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Shinshu University



*Habitat Selection by Asiatic Black Bears
Inhabiting on the Periphery of
Human-Dominated Lands*

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HABITAT SELECTION BY ASIATIC BLACK BEARS INHABITING THE PERIPHERY OF HUMAN-DOMINATED LANDS

ABSTRACT:

The frequent occurrence in recent decades of Asiatic black bears (*Ursus thibetanus*) on the periphery of human-dominated lands in Japan is an instance of a worldwide increase in the observation of carnivores within or around anthropogenic landscape. While advanced studies have already investigated the effect on both people and animals of this phenomenon, the causal mechanisms have rarely been explored.

Given the high probability that the prevalent recourse to lethal control will result in serious impacts on the populations of these low reproductive animals, a long-term management scheme to reduce human-bear interactions is essential not only for the prevention of damage to property but also for the persistence of viable bear populations. Despite the fact that our knowledge of bear habitats offers considerable potential for identifying the causes underlying the frequent use of anthropogenic lands by bears, to date few studies of habitat selection have been conducted in Japan.

This study aims primarily to initiate the compilation of baseline knowledge relating to habitat selection by Asiatic black bears. On the assumption that land use changes by humans has a profound impact on the habitat of bears, I have focused on searching for the linkages between current habitat selection by bears and land use patterns by humans that might be the ultimate cause of increased human-bear interactions. Evaluations of the quality and quantity of habitat in the mountain-valley region that was the focus of this study were undertaken on the basis of predictive models for habitat distribution. The eventual goal of the study was to address large-scale and long-term issues of human responsibility in managing lands in order to reduce the frequency of human-bear conflicts.

Accurate locations of 15 females and 13 males acquired by global positioning systems (GPS) were the foundation used to estimate habitat selection by Asiatic black bears in two seasons, summer and autumn. On the basis of biologically relevant covariates generated by the

geographical information system (GIS), the relative probability of habitat selection was predicted using resource selection functions (RSF) to identify season specific habitat in relation to human land use. Interaction terms in logistic regression were employed to investigate how effects of distance from linear landscape features on bear response vary among season and landscape types, and human-bear boundaries where interaction between humans and bears was most likely to occur were delineated.

The habitat selection models clearly suggested that there was specific landscape components selected by bears during summer, the season of prevalent human-bear conflict. Asiatic black bears positively selected red pine forests, open regenerating lands, and areas nearby forest edges, forest roads and rivers in this season. The study also revealed a remarkable consistency of selection for deciduous broad-leaved forests and avoidance for coniferous plantations among seasons. Areas of high probability in the selection estimated by the RSF models showed that the distribution of summer habitat for bears was significantly skewed toward lower lands intensively used by humans, and strongly affected by linear landscape features that resulted in the secure habitat remaining for bears being noticeably confined.

The characteristics of the landscapes positively selected by bears imply that available summer food is severely restricted in marginal lands consisting of unmanaged forests near human-dominated lands and riparian forests. This indicates that human land use changes are the underlying cause of the frequent use by bears of the peripheries of human-dominated lands, and thus ultimately the cause of the increase in human-bear conflicts.

Given what is now known about the effects of human land use on bear habitat use, it is possible to propose several management strategies that might reduce human-bear interactions by restoring heterogeneous forests in remote mountains, prioritizing areas to create buffers and disseminating information about pre-avoidance measures among local communities and tourists. In view of our still limited knowledge of the habitat of Asiatic black bears, further exploration of habitat selection is crucial if we are to identify the specific human disturbances affecting the habitat of bears or other wildlife in Japan. This research has confirmed that knowledge of the causal mechanism underlying the frequent use of marginal habitat near human-dominated lands has the potential to enable the creation of more effective mitigation measures for the long-term conservation of the elusive large carnivore struggling to survive in this populous country.

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INTRODUCTION:

PREFACE

A considerable number of species in diverse groups today are at risk of reaching the end of their millions of years of evolutionary history due to the global activities of human beings, and mammalian carnivores are no exception as 76 of the 286 known species have been listed as threatened (IUCN 2014). In particular, large carnivores require extensive lands to fulfill their daily energetic needs and to search for spatially and temporally dispersed food sources, and as a result there has been an increase in the chances of their habitats overlapping with lands intensively used by humans. A negative correlation between the occupancy of large carnivores and human population density indicates that it is land domination by humans on a large scale that is mainly responsible for the disappearance of species (Woodroffe 2000). This implies that large predators are highly vulnerable to habitat contraction even though they are thought to be adaptable to landscape changes due to their mobility and learning ability.

The predatory nature of carnivore species has led to severe conflicts with humans, resulting in enormous levels of persecution. For instance, brown bears *Ursus arctos* and wolves *Canis lupus* were actively destroyed to prevent livestock predation and reduce competition for game species with hunters, particularly in the Western world. The current worldwide expansion of the human population has also led to an increase in human-carnivore conflicts in the rest of the world. In addition, poaching and fear in people have also exacerbated the threatened status of these species. Large carnivores are significantly vulnerable to frequent lethal control because of their weak population resilience. Low reproductive rates mean that their population size is slow to recover once it has been severely reduced. Therefore, the need to find ways to mitigate conflicts with humans is an inevitable challenge for those who wish to conserve carnivore populations.

Habitat contraction and conflict with humans have been described as the major causes for the population decline of large carnivores; however, the linkage between the two has rarely been investigated. Finding the causal relationship between the availability of remnant habitats and the severity of conflicts may be difficult, particularly where human land domination began a long time ago or where conflicts occur sporadically or chronically all year round. As human-carnivore

conflicts are highly seasonal, there is an opportunity to unravel the relationship by studying wildlife habitat selection in the peak conflict season in order to identify the key landscapes associated with conflicts. We may also be able to define further linkages between human land use changes and habitat selection because the features of lands selected by animals usually reflect the way in which they have been modified or managed over time by people.

There are large carnivores in Japan: brown bears in the Hokkaido island and Asiatic black bears *Ursus thibetanus* in the Honshu and Shikoku islands. Despite their body size, thousands of bears still inhabit the confined land mass of the Japanese archipelago, which is home to over 100 million people. In this study, I focused on Asiatic black bears, which have become a source of concern for local residents, governmental officials and the general public in recent decades due to their frequent occurrence in areas close to human-dominated lands, resulting in a surge in conflicts. In general, no drastic habitat destruction has taken place after the end of large-scale afforestation during the 1950-1970s. Therefore, the increased occurrence of bears near human settlements may indicate an underlying complex mechanism in relation to gradual changes in rural landscape and the quality and quantity of bear habitat. In order to explore the mechanism of the massive occurrence of bears, I studied habitat selection by Asiatic black bears, in particular, by focusing on the season when conflicts are most prevalent in order to identify the specific landscape attributes that may be the indirect causes of the selection of the periphery of human-dominated lands by bears.

In this research, I aimed to identify the linkages between habitat selection by the animals and key land use changes by humans in relation to the frequency of conflicts, and by doing so, to draw attention to the potential of habitat management as a strategy for the kind of long-term conflict mitigation urgently required for the conservation of this elusive large carnivore in Japan.

ASIATIC BLACK BEARS IN JAPAN

1. Geographical background

The Japanese archipelago, lying between the eastern end of the Eurasian continent and the western verge of the Pacific Ocean, has a high diversity of species owing to the dynamic changes in seasonal temperature and year-round humidity caused by the Asiatic Monsoon and oceanic

climate. The characteristics of the terrain amplify the diversity. The ragged montane surface, for example, has a wide range of elevation in spite of its small area (0-3776m in 378,000 km²). The islands and peninsulas vary widely in size and have been geologically isolated from the continent since the last glacial epoch (10-20 thousand years ago). The described species number over 300,000 and 40% of terrestrial mammals and vascular plants and 60% of reptiles are endemic. Of the 112 marine mammals in the world, 50 species inhabit the seas surrounding the Japan islands (the Ministry of the Environment 2008).

In 2008, the Japanese population decreased for the first time since World War II. However, the real density is much higher than is implied by the simplified figure of 340 per km² because the population is highly aggregated in the lower plains, which account for about 25% of the total land, and are where the majority of urban areas are located. During the period of rapid economic growth between the 1960s and 1990s, construction budgets increased 30-fold and residential areas increased 20 times more in averaged increase in the 1970s from averaged increase in 50 years before the 1940s. Due to the ceaseless land transformation needed to support industrialization, 8 million ha of coastal areas were reclaimed, and 40% of tidal flats, almost half of the natural coastal areas and over 60% of wetlands disappeared between 1975 and 1997. Furthermore, 17000 ha of agricultural land and forest have been converted into lands for housing annually since 1995. In the same period, the proportion of laborers working in primary industries, including agriculture, forestry and fishery, to the workforce as a whole, decreased significantly from 50% in 1945 to 5% in 2000. On the other hand, the proportion of workers over 50 years old in the primary industries increased dramatically from 20% in 1987 to 57% in 2005.(The Ministry of Environment 2007). One consequence of this rapid aging and decline in rural populations was that the percentage of abandoned farmlands increased to about 11% by 2007 (Ministry of Agriculture, Forestry and Fisheries 2012). Coincidentally, the aging of rural communities combined with the effects of a fuel usage revolution have left private- or community-owned forests unmanaged and a large part of such forests has been cleared for housing, landfill sites and golf courses. Such secondary forests, so called *Satoyama*, are commonly distributed near human settlements and form a mosaic of diverse landscapes exposed to a moderate degree of human disturbance, and have therefore been thought to offer great potential in the struggle to maintain biodiversity (Kato et al. 2009, Takeda et al. 2006).

After World War II, the remnants of native old-growth forests, consisting mainly of broad-leaved deciduous trees, were converted into coniferous plantations, which were expected to have a high economic value due to their rapid growth rate. These drastic conversions continued up

to the 1970s. Although 68% of the land is covered by forest, over 40% of these forests are artificially generated, and the Japanese public blames the vast range of unmanaged evergreen coniferous plantations for prevalence of the pollen allergy which has become a nationwide health problem. Most of what remains is secondary natural forest, whereas the ratio of intact native forests (< 20 %) has not increased since the beginning of the era of large-scale afforestation. The intensive afforestation almost ceased in the late 1970s due to the rapid decline in market demand for imported cheap timber. Nowadays, Japanese forests, whether the result of plantation or secondary growth, have reached a mature stage characterized by dense canopy cover (Yamaura et al. 2012).

2. Ecology and habitat

Distribution

On a geographical scale, the distribution of bears is negatively associated with human population densities. While bears commonly occur in relatively isolated lands in North America and Europe, bear distribution in highly populous Asian countries can reasonably be expected to substantially overlap with human-occupied lands (Mattson 1990, Fig I-1). In Sichuan Province, China, the distribution of bears corresponded to forest cover at a coarse scale (15 km² grid, Liu et al. 2009), and it has been assumed that Asiatic black bears are heavily dependent on broad-leaved forests including evergreen and deciduous oak species. Therefore, large-scale deforestation would have a great impact on the distribution of bears, although it is actually poaching for gallbladder that is primarily responsible for the absence of Asiatic black bears even in the suitable remaining habitat, particularly in China and Korea (Servheen et al. 1999).

The emigration of Asiatic black bears into the Japanese archipelago is estimated to have taken place 300-500 thousand years ago during the last glacial period when the Eurasian continent and Japanese islands were partly connected (Dobson and Kawamura 1998). Black bears probably thrived in most of the Japanese archipelago thanks to the predominance of extensive oak forests before the arrival of humankind. Nowadays, the range of Asiatic black bears in Japan is restricted to mountain areas covered by forests, while humans dominate the more productive lower and flatter areas (Oi and Yamazaki 2006).

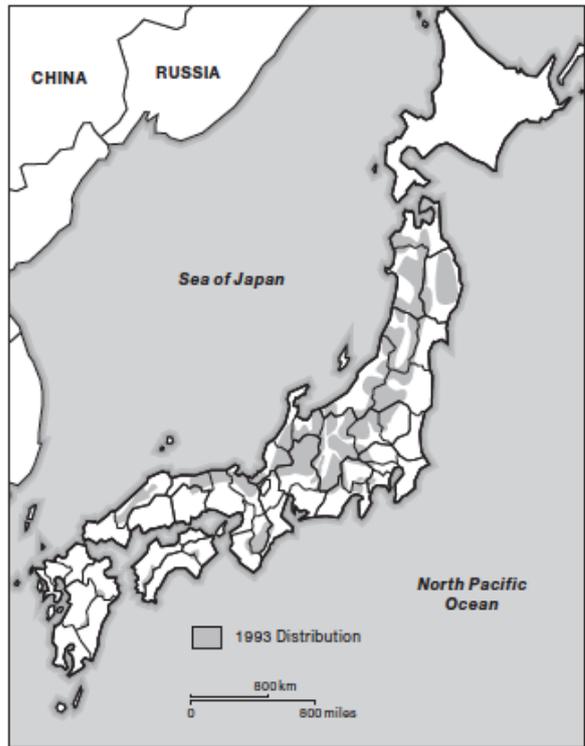
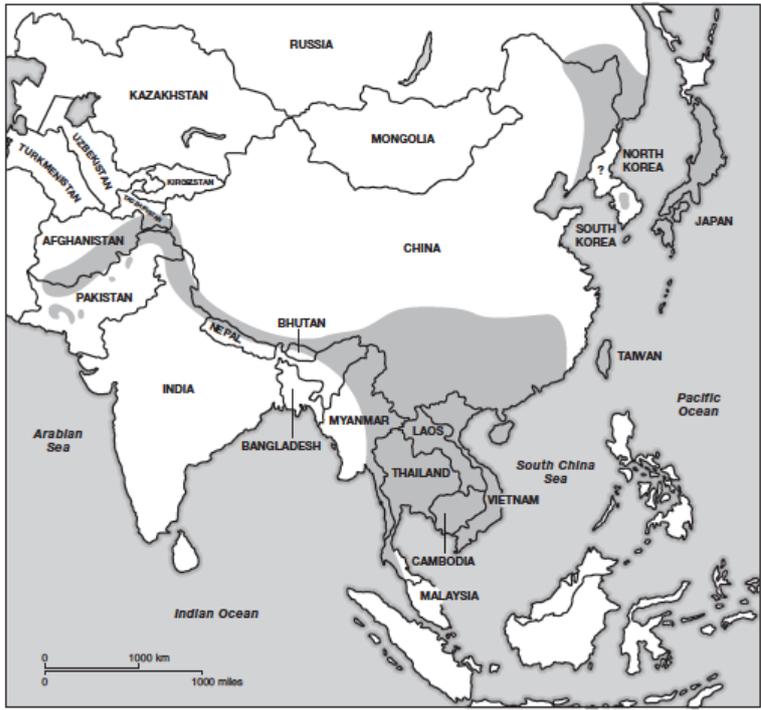


Fig. I-1
 Distribution of Asiatic black bears in
 Japan and other Asian countries.

Diet

Biological knowledge about Asiatic black bears in Japan is currently being expanded through research in two specific subjects. One is the study of food habits by intensive field surveys, and the other is the study of movement and activity patterns undertaken by utilizing recently improved tracking methods for making detailed observations of bear behavior. Knowledge of primary food is pivotal to gaining a better understanding of wildlife-environment relationships, and consequently also to an evaluation of the quality of habitat by measuring the availability of food resources for particular species.

Over 200 species, mainly plants, were found in bear feces and they were highly seasonal. The presence of fruiting species in a large part of these feces (Hashimoto 2002, Huygens et al. 2003) has provided evidence of the frugivorous nature not only of Asiatic black bears but also of sun bears (Steinmetz et al. 2011) and American black bears (Rode and Robbins 2000, Willson 1993). After den emergence, bears forage for early spring sprouts and the flowers of some deciduous broad-leaved trees (Beech *Fagus crenata*, Willow *Salix spp*) and vines (e.g. *Akebi quinata*) as well as ephemeral herbaceous plants such as Japanese sweet coltsfoot *Petasites japonicus*, and some sedge species (e.g. *Carex spp*). Remnant acorns from the previous autumn also play an important role in supporting bears in early spring. In late spring, bears were frequently found to be foraging for bamboo shoots (*Sasa spp*) (Huygens et al. 2003), and their diet gradually shifted to cherry and berry species (*Rubus crataegifolius*, Japanese Wineberry *Rubus phoenicolasius*) ripening one after another till mid-summer in July. From mid- to late summer, black bears rely on a series of soft mast produced by cherry trees (e.g. *Prunus jamasakura*, *Prunus verecunda*, *Prunus grayana*), succulent plants growing on the relatively wetter forest floor (e.g. *Aralia cordata*, *Arisaema*). Fruiting species in late summer (Japanese walnuts *Juglans mandshurica Maxim. var. sieboldiana*, giant dogwood *Swida controversa*) are also critical for bears in the transition period between summer and autumn. Another source of summer food is provided by colonial nesting insects: ants (*Formicidae spp*), termites (*Termitidae spp*), wasps (*Vespoidea spp*) and bees (*Hymenoptera spp*). For their protein intake Asiatic black bears rely on eggs, pupas and larvae, and insects account for over 50% of their diet (Fujiwara et al. 2013).

As with other groups of bears relying on fat reserves for the long fast period of hibernation, autumn is hyperphagia season for Asiatic black bears and triggers feeding on high caloric food (Hashimoto et al. 2003). The major species providing such critical nutrition are deciduous beech *Fagus crenata*, Mongolian oak *Quercus mongolica*, and other evergreen oak trees (*Quercus spp*) available from September until denning. Given the importance of nutrition in determining the

success of parturition for female bears, the abundance of such hard mast during hyperphagia has a significant impact on reproduction for bears (Tsubota et al. 2008). However, significant yearly fluctuations of mast production have occurred in many regions in Japan (Oka et al. 2004). In years of autumn crop failure, soft mast (*Vitis coignetiae*, *Actinidia arguta*), which is usually optional in a year of plentiful hard mast production, accounts for a relatively large proportion of autumn food (Hashimoto et al. 2003).

The seeds of various fruiting plants found in the feces of black bears during summer and autumn indicate an ability to detect ripening along with shifting fruiting periods (Nakajima et al. 2012). Given the considerable fluctuation of hard mast production from year to year, diverse fruiting plants must be critical as supplements or alternatives to staple food (Koike 2011). Obviously, this indicates the importance for the survival and reproductive success of Asiatic black bears of the diversity in plant communities that derives from heterogeneity in forest structure and landscape configuration.

Movement

Thanks to recent technological advances in tracking individuals by radio telemetry, several important findings about bear behavior in terms of space use have been made in recent decades in Japan. According to a study using GPS collars with built-in activity sensors, Asiatic black bears exhibited shifting activity patterns depending on the changing availability of seasonal foods (Yamazaki et al. 2008, Kozakai et al. 2011). Bears have also been observed altering their core active time from diurnal to nocturnal when using areas near human disturbance (Yamada and Kamiura et al. 2009, Mizutani et al. 2007a). These results suggest the existence of trade-off behavior whereby black bears in Japan balance costs against benefits for fitness just as black bears in North America have been found to optimize their energy budgets to obtain resources or a mate (Mitchel and Powell. 2003).

The body size range of adult Asiatic black bears is 120-145cm in length and 70-120kg in weight, and a comprehensive review (Yamazaki 2011) of home range sizes estimated by using a Minimum Convex Polygon (MCP) revealed variations among regions and sex. The yearly home ranges of adult females, for example, covered areas of between 6 km² and 200 km², while the ranges of adult males were from around 15 km² to 250 km² (Yamazaki 2011). One notable finding of recent studies has been a coincidence between the expansion of home ranges and the crop failure of hard mast in autumn, and this may imply that bears change their patterns of movement in order to adapt to food scarcity, probably by searching for alternative food in an unfamiliar area

(Yamazaki et al. 2009, Kozakai et al. 2009). These findings are supportive of previous research in North America which found that resource availability had an influence on bear movement (Hellgren et al. 2005, Garshelis and Noyce 2008, Noyce and Garshelis 2011), and have made an important contribution to our knowledge of how wildlife alter their space use in response to landscape changes.

Habitat

Several previous studies have aimed to identify the characteristics of habitat use by Asiatic black bears. However, the baseline information constituted by our knowledge of habitat requirements and habitat selection in relation both to resource availability and human influence is still limited in Asian countries, including Japan.

A relatively frequent topic in habitat studies on Asiatic black bears is that of periodic migration along elevational gradients in mountains, typical terrain in the Japanese archipelago. For instance, black bears in the Northern Japan Alps foraging for the herbaceous food abundant in alpine meadows during summer selected habitat at an altitude of over 2000m, but moved down to the mid-elevation (1000-1500m) for intensive feeding on hard mast during autumn, before ascending slightly once more for denning (Izumiyama and Shiraishi 2004). Likewise, a significant temporal coincidence between elevational movement and the fruiting phenology of Mongolian oak *Quercus mongolica* was observed. Bears moved up to higher altitude and then gradually descended along with the sequential timing of acorn ripening, which is affected by temperature changes (Arimoto et al. 2011, Nakajima et al. 2012). The mountain areas, ranging in altitude from 0 to 3776m, are vast, but these studies indicate that bear habitat is limited to a narrow belt of 1000-1700m between lowlands intensively used by humans and harsh alpine zones. Even in subtropical Taiwan, Asiatic black bears mainly occupied land < 2000m in altitude (Hwang et al. 2010).

According to existing empirical or anecdotal evidence, a key habitat for Asiatic black bears in Japan is deciduous or evergreen broad-leaved forests that provide important food for survival and reproduction year round (Hazumi 1997). Those forests potentially cover almost all land surfaces < 1500 m in elevation, but, nowadays, they are patchily distributed across areas ranging between 1000m and 1500m in altitude as secondary forests due to large-scale deforestation that has converted forests into plantations. Bears have occasionally also been observed in coniferous plantations on the periphery of human settlements, foraging for food among patchy mixed deciduous trees or understory plants (Hazumi and Maruyama 1986). Asiatic black bears in Japan

also exhibit highly seasonal changes in habitat use much like bears in other temperate zones. The seasonal migration of bears corresponds to phenology, a prominent case being the use of alpine meadow (generally above 2500m) during summer for foraging. For hibernation during November to April, bears select very remote, inaccessible and rugged terrain (Huygens et al. 2001, Koike and Hazumi 2008).

This is nearly all we know about the habitat requirements of Asiatic black bears in Japan, and our knowledge of the distribution of suitable habitats, the limitations affecting the availability of habitat in specific localities, particularly critical with respect to endangered populations, and the characteristics of habitat selection by bears in relation to anthropogenic landscape, including roads, farmlands, and urban infrastructure, is considerably limited.

3. Interaction with humans

Human-wildlife conflict is not only a current phenomenon but has been common throughout the history of Japan. For example, there were many human-made ditches constructed in areas surrounding farmlands or villages to prevent damage by intruding wild boar *Sus scrofa*. These anti-boar ditches sometimes stretched a very long distance, e.g. about 120 km² in Shodo island, implying that wildlife caused severe damage throughout the *Edo* era particularly in southern regions (Hayama 2001). During the *Meiji* era, Japan experienced a rapid introduction of Western culture and its modern social system that led to large-scale harvests of wildlife for fur or other parts of animals. During the *Meiji* and *Taisho* eras, intensive hunting was responsible for the disappearance of Japanese hare *Lepus brachyurus*, Sika deer *Cervus Nippon*, wild boar, wolves *Canis lupus hodophilax* and bears from most of their primary range (Hayama 2001).

The pressure exerted by hunting on bear populations has declined in the last few decades. The annual number of bears hunted has decreased from around 1000 in the 1970s to 500 in 2006. In contrast, the number of nuisance kills has increased dramatically since 1996 to reach over 4000 in 2006. The reduction in hunting is due to the aging and declining numbers of hunters. Nowadays, many of them work to implement lethal control measures devised to prevent bears causing damage to property or threatening the safety of local residents. Despite the heavy reliance on aging hunters, the number of bears killed per hunter has risen by a factor of more than 25 times from 0.005 in the 1970s to 0.125 in 2006 (Ministry of Environment 2010). One might conjecture from this that currently bears are being killed much more systematically and with far greater ease than before.

At the same time, distinctly biased information continues to emanate from the Japanese mass media, and its influence on perceptions of and attitudes toward bears among ordinary people cannot be negligible. Sakurai et al (2013) found that, in 2006 when there was a massive occurrence of bears in human-dominated lands, only 1% of the major newspapers reported statistical or scientific information relating to human-bear incidents. In the absence of scientific or objective information, news of human injuries and deaths caused by bears come to the public's attention in the form of sensational news reports which only serve to encourage local government officials to seek for ways to eradicate bears. The resulting lethal control measures have a considerable impact on bear populations that have yet to be accurately surveyed. Were the mass media to educate the public by providing more scientific information, this would presumably play an indirect but important role in maintaining viable populations of this large carnivore in Japan.

4. Conservation Issues

Asiatic black bears are listed in Appendix I in CITES and categorized as Vulnerable in the IUCN red list. There are two major and urgent conservation needs: 1) limiting the harvest of bears, and 2) conserving their habitats (Servheen et al. 1999). The lack of knowledge about this species' status, distribution, and requirements for survival are a cause for great concern, particularly given the probability that many small, isolated populations of bears throughout Asian countries may disappear before they have even been documented (Servheen et al. 1998)

One rough estimate for the current population size of Japanese black bears is around 8400-12600 (Japan Wildlife Research Center. 2000). Several local populations are small in size and severely confined in isolated areas. For example, the bear populations in the Kii and Shimokita peninsulas, and two patchy isolated populations in the western Chugoku region are listed as endangered (Japan Environment Agency. 1991) (Fig. I-1). In 2012, black bears in the Kyushu islands were declared extinct, and bears in the Shikoku island are estimated to number around 20 and are extremely confined in remote patches of forest. Overall, in terms of their distribution and their genetic traits, there were distinct differences between black bears in the western and eastern regions of Japan. Recent genetic studies revealed that, due to their small size and severe isolation, 5 regional populations in the west exhibited a lower genetic diversity than eastern populations whose distribution was more continuous (Ishibashi and Saitoh 2004, Onishi et al. 2007). Onishi (2011) recommends that in order to conserve endangered populations more appropriate management units should be established on the basis of genetic traits.

The major drivers for the contraction and fragmentation of bear populations are thought to be habitat loss and degradation, and the prevalence of nuisance kills (Oi and Yamazaki 2006). Despite the fact that a huge area of plantations is currently almost left unmanaged considerable numbers of bears have been removed because of damage to trees (Yamazaki 2003). Such pest control conducted without regard to regulations in regions heavily dependent on the logging industry was assumed to be one of the major causes underlying the extinction of the bear population in Kyushu island and the serious threat of a similar fate now facing the small population in Shikoku island.

The Ministry of the Environment conducted nationwide surveys to estimate the distribution of bears throughout Japan in 1978, 2004, and 2014, and reported an ongoing trend of range expansion (JBN report 2014). Although these surveys have provided opportunities for local governments to recognize the importance of wildlife monitoring, critical issues remain in the methodology. Most of the data was collected from official records or by interviewing or distributing questionnaires to local residents who lacked sufficient knowledge to be able to accurately identify wildlife. Furthermore, gathering data in this way from the fringes of human settlements is likely to produce a skewed picture which places too much emphasis on the damage caused by bears. The other inevitable problem affecting the reliability of such surveys is the lack of data relating to isolated areas, including remote mountains areas, beyond the municipal borders.

On the other hand, using a recently developed and more reliable wildlife distribution model, Doko et al (2011) found small isolated populations which had not been detected by the nationwide distribution survey with its coarser scale. This showed it was possible that there were isolated endangered populations even within the large East Honshu population that had previously been expected to remain stable or even increase. In order to connect and increase the size of isolated sub-populations by selecting areas for corridors and restoration, it is crucial to understand the habitat requirements of bears and the relationship which these requirements might have with human land use. Even though many people are alarmed by the way that habitat loss and degradation have become major threats to isolated populations (Yasukochi et al. 2009), the current state of research into the habitat of Asiatic black bears in Japan leaves much to be desired.

5. Management Issues

For the last two decades, the number of bears sighted near human settlements has increased dramatically and the prevalence of lethal control has further raised public awareness. In the same period, *the Japan Bear Network* (JBN) was established (in 1996) to promote more scientifically appropriate methods of management by connecting the various people willing to build a society of coexistence with bears. These public concerns compelled both central and local government to amend the *Wildlife Protection and Hunting Law* in response to the current situation of increased human-wildlife interactions. Conversely, there has also been pressure from some rural communities to relax regulation; as a result, there has remained a substantial degree of compromise in the law. For example, expressions of support for the conservation of wildlife notwithstanding, if complaints from local residents lead the authorities to believe that wildlife has caused property damage or human casualties, culling the animal in question is permitted whatever the species or season. Therefore, despite the existence of strict hunting regulations, the law effectively has no power to place a limit on nuisance kills. While Asian black bears have been assigned the status of being vulnerable in the Japanese Act on Conservation of Endangered Species of Wild Fauna and Flora, the Japanese wildlife code lists bears as a game species, which means there can at present be no guarantee that it will be possible to maintain viable populations. (Takahashi 2009)

To deal with these difficulties, the Ministry of Environment has developed other legal structures in the *Specified Wildlife Conservation Management Plans* (SWCMP) for the conservation of bear populations throughout Japan. Most importantly, this legislation mandated the monitoring of populations that had become a cause for concern due to the negative effects of lethal control. According to a comprehensive report on the implementation of management plans established by prefectural governments across the country (Mano et al. 2008), out of 35 prefectures in which the presence of bears has been confirmed, 11 had already developed their own SWCMP, 9 had only scheduled the establishment of plans, and 15, including prefectures with endangered populations, had no plans (Mano et al. 2008). The main targets envisaged by these plans are 1) the maintenance of viable populations and the avoidance of extinction, 2) the prevention of human casualties and 3) the mitigation of economic damage by bears. Particularly, to ensure that the size of local bear populations remains viable, local managers and experts are expected to establish an upper limit on the number of animals culled. The reports pointed out the difficulties involved in establishing authorized or standardized population monitoring methods, and recommend the establishment of larger management units across prefectural borders to monitor regional populations of the wide-ranging wildlife.

The necessity of habitat research has rarely been mentioned in the context of the SWCMP, and only 4 of the 35 local governments prepared a budget for the landscape level evaluation of bear habitat (Mano et al. 2008). In response to the urgent requirement to prevent crop damage by bears, several studies have made predictions indicating specific areas prone to human-wildlife conflict. In Yamanashi prefecture, the factors affecting the frequency of human-bear contacts were distance from forest edge and settlement, and the ratio of conifer plantation (Honda et al. 2009a). The influence of these factors did not vary during a 6-year period that included 2006, a year of massive bear occurrence. The authors pointed out that people's fears of bears might be independent of food availability, and that mono cultural conifer plantations had a negative effect on habitat use by bears in terms of human-bear encounter risk (Honda et al. 2009a). Knowledge about the habitat of Japanese macaques *Macaca fuscata* has been advanced by several studies motivated partly by an increase in crop damage caused by macaques (e.g. the average annual damage cost estimated across the country, was 16.6 billion yen during 2006-2010). Overall, the habitat selection of Japanese macaques was heavily influenced by the type, configuration and structure of forests. For example, deciduous broad-leaved forests were identified as a primary habitat for macaques offering multiple benefits such as food, cover and shelter from snow (Imaki et al. 2006), whereas conifer plantations were selected particularly in areas close to farmlands simultaneously providing cover and access to the crops on which the monkeys fed (Mochizuki and Murakami 2011a). At a broader scale, macaque populations appeared to expand in lower residential areas in warmer climates, but declined in fragmented forests in colder climates (Enari 2013). Although there are only limited studies of the similarities between bears and macaques (Oi 2013), there should be some overlap between the influence of human disturbance on the habitat selection of both species and other species including deer and wild boar (Honda et al. 2009b)

As a result of the massive numbers of bears occurring near human settlements in recent years, 4340 in 2006 and 3010 in 2010, Asiatic bears have been killed across Japan. The reasons for this unusually high frequency of use of anthropogenic lands by bears have not yet been understood. One assumption made by many researchers is that there must be some connection with the failure of hard mast crops (Oka et al. 2004, Mizutani et al. 2007). Several experts have suggested that habitat changes may be one of the reasons why bears often occupy land around villages and residential areas (Oi 2011). However, no hypothesis has yet been advanced on the basis of knowledge of habitat requirements. Nor has any quantitative research been conducted on the effects of landscape change on bear habitat selection. Without understanding the causal mechanisms underlying the frequent bear use of lands near human settlements, it might be

difficult to institute the appropriate long-term management schemes needed to solve the problem of human-bear conflicts (Oi and Yamazaki. 2007).

STUDY SITE

Terrain characteristics and the major vegetation types

This study was conducted in the central Japan Alps between the Kiso and Ina Valleys located in the southern part of Nagano prefecture (35°48'927 N, 137°49'947 E) and the area measured 1,023 km² with a mean elevation of 1,268 m (Fig. I-2).

The research area consisted of two major landscapes with distinct configurations. One is a range of rugged mountain covered by various forest types including native subalpine coniferous forest, temperate broad-leaved deciduous forest and mono-cultural plantations converted from native deciduous forests. There is a preponderance of larch *Larix leptolepis* plantations (19.1%) between the foothills and the sub-alpine zone forests at the mid-elevation zone. These plantations had once been native broadleaved deciduous forest, considered to be primary bear habitat (Table. I-1).

The other major landscape type is valley basin dominated by intensive human land use such as villages, small towns, croplands and paddy fields. The foothills in the Ina Valley are typically formed from alluvial fans with several riparian forests running across the human matrix connecting the foothills and urban areas (Fig.I-3). There extend unmanaged secondary-growth forests in the lowlands that were once coppice forests and the typical cover type is Japanese red pine *Pinus densiflora* woodlands. Almost all the land except the alpine zone has been modified and used by humans for timber production, agriculture, recreational use, and urbanization with a highly dense road network (7.74km/km², elevation<900m). In contrast, abandoned farmlands and plantation areas have expanded during the last few decades and are patchily distributed across the landscape.

Japanese macaque, Wild boar, Japanese serow *Capricornis crispus*, Sika deer,,Japanese red fox *Vulpes vulpes japonica*, Raccoon dog *Cervus Nippon*, and Eurasian badger *Meles meles* occur in the same landscape.

Bears in the study region

The population of Asiatic black bears in Nagano prefecture has been estimated to be around 1900 – 7300. The bears in the study area are designated as central Alps sub-populations and their number has been roughly estimated at about 1200. 35 bears were killed due to conflicts with local people during the study period in 2008-11 (Specified Wildlife Conservation Management Plan for Asiatic black bears. Nagano Prefecture 2011).

The yearly changes in the number of harvested bears in Nagano prefecture (Fig. I-4) indicates an increase since the early 1970s, and the ratio of hunted bears to nuisance kills has gradually decreased since the 1980s. The prominent fact is the extraordinary number of bears killed in 2006 and 2010, which was part of a nationwide trend. Fig I-5 shows the monthly shifts in the number of harvested bears, and indicates that human-bear conflicts usually peak during the summer (July to September) in addition, during the exceptional year of 2010, there were two peaks.

KEY QUESTIONS

Why do Asiatic black bears currently use areas near human-dominated lands?

The frequent occurrence of large carnivores near human-dominated lands leads to tragic consequences for both people and animals. Therefore, as an initial step towards establishing long-term management schemes for the reduction of human-bear interactions, it is necessary to understand the causal mechanisms that might explain why large carnivores such as bears frequently use areas near human settlements. One hypothesis is that an indirect cause may be the densely covered *Satoyama* forests that offered suitable conditions for bears because they functioned as a refuge (Yamazaki and Oi). *Satoyama* was once intensively managed by local communities for forest products to meet their daily needs, but subsequently abandoned after the 1950s when the use of non-renewable energy resources became widespread.

Given that bears are typical forest-dwelling wildlife, the vast areas dominated by plantations must account to some degree of the negative influence on recent distribution of suitable habitat even though large-scale forest conversion ceased 30-40 years ago. The value of identifying the relationship between land use changes and wildlife habitat is that it should broaden public awareness and lead to a recognition of the need for more effective management measures than

the current policy of short-term risk prevention. However, so far studies exploring the mechanism linking land use change and habitat have been severely limited in scope.

We have yet to ascertain whether bears positively select or avoid lands near human settlements or whether there are any specific periods of intensive use in such areas. Therefore, the first key question can only be answered by first addressing the two questions presented below. Additionally, Chapter 1 will offer a review of previous studies that explore the causes and effects of the frequent occurrence of wildlife, focusing mainly on carnivores, near human settlements in other regions of the world in order to identify factors that may be of help in seeking to understand the habitat selection of Asiatic black bears in Japan.

What kinds of habitat do Asiatic black bears select or avoid?

Even though a considerable quantity of animal tracking data has been collected in Japan, habitat surveys have seldom investigated what types of vegetation or landscape features are selected or avoided by bears. Understanding how or to what degree bears select specific areas would make a significant contribution to our knowledge not only of habitat requirements but also of dynamic animal responses to changes in the environment, whether induced by humans or nature. Because nowadays habitat selection by wildlife is never independent of human influence, studies of habitat are indispensable to any evaluation of the effects which human disturbance and land conversion have on wildlife habitat. Such studies also provide the baseline information necessary for the development of more effective habitat management in order to mitigate the problems caused by increased human-wildlife interaction. The relocation data collected by the advanced Global Positioning System (GPS) provided a detailed record of the landscape characteristics of the precise area actually used by an animal. The radio-tracked location data for the GPS-collared animals was integrated with the digital map including satellite images and a digital elevation model (DEM) on the Geographical Information System (GIS) to investigate habitat selection by Asiatic black bears.

What types of land use changes by humans currently influence habitat selection by bears?

Forestry policies and practices must inevitably have an impact on the habitat, fitness and biodiversity of forest-dwelling species. The large-scale deforestation of native broad-leaved forests and the overplanting of monoculture forests during the 1950-80s continues to affect the

habitat selection of forest-dependent birds and mammal species (Agetsuma 2007, Imaki et al. 2006, Yamaura et al. 2006), because the overplanted lands have been left unmanaged in a large portion of Japanese forests (Yamaura et al. 2012).

However, it is difficult to evaluate the effects of such past disturbance due to the considerable time lag between the disturbance and current habitat selection by long-lived animals like bears. In general, the habitat of the wide-ranging bears consists of various landscape contexts, for instance, fragmented deciduous broadleaved forests recently established within the matrix of conifer plantations, or the red pine forest at a late successional stage that dominates the foothills as a result of the cessation of *Satoyama* management. It may be possible to determine the relationship between current habitat selection by bears and human land use changes by estimating which vegetation types bears are most likely to select or avoid. In view of the fact that human-bear interactions are highly seasonal in Japan, I focused on season-specific habitat selection. It seemed reasonable to assume that habitat selected during the season which is historically that in which conflicts are most prevalent would provide the key to understanding which land use change is responsible for the current increase in human-bear conflicts.

How do bears exploit areas characterized by a trade-off between benefit and risk?

Some areas are characterized by the existence of both resources and constraints, and the way animals respond to this situation can be viewed as a trade-off. It is generally humans who are responsible for the constraints. To delineate such areas, I focused on the distance effects of linear landscape features such as roads, rivers and forest edges. Because of their webbed distribution, roads inevitably present an obstacle to wide-ranging animals and have complicated negative effects on habitat use by bears. The way bears assess the risks or benefits of lands near roads, rivers and forest edges may depend on whether the matrix is constituted by forests or human-dominated lands. The range of the effects produced by such linear landscapes is therefore critical to the evaluation of the quality of bear habitat. I analyzed the distance effects of roads, rivers and forest edges on habitat selection, and categorized those effects according to season and matrix land type to further understand the linkage between those landscapes and the probability of human-bear interactions.

How is critical habitat with a high probability of bear selection distributed?

One of benefits of habitat modeling that allows the spatial patterns of wildlife habitat distribution to be visualized as a map is that it enables the making of predictions. This makes it possible to evaluate the quality of habitat in the target region as a whole, and to prioritize specific areas for habitat conservation and management at the planning stage, which often requires reliable and spatially explicit predictions. Resource selection functions (RSF), which offer a way of utilizing precise GPS relocation data and currently available GIS data, were employed to predict the relative probability that bears would select specific environment attributes.

Using coefficients estimated by logistic regression in a used-available sampling frame, I predicted habitat maps across the entire study area that presented proportional to probability of selection by Asiatic black bears at a much finer resolution (10m) than that commonly used in distribution maps (1-5 km). On the basis of the predictive maps, the quality of habitat in the conflict prevalent season was evaluated with respect to how much secure habitat existed in areas of low human access. Furthermore, areas in which there was a high probability of human-bear interactions were estimated as boundaries between bear-habitat edges and human-dominated lands. Differences in distribution among seasons and sex were also explored.

RESEARCH OBJECTIVES

This study consists of four sections; a review of existing knowledge, two research analyses based on real data collected, and a discussion which synthesizes the results from the research and a hypothesis drawn from the review.

In order to find a plausible explanation for the frequent occurrence of bears on the periphery of human-dominated lands, I searched through the key papers from the voluminous literature published worldwide in order to remedy the deficiency in our knowledge of the habitat of Asiatic black bears. I extracted six hypotheses which included several factors causing frequent occurrence (Chap 1). The differences between the various hypotheses are described to identify what is most applicable to Asiatic black bears in Japan. The first research project, described in Chapter 2, used actual animal location and geographic data targeting the study area to estimate habitat selection by Asiatic black bears, and focused on selection during summer, the peak conflict season (Fig I-5). Habitat selections by bears were then compared between summer and autumn in the 2nd research project, presented in Chapter 3, to understand season specific

selection along the boundary zone between bear habitat and human-dominated lands. Finally, in Chapter 4, the results from the two research projects on habitat selection are interpreted by applying hypotheses presented in the review (Chap1) to determine the most plausible mechanism causing Asiatic black bears to select the periphery of human-dominated landscape in Japan.

The main objective of the study was to obtain baseline information about habitat selection by Asiatic black bears to remedy the deficiency of our knowledge of the habitat requirements of this species and to determine the extent of the remaining available habitat for bears in a landscape dominated by humans. By integrating the literature review with outcomes from the research using real data, I expected to find linkages between current habitat selection by bears and land use patterns by humans that would explain the increase in human-bear interactions. The eventual goal of this study is to maintain viable populations of Asiatic black bears by addressing large-scale and long-term concerns about human responsibility in managing lands in order to reduce the frequency of human-bear conflicts in the future.

METHODOLOGICAL FRAME

The selection of an appropriate and feasible method is one of the most difficult tasks in ecological research and is best accomplished by seeking the best match between technical advances in measurement or analysis and research questions. After noting the limitations of prior studies of bear habitat in Japan, and given the advanced state of the GPS and GIS technology now available, I decided to employ resource selection function (RSF) as a robust statistical procedure to investigate habitat selection by Asiatic black bears in relation to human land use changes.

Habitat selection; definition and basic theories

There are two main purposes in habitat studies. One focuses on identifying fundamental habitat requirements, which affect species fitness, chiefly with the aim of improving biological knowledge, and the other focuses on assessing habitat quality by evaluating the human influence at the landscape level mainly for conservation purposes.

Habitat is defined as a place providing various resources and the conditions necessary for a

species to survive (Begon et al. 1996, Morrison et al. 2006). Studying habitat for a species, therefore, means understanding species-environment relationships, which is one of the major subjects of ecology (Begon et al. 1996). With respect to mobile species, there have been studies of the dynamic interactions between individuals or populations with ecosystems, and many theoretical frameworks have been proposed. For example, researchers have explored the relationships between habitat quality and abundance (Van Horne 1983, Parker and Sutherland 1986) and the effect of social interaction on habitat use (Pierce et al. 2000). The estimation of home ranges has been the core focus of wildlife habitat studies which have sought to understand why animals use particular areas as a result of complex ecological processes such as predator-prey associations, dispersal movement, population regulation (Börger et al. 2008) and the optimization of resources across shifting seasons and years (Mitchell and Powell 2007).

The need to identify human impacts on ecosystems and resource availability for particular species has also been a crucial motivating factor in habitat study, because habitat loss is a major cause of species extinction (Pullin 2002). Predictions are often made of patterns of spatial distribution in order to determine the current status of a species about which little is known apart from the fact that it exists. It should be possible to discriminate between suitable and unsuitable lands for a target species if one can estimate spatially explicit relationships between specific environment attributes and the presence of individuals. In the case of wide-ranging animals, the relationship is commonly estimated on the basis of comparisons made between occupied and unoccupied samples collected by interviews or questionnaires. However, the positive correlations between habitat quality and species occupancy have also been questioned by several authors (Morrison et al. 2006, Austin. 2007). Models for habitat selection are similar to those for species occupancy in terms of the purpose underlying the prediction, but they differ with regard to their predictive ability. To identify suitable habitat, environment attributes are examined to determine their level of contribution to the likelihood of habitat use by animals. Using relatively precise data, habitat distribution models are usually generated at more detailed resolutions than species occupancy models.

Several modeling approaches have been developed to obtain more reliable predictions of the spatial patterns of wildlife habitat. One of the most widely used habitat models is the Habitat Suitability Index (HSI) typically employed by USDI Fish and Wildlife Services (Schamberger et al. 1982). Although more advanced habitat evaluation procedures (HEP) have subsequently been developed, the deterministic predictions that result are better suited to relatively well-studied species rather than to species, like Asiatic black bears, whose habitat requirements

are poorly understood. The majority of habitat distribution models are dependent on presence-absence data for the focal species, and the prediction is made using logistic regression to analyze the contrasts between the binomial response variables which function as multivariate predictors. Such presence-absence sampling designs are more suitable for plant species or communities than widely mobile animals for whom absence data is less reliable. To overcome these analytical problems, ecological niche factor analysis (ENFA) was developed to enable habitat modeling on the basis of presence-only samples by quantifying the marginality and specialization of the used locations by species interest in terms of multi-dimensional space (Hirzel et al. 2002).

As habitat modeling techniques continue to be developed, many of them become very useful for a wide range of applications in conservation such as, for example, spatial prioritization in habitat restoration, corridor planning, recolonization or reintroduction of endangered species, and the identification of conflict prone areas. The point is that the research aim, whether for conservation or simply to satisfy ecologists' curiosity, should be clarified in advance. The selection of an appropriate modeling method then needs to take into account the inherence of data collected and the feasibility of the method, in other words, whether it will be possible to answer the research question.

Resource Selection Functions (RSF)

The selection of any place is the result of a decision made by an individual animal for a specific purpose to maintain its fitness for survival. A place will be selected because, for example, it enables the animal to forage for food, avoid risk or just move about freely. The selected site will have various environmental attributes including abiotic conditions such as climate, terrain, and water, and biotic features such as vegetation cover and the presence of food, other individuals or predators. Hence, the study of habitat selection requires to some degree an integration of behavioral and landscape ecology.

Resource selection function (RSF) offers an excellent means of parameterizing the levels of probability determining whether a specific resource (or site) would be selected or avoided by animals. The basic methodological frame entails comparison of the environmental attributes of locations actually used by an animal and the locations that were available at the time the use took place. Among several different approaches introduced by Manley et al (2002), one procedure increasingly employed in habitat selection studies involves using logistic regression

with the binary response variables of used-available samples. The equation is

$$w(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k)$$

where $w(x)$ is proportional to the probability of selection as a function of the set of independent variables ($x_1, x_2, x_3, x_4, \dots, x_k$). There is no intercept β_0 because of the uncertainty surrounding the ratio of used to available samples since the sampling range of available sites has been determined by the researchers. Animals select a resource unit if it is available. Therefore, a used resource unit is logically always part of the available resource units. Thus, the words “proportional” or “relative” are used to qualify the probability of selection. The definition of the spatial extent of the available resources should be determined by the biology of a species and the research objectives while bearing in mind the hierarchical scale of habitat selection (Johnson 1980). Using the coefficients β_1, \dots, β_k estimated in logistic regression, the relative probability of a resource unit being selected by the animals is predicted by the following equation,

$$p(x) = \frac{w(x)}{1 + w(x)}$$

where $p(x)$ is transformed of the RSF into values between 0 and 1 to provide a simple explanation using habitat indices (Nielsen 2005). The generation of predictive maps of the relative probability of selection by a species is one of the more remarkable and influential outcomes of RSF modeling as it produces a visualized habitat distribution in the target landscape. Such predictions of habitat distribution are likely to be of considerable interest to policymakers, and for this reason it is critically important that the estimations are credible because of the influence this has on assessments of the predictive performance of the model (Boyce et al. 2002).

The reasons why RSF was used to explore the key questions

The rationale for using RSF in this research, which aimed to understand habitat selection by Asiatic black bears, was threefold; the biological inference of the data collected, the limitations of previous research and the feasibility of answering the research question.

A global positioning telemetry system (GPS) offers researchers the advantage of being able to

collect precise and frequent relocation data for an individual animal, which is particularly useful in the case of elusive and vigilant wildlife that a researcher would have struggled to observe directly. The telemetry observations are presence only data, defined as “used” units in terms of animal behavior, and a GPS is unable to acquire “unused” units. This means habitat modeling using GPS observations is suitable to used-available sampling design (Manley et al. 2002, Pearce and Boyce. 2006). According to basic RSF procedure, the available resource units are usually randomly sampled from any range established by researchers, and framing the sampling range has substantial effects on the way results are inferred from the model (Boyce et al. 2002).

As many previous biological studies have shown, bears are a group of animals with a relatively well-defined home range (Powell et al. 1997). Given that the accuracy of the delineated home ranges had increased thanks to the precision of the GPS data, it seemed biologically plausible that the used-available sampling design adopted for the RSF estimation would produce a better understanding of habitat selection by Asiatic black bears. In addition, I focused on habitat selection within home ranges at the scale of 3rd order selection as defined by Johnson (1980). Because prior knowledge about the habitat of Asiatic black bears was mainly anecdotal, reliable parameters for bear habitat estimation have been severely limited in Japan. Consequently, it has been impossible to employ HIS modeling, which generally requires plenty of prior knowledge about the habitat requirement of the target species. Conversely, with RSF such difficulties can be overcome by using a statistically flexible modeling process when we are in a position to collect GPS data and employ GIS techniques using the currently more obtainable digital geographical data.

I concentrated on conducting a quantitative study which aimed to estimate spatial patterns of habitat distribution rather than on producing a hypothesis testing approaches that investigate the process of habitat selection. Knowing what types of landscape are selected or avoided by bears is crucial if we are to gain a better understanding of the current relationship between increased conflicts with humans and habitat selection. At the center of my research question was an attempt to identify the human influence on the distribution of bear habitat, and ultimately to evaluate the quality of habitat used by Asiatic black bears. By including several landscape features in relation to human disturbance, I expected that RSF modeling would be capable of estimating the level of contribution of human-derived factors on the habitat of Asiatic black bears. Furthermore, because human-bear interaction is highly seasonal in Japan, it was thought that a comparison of habitat status among seasons by the RSF would make it possible to identify the reasons for the current increase in human-bear interactions.

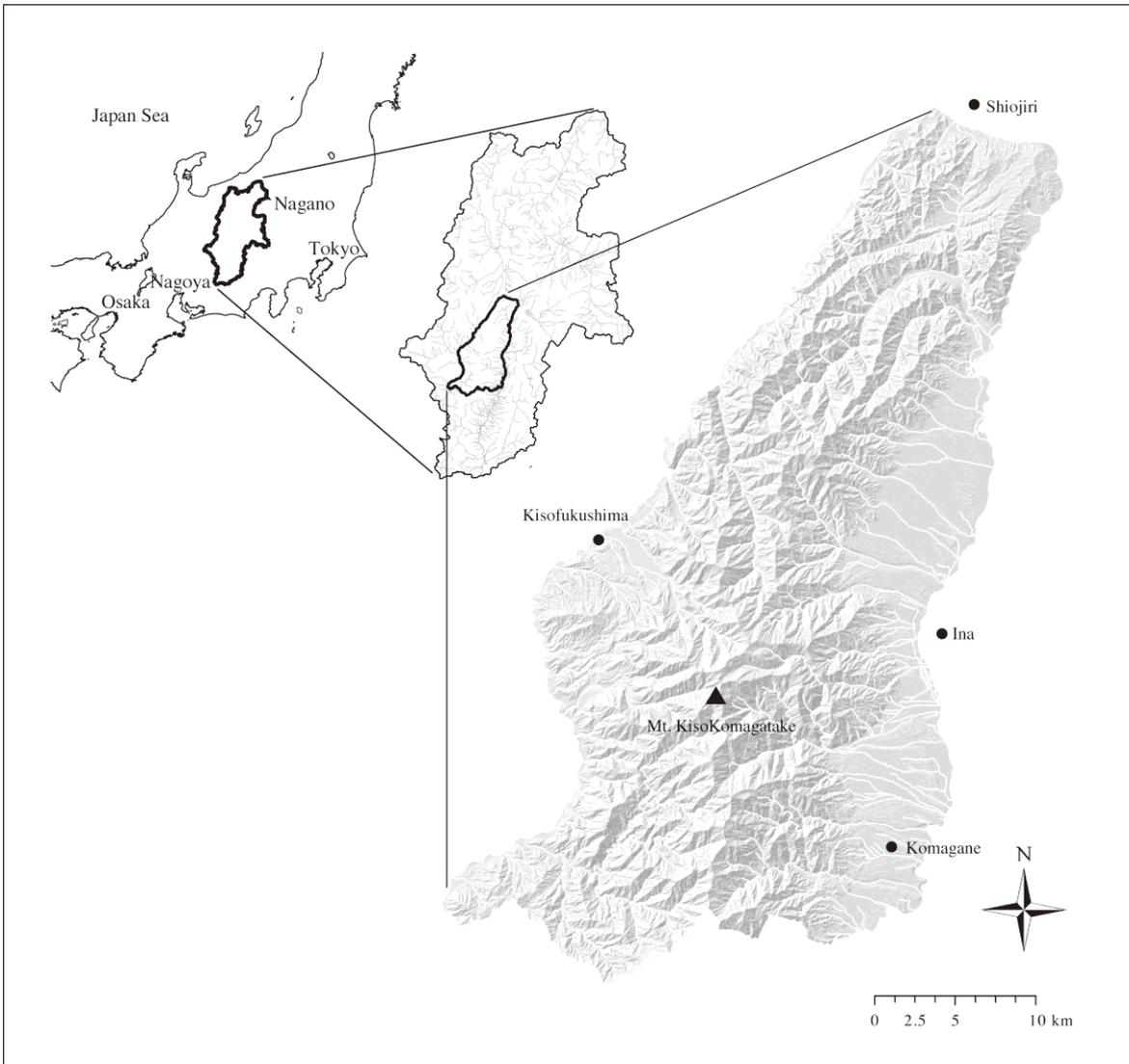


Fig. I-2.

The study area is located in the Central Japan Alps region in Honshu, Japan. The map shows the location of the main cities in the Ina and Kiso valleys and the highest mountain in the Alps.



Fig. I-3

The landscape in the Central Japan Alps region consists of high mountains, foothills, valley bottom associated with several riparian forests running through the matrix of human-dominated landscape including small villages, urban areas, crop lands, paddy fields and roads.

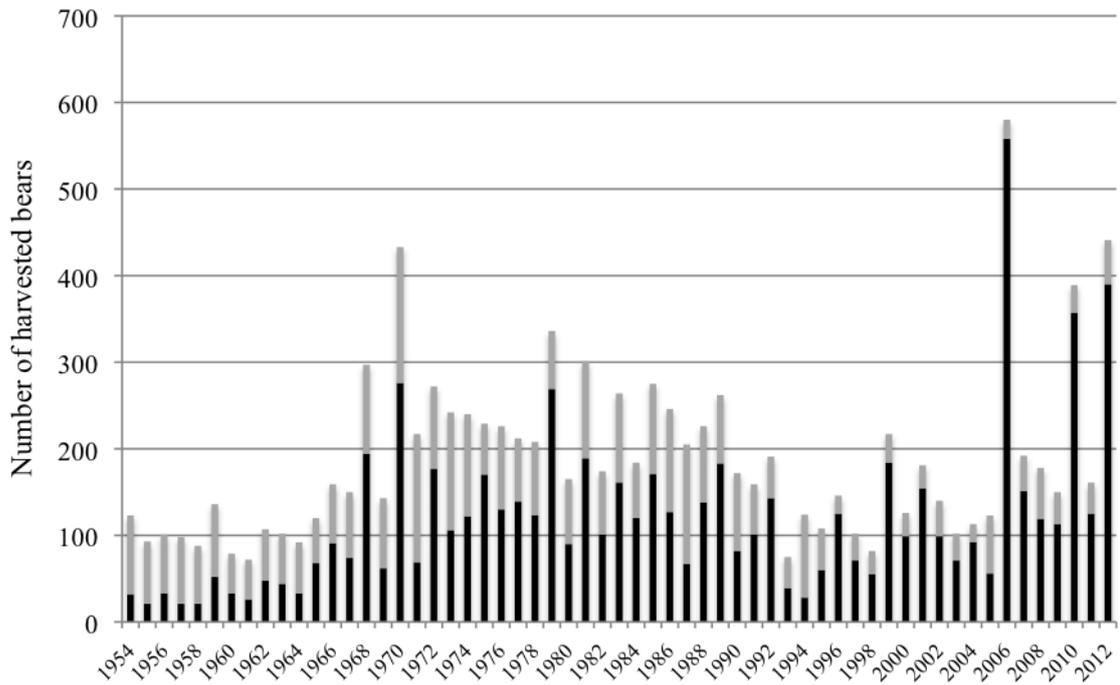


Fig. I-4

The annual number of harvested bears in Nagano prefecture. Light gray bars indicate the number of bears hunted and the black bars indicate the number of bears killed as nuisances.

(Data provision: Nagano Prefecture Office 2007)

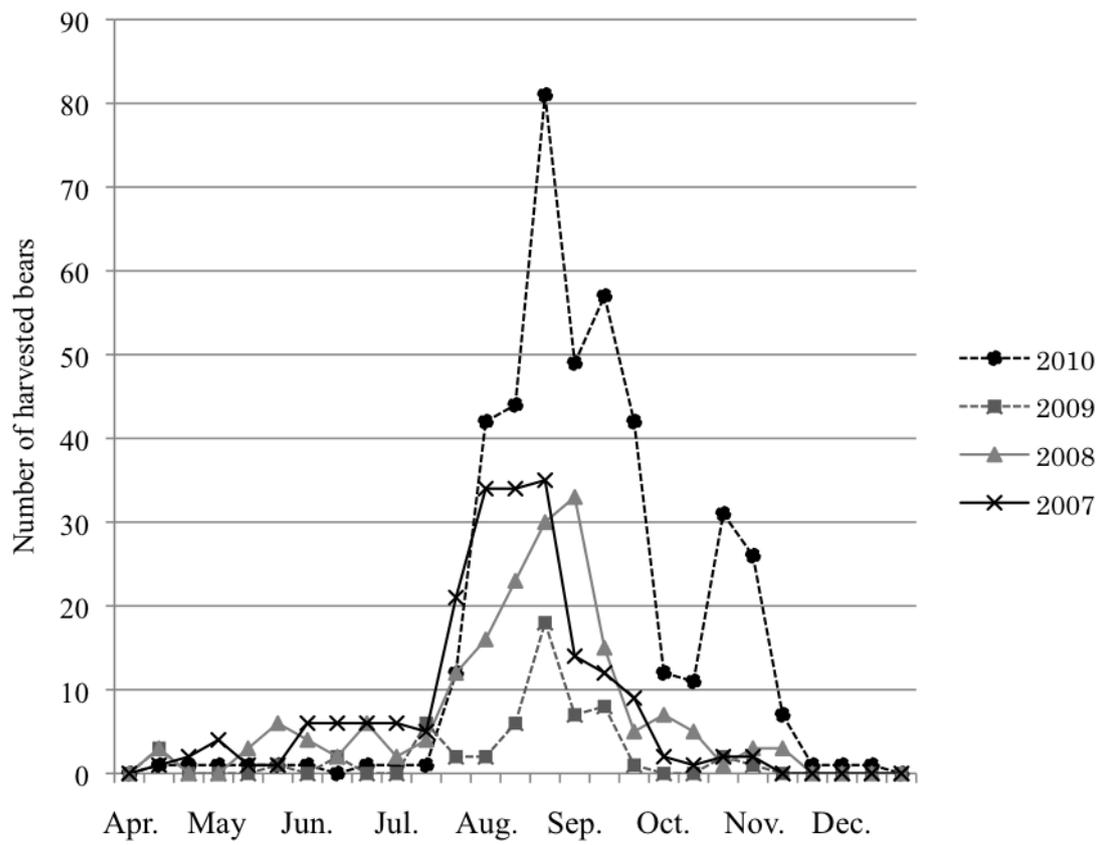


Fig. I-5

The weekly number of harvested bears in 2007-2010.

(Data provision: Nagano Prefecture Office 2007)

Table I-1.

Landscape characteristics of the target research area in the Central Alps, Japan.

Landcover	Area (km²)	Proportion (%)	Mean
Larch plantation	195.62	19.13	
Coniferous plantation	120.71	11.80	
Broadleaved forest	162.72	15.91	
Red pine forest	140.61	13.75	
Open shrubs and grasslands	31.86	3.12	
Crop/pasture lands	49.99	4.89	
Towns,villages and paddy fields	104.41	10.21	
Others	216.91	21.21	
Total size	1022.82	100.00	
Mountain area	840.76	82.2	
Forest cover area (km ²)	619.83	60.6	
Protected area (km ²)	367.77	36.0	
Road density (km/km ²)			3.51
Elevation (m)			1268.48
Slope (degree)			26.07

*Mountain area was defined as land at altitudes above 900m

CHAPTER 1

THE CAUSAL MECHANISM UNDERLYING THE USE OF THE PERIPHERY OF HUMAN-DOMINATED LANDS BY BEARS: A REVIEW

INTRODUCTION:

Land conversion has accelerated to meet increased human demands since the last century, and today, its effect on ecosystem processes and functions has extended across the globe (Ojima et al. 1994, Vitousek et al. 1997). For wide-ranging wildlife, the distribution and extent of their habitat have been severely restricted due to exclusive domination of land by humans for the purposes of the development of urban infrastructure, transportation networks, agricultural use and resource exploitation. The large carnivores we can observe today, therefore, may have already been forced either to adapt and utilize an artificially disturbed system in some way (Sunquist and Sunquist 2001) or disappeared from their primary range.

Even near urban areas, several carnivore species including red fox *Vulpes vulpes*, coyote *Canis latrans*, raccoon *Procyon lotor* and badger *Meles meles* have been increasingly observed in recent decades, and even large-bodied carnivores such as wolves and bears seem to derive some benefit from subsisting in close vicinity to areas intensively used by humans (Bateman and Fleming 2012). A number of studies have compared the demography, behavior and diets of urban settled carnivores with those of animals in remote areas. The resulting biological differences may include divergences in rates of reproduction or survival, home range, and population density, and in this context bears are a relatively well studied group of animals. Most previous studies, however, have mainly aimed to measure the effects of wildlife use in anthropogenic lands on individual fitness and population size, or to predict specific sites vulnerable to the kind of property damage that usually leads to human-wildlife conflicts. However, the causal mechanism

that explains why large carnivores like bears frequently occupy land near human settlements has rarely been investigated.

The reasons why it is important to understand this causal mechanism can be summarized under two headings: 1) the influence on public perceptions, and 2) long-term management implications. First, frequent wildlife occurrence has been subjectively perceived as an “intrusion” by animals into lands regulated for human livelihood. This “sense of being victimized” within local people has substantial effects on decision making process for policies and practices that usually aim to remove “problem animals” when scientific knowledge is either insufficient to accurately interpret the phenomenon or else is not being appropriately disseminated. To build a society willing to make the effort to coexist with wildlife, it is critical to instill a “sense of responsibility” based on a more objective understanding of the mechanisms whereby animals are affected by human activities. Second, conflict mitigation is a major issue for local managers in areas where wildlife often directly utilize resources used by humans. In general, managers tend to focus on narrow objectives in order to deal with complaints by local communities. In many cases, such short term solutions cannot prevent repeated human-wildlife conflicts (Cook et al. 2013). Such chronic conflicts may be alleviated only by long-term management actions based on a knowledge of the underlying causal mechanism of wildlife response to human-altered landscape.

For the last decade in Japan, there has been a massive presence of Asiatic black bears around villages, towns and even close to cities that has resulted in a surge in human-bear incidents and conflicts leading to unprecedentedly high mortality rates for bears. Despite the urgent need to solve this problem, scientific explanations of the causes of the frequent occurrence of bears are still limited probably due to the scarcity of knowledge about habitat selection by bears. Our perspective on this phenomenon might be broadened by conducting a review of previous studies worldwide, an exercise which might be expected to help remedy the knowledge gap.

The aims this review were to collect hypotheses relevant to this issue, to draw a whole picture of the causal relationships among the hypotheses, to point to important factors applicable to the case of Asiatic black bears in Japan, and to identify areas of further study needed to explore the causal mechanism of the current increase in the occurrence of bears on the periphery of human-dominated landscape.

MATERIALS AND METHODS:

Despite the large body size and carnivorous characteristics, nowadays bears typically occupy land near human settlements in several regions of the world. The key question of this review is why bears use areas around or within human-dominated lands. In other words, what causal mechanism is responsible for the increased selection of anthropogenic landscape by bears? In particular, by addressing factors associated with human land use, it should be possible to develop guidelines for long-term management schemes.

The physiology, biology and ecology of bears are relatively well studied. Even though abundant empirical evidence has accumulated regarding the influence of human activities on changes in the population, behavior and habitat of bears, only limited attempts have been made to synthesize this data with what can be inferred from the current presence of bears in human-dominated lands. I have tried to prioritize literature which focuses mainly on the causes rather than on the identifiable effects of the phenomenon, which are the subject of the majority of the relevant research, and have selected several key articles which explicitly explore the causal mechanism. To gather together the critical knowledge needed to understand the relationships between factors, I drew a chain of references from the key papers. The main target species for this review were groups of bear, but it also became necessary to include studies on other animal groups such as other carnivores and birds.

Overall, there were two dimensions to the hypothesis inferring the causal mechanism underlying the occurrence of bears near human settlements. One explains the causes by using behavioral ecology to investigate phenomena such as 1) food conditioning, 2) intraspecific competition, and 3) wide-ranging movement. The other strand is concerned with the role of landscape features and attempts to identify the mechanism by looking, for example, at 4) the distribution of available resources, 5) human land use patterns, and 6) large-scale niche partitioning. These 6 hypotheses are discussed sequentially. In addition, it should be noted that an important assumption made throughout this review was that the current status of bear habitat has been greatly influenced by the type of land dominated by humans, hence, careful attention was

paid to geographical differences in the results presented by previous studies. Finally, I developed a diagram showing the complex relationships among the hypotheses and the causal routes which connected them. Using these causal routes, I tried to interpret some of the previous studies of Asiatic black bears' occupation of land near human settlements throughout Japan, and identified several missing causal routes that must be key to the underlying mechanism of the recent increase in the selection of marginal areas of human-dominated lands by bears.

1. FOOD CONDITIONING

The several advantages of access to anthropogenic food are widely accepted as the cause of frequent wildlife occurrence in human-dominated lands. Among the diverse range of food originating from human activity, the most magnetic attractants for wildlife would be the food waste intensively distributed in various forms around residential areas. Garbage sites lie scattered around houses, gardens and farmlands, and in more highly concentrated locations like garbage dumps. Furthermore, in the landscape mosaic along suburban-rural gradients consisting of small villages and farmlands, there are several areas such as cultivated crops, orchards, fish farms, bee hives and fruiting trees on public or private lands which unintentionally provide feeding opportunities for wildlife.

There are quantitative studies which describe the large volume of anthropogenic origin food which wildlife was dependent on. For example, it has been shown that 50-60% of the diet of urban red foxes was human-originated food (Contesse et al.2004, Lewis et al. 1993) and 43% of coyote scats contained fruits grown in the cities of Washington State (Quinn 1997a). The food available from artificial environments is rich in both energy and nutrition, less subject to seasonal fluctuations, and relatively easier to access compared with that found in the wild. There are, then, considerable advantages to foraging for human food sources, but at the same time animals must face the associated risks. Road mortality (Gosselink 2007) and conflicts with local residents are major threats to survival. Animals foraging for food near human settlements are necessarily caught up in a trade-off between benefits and risks.

Bateman and Fleming (2012) argued that it is an animal's ability to be a generalist that is the key to its successful adaptation to a human-altered environment. In particular, characteristics of solitary carnivore species such as wide range of types of food, opportunistic feeding behavior and vagrant movement are all beneficial when it comes to utilizing anthropogenic food. Despite their large body size, bears have been broadly recognized as one of the major animal groups included on the list of human commensals which includes foxes, raccoons, badgers, and skunks, etc. The bears best-known for scavenging on artificial food waste are the so-called "dump bears" which survive on urban fringes across the North American continent.

The dependence of these bears on dumps has continued since the 1920's, and even though dump closures began in the late 1960's (Knight and Eberhardt 1985), 69% of public complaints about bears in 2006 were in the response to the behavior of garbage-related bears according to a survey conducted by state and provincial agents (Spencer et al. 2007). Numerous examples of garbage-habituated bears have been reported around or inside national parks (NP) including reports on Grizzly bears in Yellow Stone NP (Gunther 1994), and black bears in Great Smokey Mountain NP (Mclean 1990, Clark et al 2005), Jasper NP (Herrero 1980), Denali NP (Albert and Bowyer 1991), and in urban-rural gradients (Beckman and Bergers 2003a, Baruch-Mordo et al. 2013). Likewise, the behavior and demographic characteristics of the dump bears were well studied during the 1960-90s by researchers who found several types of plasticity in their behavior (Herrero 1983, Mclean et al. 1990, Pierce and Daele 2006). For instance, black bears in the Sierra-Great Basin region altered their activity patterns over a short period (Beckman and Bergers 2003a). Some individual bears using newly developed urban interface exhibited more nocturnal and less daily activity than their counterparts in the wild. This ability to change behavior in order to adapt to a novel environment is one of underlying factors that enables bears to utilize human-produced resources.

According to a comprehensive study of the differences between urban bears and wild bears, reproductive performance and body mass were much greater in urban populations than in the wildland population (Beckman and Bergers 2003b). It seems obvious that the advantages bestowed by easy access to high calorific human food are the major cause of frequent bear occurrence around human settlements. However, Beckman and Bergers (2003b) suggested that

the dominance of adult males in urban areas could be explained as “an ideal despotic distribution”, and that an increase in the occurrence of urban bears did not correspond to an increase of the population in the region as a whole. Furthermore, the dominance of specific age/sex classes among food-conditioned bears varied depending on the region in North America. For example, adult males were the major group of black bears at dumps in Minnesota (Rogers 1987), Michigan (Rogers 1976) and Jasper NP during summer (Herrero 1983). On the other hand, females with cubs fed intensively at dumps in Tennessee and Northern Carolina (McLean and Pelton 1990), and in Jasper NP during autumn (Herrero 1983) while less frequent and stable use by subadult bears was commonly reported in Alaska (Pierce and Daele 2006). Even though more young bears were commonly reported near human-dominated lands (Mueller et al. 2004), the factors affecting demographic differences might be attributable to regional differences in the size and distribution of garbage facilities, the level of aggregation among bears and human-related risks. Presumably, searching for food on the urban fringes and the sequential learning processes needed to adapt to the human landscape must take place at an initial stage before the bears become conditioned to anthropogenic food. Despite the large number of studies devoted to social interaction (e.g. antagonistic display, spacing, orienting of cubs, etc.), little knowledge exists to explain the different processes whereby each sex/age group of bears gains access to garbage sites.

2. INTRASPECIFIC COMPETITION

Elfström et al (2012) reviewed a substantial number of previous studies in a search for the most plausible hypothesis regarding the mechanism which leads bears to more frequently use human-attled areas. Two of the four hypotheses discussed in the review regard habituation to humans and food conditioning as behavioral responses to encounters with people and their property, and therefore cannot be seen as the ultimate mechanism causing bears to roam near human settlement. The third hypothesis considered naivety among young bears that lacked experience at dealing with people, particularly during dispersal movements. Naive individuals are prone to be attracted to easily accessible and high calorific food sources even in unfamiliar areas away from their natal range. However, the naivety hypothesis only works as a rational explanation for the presence of

subadult bears, but not for the other major group frequenting human settlements, such as females with cubs. Elfström et al (2012) concluded that the hypothesis of despotic distribution caused by intraspecific competition among bears is the most convincing explanation for frequent use of the periphery of human-dominated land by subordinate age/sex groups.

According to the despotic distribution hypothesis, areas of higher human presence may act as a refuge to protect females with cubs and subadult bears from intraspecific predation and aggressive behavior by mature male bears. Several studies have documented about intraspecific predation among Scandinavian brown bears (Swenson 1997, 2001) and Grizzly bears in North America (McLellan et al. 1999, Wielgus and Bunnell 2001). The monopolizing of good resources by large male bears might offer the best explanation for spatio-temporal segregation in habitat use among bears as young bear and females rearing cubs are thus forced to move to marginal habitat near lands intensively used by humans. It also suggests that subordinate individuals would have to have a greater fear of conspecifics than of people. A study of increasing brown bear populations in areas of expanding resort development showed that subadult bears were the major group within 10km distance of the human settlements (Nillemenn et al. 2007, Mueller et al. 2004). However, the level of aversion toward conspecific adult males on the part of subordinate bears and the influence this has on their movements are difficult to measure.

As many researchers reported, the major cause of bear mortality was human induced (McLellan et al 1999, Mattson 1990), and predation by people must have a greater effect than social interactions between all age/sex classes of bears. For example, brown bears prioritized human avoidance over conspecific avoidance when they selected day beds (Ordiz et al. 2011), and the spatio-temporal habitat use of black bears in Montana differed according to the season, rather than according to age/sex classes (McLellan and Hovey 2001a). Furthermore, aggressiveness among adult male bears was highly seasonal (Swenson 2001) and affected by demographic and regional factors (Garshelis and Hellgren 1994), and intraspecific infanticide was thought to be very rare among American black bears (Jonkel and 1971). Subadult black bears in Minnesota appeared to initiate their dispersal movement at times when the aggression and testosterone levels of adult males were proportionally low (McMillen et al. 1976), and this indicates that whatever cues the dispersal of subadult bears is independent of the aggressiveness

of conspecific adult males (Rogers 1987b). Therefore, a desire to avoid dominant males may not be the only cause of in the tendency of subadult bears to move into human-settled lands.

The despotic distribution hypothesis supported by Elfström et al (2012) rests on the assumption that subadult bears and females with cubs are the major sex/age group of bears regularly utilizing lands near human activities, because they perceive human landscape as a shield protecting them from conspecific predation and aggression. However, this assumption is undermined by the case of urban black bears in the Sierra Nevada in the US (Beckman and Berger 2003b). Compared with their counterparts in the surrounding wild lands, the population of bears in the urban-interface of this arid environment consisted of a disproportionate number of males with a larger body size (Beckman and Berger 2003b). The authors concluded that this skewed demography was evidence of the same kind of despotic distribution described in the hypothesis advanced by Elfström et al (2012). But the fact these groups bears in different study regions exhibit opposite demographic traits implies that there are other factors relating to geographical differences which determine sex/age groups of bears near human-dominated landscape.

3. WIDE-RANGING MOVEMENT

A wide range of movement can increase the chances for bears of traversing human-dominated matrix and encountering attractive resources that lead to the animals lingering around human settlements. One example of long-distance movement among large carnivores is dispersal behavior by subadult individuals. Bears are typically solitary animals and exhibit male-biased dispersal. Young male bears, for instance, sometimes travel distances of over 200km (Rogers 1987a). There is still some controversy over whether population density has an influence on the timing of distancing from natal place (Støen et al. 2006). A study on the genetic spatial structure of American black bears in New Mexico indicated that the level of competition in natal populations modified dispersal patterns (Costello et al. 2008). Støen et al (2006) also found evidence of density dependence for dispersal patterns when areas of higher and lower density bear populations were compared, but it was an inverse relationship. They concluded that the differences in the carrying capacity of the environment that determined the population densities

between the two areas was also the underlying indirect factor for the dispersal pattern (Støen et al. 2006). To identify factors affecting the frequency and range of dispersal movements, we need to estimate the size of the target population and source-sink dynamics among meta-populations in relation to environmental carrying capacity. Even though we may be able to identify factors initiating dispersal, these might not necessarily affect the probability of the use of human-dominated landscape. Rather, the range of available undisturbed land or the quality of the landscape matrix could be expected to have a greater influence on whether a young bear is associated with anthropogenic lands or not.

The other commonly-found instance of long-distance travelling by bears is temporal migration. Generally, food scarcity is assumed to be the major driver of migratory movement (Hellgren et al. 2005, Garshelis and Noyce 2008). For instance, highly seasonal and directional migrations were found among black bears in Minnesota, and the ratio of extensively migrating individuals in the population varied yearly (3-87% of adult bears) in accordance with the fluctuation of acorn production (Noyce and Garshelis 2011). The authors indicated that temporal long-distance travelling was determined by food availability and indirectly affected by the flatter terrain characteristics of the Minnesota landscape. According to studies of phenological effects, the variables most strongly linked to site selection were temporally adjusted available food species (Davis et al. 2006, Munro et al. 2006). All above results indicate that bears appear to recognize the changes in food availability both in space and time.

A number of previous studies of food conditioning reported that most bears left human settled areas when the availability of natural food increased. For example, the increase in human-caused mortality due to the frequent occurrence of bears outside Yellowstone NP corresponded to the years of crop failure of white bark pine seed, which is critical for Grizzly bears (Mattson et al. 1992). On the other hand, urban bears in Missoula and Montana display a complete shift in feeding behavior to focus on high-quality urban-based food, and their feeding period near houses was unrelated to the availability of natural food (Merkle et al. 2013). Although, Mattson et al (1992) and Merkle et al (2013) came to opposite conclusion with respect to the effects of natural food on bear movement, both studies suggest a common foraging strategy among bears and whether they move in or out of human-dominated lands was

determined by the seasonal and yearly changes into the availability of food resources (Lyons 2005, Swenson and Hout 1998).

4. DISTRIBUTION OF AVAILABLE RESOURCES

The spatial distribution of available resources presumably exerts an influence on the size of a bears' home range, their level of social interaction and their movement patterns, and all of these may determine whether wildlife select human-dominated lands or not. Considering the benefits and costs of feeding within urban patches for bears, the degree of accessibility to food sources was key to determining how many bears would occupy land in and around highly disturbed areas (Baruch-Mordo et al. 2013). Elfström et al (2012) emphasized that spatio-temporal segregation as a result of social interactions for competing high quality habitat in remote lands is the crucial factor that explains why subordinate individuals are frequently found near human settlements. However, the relationship between resource availability and the level of tension in social interaction may be more complicated. In lowland Alaska, there was a temporary alleviation of interspecific tensions between coexisting black bears and brown bears during moose calving season in spring while females with cubs avoided this area of abundant food by delaying den emergence and used more secure lands at higher elevations (Garneau et al. 2007).

A study of Mountain lions *Puma concolor*, thought to be highly territorial carnivores, suggested that the cats selected areas with clumps of available prey, and that their social interactions, such as territorial behavior, had no effect on site selection (Pierce et al. 2000). Defending specific areas not may be beneficial when prey distribution is highly changeable in space and time. Spotted hyenas *Crocuta crocuta* displayed territorial behavior only in situations of predictable prey occurrence, whereas no exclusive behavior was observed in areas where the distribution of prey was highly seasonal (Kruuk 1972). For migratory populations, therefore, spatial partitioning and mutual avoidance are less important when searching for scattered and ephemeral resources. These characteristics, which are typical in the distribution of food for bears, imply that social interactions are less influential than resource distribution on habitat selection. This may determine the frequency of bear presence near human settlements. In addition, food

availability had no effect on the home-range sizes of bears at a relatively small scale, but did at larger scales (Dahle and Swenson 2003, Ciarniello et al. 2007). As the authors suggest, we should first take account of the productivity of a landscape at the geographical scale before seeking to understand the effects of the spatial and temporal distribution of available resources on site selection by wide-ranging wildlife, including bears.

5. HUMAN LAND USE PATTERNS

When we explore the underlying mechanism triggering the utilization by wildlife of human-dominated lands, we must inevitably consider the landscape structure and context as the background factors that may be affecting the distribution of resources and placing constraints on animal survival (Lima and Zolner 1996). Nowadays, man-made environment systems are ubiquitous and give shape to diverse landscape structures and configurations. It is therefore unrealistic to simply divide lands into non-natural and natural. Rather, the perspective of gradients along urban-wild land provides us with a new opportunity to understand how wildlife respond differently to various levels of disturbance (McDonnell and Pickett. 1999). For instance, variables of geological gradient had more explanatory power for the presence of bird communities than patch-level variables because of wide-ranging movement of bird species (Bennett et al. 2004). Evidence of the importance of landscape context also emerged from an investigation designed to predict the habitat selection of wolves using hierarchical partitioned scales (Llaneza et al. 2012). For bobcats *Lynx rufus* and coyote *Canis latrans* occupying near urban areas, there was no association between survival rates and the relevant urban variables, because the major cause of mortality was vehicle collision and poisoning which were independent of urban locations (Riley et al. 2003). This indicates that the influence of man-made landscape structures varied according to the configuration of settlements and roads that played a significant role in the spatially linear mortality sources of wildlife (Forman and Alexander 1998).

5-1. Agriculture

One conspicuous form of human land domination is agriculture which extends over 15% of the earth's surface (Ojima et al. 1994, Turner et al. 1990). Wildlife respond directly to farmlands by feeding on the highly abundant nutritional food produced in agricultural fields. The utilization by pink-footed geese *Anser brachyrhynchus* in Northern Europe of highly productive fields as an alternative to natural grasslands was concentrated in a specific season corresponding to changes in farming practices (Jensen et al. 2008, Tombre et al. 2005). Black bears in a river basin in Louisiana also relied heavily on cultivated food and females inhabiting a small patch of forest selected crops for foraging at the landscape level (Benson and Chamberlain 2007). A similar pattern was observed in coastal North Carolina (Jones and Pelton 2003). The typical farmed landscape is a mosaic of woody patches, artificial open lands, irrigated streams, and scattered houses or small villages. Numerous studies have investigated the effects of such landscapes on quality of wildlife habitat (Lindenmayer and Fischer. 2006), and it was found that habitat edge species were better adapted to the mosaic structure than forest interior species (Sálek et al. 2010). Several authors in Europe have stressed that diverse components within traditional agricultural landscapes are critical for small carnivores in Mediterranean agro-ecosystems (Pita et al. 2009, Sokos et al. 2013), and for birds in British farmlands (Green et al. 1994). While the intensification of modern farming practices has been denounced as a threat to biodiversity (Romero-Calcerrada and Luque. 2006).

The area and shape of remnant woodlands within human-dominated matrix determined the abundance and distribution of many species (FitzGibbon et al. 2007, Meffert and Dziocik 2012). Particularly, the linear green spaces associated with rivers and streams flowing across agricultural matrix are thought to be a critical element for the heterogeneous ecosystem that provides a suitable habitat for many species (Wiens 2002) and a movement corridor by which wildlife can access the nutritionally rich food in farmlands. Furthermore, the quality of human-modified matrix should also be taken into account when investigating whether wildlife use remnant green space or not, because in many cases farmlands function as a barrier to movement. The use by bears across North America of riparian green belts as linear-shaped habitats offering foraging and refuge has been well reported (White et al. 2000, Lee and Vaughan. 2003, Muller et al. 2004, Wilson et al. 2006). Additionally, bears have never occurred in areas without refuges even though

rich food is available (Mattson 1990). Hence, riparian forests connected with larger undisturbed habitat may be important causal pathways drawing bears into lands intensively used by humans.

5-2. Forestry

Forestry practices such as, for example, large-scale conversion of native old-growth forests into mono-culture plantations, the construction of forest roads or even temporary logging, undoubtedly alter the composition of habitat for forest dwelling wildlife. Wildlife response to the habitat changes caused by forestry methods were complicated due to the pros and cons of clear cutting for foraging and the ability of various species to adapt to the altered environment. American martins *Martes americana*, appeared to adapt well, foraging for abundant prey in open regenerating lands even though they were considered to be a forest interior species (Potvin et al. 1999). Likewise, northern spotted owls *Strix occidentalis cawrina* preferred forest edges where they could hunt the highly available ground-dwelling small mammals, although selection differed depending on the region (Glenn et al. 2004).

Bears benefitted to some degree by being able to obtain a wide range of food unintentionally produced in open generating stands (Mitchell and Powell 2003), and Grizzly bears' selection of clear-cuts during hyperphagia corresponded to the occurrence of food sources (Nielsen et al. 2004a, b). It is, therefore, not surprising that intensive timber harvest influences bear movement (Brodeur et al. 2008) and activity patterns (Larivière et al. 1994). Because of the seasonal selection of early-successional stands by bears, the reduction of clear-cut area and increased canopy cover due to forestry practice based on natural disturbance had negative impacts on Grizzly bears (Nielsen et al 2008), and American black bears were reported making frequent forays into private lands due to a decrease in regenerating forests within La Maurici NP in Southern Québec (Samson and Huot 1998). Furthermore, in intensively converted plantations, narrow openings around forest roads and rivers may attract bears. Particularly in rugged terrain, rivers commonly associated with forest edges can provide bears with early serial food, and a traveling corridor connecting forested mountain to lower valley bottoms densely populated by humans. In regions where plantations extend into remote areas, forestry practices may be

responsible for an urge in wildlife to settle near anthropogenic lands due to a desire to avoid less productive plantations.

5-3. Large-scale land domination

The large-scale perspective is obviously important for a better understanding of habitat selection by wide-ranging wildlife. Nowadays, humans predominate over 50% of the terrestrial surface except in regions of permanent snow cover, and no place on earth remains unaffected by human activity (Ojima et al. 1994). The accelerating conversion globally of land to satisfy human needs is the single most important threat to biodiversity and on-going cause of species extinction (Vitousek et al. 1997). To deal with these threats, major conservation efforts are required to establish protected areas to maintain biodiversity and eco-system services as a means of regulating human activities and development. Nevertheless, such nature reserves tend to be located on economically unattractive lands such as remote and unproductive areas which have little value not only for humans but also for many species of wildlife (Pressy et al. 1996, Margulus and Pressy 2000). Allocating land to protect species which primarily inhabit ecologically productive lands, for instance, low land forests and coastal areas in temperate climate zones, is more difficult (Margulus and Pressy 2000). As Woodroff and Ginsberget (1998) pointed out, the problem with conserving wide-ranging carnivores within reserves, particularly in heavily modified landscape matrix, is that the animals would inevitably encroach on the surrounding human lands. For this reason, in the case of Grizzly bears in Yellowstone NP (Merrill and Mattson 2003, Doak 1995), black bears in the east temperate forests of the US (Fecske et al. 2001) and Andean bears in northern Ecuador (Peralvo et al. 2005), the persistence of viable populations has only been guaranteed by management schemes implemented on private lands.

Perhaps, the differences in frequency and timing of bear occurrences near settlements among the regions in North America, Scandinavia, and Asia in this review, may reflect geographical and historical differences in of the extent of suitable bear habitat remaining available after land has been converted for human use (Mattson 1990). Bears in the world today survive in marginal lands with harsh environments such as rugged mountains, plains prone to flooding, boreal dry hills or very remote arctic lands. After all, it is hard to determine which environment was the most

primary habitat for bears, because humans already predominantly occupied much of the productive land containing rich natural resources and flatter surface where is easy to move around.

The following is a useful example of the relationship between human land domination and bear response over a short period. Since the 1970s in United States, low-density housing development has increased, and resulted in 9 % of all the nation's land being converted with 39% of all houses being adjacent to wild land (Radeloff et al. 2005). These exurban developments pose a greater threat to biodiversity and cause more frequent human-wildlife interactions than metropolitan areas of intensively aggregated houses and buildings (Kretser et al. 2007). In the Midwest of United States, about 25% of houses are located in the exurban zones, and California is a hot spot of such drastic land development (Radeloff et al. 2005). Western Nevada, where black bears had historically inhabited at low densities due to the arid environment, was one such area targeted for exurban development. The lands were converted for residential use firstly on the valley bottom because of its flat surface, proximity to water supply and milder climate compared with the drier rugged mountains. Then, people created green space by planting trees and gardens around houses or public areas. In the unprecedented case of increase in both the human and bear populations in the same period (Beckman and Lackey 2008), bears have utilized novel human-induced food sources in the newly-built green towns in the valley bottom, and the authors found significant differences between the urban bears and their counterparts in the surrounding wildland in terms of demography, reproduction status and mortality rate. Contrary to expectations, the high density of bears in the urban areas did not necessarily indicate an increased population overall in this region. Rather, Beckman and Berger (2008) infer, there was simply a shift in bear distribution into the greenery of the productive valley bottoms from the arid mountains.

The male biased urban population in the case of the Nevada urban bears may be evidence of the higher quality of habitat in residential areas than in low productive remote areas. On the other hand, the major groups of bears frequently visiting anthropogenic lands were subordinate individuals such as females with cubs (Mattson et al. 1987) and sub adult males (Rogers 1976, Tietje and Ruff 1983, Gunson 1975, Nillemenn et al. 2007, Mueller et al. 2004). These geographical differences in demography may not contradict the hypothesis presented by Elfström

et al (2012) that the ultimate mechanism is that of a despotic distribution whereby high quality habitat is dominated by superior adult bears, forcing inferior individuals to use lower quality habitat. However, whether bears use or avoid human-dominated areas would be totally dependent on the extent to which beneficial resources are available in the human-altered environment compared with the surrounding primary bear habitat regardless of the existence of exclusive social interaction among bears. A study of Nevada bears concentrated on garbage sites without considering the urban vegetation, including fruit trees, seasonal attractants which may also play an underlying role in initiating the use of areas around human settlements (Merkle et al. 2013). Therefore, it is critical to evaluate quality of habitat along urban-wildland gradient by measuring the range of human dominance of productive lands, a dominance that must always differ according to regional geography.

6. LARGE-SCALE NICHE PARTITIONING

Niche differentiation has been interpreted as an instance of interspecific competition between species in ecological studies. Ecological niche differentiation can be defined as a process of separation whereby common resources are utilized by more than two competing species. So, coexistence among species occurs as a result of separation in resource use (Begon et al. 1996). On the basis of this theory, the use of common resources by humans and bears occupying the same landscape might be thought of as already differentiated. In this context, there are good grounds for assuming that the extent of available habitat remaining for bears must have a great influence on the probability of bear use of human-dominated lands.

Given the importance of multiple scales in investigations of species and environment relationships (Boyce et al. 2006), we need to address the question of which scale is the most appropriate when seeking to identify factors associated human disturbance that limit the range of wildlife habitat. While habitat for burrowing owls *Athene cunicularia* has typically been estimated at finer scales, Stevens et al (2011) found that soil and climate were the most predictable variables as underlying factors for the distribution of vegetation communities critical to the birds at geographic scale across the Canadian prairies. The importance of large scale to the

identification of factors limiting habitat distributions was also demonstrated by a study of the hierarchical habitat selection of Grizzly bears (McLoughlin et al. 2002, Ciarniello et al. 2007). Without pressure from hunting and interspecific predation, the major limiting factors were food abundance and availability, yet these can be detected only at a coarse scale. In addition, these authors suggested that age-sexual segregation in space use occurred only at finer scales as was found in a previous study of other carnivores (Rettie and Messier 2000, Wielgus and Bunnell 2000, Mace and Waller 1997).

The probability that is the characteristics of large-scale anthropogenic land use that constitute the major agent forcing animals into marginal habitat has seldom been examined. Assuming that humans are a species, we could apply the niche partitioning theory to the relationship between humans and other species (Alberti et al. 2003). It should be obvious that humans are the superior competitor or predator for many species and that they exploit their technological advantages in their domination of limited productive lands over wide-ranging wildlife (Sunquist and Sunquist 2000)

Because land transformation on a broad scale has mostly been accomplished in many countries, it is hard to detect the processes and patterns in the competitive exclusion of wildlife from their primary habitats. Several ongoing land developments, usually being targeted by conservation concerns, show how humans and wildlife compete for commonly suitable areas. For example, marine mammals have suffered from the loss of important foraging coastal habitat due to the construction of fish farms (Markowitz et al. 2004), and the overlap between wintering habitat for pronghorn *Antilocapra americana* and locations of gas extraction were found to have caused the animals to move into more marginal lands (Beckman et al. 2012). The processes and patterns of habitat loss can be observed in rapidly developing regions where large areas of intact land remain, for example, in native forests Asiatic elephants *Elephas maximus* that thrived for a long time have been continuously eliminated by superior competitors, humans (Hedges et al. 2005, Sitati et al. 2003).

As Miller and Hobbs (2002) pointed out, the high ecological value of land and the potential it might have to be used intensively by people must be taken into account if we wish to understand why wildlife use anthropogenic lands. However, the variables for land selection by humans for

the development of agriculture lands and road networks for urban construction have merely been investigated in comparison with the variables for wildlife habitat. The impacts of road networks on biodiversity have been relatively well assessed (Forman 2000, Forman and Alexander 1998), but studies which seek to identify landscape predictors for road placement are noticeably limited in ecological research. The results from one of the few studies available indicate that the variables strongly affecting road placement were intermediate terrain ruggedness and lower elevation. These greatly overlapped with the variables affecting habitat selection by Grizzly bears, and the common variables resulted in the frequent use of road side by bears (Roever et al. 2008a). This kind of overlap between wildlife habitat and road placement can typically be observed in the valley bottoms of montane landscape. Wolves in Jasper National Park selected valley bottom in their search for prey but simultaneously avoided high use roads. This indicates that highly abundant prey and ease of movement in the lower lands were fundamental habitat requirements for wolves before the settlement of humans (Whittington et al. 2005).

Valley bottom surrounded by rugged high mountains may be the kind of landscape in which the habitat of humans and wildlife most typically overlaps because it offers more productive soil, plenty of water, a milder climate and flatter surface than higher elevation with steep terrain. Mace et al (1999) proposed the novel approach for quantifying the influence of human disturbance by dividing grizzly habitat into two types: potential habitat without human presence and realized habitat that included human disturbance. They concluded that an average 14% of Grizzly bear spring habitat had been reduced due to human disturbance, because bears need to use lower altitudinal lands when foraging for season specific food. As far as management on the ground is concerned it seems meaningless to contemplate the absence of all human activities. However, the idea of potential habitat could broaden our view and lead to a better understanding of wildlife habitat.

Both bears and humans are heavily dependent on omnivorous diets, and their common food requirement mean that they are, fundamentally, competitors in the acquisition of resources (Mattson 1990). In general, humans with their technological advantages are far superior to bears in terms of niche domination. One way in which humans and bears might coexist in the same

environment would be if large-scale ecological niche differentiation gave bears the opportunity to inhabit marginal lands which humans regarded as useless or inconvenient.

In conclusion, competition for common habitat suitable for both bears and humans would be the ultimate mechanism for the current spatial distribution of both species. Bears occupy the inferior position in the ecological niche partitioning, and their potential habitat has been significantly reduced by human domination of more productive lands. Such large-scale niche partitioning is probably the major factor limiting the abundance and distribution of available resources for bears. Additionally, as noted in the foregoing review, spatial heterogeneity and the dynamics of the marginal lands bears depend on today are considerably affected by shifting policies and practices in agriculture and forestry. Bear movement in relation to intraspecific interactions may also be influenced by human disturbance at a large scale, and whether such movements result in the utilization of human-dominated lands or not are definitely determined by the range of gradients between marginal habitat and primary habitat now mostly exploited for intensive use by humans.

IN THE CASE OF ASIATIC BLACK BEARS IN JAPAN

To unravel the complex relationship, I drew a whole picture of causal routes between each of the six hypotheses (Fig. 1-1).

Becoming conditioned by anthropogenic food may easily occur among bears already inhabiting the periphery of human-dominated (PHD) lands (B1 in Fig. 1-1). It may also happen due to the broad range of movements of dispersing young males or temporal migrants searching for seasonally available foods (B2) and these broad movements may increase the chances of encountering people and their property (B3). Permanent migrants may consist of subordinate young or females with cubs forced by aggression in intraspecific competition to use more marginal lands close to human settlements (B4). These serial causes could be attributable to the behavioral characteristics of bears.

Other causes may be attributable to landscape features affecting animal behavior. The spatial pattern of land use by humans may have an indirect but profound influence on the distribution

of essential resources available to wildlife as an underlying mechanism that partitions common resources between humans and bears (L5). Consequently, the distribution of available resources for bears may have an effect on the severity of intraspecific competition because of its influence on the quality of habitat (L4), on the range or frequency of movement in terms of its spatial configuration (L3), and directly on the probability of selection of PHD lands (L1 and L2) if available resources are abundant in such lands.

Existing information about the factors involved in the frequent use of the PHD lands is limited and fragmented in the case of Asiatic black bears. Bears conditioned to garbage sites have been observed in several recreational areas including national parks and resorts, and the settlement of many female bears reported in a large resort zone (Yamamoto et al. 2013) indicates the existence of other unknown causes inducing bears to inhabit the PHD lands (L1-B1 route in Fig.1-1). Crop feeding by bears is very common in Japan, but it is highly seasonal. While a coincidence between an increase in the number of sighted bears and crop damage has often been documented, a high proportion of the bears studied did not feed on agricultural products (Izumiyama et al. 2009). This may suggest that the conditioning to agriculture products was a result rather than the cause of the use of PHD lands, and there may also be other factors drawing bears to PHD lands (L3). The failure of seed crops among staple food has been widely recognized as a factor causing an increase in human-bear conflicts (Oka et al. 2005), and the yearly coincidence between the scarcity of hard mast and massive numbers of bear occurrences in the PHD lands has also been documented in several regions in Japan. Significant expansions in the home ranges of bears in years of food shortages (Kozakai et al. 2011) may increase the chances of encountering human-dominated lands (L3-B3 route). Although the question of whether several alternative food sources exist in PHD lands has yet to be investigated, identifying such resources must be an important step in seeking to understand the processes of the usage of human-settled areas (L1 or L3). Furthermore, the occupancy by bears of PHD lands is currently not a question of specific years of seed crop failure and many cases of conflicts that were season specific did not coincide exactly with the period of mast production. Therefore, these facts also support the hypothesis that there are other factors which attract bears to PHD lands.

In Japan, the major sex-age group of bears removed due to conflicts with local people differed among regions. For example, the largest group of harvested bears in Nagano prefecture consists of young male bears (Izumiyama et al. 2009, Kishimoto 2011) while the majority of nuisance kills in Tohoku region were adult males and females (Oi 2009). There is almost a complete absence of studies on intraspecific competition among wild Asiatic black bears. Therefore, it is difficult to know whether the differences in sex-age group of killed bears between regions were the result of such social interactions or not. Notably, the fact that more adults were harvested in the years of seed crop failure should be taken into account when considering resource scarcity in remote lands (Elfström et al. 2012). However, the assumption of limited resources in natural lands cannot fully explain the fact that there are more bears in PHD lands unless we combine this with the assumption that there are more available resources in PHD lands for bears.

The extent of available resources for bears in PHD lands is probably an important factor in the selection of PHD lands, and the availability may also depend on extent of the remaining land that is suitable habitat for bears. For instance, in the mountain-valley regions commonly inhabited by bears in Japan, the productive and accessible flatter lowlands are suitable for both humans and bears. It is highly likely that humans will dominate bears in the beneficial lower plains insofar as they have modified the landscape for agriculture use or urbanization. Foothills and mid-elevated mountains have also been altered for exploitation of forest products for a long time in rural Japan. In this context, the distribution of critical resources available for bears must be primarily determined by current or historical spatial patterns of anthropogenic land modifications (L5). For example, the vast areas of plantation, unmanaged woodlands in foothills, increasing numbers of abandoned farmlands and villages, and expansion of road network; which are all typical rural landscape in Japan and may have a profound influence on the distribution of the resources bears require for their survival. However, the linkage between landscape factors in relation to human development and behavioral factors including social interactions, movement and the feeding habits of animals has seldom been explored as a means of seeking the causal mechanism underlying the current occurrence of large numbers of bears on PHD lands.

Given the great potential this would have for the study of habitat selection as an integration of landscape ecology with behavioral biology (Lima and Zallner 1996, Manley et al. 2002), an investigation of the specific types of PHD lands selected by bears might provide a clue to the causal mechanism of the increased occurrence in PHD lands in the case of Asiatic black bears in Japan as well as in that of other bears in the world.

Table. 1-1

The list of key literatures and hypotheses for the mechanism of frequent occurrence of bears and other wildlife on the periphery of human-dominated (PHD) lands.

Hypothesis	Description about hypothesis	Habitat type & region	Source
Food conditioning	Urban bears = larger and higher in reproduction but higher mortality = dominated by large males	Exurban area in arid desert basin in Western Nevada US	Beckman and Berger 2003b
Persistence to human originated food is the main reason for drawing bears into human-dominated lands	Increased habituated bears foraging within developments and along road side after dump closure	Mixed Forests in South Central Rocky Mountain US	Gunther 1994
	Food conditioned bears = more fertile and larger = more males and subadults	Temperate forests in Appalachian mountain Eastern US	McLean and Pelton 1990
	Agonistic interaction = females with cubs Dump bears = adult males in summer females with cubs in autumn	Mountain forests and valley bottom in Canadian Rocky	Herrero 1980
	Bear problems in backcountry Predictable patterns in human activities > human habituation	Wide glacial valley in South Central Alaska US	Albert and Bowyer 1991
	Peak of dump bears = low availability of natural food females with cubs = socially dominant	Wet tundra and mixed forest in South Western Alaska US	Pierce and Dale 2006
	More males in dump than residents than residents and campsites but season specific = summer	Camp grounds and residential areas in Michigan US	Rogers 1976
	Dump used by only females having dumps within their range, but avoid of gathered males in dump	Superior National Forests in North-eastern Minnesota US	Rogers 1987
Intraspecific competition	Intraspecific competition is the most plausible ultimate mechanism other than habituation, food conditioning, naivety	Europe, North America, Asia	Elfström et al. 2012

Predominance of good quality habitat by superior bears drives inferior bears to use more marginal habitat near PHD lands	Closer to settlements and resorts = average 27–51% : Younger bears = 52% of all bear use within 10 km :Older bears = more sensitive to disturbance	Rolling landscape covered by forests in South-central Sweden South eastern Norway	Nellemann et al. 2007
	Subadult bears > closer to high-use roads regardless of time when adults use night	Prerries around low land river shed in Alberta, Canada	Mueller et al. 2004
	Subadult males = killed more as nuisance: Females = higher survival rate	13 study areas: Rocky and Columbia mountains of Alberta, British Columbia, Montana, Idaho, and Washington	McLellan et al. 1999
Wide-ranged movement	Natal dispersal probability and distances = inversely density dependent High proportion of dispersing female in expanding population	Dalarna and Gavleborg counties in south-central Sweden and Hedmark County in south-eastern Norway	Støen et al. 2006
Extensive movement of bears causes the increase of chances to encounter available resources in PHD lands	Sex bias in dispersal was less pronounced in the lower-density area and competition (for mates or resources) modifies dispersal patterns	Sangre de Cristo Mountains of northern New Mexico	Costello et al. 2008
	Bears typically travelled southward, where acorns more plentiful and least apt to leave when foods were scarce in their home range: Seasonal migrations = returned to their resident ranges	the flat lowland landscape and upland forest in north-central Minnesota	Noyce and Garshelis 2011
	One-way movement as the result of the effects of environmental stochasticity (= drought and mast failure) on a small population Insufficient alternative foods > migrating	Deserts of Southwest and the Great Basin, Big Bend National Park in Texas	Hellgren et al. 2005
	Bears cognized both temporal and spatial differences in food availability Site selection by American black bears = phenologically driven	Coastal British Columbia, Canada	Davis et al. 2006
	Distinct seasonal shifts of diet > changes in food availability Phenology differences between foothills and mountains = important determinants of seasonal food use by Grizzly bears	Canadian Rocky Mountains and foothills of west central Alberta, Canada	Munro et al. 2006
	Elevational migrating > low elevations and riparian habitats Difference in habitat selection = more seasonal than sex/age group	Flathead River drainage of south-eastern British Columbia and Montana	McLellan and Hovey 2001a

	Mortality of subadult males = 3.3 times higher during years of small seed crops of the white bark pine	Yellowstone National Park of Wyoming, Montana, and Idaho US	Mattson et al. 1992
Distribution of available resource	Bears used the urban-interface patch even no anthropogenic food was available, but increase of cost to access > reduce bears to come into human-dominated lands	Aspen, in the central mountains of Colorado, US	Baruch-Mordo et al. 2013
Higher availability of resources near PHD lands determine frequent use by bears	the highest risk of human-bear interaction = residents living in intermediate housing densities that are located near large forests	Missoula situated in a valley bottom in Montana, US	Merkle et al. 2013
	Resource availability is more influential on habitat selection and territorial behavior among large carnivores than competitive social interactions	Black bears in sub-Arctic, Alaska US	Garneau et al. 2007
		Mountain Lions in the eastern Sierra Nevada, California US	Pierce et al. 2000
	seasonal changes in food availability and dispersion only have minor impacts on seasonal range size	Brown bears in Sweden and Norway	Dahle and Swenson 2003
Human land use pattern	Agricultural foods were used heavily by bears, but preferred other habitats including swamps, lowland bottomland hardwood forest	Tensas River Basin and Deltaic in Louisiana, US	Benson and Chamberlain 2007
Land use pattern by humans have effects on distribution of available resource	Abundant food and limited forested habitat influenced home range size		
	Clear-cuts, and marshes were preferred over managed pine plantations	Intensively managed forestry and agricultural environments in coastal North Carolina, US	Jones and Pelton 2003
	Bears depended heavily on crops for food obtained during short feeding forays		
	Forest management positively affected on bear habitat but had an overall negative effect on habitat suitability	the southern Appalachians in North Carolina, US	Mitchell and Powell 2003
	Intermediate-aged (30 years old) clearcuts were selected during hyperphagia, whereas recent and old clearcuts were selected during late hyperphagia	the eastern foothills of the Canadian Rocky Mountains, Alberta	Nielsen et al. 2004a, b

The declining use of the park that make females more vulnerable to exposure to humans was caused by the low occurrence of early-successional tends	La Mauricie National Park (LMNP), Quebec, Canada	Samson and Huot 1998
Existing reserve systems throughout the world contain a biased sample of biodiversity, that of remote places and unsuitable for commercial activities	All the world	Margules and Pressy 2000
Wide-ranging carnivores are likely to become extinct, irrespective of population density because of frequent contact with humans that account for high mortality of adults	All the world	Woodroffe and Ginsberget 1998
There is relatively little overlap between occupied bear habitat and high human densities. This mutually exclusive distribution of bears and high densities of humans has probably resulted from niche difference	All the world	Mattson 1990

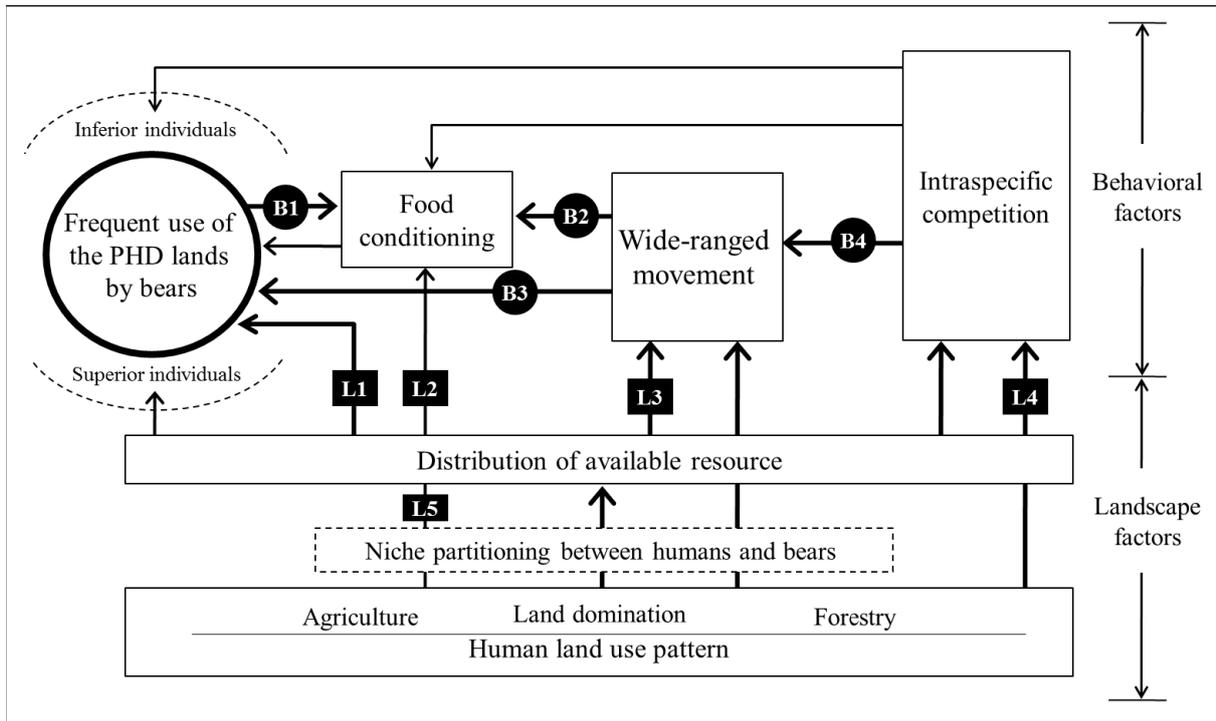


Fig. 1-1

The conceptual diagram showing causal routes between hypotheses toward the frequent use by bears on the periphery of the human-dominated (PHD) lands. The numbers inside of black circles are causal route driven by animal behavioral factors and the numbers inside of black squares are causal route affected by landscape features.

CHAPTER 2

AN EVALUATION OF HABITAT SELECTION OF ASIATIC BLACK BEARS IN A SEASON OF PREVALENT CONFLICTS

ABSTRACT:

Identifying the relationships between human land use and wildlife habitat use is an essential component in any attempt to mitigate human–wildlife conflict and conserve imperilled wildlife populations. I studied habitat selection by Asiatic black bears (*Ursus thibetanus*) by employing a resource selection function (RSF), using GPS relocation data for 9 bears in 2008 and 2009. I focused on habitat selection in summer when human–bear conflicts are most frequent in the central Japanese Alps. Logistic regression indicated that bears were positively associated with red pine (*Pinus densiflora*) forest and regenerating lands and negatively associated with both larch (*Larix leptolepis*) and coniferous plantation. Almost all bears tended to select areas with steep slopes that were close to roads and rivers. An index of human–bear encounter risk, estimated using the predicted RSF map and road density, suggested that only 5.3% of the study area was secure habitat with low human access for bears. Selection by bears for red pine woodlands is one of the reasons for the prevalence of conflicts in summer. I recommend that wildlife managers exercise caution because lethal control of bears in the most frequently selected areas may have a serious effect on the population. This study, as well as further spatially defined habitat research, can provide information crucial to the appropriate habitat management needed to conserve bears and mitigate conflict in the long term.

INTRODUCTION:

In Japan, human–bear incidents and conflicts have been on the increase in recent decades despite the fact that some local Asiatic black bear (*Ursus thibetanus*) populations face extinction. Therefore, a challenge facing managers is knowing how to shift from removing bears in a reactive way to preventative conflict mitigation without putting the maintenance of bear

populations at risk. The study of habitat has the potential to identify the areas which are most important for bears and regions in which human–bear conflicts are most likely to occur. However, very little quantitative or spatially defined work has been done to determine bear habitat selection at the landscape level.

Human activities have an impact on habitat quality and structure and on wildlife habitat use (Lindenmayer and Fischer 2006). Lacking a spatial model of wildlife habitat use makes it difficult to evaluate land-use policies for forestry or agriculture practices, let alone manage areas intended to protect local wildlife populations, particularly where human population density is high. In terms of the “potential habitat” concept proposed by Mace et al. (1998), the primary habitat for Japanese black bears, including mountainous regions, has been extensively exploited for human activities. In particular, rapid urbanization has created a highly dense road network across the country. The impact of roads on wildlife habitat has been reported in previous studies (Mace et al. 1996, Gaines et al. 2005, Ciarniello et al. 2007), but it is still necessary to assess how roads affect bears. In some cases, roads provide foraging opportunities for bears (Roever et al. 2008), but if a bear is observed near a residential area in Japan, it is often killed. Further, social change in currently depopulated and aged rural communities may lead to an increase in unmanaged farmlands and logged lands, which in turn may affect bear habitat selection positively or negatively.

Studies of bear food resources are often conducted without addressing spatial attributes and, as a result, scientific knowledge of landscape features of Asiatic black bear habitat is very limited (Carr et al. 2002, Hwang et al. 2002, Huygens et al. 2003, Izumiyama and Shiraishi 2004). For this reason, finding a link between spatial characteristics and habitat use remain difficult. The relationship between mast production and the frequency of conflicts in autumn has been studied (Oka et al. 2004), whereas associations between habitat selection and food availability in summer, when human–bear conflicts are most prevalent, have not been investigated.

Bear distribution maps are usually developed at a resolution of 1 km² or greater, which is too coarse to allow identification of areas suitable for habitat restoration or the intensive management required to mitigate conflicts. Furthermore, coarse resolution limits our understanding of why animals use a particular space. The lack of habitat research at the third order (Johnson 1980) is because bear relocation data are spatio-temporally sparse, and few wildlife habitat conservation examples exist for broad-ranging animals such as bears in Japan.

In this study, I employed a resource selection function (RSF) to predict spatial patterns of habitat use by Asiatic black bears at a landscape level with a finer resolution than current maps that estimate wildlife distribution. I chose an RSF model because its reliability has been attested by many studies in wildlife habitat selection (Johnson et al. 2003, Munro et al. 2006). In particular, RSF modelling using GPS telemetry data has been documented as robust (Nielsen et al. 2002, 2004a, Gaines et al. 2005, Johnson et al. 2006).

My research had 3 objectives: (1) to identify key environmental factors affecting the habitat selection of Asiatic black bears, (2) to produce a map of the relative probability of bear habitat use over the study area, and (3) to assess the risk of human–bear encounters. I focused on summer habitat use because this season currently has the highest frequency of human–bear conflicts.

METHODS:

Sampling bear location data

I collected relocation data on 9 bears (3 Females, 6 Males) using GPS collars during 2008 and 2009. I scheduled Televilt GPS collars (Televilt Inc., Stockholm, Sweden) to obtain locations every 15 minutes. I defined summer as 1 July–10 September on the basis of the dietary features of black bears (Izumiyama and Shiraishi 2004). To build the RSF model, hourly GPS location data were used to predict bear summer habitat selection.

I used ArcMap. 9.3[®] (ESRI, Redlands, CA, US) to convert GPS data to shapefiles, and defined the home range of each bear as the 100% minimum convex polygon (MCP) using the GIS extension Hawth tool (Beyer 2004). To compare used with available resource units, I sampled random points within each home range. I standardized the number of the random points as 10/km² within each individual MCP home range (Table 2-2).

Environmental variables

The Fifth National Actual Vegetation Map (<http://www.vegetation.jp>, accessed April 2011) was used to reclassify the land-cover layers. Primary cover types, categorized in terms of bear food distribution, were a Japanese larch plantation, a coniferous plantation of Japanese cypress (*Chamaecyparis obtusa*) and cedar (*Cryptomeria japonica*), a Japanese red pine secondary forest, and a broadleaved deciduous forest. The red pine forest was a mixture of natural growth and planted stands. Land-cover variables influenced by human activities were grouped into 3

categories: “near town” included residential areas and paddy fields; “attractants”, included croplands and livestock sheds, and “disturbance” included open regenerating lands such as grasslands and shrubs.

I used nearest distances from rivers, roads, and forest edges to explore their effects on bear habitat selection, measured from each bear location using the proximity tool in ArcMap 9.3[®]. Additionally, I used elevation, slope, and aspects generated from a 10-m digital elevation model (DEM) obtained from Digital Cartographic Data Standards (<http://fgd.gsi.go.jp/download>, accessed April 2011; Table 2-3).

Model building and statistical analysis

I developed an RSF model to estimate the proportional probability of resource use (Manly et al. 2002), using logistic regression to compare used and available locations with the coefficients (β_i) for each predictor variable (x_i) according to the formula:

$$w(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k) \quad (1)$$

where $w(x)$ is the relative probability of bear habitat use at a resource unit with multiple environmental conditions. I assessed multi-collinearity among predictors using a correlation matrix. I considered forest edge and elevation ($r = 0.706$), and roads and elevation ($r = 0.705$) to be collinear. I suspected that forest edge was too coarse a measure and thus removed it from the model. However, given the importance of both roads and elevation in the estimation of selection, I retained both in my RSF model. I included quadratic terms to examine non-linear relationships.

I determined population level selection by averaging individual selection coefficients (Nielsen et al. 2002). Habitat selection was mapped across the study area with the equation

$$\text{RSF} = \pi(x) = \frac{w(x)}{1 + w(x)} \quad (2)$$

where $\pi(x)$ is the predicted value for all environment factors representing the relative probability of habitat selection by bears across the study area in summer. The predicted map with a continuous RSF value was reclassified using quantile measures and converted into 10 ranges using the Spatial Analyst extension in ArcInfo 9.3[®].

Model validation

Validation of an estimated model is essential to the generation of credible information (Boyce et al. 2002, Johnson et al. 2006), and model assessment processes allow several important insights into animals' habitat selection. For model validation, I used 953 independent GPS data points from 9 bears (not used for model building). I tested models using an expected utilization function $U(x)$, which contrasts the expected and observed proportional habitat use (Johnson et al. 2006). $U(x)$ is the proportion of the relative likelihood of animal use, taking account of the area of each classified RSF value:

$$U(x) = \frac{w(x_i) A(x_i)}{\sum w(x_j) A(x_j)} \quad (3)$$

where $w(x_i)$ is the midpoint value and $A(x_i)$ is the area of the i th RSF class. The proportion of test data points falling within each predicted RSF class were classified as $O(x_i)$. I used standard goodness-of-fit techniques to validate the relationship between $U(x)$ and $O(x)$ with the linear regression model.

Influence of major vegetation cover types on bear habitat selection in summer

To understand how bears responded to the 5 major cover types (larch plantation, coniferous plantation, red pine forest, deciduous forest, and previously disturbed land), I calculated an odds ratio to indicate the probability of bear use of one vegetation type compared with other matrix vegetation (Nielsen et al. 2004b). I pooled the used and available data sets for all individual bears and divided the data into 2 groups: one of the 5 vegetation types (coded 1) and others (coded 0). I used logistic regression in each case to obtain the odds ratio of bear selection for each vegetation type.

Index of bear–human encounter risk

I developed a model to quantify the possibility of bear–human encounters. I quantified road density (linear roads/km²) partitioning the study area into 3 zones ranked according to human accessibility. I then rescaled the predicted RSF map to 2 levels: low (RSF classes 1–5), and high relative probability habitat selection (RSF classes 6–10). I calculated the mean RSF value of the high RSF area in each of the 3 ranked human accessibility zones. The index of bear–human encounter risk was defined as these mean RSF values multiplied by mean road density.

All statistical analyses and GIS spatial calculations were performed in R (R Development Core Team 2011) and ArcInfo 9.3[®] GIS software.

RESULTS:

Summer habitat selection by Asiatic black bears

I collected 3,469 GPS locations from 9 radio-collared bears during summers 2008 and 2009 (\bar{x} = 385/bear, SD = 264). I used 2,455 random points (\bar{x} = 273/home range, SD = 260) to represent available resource units (Table 2-2). Coefficients for the independent environmental variables for individual bears and the averages (Table 2-4) suggested that all bears avoided areas near towns (although not necessarily roads) and tended to select broad-leaf forest lands except the coniferous and larch plantations (Table 2-5). I observed substantial individual differences in the selection of crops and livestock sheds. The mean probability of bear use increased with close proximity to both roads and rivers, but these relationships were not linear. On average, habitat use was associated with high elevation, but this relationship was also non-linear. Steeper sites were positively associated with bear selection, whereas selection for aspects other than the southern slope was inconsistent among individuals. According to my predicted map drawn using the 10 reclassified RSF values (Fig. 2-1), the higher RSF level (RSF class 6–10) occupied 37.0% of the total area. Higher RSF classes occurred at lower elevations (e.g., <1,100 m). In addition, protected areas occupied 8.8% of the high RSF level area, and 3.2% of the entire study area. The test of the summer RSF model using independent GPS locations confirmed a good fit (simple linear regression: β = 0.88, R^2 = 0.78, p < 0.005; χ^2 = 60.02, df = 9, p < 0.0005).

Influence of forest cover types on habitat selection

On the basis of the reclassified vegetation map from the 5th National Actual Vegetation Map, red pine forest, previously disturbed lands, and broadleaf deciduous forest were positively associated with bear selection (Table 2-5). In contrast, both larch and coniferous plantations had a significantly negative influence on bear habitat use in summer. The odds ratio for red pine forest selection was over two times higher than selection of either plantation type (Table 2-5).

Index of human–bear encounter risk

The area with the lowest human access (Zone 3) constituted 46% of the total land, followed by 34% with moderate access (Zone 2), then the area of highest access (Zone 1, 20%). The

index of human–bear encounter risk was highest for Zone 1 and lowest for Zone 3, and the index was 24 times greater in Zone 1 than in Zone 3 (Table 2-6). The low risk zone for human–bear encounters (RSF classes 6–10 in rank 3) was about 53.6 km² or 5.3% of the studied landscape (Fig. 2-2).

DISCUSSION:

Summer habitat selection by Asiatic black bears

Asiatic black bears in the central Japanese Alps region selected for red pine forest, which is very common in lower plains and foothills that are dominated by human-altered landscapes such as farmlands, villages, and towns. The red pine forest is an early stage of succession providing good light conditions to understory plants such as berries, lianas, and herbaceous species. As time passes, the red pine forest will shift to a broadleaved forest (Miyawaki 1989), which provides favorable conditions for bears. Moreover, red pine forests are known as ecosystems that maintain diverse species, including insects such as ants, termites, beetles, bees, and wasps, which are important protein resources for bear survival in summer. This summer food is of a relatively small volume but is an important option for bears (Koike 2010).

This study supports previous research in showing that regenerating open land had significant positive effects on bear habitat selection (Nielsen et al. 2004b, Benson and Chamberlain 2007, Reynolds-Hogland and Mitchell 2007). Such open land is both anthropogenic and naturally derived. Typical examples are regenerating plantations following clear-cutting for timber production, shrublands, open meadows, and bedrock sites after a landslide event. Consequently, vegetation is commonly dominated by early serial plants such as grasses and fleshy-fruited shrubs that attract bears (Takahashi et al. 2008). Naturally open vegetation is more limited than the much larger, clear-cut areas used for timber production. However, such relatively large areas of regenerating land have contracted because of changes in forestry policy designed to restrict clear-cutting practices, and because unmanaged privately-owned forests have increased. In some smaller gaps inside the canopy closure, key seasonal edible species, such as cherries (*Prunus jamasakura*), walnuts (*Juglans mandshurica Maxim.var. sieboldiana*, *Juglans mandshurica var. sieboldiana*), and fruiting trees such as giant dogwood (*Swida controversa*) are available as

forage (Koike et al. 2008). Furthermore, roadsides, riversides and forest edges are patchy habitats that support bears in a similar manner to disturbed sites (Yoshida et al. 2002).

Steeper slopes were used by bears more often than random locations. In general, landslides occur more often on the steeper slopes, facilitating the regeneration that leads to early successional plants becoming summer food for bears. More people frequent mountain ranges in summer, and the bears' avoidance of trails or other recreational sites could provide a better explanation for their selection of rugged areas. Other anthropologic factors related to forestry practices or intensive erosion control may affect selection. However, I lacked clear evidence to identify specific factors.

Applying RSF method to Asiatic black bears

Initially, I adopted the RSF method to outline landscape traits that feature in the background habitat of Asiatic black bears, and to identify key environmental variables influencing habitat selection in summer (which is the high conflict season). The RSF model provided spatially explicit and quantified descriptions of bear habitat selection. Nonetheless, I recognize that my RSF model is only the first stage in a range of potential applications, and I see the need for further research into areas such as habitat restoration, corridor planning (Chetkiewicz and Boyce 2009), the identification of ecological traps (Naves et al. 2003, Nielsen et al. 2004a), population viability (Boyce and McDonald 1999), and the mitigation of human–wildlife conflicts.

Influence of human activity on habitat selection and its quality

That cells with a high RSF class were aggregated in foothills suggests that bears used peripheral areas between human settlements and the plantation zone (Zone 2, Fig. 2-2b). Bears selected red pine forests because these provide a diverse source of summer foods and simultaneously allow bears to avoid people and plantations. Road networks within Rank 2 areas consisted mainly of logging roads with low use, providing forest edges rich in bear resources along the roadside. However, these roads were not gated year round, thus elevating the chances of encountering humans (Table 2-6).

The lowest risk zone was patchily distributed (zone 3, Fig. 2-2c), and only 5.4% of it was within the higher of the 2 ranked RSF levels. This dispersion of secure bear habitat across a mountain range appears to be due to the fragmentation effects of disturbed lands and broadleaf forests. Within this secure habitat, gated roads in the national forest and protected areas may play a critical role in maintaining the local bear population.

In contrast, bear habitat with a high risk of human encounters was small in size (similar to secure habitat), but the risk index was 24 times higher than that in the zone 3 areas. In those areas on the map with the highest index (zone 1, Fig. 2-2a), human–bear encounters are likely to lead to bear mortality. The distance between the forest edge and settlement has been reported as an important factor in the identification of high-risk areas of human–bear contact (Honda et al. 2009). In my study area, such high-risk habitats largely included riverside woodlands through farmlands, villages, and towns. Many forest edges surrounding the human landscape can provide rich summer food for bears. This implies the existence of an attractive sink (Naves et al. 2003, Nielsen et al. 2004a) that brings both benefits and risks for bear survival. Future investigation is required to identify these areas, which play an important role in conserving the bear population.

Management implications

Summer habitat of Asiatic black bears was mainly composed of marginal land abandoned after changes in farming or forestry practices. Historically, these lands were exploited for fuel wood and timber to meet demands of rural dwellers until the modern energy supply system and the international timber market became widespread. Currently, such secondary habitats are patchily distributed close to human settlements with high road densities, where the likelihood of human–bear encounters is high. In contrast, secure summer habitat in the central Japanese Alps was considerably restricted and fragmented at higher elevations with a lower availability of food resources.

Causes of the increasing incidence of human–bear conflicts in Japan have been contentious. Bears may be resilient and highly capable of adapting to human-modified landscapes (Weaver et al. 1996). However, I remain uncertain whether increased conflicts are due to an increase in bear populations, expansion of their range, or other factors regarding human land use. The results show that bears are at a high risk of coming into conflict with people in summer. Given the absence of reliable population estimates in this region, managers should monitor the impact of nuisance kills on the bear population.

Conflict mitigation is one of the goals mandated by the conservation targets for endangered local populations of bears in several regions of the Japanese archipelago. There have also been demands for the direct prevention of crop damage, for example by the building of electric fences. Nevertheless, a practical habitat management scheme to conserve local populations in the long term is still underdeveloped because of a lack of studies concerning the influence of humans on

bear habitat use and the characteristics of bear habitats. I recognize that this study is only a starting point. There remains an urgent need for further exploration of the interactions between human land use and habitat selection by black bears.

Table 2-1.

Landscape characteristic of the study area in the Central Alps, Japan, 2008–09.

Land cover	Area (km²)	Proportion (%)	Mean
Larch plantation	195.62	19.13	
Coniferous plantation	120.71	11.80	
Broadleaved forest	162.72	15.91	
Red pine forest	140.61	13.75	
Open shrubs and grasslands	31.86	3.12	
Crop/pasture lands	49.99	4.89	
Towns, villages, and paddy fields	104.41	10.21	
Others	216.91	21.21	
Total size	1022.82	100.00	
Mountain area (>900 m above sea level)	840.76	82.2	
Forest cover area (km ²)	619.83	60.6	
Projected area (km ²)	367.77	36.0	
Road density (km/km ²)			3.51
Elevation (m)			12.68
Slope (degree)			26.07

Table 2-2.

Asiatic black bear characteristics and the number of radio telemetry points and home range sizes for RSF modeling, summer in 2009 and 2009 in the Central Japan Alps.

Bear ID	Sex	Age	Body size (kg)	Telemetry locations^a	Random locations^b	Home range size^c (km²)
G1	F	10 ^d	45	533	70	7.0
G2	M	5 ^d	70	278	266	26.6
G3	M	5	39	913	361	36.1
G4	F	8 ^d	63	274	274	27.4
G5	M	4	42	488	224	22.4
G6	M	12 ^d	73	347	914	91.4
G7	M	3 ^d	26	57	158	15.8
G8	M	7	44	72	59	5.9
G9	F	6	44	507	129	12.9
Mean(SD)		7 (1)	49.55 (15.63)	385 (264)	273 (260)	27.27 (26.03)
Total				3,469	2,455	245.5

^aLocation data collected every hour

^bAvailable locations were randomly sampled with a standardized number as 10/km² within an individual home range.

^cHome range size estimated as 100% minimum convex polygon (MCP)

^dEstimated

Table 2-3. Environmental predictors for habitat selection by bears in the study area. Land cover types reclassified for bear habitat from national vegetation inventory and topographic features.

Predictors	Description	Variable code	Units and range
Land cover	GIS vegetation polygons reclassified from National Actual Vegetation Inventory		
Larch plantation	larches <i>Larix leptolepis</i>	karamats	0 or 1
Coniferous plantation	Japanese cedars <i>Cryptomeria japonica</i> Japanese cypress <i>Chamaecyparis obtusa</i>	suginhinki	0 or 1
Broadleaved forest	deciduous broadleaved trees <i>Fagaceae, Rosaceae, Cornaceae, etc.</i>	rayuko	0 or 1
Red pine forest	Japanese red pine <i>Pinus densiflora</i>	akamats	0 or 1
Disturbance	cut lands with regeneration stages	disturbed	0 or 1
Attractants	crop lands and pasture lands	attracts	0 or 1
Near town	paddy fields, villages, and towns	near town	0 or 1
Others	permanent snow, rocks, alpine zone, and water	others	0 or 1
Topographic features	GIS and DEM model from Digital Cartographic Data Standards		
Roads distance	distance from roads (m)	roads	0–2,140 m
Rivers distance	distance from rivers (m)	rivers	0–1,546
Forest edge distance	distance from forest edges (m)	forest edge	0–7,800
Elevation		elevation	456–2,954
Slope		slope	10–81°
Aspect	extracted as polygons from DEM		
North		N	0 or 1
North east		NE	0 or 1
East		E	0 or 1
South east		SE	0 or 1
South		S	0 or 1
South west		SW	0 or 1
West		W	0 or 1
North west		NW	0 or 1

Table 2-4.

Individual coefficients and their averages for population estimate in summer habitat selection by Asiatic black bears in the Central Japan Alps.

	G1	G2	G3	G4	G5	G6	G7	G8	G9	Average
Landcover										
Coniferous plantation		0.736	0.221	-15.170	1.417	-0.013	-0.980	-0.837	1.821	-1.601
Broadleaved forest	0.821	0.341	0.515	1.199*	-0.094	0.058	0.757		0.802	0.550
Red pine forest	-0.083	-0.057	-0.418	-0.012	0.911*		3.988*	2.055	1.543	0.991
Disturbance	-0.048	0.434	0.880*	0.623	0.226	0.238			0.796	0.450
Attracts	-0.521	-0.674	-1.677	-0.849	-1.857*	0.510	3.737	0.748	0.081	-0.056
Neartown		-0.688	-0.445	1.077	-2.566*	-0.820	-15.290	-0.888		-2.803
Others		-0.547	-14.910	0.516		1.085		-16.300	-14.990	-7.524
Topographic features										
Roads distance $\times 10^2$	0.076	-0.378	-0.202	0.958*	0.792*	-0.361*	-0.189	0.484	0.211	0.155
Roads distance ² $\times 10^4$	-0.074	0.035*	0.003	-0.218*	-0.177*	0.015*	0.025	-0.144	-0.004	-0.060
Rivers distance $\times 10^2$	0.153	-0.134*	-0.370*	0.042	0.011	-0.105*	0.170	0.212	-0.028	-0.005
Elevation $\times 10^2$	-1.056	0.147	0.168	-3.617*	2.381	0.786	0.833	2.773	0.661	0.342
Elevation ² $\times 10^4$	0.025	-0.014	-0.019	0.154*	-0.139	-0.036	-0.036	-0.135	-0.049	-0.028
Slope	0.021	0.011	0.024*	0.028*	0.023	-0.007	0.0001	0.023	-0.001	0.014
Aspects										
North	-0.042	0.331	-0.106	-0.233	0.510	-0.267	-0.525	-1.245	-0.116	-0.188
North East	-0.061	0.208	-0.508	-0.198	-0.069	-0.448	-0.914	-0.192	0.054	-0.236
South East	0.165	-0.281	-0.354	-0.126	-0.402	0.111	0.727	-0.121	0.645	0.040
South	-0.984	-0.468	-18.440	-0.672	0.039	-0.173	-0.453	-0.360	1.980*	-2.170
South West	-0.571	0.045	0.005	0.012	1.567	-0.342	-0.852	0.966	-0.023	0.090
West	-0.164	-0.933	-0.016	-0.212	0.926	-0.424	-0.082	15.950	-0.833	1.579
North West	0.059	-0.124	-0.082	-0.078	0.870	-0.828	-0.912	0.024	-0.710	-0.198

* Significant mark of $p < 0.005$

Landcover reference variable is Larch plantation, and Aspects reference variable is East.

Table 2-5.

Odds ratio of bear habitat selection in summer for the major vegetation types compared to matrix vegetation types (significance defined at $P < 0.005$).

	Coefficients	SE	<i>P</i>	Odds ratio	95% CI	
					Lower	Upper
Larch plantation	-0.195	0.068	0.004	0.823	0.720	0.940
Coniferous plantation	-0.324	0.124	0.009	0.723	0.567	0.922
Broadleaved forest	0.145	0.078	0.065	1.156	0.991	1.348
Red pine forest	0.664	0.086	<0.00	1.943	1.643	2.298
			1			
Disturbance	0.524	0.141	<0.00	1.688	1.281	2.225
			1			

Table 2-6.

The index of human–bear encounter risk with respect to human accessibility and bear habitat use.

	Human accessibility	Mean road density (km/km ²)	Proportion of total area	Proportion of RSF value 6–10 in ranked area	$U(x)^a$	Index of human–bear encounter risk ^b
Zone 1	high	7.74	0.20	0.21	0.0028	0.0216
Zone 2	moderate	1.86	0.34	0.65	0.0066	0.0123
Zone 3	low or none	0.95	0.46	0.14	0.0010	0.0009

^a Frequency of RSF value for each ranked area.

^b Estimated from multiplied $U(x)$ by mean road density.

Probability of habitat selection

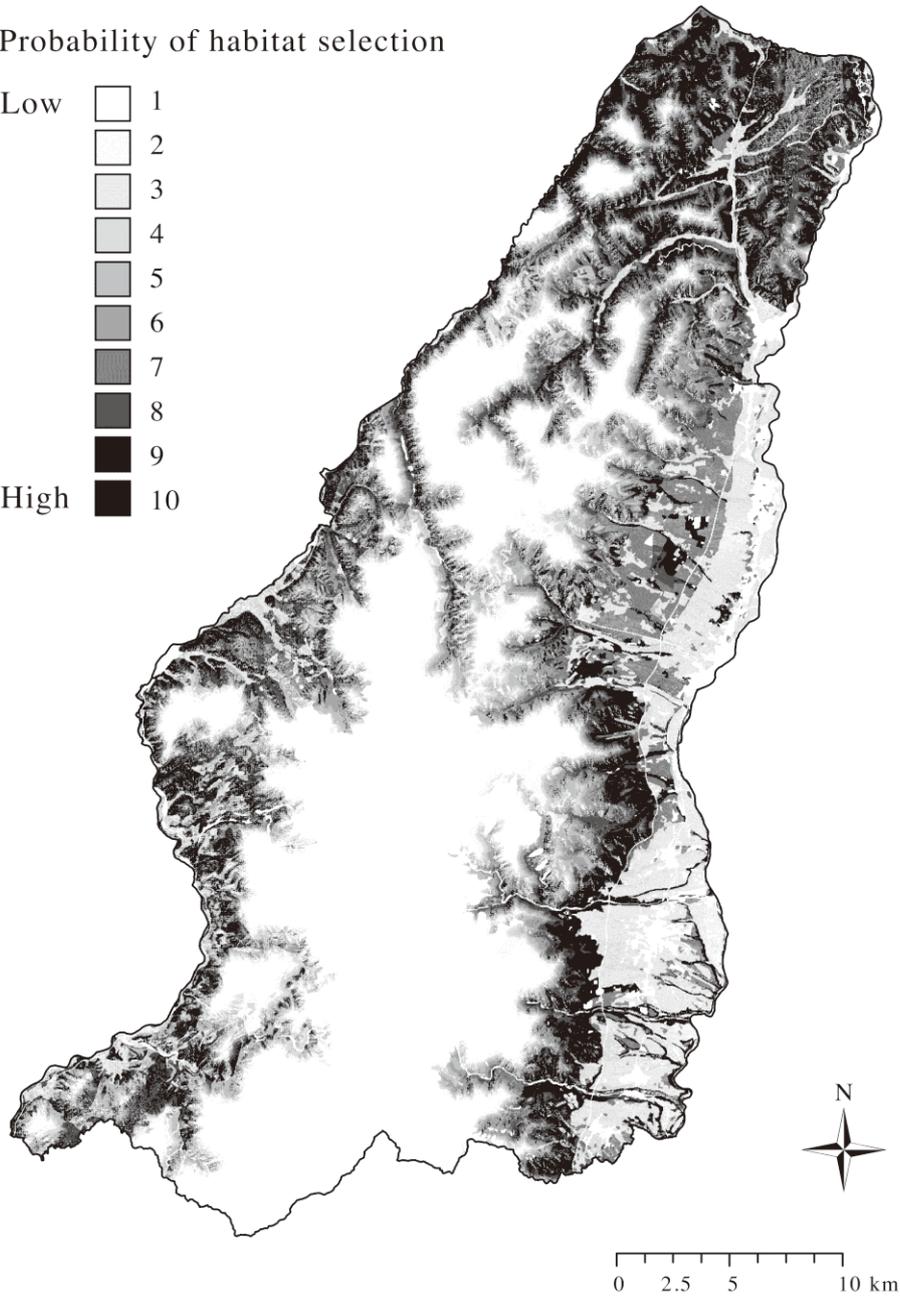
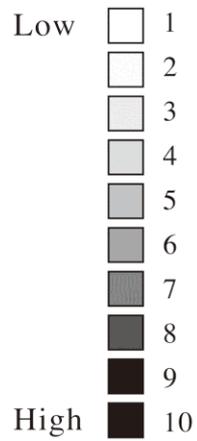


Fig 2-1.

Predicted distribution of the relative probability of summer habitat selection of Asiatic black bears in the Central Japan Alps. The levels of selection are shown from black (high probability) to white (low probability).

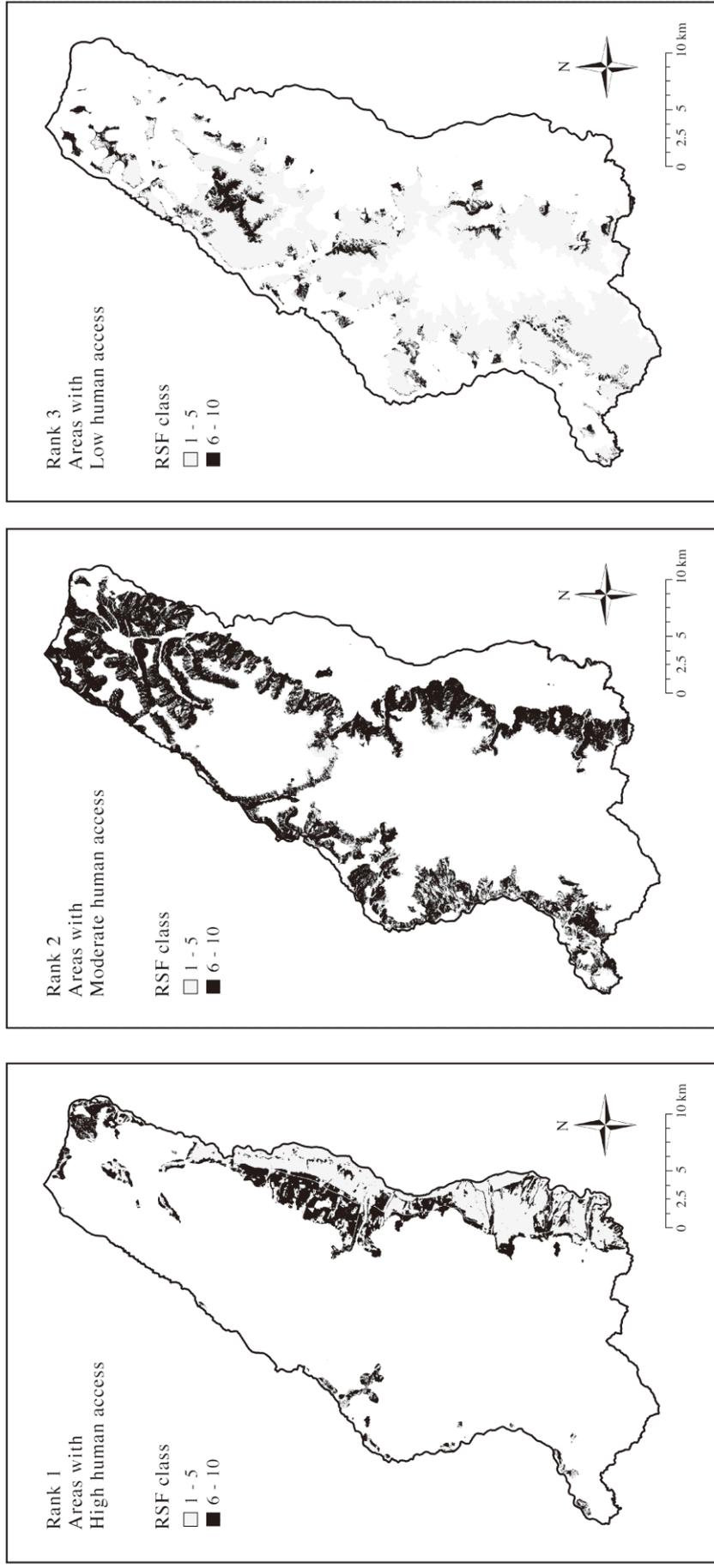


Fig 2-2.

Distribution for the relatively higher probability of bear summer habitat use (RSF class 6–10) in 3 zones of human accessibility in the Central Japan Alps.

CHAPTER 3

HABITAT SELECTION OF A LARGE CARNIVORE ALONG HUMAN-WILDLIFE BOUNDARIES IN A HIGHLY MODIFIED LANDSCAPE

ABSTRACT:

When large carnivores occupy peripheral human lands conflict with humans becomes inevitable, and the reduction of human-carnivore interactions must be the first consideration for those concerned with conflict mitigation. Studies designed to identify areas of high human-bear interaction are crucial for prioritizing management actions. Due to a surge in conflicts, against a background of social intolerance to wildlife and the prevalent use of lethal control throughout Japan, Asiatic black bears (*Ursus thibetanus*) are now threatened by high rates of mortality. There is an urgent need to reduce the frequency of human-bear encounters if bear populations are to be conserved. To this end, I estimated the habitats that relate to human-bear interactions by sex and season using resource selection functions (RSF). Significant seasonal differences in selection for and avoidance of areas by bears were estimated by distance-effect models with interaction terms of land cover and sex. Human-bear boundaries were delineated on the basis of defined bear-habitat edges in order to identify areas that are in most need of proactive management strategies. Asiatic black bears selected habitats in close proximity to forest edges, forest roads, rivers, and red pine and riparian forests during the peak conflict season and this was correctly predicted in human-bear boundary maps. These findings demonstrated that bears selected abandoned forests and agricultural lands, indicating that it should be possible to reduce animal use near human lands by restoring season-specific habitat in relatively remote areas. Habitat-based conflict mitigation may therefore provide a practical means of creating adequate separation between humans and these large carnivores.

INTRODUCTION:

As human land domination has expanded, many species have disappeared from their primary range. Nevertheless, some carnivores still survive within or near anthropogenic landscapes (Bateman and Fleming 2012). There are several reports of large carnivores periodically frequenting peri-farmlands: for instance, grey wolves *Canis lupus* (Treves and Karanth 2003); bobcats *Lynx*

rufus (Tigas et al. 2002); and American black bears *Ursus americanus* (Beckmann and Berger 2003). The inevitable consequence of the proximity of wildlife habitats to human-dominated lands is an increase in undesirable human-wildlife interactions, which in many cases involving a large carnivore can be fatal for both. The conservation of large carnivores newly adapted to human landscapes is one of the greatest challenges facing local wildlife managers because of the difficulty of reconciling the ecological requirements of animals with the need to preserve human life and property. The reduction of human-carnivore interactions is critical to the sharing of finite land, and this only seems possible through a better understanding of the processes and patterns involved in the use of human landscapes by wildlife.

Attention must first be directed to areas which animals find particularly attractive. Because only limited areas remain undisturbed in anthropogenic landscapes, animals need to find ways to derive some benefit from their habitat while simultaneously keeping their distance from the risks posed by humans. For instance, American black bears avoided frequent contact with people by shifting their core active time from day to night (Beckmann and Berger 2003). An intermediate level of housing density a short distance from a large forest edge was the main factor in human-bear interaction as it offered a combination of foraging opportunity and defensive refuge (Merkle et al. 2011). The effects which distance from human disturbance has on wildlife have been assessed worldwide (Apps et al. 2004, Waller and Servheen 2005, Reynolds-Hogland and Mitchell 2007). Most previous research has been conducted on a broad scale, and there have been few studies done at a fine scale and in highly populated areas in which there is a substantial overlap with wildlife habitats.

Areas of overlap in human-wildlife habitat result in linear-shaped boundaries where both habitats are separated by distinct dichotomic geographical and ecological features (e.g. forest cover and open, flat and rugged terrain, etc.). The extent and structure of human-wildlife boundaries are an important factor in human-wildlife interaction. For example, sufficient space and environmental gradients within a boundary may give both people and animals a chance to avoid sudden and frequent contacts. In contrast, a boundary without enough space or tonal structure becomes a potential source of human-wildlife conflict. In some developing regions, such sharpening of human-wildlife boundaries has occurred due to massive land use expansion. It also happens in other regions where, conversely, land use changes by de-populated and aged rural societies cause wildlife habitat use to shift back toward the fringes of agriculture or urban areas. Increased tension is the inevitable consequence of sharpened human-wildlife boundaries. Large carnivores in particular suffer from a high risk of mortality due to the fears of local communities who have experienced fatal encounters, even if only on rare occasions. Although conflict mitigation is critical

to the conservation of large carnivores in peripheral human lands, investigations of the habitats potentially associated with human-carnivore encounters have seldom been conducted (Merkle et al. 2011). Delineating naturally occurring human-wildlife boundaries also has the potential to help land use managers prioritize areas for management.

In Japan, current changes in human land use may have effects on the distribution and structure of human-wildlife boundaries. One of the more distinct land use changes has been a drastic reduction in the traditional use of coppice forests on the fringes of agricultural fields or settlements (see detail in (9)). Such secondary forests have become densely covered after the cessation of logging, and the area of unmanaged privately owned forests has reached about 30% of total forested lands (Forestry Agency 2011). Constant human presence and open patches in the secondary forests formally played an important role in preventing direct and frequent contact with wildlife. Moreover, about 11% of farmland has been abandoned since the 1960s due to a nationwide decline and the aging of the rural population (Ministry of Agriculture, Forestry and Fisheries 2012). For the last decade, Asiatic black bears *Ursus thibetanus* have experienced high mortality due to a surge in conflicts and contacts with people. In 2006, unusually large numbers of bears were sighted within and around rural and suburban lands, and as a result about 40% of the estimated total Japanese black bear population was killed (Ministry of the Environment 2008). In Nagano prefecture, the number of destroyed bears was 558, well in excess of the 150 estimated to be necessary to maintain viable populations (Kishimoto 2009). This was partly due to intolerance of wildlife on the part of local communities (Sakurai and Jacobson 2011), but also to an unreliable population estimate. Even though Huygens (Huygens et al. 2004) reported no association between damage costs and prior-year bear kills, lethal control is still the major management method in Japan. A precautionary principle should be applied to Asiatic black bears in Japan because carnivore populations are seriously impacted by social intolerance and the prevalence of lethal control (Ferguson and Larivière 2002, Treves and Karanth 2003). Under such circumstances, a reduction in the frequency of bear use near human-dominated lands is an urgent need if the number of bears killed is to be reduced.

I focused on habitat selection by Asiatic black bears near human landscapes to identify the key factors potentially associated with frequent contact and conflicts with humans. First, using GPS bear location data by sex-season groups, I examined how bears responded differently depending on the season to distance from roads, forest edges and rivers on the assumption that such linear landscape features influenced the shape of human-bear boundaries. I hypothesized that strongly selected variables during summer compared with autumn would be the key factors relevant to conflicts because summer is the peak season of human-bear conflict. Second, I estimated resource selection functions (RSF) to predict the distribution of relative probability of bear selection for each

sex-season group. Finally, I delineated the human-bear boundaries by defining the edges of both bear habitat and human-dominated land. It was expected that this study would provide local wildlife managers with spatial models that help prioritize the location of management needs including the re-establishment of buffer functions and the development of adequate pre-avoidance schemes. This research aimed to explore a habitat-based approach to conflict mitigation to achieve co-existence with these elusive large carnivores occupying the fringes of human-dominated land.

METHODS:

Landscape Covariates

Landscape features relevant to Asiatic black bear habitat and anthropogenic lands were reclassified into 9 land cover types from a satellite image taken on 22nd June, 2007 (ALOS-AVNIR2) by a supervised mapping technique using Multispec v 3.2.1© (Purdue University). The land cover categories consisted of 5 types of forest cover, 1 open-forest, 2 human-dominated landscapes and others (Table 3-1). Generally, a forest has diverse structures depending on its successional stage, and can provide different foraging opportunities for bears. For this reason, I generated a forest age map from the polygon layers on the Basic Planning maps produced by the National and Regional Forestry departments, and I reclassified 10 indices according to the age of the forests by referring to the historical records of forest management in the Basic Planning maps.

To explore how Asiatic black bears are affected by abiotic conditions, I created terrain raster predictors using various GIS algorithms applied to a 10 m Digital Cartographic Data Standards digital elevation model (DEM). Given the high ratio of mountains in this study area, terrain roughness was generated by calculating a square root of standard deviation of the DEM using the roughness tool (Geomorphometric and Gradient Metrics Tool). According to the general principles of ecology, conditions of sunlight and water are the major factors determining a plant community's potential to affect local wildlife food distribution. To include a variable of potential water content of soils, a compound topographic index (CTI) was developed by combining slope and flow accumulations calculated from the DEM. The degree of incoming solar energy for each pixel was computed by employing the solar radiation analysis tool in a spatial analyst extension (ArcInfo9.3©) capable of taking into account the effects of latitudinal and local terrain uniqueness on insolation. I set two days as representative for each season, 1st August for summer and 1st October for autumn. Four distance variables were estimated: roads in open land (open roads), roads in forest cover (forest roads), forest edges and rivers. I then measured the nearest distances to each

bear location. To create the forest-edge map, I reclassified the 9 land cover types into 2 major land cover types, open and forested lands. Using both the edge-enhancing and smoothing filters in the Neighborhood tool in the spatial analyst extension, I delineated the border lines between open and forest lands as forest edges. All maps were prepared as rasters at a 10m resolution to facilitate the raster calculations necessary to develop and apply an RSF value to each pixel (Table 3-1).

Animal location data and sampling design

I used hourly GPS locations collected from 24 bears (14 females and 10 males) during both summer and autumn in 2008-2011. I defined summer as the period from 1st July to 10th September, and autumn as being from 11th September to denning according to dietary pattern correlated with seasonal shift. Resource selection functions (RSF) were estimated following a design III-1, as suggested by Manley et al (2002) where individual animals are identified with used resource units defined by telemetry data and available resource units randomly chosen from within the home ranges of individual animals. I delineated MCP (the minimum convex polygon) as individual home ranges derived from the GPS relocation data for each bear, and sampled 1000 points randomly from each MCP to yield the available resource units on the assumption that all resources within the MCP would be available to the bear during a season. The landscape attributes of the used units were contrasted with those of the available resource units using logistic regression to model habitat selection by Asiatic black bears.

Investigation of spatial distance effects

On the assumption that summer-specific habitat selection would be relevant to the frequency of human-bear interactions, I focused on seasonal differences in probability of bear selection in terms of distance from roads, rivers and forest edges using logistic regression based on used-available locations as the binary response variable. Starting with a model for the single explanatory variable of continuous distance (D) as the base line, I manually structured a distance-effect model by stepwise addition of quadratic terms of distance (D^2), season (SS), sex (SX), land cover (LC) and three interactions with season (D:SS, SS:SX, SS:LC). Log-likelihood, AIC (Akaike's information criteria) and Δi values were used as measures for the selection of the final distance-effect model for each linear landscape. The final model was used to investigate which of the covariates had substantial effects on the differences between summer and autumn by predicting the odds ratio of selection by Asiatic black bears (Table 3-2).

The logit-odds of the final distance-effect model was calculated by using the following equation:

where p was probability of bear selection, and β was a coefficient. And the logit-odds for bear selection during summer (season=1) relative to autumn (season=0) were given by the equation,

The aim of the distance-effect analysis was to determine which land cover types were significantly responsible for the large differences between the two seasons with respect to bear selection. In order to yield the odds-ratio between seasons, I ran models for each sex-land cover combination by controlling the interaction terms of the categorical variables SS: SX and SS: LC in equation (2) applying the coefficients β_5 and β_7 . A total of 64 models (8 land cover: 2 sex for each linear landscape) were developed to estimate the odds ratio by adjusting the mean value of the continuous distance variable. I selected models containing land cover types that influenced the first and second largest differences between summer and autumn according to the odds ratio, their absolute differences being calculated by subtraction from 1 (= no selection) with elimination of the sign, and the significant level measured by the Wald test ($p < 0.001$). Finally, I set 6 specific distances from 0 to 2000m and predicted a mean probability of bear use at each distance to assess how much variation in seasonal response by bears would be explained by land cover variables as distances changed.

Habitat model structure and validation

Since effects of distance decline rapidly as bear locations occur beyond the linear landscape feature, I transformed distance variables into exponential decay functions, $e^{-\alpha d}$ where $-\alpha$ was the decay constant and d was distance (m) from the linear landscape. (Nielsen et al. 2009). Quadratic terms in continuous predictors, except the non-linear exponential decay variables, were included if necessary, and interaction terms potentially relevant to foraging habitat and anthropogenic factors were added. Prior to variable selection, co-linearity among linear predictors was checked, and variables correlated with more than three other variables were removed. For model selection, I employed a mixed effect logistic regression with random intercept to balance the disproportional number of observations among individual animals (Gillies et al. 2006). To develop a plausible model in terms of bear biology, I conducted univariate logistic regression and a manual step-forward procedure (Hosmer and Lemeshow 2000). After determining the full variable sets suitable to each sex-season group model, I constructed a global model incorporating all the

variables in order to make comparisons among sex-season groups to determine how the predictive human-bear (HB) boundaries differed.

I built an individual RSF model separately for each bear, and averaged the coefficients within the sex-season group. I expected that disproportional error rates would be caused by the variety of sample sizes in some variables among individual animals, and that this would have substantial effects on the averaged coefficients. For example, the reliability of coefficients for individual bears were not equal when sample sizes in a land cover type differed significantly among the bears. To deal with these imbalances, I used an inverse variance weighted method to obtain appropriate averages that incorporated the differences in standard error for each parameter estimate. (Nielsen et al. 2009). Next, I applied the mean coefficients to each predictor of GIS layers to develop RSF habitat maps. A reclassifying tool with quantile breakpoint was used to rank the RSF values into 10 classes to represent the spatial distribution of relative probability of habitat selection by Asiatic black bears across the target research area. To assess the credibility of the predictive performance of the RSF models, I prepared 2490 GPS observations for testing as samples independent of the training data used for model building. I first calculated the utilization function $U(xi)$ for each predicted RSF class. The mid-points of the RSF values were multiplied by the area of each RSF class, and divided by the total value to obtain the $U(xi)$ for each class (Johnson et al. 2006). The total number of the test data was multiplied by the $U(xi)$ to determine the expected frequencies fell within each RSF class. And then, using a linear regression, I contrasted the expected frequency and observed frequency to assess the significant level of the slope by R^2 and χ^2 goodness of fit test (Johnson et al. 2006).

Human-Bear (HB) boundary delineation

I identified HB boundaries by employing an edge-detection technique based on a focal statistical tool involving a moving window GIS operation. First, I combined farmlands, paddy fields, human-settled areas and roads into one landscape layer that represented “human lands”. Second, I created bear-habitat edges by transforming the RSF maps with a circle-shaped moving window that determined the value of each pixel from the sum of its surrounding pixels. The generated bear-habitat maps were classified into three types (0 = others, 1 = sharp edge, 2 = moderate edge) with sharp edge defined by RSF classes 9 and 10, and moderate edge by RSF classes 7 and 8, respectively. In the same manner, the edges of human lands were detected and classified into two types (0 = others, 1 = edge). The edges of both bear habitat and human lands were determined by using a moving window circle with a 6-pixel radius (60m) on the basis of animal movement. Here, I used the

median step length (sequential distance between each location), which was about 70-100m for the 4 groups of Asiatic black bears in this study. Finally, I multiplied the edges of bear habitat and human lands to generate 2 ranked boundary areas. The boundary was classified into two types (1=sharp HB boundary, 2=moderate HB boundary) by performing a raster calculation with the two edge layers as follows: (habitat edge; 0, 1, 2) × (human land edge; 0, 1). The non-overlapping edges were then zeroed out (0 0, 0 1 and 0 2) to leave only pixels of human-edge equal to 1 (1 1 and 1 2). All my GIS work was performed on ArcGIS (ESRI v9.3[©]) and statistical work was done in Stata (SE v12.0, College Station, Texas).

RESULTS:

I collected a total of 44,652 bear locations across sex-season groups (F-summer, N=10297, mean 792 ± 278 SD; F-autumn, 14357, 1044±411; M-summer, 9788, 979 ± 430; M-autumn, 10210, 1021 ± 456). On average, female MCP home ranges (summer, mean 21.96 ± 40.83km² SD; autumn, 24.45 ± 25.72km²) were smaller than those of males (summer, 38.52 ± 44.44km²; autumn, 99.55 ± 107.64km²; t-test on the paired two samples of females and males, p=0.008, df=19), and the MCP ranges of most bears included human-dominated lands (F-summer, 9/13=9 of 13 bears; F-autumn, 10/13; M-summer, 10/10; M-autumn 9/10).

Distance effects of linear landscapes on bear responses

Asiatic black bears showed significant seasonal differences in their responses to distances from open roads, forest roads, rivers and forest edges (e.g. $\chi^2=1107$, $df=2$, $p < 0.001$ in a comparison of Road_open_dist models between D+D² and D+D²+D:SS). The manually constructed model (stepwise variable entry) revealed that the land cover covariate had a substantial influence on model fit for all distance variables, and the inclusion of season and land cover interaction (SS:LC) dramatically improved models indicated by Δ_i which is the difference in AIC between models (e.g. $\chi^2=2197$, $df=15$, $p < 0.001$ in comparison of Forest_edge_dist models between D+D²+D:SS+LC and D+D²+D:SS+SS:LC) (Table 3-2). As a result, for all linear landscapes I selected the final distance-effect model with the lowest AIC that contained quadratic terms of distance and season inclusive of all interactions. I then used the models to investigate the seasonally varied response of Asiatic black bears to distance from the linear landscapes.

Table 3-3 illustrates the odds ratio yield by equation (2) using coefficients of the selected distance-effect models that resulted in an effect size for each of the land cover covariates on a seasonal difference in the probabilities of selection by Asiatic black bears. As shown in the

distance-effect models for open roads, the absolute difference in the odds ratio between the two seasons was the greatest in the model with alpine forest as a land cover covariate, followed by the model with open regenerating lands and deciduous forest ($p < 0.001$). The other three distance-effect models revealed significant seasonal changes associated with deciduous forest and red pine forest (Table 3-3). In addition, I observed a significantly positive red pine forest selection in summer relative to autumn and, conversely, a significantly positive selection of deciduous forests in autumn relative to summer regardless of sex difference.

Note that the odds ratio for summer versus autumn in the distance-effect models referred to above was estimated only by holding the continuous distance variables at their mean. Therefore, I predicted the changes of probability of bear use as changes in distance from the linear landscapes by estimation of the mean probability at the specific distance (Fig. 3-2 a-d). To develop graphs of each distance-effect prediction, I used models incorporating the top two most influential land cover covariates for seasonal difference without discriminating between sexes because sex differences had a less marked effect on seasonal changes than land cover covariates (Table 3-2). It was assumed that predictions produced using the open-road model with alpine forest were less relevant to bear selection because of the very long distances between geographical locations, so alpine forest was excluded as a predictor.

According to the predicted forest-edge distance-effect model (Fig. 3-2 a), the probability of use by Asiatic black bears increased dramatically as distances from forest edges shortened during summer. Selection within both deciduous and red pine forests exhibited similar trends in summer, and the difference between the mean probabilities for the two forests was much smaller than the difference during autumn (1/7 difference: mean of three distances; 200m, 500m, 1000m). Probability of bear use increased with increasing proximity to forest road in both seasons (Fig. 3-2 b), but the pattern varied slightly. For example, there was a dramatic decline in probability of use at a distance of 200m to 500m in red pine forest during summer whereas bear use within a 500m distance was relatively stable during autumn in both deciduous and red pine forests. In the open-road model, the probability of bear use in open regenerating lands near open roads was higher during summer than in autumn, while the probability in deciduous forests near roads was lower in summer than in autumn (Figure 2c). A high probability of bear use close to rivers occurred only in summer. The difference between the two forest types was very small in summer compared with the difference in autumn, and this was similar to patterns observed in forest-edge and forest-road models (Fig. 3-2 a,b). Overall, the changes in probabilities as distance increased were more gradual in the open-road and river models (Fig. 3-2 c,d). Therefore, it seems that open roads and rivers had more extensive distance effects on selection by Asiatic black bears than forest edges or forest roads.

Habitat Selection by Asiatic black bears

Elevation was removed from the final variable because of a close correlation with open roads ($R^2=0.75$), forest roads ($R^2=0.59$) and roughness of terrain ($R^2=0.53$). CTI was excluded due to its lower contribution. According to the results from the distance-effect models, the effects of open roads and rivers seemed more extensive than those of forest roads and edges (Fig. 3-2 c,d). Therefore, I determined the decay constant α for the exponential form of distance variables to be -0.005 for open roads and rivers, and -0.01 for forest roads and edges since a smaller value for the constant yields a more gradual decay. Those values, however, were roughly set as I had observed that the range of distance effects varied depending on the land cover types (Fig. 3-2 a-d). In the final variables selected by univariate logistic regression (Table 3-3, 3-4), there was a significant seasonal difference among predictors. In summer, both female and male bears strongly selected areas in close proximity to forest-edge. Although forest roads, rivers and solar radiation had a relatively weak influence as single predictors, once forest edges were associated with these covariates, it provided a positive or negative leverage to remain ranked in the top 5.

The habitat selection models indicated that bears constantly selected deciduous forest year round (Table 3-6). In particular, the selection during autumn was highly significant ($p < 0.001$). I found a remarkable selection of areas near forest edges during summer for both sexes. For instance, the probability of bear selection at a 20m distance from forest edges was about two times higher than at a 100m distance for female bears (odds 3.74/1.81), and about three times higher for male bears (odds 7.00/2.40). Distance to rivers was a strong predictor in the multivariate summer-habitat model, especially associated with forest edges (Table 3-6, 3-7). The difference between the odds ratio at 20m and 100m distances from rivers (Female: 3.03, Male: 7.36) increased where forest edges (20m distance) were associated with rivers (Female: 21.45, Male: 18.01). Overall, forest-edge effects on bear selection nearly disappeared during autumn. Female bears generally avoided areas near forest roads in summer (odds 0.67 at 20m), but selected in autumn (odds 2.26 at 20m). In contrast, male bears selected areas near forest roads during summer (odds 1.40 at 20m), but avoided such areas during autumn (odds 0.44 at 20m).

Habitat predictions and Human-Bear (HB) boundary maps

Overall, the averaged coefficients from individual models were consistent with population models (Table 3-7). There were large error rates in the estimates of coefficients for some bears because their home ranges were exceedingly isolated from open roads. However, I confirmed that the inverse variance weights worked reasonably well to offset these unbalancing effects on the

averaged coefficients for the population estimates. The final RSF maps had acceptable predictive performances for the independent test data sets (F-summer, $R^2=0.84$, $df=9$, $p<0.01$; F-autumn, $R^2=0.93$, $df=9$, $p<0.01$; M-summer, $R^2=0.80$, $df=9$, $p<0.01$; M-autumn, $R^2=0.93$, $df=9$, $p<0.01$). The HB boundary zones were estimated for each sex-season group (Figure 3). Boundaries stretching along rivers and the fringes of foothills were a common characteristic among the 4 group models, and the extent was greater in male than female HB boundaries. The range of female-summer HB boundaries was about 28.6% of the area of high RSF classes, and it decreased to 4.3% in autumn as male HB boundaries decreased from 49.9% in summer to 10.5% in autumn. Notably, male bears exhibited a high probability of use in the HB boundary zones during summer, as was evidenced by the fact that 9.4% of test GPS locations fell within this boundary zone (Table 3-5).

DISCUSSION:

Key habitat components relevant to human-bear interactions

Despite the common perception of bears as mature forest-interior dwellers, the frequency with which Asiatic black bears selected sites near forest edges was greater than random. Forest-edge selection has been reported in several studies on Grizzly bears (Nielsen et al. 2004a, Stewart et al. 2013), Scandinavian brown bears (May et al. 2008) and American black bears (Lyons et al. 2003). To my knowledge, this is the first report of forest-edge selection by Asiatic black bears. The importance of phenology in bear habitat selection is well attested (Munro et al. 2006, Nielsen et al. 2003, Davis et al. 2006). Therefore, the great seasonal change in red pine forest and deciduous forest indicates that the availability of food may be the main reason for the selection of forest edges, which provide herbaceous and fruiting food during the most food-scarce season (Huygens et al. 2003). On the other hand, bears may use edge space as a refuge for hiding. Grizzly bears selected forest-edge areas in open regenerating lands (Nielsen et al. 2004a), and brown bears used habitat edges for a day bed to avoid diurnal human activities (Ordiz et al. 2011). In my case, Asiatic black bears preferring to stay on the edge of a red pine forest during summer run the risk of encountering people because forests are commonly located adjacent to agricultural and residential areas in this landscape. Bears are known to have complex responses to roads, and the segregation of road types successfully revealed different responses to open roads and forest roads. There was no clear avoidance of open roads, which accords with previous findings of a neutral response to high-use roads by bears (Van Manen et al. 2012, Roever et al. 2010). However, my distance-effect model clearly demonstrated that bear response to roads differs according to the land cover near the road. Despite the differences, Asiatic black bears selected red pine forests and deciduous forests near

forest roads during both summer and autumn. This might be explained by the fact that roads in forests provide surrogates for the kind of natural openings which have recently decreased in this region. My habitat selection models support the findings of sex-season specific responses to the forest roads in earlier studies (Gaines et al. 2005, Gibeau et al. 2002). For example, subordinate individual bears such as females with cubs or young males made use of human-influenced areas (Elfström et al. 2012), and adult male bears displayed a greater tolerance of using roads as a movement corridor (Roever et al. 2010). In the case of Asiatic black bears, the greater seasonal difference found for males can be explained by the fact that their larger home range contains a relatively large portion of deciduous forest, rich in autumn food resources, at a moderate distance from forest roads.

Riverside environment strongly affected the summer habitat selection of Asiatic black bears, functioning as an eco-tonal belt providing various edible plants with a combination of light and moisture (e.g. *Cardiocrinum* sp, *Petasites* sp) (Huygens et al. 2003). The selection of red pine forest can be explained by the abundant understory of fruiting shrub species, attractive to bears during the season of food shortages. The significant reduction in the selection of red pine forest during autumn may reflect the fact that there is an abundance of food such as insects, particularly ants (Fujiwara et al. 2012), in the summer only. The forests extend continuously from the foothills to the riparian forests in the lower plains that draw bears to areas encompassed by agriculture and urban landscapes. Remnant riparian forests offer bears a linear habitat with sufficient cover for foraging and bedding (Lyons et al. 2003) and a dispersal corridor for a large range of movement (Pereira and Rodríguez 2010, Singleton et al. 2004). Despite this potential, the green corridor can undermine populations as it leads to frequent contacts with people (Wilson et al. 2006). In this study landscape, the riparian forest that ended up facing the urban fringe does not function as a corridor. Young adult males are both the largest dispersers and the group of bears with the highest mortality (Kishimoto 2009). Therefore, the riparian forests in this region have an adverse effect on the survival of these bears by playing the role of “false dispersal corridors”.

In autumn, the land-cover variable was the best predictor in my univariate logistic regression (Table 3-2), and a preference for deciduous forest was prominent during the hyperphagia season due to a high correlation with the availability of fruited oak trees (Koike 2010, Hashimoto et al. 2003). The substantial difference between deciduous and red pine forest was revealed by my distance-effect models in autumn. In contrast, the smaller difference between the two forests in summer implied the importance of bear food occurring in edges or understory regardless of forest type. Over all, the great seasonal differences in my habitat model may reflect the amplified temperature gradient caused by the combination of temperate climate and montane slope exerting a

significant influence on phenology. On the one hand, it should be noted that the habitat models did not include variables of time of day. The importance of temporal aspects in habitat selection has been stressed by several recent studies (Ordiz et al. 2013), and adding temporal variables may bring an important new dimension to our understanding of how bears use peripheral human lands.

Predicted human-bear boundaries

The human-bear boundary maps gave a reasonably accurate picture of remarkable seasonal differences, and the patterns of bear response to linear landscape features were successfully shown. Consequently, I am confident that the largest extent of human-bear boundaries during summer corresponds to the peak season of human-bear conflicts and incidents (Takahata et al. 2013). The boundaries of male bears were similarly distributed in both summer and autumn against significant seasonal differences in the females' map. I observed that some male bears were attracted by specific croplands and stayed for longer periods after the date chosen to partition the seasons. This is why the pattern of autumn boundaries remained similar to that in the summer. During the inter-crop season, croplands producing food attractive to bears (e.g. corn, apples and other fruits) have potentially negative impacts on the seasonal migration of bears by detaining bears longer, changing their intrinsic behavior and so causing chronic conflicts (Spencer et al. 2007).

Influence of human land use changes on human-wildlife interactions

Although the negative impacts of large-scale deforestation on primary bear habitat is obvious (Mattson 1990, Schoen 1990), it has also been recognized that open regenerating lands after timber harvests are beneficial to American black bears (Cunningham et al. 2003, Jones and Pelton 2003) and Grizzly bears (Nielsen et al. 2004a). Brodeur et al (2008) reported that open regenerating shrubs offer a high density of fruit plants. Likewise, patchily distributed early serial fruits were found to be an important resource for Asiatic black bears during the summer food shortage (Koike 2010, Hashimoto et al. 2003). The increasing number of abandoned villages and farmlands might offer Asiatic black bears an attractive alternative to open shrub land. I was not able to distinguish between actually used and abandoned farmlands from the satellite image, and I recognize this may be the reason for the positive association of farmlands and bear habitat in my models. Additionally, red pine forest is a typical semi-natural growth after cessation of logging. Given that they are commonly located near or within human landscape, abandoned farmlands and red pine forests are key areas with respect to the need to strike a balance between the conservation of summer bear habitat and the reduction of human-bear contacts.

Bears occurring in forest edges adjacent to human settlements risk being sighted by people, and in many cases this results in bear mortality. Mountain roads in my region are used for both forestry and recreation, such as hiking, fishing and picking wild edible plants. The unexpected human presence resulting from these irregular activities can threaten bears in nearby forest edges or on forest roads and lead to tragic encounters. It is equally important to exercise caution in riparian forest areas. And there is also a high risk that croplands located near the linear green belt will change the natural behavior of bears. Given the inevitable bear use of areas near human-dominated lands during summer, pre-avoidance schemes to regulate access to the HB boundary zones should be established to minimize encounters with bears.

Management implications and future directions

Creating spatial separation between humans and large carnivores is a challenging task for wildlife managers worldwide. One simple and efficient method is to construct physical barriers, and electric fencing around cropland has become widely used to prevent crop damage by wildlife. Another option is to create buffer zones. For example, cover can be removed by clear-cutting forest-edge shrubs to increase permeability and so deter wildlife from lingering near human lands. Such indirect means of preventing encounters by changing wildlife behavior would be effective only if implemented in the key areas predicted on the basis of reliable habitat estimates. Given the complexity of the problem, it is necessary to endeavour to change not only wildlife behavior, but also human behavior. Human security is a genuine concern for people living close to occupied carnivore habitats. There are specific areas and periods in which human-wildlife interaction becomes more likely. For example, my RSF model indicated that there is an about 80% probability that farmlands producing bear attractants within 100m of a forest edge will suffer damage. Such quantifying of risk on a fine scale in this way can be useful for wildlife managers seeking to persuade local farmers to change crops. Knowledge sharing with local communities is critically important (Glikman et al. 2009), particularly in the case of large carnivore conservation where excessive fear exists, and my visualized maps are likely to be helpful in attempts to change local attitudes.

The findings indicate that red pine forest is the main reason for bear occurrence in peripheral human lands in this region. It is, however, not practical and against conservation practices to eradicate all red pine forests in order to drive bears from the foothills. Traditional coppice forest (called *Satoyama* in Japanese) management has been shown to be beneficial to species diversity (Katoh et al. 2009), insofar as it entails only intermediate levels of human disturbance. For this reason, restoration of *Satoyama* management of red pine forest is probably the most suitable way of

creating buffer structures without the removal of the critical summer habitat of Asiatic black bears. At a broader scale, large areas of plantation are left unmanaged, resulting in increased canopy closure and a dramatic reduction of open regenerating lands and edge habitat in mountain areas. I expect that the creation of open lands in unmanaged plantation, by providing a suitable summer habitat for bears in areas isolated from human landscape, would provide a new opportunity to reduce human-bear interaction.

The rapid increase in human-wildlife interaction in Japan against a background of an aged and de-populated rural society, and the abandonment of forestry and agricultural practices, may be an exceptional case in global terms. Although the demographic process is the opposite of that found in nations of rapid human population growth, the problems caused by the sharpening of the human-wildlife boundaries are similar. As many researchers have recognized, fencing is not a panacea (Hayward and Kerley 2009), and the creation of distance between large carnivores and humans would be a more sophisticated approach to long-term mitigation. One example in this case would be the restoration of season-specific habitats in remote areas. I conclude that a habitat-based approach has enormous potential as a means of creating adequate separation between humans and wildlife. The results of my study imply that human land use has an indirect but fundamental influence on the frequency of human-wildlife interaction. However, this linkage has rarely been investigated. Thus, I recommend that further research be undertaken to understand the mechanisms of increased human-wildlife interaction in relation to the influence of anthropogenic land modification and management processes. I believe this would provide a new direction in the search for ways to achieve co-existence with large carnivores by resolving the complex issue of conflict.

Table 3-1

Landscape covariates considered to influence habitat selection by Asiatic black bears in the central Japan Alps. 9 land cover types were reclassified (6 types of vegetation, 2 human-landscape classes and others) from a satellite image with 10m resolution

Landscape Covariate	Description (Original data source, data type (unit) and range; %= a proportion of total study area)	Variable code
Land cover	Categorical	land cover
Larch plantation	Plantation of Larches <i>Larix leptolepis</i> (0 or 1), 26.2%	larch_pt
Coniferous plantation	Plantation of Japanese Cedars <i>Cryptomeria japonica</i> or Cypress <i>Chamaecyparis obtusa</i> (0 or 1), 7.3%	conifer_pt
Broadleaved forest	Forest of Deciduous broadleaved trees <i>Fagaceae</i> , <i>Rosaceae</i> , <i>Cornaceae</i> , <i>Juglans</i> , <i>Castanea</i> etc. (0 or 1), 13.7 %	deciduous_f
Red pine forest	Forest of Japanese red pine <i>Pinus densiflora</i> (0 or 1), 7.4 %	redpine_f
Open regenerating	Canopy openings with various regeneration stages consist of shrub and herbaceous plants (0 or 1), 5.3%	open_g
Subalpine forest	Forest mainly consists of evergreen conifers in subalpine zone (0 or 1), 6.2%	alpine_f
Farmlands	Multiple crop lands and livestock sheds (0 or 1), 14.6%	farmland
Near town	Paddy fields, villages and towns (0 or 1), 6.7%	neartown
Others	Alpine meadow, permanent snow, rocks, water surface and clouds (0 or 1), 10.6%	others
Forest Age	10 indices (1-10) from 0 to over 110 years old reclassified from the Basic planning maps of National and Regional Forestry	fstAge
Topographic features	Linear	
Elevation	Measured from 10m DEM (m), mean 1268, range 456- 2956	elev
CTI	Compound Topographic Index, range 0.4-21.9	cti
Roughness	Terrain Ruggedness Index, range 0-9.0	roughness
Solar Radiation Summer	Represented at 1st August, (Wh/m2), range 1087.8-7298.8	solar
Autumn	Represented at 1st October, (Wh/m2), range 115.6-5022.4	
Distance variables	Linear	
Forest edges	Distances from the nearest edge of forest cover (m), range 0-1000	fstEdg
Rivers	Distances from the nearest river (m), range 0-2686.8	rivers
Roads in open lands	Distances from the nearest road in open lands (m), range 0-6967.1	road_o
Roads in forests	Distances from the nearest road in forests (m), range 0-3284.9	road_f

Table 3-2

Comparison between distance-effect models using logistic regression with distance variables for each linear landscape features partly including interaction terms for seasons according to log-likelihood (LL), AIC, and AIC score as changes in AIC from the lowest model (Δ_i). The variable names: continuous distance (D), quadratic terms of distance (D²), season (SS), sex (SX), land cover (LC) and three interactions with season (D:SS, SS:SX, SS:LC).

Model	Road_open_dist			Road_forest_dist			Forest_edge_dist			River_dist		
	LL	AIC	Δ_i	LL	AIC	Δ_i	LL	AIC	Δ_i	LL	AIC	Δ_i
D + D ² + D:SS + SS:LC + SS:SX	-58865	11777	0	-58943	117931	0	-59296	118638	0	-59780	119607	0
D + D ² + D:SS + SS:LC	-58878	117799	22	-58967	117976	45	-59316	118675	37	-59794	119631	24
D + D ² + D:SS + LC	-60092	120193	2416	-59889	119791	1859	-60415	120842	2204	-60929	121871	2264
D + D ² + D:SS + SS:SX	-60150	120315	2538	-59925	119863	1932	-60452	120919	2281	-60977	121968	2361
D + D ² + D:SS + SX	-60152	120197	2420	-59928	119869	1938	-60457	120925	2287	-60982	121977	2370
D + D ² + D:SS	-60155	120320	2544	-59939	119888	1957	-60462	120934	2296	-60985	121980	2373
D + D ² + SS	-60465	120938	3161	-60054	120117	2186	-61198	122405	3767	-61168	122344	2737
D + D ²	-60709	121423	3647	-60216	120439	2508	-61340	122687	4049	-61306	122617	3010
D	-60721	121447	3670	-60627	121259	3327	-61344	122692	4054	-61322	122648	3041

Table 3-3

Differences between summer and autumn depending on changes of land cover types and sex in response to distances from open roads, forest roads, forest edges and rivers by Asiatic black bears in the central Japan Alps. Odds ratios for bear selection were calculated on the basis of logistic regression by controlling season inclusive interaction terms with sex and land cover. LRT denotes Log-likelihood Ratio Test in comparison with the constant only model. ^a denotes the level of significance by Wald statistics at the point estimate and ^b was the absolute difference from no selection (odds ratio=1).

model	land cover	females			males		
		Odds Ratio	P> z ^a	Diff.Season ^b	Odds Ratio	P> z ^a	Diff. Season ^b
Road_open_dist	larch_pt	0.750	0.000	0.250	1.126	0.000	0.126
adjusted distance	alpine_f	1.867	0.000	0.867	1.920	0.000	0.920
at mean=1395.42m	farmland	0.838	0.003	0.162	0.861	0.012	0.139
LRT=5022.88, <i>df</i> =22, <i>p</i> <0.001	conifer_pt	0.961	0.454	0.039	0.988	0.826	0.012
	deciduous_f	0.511	0.000	0.489	0.526	0.000	0.474
	open_g	1.607	0.000	0.607	1.653	0.000	0.653
	neartown	0.749	0.038	0.251	0.770	0.060	0.230
	others	1.140	0.596	0.140	1.172	0.520	0.172
	redpine_f	1.238	0.000	0.238	1.273	0.000	0.273
Road_forest_dist	larch_pt	0.842	0.000	0.158	0.880	0.000	0.120
adjusted distance	alpine_f	1.075	0.545	0.075	1.124	0.328	0.124
at mean=304.78m	farmland	1.065	0.279	0.065	1.113	0.062	0.113
LRT= 4868.30, <i>df</i> =22, <i>p</i> <0.001	conifer_pt	0.874	0.011	0.126	0.913	0.089	0.087
	deciduous_f	0.536	0.000	0.464	0.560	0.000	0.440
	open_g	1.190	0.017	0.190	1.244	0.003	0.244
	neartown	0.984	0.906	0.016	1.028	0.840	0.028
	others	1.587	0.064	0.587	1.658	0.042	0.658
	redpine_f	1.443	0.000	0.443	1.508	0.000	0.508
Forest_edge_dist	larch_pt	0.867	0.000	0.133	0.933	0.010	0.067
adjusted distance	alpine_f	0.774	0.027	0.226	0.834	0.113	0.166
at mean=193.52m	farmland	0.763	0.000	0.237	0.822	0.001	0.178

LRT= 4161.50, <i>df</i> =22, <i>p</i> <0.001	conifer_pt	0.885	0.019	0.115	0.952	0.355	0.048
	deciduous_f	0.583	0.000	0.417	0.628	0.000	0.372
	open_g	0.824	0.008	0.176	0.887	0.101	0.113
	neartown	0.734	0.025	0.266	0.790	0.087	0.210
	others	0.905	0.682	0.095	0.974	0.915	0.026
	redpine_f	1.262	0.000	0.262	1.358	0.000	0.358
River_dist	larch_pt	0.890	0.000	0.110	0.950	0.057	0.050
adjusted distance at mean=367.10m	alpine_f	1.084	0.484	0.084	1.158	0.202	0.158
	farmland	1.007	0.910	0.007	1.075	0.209	0.075
LRT= 3192.60, <i>df</i> =22, <i>p</i> <0.001	conifer_pt	0.893	0.029	0.107	0.953	0.362	0.047
	deciduous_f	0.533	0.000	0.467	0.570	0.000	0.430
	open_g	1.287	0.000	0.287	1.374	0.000	0.374
	neartown	0.889	0.395	0.111	0.949	0.706	0.051
	others	1.201	0.451	0.201	1.283	0.306	0.283
	redpine_f	1.518	0.000	0.518	1.621	0.000	0.621

Table 3-4

The final set of variables selected through univariate analysis in mixed effect logistic regression for the global RSF model across season-sex groups of Asiatic black bears; numbers indicate the rank of 15 variables ordered in accordance with Wald statistics.

Variables	Summer		Autumn	
	females	males	females	males
frstEdg × solar	1 *	2 *	6	8
deciduousF × frstEdg	2	3	4	3 *
frstEdg × rivers	3	1 *	5	7
road_f × frstEdg	4 *	4	8	5
frstEdg	5 *	5 *	12	9
road_o	6 *	6 *	15	10
rivers × solar	7	7	10 *	12
land cover	8	12	1	1
deciduousF × rivers	9 *	8	3	2 *
rivers	10 *	9 *	13	14
frstAge + frstAge ²	11	14	7	11 *
roughness	12 *	10 *	11 *	15
deciduousF × frstAge	13	13	2 *	4
road_f	14 *	11 *	14	6
solar + solar ²	15	15 *	9	13

Significant mark *= $p < 0.05$, all parameters were included the constant

Bold letters = the top 5 ranks

Table 3-5

Summary of human-bear (HB) boundaries for each sex-season group of Asiatic black bears in the central Japan Alps.

		Boundary zone				bear locations	
		Area of sharp boundary zone 1 (km ²)	Area of moderate boundary zone 2 (km ²)	Total area of boundary zone 1 and 2 (km ²)	Boundary zone overlapped with 9-10 RSF class (%)	Test locations within boundary zone (%)	bear
females	summer	30.2	32.8	63.1	28.6	8.4	
	autumn	22.6	12.7	35.3	4.3	1.2	
males	summer	65.3	36.8	102.1	49.9	9.4	
	autumn	22.4	44.2	66.6	10.5	5.8	

Table 3-6

Logistic regression coefficients, odds ratio and 95% Confidence Interval for the odds ratio estimated by the final habitat selection model on the basis of mixed effect logistic regression for each season-sex group of Asiatic black bears. β was a coefficient and LRT indicated Log-likelihood Ratio Test in comparison with the constant only model. n denoted were the number of observations. The odds ratios and their 95% CI were given as 10^5 (denoted a) and 10^2 (denoted b) times the original value of their coefficients.

variables	Female Summer n= 23294 LRT=1250.9, df=24, p<0.001			Male Summer n= 18782 LRT=1591.1, df=24, p<0.001			Female Autumn n= 26338 LRT=1294.2, df=24, p<0.001			Male Autumn n= 20200 LRT=1415.1, df=24, p<0.001						
	β	Odds Ratio 95% CI		β	Odds Ratio 95% CI		β	Odds Ratio 95% CI		β	Odds Ratio 95% CI					
		Odds ratio	Lower		Upper	Odds ratio		Lower	Upper		Odds ratio	Lower	Upper	Odds ratio	Lower	Upper
alpine_f	-1.455	0.233	0.170	0.321	-0.377	0.686	0.538	0.876	-1.583	0.205	0.151	0.279	-1.017	0.362	0.294	0.445
farmland	0.128	1.137	0.896	1.443	-0.365	0.694	0.565	0.853	0.348	1.417	1.131	1.775	0.457	1.579	1.216	2.051
conifer_pt	-0.297	0.743	0.661	0.835	-0.079	0.924	0.806	1.058	-0.357	0.700	0.631	0.776	-0.163	0.850	0.764	0.945
deciduous_f	0.235	1.265	0.927	1.726	0.487	1.628	1.152	2.301	0.671	1.955	1.496	2.555	0.736	2.087	1.510	2.886
open_g	0.026	1.027	0.850	1.241	-0.088	0.916	0.741	1.134	0.397	1.488	1.240	1.785	0.057	1.059	0.872	1.286
neartown	-1.118	0.327	0.236	0.453	-1.224	0.294	0.224	0.386	-0.441	0.644	0.458	0.904	-0.789	0.454	0.317	0.652
others	-0.774	0.461	0.267	0.796	-1.181	0.307	0.206	0.457	-0.333	0.717	0.417	1.233	-0.931	0.394	0.207	0.750
redpine_f	0.162	1.176	1.063	1.300	0.023	1.024	0.914	1.146	-0.530	0.588	0.519	0.667	-0.234	0.791	0.671	0.932
road_f	-0.492	0.612	0.510	0.733	0.412	1.510	1.229	1.854	0.995	2.704	2.299	3.180	-1.016	0.362	0.290	0.452
fstEdge	1.610	5.003	1.838	13.617	2.372	10.721	3.386	33.947	1.122	3.070	2.117	4.452	-0.101	0.904	0.596	1.372
fstEdg × road_f	0.986	2.682	1.934	3.718	-0.169	0.844	0.588	1.212	-1.625	0.197	0.143	0.271	0.280	1.324	0.887	1.975
fstEdg × deciduousF	0.128	1.137	0.884	1.461	-0.041	0.959	0.699	1.317	-0.380	0.684	0.547	0.855	0.124	1.132	0.880	1.456
rivers	2.067	7.900	2.579	24.199	2.812	16.639	4.758	58.182	-1.821	0.162	0.107	0.244	0.475	1.608	1.017	2.543
fstEdg × rivers	0.694	2.001	1.389	2.884	-1.022	0.360	0.240	0.539	2.357	10.562	7.588	14.700	-0.580	0.560	0.383	0.818
deciduos_f × rivers	-0.261	0.770	0.589	1.008	-0.158	0.854	0.626	1.166	0.073	1.075	0.859	1.347	-1.346	0.260	0.201	0.337
solar ^a	-0.012	0.988	0.981	0.995	-0.027	0.973	-0.036	-0.019	-0.010	0.990	-0.014	-0.006	-0.002	0.998	-0.006	0.003
solar ^b	0.104	1.110	1.033	1.193	0.232	1.261	0.146	0.318	0.052	1.054	0.032	0.072	-0.0002	0.9998	-0.022	0.022
fstEdg × solar ^b	-0.024	0.976	0.958	0.994	-0.020	0.980	-0.041	0.001	-0.049	0.952	-0.061	-0.036	-0.001	0.999	-0.014	0.012
rivers × solar ^b	-0.042	0.959	0.939	0.980	-0.038	0.962	-0.062	-0.015	0.022	1.022	0.008	0.035	0.022	1.022	0.007	0.036
fstAge ²	-0.031	0.969	0.963	0.975	-0.010	0.990	0.983	0.997	-0.006	0.994	0.988	0.999	-0.025	0.976	0.970	0.982
fstAge	0.312	1.366	1.274	1.464	0.093	1.098	1.029	1.171	0.159	1.173	1.105	1.245	0.285	1.330	1.243	1.423
deciduos_f × rivers	-0.005	0.995	0.953	1.039	-0.019	0.981	0.936	1.028	-0.007	0.993	0.958	1.031	0.040	1.040	0.995	1.087
roughness	-0.150	0.861	0.818	0.906	-0.262	0.769	0.734	0.807	0.113	1.119	1.072	1.169	-0.002	0.998	0.956	1.041
road_o	1.115	3.049	2.514	3.698	1.279	3.594	2.999	4.307	0.797	2.219	1.823	2.702	1.360	3.896	3.120	4.866
constant	-2.553	0.078	0.012	0.507	-4.685	0.009	0.001	0.086	-2.130	0.119	0.073	0.193	-1.003	0.367	0.208	0.646

Table 3-7

Estimated coefficients for RSF models of habitat selection by Asiatic black bears; averaged coefficients (mean β) estimated by individual level, and coefficients (β), standard errors (S.E.), and significance ($* = p < 0.01$) estimated by population level (sex-season group) in the mixed effect logistic regressions.

	Summer						Autumn					
	Females			Males			Females			Males		
	Individual model	P population model	S.E.	Individual model	P population model	S.E.	Individual model	P population model	S.E.	Individual model	P population model	S.E.
Land cover	mean β	β		mean β	β		mean β	β		mean β	β	
alpine_f	-0.827	-1.455 *	0.163	0.368	-0.377 *	0.124	-1.151	-1.583 *	0.157	-1.069	-1.017 *	0.105
farmland	0.265	0.128	0.122	-0.337	-0.365 *	0.105	0.442	0.348 *	0.115	0.198	0.457 *	0.133
conifer_pt	-0.208	-0.297 *	0.060	-0.045	-0.079	0.069	-0.308	-0.357 *	0.053	-0.150	-0.163 *	0.054
deciduous_f	0.308	0.235	0.159	0.400	0.487 *	0.177	0.393	0.671 *	0.136	0.592	0.736 *	0.165
open_g	-0.298	0.026	0.097	0.165	-0.088	0.109	0.191	0.397 *	0.093	0.179	0.057	0.099
redpine_f	0.141	0.162 *	0.051	0.041	0.023	0.058	-0.476	-0.530 *	0.064	-0.277	-0.234 *	0.084
neartown	-0.379	-1.118 *	0.166	-1.154	-1.224 *	0.139	-0.168	-0.441 *	0.173	-1.294	-0.789 *	0.184
others	-0.003	-0.774 *	0.279	-1.086	-1.181 *	0.203	-0.025	-0.333	0.277	-0.406	-0.931 *	0.328
Terrain												
roughness	-0.019	-0.150 *	0.026	-0.196	-0.262 *	0.024	0.143	0.113 *	0.022	0.011	-0.002	0.022
solar	2.1E-03	1.0E-03 *	3.7E-04	2.3E-03	2.3E-03 *	4.4E-04	0.001	0.001 *	0.000	5.2E-05	-2.5E-06	1.1E-04
solar ²	-2.1E-07	-1.2E-07 *	3.6E-08	-2.6E-07	-2.7E-07 *	4.3E-08	-1.1E-07	-1E-07 *	1.87E-08	-2.0E-08	-1.5E-08	2.1E-08
fstAge	0.357	0.312 *	0.035	0.016	0.093 *	0.033	0.168	0.159 *	0.030	0.266	0.285 *	0.035
fstAge ²	-0.035	-0.031 *	0.003	0.001	-0.010 *	0.004	-0.009	-0.006 *	0.003	-0.022	-0.025 *	0.003
fstEdg	1.698	1.610 *	0.511	2.357	2.372 *	0.588	1.165	1.122 *	0.190	0.431	-0.101	0.213
rivers	4.021	2.067 *	0.571	1.461	2.812 *	0.639	-1.426	-1.821 *	0.209	0.124	0.475 *	0.234
road_o	0.182	1.115 *	0.098	0.875	1.279 *	0.092	-0.847	0.797 *	0.100	0.317	1.360 *	0.113
road_f	-0.438	-0.492 *	0.092	0.270	0.412 *	0.105	0.674	0.995 *	0.083	-0.451	-1.016 *	0.114
Interactions												
fstEdg × road_f	0.139	0.986 *	0.167	-0.229	-0.169	0.185	-1.627	-1.625 *	0.163	-0.122	0.280	0.204
fstEdg × rivers	0.549	0.694 *	0.186	-0.593	-1.022 *	0.206	2.912	2.357 *	0.169	0.264	-0.580 *	0.193
fstEdg × solar	-2.1E-04	-2.4E-04 *	9.4E-05	-1.5E-04	-2.0E-04	1.1E-04	-0.001	-4.9E-04 *	6.3E-05	-2.6E-04	-9.4E-06	6.6E-05
fstEdg × deciduousF	0.169	0.128	0.128	0.135	-0.041	0.162	0.204	-0.380 *	0.114	0.174	0.124	0.128
deciduos_f × rivers	-0.473	-0.261	0.137	-0.318	-0.158	0.159	-0.441	0.073	0.115	-1.203	-1.346 *	0.131
deciduous_f × fstAge	-0.006	-0.005	0.022	0.001	-0.019	0.024	0.026	-0.007	0.019	0.032	0.040	0.023
rivers × solar	-6.8E-04	-4.2E-04 *	1.1E-04	-1.1E-04	-3.8E-04 *	1.2E-04	2.1E-04	2.2E-04 *	6.9E-05	4.4E-04	2.2E-04 *	7.6E-05
Constant		-2.553 *	0.956		-4.685 *	1.139		-2.130 *	0.248		-1.003 *	0.289
Observations		23294			18782			26338			20200	
Log Likelihood		-15001.9			-11618.5			-17050.1			-12741.2	
Wald χ^2 ($df=24$)		1250.9			1591.1			1294.2			1415.1	
Prob > χ^2		< 0.001			< 0.001			< 0.001			< 0.001	
AIC		30055.8			23289.1			34152.2			25534.4	

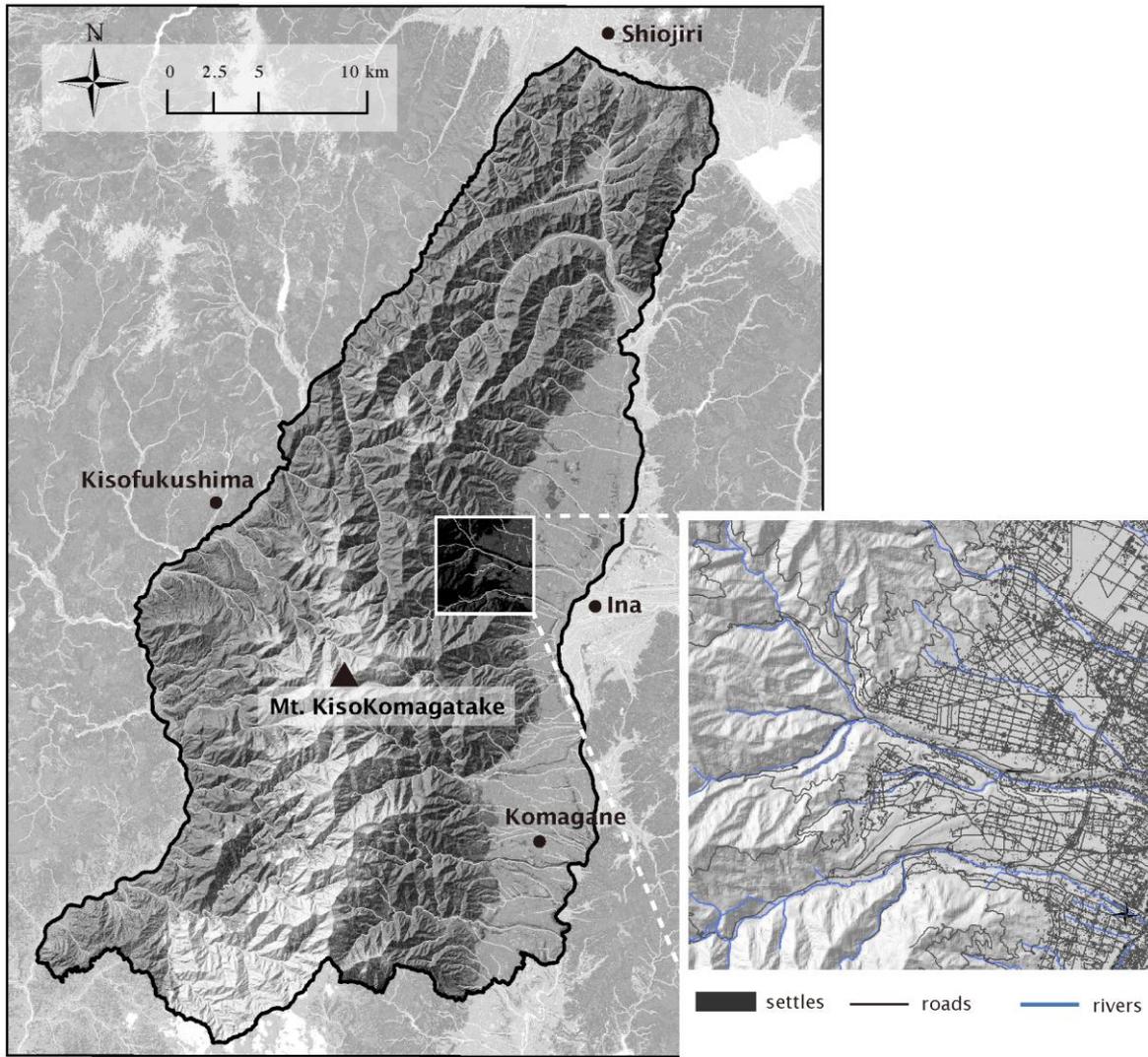
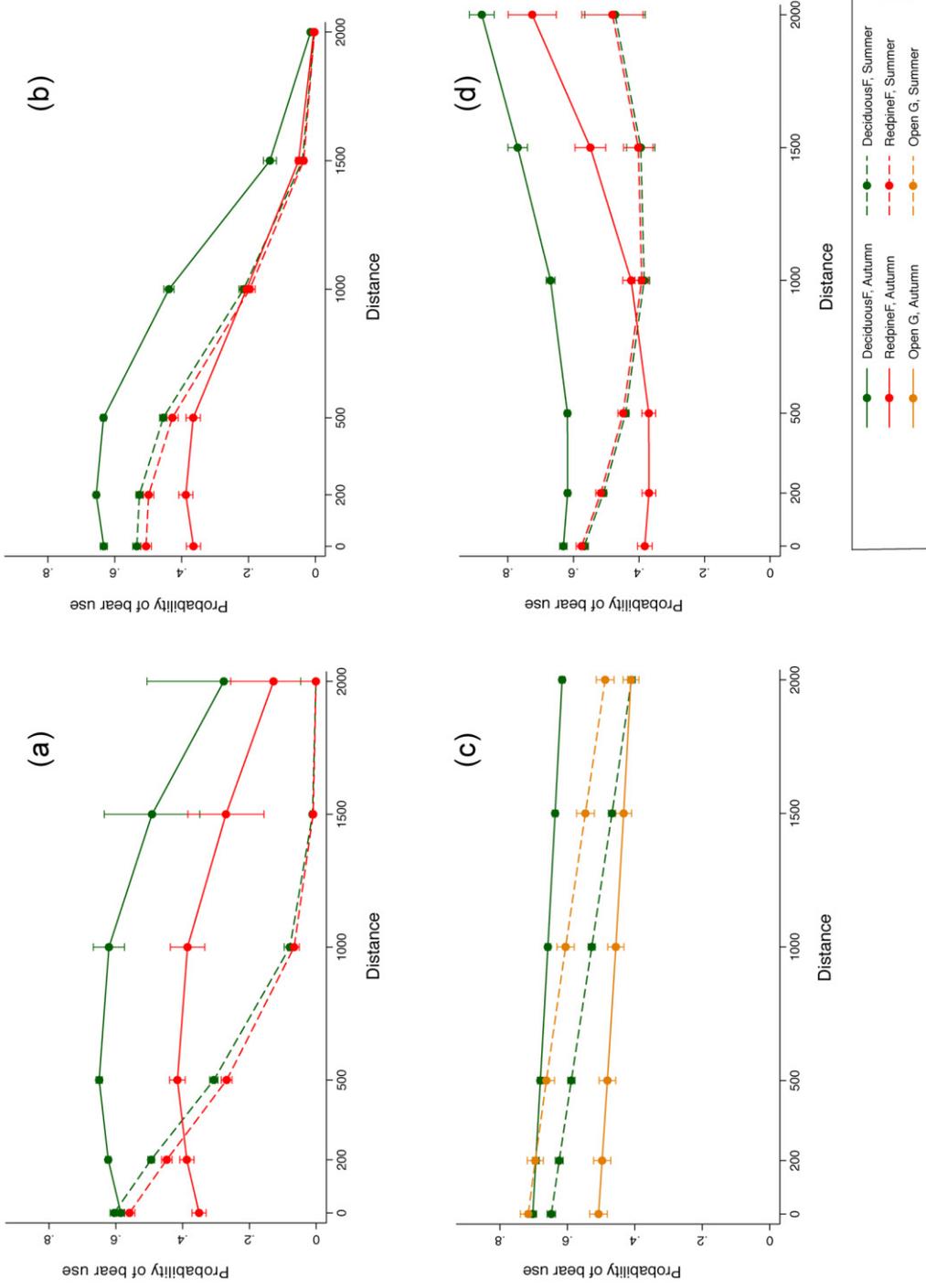


Fig. 3-1

The study area of 1,023 km² (35°48'27N, 137°49'47E) including the central Japan Alps located between Ina and Kiso valley, the southern part of Nagano prefecture in the Honshu island of Japan. The example section (bottom right) has a typical distribution of the landscape features that proved most important in the production of human-bear boundary maps.

Fig. 3-2

Changes in probability of use by Asiatic black bears along with increasing distances from linear landscape features; forest edges (a), forest roads (b), open roads (c) and rivers (d) in distance effect models. Dots represent the mean of probability at a distance, and error bars represent confidence intervals predicted in logistic regression as a function of the distance variables with interactions of land cover and season; summer (dashed line), autumn (continuous line), deciduous forest (green), red pine forest (red), and open regenerating lands (khaki).



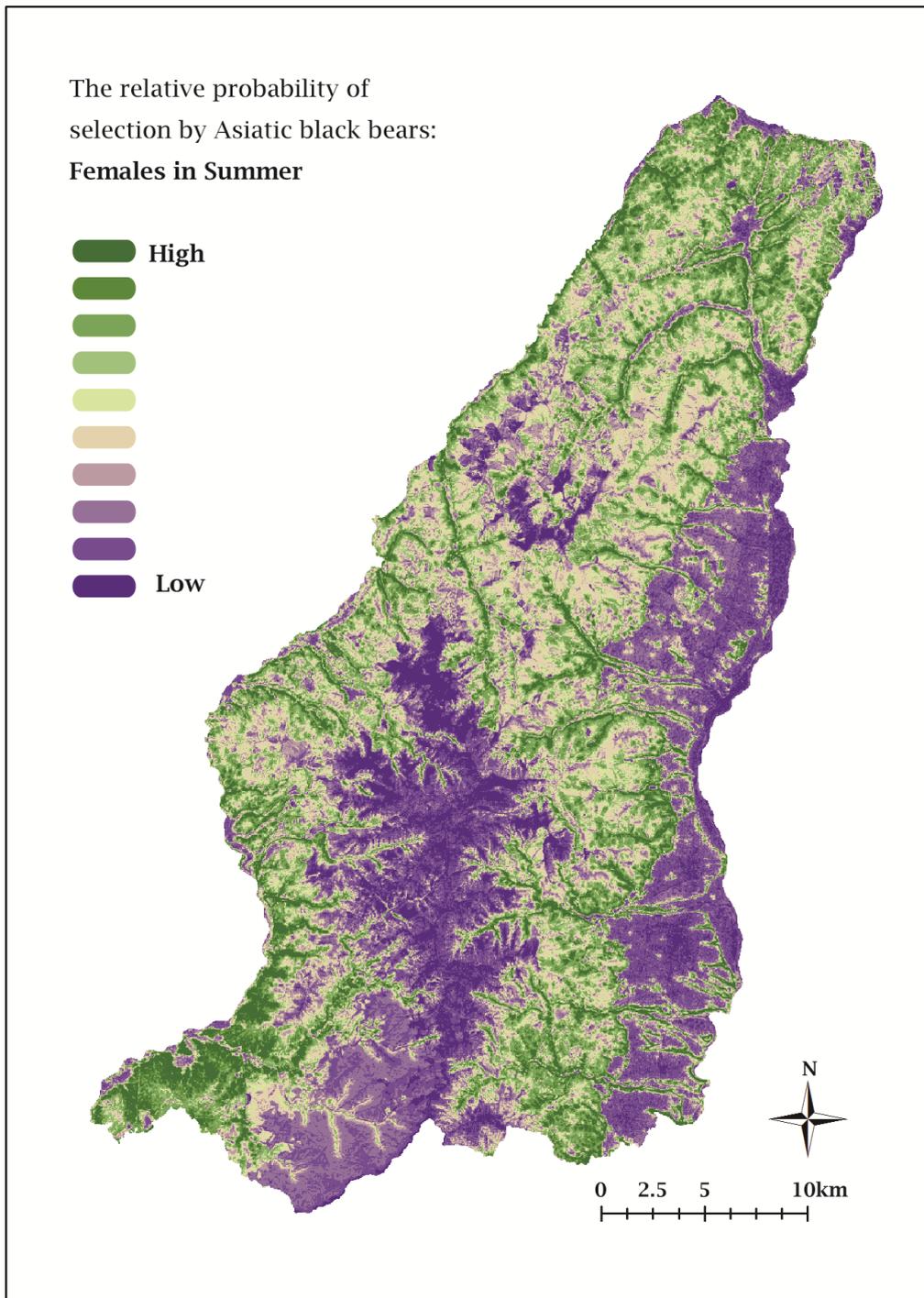


Fig. 3-3

The predictive map for the relative probability of habitat selection of Asiatic black bears in the central Japan Alps (10×10m resolution). The colors in the map show the degree of probability (high = green to low = dark violet) for each cell selected by **females during summer**.

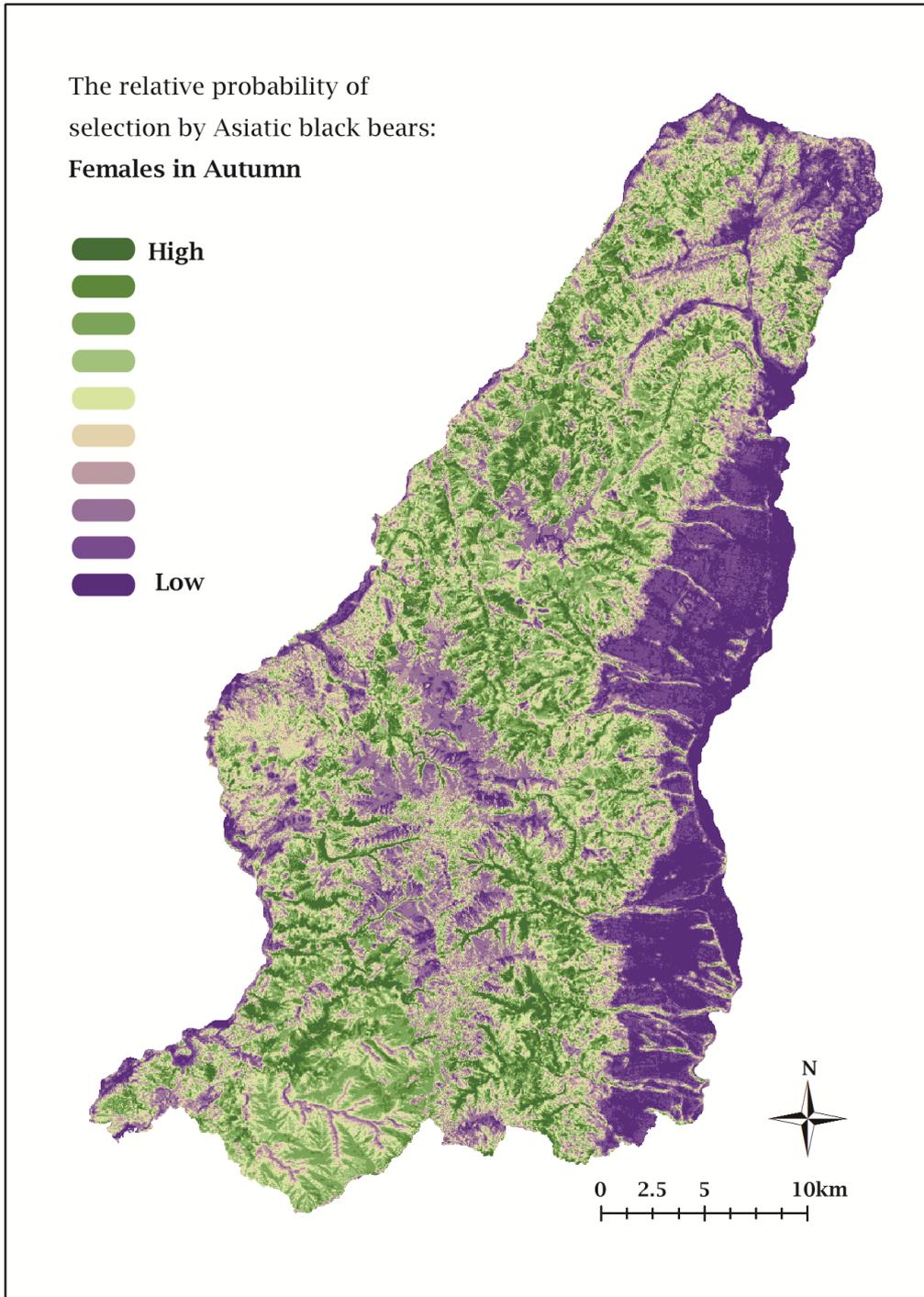


Fig. 3-4

The predictive map for the relative probability of habitat selection of Asiatic black bears in the central Japan Alps (10×10m resolution). The colors in the map show the degree of probability (high = green to low = dark violet) for each cell selected by **females during autumn**.

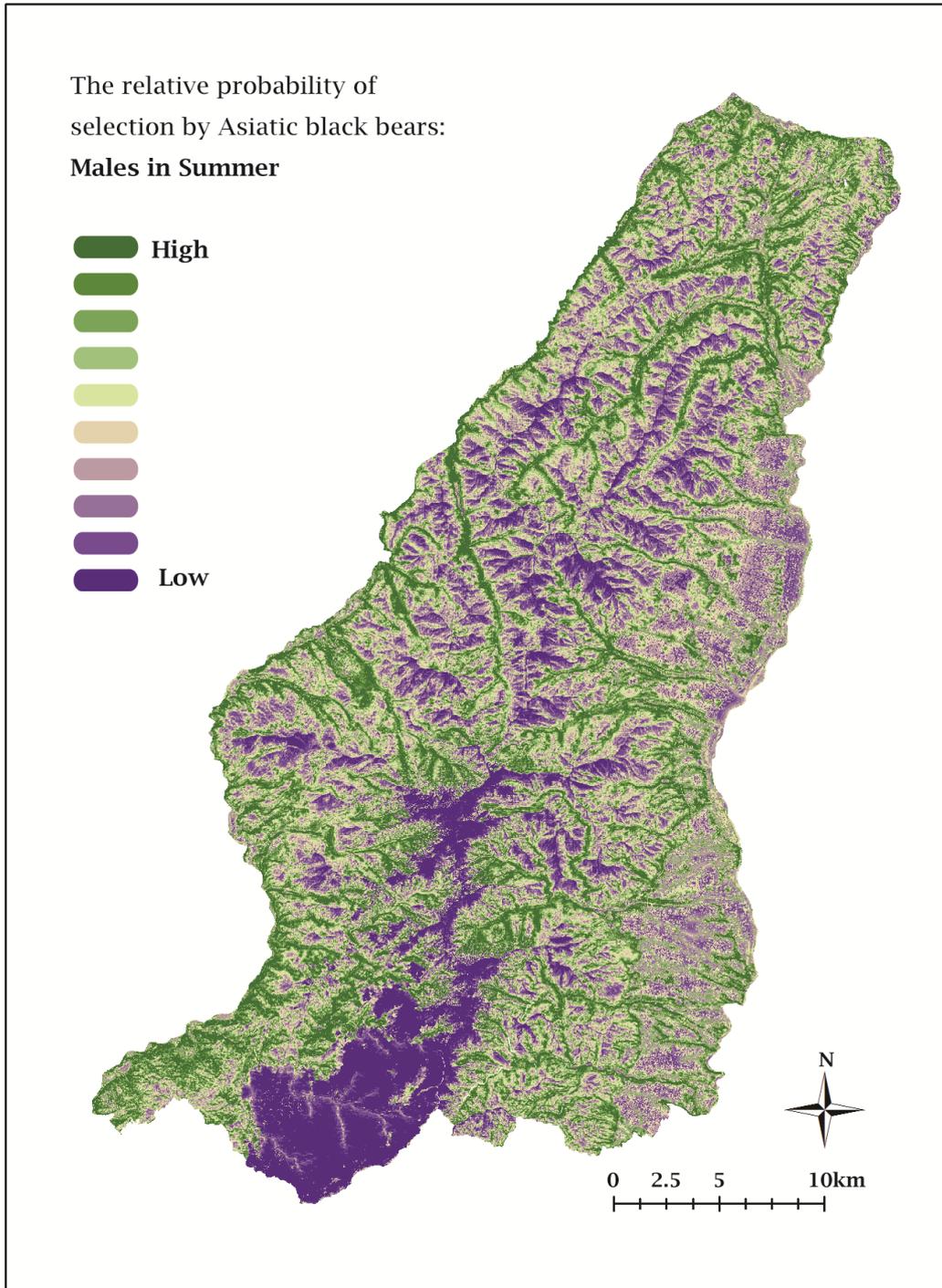


Fig. 3-5

The predictive map for the relative probability of habitat selection of Asiatic black bears in the central Japan Alps (10×10m resolution). The colors in the map show the degree of probability (high = green to low = dark violet) for each cell selected by **males during summer**.

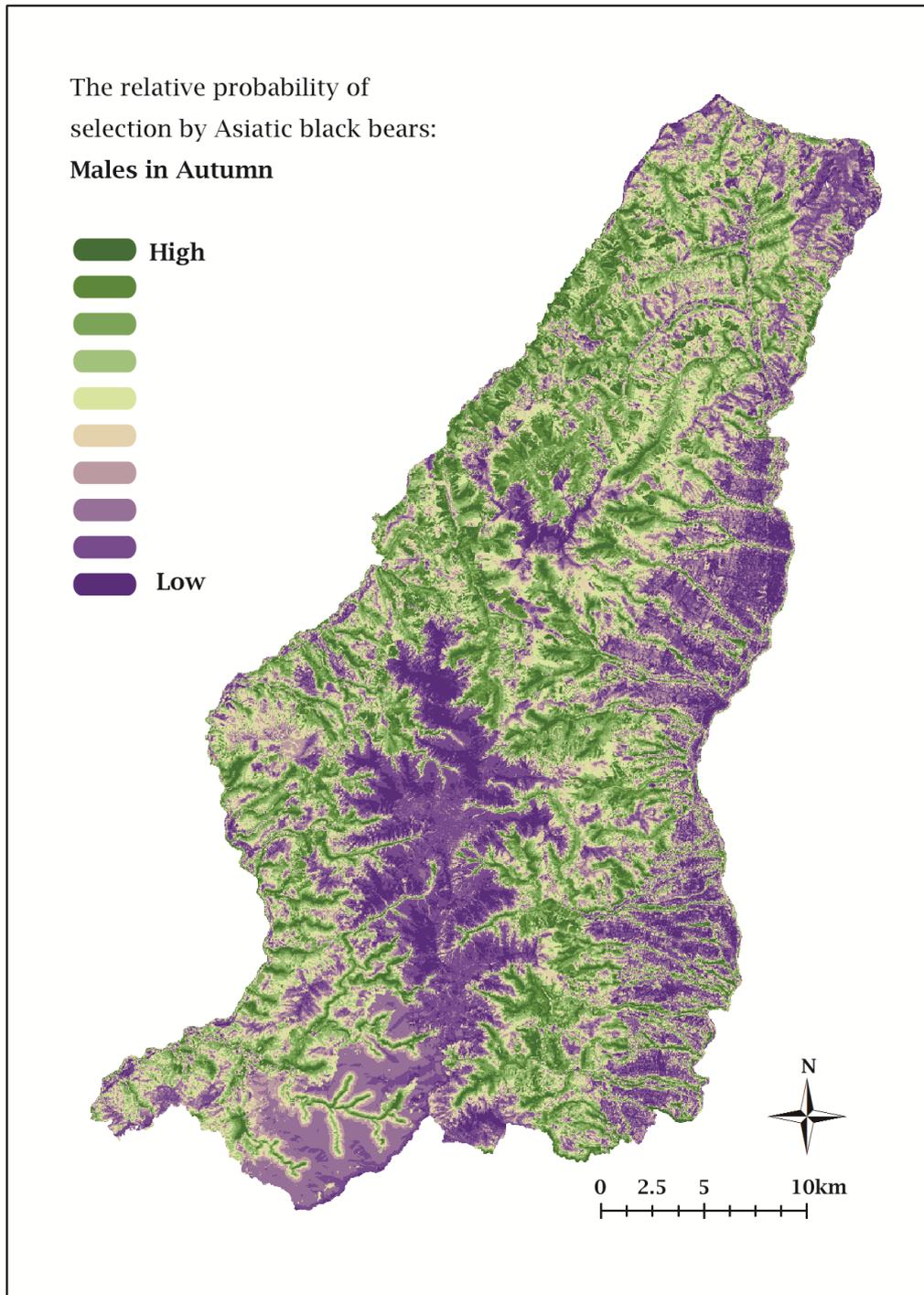


Fig. 3-6

The predictive map for the relative probability of habitat selection of Asiatic black bears in the central Japan Alps (10×10m resolution). The colors in the map show the degree of probability (high = green to low = dark violet) for each cell selected by **males during autumn**.

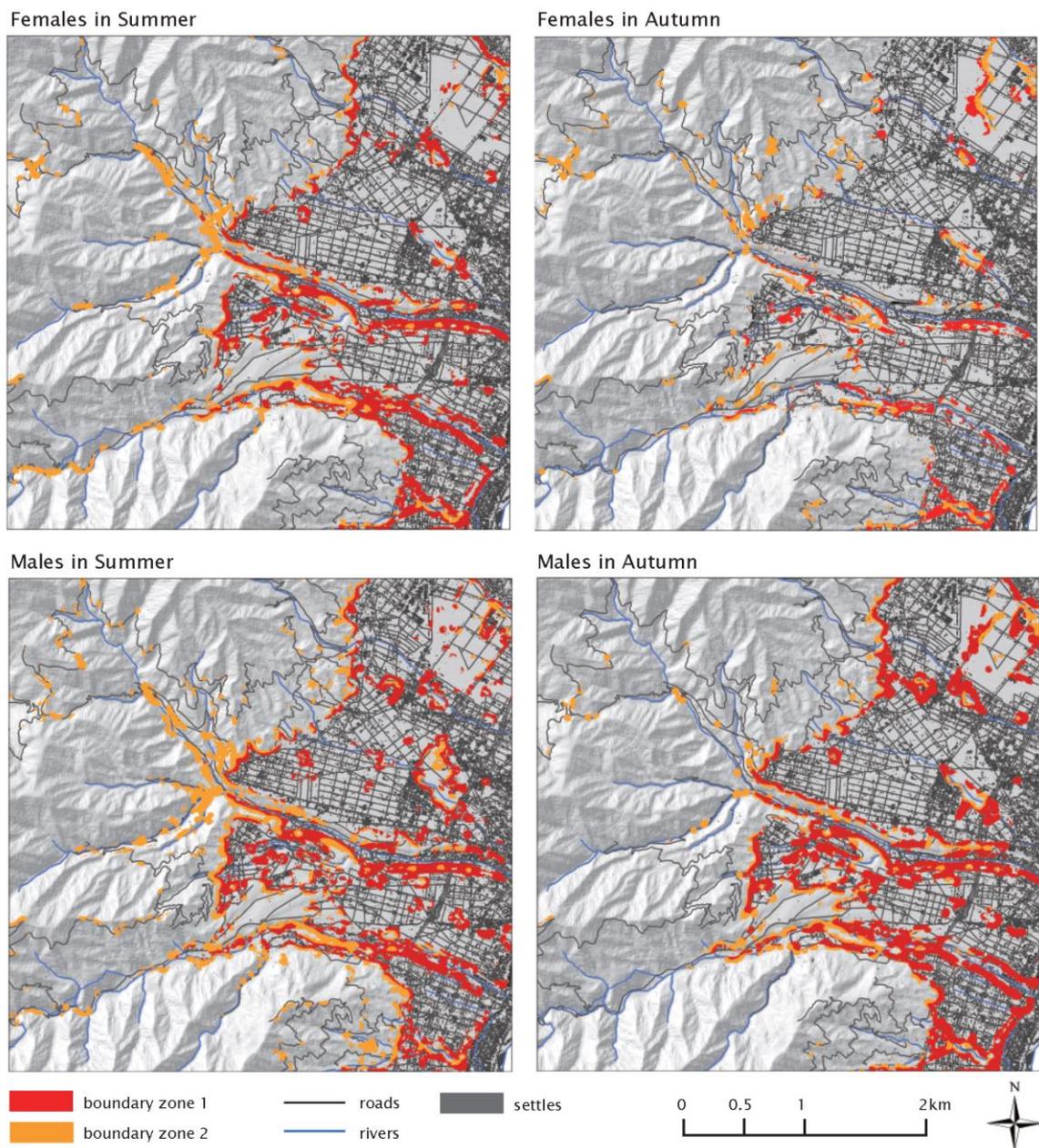


Fig. 3-7

Distribution of the boundaries between humans and Asiatic black bears in the central Japan Alps (10×10m resolution). The colors indicate sharp boundary: the overlapped edges of RSF class 9-10 and human lands (red) and moderate boundary: the overlapped edges of RSF class 7-8 and human lands (orange). The different panels show HB boundaries for females in summer (top left), females in autumn (top right), males in summer (bottom left) and males in autumn (bottom right).

THE FINAL DISCUSSION:

The subjects of this study, 15 female and 13 male Asiatic black bears, provided a total of 48,121 location data in the summers and autumns of 2008-2011 in the Central Japan Alps (Table A-1). The comparison between the two seasons led to important insights into habitat selection by the bears. The results from this study provide the baseline information about habitat for Asiatic black bears. Some of them reflect the uniqueness of the landscape features in the study region, but I expect many of them will also prove relevant to habitat selection in other regions of Japan, or extendable to other Asian countries. The methods and findings may also be useful in investigations of the habitat status of sympatric forest dependent wildlife such as Japanese macaques *Macaca fuscata*, sika deer *Cervus Nippon*, Japanese Serow *Capricornis crispus* and wild boar *Sus scrofa*, all of which are commonly influenced by changes in the structures of forests and human landscapes in this highly populous nation.

Other important outcomes were the predictions of the habitat distribution of the bears. It was confirmed that the predictive maps generated by RSF have considerable potential for researchers seeking to evaluate habitat quality at landscape level and to identify the several relationships between bear habitat and human-dominated lands. To exploit this potential, I projected the critical areas as remnant secure habitats and boundaries between bear habitat and human settlements. Through discussion of the main findings, I synthesized the results to answer the key questions addressed in the introduction of this thesis. After identifying the relationships between changes in human land use and current habitat selection by bears, I made recommendations for a novel approach to conservation, proposing management strategies to overcome the common issues emerging from human-bear interactions, whilst also suggesting directions for the further research needed to improve our knowledge of the habitat requirements necessary for co-existence with this elusive large carnivore.

THE MAIN FINDINGS

1. Asiatic black bears showed significant seasonal differences in their habitat selection.

- The positive or negative effects of habitat covariates on the selection of bears varied substantially between summer and autumn.
- Seasonal difference had a greater effect than sexual difference on habitat selection.

2. Distinct selections of specific land cover types by bears were found during the season of prevalent human-bear conflict.

- During summer, the habitat selection of Asiatic black bears was positively associated with red pine forests and open regenerating lands, and these associations dramatically faded out during autumn.
- The types of land cover where the study found the largest seasonal differences in the effect of distance from linear landscape on bear habitat selection were red pine forests and deciduous forests.

3. Significant influence of linear landscape features on season specific habitat selection was revealed.

- As the distance from forest edge or forest road shortened, the probability of bear selection magnified accordingly during summer regardless of the land cover type.
- The strong selection of areas closer to forest edge or forest road was weakened in autumn.
- The distribution of summer habitat in the entire area was profoundly influenced by the linear configuration of forest edges, forest roads and rivers.

4. Land cover covariates had a greater effect on habitat selection during hyperphagia season.

- According to univariate analysis in logistic regression, land cover covariates had the greatest influence on habitat selection during the bears' hyperphagia.
- The fact that deciduous broad-leaved forest was the land cover type with the highest probability of selection in autumn confirmed that this was the critical during the period of hyperphagia. for bears.

5. Asiatic black bears consistently avoided coniferous plantations both in summer and autumn.

- Plantations of both deciduous and evergreen coniferous trees had a considerable negative influence on habitat selection, and the negative associations were consistent across the seasons.

6. The predictive distribution of summer habitat showed a significant bias toward human-dominated lowland.

- A conspicuous convergence of habitat with a high probability of bear selection was observed on the periphery of human-dominated lands during summer.
- Secure habitat with low human access in summer was severely restricted in remote mountains and was substantially small in size.

7. Human-bear boundaries in summer were more extensive than in autumn.

- Human-bear boundaries were remarkably identical in the way their shapes were more affected by linear landscape than by land cover types in the peak conflict season.
- Red pine forests, forest roadside and riparian forests extending within anthropogenic matrix, and combinations of these land cover types, were the major components of human-bear boundaries.

THE SYNTHESSES FROM THE MAIN FINDINGS

1. Asiatic black bears showed a remarkable consistency in their selection of deciduous forests and avoidance of coniferous plantations in the Central Japan Alps.

The consistent selections during the two seasons

The odds ratio estimated by logistic regression clearly showed that cool-temperate deciduous forests were the critical habitat strongly selected by Asiatic black bears across the two seasons. The importance of this forest cover in temporal climate regions has been widely observed (Servheen et al. 1999), but the quantified evidence for this preference has not been explored for black bears in Asian regions while it has been rigorously investigated for counterparts in North America (Noyce et al.

1990, Mitchel and Powell 2003, Welch 1997, Inman and Pelton 2002, Reynolds-Hoglands et al. 2007). As many studies of the feeding ecology of Japanese black bears have clearly indicated, forests offer bears the benefit of the highly nutritious hard mast produced by the various varieties of oak and beech (Hashimoto et al. 2003, Huygens et al. 2003), and this seems an obvious reason for the positive selection of forests primarily dominated by such mast-producing trees. Besides providing food for forest floor species, forests also contain a diversity of tall tree species (Nagaike 2002) including several cherry trees which are important summer food for bears in Japan (Koike 2009). During summer, the odds ratios of bear selection for red pine forests and open regenerating lands were higher than for deciduous forests (Chap 2 Table 5), which is an indication of the relatively lower quantity of resources deciduous forests can provide. This might partly explain why deciduous forests at a lower productive stage, 50-60 year-old stands with maturing 2nd growth, or with a floor densely covered by bamboo grass (e. g, *Sasa kurilensis*) in the large proportion of this study region.

Bears consistently avoided both evergreen and deciduous coniferous plantations (54.4% of the total forest cover in this area) throughout the two seasons. During the last 20 years, a severe decline of open shrub dependent birds has clearly indicated the occurrence of a significant maturation in Japanese plantations (Yamaura et al. 2009). Consequently, it is highly likely that these artificial forests are now reaching a stage in which they are virtual non-habitats, and hence an unproductive matrix for bears. Given that a large portion of planted forests are left unmanaged, the negative fragmentation effects on the many wildlife species that are dependent on deciduous broad-leaved forests will probably become more serious in the long run than during the period shortly after logging (Yamura et al. 2006, Agetsuma 2007). This analysis contrasts with more superficial views of the continuous forest covering observed throughout Japan today.

The differences between seasons in selection of vegetation

Seasonal changes are well known as a great driver of dynamic shifts in habitat selection by bears (Izumiyama and Shiraishi 2004, Nielsen et al. 2010, Nakajima et al. 2012). In contrast to the consistency in the selection of deciduous broad-leaved forests and the avoidance of plantations, selection of other vegetation types and the effect of distance from linear landscapes were highly seasonal. These significant seasonal variations may be largely due to dynamics in the spatio-temporal

distribution of the diverse food needed to fulfill the requirements of omnivorous bears. Several studies have found temporal adjustments in site selections corresponding to specific food items (Davis et al. 2006, Munro et al. 2006), and phenology has been identified as the major factor for the seasonal difference in habitat selection by Asiatic black bears as well. Given the dispersed and ephemeral characteristics of bear food, it is understandable that seasonal migrations of bears in search of food have often been documented (Noyce and Garshelis 2006, Noyce and Garshelis 2011, Yamazaki et al. 2009, Landriault et al. 2006). The areas selected by Asiatic black bears shifted toward higher elevations during the transition from summer to autumn, and such changes have been commonly observed in mountain regions in Japan. These elevational migrations corresponded to phenological changes in several species of plants which are important as bear food (Nakajima et al. 2012, Mace et al. 1999), and the phenological effects may have been amplified by temperature gradients along the steep mountain slopes. The greatest fitness of the land cover covariates in autumn according to univariate logistic regression (Chap 3 Table 4) is probably evidence that it is food distribution which most influences bear selection during the period of hyperphagia.

The summer food of bears consists of cherries, berries, lianas, other succulent fruits, herbaceous plants and colonial nesting insects (Hashimoto and Takatsuki 1997, Takahashi 2006, Koike 2010, Huygens et al. 2003). The majority of these plant species prefer the good light conditions provided by forests edges and the canopy openings occasionally generated by natural or artificial disturbance. The most conspicuous vegetation in the study region strongly selected by Asiatic black bears during summer was red pine forest. The odds ratio was two times greater than that for plantations in summer while the probability of selection decreased dramatically in autumn. In general, red pine forests in Japan are secondary forests naturally grown on lands after the cessation of intensive logging, and therefore they exhibit early successional structures providing good light conditions for forest floor plants including various fruiting shrubs and young broad-leaved deciduous trees that gradually take over the red pine trees provided nothing disturbs the process of succession. In the study region, the forests are commonly distributed in foothills at elevations of <1100 m. Many are over 50 years old, and privately owned with limited management practices. Fallen and withering trees were much more abundant in unmanaged red pine forests than in managed forests (Kondo and Koyama 2004), and the abundant decomposing woody materials found in lowland forests in relatively warmer climates are

supposed to be beneficial for several colonial insects such as beetles, ants and termites which are an important source of summer protein intake for bears.

The other significant land cover type associated with the summer habitat of bears was the open regenerating land thinly scattered within the dense forest cover found throughout the mountains (Odds ratio 1.688, $p < 0.001$, Chap 2, Table 5). Open generating lands, whether naturally (e.g. as a result of wildfire, landslide or gale) or artificially (e.g. because of clear-cutting) generated (Brodeur et al. 2008), have often been reported as favorable habitat thanks to the thriving early successional shrubs that provide bears with a good feeding opportunity (Mattson 1990, Nielsen et al. 2004, McLellan and Hovey et al. 2001). Although such open shrub lands provide diverse summer food, the area is small in size and accounts for only 11.5 % of the entire mountain range in this study region (>1000m elevation). According to the vegetation map reclassified from a satellite image, the scarcity of open regenerating lands in the mountains may be one of the reasons for the inconsistency of their effect on bears' habitat selection according to multivariate logistic regression (Chap 3 Table S1-S2).

Distance from forest edges and forest roads had a great effect on the probability of bear selection during summer. Because of the hot and humid climate in Japan during summer, forest edges are densely covered by mantle plant communities rich in fruiting lianas, making them more favorable place for bears than forest interiors. However, the bears in our region seemed to select areas near forest edges because they offered refuge as well as foraging, since the pattern of selection was not greatly affected by vegetation cover types (Chap 3 Fig 2). This assumption is supported by the fact that seasonal difference had no effect on distance from forest edges when bears were in farmlands and areas near towns. In addition, the bears showed a strong preference for red pine forests covering foothills and riparian zones in lowlands where there was intensive human activity. Consequently, it must have been necessary for them to hide in densely covered forest edges to avoid being sighted by people. Similar behaviour has been observed in Scandinavian brown bears, which also selected habitat edge zones for their day bed because they offered a refuge (Ordiz et al. 2013). Although the selection of areas near forest edges was less evident in autumn particularly in red pine forests, it was still influential in deciduous forests, and this may indicate the importance of edge structure for foraging during both seasons in this type of forest.

Influence of linear landscape features on habitat distribution in summer

The positive selection of red pine forests indicate that bears may find themselves in a trade-off situation in areas close to farmlands or settlements. The result from distance effect models (Chapter 3) revealed that habitat selection in summer was more affected by distances from linear landscape like forest edges, roads, and rivers than selection in autumn, meaning that one can reasonably expect a higher probability of encounters between bears and people in summer.

Against expectation, the bears showed a slight preference for areas relatively close to open roads in summer, but this tendency disappeared in autumn. Some prior studies have reported that bears responded neutrally to high use roads (Van Manen et al. 2012, Roever et al. 2010), and the black bears probably only used open meadows by the roadside when traffic volume was relatively low. This can also be explained by the fact that bears can become habituated to environments which are chronically disturbed. At larger scales, the locations of open lands are concentrated in valley bottoms that correlate with housing densities and agricultural lands used for daily human activities as in the United States (Radeloff et al. 2005). High-use roads have a wide range of influences, but it is their positive associations with more productive lowlands that offer the most plausible explanation for the selection of open roads by bears (Chap 3 Fig 2).

Bear response to distance from forest roads differed significantly from their response to open roads. A remarkable increase in the probability of selection was found as distance from forest roads shortened during summer (Chap 3 Fig 2), and the selection was greatly influenced by cover types. . The majority of forest road network stretches around foothills and generates heterogeneous habitat patches like narrow canopy openings and forest edges that are positively associated with summer habitat. Even though the positive selection near forest roads can be attributed to increased foraging opportunities, as can selection near forest edges, the pattern was slightly different. For example, an adverse seasonal response to forest roads among both females and males was observed, avoidance in summer and selection in autumn by females, and selection in summer and avoidance in autumn by males. One factor underlying the difference in bear response to forest roads and forest edges may be the higher probability of irregular access by people in the case of the former. Female bears are thought to be more vulnerable and sensitive to human disturbance because of their constrained home

ranges (Powell et al. 1997). During summer, frequent human presence around forest roads for recreational purposes makes female bears reluctant to use such areas. With the lower usage by people in autumn, bears begin to use forest road areas more for foraging. Such trade-off behavior represented by inverse habitat selection among sex groups has been observed in American black bears (Gaines et al. 2005), Grizzly bears (Gibeau et al. 2002) and Scandinavian brown bears (Nilleman et al. 2011).

Riverine environment in the central Japan Alps was positively associated with summer habitat for Asiatic black bears. Bears may benefit from being able to forage for mesic herbaceous plants (e.g. Japanese sweet coltsfoot *Petasite* spp., Japanese knotweed *Reynoutria* spp., Udo *Angelica cordata* spp., etc) (Huygens et al. 2003), which thrive thanks to the ecotonal conditions of light and moisture. Distance to rivers also had a great effect on RSF predictions in summer as shown in the table of coefficients (Chap 3 Table S1-S2) and in predictive maps for both females and males (Chap 3 Fig 3-6). It should be noted that the conditions found in matrix surrounding rivers in mountains are the opposite of those found in matrix surrounding lowland rivers. In higher mountains, small streams generally covered by forests gradually congregate to form a wider river associated with canopy openings, and where a river flows in a lower plain, it forms riparian forest as a linear green belt on the matrix of anthropogenic landscape. The less significant results from the distance effect model for rivers probably reflect these opposing conditions characterizing the matrix in mountains and lowlands (Chap 3 Fig 2).

2. The relationships between season specific habitat for bears and changes in human land use.

The results of this study indicate that it is human land use changes that are mostly responsible for causing Asiatic black bears to select the peripheries of human-dominated lands.

One of the more remarkable outcomes from this study was the finding that red pine forests are the most important areal component of bear habitat during summer. The fact that selection of red pine forests had a higher odds ratio than selection of deciduous forests indicates that the current range of deciduous forests are not satisfactorily supportive during summer despite their role as the primary

bear habitat. Red pine forests are the dominant forest cover in foothills at altitudes of around <1100m, and partly mixed with coniferous trees in this landscape. The foothills surrounding villages and farmlands were once carefully managed as community forests called “*Satoyama*” in Japanese, but exploitation of these forest resources ceased in the 1960s throughout Japan. The forests are partly planted, but mostly naturally grown after clear-cutting, and the fact that the secondary forests in the study area are fifty years old indicates that their growth corresponds to the period that has elapsed since the end of *Satoyama* management. It was not possible to confirm that the benefits offered by red pine forests are sufficient to maintain viable populations of bears. However, it does at least seem plausible that *Satoyama* abandonment is one of the indirect causes of the increased use of foothills by bears.

The other key finding is the importance of early successional vegetation for bears in providing a great variety of summer food sporadically scattered in small quantities across a heterogeneous landscape. The positive selection of open regenerating lands and areas close to forest edges provided explicit evidence that bears were searching for these food items. Nowadays, open canopies in mountain ranges are extremely limited and patchily dispersed, and the distribution of forest edges is restricted to the side of roads, rivers and lowland forests. Bears may search for alternative foraging lands such as abandoned farmlands or forest roadsides in what might be seen as an instance of the initial process whereby bears become habituated to using land near human settlements.

On the other hand, the vast areas of heavily maturing plantations (about 42% of all Japanese forests) are now increasingly closed canopy (Yamaura et al. 2012), and this may be largely responsible for the lack of diversity in the structure of forests which leads Asiatic black bears to select more heterogeneous landscape in lower plains. The never-ending influence of large-scale habitat disturbance in the past cannot be ignored when seeking to understand current habitat selection by wildlife in Japan (Agetsuma 2007). The case of Asiatic black bears in the central Japan Alps illustrates the importance of the inevitable relationship between policy and practices in forestry and habitat selection. Clearly, changes in forest management are one of the primary causes of the increase in human-wildlife conflicts across Japan’s rural landscape.

3. Evaluations of habitat distribution and its quality for Asiatic black bears in the central Japan Alps during summer and autumn.

The spatial distribution of habitat for bears was widely influenced by seasons and landscape features in the distinct dichotomic mountain-valley.

According to the maps showing distribution of relative probability of bear selection predicted by the indices of RSF during summer (Chap 3 Fig3-6), linear landscape features had significant effects on habitat distribution that correctly reflected the positive association with close distance from forest edges, forest roads and rivers. The fact that suitable habitats have such a linear shape suggests a lack of large areal habitats during this season, and in all likelihood this indicates that bears were forced to utilize highly marginal lands. In addition, the areas of high probability of bear use are significantly concentrated in riparian forests in low lands. Those striped green belts of around 70-100m in width formed by river terraces, which are a unique geological feature in this landscape, are surrounded by open anthropogenic matrix. The frequent use of the riparian forests by bears is the key to understanding the mechanism of increased human-bear interactions. The bears' opportunistic foraging nature may lead to the problematic behavior of feeding on crop growing near the linear forests. Predictions showed that human-bear boundaries were clearly much larger in extent in summer than in autumn, and this correlates with the fact that summer is the peak conflict season. More caution should be exercised in boundaries associated with forest edges, forest roads and rivers than in any other areas because of the high probability of human-bear encounter. The delineated human-bear boundaries during summer also represented a distribution of bear habitat skewed downward towards lower lands.

The differences in RSF prediction between the two seasons suggest that seasonal migration by bears has taken place. This might be seen partly as evidence of the existence of a better quality of autumn habitat available in the mountain range. The dynamic shift in the spatial distribution of seasonal habitat does not necessarily support the hypothesis of the expansion of bear range. Rather, there is little doubt that one needs to take more account of the decline in summer habitat in the mountains. Several previous studies have expressed alarm at the cumulative effects of human development on wildlife habitat, and our study too found that the secure habitat remaining in remote

mountains during summer was extremely limited (5.3% of the study range. Chap 2 Fig 2) when road density was introduced into the model as a surrogate for human disturbance. Namely, most bears seem to face a severely high risk of being sighted by people when they select marginal and dispersed habitats near human settlements in summer. As a whole, the results from habitat estimation in this study suggest the importance of heterogeneous landscape structure, particularly in mountains, in providing summer habitat for Asiatic black bears in this mountain-valley landscape. Hence, it can be stated conclusively that unmanaged coniferous plantations have an on-going negative impact on the season-specific habitat of bears due to the increase in canopy closure over time. This means that mono-cultured forests have the undesirable consequence that local residents suffer from frequent contacts with these large carnivores.

4. Why do Asiatic black bears currently use the peripheries of human-dominated lands?

The frequent occurrence of Japanese black bears near human settlements is a significant seasonal event. Except in years when there is a crop-failure of acorns, bears usually leave human-dominated valley bottoms and migrate toward mountains where natural food becomes more available. This indicates that season specific habitat use close to human-settled lowlands cannot be explained by assuming an increase in the bear population. The shifting location of available food resources seems to offer a more plausible explanation (Barch-Mordo et al. 2013) than high population density since it does not always represent abundance of animals in a specific area. (Beckman and Bergers 2003). Nor can seasonal migration be used to support the despotic distribution hypothesis that argues that subordinate individuals are forced to use relatively risky areas near human settlements. Although the majority of bears killed as nuisances in Nagano prefecture have been young male bears (Kishimoto 2009), the killing of larger adult males and single females has not been exceptional in the last few years (Takii et al. 2013). As Elfström et al (2012) have cautioned, the presence of dominant individuals must be seen as an indication of food scarcity in wild lands.

Fig.D-1 is a diagram of the relationships between the hypotheses connected by causal routes leading to the frequent use of the periphery of human-dominated (PHD) lands by bears. It was

reworked from Fig.I-1 in chapter I in order to apply the key findings from this research into the case of Asiatic black bears in mountain regions in Japan.

The significantly positive selection of red pine forests occurring only in summer indicates that there are season-specific resources available for bears in these forests, which are typically located around valley bottoms in the central Japan Alps region. Hence, this seems the most important direct factor encouraging bears to select PHD lands (L1, Fig.D-1). Riparian forests running through anthropogenic matrix consisting of a river, forest edges and red pine forests were also the key linear landscape positively associated with summer habitat for bears. These green corridors must play a pivotal role in luring bears from mountains into low lands by providing multiple habitat functions such as food sources, refuges and a moving pathway (L3-B3 route, Fig.D-1). Damage caused by bears to agricultural crops near forest edges, riversides or foothills has become a common problem in this region. This may indicate that the conditioning occurs after frequent use of PHD lands (B1, Fig.D-1) rather than being the direct cause luring bears into such areas in advance (B2, Fig.D-1). All of the results mentioned above suggest that it is the available season-specific habitat for bears distributed near human settlements that may be the major cause of the frequent occurrence of bears on PHD lands. Furthermore, areas of high probability of selection by bears were concentrated in PHD lands according to the RSF predictive maps. Attention needs to be paid to the strong effects of linear landscape features on the distribution of summer habitat, because the pattern of habitat distribution may indicate a high probability of a lack of areal habitat in remote mountains during this peak conflict season.

This study revealed that coniferous plantations had significantly negative effects on habitat selection by Asiatic black bears across the two seasons. Such consistent avoidance of these vast areas in the mountains may be a factor underlying the aggregation of summer habitat in PHD lands. In addition, most of the plantations have been unmanaged for a long while, leading them to reach a mature stage in which the structural diversity of the forests is reduced, resulting in a deficiency of various food for bears in the summer season. Therefore, this is probably one of the underlying causes of the frequent use of PHD lands by bears (L5-L1 route, Fig.D-1).

To summarize, the proximate causes for the frequent use of areas near human-dominated lands by Asiatic black bears are their positive selection of red pine forests and riparian forests commonly

located in or around anthropogenic landscape at lower elevations. The ultimate cause of the frequent occurrence of bears in PHD lands in Japan is probably the unmanaged forests, both in foothills and mountains, which were a result of changes in land use pattern by humans.

Typically in a mountain-valley landscape, humans dominate more the productive lower plain thanks to the moderate climate and flatter terrains that are suitable for housing, farming and transportation. As a result, a large part of the wildlife habitat contracts as animals become confined to the harsher and less productive areas at higher elevations. Even when human activities have ceased due to depopulation and the aging of society, phenomena which are currently increasing in rural Japan, it may be a long time before such productive lower lands are utilized by wildlife for feeding on early serial food resources. Therefore, in the case of Asiatic black bears in mountain-valley landscape, a large-scale spatial niche partitioning among common habitats between humans and bears is presumably the best explanation for the frequent occurrence of bears near human settlements. In addition, the loss of habitat in remote areas may also have caused more bears to use lower lands densely populated by humans. The combination of a scarcity of habitat in the mountains and more suitable habitat in lowland forests may be the proximate mechanism causing the frequent occurrence of bears near human settlements, and the vast area of densely covered artificial forests have had an indirect but inevitably negative impact on the distribution of seasonally suitable habitat for bears in the mountains. All of these key causal mechanisms originate both from the large scale disturbance of bears' primary habitat in the past and from the current abandonment of forestry practices by humans.

In conclusion, this research has shown that historical human land use changes carry the greatest responsibility for causing Asiatic black bears to use the marginal habitats which are currently more available near human-dominated lands.

MANAGEMENT IMPLICATIONS

1. Prioritizing specific areas for reduction of human-bear interactions

Given the extremely scarce public funds and staff available for wildlife conservation and management issues in Japan, the first consideration should be the alleviation of the burden of responsibility currently falling on local managers, who as local civil servants generally have other concurrent commitments. Therefore, prioritizing specific periods and areas on which management action can focus is essential to any attempt to mitigate human-wildlife interactions. The key findings in this study suggest that the three focal landscapes which need to feature in guidance given to local residents to enable them to avoid encountering bears are red pine forests, riparian forests and land near forest roads.

Within the red pine forests located in foothills in the study region, small camping grounds, sport facilities and recreational parks are patchily distributed. These are often scenic spots which attract numerous tourists, and many of them are located near riversides. Provision of detailed information about the areas and periods of high probability of bear occurrence is necessary to prevent direct human-bear contact. Moreover, there are many small hot spots which hold an inevitable attraction for bears during the season in which food is scarce. Small fish farms, beehives, compost heaps of agricultural waste, and small cattle farms, though commonly located near villages, offer a particular enticement to bears when, as is often the case, no human beings are present. Such sites are small but strongly sufficient enough to transform the natural behavior of bears, conditioning them in ways that lead to tragedy for both people and bears. Likewise, croplands producing food favored by bears, e.g. maize, apples or other fruits, near the edge of red pine forests or riparian forests, can quickly become attractive to bears even though located in human-dominated open lands if nearby forest edges can provide cover.

Most of challenges of management can be met by using visually predicted maps showing areas of high probability of bear occupancy and human-bear boundaries, the areas in which human-bear interaction is likely to occur. Such visualized predictive maps of the actual landscape can be highly effective tools when talking to the people living in the areas concerned. This should lead to

appropriate decisions being made and action being duly focused on the relevant areas by sharing the spatial information actually needed to reduce the probability of encounters with bears. The human-bear boundary maps would also help in the selection of sites to which local people might be persuaded to regulate access and so reduce disturbance.

2. A novel approach to conflict mitigation through season-specific habitat restoration and management

It seems obvious that a large-scale perspective is essential for the conservation of wide-ranging wildlife. According to the habitat selection by Asiatic black bears estimated by RSF models, the scarcity of areal habitat in mountains coincided seasonally with increased human-bear interactions. This coincidence clearly suggests that the restoration of season-specific habitat may have a great potential to reduce undesirable interactions. There are two recommendations that might be made regarding management practice: 1) the revival of *Satoyama* management in lowland forests, and 2) the restoration of the mosaic of diverse forests in the mountains.

Red pine forests in the foothills of this region have two key roles in both providing critical summer habitat to bears and increasing the risk of human-bear encounters. One way to conserve season-specific habitat and at the same time mitigate human-bear encounters, would be to revive the practice of *Satoyama* management, desirable in itself as an instance of sustainable resource use. The traditional management scheme was typically conducted by circulation between small patches of clear-cutting and secondary growth. Such moderate and periodic disturbance increases the heterogeneity within forested landscape that is beneficial in the way it promotes both season-specific bear habitat and biodiversity. In addition, *Satoyama* management would function to restore and maintain buffer zones preventing bear habitat and human settlements becoming directly contiguous, and so would mitigate tensions between humans and bears. It should be noted that these management practices should not be implemented during summer in order to avoid a reduction of bear habitat and an increase in tragic human-bear encounters. Together with the benefits that *Satoyama* management has for biodiversity conservation, as confirmed by several ecological studies (Kato et al. 2009), there are further advantages with respect to the mitigation of human-wildlife

conflict that might reinforce support for such initiatives. In addition, the introduction of recreational management suited to the demands of modern life might be a successful means of encouraging a wider involvement of civil participants. The most successful solution in conservation terms is likely to come from taking an integrated approach that maximizes the benefits not only for bears, but also for other wildlife, biodiversity and human wellbeing.

Compared with edge-dominated lowland habitat, coniferous plantations at intermediate elevations were less important for bears regardless of the season. The majority of these plantations have been unmanaged for over 40 years and this has worsened biodiversity as a result of the increased canopy closure over time. Intensive flood and landslide control, as well as dam construction, have also spurred the decline of the once diverse mosaic of montane vegetation that included swamps, marshes and other eco-tonal habitats. The creation of canopy openings within the aging over-planted forests is probably one of the practices that would most efficiently increase heterogeneity in forest structure and so provide the variety of food which is so important for bears, not only during summer. Early successional plants typically occurring in open canopies are also critical in autumn as a supplemental food source when crop-failure occurs among acorn species. Once the diversity of forest structures has been restored, we could expect a decrease in the probability of frequent bear use of lowlands near human lands.

3. Caveats regarding estimates of population size and distribution of Asiatic black bears in Japan

There remains great uncertainty in estimates of population size and distribution range of Japanese black bears that may mislead the public and steer management towards practices which prove detrimental to conservation. Incorporating habitat parameters into the research design is sufficient to reduce the likelihood of the kind of sampling bias that might distort statistical results and reduce the precision and reliability of estimates.

The nationwide surveys in 1978, 2004 and 2014 concluded that the range of black bears in Japan had expanded. These results, however, are to a great extent contradicted by the outcomes from the present study on habitat selection at landscape scale using more statistically rigorous models based

on accurate GPS location data, as opposed to previous studies in which coarse scale estimates were based on imprecise questionnaires and official records from national surveys. For example, even though bears have commonly been observed to range widely during their seasonal migrations, distribution estimates never included variables of season. According to the predictions of season-specific habitat selection in this research, there was strikingly skewed habitat distribution toward anthropogenic lowlands during summer, indicating that the remaining habitat in remote mountains was severely restricted. Because data for isolated areas was almost absent, it is highly probable that the data in which bears were treated as present in such areas in the nationwide survey gave rise to overestimates due to the inevitable sampling biases. Several experts have warned that the occasional aggregation of species can lead to a failure to accurately determine the real range or population size of an animal (Van Horne 1983), and we should take into account the likelihood of overestimates in assertions that there has been an expansion in the range of bears. Partitioning sampling units by stratified design using habitat variables may be one way to minimize the bias in a large scale survey.

As far as the impact on bears of the prevalent lethal control is concerned, population monitoring should be considered in the first instance for evaluating such management practices. Although several advanced sampling techniques have been developed, there are still considerable difficulties to be overcome when it comes to making comprehensive estimates due to the limited financial support available for the huge undertaking of collecting data on these elusive animals. It should be noted that population size poorly predicted the likelihood of the extinction of large carnivores while a high ratio of encounters with people had a greater influence on the probability (Woodroff and Ginsberg 1998). Theoretically, the relationship between the minimum viable population (MVP) is negatively correlated with habitat quality (Van Horne 1983). For instance, a larger number of bears is necessary to maintain the population in a low-quality habitat because of the need to compensate for the lower rate of reproduction, whereas even a relatively small population of bears in a high-quality habitat can maintain itself without such off-setting. An unpredictable stochastic event has sometimes generated an occasional aggregation of wide-ranging animals in low-quality habitat with a high risk of exposure to humans as it resulted in a high mortality. Moreover, the opportunistic nature of bears probably magnifies the effects of aggregation (Garshelis 2002). Thus, over-killing bears in a

low-quality habitat may have a detrimental impact on population persistence. In this context, the evaluation of habitat quality should be considered first when attempting to control or manage populations, otherwise we might fail to detect a real decline in population.

Unless the population size of bears is reliably estimated, there will inevitably be too much uncertainty in management decisions. In the case of Asiatic black bears in Japan, there also remain additional uncertainties relating to the distribution and the quality of available habitat. At the very least, monitoring population trends is necessary if we want to test responses to management actions, but caution is called for when population trends are estimated by the number of bears killed, since there are questions about the accuracy of this approach and, in many cases, a high probability of overestimates being made (Garshells 2002). If viable populations of bears are to be conserved in Japan, precautional principle such as a cautious attitude is essential and efforts made to avoid type II errors. For instance, an overestimate that leads to an increase in the number of bears culled carries a risk of population decline if the real population size is much smaller than suggested by the estimate. According to the results from this study, it is highly likely that over killing bears in areas close to human settlements which function as a attractive sink will has a detrimental impact on the population (Nielsen et al. 2006). Given the time-lagged response to human disturbance by these long-lived animals, the need to recognize when there has been a real population decline is extremely important for the conservation of bears in Japan.

FUTURE DIRECTIONS

1. Further investigation is needed to identify the causes and effects of the frequent occurrence of bears on the periphery of human-dominated lands.

The causal mechanisms underlying the high frequency of bear use in areas close to human settlement have not yet been fully investigated, even though my research found evidence of a relationship between human land use changes and reductions in the extent of season-specific habitat for Asiatic black bears. If we could clarify the mechanisms related to land use changes; e.g. forestry

and agricultural policy and practices, habitat-based approaches to the mitigation of human-wildlife conflicts would be widely recognized as an effective management practice.

Spatial data relating to the history of land use such as aerial photos, and forestry and land-use records can be useful in creating maps of landscape changes, and overlaying habitat maps onto such maps might enable us to detect wildlife responses to gradual changes in landscape over time. Systematic field surveys which enable the collecting of spatial data relating to food distribution are also necessary if we want to know how critical resources for bears varied through history and in response to different practices in forest management. They may also provide a clearer picture of the associations between human land use and the distribution of available resources. A more direct and effective way of investigating the cause and effect relationships is by pursuing experimental research on the actual sites in order to compare unmanaged forests and restored habitat, and to examine the differences in bear response. For example, a combination of the clear-cutting of mature plantation to generate open habitat and monitoring responses to the newly created season-specific habitat by bears would enable us to confirm whether forest management can change bear habitat selection by encouraging the bears to forage in areas further away from human settlements.

2. Increase of baseline knowledge about critical habitat for the persistence of bear populations.

In most of the *Specific Wildlife Management Plans* made by several Japanese prefectural offices, the heading “*Appropriate habitat conservation and management*” announces as one of the goals of wildlife management, but this has usually been a mere façade cited in lists of achievements even though no practical plans have in fact been made. Giving a position of secondary importance to habitat may be largely attributable to the limited understanding of habitat requirements for the target species. The lack of reliable and scientific knowledge delays the fostering of awareness of human responsibility for the large-scale land transformations and domination that have seriously affected the quality of remaining wildlife habitat. To overcome this deficiency, an accumulation of baseline scientific information about the dynamic changes in available habitat for the reproduction, survival and movement of wide-ranging wildlife should be prioritized.

Even with the completion of the present study, there still remain gaps in our knowledge of the habitat of Asiatic black bears in this mountain-valley landscape. For instance, research is still needed on habitat selection in spring, during the hibernation period, and in the mating season, as well as on the selection of alpine meadows in summer. Various further avenues of research in habitat selection study have been opened by the use of RSF models to investigate wildlife-environment relationships by incorporating various theories and topics such as multi-scale considerations, functional responses to changes in available resources, temporal behavioral adaptation to human disturbance, and genetic traits, etc. Nowadays, habitat studies of wildlife are greatly encouraged both by technological advances that have made it possible to collect massive amounts of accurate data and up-to-date analytical methods without which we would be left to puzzle over overwhelming data sets. It appears to have become more important to adopt a wider perspective and to find the best match between research question, modeling theory and tools.

3. Issues in the application of habitat prediction using RSF.

One of the outstanding advantages of habitat modeling is its ability to make predictions. Despite the many avenues already tried, there are several challenging issues with respect to how the results from a specific area can be applied to other regions.

There seems little doubt that habitat selection by Asiatic black bears in a specific region cannot be taken as representative for populations in other regions of Japan and let alone in other Asian countries. In the other extreme case, one-off research studies tailored to each sub-population in order to make precise estimations are also pointless and not cost effective. The challenge is how to apply the results from one context to another. Explanatory variables must be carefully selected to estimate the parameters which most reasonably describe the data in the model building process. The set of variables selected might stem from the universal traits of biology of the target species and the uniqueness of the geographical characteristics of the target area. Therefore, a somewhat exploratory investigation can be useful to segregate common variables (e.g. terrain features, water, climate) from endemic variables (e.g. vegetation types, anthropogenic land use) among regions. Ironically, there is a dilemma in that comparison that becomes impossible if we change the variable set for each study

region. In the real world, the large differences between regions in terms of the amount of existing animal location data are due to the huge costs of acquiring such data. On the other hand, more obtainable and more freely downloadable geographical map data from global web servers has become useful in the preparation of various environmental variables, and many of the operational modeling techniques on GIS are rapidly progressing.

One method I would recommend here is: 1) collecting as much GIS map data on the target region as possible to prepare habitat variables; 2) cautiously selecting variable sets and estimating habitat parameters wherever a large data set of animal locations is available; 3) applying the parameters to build a habitat model for the target region; and 4) conducting a model validation by using observation data collected in the target region to test whether the applied habitat parameters are successfully able to predict or not. Optionally, we can analyze similarity in landscape structures and configurations (e.g. mean patch size of critical vegetation) between regions, and include the weight of similarity in the new model. Functional response can be used by applying parameters estimated in a region with a large data set to other regions with little data. RSF modeling is capable of correlating the functional responses of animals with changes in the availability of resources. The differences in available resources may be greater than the difference in the types of resources selected by bears, because we can reasonably assume that the biological traits of bears will be more consistent among regions than landscape conditions.

Numerous habitat models using RSF have already been developed for various taxonomic groups, for example, other large terrestrial mammals (Johnson et al. 2004, Osko et al. 2004, Harju et al. 2011), marine mammals (Goetz et al. 2007, Kaschner 2004), birds (Aldridge and Boyce 2007, Meager et al. 2012), reptiles (Martino et al. 2012) and amphibians (Williams et al. 2012, Montieth et al. 2006). It is, therefore, entirely valid to employ RSF model procedure for other wildlife inhabiting the Japanese rural landscape in order to acquire knowledge of their habitat. In particular, for large sympatric mammals such as Japanese macaques, wild boar and sika deer, to which it is possible to attach a GPS collar to collect precise location data, prediction of habitat distribution is useful when seeking to prevent crop damage while at the same time helping to conserve these species, as has been shown by this study in the case of the black bears.

4. Toward establishment of a conservation planning.

Unfortunately, there have been many obstacles to the establishment of biodiversity conservation as a consideration in the general land use planning processes in Japan due to many socio-political difficulties to do with, for example, the territorial jurisdiction of the authorities concerned, the complex and opaque decision making process, and the crowded mosaic tiny pieces of private land. In particular, for a long time in this country the severely limited jurisdiction of the Ministry of Environment with respect to land use planning has allowed large-scale land development and conversion to support economic growth, which has resulted in unlimited and endless habitat loss for many species.

To overcome these difficulties, one thing I can recommend from this study is the improvement of *the Specified Wildlife Conservation Management Plans for Asiatic black bears* (see Introduction) by the addition of practical suggestions under the heading of “*Appropriate habitat conservation and management*”. For instance, the restoration of summer habitat in mountains by clear-cutting plantations is one practical measure, and promoting *Satoyama* management another that should be welcomed by authorities who have already introduced initiatives to promote biodiversity conservation. If it could be proved that such management actions were effective in reducing human-bear interactions, the concept of habitat-based mitigation measures would be viewed as widely applicable to other regions and other wildlife which have similarly complex relationships with people.

A visualized map showing the relative probability of bear occurrence in actual landscape may have a great impact on local people whose fear of these large carnivores might lead them to react quite negatively. Therefore, we should use predictive maps cautiously. Furthermore, utilizing visualized maps is also challenging because active conservation planning at landscape level has yet to become established in Japan, despite the fact that predictions developed by scientifically reliable methods have incredible potential. Important stakeholders in the decision-making processes and competent authorities actually undertaking planning projects should be identified so that visualized and predictive maps can find an application in the real planning world. Drawing the attention of a Public Works Department that usually has no interest in species conservation can be one way to synthesize

human needs with the conservation of biodiversity. In general land use planning, the planners use multiple map layers, and each of them is developed for a specific purpose, e.g. disaster control and mitigation, construction or maintenance of water supply systems, transportation networks. It would be ideal if we could add habitat maps to these multiple map layers, thus making the spatial distribution of wildlife habitat one of the considerations in the conventional planning process. For both human-bear conflict mitigation and the maintenance of viable populations of bears, harmonizing habitat requirements with human needs at the regional level is critical in large-scale habitat conservation and management.

It seems likely that studying bear habitats may have an umbrella function in helping to preserve other sympatric species because of their dependency on the diverse food resources produced by heterogeneous native forests. Although representative populations should be investigated to estimate how many species would stand to benefit from the conservation or restoration of bear habitat, the integration of the results of such research with habitat studies of native fauna and flora might be expected to contribute significantly to the prevention of the undermining of remnant habitat. Identifying the benefits which conservation might have for human well-being is essential if habitat conservation is to become more realistic. Collaboration not only with specialists in the same field, but also with experts in a wide range of other disciplines will be equally important in seeking to overcome the difficulties of establishing effective conservation planning.

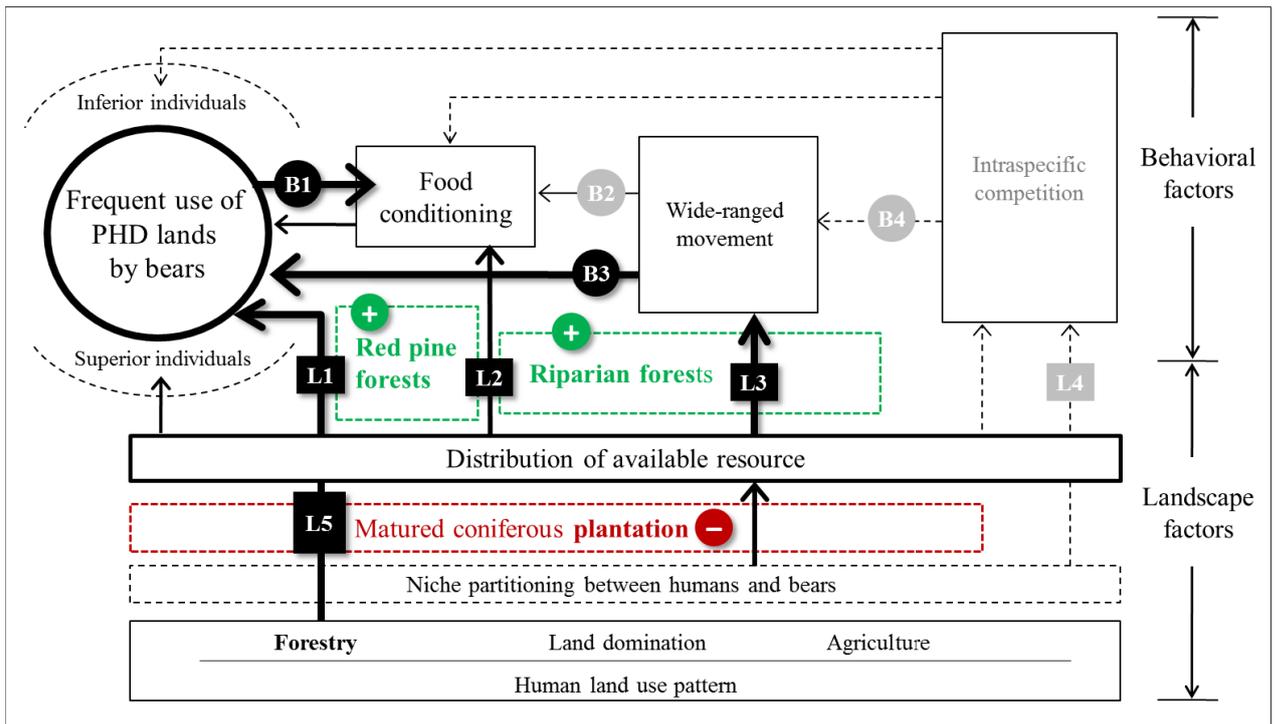


Fig. D-1

A conceptual diagram, reworked from Fig. 1-1 in Chapter 1, showing the relationships between key findings from habitat study and the hypotheses described in Chapter 1. The shadowed lines represent the causal routes toward the frequent use of PHD lands by Asiatic black bears in mountain-valley regions in Japan. The green and red circles, respectively, indicate positive and negative associations with habitat selection by Asiatic black bears.

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APPENDIX:

Table A-1.

The summary of captured Asiatic black bears and the relocation data from GPS telemetry in 2008-2011.

bear identity	Sex	Age ^a	Body size /kg ^b	MCP home range size/km ² ^c		GPS radio Telemetry locations ^d	
				Summer	Autumn	Summer	Autumn
F1	F	10*	45	5.6	7.89	760	1489
F2	F	4	43	3.7	13.53	832	1959
F3	F	6	40	28.1	31.65	1233	1216
F4	F	4	34	3.2	11.89	580	1203
F5	F	4*	40	9.6	11.52	490	775
F6	F	2	37	154.3	94.95	1293	1296
F7	F	6*	43	5.7	60.45	577	805
F8	F	8	39	7.4	7.38	993	1101
F9	F	4	34	11.1	18.93	505	746
F10	F	7	40	5.8	6.11	739	481
F11	F	3	37	33.9	22.91	562	611
F12	F	10*	64	8.7	9.15	1100	1227
F13	F	8*	47	8.4	21.48	633	1448
F14	F	8*	63	27.4	–	458	–
F15	F	6	44	12.9	–	753	–
M1	M	6*	76	9.9	75.42	389	1131
M2	M	5	40	36.2	31.80	1431	1667
M3	M	4	42	5.1	10.02	691	459
M4	M	6	56	144.4	228.77	1308	1521
M5	M	5	48	28.8	58.96	1238	1257
M6	M	4	61	17.4	17.87	739	496
M7	M	5*	56	40.8	338.76	527	571
M8	M	12	64	6.5	24.50	578	1099
M9	M	7	65	10.3	144.48	1411	1415
M10	M	3*	35	85.9	64.92	1476	594
M11	M	12	73	91.4	–	518	–
M12	M	3	26	15.8	–	77	–
M13	M	7	44	5.9	–	96	–

^a Age at the year of data collection

^b Body weight at the year of data collection

^c Home range size estimated as 100% minimum convex polygon (MCP)

^d Telemetry locations sampled every 1 hour

* estimated by experts

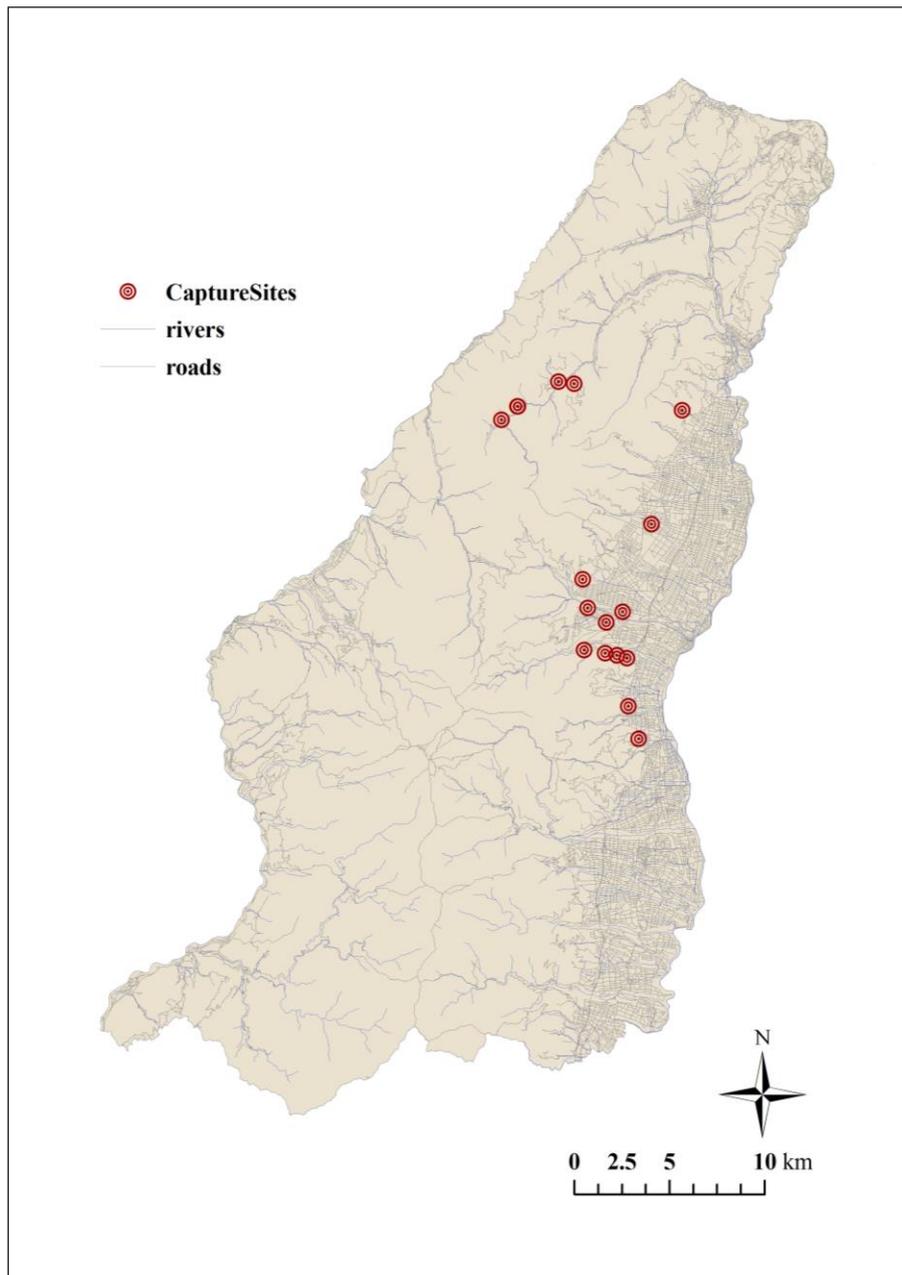


Fig. A-1

The locations of a trap site for capturing Asiatic black bears in the study area.

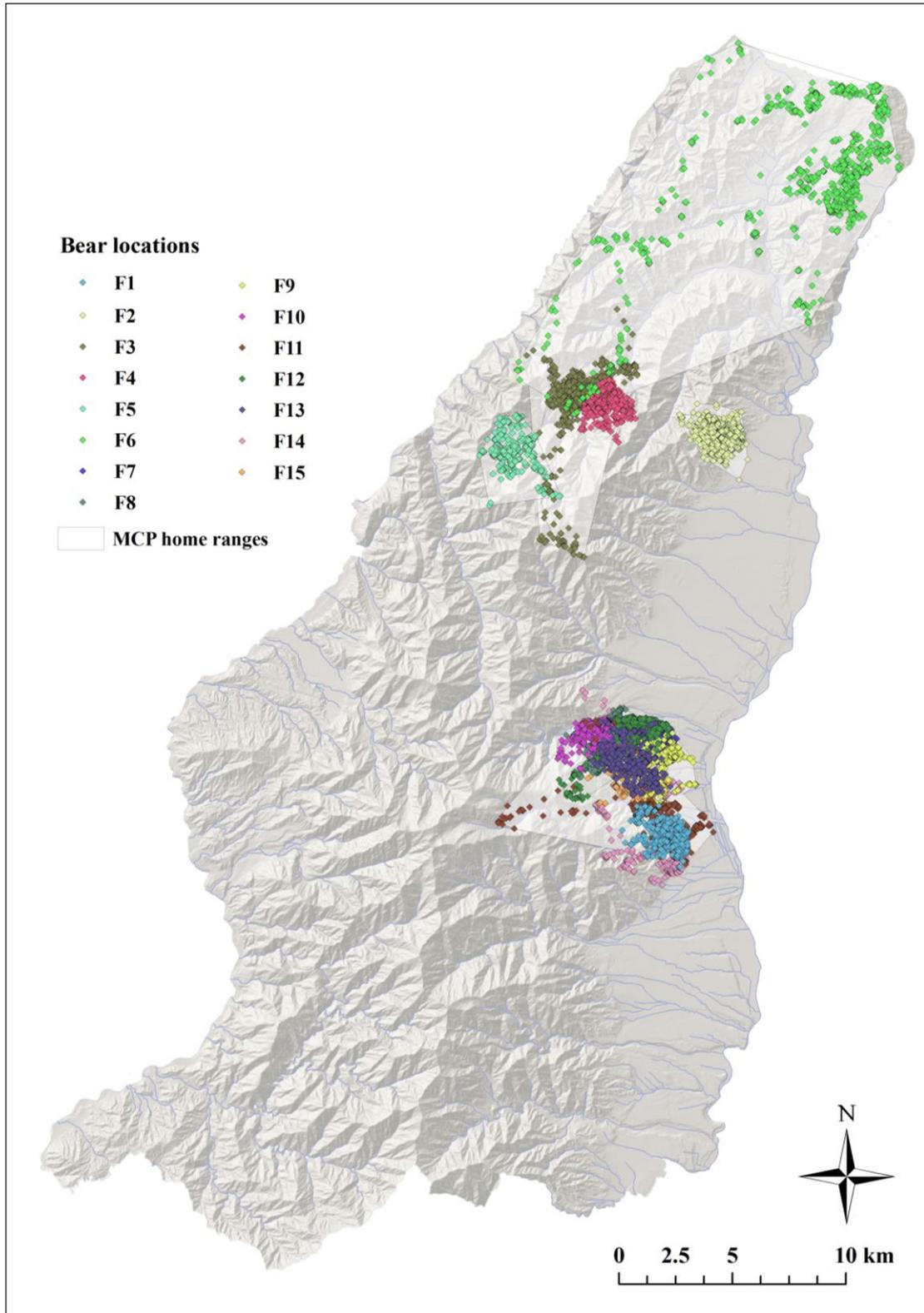


Fig. A-2

Acquired GPS telemetry locations from collared **female Asiatic black bears during summer** and their individual home ranges estimated by 100% Minimum Convex Polygon (MCP).

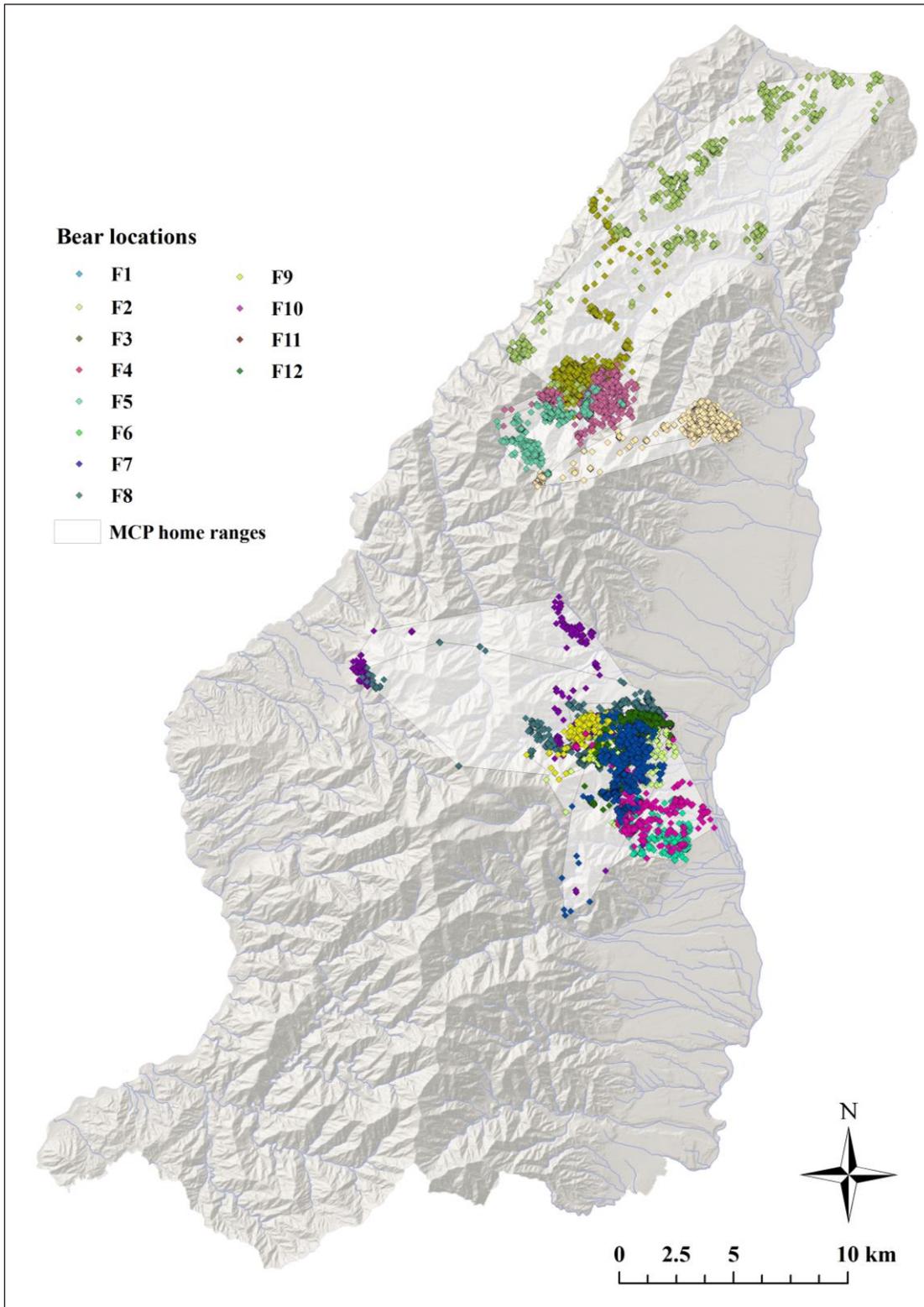


Fig. A-3

Acquired GPS telemetry locations from collared **female Asiatic black bears during autumn** and their individual home ranges estimated by 100% Minimum Convex Polygon (MCP).

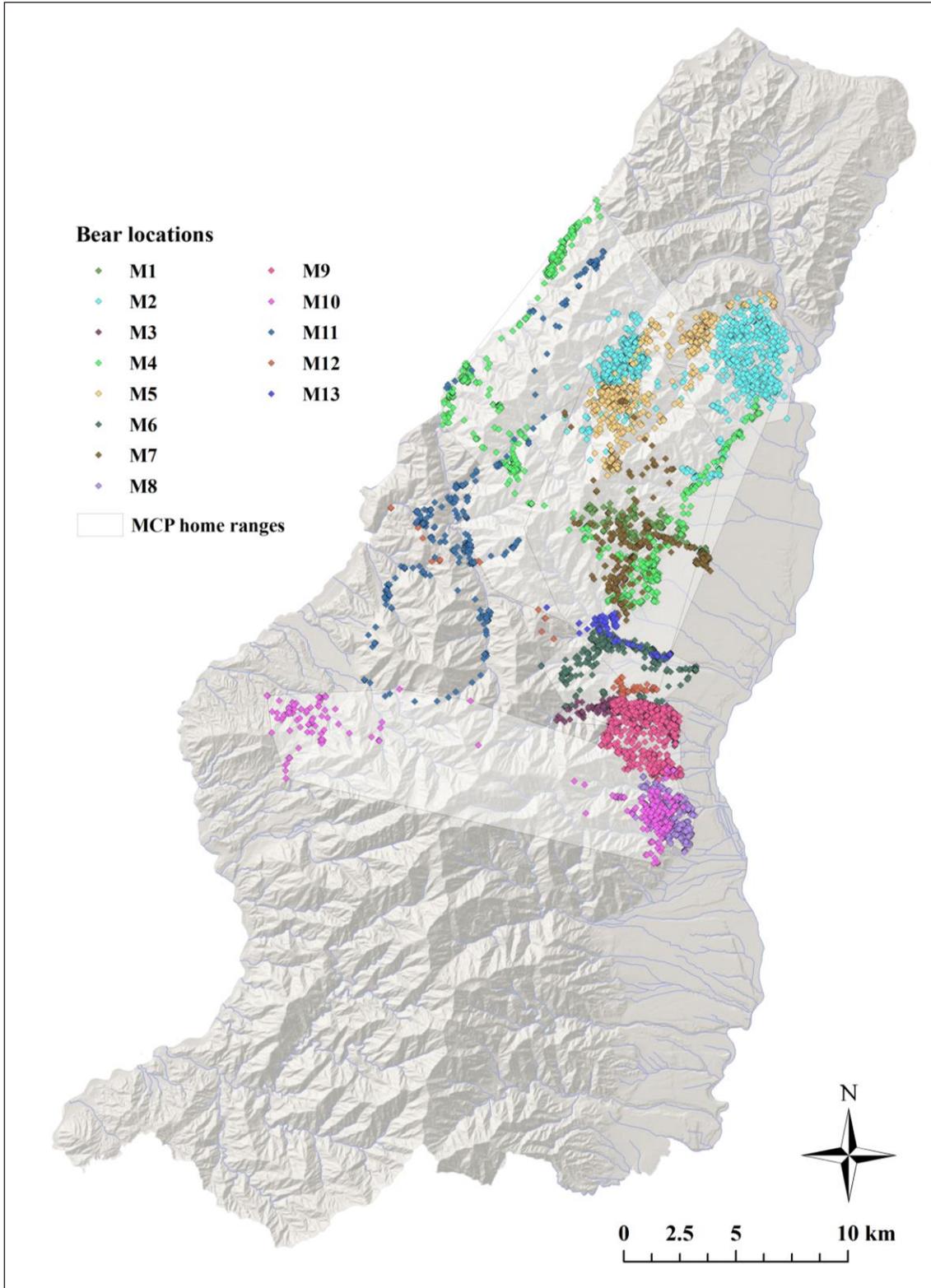


Fig. A-4

Acquired GPS telemetry locations from collared **male Asiatic black bears during summer** and their individual home ranges estimated by 100% Minimum Convex Polygon (MCP).

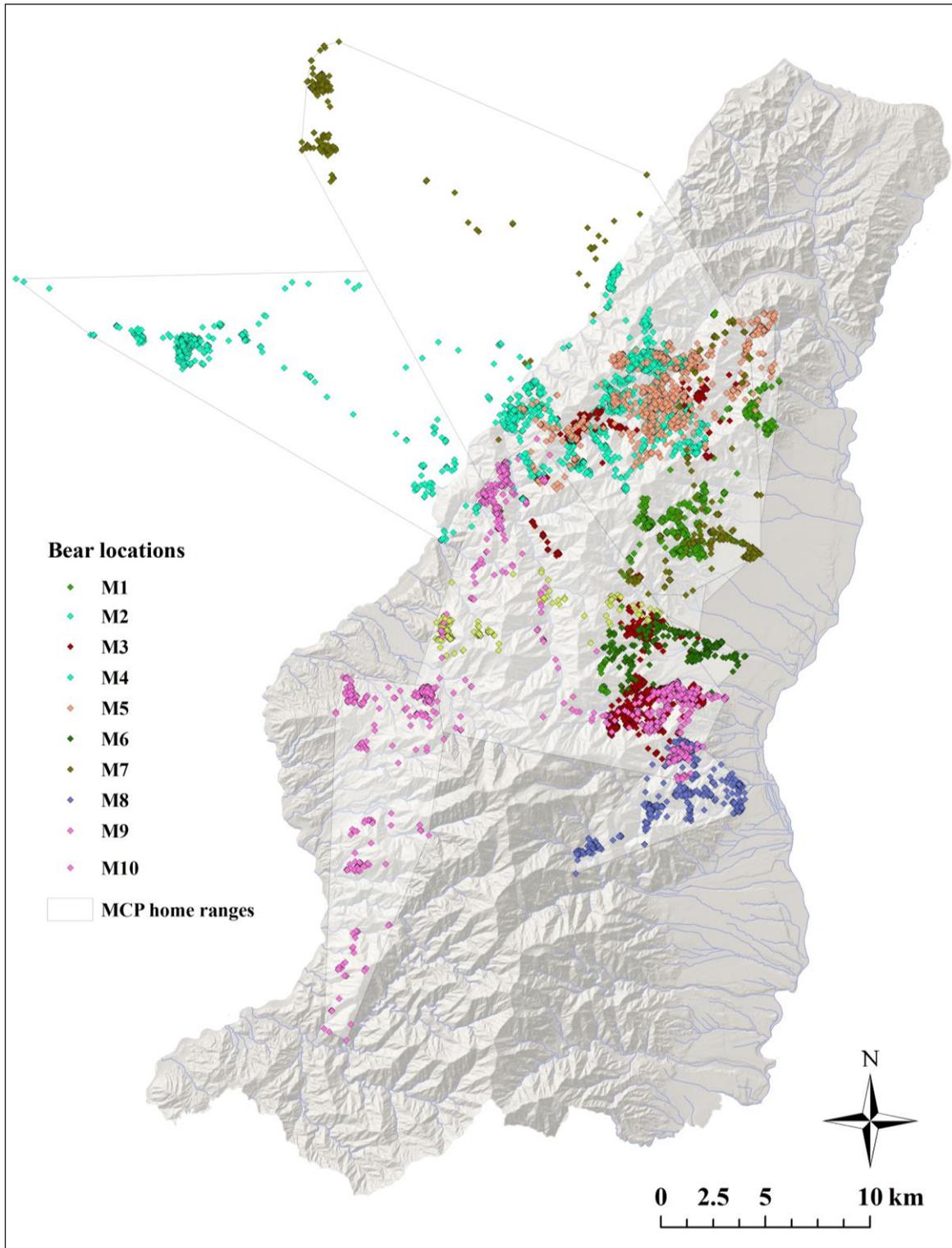


Fig. A-5

Acquired GPS telemetry locations from collared **male Asiatic black bears during autumn** and their individual home ranges estimated by 100% Minimum Convex Polygon (MCP).

