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Brown bear-caused human injuries and fatalities in Russia are linked to human encroachment

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habitat degradation; human–bear conflict; *Pinus sibirica*; road density; *Ursus arctos*; Russia; human–wildlife conflict; carnivores.

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Abstract

Threat to human safety is the most dramatic conflict between humans and large carnivores. Although carnivore attacks are generally rare, bears are relatively often involved. Here, we reveal an association between human encroachment into the landscape, that is, increasing road density, and brown bear-caused human casualties (injuries and fatalities) in Russia. In European Russia, the frequency of casualties correlated positively with bear population size and negatively with the presence of Siberian pine, a crucial bear food in the predenning period and a commonly gathered human resource. In Siberia, however, the number of casualties was not related to the number of bears, but it was positively associated with both road density and the presence of Siberian pine. Increasing casualties there were seemingly linked to increasing access to areas where both humans and bears concentrated simultaneously to harvest the same resource, edible pine seeds. The latter are more often collected commercially in Siberia than in European Russia. Our study shows the link between habitat degradation and human–wildlife conflict. Indeed, interacting effects of habitat change and coexistence with large carnivores deserve further attention, as we illustrate here for Russian forests; a wide boreal ecosystem where human encroachment can have severe repercussions for wildlife and ecosystem functioning at multiple spatial levels.

Introduction

Large carnivore attacks on people and livestock fuel antipathy toward apex predators (Woodroffe *et al*. 2005; Penteriani *et al*. 2016) and challenge conservation management (Dickman & Hazzah, 2016). Even though carnivore-caused attacks are very rare, compared to incidents caused by other wildlife, attacks have increased worldwide, and bears are among the carnivores that most often attack humans (Can *et al*. 2014; Bombieri *et al*. 2019). In North America and Eurasia, the frequency of attacks has been associated with increasing bear populations, bear food conditioning and human disregard of safety rules in bear country (Can *et al*. 2014; Penteriani *et al*. 2016; Støen *et al*. 2018). Environmental and landscape-related features also explain patterns of large carnivore attacks (Bombieri *et al*. 2018). Habitat destruction is one of the most serious threats to biodiversity and also fuels human–wildlife conflict. In Africa, for instance, land conversion to agriculture was positively associated with an increase in conflict, including attacks on humans (Mukeka *et al*. 2019). In turn, retaliatory killing in response to human–wildlife conflicts is an important mortality 201 factor for large carnivores (Treves & Karanth, 2003; Lennox *et al*. 2018). Food availability has also been associated with annual variation in human–carnivore conflict, such as in the Yellowstone Ecosystem, USA, where brown bears (*Ursus arctos*) move closer to human habitation and experience higher human-caused mortality during years of poor crops of whitebark pine (*Pinus albicaulis*) seeds (Mattson *et al*. 1992). Thus, carnivore attacks on humans are costly in terms of both human safety and carnivore conservation, highlighting the need for a better understanding of this issue to inform conservation and management (Penteriani *et al*. 2016; Støen *et al*. 2018; Bombieri *et al*. 2019).

Russia contains the world's largest brown bear population (Morrison *et al*. 2007; McLellan *et al*. 2017), mostly in

Asian Russia (Siberia and the Far East) (Komissarov & Gubar, 2013). However, brown bears have not been studied to the same extent in Russia as elsewhere (Ritchie *et al.* 2012; Ripple *et al.* 2014). As of 2019, just 4.3% of the published papers on brown bears worldwide (n = 4820, based on a search in ISI, the Web of Science, on 26 September 2019) originated from Russia, even though it holds ~50% of the world's population (Kudrenko *et al.* 2020). Nevertheless, Russia has one of the highest recorded number of brown bear attacks on humans worldwide and recent studies have highlighted the need of further research to understand explanatory factors and inform management (Bombieri *et al.* 2019; Kudrenko *et al.* 2020).

Forest loss and degradation, due to fire and timber harvesting, has occurred in Russia at large scales for a long time (Hansen *et al.* 2013), especially in European Russia, but permanent anthropogenic alteration of the forest in the vast Asian Russia is a relatively new phenomenon. For instance, the density of paved roads there has rocketed since 1991 (Federal State Statistics Service (FSSS), 2019) (Fig. 1), favoring human access, disturbance and forest fragmentation, with potential alteration of ecosystem services (Haddad *et al.* 2015).

In this scenario and to better understand the causes of temporal and spatial patterns of bear-caused human casualties in Russia, we hypothesized that casualties would be related to both bear factors and to human encroachment of bear habitat (Table 1). In particular, we pose that (1) casualties are positively related to brown bear population size (Penteriani *et al.* 2016; Bombieri *et al.* 2019); (2) increasing road density leads to more casualties (Penteriani *et al.* 2018); (3) casualties occur more frequently within the range of the edible seed-producing Siberian pine (*Pinus sibirica*) (Mattson *et al.* 1992), because within Siberian pine range, seeds of this species provide a crucial autumn food resource for brown bears and other taiga species (Vaisfeld & Chestin, 1993) and are harvested also by humans, causing spatial overlap for a critical, shared resource (Danilov *et al.* 2016); and (4) trends in bear incidents are influenced by changes in road density, forest cover and degraded forest area, which includes forest loss to diseases, droughts, pests, logging and fires (many of the latter being started by people) (Agency and of Geodetics and Cartography (Roscartography), 2007a; Unified Interdepartmental Information and Statistical System (EMISS), 2018a). In our study, we investigated whether there may be a link between habitat degradation and human–wildlife conflict at a large spatial and temporal scale, that is, across Russia and over two decades. Beyond our specific hypotheses and target species, disentangling links between human disturbance and wildlife is crucial to inform both conservation of multiple species and management of human activities affecting them directly and indirectly (e.g. via habitat degradation).

Materials and methods

We modeled the association between the annual number of bear-caused casualties (injuries plus fatalities) and paved road density, human population, area of degraded forest, as well as the regional presence/absence of Siberian pine separately for European Russia, Siberia and the Far East. We did not include conflicts without injury, as many/most of them go underreported. Data about casualties included a long-term dataset compiled by Russian scientists, scientific publications on human–bear conflicts in Russia and Russian media reports accessed over the Internet. We used the methods of Smith & Herrero (2018) and accepted all collected reports as true, if they included a minimum amount of information,

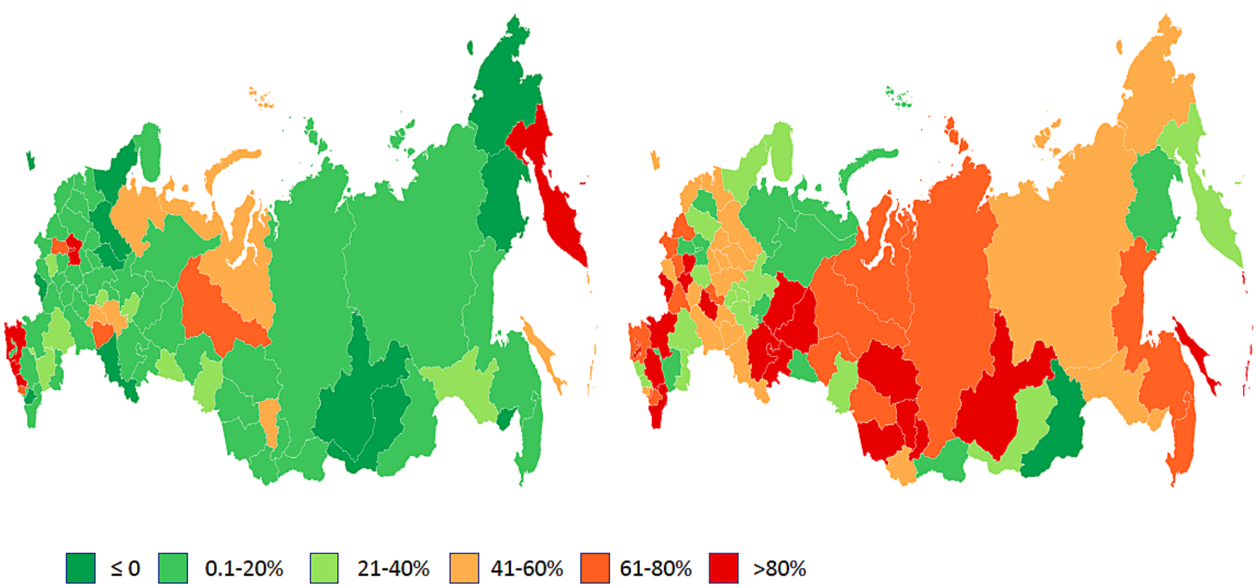

Figure 1 Changes in paved road density (km/1000 km^2) in Russian administrative units between 2001–2009 (a) and 2010-2016 (b).

Table 1 Description of variables in candidate models of bear incident occurrence in European Russia, Siberia, and the Far East during 2001-2018.

Variable	Category	Description
Bear population	Bear	Estimated annual brown bear population calculated for each geographic region (European Russia, Siberia and the Far East) based on population numbers in each administrative unit (oblast, krai, okrug) within these geographic regions
Human population	Human	Annual human population calculated for each geographic region (European Russia, Siberia and the Far East)
Siberian pine	Environmental	The presence/absence of Siberian pine stands based on the incident coordinates
Forest area degraded	Environmental	Forest area degraded because of fires or other factors (such as diseases, pests, logging) per year calculated for each geographic region based on the data for each administrative unit within these geographic regions
Forest cover	Environmental	Percentage of land covered by forests within each geographic area
Paved road density	Environmental	Average paved road density (km/1000 km^2) within each geographic region per annum based on the annual paved road densities for each administrative unit within the geographic regions

because we were not able to interview involved people or police reports, as in some studies at smaller spatial scales (Smith & Herrero, 2018; Støen *et al*. 2018).

We conducted the analysis at the regional scale. First, we collected the data for each administrative unit (oblast, krai, republic) and then categorized them into three regions (European Russia, Siberia and the Far East) based on climatic, ecological features and human footprint. For each region, we used the annual road density, bear population, area of degraded forest, human population, etc. Annual data on forest areas burned and degraded due to other causes (fires, forest diseases, droughts, pests and logging) were obtained for every administrative unit since 2000 using MODIS satellite active fire and land cover data at 230-m resolution (Bartalev *et al*. 2013, 2015, 2016). Then we calculated the cumulative degraded area within each region annually. We omitted percentage of forest area from the final models, because of their insignificant annual variation throughout our study period and because the dataset included ground-based and not satellite-based data (Unified Interdepartmental Information and Statistical System (EMISS), 2018b, 2018c). We assigned each attack to whether it occurred within or outside the Siberian pine range.

Annual brown bear population estimates were obtained for administrative units for the periods 2001–2007 (Gubar, 2007), 2008–2013 (Komissarov & Gubar, 2013) and 2014–2018 (Matveev, 2018; Table S4 in Kudrenko 2018). Bear-monitoring methods in these studies included annual surveys on established plots and oat fields, and written surveys completed by hunters. This was the official data from the state authority responsible for wildlife monitoring ('Centrokhotkontrol') and other sources that referred to local authorities responsible for the management of hunting species. We could not check the reliability of these estimates. Nevertheless, they are the only available data at the scale of administrative units, and they are likely representative of bear population trends, which were more relevant for our analyses than specific estimates in a given year. We then calculated the approximate annual bear population (by adding annual bear populations in administrative units for each region), human population and road density (density of paved roads in km/1000 km^2) for the regions. Human population and road density (density of paved roads in km/1000 km^2 within an administrative unit) for the regions were obtained using the same approach. Datasets on unpaved roads for Russia are not comprehensive and complete for the entire study period (Unified Interdepartmental Information and Statistical System (EMISS), 2020). Moreover, the presence and changes in unpaved road network might not always be included in official maps/datasets. Paved roads, however, were constructed by the state and changes in their density were available (Federal State Statistics Service (FSSS), 2019) (Fig. 1). Human population remained stable during most of the study period (Federal State Statistic Service (FSSS), 2020); we included it to check its effect on the incident occurrence.

Statistical analyses

We used generalized linear models to test whether changes in human population size, bear population size, paved road density, annual forest area degraded (a proxy of fires, forest diseases, pests and logging) and the presence/absence of Siberian pine were related to the annual number of bear-caused casualties (i.e. injuries plus fatalities) in Russia, 2001–2018. The response variable was the annual number of casualties per region (European Russia, Siberia, the Far East). Paved road density and estimated brown bear population showed continuous increases and were correlated in all three regions: $r = 0.97$ (European Russia), $r = 0.95$ (Siberia),

$r = 0.7$ (Far East) and inclusion of both variables caused multicollinearity in models for European Russia ($VIF_{bears} = 17.32$, $VIF_{roads} = 17.94$) and Siberia ($VIF_{bears} = 10.18$, $VIF_{roads} = 10.003$). Therefore, we included candidate models with both variables and separate sets of models with either bear population or road density (Table 2). We scaled the variables by dividing each numerical variable by one standard deviation (Zuur *et al*. 2007).

We selected the most parsimonious model, based on the corrected Akaike's information criteria (AICc), assuming that models with ΔAICc <2 were equivalent (Burnham & Anderson, 2002), and interpreted the importance of parameters retained in final models using 95% confidence intervals (Zuur *et al*. 2009); that is, we examined whether 95% confidence intervals overlapped 0 to determine if variables retained in top models were significant and to interpret the direction of their effects on the response variables (annual number of incidents). If it overlapped 0, the direction of a given effect on the response variable was considered unclear. We tested the models for overdispersion and corrected the best models with dispersion parameters >1 using a quasi-Poisson link function (Zuur *et al*. 2009) (Table 2, Table S2). The final interpretation of model outcomes was based on the Poisson versions (Table S1). Statistical analyses and data visualization were conducted using RStudio version 3.6.1 (R Core Team, 2019), QGIS (QGIS Development Team, 2019) and the open-source web tool (Datawrapper, 2018).

Results

In 2001–2018, brown bears injured at least 178 and killed 132 people in Russia, with most (82%) of the casualties occurring in Asian Russia ($n = 264$, $\chi^2 = 34.98$, $P < 0.001$), that is, in Siberia and Far East, compared to European Russia (Fig. 2). Most victims were gathering wild resources (22%) and hiking (17%), although bears also injured/killed people in human settlements (16%), or while working outdoors (13%), fishing (10%) and hunting (10%). Affected hunters were unequally distributed between the regions, with 69% of the cases in Siberia ($n = 32$, $\chi^2 = 18.25$, $P < 0.001$). Bear hunters were rarely injured/killed ($n = 2$ in European Russia and $n = 5$ in Asian Russia), yet this might be due to underreported cases related to this particular activity. Casualties were positively associated with the size of the brown bear population and negatively with Siberian pine presence in European Russia, where human population density is very low within the very limited range of Siberian pine and commercial seed gathering is less (Fig. 3, Table 2 and Table S1).

However, in Siberia, casualties were not related to bear numbers, but were positively associated both with road density and the presence of Siberian pine. In Siberia, every additional kilometer/1000 km^2 of road density led to an increase in the casualty occurrence of 0.69 annually (95% CI 0.45, 0.94). During 2010–2018, road density in Siberia and the Far East increased unevenly in the administrative units from less than 1 km to up to 17 km per year. In Siberia, the chance of a casualty was predicted to rise by 1.9 times (95% CI 1.36, 2.53) with the presence of Siberian pine, whereas in European Russia it was predicted to decrease by −1.61 (95% CI −2.59, −0.8). During 2010–2018, the bear population estimates in European Russia varied from 48 190 to 72 165 bears. With a bear population increase of 1000 individuals/year, the risk of a casualty was predicted to rise by 0.9 times (95% CI 0.45, 1.62). Our results were less clear in the Far East, where the annual number of attacks seemed to be related to area of degraded forest (forest burned and lost due to diseases, pests and logging) and changes in the human population size, but the 95% confidence intervals around the estimates of those variables included 0, giving no clear indication of the direction of the effect of those variables on the response (Table 2 and Table S1).

Discussion

At least 310 people were injured (57%) or killed (43%) by bears in 2001–2018 in Russia, with most casualties occurring in Asian Russia (~80%) and affecting people engaged in a variety of outdoor activities (80%). Both bear numbers and human encroachment were involved in the occurrence of casualties, but the importance of these factors varied across Russia. Bear numbers, which have significantly increased in European Russia (Komissarov & Gubar, 2013), were positively related to casualty occurrence in that part of the country. In Siberia, we found a correlation between the presence of Siberian pine, increasing road density and occurrence of casualties, even if Siberia has one the lowest road densities at a global scale (Ibisch *et al*. 2016; Wang et al. 2018).

The negative effects of road construction on habitats and wildlife conservation is a major issue globally (Ibisch *et al*. 2016; Whittington *et al*. 2019), and Russia is no exception. Increasing road density allows increased human access to remote areas and causes forest fragmentation, a critical driver of human–wildlife conflicts. For instance, attacks on humans by tigers (*Panthera tigris*) and Asian elephants (*Elephas maximus*) were strongly associated with forest fragmentation in Nepal (Acharya *et al*. 2017). Roads alter brown bear dial activity patterns (Ordiz *et al*. 2014; Whittington *et al*. 2019), spatial habitat use (Bischof *et al*. 2017) and cause attractive sinks, where bears not only find preferred foods but also suffer high mortality (Penteriani *et al*. 2018; Lamb *et al*. 2020).

The expanding network of paved roads in Russia (Fig. 1), especially during the last decade, has provided greater public access to remote areas within the Siberian pine range (Fig. 3). This increased access may have increased encounters between people and bears seeking the same resources, for example, edible seeds and berries. Seeds provide nutritious food for bears before denning (Vaisfeld & Chestin, 1993) and substantial seasonal income for locals who gather pine seeds commercially for sale and export (Danilov *et al*. 2016), resulting in more bear-inflicted injuries and deaths in Siberia. The Siberian pine range also overlaps with highly productive areas for wild berry species (Agency and of Geodetics and Cartography (Roscartography), 2007b), another essential fall food for bears that is also harvested by people (Danilov *et al*. 2016). This might further explain the high frequency of bear attacks on people gathering wild

Table 2 Results from generalized linear models (GLM) using Poisson link function explaining the annual number of people injured/killed by brown bears in European Russia, Siberia, and Far East 2001-2018. β = parameter estimates, LL=lower limit of the 95% confidence interval, UL=upper limit of the 95% confidence interval, φ= dispersion parameter. The parameters within each model whose 95% confidence interval did not include 0, i.e., the positive or negative direction of effect of those parameters on the response was clear, are highlighted in bold letters.

Model structure	β	LL	UL	AICc	Delta	Weighted AICc	φ
European Russia							
Incidents ~ forest degraded + Siberian pine + bear population + human population				84.3	0.00	0.67	1.39
(Intercept)	−0.07	−1.44	0.6				
Parameter: forest degraded	−0.23	−0.93	0.18				
Parameter: Siberian pine	−1.61	−2.59	−0.8				
Parameter: bear population	0.9	0.45	1.62				
Parameter: human population	−1.3	−4.52	0.04				
Incidents ~ forest degraded + Siberian pine + road density + human population				87.2	2.90	0.158	
(Intercept)	−0.08	−1.2	0.65				
Parameter: forest degraded	−0.23	−0.97	0.21				
Parameter: Siberian pine	−1.6	−2.59	−0.8				
Parameter: road density	0.78	0.37	1.43				
Parameter: human population	−1.01	−4.08	0.04				
Incidents ~ Siberian pine + bear population + human population				88.6	4.27	0.079	
(Intercept)	0.04	−1.23	0.64				
Parameter: Siberian pine	−1.64	−2.54	−0.89				
Parameter: bear population	0.96	0.54	1.66				
Parameter: human population	−1.08	−4.02	0.08				
Incidents ~ Siberian pine + bear population				89.1	4.75	0.062	
(Intercept)	0.35	−0.11	0.75				
Parameter: Siberian pine	−1.64	−2.53	−0.89				
Parameter: bear population	0.84	0.51	1.2				
Incidents ~ Siberian pine + road density + human population				91.9	7.59	0.015	
(Intercept)	0.19	−0.87	0.69				
Parameter: Siberian pine	−1.64	−2.54	−0.89				
Parameter: road density	0.85	0.47	1.44				
Parameter: human population	−0.82	−3.31	0.09				
Incidents ~ Siberian pine + road density				92.2	7.84	0.013	
(Intercept)	0.39	−0.06	0.78				
Parameter: Siberian pine	−1.64	−2.54	−0.89				
Parameter: road density	0.79	0.46	1.15				
Incidents ~ bear population				108.1	23.87	0.00	
(Intercept)	−0.16	−0.61	0.21				
Parameter: bear population	0.84	0.51	1.2				
Incidents ~ road density				111.2	26.87	0.00	
(Intercept)	−0.12	−0.55	0.24				
Parameter: road density	0.79	0.46	1.15				
Incidents ~ Siberian pine				113.6	29.26	0.00	
(Intercept)	0.69	0.35	1.00				
Parameter: Siberian pine	−1.64	−2.54	−0.89				
Null model				132.8	48.42	0.00	
Siberia							
Incidents ~ forest degraded + Siberian pine + road density + human population				119.7	0.00	0.796	1.32
(Intercept)	−0.43	−1.05	0.08				
Parameter: forest degraded	0.01	−0.23	0.22				
Parameter: Siberian pine	1.9	1.36	2.53				
Parameter: road density	0.69	0.45	0.94				
Parameter: human population	−0.61	−1.26	−0.48				
Incidents ~ forest degraded + Siberian pine + bear population + human population				122.6	2.90	0.187	
(Intercept)	−0.46	−1.08	0.06				
Parameter: forest degraded	0.034	−0.2	0.25				
Parameter: Siberian pine	1.9	1.36	2.53				
Parameter: bear population	0.68	0.44	0.93				
Parameter: human population	−0.41	−1.05	0.16				

Table 2 Continued.

Model structure	β	LL	UL	AICc	Delta	Weighted AICc	φ
Incidents ~ bear population + Siberian pine				128.8	9.04	0.009	
(Intercept)	−0.49	−1.08	0.02				
Parameter: bear population	1.86	1.33	2.47				
Parameter: Siberian pine	0.71	0.49	0.94				
Incidents ~ Siberian pine + bear population + human population				129.7	10.00	0.005	
(Intercept)	−0.48	−1.07	0.02				
Parameter: Siberian pine	1.86	1.33	2.47				
Parameter: bear population	0.75	0.52	0.98				
Parameter: human population	0.14	−0.07	0.4				
Incidents ~ Siberian pine + road density				132.2	12.42	0.002	
(Intercept)	−0.46	−1.05	0.04				
Parameter: Siberian pine	1.86	1.33	2.47				
Parameter: road density	0.66	0.45	0.89				
Incidents ~ Siberian pine + road density + human population				132.2	12.50	0.002	
(Intercept)	−0.47	−1.06	0.03				
Parameter: Siberian pine	1.86	1.33	2.47				
Parameter: road density	0.74	0.51	0.98				
Parameter: human population	0.17	−0.04	0.4				
Incidents ~ Siberian pine				170.7	50.95	0.00	
(Intercept)	−0.25	−0.83	0.23				
Parameter: Siberian pine	1.86	1.33	2.47				
Incidents ~ bear population				188.4	68.65	0.00	
(Intercept)	0.83	0.57	1.05				
Parameter: bear population	0.71	0.49	0.94				
Incidents ~ road density				191.8	72.03	0.00	
(Intercept)	0.85	0.6	1.07				
Parameter: road density	0.66	0.45	0.89				
Far East							
Incidents ~ forest degraded + human population				235.3	0.00	0.416	4.93
(Intercept)	0.73	0.41	1.01				
Parameter: forest degraded	−0.32	−0.56	−0.1				
Parameter: human population	−1.14	−1.75	−0.59				
Incidents ~ forest degraded + road density + human population				235.5	0.21	0.374	
(Intercept)	0.88	0.52	1.2				
Parameter: forest degraded	−0.27	−0.52	−0.04				
Parameter: road density	0.26	−0.07	0.61				
Parameter: human population	−0.53	−1.51	0.38				
Incidents ~ forest degraded + bear population + road density + human population				236.7	1.37	0.210	
(Intercept)	0.77	0.37	1.13				
Parameter: forest degraded	−0.28	−0.54	−0.05				
Parameter: bear population	−0.21	0.54	0.12				
Parameter: road density	0.27	−0.06	0.6				
Parameter: human population	−0.92	−2.01	0.17				
Incidents ~ forest degraded				250.6	15.35	0.00	
(Intercept)	1.07	0.86	1.27				
Parameter: forest degraded	−0.32	−0.56	−0.10				
Incidents ~ road density				254.7	19.40	0.00	
(Intercept)	1.05	0.54	1.47				
Parameter: road density	0.46	0.05	0.9				
Incidents ~ bear population				269.5	34.17	0.00	
(Intercept)	1.11	0.59	1.54				
Parameter: bear population	0.3	−0.16	0.79				
Null model				276.8	41.54	0.00	
Incidents ~ human population				279.0	43.74	0.00	
(Intercept)	1.15	0.96	1.33				
Parameter: human population	−0.02	−0.23	0.15				

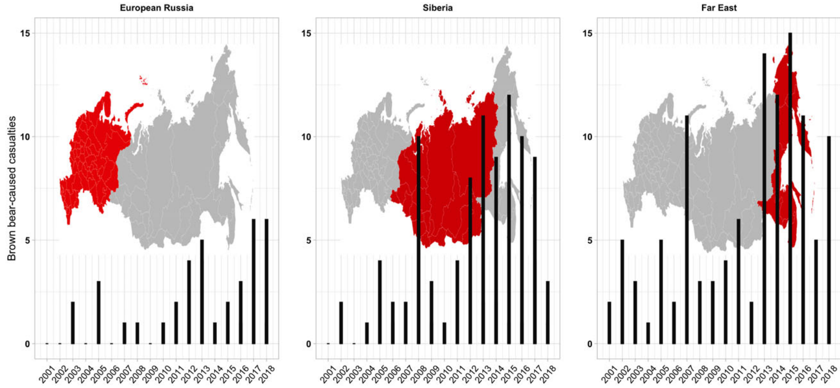

Figure 2 Spatial distribution of brown bear attacks on people during 2001–2018 in Russia, divided into three main geographical regions – European Russia [4 350 626 km^2; brown bear population ~ 72 165 (2018)], Siberia [9 917 620 km^2; brown bear population ~ 91 700 (2018)], and the Far East [3 112 700 km^2; brown bear population ~ 63 000 (2018)].

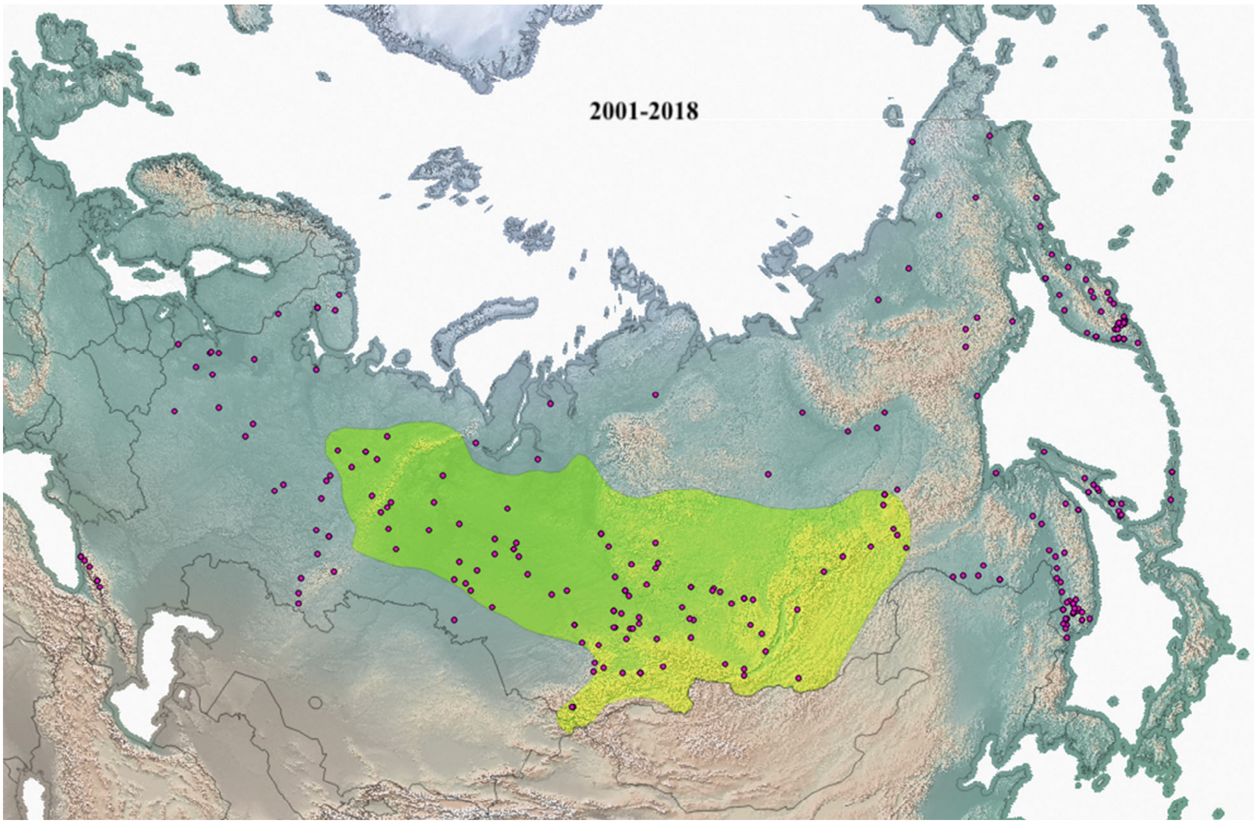

Figure 3 Spatial distribution of brown bear attacks during 2001-2018 within (yellow-green color) and outside the Siberian pine (*Pinus sibirica*) range in Russia (Malyshev et al. 2008).

resources in 2001–2018, whereas in earlier decades, hunting and professional outdoor activities had been the most common activities related to casualties (Kudrenko *et al*. 2020). The apparent link between the number and location of casualties and road density highlights the importance for wildlife managers to reduce human access into areas with resources for both bears and humans, when possible, by closing or removing appropriate unpaved roads. Managers should also consider promoting the use of bear deterrent spray, which has proved to be effective in North America (Smith *et al*. 2008), and to initiate public education campaigns on carnivore behavior. For instance, guidelines for human behavior in bear country should recommend not entering the forest alone (Penteriani *et al*. 2016), avoiding dense vegetation (Ordiz *et al*. 2013) and keeping dogs on a leash (Penteriani *et al*. 2016; Støen *et al*. 2018). These preventive actions should increase the safety of humans exploiting Siberian pine seeds and conducting other outdoor activities, thus favoring carnivore conservation.

Bears inhabiting human-dominated landscapes display multiple behavioral responses and adaptations (Morales-González *et al*. 2020). For instance, a variety of human activities trigger bears (and many other species) to be more nocturnal in areas with higher human encroachment than in remoter areas (Gaynor *et al*. 2018). Bears likely have learned to coexist better with people in highly humanized regions (Komissarov & Gubar, 2013; Zarzo-Arias *et al*. 2018), compared to areas with low human density, as Asian Russia. This may be a reason for the higher number of casualties in Asian Russia; at the worldwide scale, bear attacks are more frequent in areas where human density is lower and bear density higher (Bombieri *et al*. 2019), a pattern supported by our study, where many more attacks occurred in Asian Russia than in European Russia.

As pointed out earlier (Kudrenko *et al*. 2020), the limitations of our research relate to the huge study area and necessarily coarse-scale environment-, bear- and human-related variables. Nevertheless, our results demonstrated the link between human- and bear-related variables and the frequency of bear attacks thus reinforcing the findings of previous studies at local (Smith & Herrero, 2018; Støen *et al*. 2018) and worldwide (Bombieri *et al*. 2019) scales. Furthermore, our study also revealed a pervasive association between habitat degradation (with increasing road density as its proxy) and injurious encounters between large carnivores and people, reinforcing recent results for other species elsewhere (Acharya *et al*. 2017). Human transformations of landscapes, in conjunction with climate change, also a threat for bears (Can *et al*. 2014; Penteriani *et al*. 2019), precipitated the decline of brown bear populations in the past (Albrecht *et al*. 2017). Yet, the ultimate cause of carnivore decline, bears included, is human persecution (Morrison *et al*. 2007; Wolf & Ripple, 2017), which could be continuing to fuel the most dramatic form of human–wildlife conflict nowadays. During our study period (2001–2018), at least 81 bears involved in casualties were killed and 3 wounded (43% of 196 casualties with reported outcome for bears). We did not access data to test any specific hypothesis related to the trends in salmon (*Oncorhynchus* spp.) numbers in the Russian Far East. Yet, we suggest that investigating the changes in salmon numbers or annual catches of salmonids would contribute to better understanding of the role of salmonids in bear seasonal diet in the coastal Far East, as has been conducted in Japan (Shirane *et al*. 2021), and how varying salmon abundance may potentially result in more frequent conflicts with people.

In European Russia and elsewhere in Western Europe, anthropogenic deforestation and intensive hunting caused megafaunal extinctions and forest habitat loss already by the 19th century (Kaplan *et al*. 2009; Albrecht *et al*. 2017). Asian Russia, however, still contains complex large carnivore assemblages, but they are threatened by habitat degradation, for example, by poorly regulated, intensive timber extraction (Food & Agriculture Organization (FAO), 2019), and road construction (FSSS 2019). Therefore, it is crucial to mitigate the ecological influence of roads and other sources of human encroachment that, beyond causing habitat loss and fragmentation, fuel encounters with wildlife and thus potential conflict. This concern applies for the conservation of multiple species and their habitats, but may be especially urgent where extensive human development has not yet occurred.

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Conflict of interest

The authors declare no competing interests.

Data availability statement

Our dataset contains sensitive information about bear attacks on people ('human subject data') and should not be made public easily.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Results from the most parsimonious generalized linear models (GLM) using quasi-Poisson link function explaining the annual number of people injured/killed by brown bears in European Russia, Siberia, and Far East, 2001-2018. β = parameter estimates, LL = lower limit of the 95% confidence interval, UL = upper limit of the 95% confidence interval, φ = dispersion parameter.