Supplemental feeding with carrion is not reducing brown bear depredations on sheep in Slovenia

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Abstract: Supplemental feeding is often believed to be a successful tool for reducing human–bear (*Ursus arctos*) conflicts, especially in Europe. However, effectiveness of this measure is poorly understood and there is growing concern for potential negative side-effects. This is particularly true for supplemental feeding using livestock carrion. Carrion feeding is considered especially effective in reducing livestock depredations by diverting bears from pastures and meeting their protein needs. In Slovenia, year-round supplementary feeding of bears with livestock carrion and corn was intensive and in some areas practiced for over 100 years. However, in 2004 the use of livestock carrion was banned in accordance with European Union regulations. This provided an opportunity to study the effects of carrion feeding on livestock depredations by bears. We used sheep as they represented 97% of all depredation events by brown bears in Slovenia. We analyzed whether bears selectively used carrion feeding stations over corn feeding stations (i.e., indicating that carrion might be more effective in diverting bears from sheep pastures) during 1994–2011, and compared the annual frequency and seasonal distribution of sheep depredations 5 years before and after the ban on livestock carrion feeding during 1999–2009. We found no support that bears selected carrion feeding sites over feeding sites with corn. When controlled for changes in bear and sheep numbers, there was no indication that the ban on carrion feeding increased sheep depredations. Moreover, complementary data indicated that natural protein sources were considerably more important than livestock carrion and that use of carrion peaked in spring, when sheep are rarely outdoors and thus unavailable for depredation. Because of the observed lack of effectiveness, high costs, and potential negative side-effects, we discourage supplemental feeding with livestock carrion to reduce livestock depredations.

Key words: baiting, brown bear, carrion consumption, conflicts, depredation, livestock, scavenging, sheep, Slovenia, supplemental feeding, *Ursus arctos*

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Brown bears (*Ursus arctos*) are opportunistic omnivores, feeding mainly on plant material, but they also consume animal and various anthropogenic food sources when available (Craighead et al. 1995, Rode and Robbins 2000, Krofel et al. 2012a). In Europe, brown bears were exterminated from a large part of their historic range (Swenson et al. 1995, Zedrosser et al. 2001), with the few remaining populations occurring mainly in human-dominated landscapes. Coexistence of brown bears and people often leads to human–bear conflicts, with many conflicts a consequence of bears searching for anthropogenic food near human settlements (Gunther et al. 2004, Wilson et al. 2005). In many areas of the world, conflict resolution is attempted by lethal methods, including management removals, increased harvest quotas (Kaczensky 1999, Jerina et al. 2003), and illegal harvest (Kaczensky et al. 2011), which can threaten the long-term viability of brown bear populations. Human–bear conflicts are often a main threat to bear conservation (Kaczensky 1999, Gunther et al. 2004, Krofel and Jerina 2012).

Supplemental feeding is a non-lethal management measure used for conflict mitigation. By providing alternative food in remote areas, managers attempt to divert bears from settlements or reduce damage to human property, such as livestock (Landers et al. 1979, Kaczensky 1999, Huber et al. 2008, Krofel and Jerina 2012). Among experts, beliefs about effectiveness of supplemental feeding for conflict mitigation

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are contrasting: some report it can reduce damage (Partridge et al. 2001, Ziegltrum 2008) and conflicts (Rogers 2009), while others believe that supplemental feeding creates habituated bears, increases the frequency of conflicts (Hererro 1985, Gray et al. 2004), and is not efficient long-term (Dunkley and Cattet 2003, Will and Hampton 2007).

Thus, it is not surprising that supplemental feeding policies for brown bears vary considerably among countries. While supplemental feeding is practiced in Bosnia and Herzegovina (Kunovac et al. 2008), Croatia (Dečak et al. 2005), Romania (Ministry of Agriculture, Forestry and Rural Development and Ministry of Environment and Water Management 2006), Serbia (D. Čirović, Department of Animal Ecology and Geography, Faculty of Biology, University of Belgrade, Serbia, personal communication, 2012), Slovakia (Rigg and Adamec 2007), and Slovenia (this study), it is prohibited in Sweden (Swenson et al. 2007, Bischof et al. 2008) and many parts of North America (Dunkley and Cattet 2003, Gray et al. 2004). In some countries including Austria (Zedrosser et al. 1999) and Poland (Selva et al. 2011), bears are not intentionally fed, but regularly use supplemental feed intended for wild ungulates. Although supplemental feeding is expensive, its effects on human–bear conflicts have been poorly studied. This is even more pronounced for supplemental feeding with carrion from domestic animals, which is practiced in several European countries including Croatia (Dečak et al. 2005), Bosnia and Herzegovina (Kunovac et al. 2008), Serbia (D. Čirović, Department of Animal Ecology and Geography, Faculty of Biology, University of Belgrade, Serbia, personal communication, 2012), and Finland (Kojola and Heikkinen 2012).

Slovenia represents a good case study to explore the efficiency of supplemental feeding to reduce conflicts, since bears and people coexist in a high density in a multiple-use landscape and supplemental feeding of wildlife, including bears, has a long tradition (Jerina 2012, Jerina et al. 2013). In parts of Slovenia, bears have been fed for more than a century (Simonič 1994). Previously, bears were fed mainly corn and livestock carrion. However, with Slovenia joining the European Union (EU) in 2004, the use of carrion was forbidden for feeding brown bears and other animals used for human consumption in accordance with the EU veterinary legislation (European Parliament and Council1774/2002). It is commonly believed in Slovenia that the ban on use of carrion in supplemental feeding of bears is a primary reason for the recent increase in human–bear conflicts, especially livestock depredations (e.g., Štrumbelj 2006). This is based on the unsubstantiated premise that bears select carrion over corn (making supplemental feeding with corn less effective for diverting bears from urban areas and pastures with livestock) and that bears without access to carrion more frequently attack livestock to meet their dietary needs, especially for proteins (Štrumbelj 2006, Krofel and Jerina 2012).

This abrupt, country-wide change in management provided an opportunity to assess the effectiveness of supplemental feeding with carrion for reducing livestock depredations. Although bears occasionally kill other livestock, we analyzed only sheep depredations as they represent 97% of all depredation events by brown bears in Slovenia (Krofel and Jerina 2012). We assessed the effectiveness of supplemental feeding by comparing bear use of feeding sites supplied with carrion and those supplied only with corn. As carrion feeding sites are supposed to more effectively divert bears away from pastures than corn feeding sites (Štrumbelj 2006), we predicted that bears would more frequently use carrion feeding sites. We also compared the annual frequency of sheep depredations before and after the ban on carrion feeding. If carrion feeding reduced sheep depredations, the frequency of attacks should increase after the ban on carrion use, even when controlling for changes in bear and sheep numbers. Finally, we compared the seasonal distribution of sheep depredations before and after the ban on carrion use. It is believed that bears attack sheep to meet their dietary protein needs (Štrumbelj 2006). Therefore, we predicted that after the ban on carrion use, sheep depredations will increase particularly during the spring, when carrion consumption peaks and most important natural protein sources (i.e., insects) are scarce (Adamič 2005).

Study area and methods

Study area

We conducted the study in the Core Bear Protective Area in Slovenia (45°30′–46°15′N, 13°30′–15°15′E, approximately 4,000 km^2), where about 95% of the 400–500 bears in Slovenia occur (Jerina et al. 2013). During the study the bear population increased, and in the last 5 years brown bear densities in Slovenia were one of the highest

reported in the world, locally exceeding 40 bears/100 km^2 (Jerina et al. 2013). Bears in Slovenia coexist with people with a density of 28–42 inhabitants/km^2 (Perko and Orožen Adamič 1998). Each year, about 104,500 € (euros; 1 € equals $1.29 US, July 2013) in compensations in paid for all bear-caused damage in Slovenia (Krofel and Jerina 2012). Sheep farming occurs throughout bear range, and during the study period the number of sheep increased 3.5-fold to about 138,000 animals (Krofel et al. 2011), with most flocks relatively small and dispersed. Most flocks are inadequately protected by permanent electric fences used to keep sheep in their respective pastures rather than protect them from large carnivores. Forests are dominated by silver fir (*Abies alba*) and common beech (*Fagus sylvatica*) associations and intermixed with agricultural fields and small settlements; the average distance to the nearest house in the study area is about 1 km. Annual precipitation averages 1,500 mm with average, annual temperatures of 7–8°C; average temperatures range from −4 to 0°C in January and 16 to 20°C in July (Ingolič 1993). Snow cover lasts from 20 to 30 days at 500 m and up to several months at higher elevations. The vegetation growth period lasts from late April to late October.

Before the ban on carrion feeding in 2004, the national brown bear management strategy prescribed one carrion feeding site for every 60 km^2 (Ministry of Agriculture, Forestry and Food 2002). Bears also had access to ungulate feeding sites provided with corn, which occurred at densities of 14–23/100 km^2 (Grosse et al. 2003). The annual amount of supplemental carrion varied among different parts of the study area from 33 to 146 kg/km^2, and the annual amount of supplemental corn varied from 70 to 280 kg/km^2 (Kaczensky 2000, Adamič 2005). The amount of supplemental corn provided was similar before and after the ban on carrion feeding. Both types of supplemental food were available to bears throughout the year.

Use of supplemental feeding sites before and after the ban on carrion feeding

We used data from systematic bear counts at feeding sites to analyze effects of carrion feeding on the use of supplemental feeding sites. In Slovenia, systematic monitoring of brown bear at supplemental feeding sites has been conducted since 1993 by hunters, Slovenia Forest Service, students of the Biotechnical faculty at University of Ljubljana, and other volunteers to monitor trends of population size and other demographic parameters (e.g., proportion of females with cubs, litter size). Bear counts were conducted 2–3 times each year, in spring and autumn, on the last Friday before the full moon from 1800–2400 hr simultaneously over the entire brown bear range in the country (see Krofel et al. 2012b, Jerina et al. 2013). Between 1993 and 2004, bear counts were not conducted at fixed feeding sites. Bears were annually counted at 100–370 feeding sites; however, not all of the feeding sites were included in monitoring each year (on average each site was monitored in one out of 3 years). About 1/3 of feeding sites included in monitoring were supplied with carrion and 2/3 with corn. When carrion feeding was banned in 2004, all carrion feeding sites were supplied with corn. At the same time monitoring was standardized and counting was conducted at 167 fixed feeding sites every year. All fixed feeding sites were included in at least 2 counts before 2004. Feeding sites for bear monitoring were spaced about 3 km apart across the entire Core Bear Protective Area, so we considered them representative of feeding sites used by bears throughout Slovenia.

Carrion feeding sites were designed exclusively for bears and were thus established at locations with greater than expected bear activity. Therefore, difference in use of carrion and corn feeding sites could be a consequence of factors other than food. Post-ban carrion feeding sites were supplied with corn, and by comparing pre- and post-ban bear use we tested whether their use by bears declined. Use of feeding sites is strongly affected by local bear densities (Jerina et al. 2013), which were generally increasing during the study period (Jerina and Adamič 2008). Therefore, we analyzed the change in the use of feeding stations that were always supplied only with corn (pre-ban versus post-ban use index; see below) and compared pre- and post-ban indices for both types of feeding sites. Our null hypothesis was that index of pre- and post-ban use was the same for both types of feeding sites.

We calculated the average annual number of observed bears during pre- and post-ban periods for each feeding site. We then used these averages instead of raw data from individual counts. We calculated an annual index of feeding site use by pooling data from all feeding sites (average number of bears counted at feeding sites in post-ban period divided by average number of bears counted in pre-ban period). Subsequently, we used bootstrapping with 1,000 simulations to test for differences between

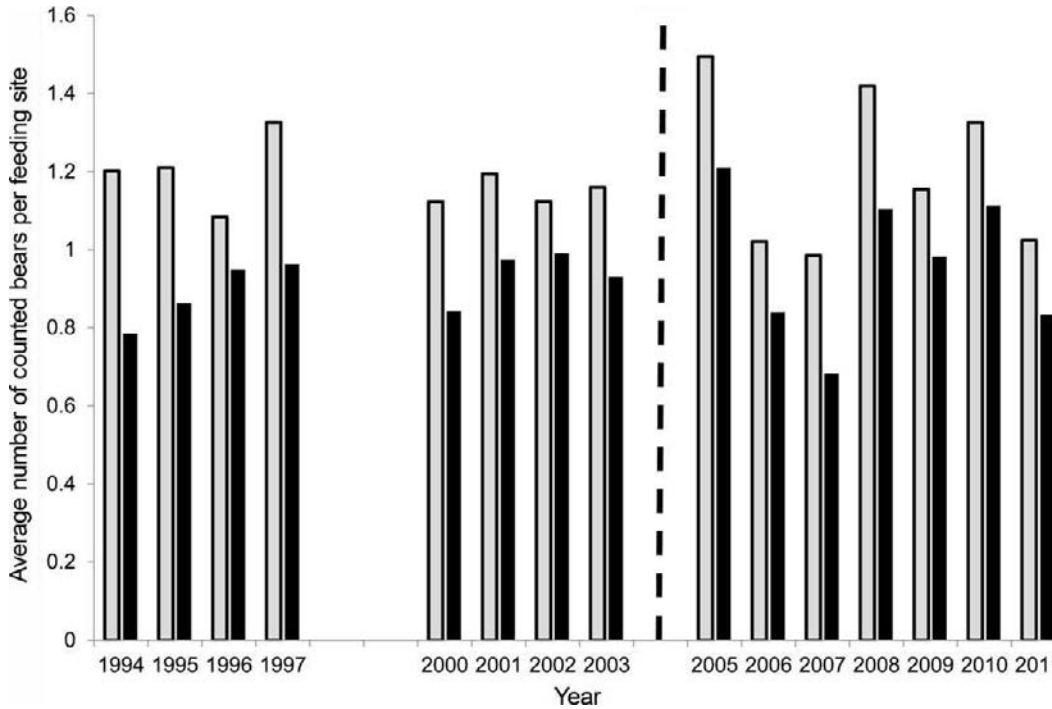

Fig. 1. Average annual number of brown bears counted per feeding site in Slovenia for sites supplied only with corn throughout the study (black) and sites supplemented with livestock carrion in the pre-ban period (before 2004; grey). Dashed line represents 2004, the year of ban on feeding with carrion. Data are lacking for years 1998, 1999, and 2004.

corn and carrion feeding site indexes and to estimate 95% confidence intervals (CI) for all parameters. This approach does not control for inter-year differences in the use of feeding sites; however, it buffers the potential effect of inter-annual differences (Fig. 1) in the use of feeding sites. This was not possible with available data, because not all feeding sites were monitored every year during the pre-ban period; in addition, the distribution of bears observed per feeding site per night is exceedingly asymmetrical and discrete, and it was not possible to normalize it with any of the tested transformations.

Livestock depredation before and after the ban on carrion feeding

To test the effectiveness of supplemental feeding with carrion to reduce livestock depredations, we compared data on sheep depredations during pre- and post-ban periods. In Slovenia, all sheep depredations by large carnivores are compensated by the government. Therefore, there is high motivation for sheep farmers to report attacks. All animals killed or injured are inspected in the field by trained personnel of the Slovenia Forest Service. Compensation for bear damage is paid only when material evidence is available that livestock were killed or injured by bear. If no consensus is reached between the owner and the Slovenia Forest Service official on the cause of damage, the carcass is sent for autopsy to the National Veterinary Institute. Since 1994 detailed data on all reported damages caused by large carnivores have been maintained in a database by the Slovenia Forest Service (Slovenian Forest Service 2011). We refer to all depredations as killed sheep, although some were only injured and slaughtered later by the owner (in cases of minor injuries, sheep are kept alive and are not compensated or recorded as depredated).

We compared sheep depredation patterns for a 5-year period before the ban on carrion feeding (1999–2003; pre-ban) and a 5-year period after the ban (2005–09; post-ban). Five-year periods were used to reduce the effects of annually variable non-target factors on the extent of damages caused by bears (e.g., annual availability of natural food). We analyzed several parameters that characterize the extent of depredations including mean annual

number of sheep killed by bears (no. sheep killed) and mean annual number of all sheep in Slovenia (total sheep). We used sheep number data for the entire country as no data on sheep numbers within the bear area were available for the entire study period. However, the trends in number of sheep were relatively similar throughout Slovenia (G. Gorjanc, University of Ljubljana, Biotechnical faculty, Department of Animal Science, unpublished data). We also calculated mean annual proportion of sheep killed by bears among all sheep in Slovenia (proportion sheep killed), mean annual number of bears in Slovenia (total bears; data from Jerina and Krofel 2012), mean annual number of sheep killed per bear (sheep killed per bear), mean annual number of sheep multiplied with mean number of bears (total bears x total sheep; this variable was included since we expected the probability of a random encounter between a bear and sheep — and thus also the probability of damage — increases simultaneously with both numbers), and mean annual number of sheep killed per bear per year divided by total bears x total sheep (sheep killed/ total bears x total sheep).

To test effects of carrion feeding on the number of sheep killed (dependent variable) by bears, we used generalized linear models with total sheep, total bears, and total bears x total sheep as covariates, and period (pre-ban versus post-ban) as a binary variable. We calculated all possible models with algorithm best subsets and selected the models with the lowest Akaike Information Criterion (AIC_c) value. We explored the structure of all candidate models with ΔAIC_c scores <2, calculated Akaike weights, and used them for model averaging to obtain robust parameter estimates (Burnham and Anderson 2002, Johnson and Omland 2004). We compared changes in monthly percentages of sheep depredations between pre- and post-ban periods on monthly level using exact homogeneity test with 1,000 simulations. We used software Statistica 8.0 (StatSoft Inc., Tulsa, Oklahoma, USA) and IBM SPSS Statistics 21 (International Business Machines., Armonk, New York, USA) for all statistical analyses.

Results

Use of feeding sites

During the pre-ban period, the average number of bears observed per monitoring night was 1.16 (CI = 0.99–1.33) on carrion feeding sites (n = 54; 514 monitoring nights) and 0.93 (CI = 0.82–1.01) on corn feeding sites (n = 117; 738 monitoring nights; Fig. 1). In the post-ban period, mean number of bears observed per monitoring night at carrion feeding sites now supplemented with corn was 1.2 (CI: 0.99–1.42; 954 monitoring nights) and at corn feeding sites 0.98 (CI: 0.83–1.09; 2037 monitoring nights). Indexes (pre- versus post-ban period) did not differ between carrion and corn feeding sites (1.03, CI = 0.96–1.12, and 1.05, CI = 0.95–1.12, respectively).

Difference in depredation patterns between pre- and post-ban period

The mean number of sheep killed annually by bears increased 64% (CI = 10–150%) in the post-ban period (from 245 to 400; Table 1). However, from the pre- to the post-ban period there was a 41% (30–60%) increase in the overall sheep population and a 16% (10–30%) increase in the bear population. When considering these 2 factors, and using ratios instead of absolute numbers (proportion of killed sheep, sheep killed per bear, sheep killed/ total bears x total sheep), there were no differences in level of sheep depredation between the pre- and post-ban periods (Table 1).

Variation in the number of sheep killed by bears was best explained by the model that included only the interaction total bears x total sheep (Table 2). The second best model (and the only one with ΔAIC_c <2) also included the variable period, which was considerably less important (beta in weighted average model = 0.812 for total bears x total sheep and 0.016 for period).

Percentage of sheep depredations generally increased from January through September–October then decreased through December (Fig. 2), but differed between pre- and post-ban periods (exact homogeneity test; χ^2 = 47.4, 11 df, $P < 0.05$). In the post-ban period there was a relative increase in depredations from November to April and a corresponding decrease in other months of the year. Sum of differences between pre- and post-ban distributions for November to April was 13.2%.

Discussion

Feeding with carrion is used in several European countries for eco-tourism, hunting, and conflict mitigation (Dečak et al. 2005, Kojola and Heikkinen 2012). Although feeding with carrion from domestic animals is currently not practiced in Slovenia, there are repeated requests to re-introduce this practice. It is widely assumed that supplementary feeding with

Table 1. Comparison of depredations, sheep numbers, and brown bear numbers before (1999–2003; pre-ban) and after the ban on feeding with carrion (2005–09; post-ban) in Slovenia.

Variable	Pre-ban average (95% CI)	Post-ban average (95% CI)	Ratio post-/pre ban average (95% CI)
No. sheep killed	245 (174–347)	400 (319–500)	1.64 (1.1–2.5)
Total sheep	95,200 (83,700–104,800)	133,800 (130,300–137,400)	1.41 (1.3–1.6)
Proportion sheep killed	0.28% (0.18–0.44)	0.30% (0.24–0.38)	1.08 (0.6–1.9)
Total bears	389 (357–417)	450 (434–464)	1.16 (1.1–1.3)
Sheep killed per bear	0.65 (0.44–0.99)	0.89 (0.71–1.10)	1.36 (0.9–2.2)
Total bears x total sheep	3.74×10^9 (3.1×10^9–4.3×10^9)	6.01×10^9 (2.4×10^9–6.1×10^9)	1.61 (1.3–1.9)
Sheep killed / total bears x total sheep	7.5×10^{-6} (4.4×10^{-6}–1.3×10^{-5})	6.6×10^{-6} (5.4×10^{-6}–8.2×10^{-5})	0.89 (0.5–1.6)

carrion is more effective than feeding with corn to reduce livestock depredation (Štrumbelj 2006, Krofel and Jerina 2012). However, in our study we found little support for this assumption. Indexes in bear use between the pre- and post-ban periods suggest that carrion feeding sites were not visited by more bears than corn feeding sites. Also, after correcting for increases in sheep and bear abundance, we did not detect any functional increase in livestock depredations after the ban on carrion feeding. Furthermore, analyses of bear scats and stomach contents (Adamič 2005, Krofel et al. 2008; I. Kavčič, M. Adamič, M. Krofel, K. Jerina, and P. Kaczensky, unpublished data) showed that carrion has the greatest dietary importance to bears during February and March, when sheep are rarely outdoors and thus unavailable for bears. Carrion from feeding sites was also less important than natural protein sources, as on an annual basis insects and wild ungulates were consumed 4-times more often than livestock carrion in the pre-ban period (I. Kavčič, M. Adamič, M. Krofel, K. Jerina, and P. Kaczensky, unpublished data).

The only potential support for the effectiveness of carrion feeding to reduce sheep depredations by brown bears is in the slightly greater depredation levels observed in spring and winter (Nov to Apr) in the post-ban period, corresponding to the time of year when bears were most frequently feeding on carrion (Adamič 2005; I. Kavčič, M. Adamič, M. Krofel, K. Jerina, and P. Kaczensky, unpublished data). However, the differences were small (about 58 sheep killed annually at current level of depredations or 13% of all depredations) and could be explained also by changes in sheep husbandry. After Slovenia joined the EU in 2004 and adopted their Common Agriculture Policy, farmers tended to extend the outdoor grazing period (M. Vidrih, University of Ljubljana, Biotechnical faculty, Department of Agriculture, personal communication, 2012), thus also increasing availability of sheep to predation in spring and winter.

Although we did not test effectiveness of supplemental feeding in general (i.e., any feeding irrespective of the type of food provided), there are indications that this is not an effective measure to prevent depredations. For example, supplemental feeding sites in the forest do not appear to attract bears to the degree that bears would stop searching for anthropogenic food sources such as sheep. In our study area, several radiocollared bears visited feeding sites and human settlements or pastures during the same night (Jerina et al. 2012). In spite of high abundance of food placed at feeding sites, the number of livestock depredations in Slovenia is still relatively high (Krofel and Jerina 2012). At the same

Table 2. Parameter estimates for the best generalized linear models ($\Delta AIC_c < 2$) and weighted average model explaining annual number of sheep killed by brown bears in Slovenia during 1999–2009; ω_i = model Akaike's weights.

Model	Variable	Estimate	ß	ω_i
1	total bears x total sheep	1.05×10^{-5}	0.828	0.73
2	total bears x total sheep	9.75×10^{-6}	0.770	0.27
	period (post-ban versus pre-ban)	15.8	0.061	
Weighted average	total bears x total sheep	1.03×10^{-5}	0.812	
	period (post-ban versus pre-ban)	4.27	0.016	

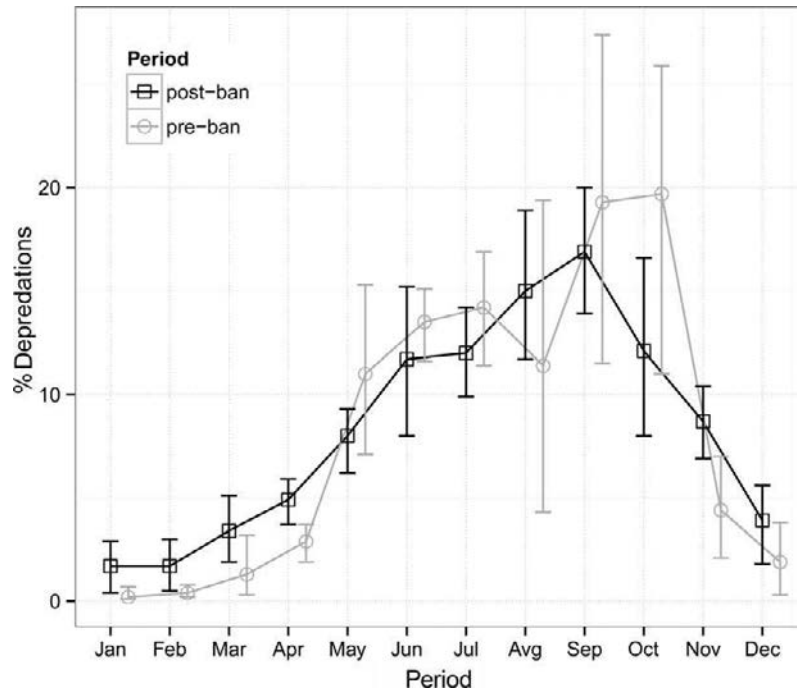

Fig. 2. Percent monthly sheep depredations by brown bears before (1999–2003; pre-ban) and after (2005–2009; post-ban) the ban on feeding livestock carrion in Slovenia.

time, increased food availability may support very high bear densities and natality rates in Slovenia (Krofel et al. 2012b; Jerina et al. 2013), thus any positive effects that supplemental feeding may have on conflict rates at the individual level could be offset by increased bear densities and consequently higher absolute depredation at the large scale.

According to our findings, supplemental feeding of bears with carrion did not appear to influence rates of sheep depredations. However, allowing supplementary feeding with carrion could have far-reaching consequences for bear management. According to EU legislation, culled brown bears that had access to carrion feeding sites are banned from human consumption and need to be destroyed. This would mean that the current income from the sale of bear meat (annually about 90,000 €; Krofel and Jerina 2012) would be lost and additional costs for carcass disposal would be incurred. As a result, the value of brown bears as a game species would decrease considerably, which in turn could decrease tolerance by hunters and local inhabitants toward bears and thus jeopardize long-term conservation of this species. In addition, EU regulations would require veterinary inspections of all livestock carcasses to be placed at feeding sites. To resume pre-ban conditions, veterinary and transportation costs are estimated at about 500,000 € each year, which is greater than the entire country bear management budget. Consequently, we strongly discourage the re-introduction of the livestock carrion for bear supplemental feeding in Slovenia as a conflict mitigation measure. We rather suggest management of natural carrion by preventing excessive removal by humans of wildlife carcasses from the ecosystem. We believe that similar constraints and general ineffectiveness of livestock carrion feeding can be expected outside Slovenia and encourage other countries to fully consider the potential costs and benefits regarding use of livestock carcasses for bear feeding.

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