis.

Two types of temporal analyses were conducted. 1) We analyzed correlations among all focal variables (e.g. damages, population size, time, masting). 2) We conducted multivariate analysis of effects of year, bear population size and beech masting on damage WCI and separately only for agriculture damage WCI. Agriculture damage was analyzed separately as this is the most frequent damage type and because it is

[1] one for damage on sheep (300 €) and other 13 for damage on beehive (average 500 € per damage case)
[2] For Trentino road accidents were not included, but their number was minimal (i.e. 3 cases).

presumably most related with the natural food availability (i.e. masting). For this analysis we used general regression models (GRMs). We calculated all possible models with algorithm best subsets, selected the model with the lowest corrected Akaike information criterion value (AICc) and explored the structure of all candidate models with ΔAICc scores lower than 2. Since there was no model with ΔAICc<2, we used only the best model for further analysis, in which we calculated effect on the WCI for each independent variable in the model, when the value of this variable changes from the first to the last decile and the other independent variables are held constant.

2.2.2.4 Spatial analysis

All spatial analyses were based on data attributed to a raster grid with 1 km^2 cell size. First we visualized the distribution of independent variable, which was markedly zero-inflated and non-negative part J distributed. Therefore we separated analysis into two stages. Firstly, we only distinguished cells with or without conflicts and tested the parameters that affected the probability of conflict occurrence. For this we used generalised linear models (GLMs) with binary dependent variable and logit link function. In the second phase we included only cells with recorded conflicts and analyzed their intensity (WCI). We used GRMs with identity link function and normally distributed error. Due to asymmetric distribution of dependent variable, we log-transformed the WCI values to achieve normal distribution. In both phases we used forward stepwise approach to select the final model. For both final models we calculated odd ratios/effects on the WCI for each variable, when the independent variable changes from the first to the last decile. For easier interpretation of relative importance of individual variables, we also ranked all significant variables for both models and then summed these ranks. Thus we obtained the order of importance of variables from both models.

Based on predicted values from both models we constructed joined spatially explicit model of conflict occurrence and intensity (figure 20). In addition, we used empiric georeferenced data of conflicts (figure 19) and subtract it from the spatially explicit model. Resulting map (figure 21) presents local differences between the predicted and actual conflict intensity. This could be due to model shortages or it could indicate local importance of variables not included in the model (e.g. politically- or socially-related parameters).

Table 4: List of variables used in logistic regression model and generalized linear model in terms to identify the relation between different influential factors and human-bear conflicts in Slovenia.

Short name of variable	*Description of variable*
Dependent variables	
conflicts (presence)	Presence or absence of human-bear conflicts (dependent variable in binary logistic regression, whether conflict occurred or not in given cell)
WCI	weighted conflict intensity (continuous value, ln transformed variable, used as dependent variable in GLM)
Explanatory variables	
exposition diversity	index of exposition diversity
urbanized areas	percentage of urbanized areas
forest areas	percentage of forest and forest tree plantations
extensive orchards	percentage of extensive orchards
fields and gardens	percentage of fields and gardens
meadows	percentage of meadows
mixed forest-agriculture land use	percentage of overgrowing areas and mixed (forest-other) land use
outside distance from forest edge	average distance of non-forest areas from the closest forest edge [m]
inside distance from forest edge	average distance of forested areas from the closest forest edge [m]
forest edge length	forest edge length [m/100 ha]
broadleaves	percentage of broadleaves (those which bear fruit) in growing stock (2nd and 3rd diameter class)
plant diversity	index of plant community diversity
roads	distance from the closest main road [m]
settlements	distance from the closest settlement [m]
bear density	local bear density in 15 km radius
supplemental feeding	amount of supplemental food for bears [kg/km^2]
feeding sites	number of feeding sites which are suitable also for bears [number/km^2]
non forest vs. forest	whether presence or absence of forest cover
history	inside and outside distance from the edge of the bear core area (this is a relative measure of historic presence of bears in the area, as the bear re-colonization process in Slovenia originated outwards from the core area)

3 RESULTS AND DISCUSSION

3.1 Comparison between the countries

3.1.1 Damage types, frequencies and temporal trends

In the project area we recorded high diversity of bear-caused damages, ranging from damage on livestock, pets, captive game animals, and fish to various damages in agriculture, forestry, equipment and other human property (tables 5-8). We also noted substantial differences among the countries, both regarding extent and distribution of damages (figure 1), as well as in the costs of the damages (figure 2). In Austria and Italy by far the most common damage was on domestic animals, mainly sheep and beehives (table 6 and table 8). In Slovenia and Croatia the most frequent damages recorded were in agriculture, mainly on corn and orchards, followed by damage on domestic animals, again mainly sheep and beehives (table 5 and table 7). Although it is difficult to identify the main cause of these differences among the countries, lower proportion of damages in agriculture in Italy and Austria is likely the result of less intensive agriculture in the Alpine regions compared to Dinaric Mountains of Slovenia and Croatia. In all four countries the highest costs were associated with damages on domestic animals.

The greatest differences among the countries are noted when frequencies and costs of damages are calculated per an average bear living in the country (table 9 and figure 3). Most damages are caused by an average bear in Austria – approximately 2-times as much as in Italy, 5-times as in Slovenia and 160-times as in Croatia. Similarly large differences are in the costs per bear, which are in Italy more than 3-times higher than in Slovenia and in Slovenia 30-times higher than in Croatia. In absolute terms, the total number of damages and costs was highest in Slovenia – more than double compared to any other country. This could be expected due to combination of high bear densities and large amount of damage caused per bear.

We assume that there are two main reasons for huge differences among countries in damages per average bear: 1) differences in bear management, especially who is responsible to pay for the damage, and 2) the historic presence of bears in the region. Important to note is that the amount of damages increase with increasing level of protection of bears in a country: in Italy and Austria bears were strictly protected and no hunting quotas are issued on regular basis, in Slovenia bears were protected species but hunting quotas for lethal removal of about 20% of the population are issued every year, while in Croatia bears had the status of a game species with annual hunting quotas[3]. Therefore in Croatia damages caused by bears were not compensated by the government, but by the hunting organizations. Since members of these organizations are predominantly local people, the compensation claims were often informally settled with goods (e.g. sacks of corn) rather than money (Knott et al. 2014). Consequently large part of damages were not reported and/or recorded. Additionally, local hunters likely paid more attention to prevent fraud by the owners and also likely reacted faster to prevent costly damages repeating at single localities, which are for example characteristic for Slovenia (Černe et al. 2010). It is expected that amount of reported damages will substantially increase in Croatia in the next years with the change in bear status and compensation system (Knott et al. 2014). Consequently there will likely be also stronger interest in the preventive measures from the government perspective.

Higher damages per bear in Austria and Italy compared to Slovenia could be at least partly explained by the different history of bear occurrence. In Slovenia, especially in the Dinaric part, bears have never been exterminated and have occurred here in relatively high densities already for several decades (Jerina &

[3] At the end of the study period in 2013 Croatia joined the European Union and consequently bears became protected species. However, they were game species throughout most of the study period.

Adamič 2008). Therefore local people are generally accustomed of living with bears and there is some tradition in preventing human-bear conflicts. On the other hand, bears were completely exterminated in most of the Alps and re-colonized (but just by dispersing males) these areas relatively recently. Thus large part of knowledge of how to coexist with bears was lost, as were the conflict preventive measures. Similar pattern was actually observed also within Slovenia. Between 1994–2002, bear damage in the Alpine and sub-Alpine parts of Slovenia accounted for 67% of all compensation payments for bear damage in the country, even though fewer than 5% of the country's bears were estimated to live there (Kaczensky et al. 2011).

Additional factor that could cause differences among regions is the local structure of bear population and individual behavior of certain bears. For example, in the core areas of bear population (Dinaric region of Croatia and Slovenia and the core area in Trentino) the proportion of reproductive females is considerably higher compared to the periphery of the populations in the Alpine region along borders between Slovenia, Italy and Austria, where adult and sub-adult males predominate (Krofel et al. 2010). In general, sub-adult bears and adult females with offspring more frequently cause conflicts (Majić Skrbinšek & Krofel 2015). Due to low number of bears in the periphery of the population, in such regions also individual behavior of few bears could importantly affect the damage rate

During the study period we noticed general increasing trend in bear-caused damages in all countries but Croatia. The highest damages in Slovenia and Croatia were recorded in 2005 and in Italy in 2010 (figure 4). High annual variation in the amount of damages was observed only in Slovenia, where it was most likely connected with annual changes in beech masting (see chapter 3.2.1). At present it is not clear why similar patterns were not observed to such extent in other countries.

Table 5: Summary of damages caused by bears in Slovenia in 1994-2014.

Damage type	*Frequency [av. per year]*	*Relative frequency [%]*	*Cost [av. € per damage]*	*Cost [av. € per year]*	*Cost [%]*
Domestic animals	**175,1**	**47,9**	**510**	**89273**	**71,8**
Sheep	124,4	34,0	461	57307	46,1
Beehives	36,0	9,8	561	20168	16,2
Cattle	8,0	2,2	789	6313	5,1
Horse	2,5	0,7	1580	3987	3,2
Chicken	1,4	0,4	101	140	0,1
Other pets	1,1	0,3	537	613	0,5
Captive deer	0,6	0,2	307	190	0,2
Donkey	0,6	0,2	408	253	0,2
Fish	0,2	0,1	1109	264	0,2
Domestic pig	0,2	0,1	137	26	0,0
Hunting dog	0,0	0,0	256	12	0,0
Crops and orchards	**175,7**	**48,1**	**157**	**27578**	**22,2**
Fruit trees	68,0	18,6	180	12242	9,8
Bale grass silage	46,4	12,7	167	7724	6,2
Corn	39,4	10,8	131	5146	4,1
Other plant/vegetable	13,4	3,7	57	757	0,6
Other than grass silage (feed)	5,1	1,4	230	1172	0,9
Turf rooting	1,9	0,5	151	287	0,2
Grapes	1,5	0,4	170	250	0,2
Objects	**13,3**	**3,6**	**480**	**6377**	**5,1**
Facility object	12,4	3,4	474	5873	4,7
Wildlife feeding machine	0,8	0,2	372	283	0,2
Vehicle	0,1	0,0	1545	221	0,2
Other	**1,3**	**0,4**	**856**	**1101**	**0,9**
Unknown	0,8	0,2	114	92	0,1
Other object/subject	0,2	0,1	71	17	0,0
Human injury	0,2	0,1	4167	992	0,8
Total	**365,3**	**100,0**	**340**	**124329**	**100,0**

Table 6: Summary of damages caused by bears in Austria (Carinthia) in 1993-1999 and 2007-2014. No data were available for the period 2000-2006. Data for the period 2007-2014 are based on screening of local media. Cost is known only for 14 damages in the period 2011-2014, therefore credible calculation of cost/year and cost/damage case could not be performed.

Damage type	*Frequency [av. per year]*	*Relative frequency [%]*
Domestic animals	**8,9**	**91,2**
Sheep	4,0	40,8
Beehives	4,0	40,8
Cattle	0,6	6,1
Horse	0,1	0,7
Rabbit	0,1	0,7
Goat	0,2	2,0
Crops and orchards	**0,2**	**2,0**
Fruit trees	0,1	0,7
Silage bale	0,1	1,4

Objects	**0,7**	**6,8**
Fence around beehive	0,1	1,4
Sheep pen	0,1	0,7
Fish feed box	0,1	0,7
Fishpond	0,2	2,0
Queen bee breeding box	0,1	1,4
Rapeseed oil can	0,1	0,7
Total	**9,8**	**100,0**

Table 7: Summary of damages caused by bears in Croatia in the period 2004-2014

Damage type	*Frequency [av. per year]*	*Relative frequency [%]*	*Cost [av. € per damage]*	*Cost [av. € per year]*	*Cost [%]*
Domestic animals	**10,5**	**32,2**	**473**	**4984**	**48,1**
Sheep	2,1	6,4	376	785	7,6
Beehives	4,5	13,6	639	2846	27,4
Cattle	0,3	0,8	1200	327	3,2
Horse	0,1	0,3	1087	99	1,0
Chicken	1,6	5,0	134	220	2,1
Ostrich	0,1	0,3	300	27	0,3
Captive deer	0,1	0,3	2500	227	2,2
Donkey	0,1	0,3	404	37	0,4
Goat	0,5	1,4	609	277	2,7
Domestic pig	0,2	0,6	107	19	0,2
Rabbit	0,7	2,2	80	58	0,6
Turkey	0,3	0,8	198	54	0,5
Dog	0,1	0,3	92	8	0,1
Crops and orchards	**17,7**	**54,2**	**170**	**3013**	**29,0**
Fruit trees and fruits	6,6	20,3	167	1106	10,7
Grass silage	0,4	1,1	514	187	1,8
Corn	3,7	11,4	209	777	7,5
Vegetable	4,6	14,2	34	155	1,5
Hay	0,2	0,6	1192	217	2,1
Grain	1,9	5,8	233	444	4,3
Strawberry	0,1	0,3	1234	112	1,1
Grapevine	0,2	0,6	75	14	0,1
Objects	**4,2**	**12,8**	**551**	**2302**	**22,2**
Feeder for wildlife and feed within it	2,6	8,7	1564	1183	11,4
Henhouse	0,1	0,3	137	12	0,1
House (windows, doors)	0,2	0,6	217	39	0,4
Barn (windows, doors and other)	0,3	0,8	27	7	0,1
Car	0,6	1,9	1627	1035	10,0
Hunting post	0,2	0,6	136	25	0,2
Other	**0,3**	**0,8**	**265**	**72**	**0,7**
Unknown	0,1	0,3	7	1	0,0
Spruce and fir trees (in forest)	0,1	0,3	679	62	0,6
Dry meat	0,1	0,3	109	10	0,1
Total	**32,7**	**100,0**	**317**	**10371**	**100,0**

Table 8: Summary of damages caused by bears in Italy (regions Friuli and Trentino) in 2004-2014 (Friuli: 2009-2014; Trentino: 2002-2014).

Damage type	*Frequency [av. per year]*	*Relative frequency [%]*	*Cost [av. € per damage]*	*Cost [av. € per year]*	*Cost [%]*
Domestic animals	**95,7**	**79,3**	**477**	**44688**	**82,1**
Sheep	25,9	20,3	476	11886	21,8
Beehives	48,4	40,3	478	22413	41,2
Cattle	1,5	1,3	2123	3103	5,7
Horse	1,6	1,5	1242	2006	3,7
Poultry	11,8	10,6	206	2417	4,4
Captive deer	0,2	0,1	2628	438	0,8
Donkey	0,5	0,2	317	158	0,3
Goat	4,7	3,9	375	1890	3,5
Domestic pig	0,1	0,1	1512	116	0,2
Rabbit	1,2	1,1	225	259	0,5
Crops and orchards	**14,8**	**13,5**	**489**	**7258**	**13,3**
Fruit trees and fruits	6,9	6,3	685	4742	8,7
Silage of maize	1,7	1,5	331	560	1,0
Corn	1,3	1,2	110	144	0,3
Grapes	4,9	4,5	368	1812	3,3
Objects	**1,5**	**1,1**	**115**	**227**	**0,4**
Protective net/fence	1,0	0,9	69	69	0,1
Feeder for wildlife	0,5	0,2	315	158	0,3
Other	**7,0**	**6,1**	**320**	**2239**	**4,1**
Unknown	0,5	0,2	354	177	0,3
Other	6,5	5,9	319	2062	3,8
Total	**119,0**	**100,0**	**385**	**54411**	**100,0**

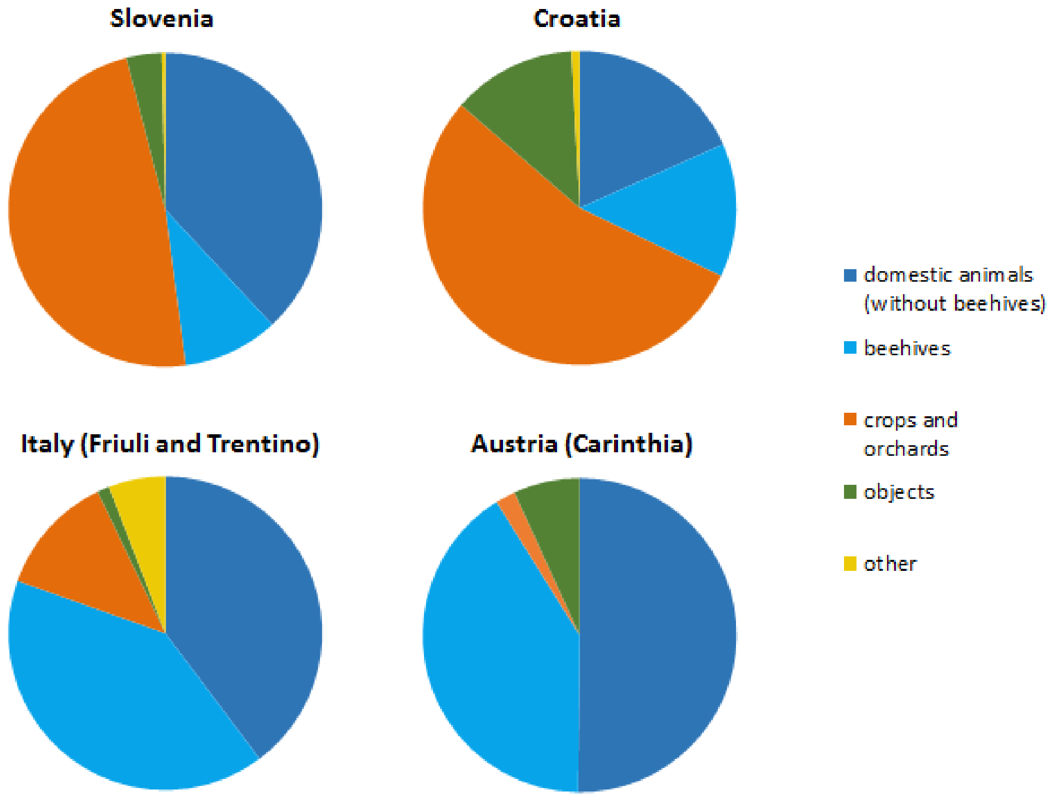

Figure 1: Average annual frequency of main damage types by country.

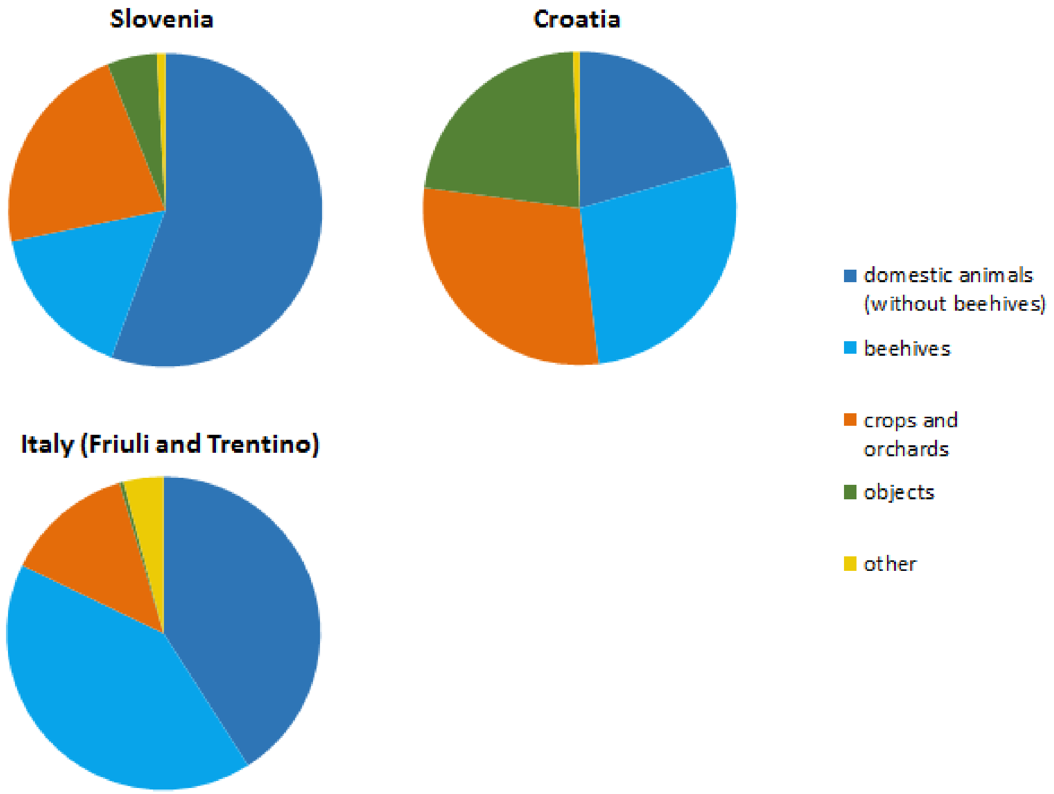

Figure 2: Average annual costs of main damage types by country. Due to small sample size, reliable estimates of costs were not possible to calculate for Austria.

Table 9: Annual number of damages per bear and annual cost of damages per bear, by country. Time frames correspond to time frames from tables 5-8.

country	*avg. number of damages per year*	*avg. cost per year [€]*	*estimated annual number of bears*	***avg. annual number of damages per bear***	***avg. annual cost per bear [€]***
Austria (Carinthia)	9,8	data not available	2*	**4,90***	**data not available**
Italy (Friuli, Trentino)	119,0	54.411	51	**2,33**	**1067**
Slovenia	365,3	124.329	400	**0,91**	**311**
Croatia	32,7	10.371	1000	**0,03**	**10**

* numbers very uncertain

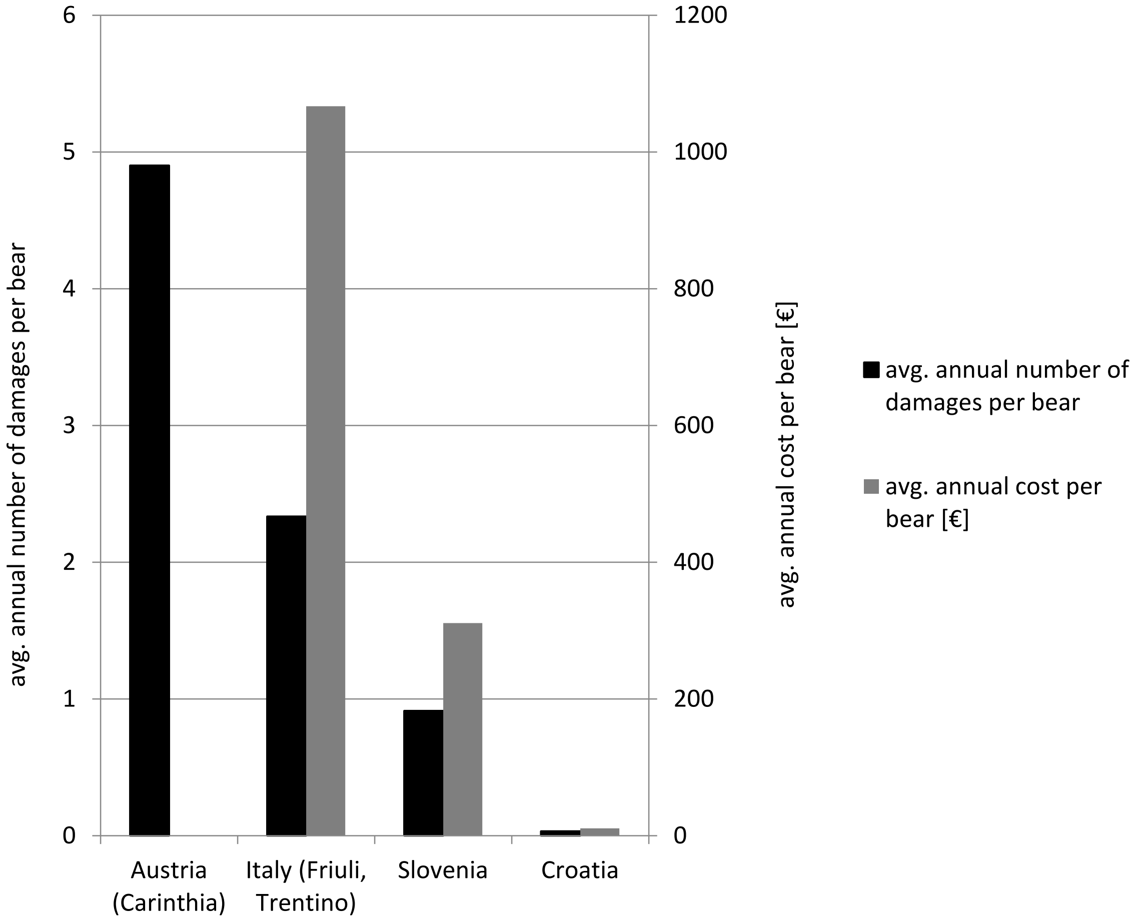

Figure 3: Annual frequency of damages calculated per average bear living in the country and average cost of damages per bear. Due to uncertain bear population size in Austria, the value of damages is only approximate for this country. In addition, sample size for costs in Austria was too small to be able to provide an estimate for average cost.

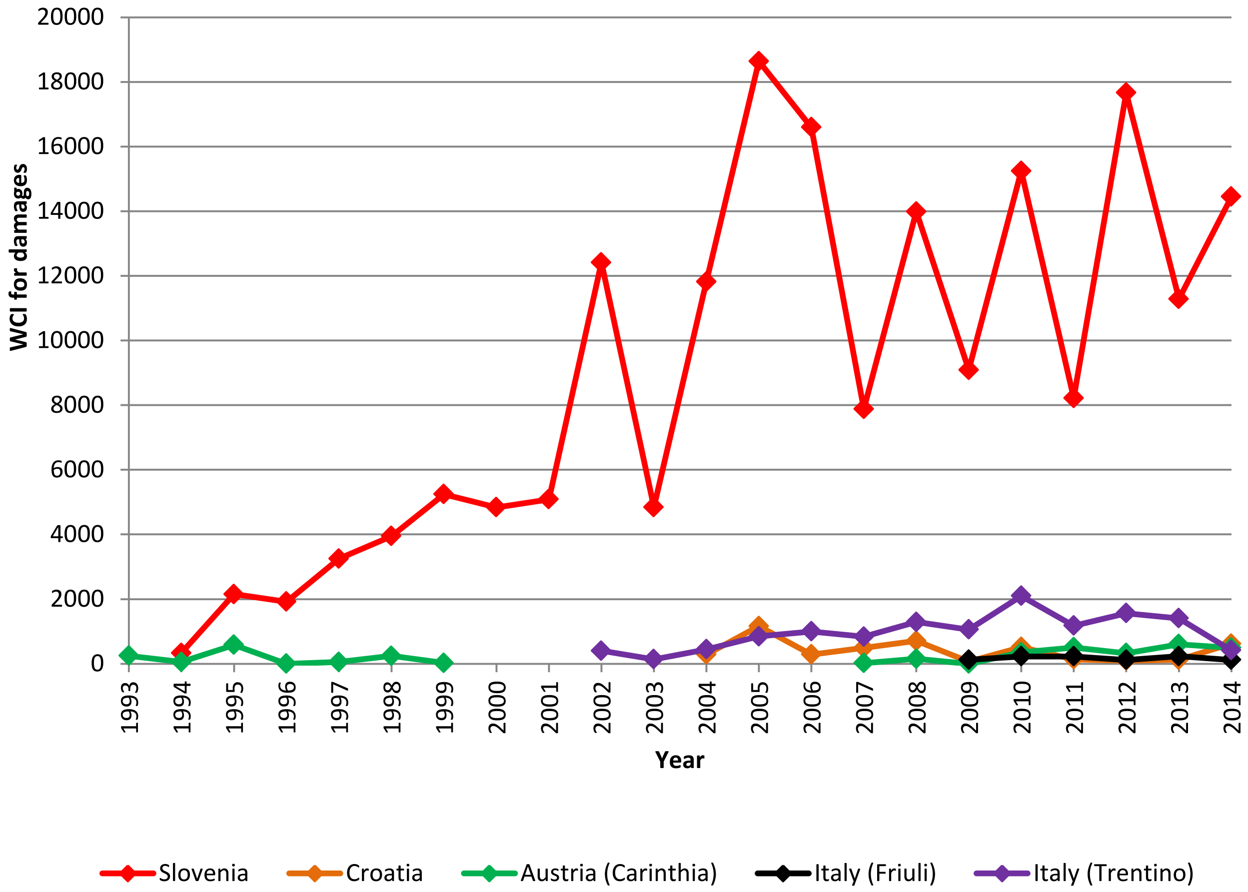

Figure 4: Temporal dynamic of weighted conflict intensity (WCI).

3.1.2 Spatial distribution of conflicts in the project area

Figures 5-8 depict spatial distribution of human-bear conflicts in the project area. The highest overall conflict intensity during the study period was observed in the Dinaric Mountains of Slovenia. This is in contrast with period before 2002, when damages were higher in the Alpine part of Slovenia (Kaczensky et al. 2011). However, damages are still high also in some parts of the Alpine region, especially along the national borders between Slovenia, Austria and Italy. Interventions were most frequent in the western part of Slovenian Dinaric Mountains and road accidents are mainly concentrated at few road locations throughout Dinaric Mountains in Slovenia and Croatia.

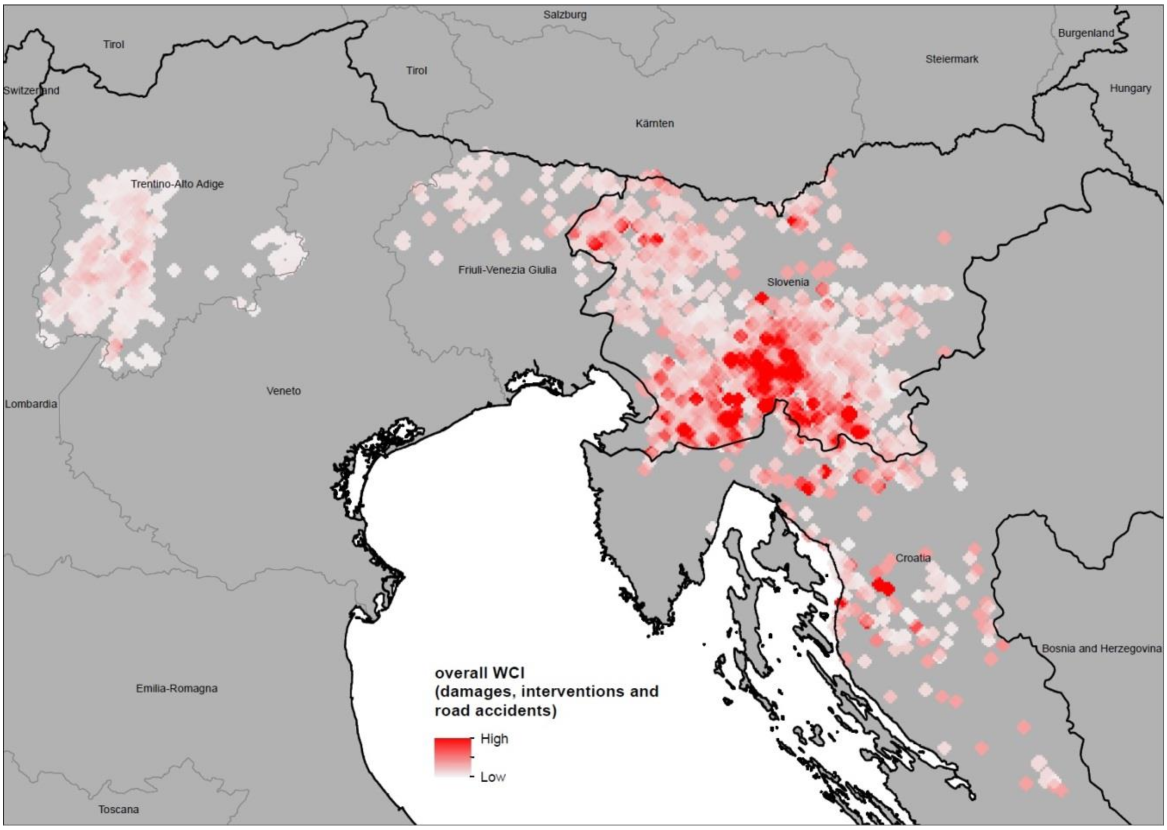

Figure 5: Mapped overall weighted conflict intensity (WCI) for Trentino, Slovenia and Croatia. Due to incomplete or complete lack of data, the conflict intensity is not shown for Austria and the Italian province Veneto.

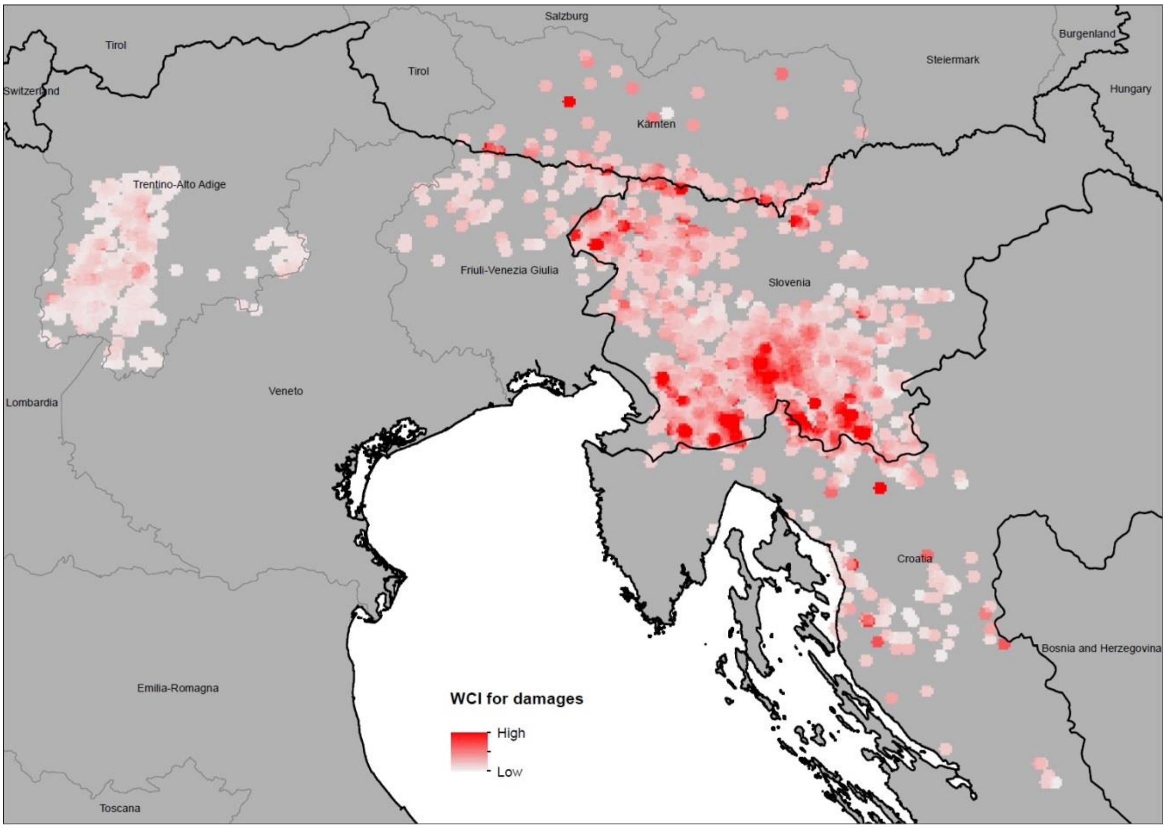

Figure 6: Mapped weighted conflict intensity (WCI) for damages for entire project area except Veneto.

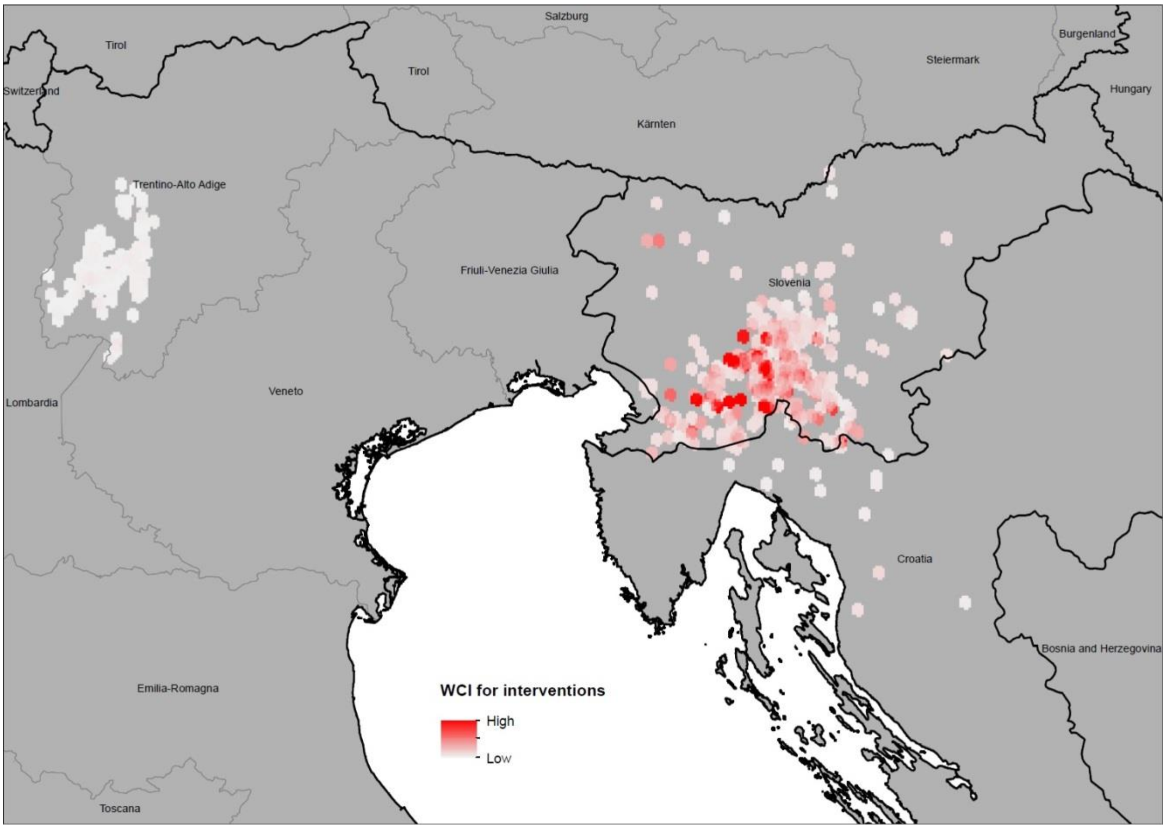

Figure 7: Mapped weighted conflict intensity (WCI) for interventions in Trentino, Slovenia and Croatia.

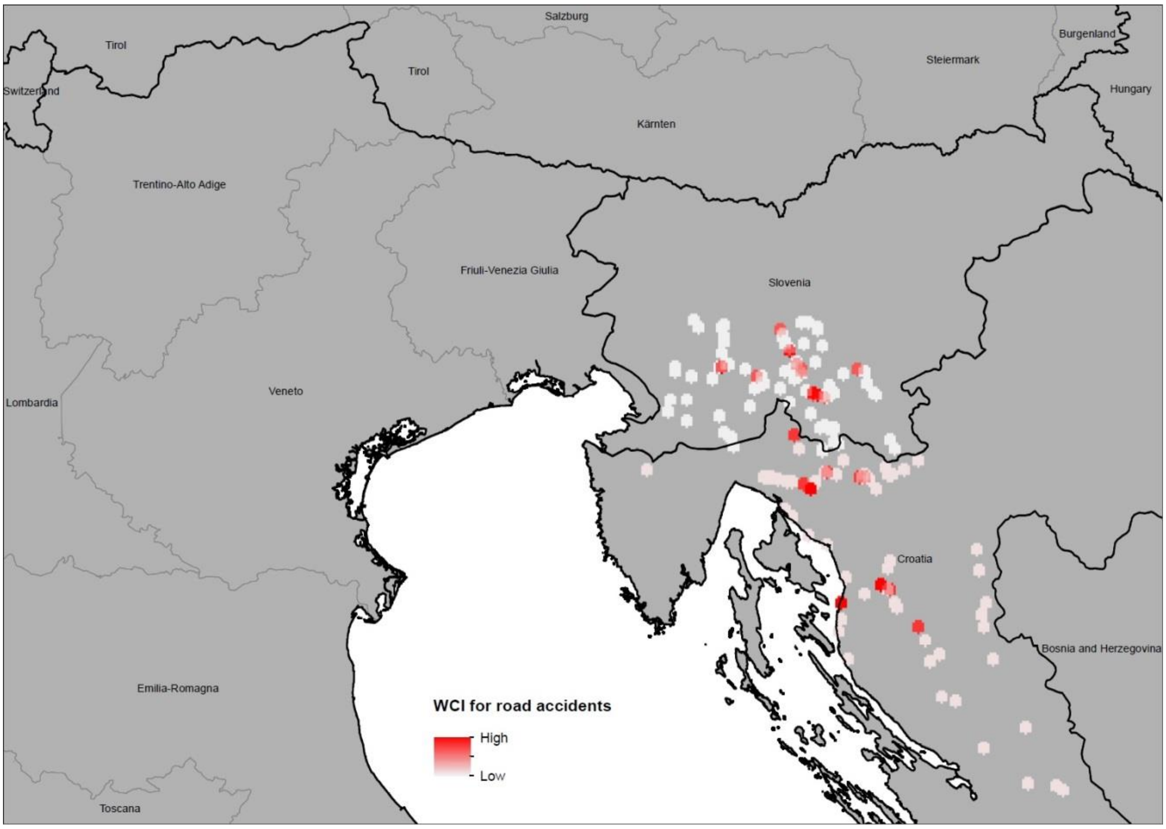

Figure 8: Mapped weighted conflict intensity (WCI) for road accidents in Slovenia and Croatia.

3.2 Detailed analysis of human-bear conflicts in Slovenia and effects of explanatory variables

3.2.1 Temporal analysis

During the study period (1998-2014) annual frequency of reported bear-caused damages in Slovenia varied from 180-809 cases per year (costs 44.500-258.700 € per year). Temporal analysis showed substantial increase in damages between 1998 and 2005. Since 2005 this trend stabilized, although with high inter-annual variation (figure 9). All types of damages were changing in time similarly and were overall increasing in time. The bear population size varied between 338 and 486 bears and was also generally increasing in time ($r = 0,80$, $p<0,05$). Analysis indicated that beech masting (figure 10) and bear population size (figure 11) importantly affected number of damages. Population size appears to have been more important, especially in years before 2005 when bear numbers were increasing, while after that year high inter-annual oscillation is well explained by the beechnut productivity.

Similarly, cross-correlation analyses (table 10 and table 11) indicate that damages correlated with bear population size, time (from past to present) and beech masting. When considering most important damage types, bear population size significantly positively correlated with damages in agriculture, livestock and beehives, while masting significantly negatively correlated with damages in agriculture and beehives, but not with livestock depredations. Also weighted conflict intensity (WCI) correlated significantly with bear population size (positively) and masting (negatively), as well as with the use of feeding sites in autumn (positively), but not with bear nutritional status (body mass residuals). Interestingly, beech masting did not significantly correlate neither with bear nutritional status nor with use of feeding sites, although there was higher use of feeding sites and somewhat lower body mass in years with poor masting. During the good masting years the bears used feeding places for 36% less compared to poor masting years. This also coincides with conclusions from the analysis of bear diet in Slovenia (Kavčič et al. 2015) that bears prefer feeding on natural food sources, when they are available.

The best GRM model to explain weighted conflict intensity for damages is shown in table 12, while all other models had $\Delta AICc>2$. The model predicts that damages increased for 58% from best to poorest masting years, and increased for 137% when the population size increased from the lowest to the highest decile (i.e. from 375 to 480 bears). Using the same approach we also analyzed effects of explanatory variables only for damages in agriculture. Results where similar with best GRM model including bear population size and masting intensity (table 13) and predicting that in poor masting years damages in agriculture increased for 127% compared to good masting years and increased for 161% when the population size increased from the lowest to the highest decile.

Models showed important effect of bear densities on the level of conflict rate in Slovenia, as has been also already shown for livestock depredations (Kavčič et al. 2013). However, the effect of population size predicted by the models was likely somewhat overestimated, because of the confounding factors related with time. These for example include changes in forest cover, number of sheep and other small livestock, and expansion of urban areas, which generally increased during the period of increasing bear numbers (1998-2005). Including these parameters in the models would likely provide more realistic estimate of the effects of bear population size.

Our results also indicated that bears are able to compensate the lack of natural food in poor beech masting years by increasing their foraging on supplemental food at the feeding sites and thus prevent loss of their weight, which would be expected in natural conditions. This could have important ecological and management implications. For example, supplemental feeding of bears likely enables high reproductive rates in all years (including poor masting years), which could explain high local bear densities (Jerina et al. 2013) and sustainability of high culling rates (Jerina & Krofel 2012, Krofel et al. 2012). However, although it appears that bears are able to compensate their dietary needs at the feeding sites, this obviously does not prevent conflicts with people, since in poor beech masting years the number of conflicts still more than doubled. Importance of natural food availability has been already also observed in a study on American black bears (*Ursus americanus*) in the USA, where conflicts similarly increased in years with poor food availability (Baruch-Mordo et al. 2014). With our study we could confirm importance of variable food availability for occurrence of human-bear conflicts also in region with intensive supplemental feeding. This measure is evidently not able to completely prevent increases in conflict rates in years with poor food availability. Whether supplemental feeding prevents these increases at least to certain extent is at present difficult to assess, since it is unknown whether the conflicts would be even be higher in poor food years, if no feeding would be conducted.

Seasonal dynamic of human-bear conflicts in Slovenia (figure 12) showed that conflicts were most frequent in autumn. Most pronounced autumn peaks were noted for damages and road accidents, while interventions were most common in spring. Among damages, livestock depredations were most common during summer and early autumn, damages on beehives reached peak in late spring and damages in agriculture had very pronounced peak in autumn (figure 13). Observed patterns are consistent with bear activity (hibernation in winter), bear foraging patterns (hyperphagia in autumn) and availability of anthropogenic food sources (ripening of fruits and crops in autumn, higher bee activity in spring/summer, summer outdoor keeping of small livestock).

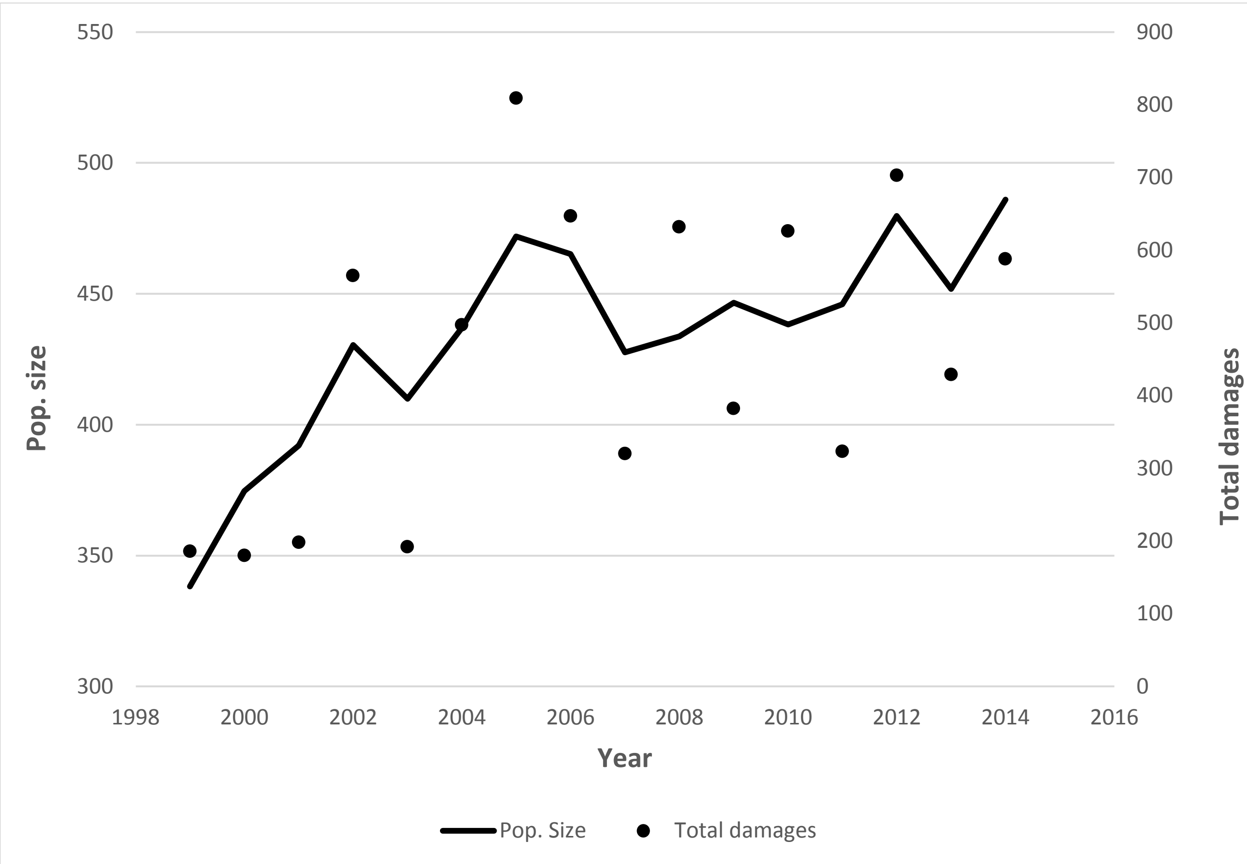

Figure 9: Temporal dynamics of bear population size and number of damage cases in Slovenia.

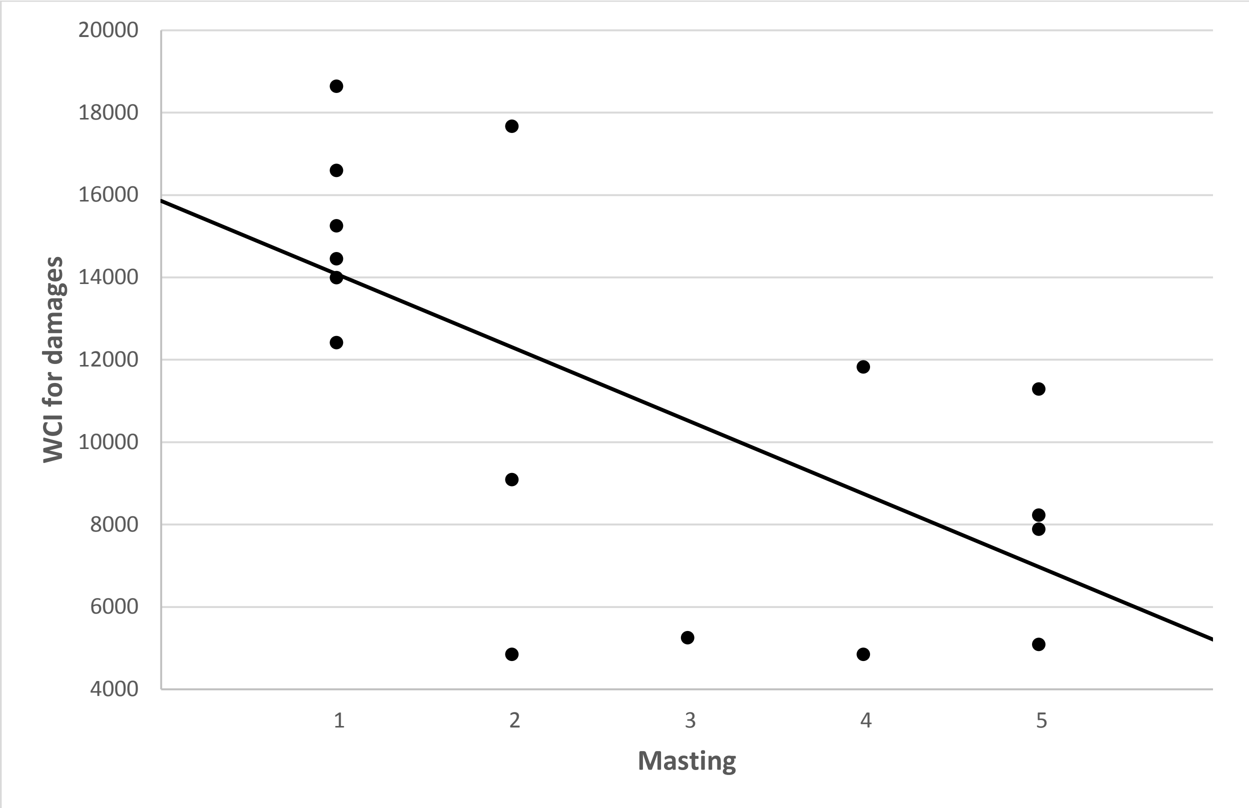

Figure 10: Relation between beechnut productivity (masting) and weighted conflict intensity (WCI) for damages.

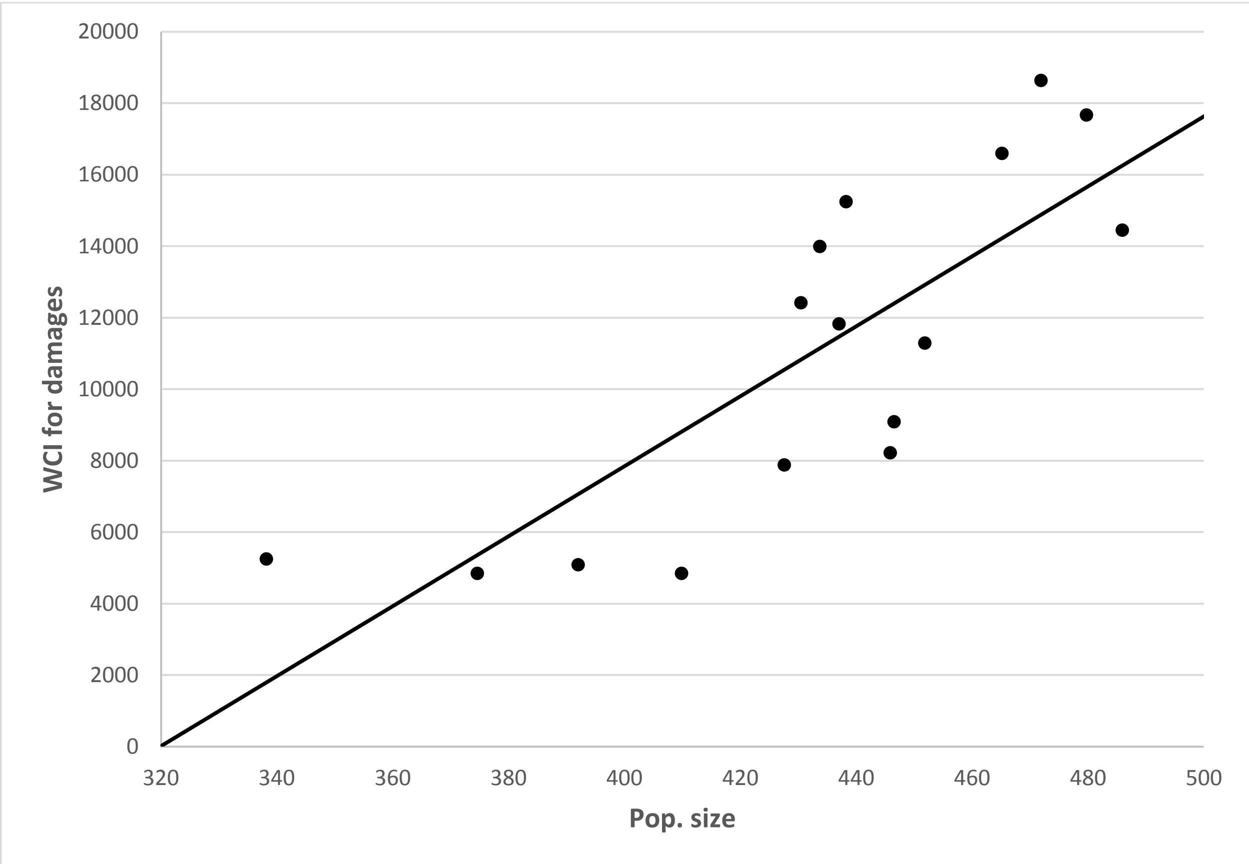

Figure 11: Relation between population size and weighted conflict intensity (WCI) for damages.

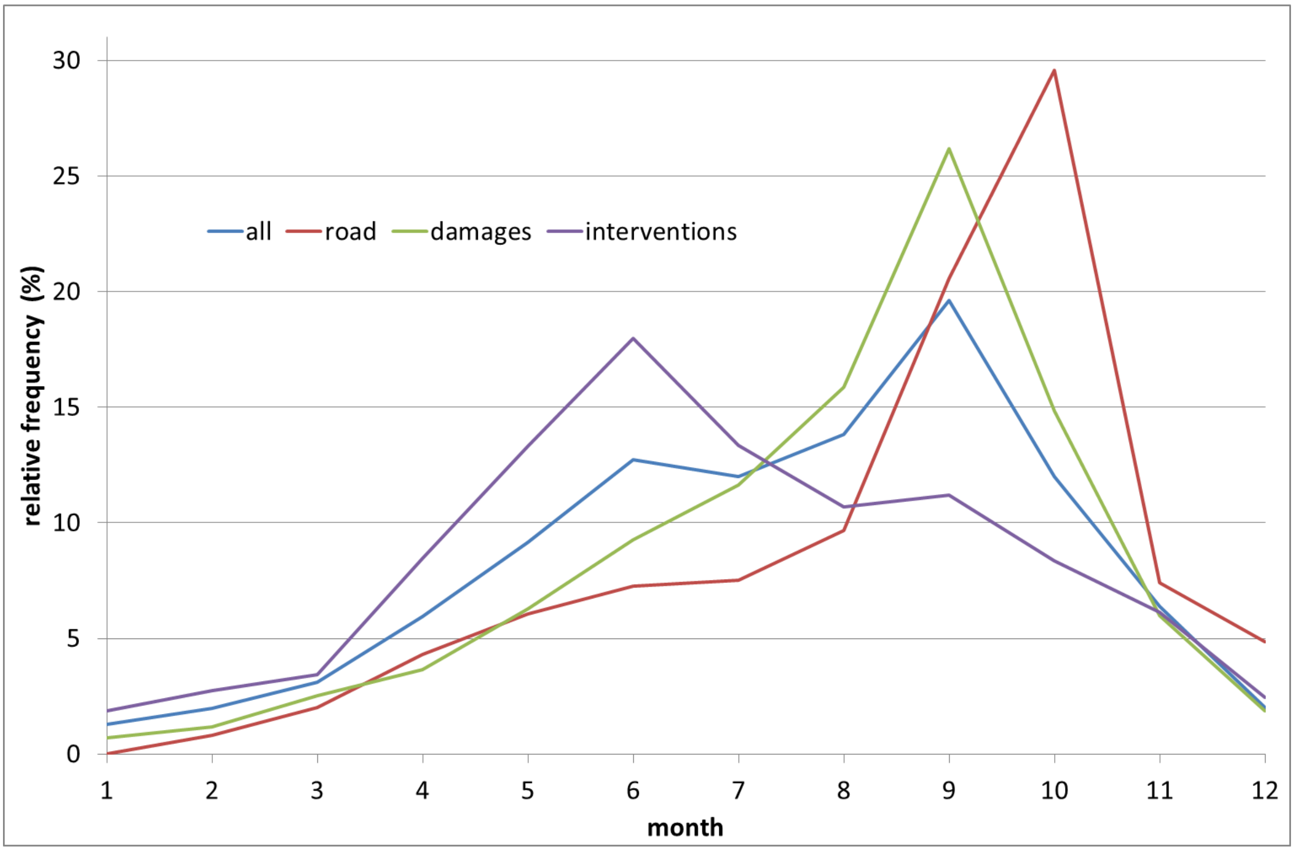

Figure 12: Seasonal dynamic in occurrence of human-bear conflicts in Slovenia.

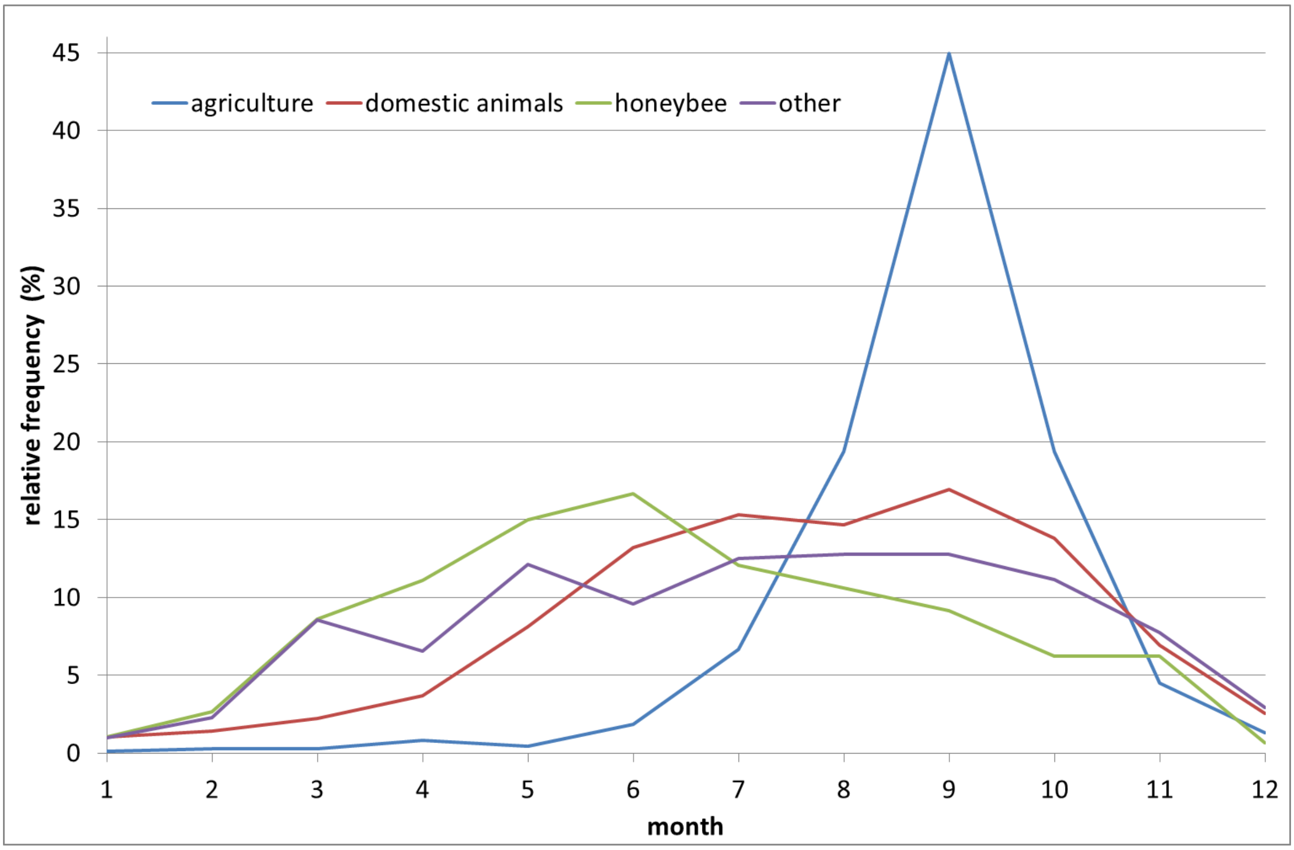

Figure 13: Seasonal dynamic in occurrence of bear-caused damages in Slovenia.

Table 10: Correlation coefficients between the different damages variables, year, bear population size and beech masting. Bold: significant correlations (p<0.05). WCI = weighted conflict intensity.

Variable	*Year*	*Pop. size*	*Total damages*	*WCI*	*Damages in agriculture*	*Damages on animals*	*Damages on beehives*	*Damages value (€)*
Year	1	**0,80**	**0,51**	**0,51**	0,37	**0,60**	**0,68**	**0,74**
Pop. size	**0,80**	1	**0,79**	**0,81**	**0,60**	**0,72**	**0,89**	**0,83**
Total damages	**0,51**	**0,79**	1	**0,98**	**0,90**	**0,67**	**0,91**	**0,84**
WCI	**0,51**	**0,81**	**0,98**	1	**0,87**	**0,74**	**0,91**	**0,88**
Damages in agriculture	0,37	**0,60**	**0,90**	**0,87**	1	0,34	**0,76**	**0,72**
Damages on animals	**0,60**	**0,72**	**0,67**	**0,74**	0,34	1	**0,71**	**0,75**
Damages on beehives	**0,68**	**0,89**	**0,91**	**0,91**	**0,76**	**0,71**	1	**0,90**
Damages value (€)	**0,74**	**0,83**	**0,84**	**0,88**	**0,72**	**0,75**	**0,90**	1
Mast	-0,07	-0,37	**-0,66**	**-0,67**	**-0,68**	-0,30	**-0,60**	**-0,58**

Table 11: Correlation coefficients between the weighted conflict intensity (WCI) and explanatory variables. Bold: significant correlations (p<0.05).

Variable	*Year*	*Pop. size*	*WCI*	*Mast-ing*	*Body residuals*	*Use of feeding sites (annual)*	*Use of feeding sites (spring)*	*Use of feeding sites (autumn)*
Year	1	**0,80**	**0,51**	-0,07	-0,05	0,30	0,55	0,30
Pop. size	**0,80**	1	**0,81**	-0,37	0,05	0,54	**0,85**	0,54
WCI	**0,51**	**0,81**	1	**-0,67**	-0,13	**0,70**	0,27	**0,70**
Masting	-0,07	-0,37	**-0,67**	1	0,23	-0,54	-0,07	-0,54
Body mass residuals	-0,05	0,05	-0,13	0,23	1	-0,62	0,13	-0,62
Use feeding of sites (annual)	0,30	0,54	**0,70**	-0,54	-0,62	1	0,49	1,00
Use feeding of sites (spring)	0,55	**0,85**	0,27	-0,07	0,13	0,49	1	0,49
Use feeding of sites (autumn)	0,30	0,54	**0,70**	-0,54	-0,62	1,00	0,49	1

Table 12: Regression results of best-fit model on weighted conflict intensity for damages. R= 0,902. Adjusted R-squared= 0,784. F (2,13)= 28,277. P < 0,00002. Std. Error of estimate: 2212,7. Number of observations: 16.

	Beta	*Std. Err.*	*B*	*Std. Err.*	*t*	*p-level*
Intercept			-21159,90	7013,3	-3,02	0,010
Pop. size	0,67	0,13	81,91	15,3	5,34	0,000
Masting	-0,43	0,13	-1203,09	352,6	-3,41	0,005

Table 13: Regression results of best-fit model on damages on agriculture. R= 0,821. Adjusted R-squared= 0,624. F (2,13)= 13,427. Number of observations: 16.

	Beta	*Std. Err.*	*B*	*Std. Err.*	*t*	*p-level*
Intercept			-464,94	277,38	-1,68	0,118
Pop. size	0,51	0,17	1,87	0,61	3,08	0,009
Masting	-0,50	0,17	-42,27	13,94	-3,03	0,010

3.2.2 Spatial analysis of conflicts in Slovenia

Spatial distribution of human-bear conflicts in Slovenia is presented in maps on figures 14-20. The highest conflict rate was observed in the north-central part of Dinaric Mountains range in Slovenia in the arch from the town of Ig due south towards Velike Lašče and Sodražica and from there towards west to Bloke and Lož valley. Local conflict hot-spots also include areas around Grosuplje, several areas of Kočevsko region, as well as Kostel, Čabar, Rakek-Unec and Šembije (figure 18 and figure 19). When considering only damages, hot-spots can be observed in Kočevsko, Bloke, around Čabar, Šembije and Brkini (figure 15). Most frequent interventions were recorded in similar areas as conflicts in general with addition of surroundings of Cerknica, Pivka and Babno polje (figure 16). Traffic accidents are concentrated at several sections of the road Ljubljana-Kočevje and on highway section Unec-Postojna (figure 17). This highway section has already been identified as problematic for bear crossing in previous study (Adamič et al. 2000).

Tables 14-16 and figure 20 show results of the multivariate analyses of effects of explanatory variables on human-bear conflicts in Slovenia. Models were more successful in predicting the presence or absence of conflicts (table 14) rather than the amount of conflicts (table 15). The most important factor predicting presence and intensity of conflicts was density of bears in the 15 km radius. With the change in local density from the first to the last decile the model predicted 28-fold change in conflicts. Importance of bear densities was already indicated by the temporal analysis (chapter 3.2.1) and results given by the spatial analysis provide further understanding of this parameter. The 15 km radius, which was most influential, is biologically meaningful, as it corresponds approximately to the average home range diameter of brown bears in Slovenia (Jerina et al. 2012). In this respect it is important to note that in Slovenia there are almost no areas that would be more than 15 km away from closest human settlement. Therefore concentrating bears in remote areas is for Slovenia generally not a useful option.

Interestingly, the second in the rank of importance was the presence of extensive orchards. Reason for this is not immediately apparent, since reported damages on orchards are not very common in Slovenia and they alone cannot explain this result. More likely explanation is that orchards may act as attractants that draw bears closer to the settlements, which then leads to further conflicts. This is supported by the results of the GPS-telemetry study of bears in Slovenia, which indicated that anthropogenic food sources are one of the main factors that attract bears to human settlements (Jerina et al. 2012). Orchards were the only type of anthropogenic food sources besides feeding sites for which detailed spatial data were available and could be included in this study. This also indicates that including additional data of anthropogenic food sources might further improve the models. Another possible explanation for importance of orchards in the model may be that they correlate with some other important parameter (e.g. specific type of land use practice).

Other variables identified as important by the models include exposition diversity, historical presence of bears, presence of urbanized areas and presence of settlements. This was followed in importance by the distance to the forest edge, presence of meadows, mixed forest-agriculture land use, proportion of broadleaf forests, intensity of supplemental feeding and presence of forest cover (table 16). These results indicate the importance of landscape characteristics for occurrence of conflicts, especially habitat fragmentation. Presence of forest cover was even characterized by the highest odd ratio of all parameters in the model, predicting 125-fold change in conflict probability. However, due to small number of conflicts occurring inside forests, relative importance of this parameter was smaller compared to other parameters (table 14). As was already noted for the Alpine region (see chapter 3.1.1), the historical presence of bears appears to be important also within the Dinaric Mountains, since inhabitants with more past experiences with bears report lower conflict rates than people from areas with recent bear re-colonization. Presence of meadows is likely connected with presence of livestock and consequent higher probability for depredations. Food availability in the surrounding forests (presence of broadleaf forests and intensity of supplemental feeding) on the other hand appears to decrease the conflict probability. In conclusion, areas with highest conflict probability were characterized by higher bear densities, more fragmented landscape, less experiences with bear coexistence and higher availability of anthropogenic food sources.

Figure 21 represent differences between empirical data of conflicts in Slovenia and results of the models constructed using variables listed above. It indicates that other important variables, which were not included in the model, cause higher conflict rates in areas around Ig, Grosuplje, Velike Lašče, Sodražica, Bloke, Ivančna Gorica, Kostel, Knježja Lipa, Sinji vrh, Lož valley, Šembije and Brkini. On the other hand, conflicts are rarer than predicted by the model around Struge, Draga valley, Babno polje, Borovnica and Logatec.

Among these other variables not included in the model are likely the anthropogenic food sources, for which we lack suitable spatial data, but which have been shown by the GPS-telemetry study to importantly affect human-bear conflicts. Such attractants for example include illegally discarded slaughter remains, legal and illegal garbage dump sites, scattered garbage and various organic waste, unprotected garbage bins, composts, and food leftovers at picnic sites (Jerina et al. 2012). Some of the areas with higher than expected conflict rates also include localized, site-specific anomalies. For example, the pastures above Šembije (Volovja reber ridge) stand out due to abnormally high damages caused on the single flock of sheep, which was likely due to abuse of the damage compensation system by the owner. After this pasture received improved protection of livestock in 2011, the damages in this entire region decreased abruptly (Kavčič et al. 2013; Krofel & Černe 2013). Important part of discrepancies between the predicted and empirical model is likely connected also with politically- or socially-related parameters. For example, in areas where local inhabitants are more tolerant of bears, there is lower probability that sighting of a bear will be reported as a conflict or that minor damage will be called for compensation. On the other hand, in areas with lower tolerance towards bears (e.g. due to fear or lack of experiences) or where bears are used for presumed political benefits, probability for a bear incident to be reported is likely higher. Comparison of the map on figure 21 with the spatial differences in public attitudes towards bears could provide further evidence for importance of socially-related parameters and for interpretation of results presented here.

It is important to note from figures 20 and 21 that the area with the highest conflict intensity in Slovenia (arch from Ig through Velike Lašče to Sodražica, Bloke and Lož) are characterized by both, parameters included in the analysis (e.g. strong habitat fragmentation, high bear densities in the southern part, recently colonized areas in the northern part), as well as by other, unknown parameters.

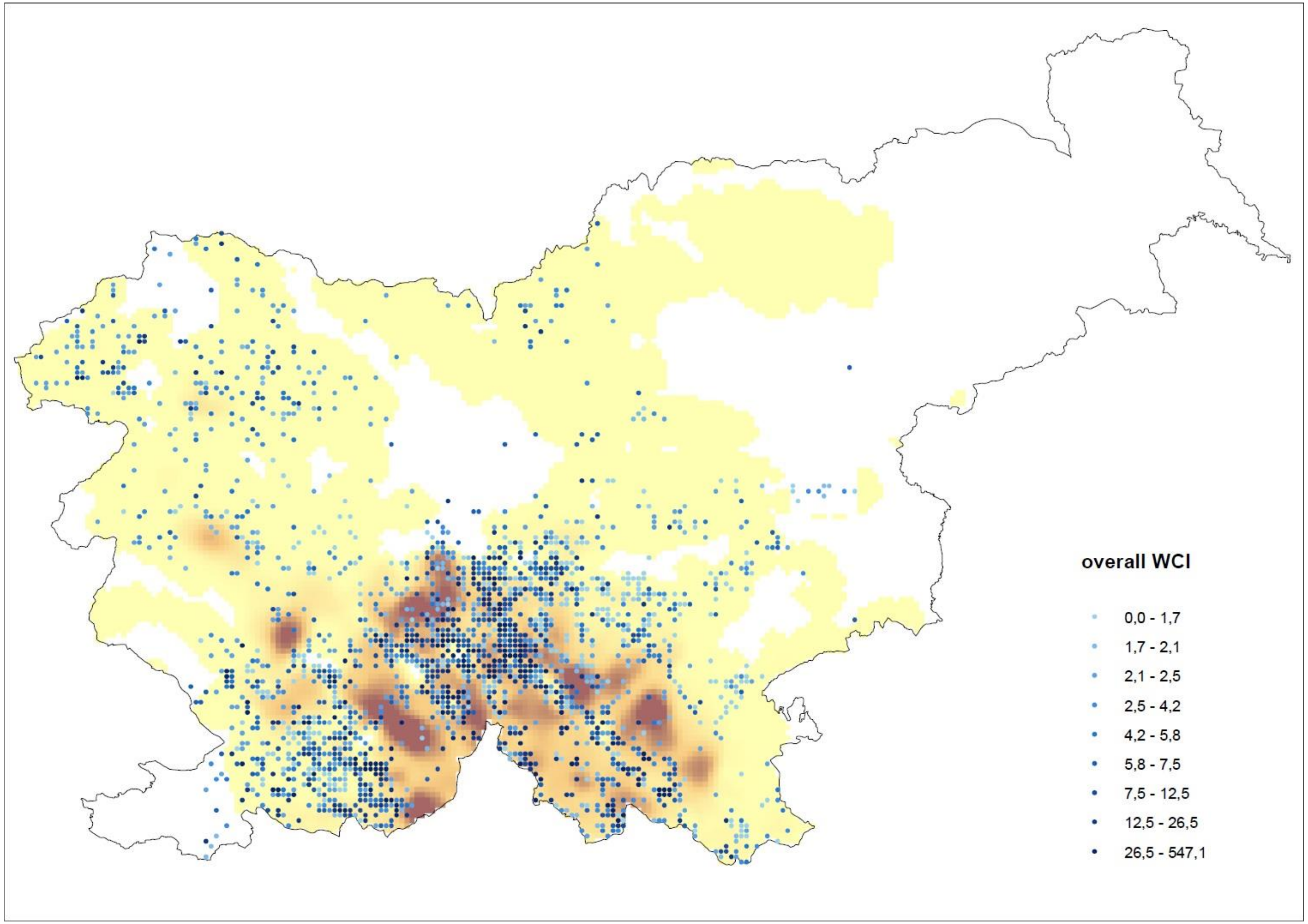

Figure 14: Mapped overall (damages, interventions and road collisions) weighted conflict intensity (WCI) for Slovenia. WCI is shown together with local bear densities in the background. White areas are areas without bears, areas with bears are shown with colors from yellow to dark brown (light colors indicate low bear densities and dark colors high local bear densities). It is noticeable that higher bear density not necessarily means more human-bear conflicts. Conflict hotspots are mostly located on areas with relatively low bear densities.

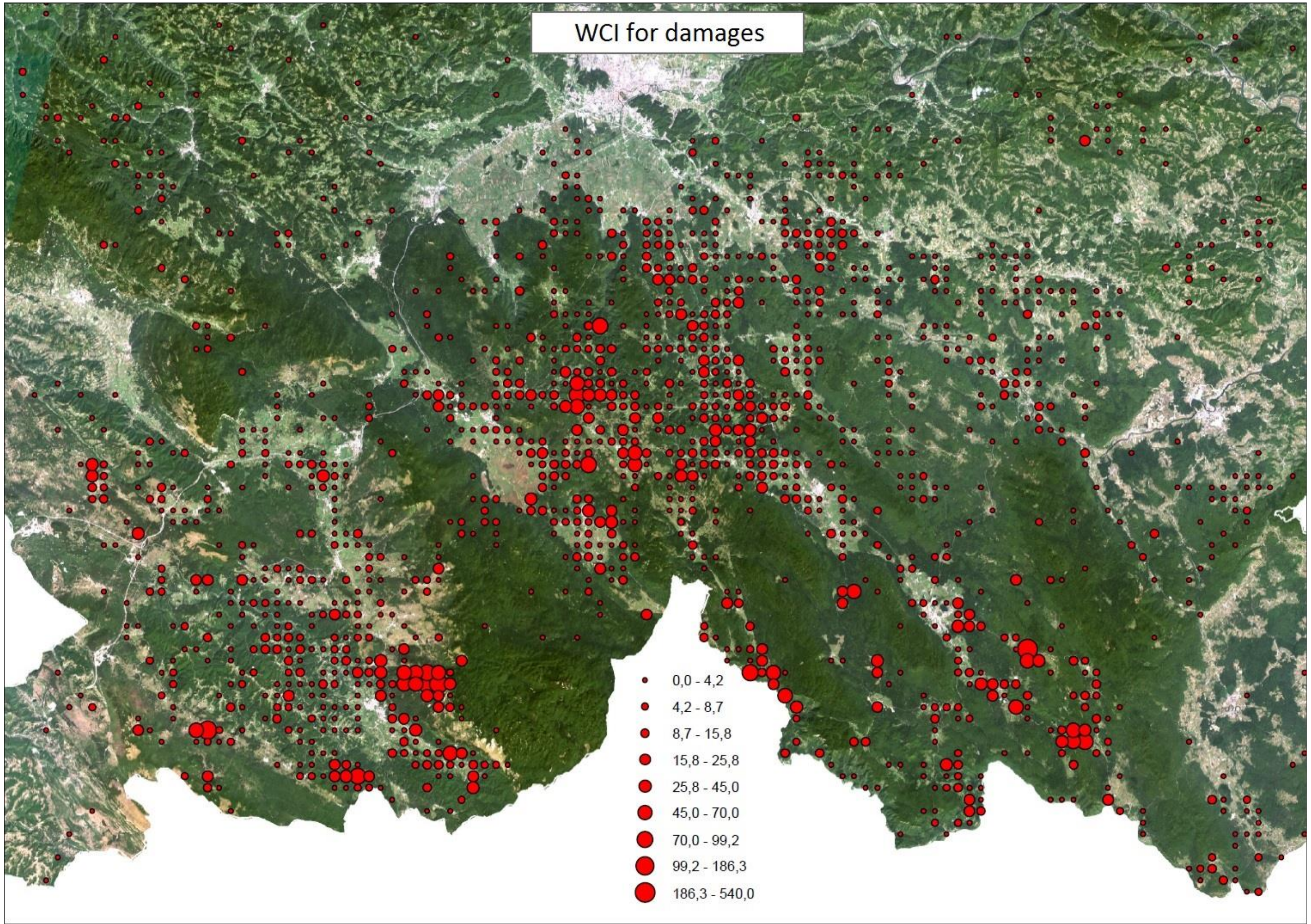

Figure 15: Weighted conflict intensity (WCI) for damages in the bear core area in Slovenia, calculated for each 1 km² cell.

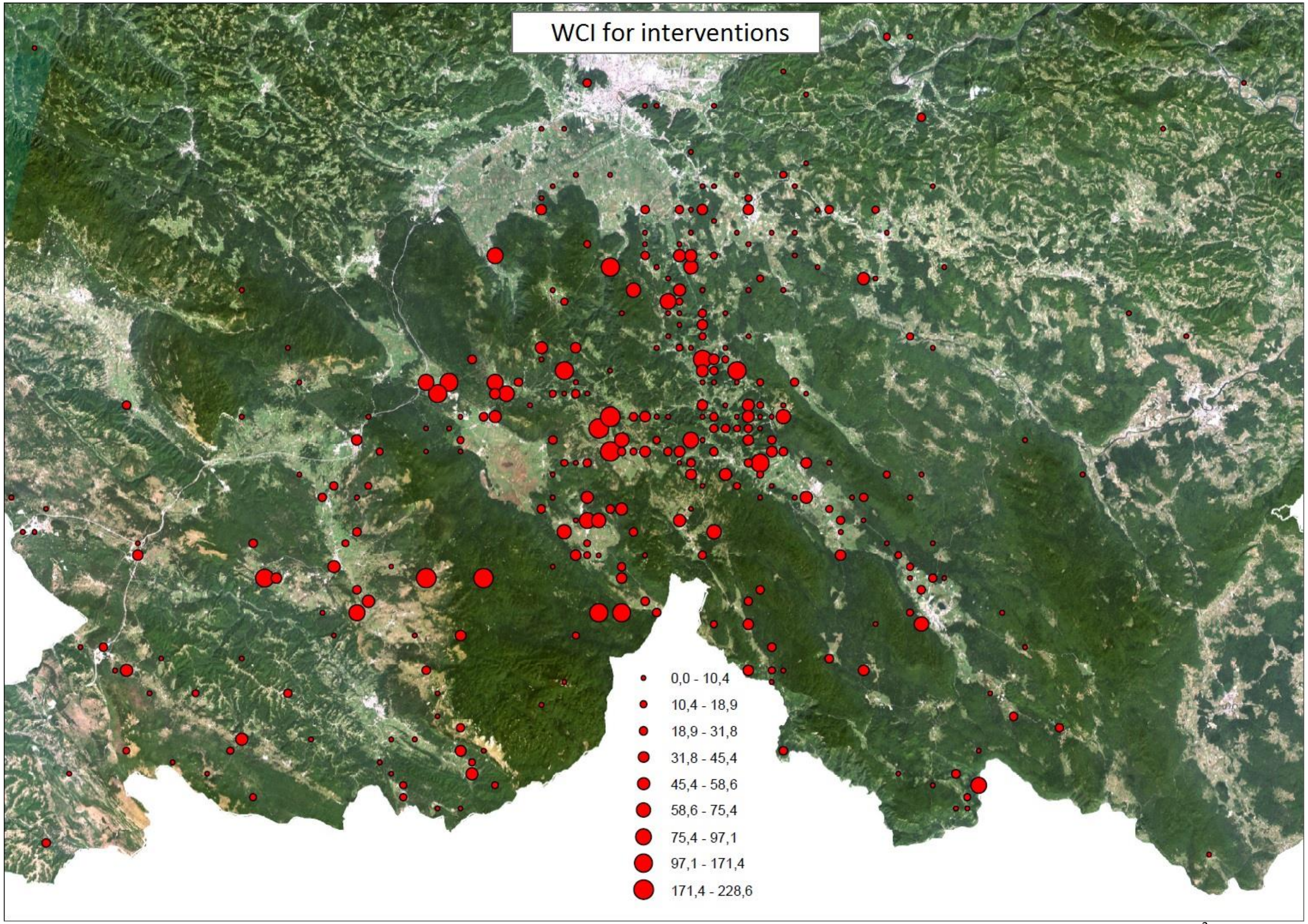

Figure 16: Weighted conflict intensity (WCI) for interventions of intervention team in the bear core area in Slovenia calculated for each 1 km² cell.

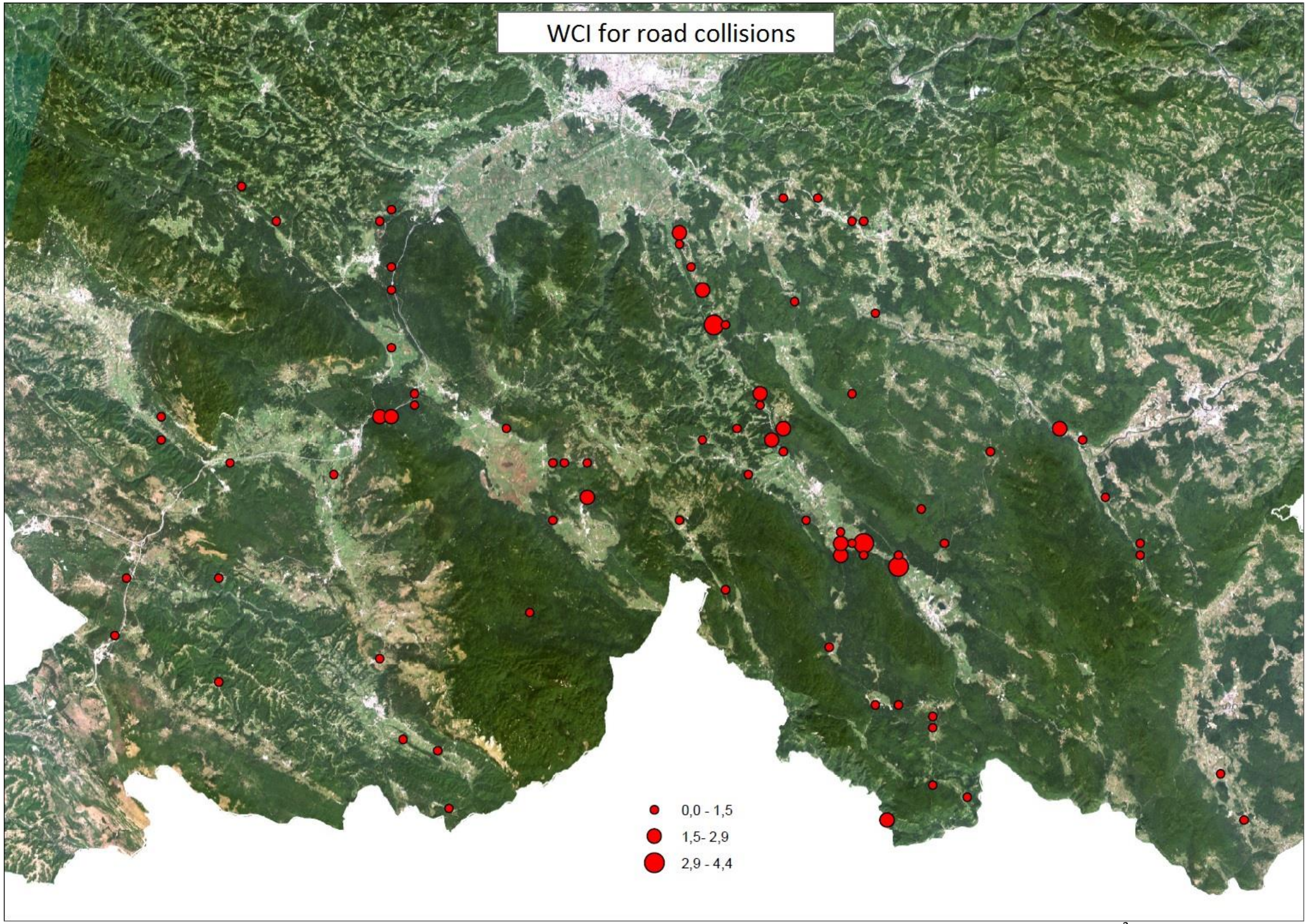

Figure 17: Weighted conflict intensity (WCI) for road collisions in the bear core area in Slovenia, calculated for each 1 km^2 cell.

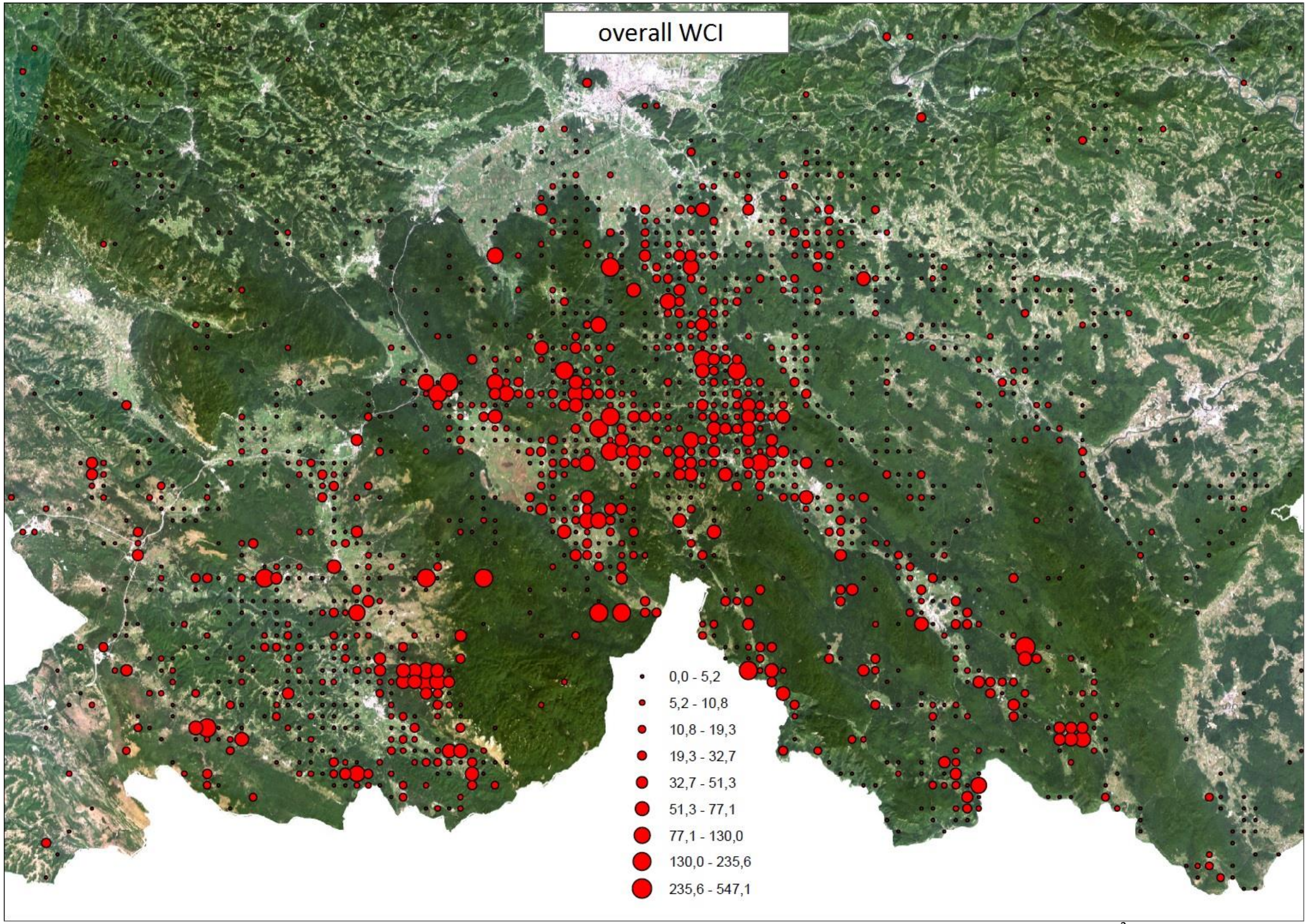

Figure 18: Overall (damages, interventions, road collisions) Weighted conflict intensity (WCI) in the bear core area in Slovenia, calculated for each 1 km^2 cell. The most conflict locations are mostly on the areas with high fragmentation and outside of the forest or on a forest edge.

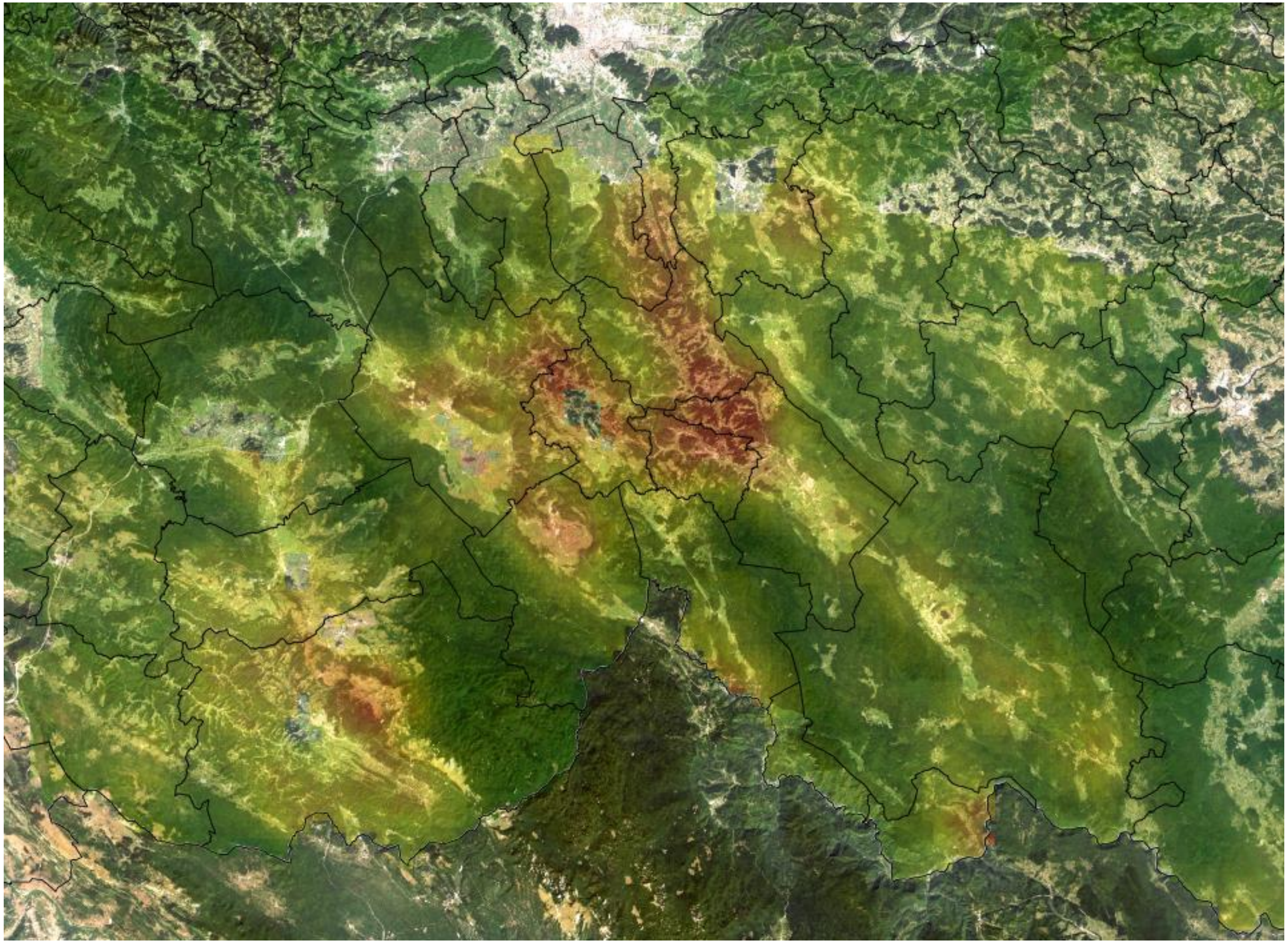

Figure 19: Intensity of human-bear conflicts (empirical data). Green indicates lower, yellow intermediate and red high conflict rate.

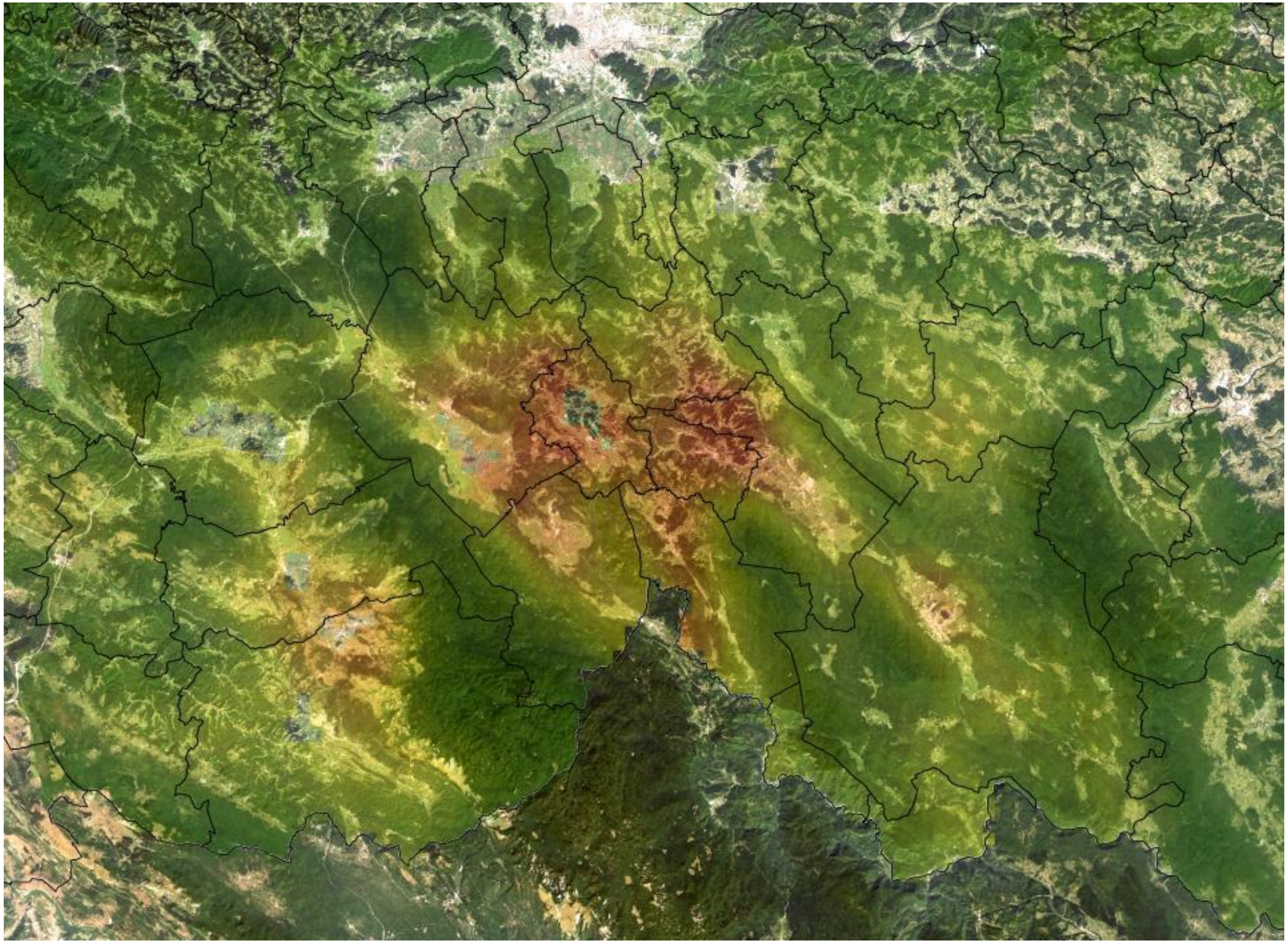

Figure 20: Spatially explicit model of the intensity of human-bear conflicts in Slovenia. Green indicates lower, yellow intermediate and red high conflict rate predicted according to the combined predictions of the binary logistic regression model and generalized linear model incorporating all the parameters that proved significant in the analysis.

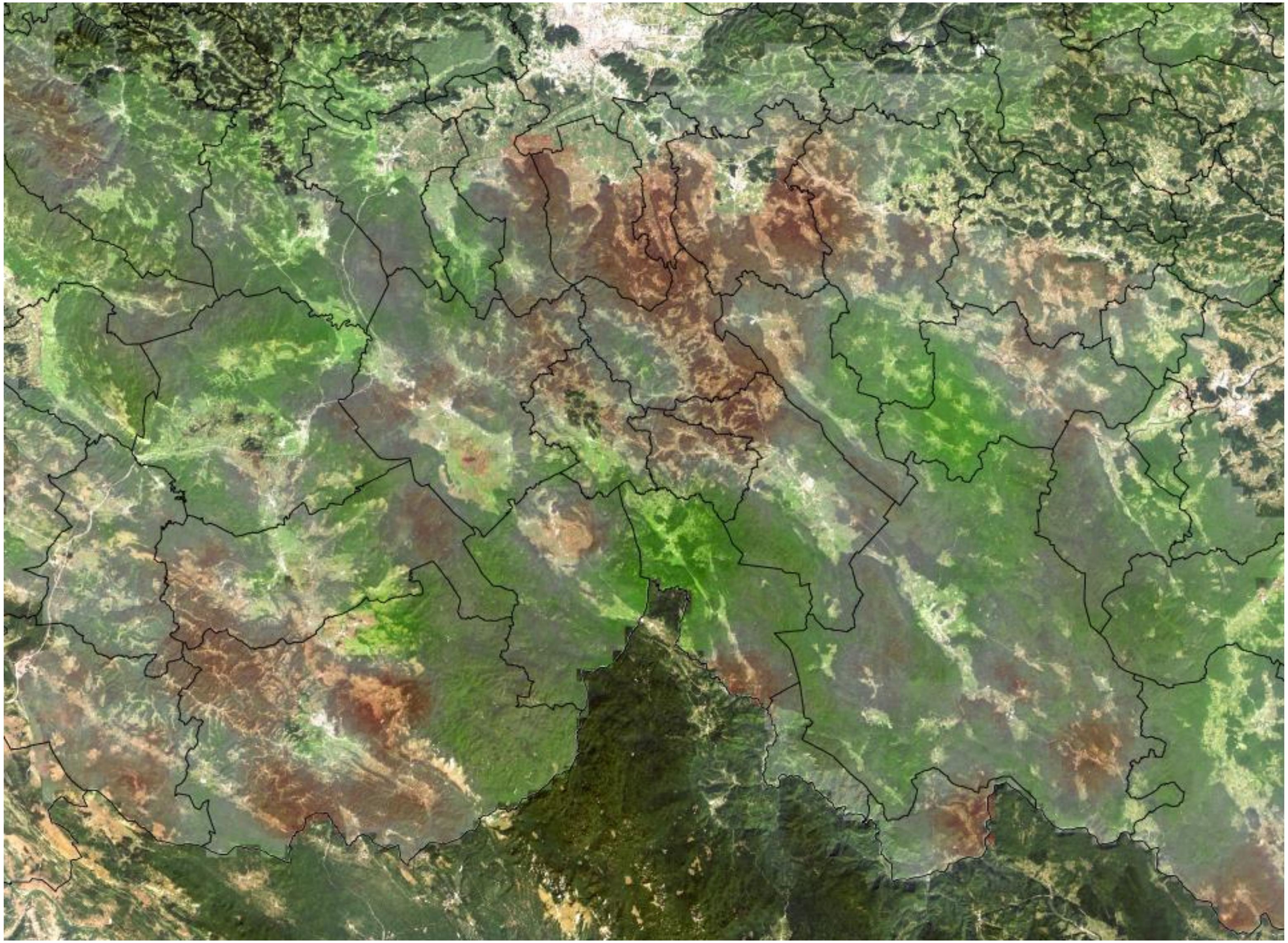

Figure 21: Intensity of human-bear conflicts: difference between empirical data and spatially explicit model (red represent areas with higher conflict intensity compared to model predictions, green areas with lower conflict intensity compared to model prediction and white areas are neutral).

Table 14: Binary logistic regression model predicting occurrence of human-bear conflicts in Slovenia. Model correctly classified 79 % of all cells, accuracy of classification for conflicts is 84 % and for non-conflict cases 72 %.

	B	*Std.Err.*	*Wald*	*Significance*	e^B	*first decile*	*last decile*	*odd ratio*
bear density (15 km)	23,289	0,830	787,246	0,000	$1{,}3\times10^{10}$	0,010	0,153	27,989
settlements	-0,000	0,000	253,386	0,000	1,000	283,000	3134,600	0,369
inside distance from forest edge	-0,003	0,000	184,539	0,000	0,997	44,000	419,000	0,351
extensive orchards	31,165	2,355	175,119	0,000	$3{,}4\times10^{13}$	0,000	0,030	2,579
meadows	2,388	0,183	169,962	0,000	10,892	0,002	0,528	3,514
mixed forest-agriculture land use	5,338	0,562	90,248	0,000	207,992	0,000	0,085	1,577
non forest vs. forest	4,828	0,512	89,029	0,000	124,927			124,927
Exposition diversity	0,004	0,001	60,503	0,000	1,004	60,000	186,000	1,674
history	0,000	0,000	17,190	0,000	1,000	-16712,200	25755,067	1,485
constant	-6,810	0,499	186,261	0,000	0,001			

Table 15: Generalized linear model predicting intensity of human-bear conflicts in Slovenia (r^2 = 0.43).

	Beta	*Std.Err.*	*B*	*Std.Err.*	*t (num. of units: 1643)*	*p-level*	*prediction for first decile*	*prediction for last decile*	*relative difference*	*proportion of explained variance*
bear density (15 km)	0,453	0,039	10,267	0,878	11,700	0,000	0,889	2,296	0,867	0,559
urbanised areas	0,104	0,025	2,115	0,508	4,161	0,000	1,538	1,751	0,132	0,071
history	0,154	0,038	0,000	0,000	4,037	0,000	1,442	1,812	0,228	0,067
Exposition diversity	0,097	0,025	0,002	0,001	3,931	0,000	1,442	1,746	0,187	0,063
broadleaves	-0,091	0,023	-0,730	0,186	-3,926	0,000	1,757	1,472	-0,175	0,063
Supplemental feeding	-0,089	0,024	-0,001	0,000	-3,638	0,000	1,678	1,533	-0,089	0,054
extensive orchards	0,084	0,024	6,220	1,790	3,475	0,001	1,573	1,723	0,092	0,049
mixed forest-agriculture land use	0,068	0,023	1,549	0,531	2,919	0,004	1,571	1,702	0,081	0,035
meadows	0,061	0,026	0,370	0,159	2,326	0,020	1,536	1,726	0,117	0,022
non forest	-0,048	0,024	-0,523	0,258	-2,026	0,043	1,629	1,106	-0,322	0,017
intercept			0,370	0,138	2,676	0,008				

Table 16: Relative importance of parameters predicting human-bear conflicts in Slovenia based on joined results of the binary logistic regression and generalized linear models (Tables 14 and 15). Columns odd ratio and % change represent the predicted change in the conflict rate, if the given parameter changes from the first to the last decile, while other parameters are held constant.

	logistic regression		*multivariate regression*		*sum of relative ranks*
	relative rank	*odd ratio*	*relative rank*	*% change*	
bear density (15 km)	9	28,0	9	0,87	18
extensive orchards	6	2,6	3,6	0,09	9,6
Exposition diversity	2	1,7	6,3	0,19	8,3
history	1	1,5	7,2	0,23	8,2
urbanized areas			8,1	0,13	8,1
settlements	8	0,4			8
inside distance from forest edge	7	0,4			7
meadows	5	3,5	1,8	0,12	6,8
mixed forest-agriculture land use	4	1,6	2,7	0,08	6,7
broadleaves			5,4	-0,18	5,4
Supplemental feeding			4,5	-0,09	4,5
non forest vs. forest	3	124,9	0,9	0,32	3,9

4 CONCLUSIONS

In the project area we recorded high diversity of bear-caused damages. In Austria and Italy the most frequent damage was caused on domestic animals (mainly sheep and beehives), while in Slovenia and Croatia the most frequent damages recorded were in agriculture, mainly on corn and orchards, followed by damage on domestic animals. When calculated per average bear, there were very large differences among the countries in frequencies and costs of damages. The highest damages per bear were noted in Austria, followed by Italy, Slovenia, and Croatia. In Austria damages were for 160-times more frequent than in Croatia. The most probable reasons for this are differences in bear management, especially compensation system, and in the historic presence of bears in the region. Due to different compensation system in Croatia, damages there are likely considerably underestimated. This will probably change with recent changes in bear management in Croatia due to joining the EU. In absolute terms, the total number of damages and costs was highest in Slovenia – more than double compared to any other country.

Further detailed analysis for Slovenia indicated that local bear density (in the radius of 15 km) was the most important factor affecting occurrence of human-bear conflicts in the country among the parameters included in the model. Additional important factor explaining the large interannual variation in conflicts was the beech masting (annual productivity of beechnuts). Beech masting however did not significantly correlate with bear nutritional status, as bears apparently compensated lack of natural food availability by feeding on supplemental food provided at feeding sites. This however did not fully prevent increase of conflicts in poor masting years. Models also indicated the importance of landscape characteristics for occurrence of conflicts, especially habitat fragmentation. Presence of forest cover was even characterized by the highest odd ratio of all parameters in the model. Conflicts were also more common in areas that were more recently re-colonized by bears in comparison to areas where inhabitants have more experiences with coexisting with bears. Additional important parameter was the presence of extensive orchards, which may act as attractants that draw bears closer to the settlements. Previous study with the use of GPS-telemetry showed that anthropogenic food sources (e.g. slaughter remains, organic waste, garbage) were one of the main factors that attract bears to human settlements. However, due to lack of data on anthropogenic food sources besides orchards and feeding sites, this parameter could not be sufficiently included in the model. We nevertheless were able to identify which areas are likely to be importantly affected by this and other parameters not included in the model (e.g. socially- and politically-related parameters).

The highest conflict intensity in Slovenia was observed in the north-central part of Dinaric Mountains range in Slovenia, especially in the arch from Ig through Velike Lašče to Sodražica, Bloke and Lož. This region is characterized by parameters shown to increase probability for human-bear conflicts: strong habitat fragmentation, high bear densities in the southern part, recently colonized areas in the northern part and presence of anthropogenic foods. In addition, also other parameters not included in the analysis further increase the conflict rates in this region.

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