The Future of Urban Brown Bear Management in Sapporo, Hokkaido, Japan: a Review

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Invited Review

The future of urban brown bear management in Sapporo, Hokkaido, Japan: a review

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Abstract. Recently, brown bears have moved deeper inside urban areas in Sapporo, the fifth-largest city with a population of 1.9 million in Japan. Here, I review urban large carnivore management and its human dimension and discuss how to create a model of harmonious coexistence that includes both management of human–brown bear conflict (HBC) and conservation of the lush, green environment of Sapporo. Although large carnivores that use urban landscapes can temporarily obtain an abundance of high-energy foods, they are also subject to high rates of human-derived mortality. Brown bear invasions of the city center of Sapporo are still rare and are likely caused by bear population increase and distribution expansion within the last decade. It is important to manage urban borders to reduce their attractiveness. A verdant environment and biodiversity conservation are considered to be important to urban residents in Sapporo. Urban HBC, however, is an unavoidable consequence of this style of living. Because a variety of stakeholders affected by HBC and its management live in the city, their various values should be reflected in wildlife management policy through a more collaborative, community-based decision-making model.

Key words: human dimension, human–wildlife conflicts, large carnivore, *Ursus arctos*, wildlife management.

For the first time in human history, the world's population is now dominated by populations in cities rather than in rural areas (Gehrt 2010). As the global human population increases, the patchwork of urban sprawl and modified environments will come to dominate most landscapes (Western 2001). As human development sprawls into formerly wild habitat, and as wildlife species attempt to adapt to the presence of humans, conflict between humans and wildlife has increased and has become inevitable (Adams and Lindsey 2010; Bateman and Fleming 2012). Large carnivores (LCs) are especially sensitive to human activity (Woodroffe et al. 2005a). Because their requirements often conflict with those of local people, they have been actively persecuted in most regions of the world (Woodroffe and Ginsberg 1998; Woodroffe 2000). Where LCs survive outside protected areas, intentional or accidental killing by humans frequently limits their numbers (Woodroffe and Ginsberg 1998). LCs have large home ranges; all of the secure habitats within their geographic ranges are small and can be conserved only by sharing multiple-use landscapes with local people (Woodroffe et al. 2005a). In recent decades, the numbers of LCs appearing in cities have apparently increased (Gehrt et al. 2010; Bateman and Fleming 2012; Chapron et al. 2014). This increase could be the result of efforts to conserve habitat quality and protect predators in remote or rural areas (Woodroffe et al. 2005a; Gehrt et al. 2010; Chapron et al. 2014). Likewise, urban planners' emphasis on green space may have provided opportunities for LCs to move from rural or remote sites into urban landscapes (Gehrt et al. 2010).

Life in urban environments (including both cities and suburbs) has changed peoples' attitudes and expectations toward wildlife (Adams and Lindsey 2010). Urban residents live in modified environments where they are separated from wildlife and the natural world, but they have not lost their curiosity about both, which are seen as enhancing quality of life (Adams and Lindsey 2010). Moreover, urban residents have acquired a sense of the importance of nature conservation and biodiversity maintenance from a global perspective: they are aware of their social responsibilities as global citizens. However, many

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are several generations removed from a culture of living close to the land (Adams and Lindsey 2010). They may therefore not have had direct contact with wildlife and may embrace only its positive side. However, once urban residents are faced with direct everyday interaction and conflict with urban wildlife, they may be likely to change their perspectives on wildlife and develop a variety of emotional reactions to it (Adams and Lindsey 2010; Decker et al. 2012). This shift creates a problem with respect to managing wildlife, especially in the case of LCs in urbanized landscapes: the increased diversity of values and perceptions increases the likelihood of social conflict regarding wildlife management, while at the same time making socially acceptable solutions more difficult to achieve (Patterson et al. 2003).

Urban sprawl has also been progressing in many areas of Japan as the human population increases. The Preliminary Count of Japan's 2015 Population Census revealed that, in Japan, there are 11 cities with populations of more than one million, 282 cities with populations of between 100,000 and one million (including 23 special districts in the Tokyo metropolis), and 259 cities with populations from 50,000 to 100,000. These cities account for 84% of the total population of 127,110,000 (Ministry of Internal Affairs and Communications 2016). However, Japan's population has been declining since 2015.

Because Japan is an island nation off the east coast of Asia, only two terrestrial LC species, namely brown bears (*Ursus arctos*) in Hokkaido and Asiatic black bears (*Ursus thibetanus*) in Honshu and Shikoku are distributed (Ohdachi et al. 2015). Both of Japan's wolf species—*Canis lupus hattai* in Hokkaido and *Canis lupus hodophilax* in Honshu, Shikoku, and Kyushu—have been extinct since at least the early 20th century (Ohdachi et al. 2015). Nevertheless, despite Japan's dense human population, 66.7% of the country's land is still covered with forests because of the steep mountainous topography and abundance of precipitation. These forests are inhabited by a number of wild mammals, including six large species, namely the Japanese macaque (*Macaca fuscata*), the two bear species mentioned above, the sika deer (*Cervus nippon*), the wild boar (*Sus scrofa*), and the Japanese serow (*Capricornis crispus*). Most local populations of these six species, and their distributions, have recovered in the last several decades (Biodiversity Center of Japan 2004; Japan Bear Network 2014). Human–wildlife conflict (HWC) through events such as invasion of human settlements and crop-raiding by large mammal species from these recovered populations has now become a serious problem in both urban and rural areas. Most people living in rural Japan have experienced HWC for the first time in several decades (i.e., since about the 1990s). They have therefore lost their traditional ecological knowledge of how to manage HWC (Suzuki 2008). The majority of urban residents have likely never experienced HWC until now.

Recently, the number of instances of brown bears invading not only the borders between forest habitats and urban areas of Sapporo but also the centers of urban areas has increased (Sapporo City 2012). Urban sprawl associated with human population increase and rapid economic growth peaked in the 1990s in Sapporo, where urban residents have not experienced human–brown bear conflict (HBC) for 100 years. Sapporo is an eco-friendly city that is home to 1.9 million people. The lush, green environment around the urban area is an important resource for city-dwellers (Sapporo City 2011, 2013b). Goal of Sapporo City Administration is to create a model of harmonious coexistence in Sapporo through both management of HBC and conservation of the verdant local environment and its biodiversity. Here, I review urban LC management and its human dimension, and I discuss how to meet the above-mentioned goal in Sapporo. I hope that this review will help to break down the social barriers between urban and rural residents in terms of HBC management in Hokkaido.

Development of Sapporo City

The city of Sapporo (location of city center: 43°3N, 141°20E; 18 m a.s.l., total area 1,121 km^2) is located on the southwestern Ishikari Plain facing the Sea of Japan. This area is mountainous, and its highest summit is Mt. Yoichi at 1,488 m (Fig. 1). The mountainous land is covered mainly by mixed forests of deciduous broad-leaved trees such as *Quercus crispula*, *Acer pictum*, and *Tilia japonica*, and coniferous trees such as *Abies sachalinensis* and *Picea jezoensis*. The southern part of this area is designated the Shikotsu-Toya National Park. The natural forest at the eastern border between the mountains and the urban region is designated a natural monument (Sapporo City 2013a).

The Hokkaido Development Commission was established in Sapporo in 1869 and began development thereafter. At the time, lowland forests remained in the alluvial fan of the Ishikari and Toyohira Rivers on the Ishikari Plain. Chum salmon (*Oncorhynchus keta*) and pink salmon (*O. gorbuscha*) run these rivers every year

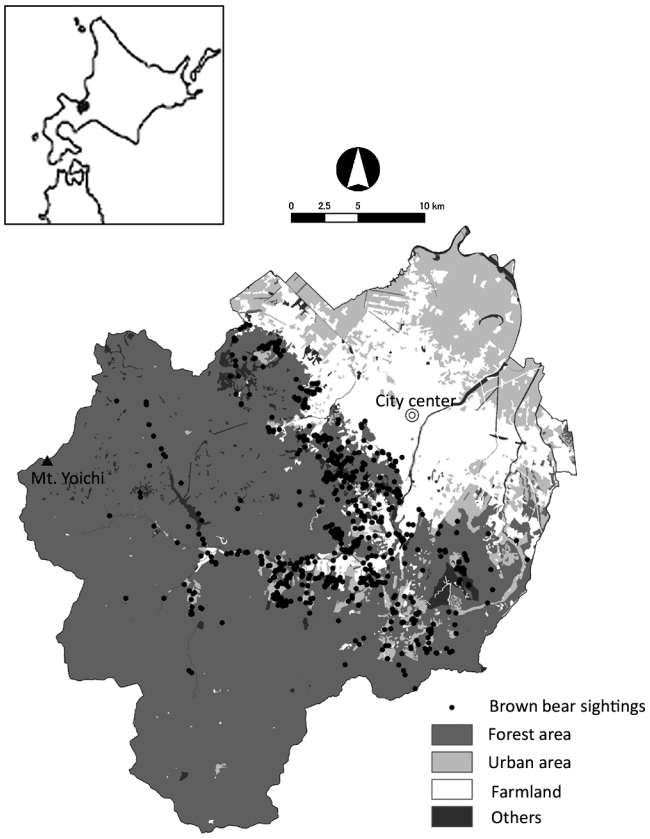

Fig. 1. Location of Sapporo City and points of brown bear sightings during 2010–2014 (Sapporo City unpublished data).

(Sapporo City 2013a). Brown bear also inhabit these lowland forests: records tell that, in the late 19th century, bear dens were located in today's center of downtown Sapporo, and bear invasions of human residences—and bear attacks—occurred in the city (Kimura 1995). As a result of development, the lowland and surrounding forests were logged, farmlands and residential areas were constructed, and the human population continued to increase (Sapporo City 2013a). During the postwar years of rapid economic growth, from the 1960s onward, socially driven population translocation occurred from rural areas to Sapporo. Moreover, development of urban areas was accelerated in relation to the 1972 Sapporo Winter Olympic Games, increasing the human population to over one million (Sapporo City 2013a). Most of the wilderness and grassland of the lowlands were thus turned into farmland. The increasing human population and its activities in Sapporo brought environmental issues such as air pollution and water contamination, and urban sprawl led to loss of the natural environment around residential areas, as occurred in other large cities in Japan (Sapporo City 2015). In the Toyohira River (the main river running through urban Sapporo), wild salmon disappeared in the 1950s (Hokkaido Sake Tomonokai 1998).

The experience of environmental issues and a decrease in wildlife populations and habitats raised public awareness of the need to solve these environmental problems and conserve wildlife. As an environmentally advanced country, Japan also developed an awareness of the need for biodiversity conservation and sustainable ecosystem management. Public awareness and political prioritization of environmental issues by the Sapporo City Administration have increased with the aim of improving quality of life and fulfilling people's global responsibilities as urban residents. Sapporo's first citizen-driven nature-protection movement—to restore salmon to the Toyohira River—was initiated in 1978 (Hokkaido Sake Tomonokai 1998). The first salmon returned to the river in 1981. In the 1990s Sapporo's residential area continued to expand, and a compact urban area that was home to 1.7 million people, with lush greenery provided by neighboring forests, was formed as a result (Sapporo City 2013a). Sapporo City Administration has promoted a policy of environmental symbiosis since the 2000s, including the declaration of "Eco Capital Sapporo" in 2008, revision of the master plan for green environment conservation and green space development in 2011, and publication of a vision for biodiversity conservation in 2013 (Sapporo City 2011, 2013a). The human population in Sapporo peaked at 1.95 million in 2015, making it the fifth-largest city in Japan, including the capital Tokyo (Statistics Bureau, Ministry of Internal Affairs and Communications 2016). The verdant environment is of high value to Sapporo's urban residents (Aikoh et al. 2008), as is the case in similar large cities in the United States (Nelson 1986). Green space, therefore, attracts both urban residents and wildlife, leading to HWC.

In the revised version of the master plan for green environment conservation and green space development, Sapporo City Administration promoted the concept of "circular greenbelts" to connect the green environment around urban areas and "green networks" to connect forests and the center of urban areas via corridors such as riparian forests along rivers and lush greenery along streets (Sapporo City 2011). Although these greenbelts and networks contribute to Sapporo's green conservation policy, they also serve as corridors for wildlife and have thus led to an increase in undesirable HWCs (Sapporo City 2012). The presence of large expanses of connected habitat in cities provides refuge that may act as resources

for animals (Bateman and Fleming 2012). The urban red fox (*Vulpes vulpes*) has become common in Sapporo since the 1990s (Uraguchi et al. 2009). This animal has invaded and colonized urban areas via the green corridors. Urban foxes might be highly interesting to the public, as it illustrates the success of green corridors in conserving biodiversity, but they can cause a variety of problems, including traffic accidents, damage to gardens, and scavenging from dustbins. They may also infect humans with rabies or alveolar echinococcosis by the tapeworm *Echinococcus multilocularis* (Uraguchi et al. 2009). The first case of alveolar echinococcosis infection in a Sapporo resident was reported in 1997 (Tsukada et al. 2000). The public health issues such as preventing risk of zoonosis associated with the presence of wildlife in cities are the focus of much research, as is the drive for extensive control measures (Bateman and Fleming 2012).

Sika deer invasion of central Sapporo from surrounding forest habitats via the corridors has also increased since the 2000s (Sapporo City 2012). The presence of sika deer in urban areas increases the risk of wildlife–vehicle accidents. Since the 2010s, brown bears have also begun to invade not only suburban farmland and orchards but also residential areas (Sapporo City 2012). LC invasion of urban areas increases the likelihood of encounters with urban residents, thus also increasing the associated risk and fear of bear attacks. Although injury to people from human–carnivore interaction is rare in both rural and urban areas, even so, the high level of media involvement when such attacks do occur may raise the perception of wildlife-associated risks, making such events the focus of management considerations in urban areas (Riley and Decker 2000; Hudenko et al. 2010). Urban HWC caused by invasion of urban areas via the corridors is thus threatening human safety and comfort in urban Sapporo.

Brown bears in Sapporo

Before the beginning of modern development in the late 19th century, brown bears inhabited the entire island of Hokkaido, including the coastlines and the lowland plains on which today's Sapporo stands (Mano and Moll 1999). With the progress of development of lowland habitats from temperate deciduous forest to farmland or residential areas, the bears were eliminated from these areas (Kaji 1982; Mano 2006). Around this time, brown bears were considered a dangerous impediment to development of the island (Mano and Moll 1999). Distribution monitoring has been performed by the Hokkaido Government, with six- to seven-year-interval questionnaire surveys, since 1978 (Hokkaido Institute of Environmental Sciences 2004). By 1991 the distribution of brown bears had shrunk to its smallest, at about 50% of the whole island of Hokkaido. The number of annual brown bear kills in Hokkaido was about 500 in the 1950s and 1970s, declining to about 200 in the late 1980s and early 1990s. The brown bear subpopulation of western Ishikari, including Sapporo, has been listed as endangered in Japan's Red Data Book since 1991 owing to its small distribution area and isolation from other subpopulations (Ministry of Environment of Japan 2002). In the 1990s, the Hokkaido Government changed its brown bear management policy from proactively decreasing the bear's numbers to coexistence of humans with bears; it also prohibited spring prophylactic control kills and the use of specific hunting methods such as box traps and leg-hold snares (Mano and Moll 1999). By the 2010s, the distribution of brown bears had expanded to cover about 60% of Hokkaido (Hokkaido Institute of Environmental Sciences 2004; Japan Bear Network 2014). The total population of brown bears in Hokkaido is also considered to have been increasing since the 1990s (Hokkaido 2015). Annual kills of brown bears increased to around 600 in the 2010s.

For the past 100 years, the bears recorded in Sapporo were only occasional migrants from core population areas located in deep forest. However, the beginning of total protection of bears in Hokkaido, and of the western Ishikari subpopulation, increased the dispersal of bears into forest habitats near urban Sapporo (Sapporo City 2012). HBCs have been recorded since the 2000s.

The reported locations of brown bear sightings in Sapporo between 2010 and 2014 are shown in Figure 1. In 2011, the first invasion of central Sapporo was observed and over the whole of Sapporo seven bears were shot for nuisance control. This was the first mass intrusion since 1989. These events resulted in the formation of a brown bear management section in the Green Conservation Promotion Department, Environmental Bureau, Sapporo City Administration, along with a revised action plan for brown bear invasion (Sapporo City 2013b). Genetic analysis with noninvasive sampling identified several tens of bears in the forests adjoining urban Sapporo during the period 2003 to 2013 (Sapporo City, unpublished data). Stable populations of female bears have been confirmed near urban areas since the 2000s. Forests adjoining urban areas have thus become brown bear habitats—not places that bears visit on rare occasions but places in which they persistently live, hibernate, and give birth.

Urban landscapes for LCs

With the spread of urban environments, many terrestrial species have withdrawn into reduced ranges; this response is particularly noticeable in mammalian carnivores (Hudenko et al. 2010; Bateman and Fleming 2012). It is, however, evident that increasing numbers of carnivores are using urban areas (Gehrt et al. 2010; Bateman and Fleming 2012). Nearly all well-established urban-dwelling carnivores are generalists that are able to make use of carrion and human waste food (Fuller et al. 2010). For carnivores, a body mass of 20 kg marks the shift in prey from small prey to large vertebrates (Carbone et al. 2007). All well-established urban-dwellers, with the exception of the occasional coyote (*Canis latrans*), are well below this mass (Iossa et al. 2010; Bateman and Fleming 2012). In addition, although they may not live permanently within cities, even LCs such as bears, wolves, and hyenas (*Crocuta crocuta* and *Hyaena hyaena*) derive substantial benefit from living adjacent to urbanized areas (Fuller et al. 2010; Bateman and Fleming 2012). Their home ranges may include some urban areas, or they may use the fringes of cities or towns for foraging, but they do not live exclusively within urban areas (Riley et al. 2010; Bateman and Fleming 2012).

Although the presence of abundant, high-energy, non-seasonal food sources in urban areas may have an important effect on the growth of carnivore species, it is intuitive that the likelihood of road accidents and infectious diseases among carnivorous species, resulting human-derived mortality of LCs increased (Bateman and Fleming 2012). In many urban areas, wild carnivores will raid human refuse from garbage dumps, vegetables from kitchen gardens, and dog or cat food that is left accessible (even though these resources may not have been left out deliberately), leading to increased nuisance culling of these species. Animals that raid human refuse for food are likely to also ingest substantial quantities of non-food refuse (e.g., plastics), which can be detrimental to their health (Sato et al. 2005; Bateman and Fleming 2012).

Some LCs have adapted to urban environments, which have demonstrated higher carrying capacities than wild habitats. In such cases, ecological changes have occurred in the species as an adaptive response to urban development (Baker and Timm 1998; Gehrt 2007). These changes are referred as "synurbanization" by Adams and Lindsey (2010). For example, American black bears (*U. americanus*) in Nevada, in the United States, showed typical differences in their ecology between urban areas and wildlands. Individual black bears in urban areas of Nevada had three times higher population densities than the historical values in non-urban areas, and sex ratios were skewed toward males at 4.25:1. Urban bears had 30% greater body mass and their home ranges were reduced by 90% for males and 70% for females. They were active for significantly fewer hours each day, shifting their activity to nocturnal periods: they entered their dens significantly later and remained in them for significantly fewer days. Urban females had greater reproductive success than their wildland conspecifics (Beckmann and Berger 2003a, 2003b). Another "synurbanization" example is that of the urban coyote in the United States. The coyote has become established in an increased number of metropolitan areas across the country, and in most of these areas it represents the largest carnivore maintaining residency near people (Gehrt 2007). In metropolitan communities, including Chicago and Los Angeles, urban coyotes have high survival rates and small home ranges. They avoid people and car traffic by shifting to night-time activity, and they tend to avoid developed areas within their home ranges. They are opportunistic predators and scavengers with a low frequency of use of human-related food, selecting more "natural" areas as denning and resting sites and having no natural predators or competitors (Gehrt 2007; Adams and Lindsey 2010). These tendencies suggest that coyotes are successful at establishing high-density resident populations close to people around metropolitan areas (Gehrt 2007). Both urban black bears and coyotes are generalists that are able to make opportunistic use of available foods.

Human actions, however, can affect black bear and coyote behavior in negative ways. In particular, the opportunistic nature of both species can cause them to take advantage of anthropogenic foods, thus altering their tendencies to avoid people (Baker and Timm 1998; Timm and Baker 2007; Beckmann and Lackey 2008). Wild animals living near the borders between wildlands and developed areas have frequent contact with humans, vehicles, and settlements, and this increases their chances of learning from these interactive experiences in both rural and urban areas (Naughton-Treves et al. 1998; Mazur and Seher 2008; Donaldson et al. 2012; Elfström et al. 2014). The inadvertent enticing of animals closer to human settlements by providing human-derived resources is likely to be the first step toward these animals becoming habituated to human presence (Bateman and Fleming 2012). In densely settled and human-altered landscapes there is a high level of potential for LCs to lose their fear

of people and become habituated to humans, or to associate them with food and thus become conditioned (Woodroffe et al. 2005a). Regular exposure of wildlife to anthropogenic food resources may not just set the stage for localized conflict—it may also foster the development of "problem" behavior such as stock-killing or crop-raiding and increase the physical risk of attacks on humans and their pets (Woodroffe et al. 2005a). Human presence affects the habituation behavior of brown bears, resulting in an increase in negative encounters with humans, including fatal accidents (North America: Mattson et al. 1987, 1992; Olson et al. 1997; Herrero et al. 2005, Europe: Rauer et al. 2003; Martin et al. 2010). Recent adaptation to urban and suburban habitats likely took place over several generations, and such adaptation may have involved learned behaviors passed from parent to offspring (Baker and Timm 1998). Baker and Timm (1998) suggested that coyote attacks are precipitated not by hunger alone, but also by a lack of aggression from humans. Media coverage of negative encounters with LCs in urban settings may amplify risk perception among stakeholders (Hudenko et al. 2010). An increase in negative encounters with humans may increase the number of human-derived LC mortalities as a response aimed at protecting the security of human residents (Naughton-Treves et al. 1998; Mazur and Seher 2008; Donaldson et al. 2012).

In some cases, synurbanized carnivores meet their caloric intake requirements more quickly than do carnivores in wildlands (Beckmann and Berger 2003a; Gehrt 2007). However, this never means that synurbanized carnivores are always realizing higher fitness than carnivores in wildlands (Beckmann and Lackey 2008). Female black bears in urban areas of Nevada have higher age-specific fecundity rates than do wildland female bears. However, despite this difference, female bears in urban areas never realize this putative gain in fitness because they experience higher age-specific mortality rates, leading to the creation of sinks (Beckmann and Lackey 2008). In other words, in urban areas, deaths exceed recruitment, meaning that urban areas are sinks for this species (Beckmann and Lackey 2008). For some carnivores, urban environments may represent refugia and possibly even sources of migrants for populations located outside the urban areas, whereas for others, urban areas and their borders with wildlands serve as population sinks in the landscape (Gehrt et al. 2010).

Moreover, maladaptive dispersal or movement from wildlands to these population sinks in the landscape likely occurs repeatedly until a crucial size of population is reached. At this size, there are attractive anthropogenic resources and conditions for individuals; the visible, high-mortality risks of these sinks are not recognized by migrant individuals, because such environments have been altered suddenly by humans and it is difficult for the animals to assess the risks of high mortality from lethal controls such as traps and poisonous foods or from traffic accidents. These landscapes are called "attractive sinks" or "evolutionary traps" (Delibes et al. 2001; Schlaepfer et al. 2002). The spatial distribution of individuals in a population is an ideal despotic distribution when there is a social hierarchy in the population, whereby dominant individuals are predicted to exploit habitats of high quality (in terms of food or security, or both) more often than do their subordinate conspecifics (Fretwell and Lucas 1969; Elfström et al. 2014). In cases where habitats in or near urban areas became attractive sinks, spatial redistribution occurs and the socially dominant individuals select these habitats on the basis of this despotic distribution. Increases in the sightings of carnivores in or near many urban settings could be the result of either local population increases and the consequent appearance of subordinate individuals or the redistribution of dominant individuals across the landscape; however, these are not the only alternatives (Beckmann and Berger 2003a). The increased prevalence of American black bears in Nevada has been viewed as an overall increase in population size by local government and by the public, without recognition of the possibility that nearby wildlands have been partially or mostly depopulated (Beckmann and Berger 2003a). In the case of brown bears, these two different possibilities could be distinguished by determining whether the increased sightings are of subordinate subadult males or females with dependent young or of dominant adult males (Sato et al. 2011; Elfström et al. 2014; Sato et al. 2014). A change in the landscape in and near an urban area to an attractive sink for carnivores would lead to an undesirable increase in HWCs, including the potential risk of attacks on humans and of increased mortality for carnivores. For both the security of urban residents and the conservation of carnivore populations near urban areas, it is important not to change the habitats in and near the urban areas such that they become attractive to carnivores.

Urban LC management

Human–LC conflicts in urban areas are usually patchily distributed. This means that conflicts over a wide area

might be reduced by dealing with problems in a few small areas (Woodroffe et al. 2005a). Comparison of areas where conflicts do and do not occur may reveal the underlying causes of the conflicts and not only point to the most effective management solutions but can also allow to predict when and where future conflicts may occur (Woodroffe et al. 2005a). The numbers of problem animals causing HWCs in urban environments are usually limited; greater numbers of animals of the same species will be living near these urban areas. An important issue in urban LC management is dealing with these problem animals, rather than dealing with overabundance (Adams and Lindsey 2010). Without appropriate management efforts, including lethal control, urban LCs would lose their fear of humans and the urban environment (Baker and Timm 1998). In cases where lethal control is needed, selective removal rather than culling is preferable (Adams and Lindsey 2010). Lethal control of problem animals in an appropriate manner not only removes the problem animals from the urban area but also scares, and thus modifies the behavior of the local population, resulting in an overall decrease in the numbers of potential problem animals (Baker and Timm 1998).

In cases where the numbers of problem animals in urban areas increase along with population expansion as a result of the redistribution of socially subordinate animals in an ideal despotic distribution manner (as referred to by Elfström et al. 2014), lethal control would be effective in preventing settling of the subordinate animals in the urban areas. In some cases, however, lethal control can increase conflict. Selective removal of carnivores tends to achieve only a temporary reduction in conflict if immigrants can rapidly fill the vacancies left after removals (Sagør et al. 1997; Treves and Naughton-Treves 2005). This is the case when habitats near human settlements become attractive-sinks (Delibes et al. 2001; Naves et al. 2003; Sato et al. 2011, 2014). Donnelly et al. (2003) showed that a badger (*Meles meles*) culling strategy that had been in place for nearly 30 years apparently increased, rather than decreased, the impacts on farmers' livelihoods in Great Britain. Rabinowitz (2005) showed that preemptive attempts to kill jaguars (*Panthera onca*) as pests in Belize in fact helped to turn non-problem jaguars into livestock predators. Sato et al. (2011, 2014) also showed that brown bear culling at a forest–farmland border in Hokkaido never decreased conflict. If "conflict" behavior is a predictable response to local conditions, then "problem" animals, once eliminated, are likely to be replaced by other animals that themselves develop the same "conflict" behavior sooner or later; this perhaps explains the short-term success of many attempts at lethal control (Woodroffe et al. 2005a). The short-lived effects of removal operations on LCs could be due to occasional or frequent removal of the wrong animals (Treves and Naughton-Treves 2005). Selective removal should be applied not in isolation but with other non-lethal management options to decrease those factors that attract animals to urban areas.

Wide-ranging carnivores are more likely to become extinct than those with smaller home ranges, irrespective of population density, and human-induced mortality contributes more to the extinction of populations of LCs isolated in small reserves than do stochastic processes (Woodroffe et al. 2005b). Lethal control of animals in restricted areas along the borders between human settlements and wildlands could affect the broader population distribution in the wildlands (Mace and Waller 1998; Frank et al. 2005). Some species such as bears, wolves, and hyenas exhibit movements that traverse the urban–rural gradient, such that policies and management applied to those species in one area may well influence those in another (Gehrt et al. 2010). Edge-related mortalities of this kind are extremely common among LCs (Woodroffe et al. 2005b). Conflict with people on borders is the major cause of mortality in LCs inhabiting wildlands; border areas are thus population sinks (Woodroffe and Ginsberg 1998). Such sinks have the greatest impact on overall population dynamics in small reserves with high perimeter-to-area ratios and in species that range widely and therefore come into frequent contact with reserve borders (Woodroffe and Ginsberg 1998). If edge mortality is high enough, it can cause species decline or even extinction. Moreover, mortality of adult males—the socially dominant class—leads not only to a direct decrease in population but also to the redistribution of individuals in the population, resulting in indirect effects on population dynamics through an increase in sexually selected infanticide and a decrease in fecundity (Young and Ruff 1982; Swenson et al. 1997; Woodroffe et al. 2005b; Gosselin et al. 2015). Management priority should be given to measures that seek to mitigate carnivore persecution on borders and in buffer zones (Woodroffe and Ginsberg 1998).

Forest habitat near urban area of Sapporo for brown bears

The increase in brown bear sightings in and near urban

areas of Sapporo (see Fig. 1) can be explained by the population increase in the western Ishikari population (Hokkaido 2015) and a subsequent expansion in distribution (Japan Bear Network 2014) through colonization process by dispersing individuals (Elfström et al. 2014). Invasions of the city center by brown bears are still rare and can be considered as temporary incursions by socially subordinate sex- or age-class individuals (i.e., subadult males and females with dependent young), not because of their attachment to resources or conditions in the city center but simply because of occasional straying (Sapporo City, unpublished data). Except in the case of suburban areas, where repetitive invasion and crop-raiding by brown bears has occurred on farmland and in orchards, urban areas are likely not yet attractive habitats for bears in Sapporo (Sapporo City, unpublished data). Sightings of dominant bears (i.e., adult males) in the forests adjoining urban areas are rare (Sapporo City, unpublished data). Bears living in the forests adjoining urban areas might have moved there because of habituation to the human presence around their habitat; these habituation likely progresses through the generations. Part of the forest environment adjoining urban Sapporo consists of primary forests designated as a natural monument; this area would be a suitable habitat for wildlife, including brown bears. Brown bears, as with other LCs, pose a threat to humans and, clearly, human tolerance is a factor limiting population viability (Iossa et al. 2010). It is important to manage the borders between urban areas and adjoining habitat so as not to make them attractive, and to have an appropriate lethal control option for selectively removing problem bears as necessary.

Coexistence with the natural environment and urban HWC: the human dimension

Urbanization has produced changes in our sociocultural landscapes along with changes in the physical landscape (Patterson et al. 2003), resulting in changes in peoples' attitudes and expectations concerning wildlife (Manfred 2008; Adams and Lindsey 2010; Decker et al. 2012). Therefore, urbanization has changed not only the ecology of wildlife adapted to urban environments but also people's attitudes toward wildlife. Urbanization has advanced in an eco-friendly manner, whereby lush, green environments, and biodiversity conservation have come to be seen as important requirements of urban residents. Increased distancing of urbanized societies from direct interaction with wildlife has led to the emergence of a culture whose meanings for wildlife are less grounded in the traditional utilitarian or instrumental orientation of rural agrarian systems (Patterson et al. 2003). As people become more urbanized, their attitudes seem to become more positive toward wildlife; of course, though, they also become more insulated from the problems of actually living with wildlife (Woodroffe et al. 2005a).

Some species, including bears, in developed countries have responded well to conservation measures and are now re-expanding their geographic ranges (Swenson et al. 1998, 2000; Hristienko and McDonald 2007; Chapron et al. 2014; Japan Bear Network 2014). Not only do these animals encounter conflicts with people as they recover; they also experience conflicts with people who have not encountered them for decades (Woodroffe et al. 2005a). HWCs in the form of zoonotic diseases, transportation hazards, risks of attack, and sanitation problems are a subset of issues related to living with wildlife for residents in urban environments (Adams and Lindsey 2010). Most urban residents like wildlife. They believe that wildlife around their homes (e.g., singing birds and running squirrels) adds to their quality of life (Adams and Lindsey 2010). However, this can quickly turn sour when animals "cross" the line from acceptable to unacceptable behavior (Adams and Lindsey 2010). It is hard to enjoy something that you do not understand (or that you even fear), and in these circumstances there is a tendency to misinterpret wildlife behavior (Adams and Lindsey 2010).

According to a questionnaire survey, 70% of the residents of Sapporo recognized the presence of damage caused by sika deer or brown bears in their city (Sapporo City 2012). Ninety percent of these people had found out about the damage from the mass media (Sapporo City 2012). The questionnaire survey also revealed that 80% of Sapporo residents thought that there was no choice but to use lethal management of repeatedly problematic bears (Sapporo City 2012). This high level of acceptance of lethal management of problem bears, however, was caused not by a high rate of brown bear intrusions into the city but by a latent fear of attacks on humans—a fear generated by negative information from the mass media. This is likely a critical problem in the case of LCs. When LCs "cross" the line in a particular area of the city, residents in that area demand lethal management, whereas urban residents far from the area are less likely to accept lethal management techniques; this pattern is similar to that of the typical conflicts between rural and urban residents. In a particular area where HWC has become a severe

problem, local people tend to have a victim mentality regarding the conflict, resulting in the convergence of demand for lethal management, even though that management may never decrease the damage (Suzuki 2008). Lethal control–oriented conflict management in urban areas, therefore, tends to lead the conflict among stakeholders for wildlife. Although people who have suffered damage from wildlife often have a complex victim mentality with regard to HWC, they tend to emphasize the negative aspects of conflict, and this in turn may lead to the convergence of demand for lethal management against the wishes of other stakeholders, resulting in a prevailing negative mentality among communities (Suzuki 2008). Urban HWC is a natural hazard for residents living in lush and green urban environments. Urban residents may need to accept that they should pay the costs of coexisting with wildlife (Woodroffe et al. 2005a; Manfred 2008).

Because coexistence of a verdant environment and biodiversity conservation are a major concern of the Sapporo City Administration (Sapporo City 2011), a proper management plan for urban HWC—especially for bears—needs to be implemented by the administration. Residents of Sapporo should also share some of the risk of conflicts. Sapporo City Administration needs to formulate an action plan for urban brown bears so as to achieve both mitigation of conflict and conservation of the bear population, including strengthening of the management implementation system; consecutive monitoring of bear behavior, major food resources, population trends, and bear-related damage; and increasing public awareness of bear ecology status, the biological consequences of HBC, and available options for appropriate management. In addition, as discussed in the following section, the human dimension of HBC needs to be monitored.

People living near bear habitats often feel a latent fear of attacks (Herrero 1985; Iossa et al. 2010; Japan Bear Network 2011). Because ensuring public safety and security is always a high priority for public administration, lethal control tends to be easily adopted as a management option for HBC in urban areas as well as in rural areas. Occasional lethal control may be a necessary component of conservation strategies. Carefully targeted lethal control may have the potential to reduce serious wildlife impacts on human lives or livelihoods—impacts that cannot be resolved in other ways. Perhaps more importantly, lethal control may help to engender public support by demonstrating managers' willingness to acknowledge the impacts that wildlife may be having on local people (Woodroffe et al. 2005a). Intensive lethal management of bears, however, is often accompanied by criticism and opposition from urban residents. As mentioned above, an important concern for lethal control in urban wildlife management is dealing with problem animals. The availability of lethal control as a management tool may also promote stakeholder acceptance of non-lethal alternatives (Woodroffe et al. 2005a).

Human dimension on wildlife management and adaptive governance

In conventional wildlife management, wildlife experts or managers usually focus on the causes and biological consequences of HWC and on the prevalence of negative impacts on human life and property and techniques of mitigating these impacts. Therefore, in formulating wildlife management policy, these experts have rarely considered the perceptions of those local residents who have suffered wildlife-related damage (Suzuki 2008). An understanding of the biology of these species is going to become more important if it is to make the best of the circumstances unfolding toward the conservation of LCs and to mitigate the potential impacts of LCs on our lives (Bateman and Fleming 2012). Understanding is, however, rarely sufficient to resolve conflicts (Woodroffe et al. 2005a; Decker et al. 2012), because there is a perception gap between wildlife professionals and local residents with regard to wildlife issues (Suzuki 2007; Miyauchi 2013). The meaning of an animal in human society is less a matter of biology than a question of culture and human perception. Because a variety of HWC management stakeholders live in cities, their varying values need to be reflected in wildlife management policy. Engagement with local people is clearly a key concept of any strategy to resolve HWC (Woodroffe et al. 2005a; Decker et al. 2012). Information from the social sciences regarding which measures are perceived by local people is required to be the most effective at resolving conflicts from the stakeholders' point of view (Woodroffe et al. 2005a). The social changes that have emerged as a consequence of urbanization demand a fundamental change in decision-making philosophies to emphasize a more collaborative and political process. This shift requires a fundamental reconsideration of the role and nature of science in decision-making processes (Patterson et al. 2003). This in turn requires fundamental changes in decision-making programs, such as the introduction of multi-criteria decision modeling to resolve HWCs, along with changes in the research approaches used to inform these decisions

(Patterson et al. 2003).

In the management of LCs that may cause conflict with local people, including latent fear of attack, whereby local populations are potentially endangered, management policy should prioritize the conservation of local wildlife populations under global conservation goals for biodiversity and sustainable ecosystems. In terms of the conservation of local populations of LCs, top-down decision-making based on scientific data and attempts to gather information from local communities are preferable so as to avoid the risk of local population extinction or habitat loss. In contrast, mitigation of the risk of potential impacts on human life is more suited to bottom-up decision-making, such as a transactional approach in which managers work with interested parties to find acceptable objectives and actions based on scientific data and management options recommended by experts (Adams and Lindsey 2010; Decker et al. 2012). A transactional approach to wildlife-damage management has recently been adopted in some local communities in Japan. One of the important aspects of HWC management, besides decreasing the total amount of damage caused by wildlife, is to mitigate the levels of consciousness suffering damage by various way of human dimension as is described below (Suzuki 2008). This includes 1) adding positive value to wildlife damage management, for example by using harvested animals efficiently or increasing the numbers of visitors to local communities where residents suffered wildlife damage; 2) re-evaluating the benefits of wildlife damage management from a local point of view; and 3) sharing perceptions and experiences of wildlife damage and its management through, for example, experience-based activities so as to prevent the development of a victim mentality in local communities (Suzuki 2008). In regard to actions 1) and 3), Enari and Maruyama (2005) introduced a wildlife damage-management activity wherein city-dwellers participated in a Japanese macaque patrol with rural residents to prevent the monkeys' intrusion into farmlands; the result was a mitigation of people's perceptions of the damage suffered to rural properties. In this case, part of the rural cost of wildlife damage management was recovered by the benefits received by the rural community in terms of money spent there by visitors from the city. Moreover, rural people shared the present status of, and their feelings about, wildlife damage with the city-dwellers through collaborative activities, which progressed to mutual understanding (Enari and Maruyama 2005). In the case of action 2), Yamanaka et al. (2008) reported that wildlife damage management by the grazing of Japanese cattle (*Bos taurus*) and other livestock at the borders between forest and farmland by local communities not only decreased the total amount of damage but also added positive effects, including increased motivation for farming, improvement of the rural landscape, emotional education for rural residents, and an increase in rural incomes. Yamabata (2010, 2011) also pointed out that local community-based wildlife-damage management inspired rural communities by decreasing damage; before this happened, residents had lost their motivation for farming. These cases illustrate the importance of local community-based wildlife-damage management, which has an additive effect beyond decreasing damage. A community-based wildlife-damage management approach would also be effective in urban wildlife management.

There is a need to trial wildlife conflict management, including science-based (top-down) population conservation and community-based (bottom-up) wildlife damage management, in a sustainable way. For the results to be commonly accepted as best practice in a social context, local communities need to interpret global conservation goals in their own way: they need to feel they have achieved these goals for their own benefit in their own social contexts (Miyauchi 2013). These approaches aim to satisfy every wildlife stakeholder, from global to local. It is therefore needed to manage the human dimension of urban HWC by taking a new approach, such as adaptive governance (Folke et al. 2005; Miyauchi 2013). Wildlife managers must now respond to two seemingly contradictory mandates. Part of the public (mainly urban-dwellers) demands that wildlife be protected from people, and part of the public (mainly agriculturists and livestock producers) demands that people be protected from wildlife (Treves and Naughton-Treves 2005). Urban wildlife professionals must constantly consider both biological and sociopolitical factors when developing management strategies (Adams and Lindsey 2010). Wildlife professionals have long joked that their job is really about managing people, and developing management solutions and communication strategies to meet the needs of all stakeholders has proven to be a challenge for both wildlife management agencies and the wildlife professionals they employ (Adams and Lindsey 2010). Bridging persons or organizations are key to meeting the need to connect all stakeholders, including individuals, organizations, government agencies, and research institutes (Folke et al. 2005). Use of a bottom-up process, including communication among all stakeholders, is desirable for decision-

making to develop urban wildlife-management plans. It is now needed that a more collaborative, community-based decision-making model in which groups composed of individuals representing the relevant stakeholders within communities of place or communities of interest (or both) are formed to make decisions by using consensus-based processes (Patterson et al. 2003). Government agencies and wildlife professionals need to understand the importance of this collaborative community-based decision-making process and to include it in action plans for urban wildlife management. The collaborative model views science as one of many forms of input and understands science as a social process; in a collaborative model, rather than the goal of science being defined as the provision of answers to a social conflict or problem, one of the chief goals of science is to map the problem (Patterson et al. 2003).

Long-term solutions for HWC will require changes in human behavior. Humans must come to view LCs as potential hazards. Increased public information, education, and awareness regarding wildlife are needed to solve wildlife issues (Gehrt 2007; Adams and Lindsey 2010). Lack of these items has been identified as important, and wildlife managers need to promote them at every available opportunity. It is important to integrate science and decision-making explicitly (Patterson et al. 2003).

Conclusion

As is the case with other LCs living near the borders between wildlands and urban areas, the brown bears of Sapporo are at high risk of human-derived mortality. These animals have the potential to habituate to human presence, and this habituation might foster the development of problem behaviors, including attacks on humans. On the other hand, the western Ishikari population of brown bears including those in Sapporo, is listed as endangered. The Sapporo City Administration needs to formulate an action plan for urban brown bears so as to both mitigate conflict and conserve the population. Because HBCs usually have a patchy distribution in urban areas owing to their association with particular problem animals, management should be focused on those problem animals. The City Administration needs to have a clear policy on adopting selective removal of problem bears as a lethal control option; it needs to strengthen the system by which it implements lethal control and to become accountable for the need for lethal management and appropriate ways of implementing it. The administration also needs to mitigate brown bear persecution on the borders by preventing these areas from becoming attractive habitat and thus discouraging the bears' presence there.

Various stakeholders in HBC and its management live in Sapporo. These people's diverse values should be reflected in urban brown bear management policy. Stakeholders in Sapporo have likely had no experience of HBC for decades. Urban residents in Sapporo share their verdant environment as an important contributor to their quality of life, and they also have an interest in biodiversity conservation. Urban HWC, however, is a natural hazard for residents living in these green urban environments. Residents in Sapporo need to also share some of the risk of conflict.

In terms of the conservation of local populations of LCs, top-down decision-making based on scientific data is preferable. On the other hand, to mitigate the risk of potential impacts on our lives, the use of bottom-up decision-making is preferable for finding acceptable objectives and actions. To implement these approaches, the Sapporo City Administration and local communities need to adopt a more collaborative, community-based decision-making model—in other words, adaptive governance.

It will be a great challenge for the 1.9 million urban residents of Sapporo, with its lush surroundings, to achieve coexistence with brown bears in the forests adjoining urban areas through appropriate local population conservation and management of HBC. Now it is needed to discuss how to establish a plan and an implementation system for the conservation and management of brown bears in Sapporo. Through these efforts, urban residents should come to understand HBC in rural areas of Hokkaido and the perceptions of rural residents; this may enable city-dwellers to share the cost of coexisting with brown bears—a cost that is currently imposed upon rural residents.

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