An ecological study on human-bear conflicts in Urahoro, Hokkaido

北海道浦幌地域における

ヒグマによる被害の発生機構に関する生態学的研究

佐藤 喜和

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Doctoral dissertation

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Yoshikazu Sato

佐藤 喜和

Department of Animal Resource Sciences,

School of Agricultural and Life Sciences,

The University of Tokyo

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Supervisor: Dr. Seiki Takatsuki

Contents

Chapter 1. **General Introduction**

The brown bear (*Ursus arctos*) ranges through Europe, Asia, and North America from northern arctic tundra to dry desert habitat (Servheen 1990). Bears including the brown bear are large-bodied members of Order Carnivora, and the family Ursidae. The home range of brown bears sometimes exceeds a thousand square kilometers (Herrero 1999). Therefore, they require large areas of habitats to support stable populations. The range of the brown bear has been significantly reduced since the mid-1800s by the advent of firearms, human occupancy of parts of its range, and habitat alteration or destruction (Servheen 1990). Since they are occasionally aggressive to people (Herrero 1985), numerous bears have been killed to protect human lives and bear populations are decreasing in many areas of the world. In Europe and North America where the bear populations are in danger of local extinction, active conservation programs are practiced (Servheen 1990, Servheen et al. 1999).

The brown bear in Japan (*U. a. yesoensis*) exists only on the island of Hokkaido (Abe et al. 1994). Until the later half of the 19th century, it was distributed throughout the mountains, plains, and coastal area in Hokkaido. However, after the colonization and development of the island by the Meiji Government, since 1971, forests of low elevations were logged to be replaced with cultivated and residential land (Aoi 1990, Mano and Moll 1999). The distribution of the Hokkaido brown bear decreased from an area of approximately 47,000km^2 or 60 % of the island in 1978 to roughly 40,000km^2 or 50 % of the island in 1991 (Mano and Moll 1999). The populations are fragmented into 5 regional subpopulations (Hokkaido Government 1986). Of these, the western Ishikari subpopulation has warranted entry into Japan's

Red Data Book (Environmental Agency 1991) because of its small size and isolation.

Nevertheless, nuisance bears are killed throughout the year because of human-bear conflicts such as attacks on people, agricultural damage, and the invasion of villages. Sport hunting using firearms is also permitted during the period between 1 October and 31 January. The average annual harvest during 1991-1998 in Hokkaido was 236.21 bears per year (Hokkaido Institute of Environmental Sciences [HIES, hereafter] 2000).

The current brown bear population in Hokkaido is estimated as 2000 – 3000 (HIES 1995, 1996, 2000). The crude density is 5.0-7.5 bears / 100 km^2 according to the current distribution area of bears in Hokkaido (approximately 40,000km^2) (Mano and Moll 1999). Though the ecological density is higher than this, the crude density exceeds that of Yellowstone ecosystem (1.4-1.8 bears per 100 km^2, Servheen 1999), and is equivalent to that of coastal region in Alaska, which is known as a high-density area of brown bears (Miller and Schoen 1999).

Natural forest cover is high in Hokkaido due to historically later agricultural development than in southern islands of Japan. Agricultural fields boarder these forests. There are many conflicts between human and wildlife, especially brown bears, which is different from Europe and North America where the human-bear conflicts have longer histories than Hokkaido. Considering these differences, unique and appropriate practical provisions are needed for conservation and management of the brown bears in Hokkaido.

In Hokkaido, local people complain that encounters with bears, village invasions, and crop damage have increased during the last decade (HIES 1995, 1996, 2000). Human-bear conflicts caused by Hokkaido brown bears are categorized into three; attacks on people, damage to crops and livestock, and latent fear of attacks induced by the invasion of farmlands or villages. Local people speculate that these conflicts have increased because of the growth of bear populations and because of the changes in bear ecology due to the deterioration of their habitat (HIES 1995, 1996, 2000). Control killing is almost the only strategy used to resolve human-bear conflicts at present. It is possible that the Hokkaido brown bears may face extinction as in Europe and North America, if this situation continues. This is partly due to a lack of scientific information on the ecology of the Hokkaido brown bears relating to their conservation. In order to reduce the conflicts and to conserve the population, we should search for non-lethal options. It is therefore crucial to study the population trends and the ecology of bears, and to clarify the context of bear-related damages.

Studies on the Hokkaido brown bear have so far been done for high-density populations in *e.g.*, Oshima Peninsula and Shiretoko Peninsula. Food habits (Hokkaido Government 1987, Yamanaka and Aoi 1988), home ranges (Mano 1994a, Yamanaka et al. 1995, HIES 2000), harvest history (Mano 1987, 1995a), population estimates (HIES 2000), and non-lethal damage management (Yamanaka 2001b) have been studied. However, conflicts occur extensively in Hokkaido regardless of the population density (HIES 1995, 1996, 2000), and studies in the interior of Hokkaido are particularly needed.

On the other hand, in eastern Hokkaido, the sika deer (*Cervus nippon*) population has grown rapidly in the last decade (HIES 1997). Sika deer cause damages to agriculture and forestry (Hokkaido Government 2000a). They also influence forest ecosystems through bark stripping, vegetation alteration, and by killing young trees (Kaji 1993, Okada et al. 1997, Akashi and Terazawa 2001, Terazawa and

Akashi 2001). The increasing deer population influences other wildlife as well. For example, deer carcasses arising from sport hunting and control killing have lead to an expanded distribution inland of the sea eagles (*Heliaeetus albicilla* and *H. pelagicus*), internationally conserved birds (Lead Poisoned Eagles Network 1999, 2000, 2001). Lead bullets remaining in the deer carcasses are harmful to the eagles (Lead Poisoned Eagles Network 1999, 2000, 2001). It is also reported that deer meat has increased in the diet of brown bears in Shiretoko Peninsula (Yamanaka 1995). Due to the potentially large food source represented by deer, it is expected that the increased deer population in many areas in eastern Hokkaido would influence the ecology of the brown bear.

This study intends to reveal the background to the recent increase in human-bear conflicts. As the first step, I collected information of the trend in human-bear conflicts in the whole area of Hokkaido. Then, I made a detailed study in Urahoro in eastern Hokkaido. Urahoro is a typical inland Hokkaido town where human-bear conflicts have been increasing from the late 1990s. Fortunately, a previous study on the brown bears was done in Urahoro in 1978. I could compare the available information with present data. In Hokkaido such old data is only available for Urahoro.

This dissertation is constructed of 8 chapters including Chapter 1. General introduction. In Chapter 2, I examine a suitable time saving method for analyzing many bear diet samples. Then, in Chapter 3, I analyze a lot of stomach content samples of brown bears that were collected from 3 regions in Hokkaido for 8 years of the 1990s.

In Chapter 4, I interpret the background of Urahoro, a typical town in eastern

Hokkaido. Then, I explain the changes in the density and food habits of the brown bears in Urahoro by comparing with those of the past study. This aims to find out the causes of current conflicts. My particular concern is to find out whether the conflicts are caused by the population increase or by changes in the food habits of brown bears.

Chapter 5 demonstrates seasonal habitat use of a brown bear by using the radio telemetry in relation to the food habits.

In Chapter 6, I try DNA analysis using the hairs of brown bears that were collected in the fields to identify "problem bears" genetically. I also estimate the population size of the bears by this technique.

The changes in environmental factors such as changes in forests, the population increase of sika deer, and changes in agricultural systems in Hokkaido and in Urahoro that possibly affect the ecology of the brown bear are shown in Chapter 7.

Finally, in Chapter 8, I discuss the possible causes of current human-bear conflicts by synthesizing these results, and propose some management implications.

Chapter 2. **Applicability of the point-frame method for quantitative evaluation of brown bear diet**

Introduction

Food habit studies are prerequisite to understand animal ecology, and to perform conservation and management (Korschgen 1980). However, quantitative evaluation has not been used routinely in diet studies of bears. For example, diets of the brown bear have been described in various areas of North America (Hamer and Herrero 1987, Mattson et al. 1991, McLellan and Hovey 1995) and Eurasia (Cicnjak et al. 1987, Ohdachi and Aoi 1987, Clevenger et al. 1992, Elgmork and Kaasa 1992, Krechmar 1995). It is important to standardize the methodology in order to compare the food habits among brown bear populations. However, most studies used subjective methods such as visual estimation (Hamer and Herrero 1987, Mattson et al. 1991, Clevenger et al. 1992, McLellan and Hovey 1995), only few studies quantified diet compositions by such objective methods as dry weight and volume (Cicnjak et al. 1987, Ohdachi and Aoi 1987). This is partly because separation and identification of individual diet items is laborious. Consequently, precise comparisons across studies have been difficult as there is not a standard protocol. The point-frame method, developed for diet studies of ungulates, assesses diet items by spreading food plants in trays and counting fragments lying over points of intersection of an underlying grid (Chamrad and Box 1964).

Compared to volumetric and gravimetric methods, point-frame estimates may be biased when samples include multiple shapes because items are quantified by surface area. The main diets of ungulates are flat leaves or grass blades, in the case the point-frame method is unbiased and saves time (Robel and Watt 1970, Puglisi et al. 1978). Omnivorous bears, however, eat a wide variety of foods of various shapes and, therefore, it is expected that the point-frame method may underestimate bulky items, while overestimating flat ones. Finding the preferred method for diet studies involves taking into account both the precision of the data needed for the purpose of the study and the effort required.

In this chapter, to evaluate applicability of the point-frame method in analyzing bear diets, I compare estimates of bear diets by 3 quantitative methods: the point-frame, the volumetric, and the gravimetric methods. I also compare the time required for analyses by the point-frame and the volumetric methods.

Methods

I collected stomach contents from 55 bears (37 males, 18 females) harvested throughout Hokkaido (see Chapter 3 for description of Hokkaido) between April and December 1995 and 90 bears (61 males, 29 females) of those between April and December 1996. One hundred six of the 145 bears were lethally controlled due to damage complaints and the remainders were harvested via sport hunting. The Nature Preservation Sections of Hokkaido, the Nature Preservation Divisions of 14 subprefecture offices, and the Forest Units of various cities, towns, and village offices collected these samples. Stomach contents were immediately sent to the Hokkaido Institute of Environmental Sciences after collection. I stored stomach samples in a freezer at - 40 ℃ before analysis. The time between sample collection and freezing was, on average, 3 days.

I thawed and washed the contents with tap water on a sieve (2.0-mm mesh aperture). When the entire contents of a stomach consisted of items smaller than the 2.0-mm mesh aperture, such as ants or seeds, I used a sieve of 1.0-mm mesh.

Point-frame evaluation

Quantitative evaluation was first made using the point-frame method following Takatsuki (1978). I spread materials remaining on a sieve onto an enamel tray (38 cm by 33 cm) marked with a 1 cm by 1 cm grid with intersection points as point frames at the bottom. I identified each diet item lying on points of intersection on the tray and counted the number of points each item was lying on. I used 29 categories to classify food items. I counted ≥ 400 points / sample.

Volumetric evaluation

I separated each of the 29 food categories and placed items, by category, in a graduated cylinder and measured its volume (ml) by water displacement.

Gravimetric evaluation

After the diet item groups were analyzed by the volumetric method, I oven-dried each item for at least 48 hours at 60℃ and then weighed them by an electronic balance (Sartorius Co. Ltd.) to the nearest 0.001 g. To compare estimates among 3 quantitative methods, I used the 55 samples of 1995.

Time evaluation

As the same protocol was used for washing, to separate each item for the volumetric and gravimetric methods, and because it is very time consuming to measure the volume of each item by drying in the gravimetric method, I did not measure the time required for the gravimetric method. I did compare the time required for analysis of the point-frame versus the volumetric methods. In 36 cases, > 1 person conducted the analyses for the volumetric method. I was only able to record time data for 19 samples using the volumetric method, but I was able to measure time required for the point-frame method for all 145 samples.

Data analyses

Using the three methods, I calculated percentage volume of each food category for each sample based on the ratio of number of counts, volumes, and weights for each item to the total quantity of them. Each percentage volume was summarized in terms of total percentage volume for each item for the 3 methods. All percentage data was arcsine-transformed prior to analysis.

I first tested the hypothesis that there was no difference in the total percentage volume of each item using the 3 methods. I tested this hypothesis using a 1-way repeated-measures analysis of variance (ANOVA).

I then tested the hypothesis that there was no difference in the percentage volume of each sample using 2 methods (point-frame and volumetric) for 2 primary items (berries and forbs). I tested this hypothesis using a linear regression with no intercept and t-test ($\alpha = 0.05$) between slope of the regression equation and theoretical slope "1.0" for complete correspondence.

Next, I tested the hypothesis that there was no difference in the total percentage volume for each item between the point-frame and the volumetric method, and between the point-frame and the gravimetric method. I tested this hypothesis using a linear regression with no intercept and *t*-test (α = 0.05) between slope of the regression equation and theoretical slope "1.0" for complete correspondence.

Results

Although I determined percentage volumes for all of the 29 diet items, only 15 categories had enough frequencies (≥5) to be compared (Table 2-1).

The 3 methods resulted in significantly different estimates for 5 of 15 diet groups; acorn and nuts, woody fragments, berries, forbs, and dead coniferous leaves (Table 2-1). The Tukey's multiple comparisons of these 5 items revealed that the point-frame method estimates were less ($P < 0.05$) than that of the gravimetric method for acorn and nuts and woody materials and was less ($P < 0.05$) than the volumetric and gravimetric methods in berry estimates (Table 2-1). The point-frame and volumetric methods were greater ($P < 0.05$) than the gravimetric method in forbs estimates and the point-frame and gravimetric methods were greater ($P < 0.05$) than the volumetric method in dead coniferous leaf estimates (Table 2-1).

Only berries and forbs had sufficient sample sizes (≥20) to conduct linear regression analyses. Estimates by the point-frame method were related directly to those of the volumetric method ($P \leq 0.001$, Figure 2-1). The slope obtained above (0.913) differed significantly from the theoretical slope "1.0" for forbs ($t = 2.122$, 25df, $P < 0.05$), but did not differ significantly for berries ($t = 1.545$, 19df, $P > 0.1$).

Percentage volume for each item using the point-frame method corresponded directly to those of the volumetric method and the gravimetric method ($P \leq 0.001$, Figure 2-2). Slopes obtained for the point-frame method versus the volumetric method (slope = 0.983, t = 0.436, 13df, $P > 0.5$) and the point-frame method versus the gravimetric method (slope = 0.957, $t = 0.768$, 13df, $P > 0.2$) did not differ significantly from 1.00.

Time required for the point-frame method ($\bar{x}$ = 43.57 min, SE = 1.50, n = 145) was only 16 % of that of the volumetric method ($\bar{x}$ = 278 min, SE = 35.17, n = 19).

Discussion

The results indicate that the point-frame method is an acceptable technique because, when all diet items were regressed, a large coefficient of determination with no significant difference from the theoretical slope was obtained (Figure 2-2). However, the expected biases of the point frame method regarding size and shape of diet items were observed. Bulky items, such as acorn and nut, woody materials, and berries, tended to be underestimated; whereas flat items, such as leaves, tended to be overestimated by the point-frame method when compared to the volumetric and the gravimetric methods.

Besides quantitative precision, time and effort should be considered for diet analyses (Korschgen 1980). The point-frame method required only 16% of the time required for that of the volumetric method because of the extended time required in the volumetric method to separate materials (Robel and Watt 1970).

Visual estimation has often been used for bear diet analyses (Hamer and Herrero 1987, Mattson et al. 1991, Clevenger et al. 1992, McLellan and Hovey 1995). This requires a similar amount of time as the point-frame method for identification but is not a quantitative method.

As long as potential biases are considered, the point-frame method is a simple and quantitative method of reasonable precision to study bear diet, particularly when a large number of samples is available.

Chapter 3. **The stomach contents of killed brown bears in Hokkaido, Japan**

Introduction

Since the brown bear has the widest range of all bear species and is found from the northern arctic tundra to dry deserts (Servheen 1990), they have the ability to adapt themselves to the surrounding environment and its change (Mano 1995b). During the 1980s there were several studies on the food habits of brown bears in Hokkaido (Aoi 1985, Ohdachi and Aoi 1987, Yamanaka and Aoi 1988). These studies, however, only cover small areas and the study periods are short. The environments for the bear food supply have been increasingly altered during the 1990s. For example, the sika deer population is increasing at a remarkably rapid rate in the eastern part of Hokkaido (HIES 1997). It is to be expected that these changes would affect the food habits of the bears. Long term extensive monitoring of the food habits is needed.

From 1991, the Hokkaido government started to collect the necessary samples including stomach contents from killed brown bears to serve their scientific management program. By using these stomach content samples, I describe the food habits of brown bears collected from various areas in Hokkaido for 8 years of the 1990s.

Study area

Hokkaido is located in northern Japan and is about 78,500 km^2 in area (Figure 3-1). The mean annual temperature is 5 to 10 °C and the average annual precipitation is from 800 to 1,200 mm. Forests cover about 70 % of the area. Most areas lie in the climatically intermediate zone between the Northern Asiatic temperate zone and the sub-arctic zone. The land is dominated by mixed forests of conifers like *Abies sachalinensis* and *Picea jezoensis* and deciduous broad-leaved trees like *Acer mono* and *Tilia japonica* (Tatewaki and Igarashi 1971). The Oshima Peninsula region is located in the southwestern part of Hokkaido, and entirely lies within the Northern Asiatic temperate zone characterized by *Fagus crenata* forest. The major land use is farmland (dry and paddy) in the southwestern and central regions, while dry fields and pastures are dominant in the eastern and northern regions.

About 6 million people live on Hokkaido. When bears cause trouble, for example damage to crops, invasion of human residential areas, attacks on humans, or dangerous encounter with humans, control killing is permitted. Sport hunting is also permitted during the period from 1 October to 31 January. The Hokkaido government divides the bear population into 5 regions for management objectives (HIES 1994). Number of kills for each region between 1991 and 1998 was as follows; Oshima Peninsula: 512 (171 females, 338 males, and 3 unknowns), Shakotan-Eniwa: 21 (10 females, 11 males), Teshio-Mashike: 11 (1 females, 10 males), Doto-Sohya: 696 (275 females, 415 males, and 6 unknowns), and Hidaka-Yubari: 640 (227 females, 403 males, and 10 unknowns) (HIES 2000).

Materials and methods

The HIES has been collecting the stomach contents from bears since 1991. They were sent to HIES about 3 days after the bear kill, and preserved in a freezer at -40 °C before analysis. Since a substantial proportion of control killings during hunting season are counted as sport hunting, it is impossible to ascertain with complete accuracy the correct numbers of both categories to be used in the calculation of statistics. I, therefore, include both figures in the analyses.

I washed the contents with tap water on a sieve (2.0 mm mesh aperture). Then I spread part of the materials remaining on the sieve onto an enamel tray (38 cm by 33 cm).

I recorded the frequency of occurrence for each diet item. Thereafter, I used 2 methods to determine the percent volume of each food item. The samples collected from 1991 to 1993 were analyzed by the graduated cylinder method. I separated the contents by each item, placed it in a graduated cylinder, and then determined the volume (ml). The samples collected from 1994 to 1998 were analyzed by the point-frame method (Chapter 2, Sato et al. 2000). The tray where the contents were spread was marked with a 1 cm by 1 cm grid on the bottom and the points of intersection were regarded as point frames. I counted more than 400 points. In chapter 2, I confirmed that the 2 estimates agreed well.

I divided the samples into 4 seasonal categories according to plant phenology: spring (March – May), early-summer (June – July), late summer (August – September), and fall (October – January).

I analyzed 758 stomach contents collected from March to January for each year between 1991 and 1998. This included 40.3% of all the killed bears (HIES 2000). Among the samples, 186 samples (19 source-unknown, 102 box trapped or baited, 65 empty stomachs) were excluded for analysis, while the remaining 572 samples were used. I divided them into 5 regions according to the locations: 223 from Oshima Peninsula, 14 form Shakotan-Eniwa, 2 from Teshio-Mashike, 218 from

Doto-Sohya, and 115 from Hidaka-Yubari. Shakotan-Eniwa and Teshio-Mashike regions were excluded due to the small sample sizes, therefore I described the food habits only from the remaining 3 regions.

Results

Seasonal changes in the diet of the 3 regions in Hokkaido

Oshima Peninsula region: Herbaceous plants were predominant and common in all seasons, particularly in spring and early summer (Table 3-1). In spring, herbaceous plants were dominant. Acorns and nuts of the previous fall were also important in spring. In early summer, herbaceous plants remained frequent, though the volume decreased. Insects increased markedly in early summer. It was also noticeable that berries increased in early summer. In late summer, crops suddenly increased, though forbs continued to contribute largely to the diet. Other berries increased, while insects decreased. In fall, the same berries as those in late summer and more kinds of acorns and nuts greatly increased, while crops decreased. Anthropogenic wastes appeared consistently in all seasons.

Doto-Sohya region: In spring, herbaceous plants were predominant (Table 3-2). Sika deer also occupied a high portion of the spring diet, and acorns and nuts relatively important. In early summer, herbaceous plants maintained a high contribution to the diet. Insects frequently occurred and made up a large proportion of the diet. Crops suddenly appeared to take 12.5 %. In late summer crops were most important, followed by forbs. Insects were the most important item throughout the seasons. In fall, both sika deer and berries take quarters in volume of the diet, while herbaceous plants, insects, and crops decreased. Acorns and nuts were most important among the seasons. One characteristic of this local population is that mammals consistently appeared through the seasons.

Hidaka-Yubari region: In spring, herbaceous plants were exclusively dominant (Table 3-3). Anthropogenic wastes occupied about 13 % of the diet. The composition in early summer was similar to that of spring, though anthropogenic wastes were not found. In late summer, herbaceous plants decreased, and the composition suddenly changed. Crops such as melons and corns made up a great proportion of the stomach contents, and insects and berries suddenly appeared. In fall, herbaceous plants and crops decreased, while berries, acorns and nuts, and mammals increased. It was noteworthy that sika deer occupied as much as 16.3 % of the contents.

Comparison among regions

Diet compositions showed marked seasonal changes, which were consistent among the 3 regions. Characteristic food items were: herbaceous plants in spring, herbaceous plants and insects in early summer, crops and herbaceous plants in late summer, and berries and acorns and nuts in fall (Figure 3-2). Below I described the local characteristics of the diet for each category.

Herbaceous plants: The buds, leaves, petioles, and/or stems of forbs occupied a great proportion of the diets in each season in all regions. Though some characteristic species such as *Petesites japonics*, *Artemisia* spp., and *Urtica platyphylla* were identified, many were difficult to classify. Graminoids and *Symplocarpus renifolius* were important among monocotyledons. *Symplocarpus renifolius* appeared in early spring in the samples collected in the northern part of the Doto-Sohya region, and was common in spring in the Oshima Peninsula region. It also appeared in late summer and fall in the Hidaka-Yubari population. Most of graminoids which appeared in spring in the Oshima Peninsula region bore grains, which means that the bears ate over-wintering plants.

Berries: The fruits of *Actinidia arguta* and *Vitis coignetiae* were dominant among the berries in fall for all of the regions. The fruits of *Actinidia polygama*, *A. kolomicta*, *Sorbus commixta*, and *Swida conroversa* were also important in fall. In late summer, early maturing berries such as *Prunus* spp., *Rubus* spp., *Aralia* spp., and *Morus australis* appeared, though the occupancies were not great. The proportion of berries was similar among the regions.

Acorns and nuts: In each region, the proportion of acorns and nuts in fall was not great (10-15 %). Acorns of *Quercus crispula* were the commonest item among them. It is characteristic for the Oshima Peninsula region that beechnuts were also present. The nuts of *Juglans mandshurica* matured earlier than others, and appeared in the diets in late summer in the Oshima Peninsula and the Doto-Sohya regions.

Mammals: The proportion of animal materials in the diet of the Oshima Peninsula region was lower than that of other regions. Sika deer occupied as much as 64.8 % of the stomach contents containing mammals for the total of 3 regions. Claws of small carnivorous mammals appeared in both the Hidaka-Yubari and the Doto-Sohya regions. The samples containing sika deer were concentrated in the central and eastern parts of Hokkaido, which corresponds to the sika deer distribution (Kaji et al. 2000). Sika deer occurred more frequently in the samples from the area with high-density sika deer populations (HIES 1994, shaded area in Figure 3-1) than over Hokkaido as a whole (25.23 % vs. 14.95 %). During 1991 and 1993, sika deer appeared only in late summer and fall, yet they appeared in spring and early summer after 1994 (Figure 3-3).

Insects: Ants of Formicidae were the most abundant insect materials for all the 3 regions. They included *Formica yesoensis*, *F. Japonica*, *F. lemani*, and *F. sanguinea* (colonize on or in soil), and *Camponotus obscuripes* (colonizes in rotten trees). *C. japonics*, *C. herculeanus*, and *Myrmica jessensis* were also found in bear diets. Wasps of Vespidae were also common. Maggots occupied greater proportions in the diets of the Doto-Sohya and the Hidaka-Yubari regions than the Oshima Peninsula region. This is because maggots are generally eaten with deer meat which is mainly eaten in the Doto-Sohya and Hidaka Yubari regions. Other than insects, *Cambaroides japonicus* was the most dominate invertebrate.

Crops: Crops were predominant in late summer in all 3 regions. In the Oshima Peninsula region, higher proportions of crop use continued from late summer to fall. Crop use in early summer only appeared in the Doto-Sohya region. Among the crops, corn was the most important and occupied about 60 – 70 % by volume for all of the regions. The second major crop differed among regions (rice for Oshima Peninsula, sugar beets for Doto-Sohya, and melons for Hidaka-Yubari).

Anthropogenic waste: Anthropogenic waste included scraps such as apples, persimmons, watermelons, peaches, corn, onions, carrots, eggplants, potatoes, radishes, Asian leek, boiled fish pastes, slices of raw fish, chicken, pickled ginger, seeds of dried plum, breads, fishery waste such as squids, ascidians, scallops, and seaweeds, and other items such as aluminum foil, glass, steel fragments, sponge, polystyrene, cigarette filters, vinyl, straps, papers, and clothing materials. Among the 3 regions anthropogenic waste especially scraps and fishery waste was most frequently found in the Oshima Peninsula region.

Others: Fallen leaves/twigs and soils/pebbles showed high values of percentage frequency of occurrence and low values of percentage volume in every season for every region, because major items on the ground such as mammals, insects, and fruits were frequently accompanied by these items.

Discussion

Seasonal changes in the diet of Hokkaido brown bear

In all 3 regions the bears showed a similar seasonal change in food, *e.g.*, dominant food items were herbaceous plants in spring and summer, fruits in summer and fall. This pattern corresponds with those of other brown bear populations in Europe and North America (Yugoslavia, Cicnjak et al. 1987, USA, Mattson et al. 1991, Spain, Clevenger et al. 1992, Norway, Elgmork and Kaasa 1992, Canada, McLellan and Hovey 1995). It is, however, difficult to conclude this for the Hidaka-Yubari region because of small amount of samples in spring and early summer.

In early spring when herbaceous plants have not grown, over-wintered fruits were eaten in the Oshima Peninsula and the Doto-Sohya regions. A similar phenomenon is reported in southern Siberia, USSR (Bromlei 1965), Montana, USA (Mace and Jonkel 1986), and Alaska, USA (Stelmock and Dean 1986). Deer meats were found in the Doto-Sohya region. This has been reported in Spain (Slobodyan 1976), Pyrenees, France (Berducou et al. 1983), Yellowstone, USA (Mattson et al. 1991), and British Columbia, Canada (McLellan and Hovey 1995).

In late summer, crops were important in all 3 regions. Since late summer is an intermediate season when the nutritional values of herbaceous plants decrease

(Cicnjak et al. 1987) and berries are still immature, brown bears eat various items. Bears living in a habitat where various berries are available eat berries (*e.g.*, British Columbia, Canada, McLellan and Hovey 1995). In some populations, bears move to various places to eat premature herbaceous plants, *e.g.*, north-facing slope (Spain, Clevenger et al. 1992), bottoms of creeks (Yellowstone, USA, Mealey 1980), or alpine habitats (Alberta, Canada, Hamer and Herrero 1987). In other populations, bears eat alternative foods such as roots of Leguminosae (Alaska, USA, Stelmock and Dean 1986; Alberta, Canada, Hamer and Herrero 1987), ants (southern Siberia, Bromlei 1965; Pyrenees, France, Berducou et al. 1983), livestock (Pyrenees, France, Berducou et al. 1983), and fish (Yellowstone, USA, Mattson et al. 1991). It is considered that Hokkaido bears use crops because of the shortage of alternative natural foods in this season.

Use of sika deer

It is noteworthy that the amount of sika deer meat in the bear diets increased in the 1990s. Although there were some instances of Hokkaido brown bears consuming deer before then (HIES 2000), food habit studies in the 1980s show no or small amounts of sika deer meat (Aoi 1985, Ohdachi and Aoi 1987, Yamanaka and Aoi 1988). The extinction of Hokkaido wolves (*Canis lupus hattai*), the replacement of native mixed hardwood forests with conifer plantations, and increased pasturelands possibly contributed to the expansion in the deer's distribution in the late 1900s (Kaji et al. 2000). It is quite probable that increase of deer meat in the bear diet is caused by the marked population increase of sika deer during the 1990s (HIES 1997).

Exploitation of human intervenient resources

Crops: The exploitation of crops was greatest in late summer and continued into fall. It is known that brown bears invade cultivated fields and villages in the fall. This is seen in North America (Blanchard and Knight 1991, Mattson et al. 1992 for Yellowstone, USA; Waller and Mace 1997 for Swan Mts., USA) and Eurasia (Slobodyan 1976, Clevenger et al. 1992 for Carpathian, Spain; Ustinov 1976 for Baikal, Russia), particularly in years when other food resources were lacking. This seems to be the case in Hokkaido. In the fall of poor years, the bears are forced to invade farmlands, which result in control killing.

Bears fed on a limited number of species of crops cultivated in Hokkaido. Corn in particular was found in abundance in all regions. This must be because of the high nutritional value of corn. It may also be because cornfields function as cover for bears. In the Hidaka-Yubari region, melons were the second most common crop exploited. Melons are of high economic value particularly in the Yubari district and so damage is treated seriously. In the Doto-Sohya region, crops especially sugar beets made up 12.5 % of the volume in early summer because the roots of beets are available earlier in the season than other crops.

Anthropogenic Wastes: It was expected that much anthropogenic wastes would appear in stomach contents, because the samples were mostly collected from "controlled" bears. Particularly, in the Oshima Peninsula region, bears ate a lot of garbage such as scraps and fishery waste. It is reported that bears are strongly attracted by anthropogenic waste (Herrero 1985, Craighead et al. 1995). Such food-conditioned bears tend to be accustomed to people and so will invade human residential areas. Then, they are often regarded as a "nuisance", and killed. In order to avoid this, it is necessary to be careful when disposing garbage. Such unnecessary kills have been reduced by the proper treatments of garbage at camping sites in Yellowstone National Park (Herrero 1985).

Deer carcasses: At the beginning of the 1990s, the bears in eastern Hokkaido only consumed deer meat during late summer and fall (Figure 3-3). After 1994, however, the meat appeared in spring and also in early summer. The fact that deer is eaten by the Hokkaido brown bears throughout the year is unique because brown bears in other areas usually eat ungulates meat in spring (Boertje et al. 1988, Green et al. 1997, Mattson 1997). In Hokkaido, about 30 thousands of deer were hunted from 1994 to 1999 (from November to January) and more than 20,000 deer were shot for control killing every year (Hokkaido Government 2000a). Hunters in extensive areas of eastern Hokkaido often leave the deer carcasses in the fields after shooting the deer (HIES 2000, Lead Poisoned Eagles Network 1999, 2000, 2001). These carcasses are then consumed by the bears. High frequency occurrence of maggots accompanied with deer meat means that bears scavenge on deer. Though it is impossible to distinguish whether the deer meat found in the stomachs is that of living deer or carcasses, I think that the Hokkaido brown bear consumes more deer meats by scavenging than by aggressive predation. Since shot deer carcasses are often left in and around human residential areas, encounters between people and bears would become more frequent. This problem is more serious in Hokkaido than *e.g.*, North America because people live closer to bears' habitats.

Chapter 4. **Changes in the density and diet of brown bears in Urahoro**

Introduction

To explain the increase of human-bear conflicts, local people speculate that there has been a growth in the bear population and/or because of changes in bear ecology as a result of the deterioration of their habitats (HIES 1995, 1996, 2000).

For the population size, some studies support a downward trend. If the annual numbers of bears shot for control killing and sport hunting is considered, the whole population in Hokkaido appears to have decreased (Aoi 1990, Mano and Moll 1999). A case study in Teshio Experimental Forest of Hokkaido University also supports a population decline (Aoi 1990, Niizuma et al. 1995). It is therefore unlikely that the conflicts are caused by the growth in the bear population.

It is unrealistic that the population can rapidly recover under such a heavy pressure because of the low reproductive rate of bears (Bunnel and Tait 1981). It is more probable that changes in bear behavior have caused the increase in human-bear conflicts. Nevertheless, there is little evidence to support ecological changes in bear ecology in Hokkaido. Using the stomach content analyses, it was found that the bears ate crops (Chapter 3). Based on scat analyses, it can be said that the amount of sika deer in the bear diets of Shiretoko Peninsula increased during last decade (Yamanaka 1995). These studies suggest that the bears have recently changed their food habits. An increase of conflicts would occur as long as bears are attracted to human residential areas, irrespective of whether bear population is stable or even decreasing.

It is, however, often difficult to prove this because past information is not available. Fortunately, bear scats were collected in Urahoro in 1978 by Hokkaido University Brown Bear Research Group (Aoi and Kaji unpublished data). Urahoro in eastern Hokkaido has seen an increase in human-bear conflicts during the late 1990s. First, I describe the human-bear conflicts and control killing of bears in Urahoro. Second, by comparing the past data with the present situation of the Urahoro bears, I show changes in density and diet.

Study area

I focused on Urahoro as the study area, because the number of control killing has increased recently. It is located at the end of the Shiranuka Hill (N 42'48, E 143'39, Figure 4-1). Approximately 7,000 people live Urahoro. It is 730 km^2. Forests cover 74 % of Urahoro. 60 % of the forested area is natural and 36 % is planted.

Brown bears in Urahoro

A bear attack on a person has not occurred since 1975 when a woman who was logging was injured by a bear (Hokkaido Government 2001a). In recent times there has been crop damage and the latent fear of attacks. According to Urahoro Agricultural Cooperative, since 1993, crop damage mainly on sugar beets and corn has fluctuated between 20 and 100 ha (Urahoro Agricultural Cooperative unpublished data, Figure 4-2). There are no records for before 1993 since the damage was not severe.

In Urahoro, control killing is the main form of management in relation to bear damage, although some farmers have posted electric fences to protect their land from invasion of bears. Urahoro Town Office holds a long-term record of bear kills in

Urahoro since 1966 (Urahoro Town Office unpublished data). According to the record, the numbers of bear kills increased abruptly in the late 1990s (Figure 4-3). More males were killed in June-July of 1994-2001 than before (Urahoro Town Office unpublished data, Figure 4-4). No bear was killed in the spring from 1994-2001, because the Hokkaido Government prohibited spring prophylactic killing in 1990 (Mano 1998, Mano and Moll 1999).

Materials and methods

Records of Field sign survey in 1978

In July and August 1978, the members of Hokkaido University Brown Bear Research Group searched for bear field signs, mainly scats, in a forest belonging to the Hokkaido Government in the Urahoro district (Kaji unpublished data). From 11-16 July 1978, 5 parties explored streams and paths through the forest, a distance of 33.5 km in total. From 26-29 August 1978, 4 parties walked for 32.3 km. The numbers and the location of bear scats were recorded and the scats were collected.

Field sign survey in 2000

In July and August 2000, I searched for bear field signs, mainly scats, in cooperation with the members of the Urahoro Brown Bear Research Group and the Hokkaido University Brown Bear Research Group. From 15-16 July 2000, 8 parties explored streams and paths through the forest for 58 km. This distance covers the whole of that explored in July 1978. From 27-29 August 2000, 8 parties walked for 58 km, therefore also covering the whole distance of August 1978. Moreover, I explored the same 58 km route in October 2000. The same records as in 1978 were taken.

Scat collection in 1998-2000

In addition to the above survey, I searched for bear scats during the field surveys of radio tracking, hair traps, and rub trees from May to November in 1998-2000. Only fresh scats were collected.

Quantitative analyses of scats

Thirty-four bear scats collected in 1978 were quantitatively analyzed. About 30 g of materials was sampled from each scat (Aoi unpublished data). These samples were then separated into individual food categories, oven-dried for 24 hours at 60 ℃, and weighed. Each category was presented by percent frequency of occurrence and as percent dry weight.

All the 117 scats collected in 1998-2000 were analyzed by the point-frame method (Chapter 2). I washed the contents with tap water on a sieve (2.0 mm mesh aperture). Then I spread a 500g of the material remaining on the sieve onto an enamel tray (38 cm by 33 cm). The tray where the contents were spread was marked with a 1 cm by 1 cm grid on the bottom and the points of intersection were regarded as point frames. I counted more than 400 points. I have confirmed that the point-frame method can reflect dry weight (Chapter 2).

Animal material is generally underestimated as a part of the ingested composition because they are more digestible than plant materials. I therefore recalculated 6 categories (herbs, berries, acorn and nuts, deer, ants, and crops) by correction factors proposed by Hewitt and Robbins (1996). Correction factors were

0.25 for herbs, 1.2 for berries, 1.5 for acorn and nuts, 3.0 for deer, 1.1 for ants, and 1.0 for crops.

I divided the samples of 1978 into 2 seasons and those of 1998-2000 into 4 seasons according to plant phenology, *e.g.*, spring (March – May), early-summer (June – July), late summer (August – September), and fall (October – January).

Results

A comparison of scat densities

I compared the scat density between 1978 and 2000 (Table 4-1). The scat density in July and August 2000 tended to be lower than that of 1978. These summer months correspond with the period of agricultural damage by bears (Urata 2001). This change suggests the possibility that bears moved to farmlands in July and August 2000. I therefore also compared the October scat densities. They were almost the same as those of July and August. This suggests that the bear density was lower in 2000 than in 1978.

A comparison of the diet

In 1978, herbaceous plants predominated in early and late summer (Table 4-2). In early summer, they were exclusively dominant in the scats. In late summer, they continue to have a high frequency, though their volume decreased. Berries increased markedly both in frequency and volume in late summer. They mainly included *Rubus* spp., followed by *Actinidia kolomicta.* As for animal materials, only ants (Formicidae) showed a high frequency in each season, though the volume was low. I could find no evidence of crop eating.

From 1998-2000, herbaceous plants were predominant and common in spring, early summer, and late summer as in 1978 (Table 4-3). During all seasons, the percentage of sika deer both in frequency and volume was high. This was not the case in 1978.

In spring, herbaceous plants and sika deer were predominant, and they occupied as much as 98.4 % of the volume. In early summer, insects (mainly Formicidae), and crops (mainly sugar beets with a small amount of wheat) increased. The composition in late summer was similar to that of early summer, while frequency of occurrence of berries increasing. Crops included sugar beets, corn, and to a lesser extent of meadow grass. In fall, berries, mainly *Actinidia arguta* and *Vitis coignetiae*, were dominant, and acorns and nuts increased, while herbaceous plants decreased.

The scat compositions corrected by the correction factor (Hewitt and Robins 1996) indicated that the contribution of sika deer from 1998-2000 was large during all seasons, *e.g.*, 85 % for spring, 52 % for early summer, 43 % for late summer, and 34 % for fall (Figure 4-5). The contribution of herbaceous plants from 1998-2000 was smaller than what it is in 1978.

Discussion

A comparison of scat density

I used the scat density of brown bears to give an indication of the population densities in 1978 and 2000. I have shown that the present bear density in a forest is lower than in 1978. From 1995-1998, while maintaining electricity lines throughout Hokkaido, extensive surveys of scat densities were done (HIES 2000). The result of the Akan-Shiranuka region, where Urahoro belongs, averaged 3.1 ± 3.4 (SD) per

100 km, which almost corresponds with the scat density of this study in 2000. This supports the conclusion of this study, that is to say the decrease in scat density. Though the process of the density change is unknown, there is a possibility that current human-bear conflicts are caused by an abrupt population increase after 1978. Between May and October in 1983-1985, the members of Obihiro University of Agriculture and the Veterinary Sciences Brown Bear Research Group searched for bear field signs in a Hokkaido Government forest of the Urahoro district (Osa personal communication). The scat density was quite low (1 scat per 100 km at most). This suggests that the brown bear population had already decreased in the mid 1980s. It is likely that current increase of human-bear conflicts is not caused by the abrupt population increase in the 1990s. It seems that the current increase of brown bear kills does not reflect the changes in the population.

A comparison of the diet

The sizeable presence of herbaceous plants in the early summer of 1978 and from spring to early summer in 1998-2000 correspond with the former studies on Hokkaido brown bears and those of other regions of the world (Cicnjak et al. 1987, Mattson et al. 1991, Clevenger et al. 1992, Elgmork and Kaasa 1992, and McLellan and Hovey 1995).

No earlier studies have reported that brown bears ate such a large amount of berries, yet in the late summer of 1978 *Rubus* was particularly prevalent. The dominance of *Rubus* berries in the Urahoro brown bear diet seems unique, because berries eaten by brown bears in the late summer of other countries are composed of *Vaccinium* spp. (Norway, Elgmork and Kaasa 1992, France Berducou and Barrat 1983, Spain Clevenger et al. 1992, Alaska Stelmock and Dean 1980, Canada Hammer and Herrero 1987, Hammer et al. 1991, McLellan and Hovey 1995).

From 1998-2000, sika deer meat occupied a large proportion of the diet throughout the year. Since no or quite small amounts of sika deer meat appeared in the bear diets in the 1980s (Aoi 1985, Ohdachi and Aoi 1987, Yamanaka and Aoi 1988), it can be said that sika deer meat have increased in the 1990s. This change is probably caused by a marked population increase of sika deer after the 1990s (HIES 1997, Kaji et al. 2000). There have been reports to show the use of ungulate meat by brown bears in many regions of the world (Berducou and Barrat 1983, Boertje, et al. 1988, Elgmork and Kaasa 1992, McLellan and Hovey 1995, Green et al. 1997, Mattson 1997). The brown bears in these areas eat mostly the carcasses of ungulates that died in spring after over-wintering. Brown bears occasionally prey on the calves of ungulates in early summer (Boertje et al. 1988), and livestock in late summer (Berducou and Barrat 1983, Elgmork and Kaasa 1992). It is noteworthy that brown bears in Urahoro use deer meat throughout the year. I conclude that the food habits of the Urahoro brown bears have changed having become more dependent on animal foods in the last decade. These changes would have occurred extensively in eastern Hokkaido where the number of sika deer has increased.

During the summer of 1998-2000, the amount of crops in the bear diet increased greatly. Crop use by the Hokkaido brown bear is known to occur widely in Hokkaido (Chapter 3) and has caused human-bear conflicts (HIES 2000). Whereas corn was the most important crop for bears in Hokkaido as a whole, in Urahoro corn was the second most important crop. Sugar beet was the most important crop used by Urahoro brown bears, as it was for bears in other areas of eastern Hokkaido where there is a large amount of sugar beet cultivation (Chapter 3). Urata, a cooperative researcher, revealed that 1) crop damages by bears occurred from late June to late September, 2) the crops mostly eaten by bears were sugar beets and corn (Urata 2001). The bears eat sugar beets over a long time because the rootstock is available throughout the growing season, whereas ripened corn is only available from late August to early September. Crop damages by bears were quite small in 1978 (Kaji personal communication) and from 1983-1985 (Osa personal communication).

In fall, from 1998-2000, bears ate berries, acorns and nuts. These results correspond with the studies in other regions of Hokkaido (Aoi 1985, Ohdachi and Aoi 1987, Yamanaka and Aoi 1988, Chapter 3), and in the world as a whole (Cicnjak et al. 1987, Mattson et al. 1991, Clevenger et al. 1992, Elgmork and Kaasa 1992, and McLellan and Hovey 1995).

In summary one can say that herbaceous plants and berries decreased in the bear diets, while deer meat and crops increased during the last 2 decades. These changes in diet are important in relation to the current increase in human-bear conflicts.

Chapter 5. **Home range and habitat use of brown bears in Urahoro**

Introduction

In Urahoro, bear-related damage is increasing (Chapter 4). Crop damage by brown bears was worse in 2000 than it was in 1978, though the scat density of brown bears was lower (Chapter 4). One of the most striking changes in their food habits was the increase of crops as a summer food (Chapter 4).

A change in the food habits of a bear is often related to changes in its habitat use. For example, brown bears extended home ranges and increased their movements in fall of poor fruit production (Yellowstone N. P.: Blanchard and Knight 1991, Mattson et al. 1992, Montana: Waller and Mace 1997, Spain: Clevenger et al. 1990). During difficult falls American black bears (*Ursus americanus*) have been seen to move to different areas in search of food in spite of being increasingly vulnerable to hunting and poaching (Garshelis and Pelton 1981). These studies clearly show that yearly variation in fruit production affects home range of bears. However, the use of crops by Urahoro brown bears was seen, not in fall but in summer. This suggests that the bears do not invade the farmlands because of poor fruit production in fall and that it is probable that crop use is habitual.

There were 3 studies of bears' habitat use by radio tracking in Hokkaido: Oshima Peninsula (Mano 1994a), the Tomakomai region (Waseda 1999), and Shiretoko Peninsula (Yamanaka et al. 1995). Though they studied home range use of the brown bears, there is no study on habitat use of brown bears in relation to crop damages.

In order to explain the increase of crops as a food of Urahoro brown bears, one needs to show the seasonal home ranges and habitat selection. I examine this behavior by radio tracking, paying particular attention to use of farmlands.

Materials and methods

Capturing

In order to capture bears I used barrel traps designed by Mano et al. (1990). During July 1998 and November 1999, I placed 10 traps along streams and ridges of a Hokkaido Government forest in the Urahoro district. Honey and sika deer meat was placed in the traps as bait. I attached a radio-transmitter to each trap. The transmitter notifies bear capture by switching off. I patrolled the traps almost every day.

In 1998, I failed to capture bears. In 1999, I captured 3 bears, an adult female named "Minmin" (15 June); a yearling male named "Rocky" (5 August); and an adult female named "Kanna" (21 October). Once the bears were captured, they were immobilized with intramuscular injection of atropine (Atropine sulfate injection, Tanabe Seiyaku Co., Ltd., Osaka, Japan) at a dose of 0.01 mg/kg estimated body weight, xylasin (Celactal, Bayer Ltd., Leverkusen, Germany) of 1 mg/kg and ketamine HCl (Ketalar, Sankyo Co., Ltd., Tokyo, Japan) of 10 mg/kg. These anesthetics were administered with a direct injection or by a blowgun. Adult females were fitted with collars attaching 144 Mhz radio transmitters (Advanced Telemetry Systems Co. Ltd., Minnesota, USA). The male yearling was fitted with the same collar but with a release belt made of cotton and was marled with a numbered, color-coded tag in consideration of his growth.

Radio tracking

After tagging, searches were conducted using portable receiving equipment (FT-290 mkⅡ, YAESU MUSEN Co. Ltd., Japan) and rod antenna attached to the car bonnet, and were located by triangulating on the ground from known positions with portable receiving equipments and a 3 elements Yagi antennas (White and Garrot 1990). When I lost their locations for a month or 3 bears entered the dens, aerial tracking was conducted with an aircraft (Cessna 172) equipped with 3 elements Yagi antennas on the wing tips as was done by Mano (1994b) and Igota (2000). I located Minmin for 4-5 times per a week, though I often failed to locate Rocky and Kanna because they moved over long distances where there were no roads. On average, Rocky was located successfully two per a week, and Kanna one per a week. Telemetric locations were made from the 16 June 1999 to the 31 July 2001 for Minmin, from the 6 August 1999 to the 13 August 2000 for Rocky, and from the 22 October 1999 to the 24 September 2001 for Kanna.

Home range estimation

Location estimates of radio-collared bears were plotted on the 1/25,000 scale maps using the ArcView™ GIS (Geographic Information System, Environmental System Research Institute, Inc., Redlands, California), and converted to UTM (universal transverse mercator) coordinates. I calculated the MCP (minimum convex polygon) sizes as the total home ranges of the 3 bears. In order to determine the seasonal home range sizes and habitat use, I used 249 location estimates for Minmin, with MCP and the 50 % fixed-Kernel method for June-July, August-September, and October-November in 1999 and 2000, and April-May in 2000, respectively. I defined the area estimated by the 50 % fixed-Kernel method as the core area. I adopted the program extension, Animal Movement, to the ArcView™ (Hooge and Eichenlaub 1998) for home range analysis.

Habitat preference analyses

I analyzed the seasonal habitat preference of Minmin. The proportions of habitat categories that included the total MCP home range were considered to be available habitat categories for the bear. Though it is possible to determine "pin-point" locations, the correspondences of these location points and habitat categories do not always reflect habitat selection of wildlife, because such "pin-point" location inevitably contains telemetry errors (White and Garrott 1986, Nams 1989, Powell et al. 1997). It would be more meaningful to draw "core areas" using those location plots, and compare with habitat categories. I categorized the habitats into 4; natural forests, planted areas, farmlands, and riparian communities, modifying the categories of the Environment Agency (Environment Agency 1997). These were calculated by using Spatial Analyst extension to the ArcView™. The size of each habitat category was totaled in the home ranges.

Preference or avoidance of each habitat category was determined by the method of Neu et al. (1974) using χ^2 goodness for the fit test, and the Bonfferoni's Z-statistics to control the experiment-wise error by confidence interval on proportion of habitat use (90% confidence coefficient).

Results

MCP home ranges

Table 5-1 summarizes the date of capturing, sex-age classes, body weight, duration of tracing, numbers of locations, and MSP sizes of the 3 brown bears. Figure 5-1 shows the distributions of the MCP home ranges. I located Minmin for 106 points in June-November, 1999, 121 points in May-November, 2000 and 22 points in May-July, 2001. She was shot on July 31, 2001, when she appeared in a beet field. Her MCP home range was 61.09 km^2. I located Rocky for 50 points in August-December, 1999 and 8 points in April-August, 2000. I confirmed the tag dropping in August 2000. His MCP home range size was twice (127.36km^2) as large as that of Minmin, though the tracing period was shorter. I located Kanna for 6 points in October-November, 1999, 12 points in April-December, 2000, and 17 points in May-July, 2001. Her MCP home range size was 51.06 km^2.

Air location determined winter denning sites of the females, which showed that they denned in the near locations both in 1999/2000 and 2000/20001 winters (Figure 5-1). Of the 3 bears the denning point of Rocky was closest to the central Urahoro (Figure 5-1).

Seasonal changes in a female's home range

I compared the locations and sizes of Minmin's home ranges, which I could trace most frequently through the seasons of 1999 and 2000. Her home ranges and core areas were located in the forest in June-July and October-November, 1999 and May, June-July and October-November, 2000 (Figure 5-2). In contrast, the range was shifted to be the west or closer to the farmlands in August-September of both 1999 and

2000. The core areas in the both years were also concentrated towards the farmlands and their surrounding areas.

In May the home range size was small (9.5 km^2), it increased in June-July (1999 : 42.1 km^2 in 1999, 24.6km^2 in 2000) and in August-September (42.9 km^2 in 1999, 28.5km^2 in 2000) , and then decreased again in October-November (25.8km^2 in 1999, 9.4 km^2 in 2000, Figure 6-3). It is noteworthy that the core area was, in contrast, smaller in August-September (2.1 km^2 or 4.9% of the home range in 1999, 4.6 km^2 or 16.1% of the home range in 2000) and larger in October-November (14.1 km^2 or 25.8% of the home range in 1999, 8.2 km^2 or 87.2% of the home range in 2000). These results suggest that Minmin enlarged the home range in summer and at the same time intensively used particular small areas within short distances, though she sometimes returned into forests while chiefly using farmlands (Figure 5-4).

Habitat selection

I calculated the composition of habitat categories in each seasonal MCP home range and core area from all locations of Minmin and compared them with habitat availability (Table 5-2). Many of the habitat categories were not selectively used or avoided, but significant differences were found in August-September of both 1999 and 2000 (χ^2 = 79.67, 3df, P < 0.0001 for 1999, χ^2 = 10.26, 3df, P = 0.016 for 2000). Minmin avoided natural forests and selectively used farmlands (farmlands were significantly selected only in 1999).

Discussion

Seasonal changes in habitat use of a female brown bear

The MCP home ranges of Minmin were located in the forest during spring, early summer, and fall. She did not select any categories of vegetation in these seasons. In contrast, however, the range was shifted to the west and she selectively used farmlands in August-September. Additionally, there was further evidence that she invaded farmlands besides the radio tracking data. For example, I saw her invading a sugar beet field with 2 yearlings on 15 August 1999, and farmers and a hunter saw her invading a sugar beet field with 2 yearlings on 31 July 2001. As a whole, she habitually invaded farmlands to eat crops in late summer. A hunter shot her for control killing at that time.

This habitual movement is different from that related to yearly fluctuation of fruit and nut production (Blanchard and Knight 1991, Clevenger et al. 1992, Mattson et al. 1992, Waller and Mace 1997). Crop damage by Hokkaido brown bears is most frequent in late summer (Chapter 3), when most fruits have not ripened. She invaded farmlands in the summer of both years in spite of the danger of control killing and the available food in the forest.

Since the bear population is decreasing, it is desirable to devise a non-lethal management option for such "problem bears". In Hokkaido, several initiatives have been started, including electric fences (Tazawa 2000, Tsuruga and Tomizawa 2000, Urata 2001), repelling bears by trained dogs, plastic slugs, and cracker shells (Okada 2001, Yamanaka 2001a, b), and the removal of attractants from the side of the road (Okada 2001). Habitat alteration has also been used, such as the removal of undergrowth plants in the forests near farmlands, which improves visibility and would consequently reduce bear invasion (Tazawa 2000, Tsuruga personal communication).

Seasonal changes in home range size of a female brown bear

Minmin used broader ranges in summer than in spring and fall. It is shown that the seasonal home range sizes of brown bears are largest in summer, smallest and stable in spring, and medium and unstable in fall (Blanchard and Knight 1991). These seasonal changes are explained as follows; body mass and food intake decreases in spring (Blanchard 1987, Mattson et al. 1991), food sources are most diverse in summer (Mattson et al. 1991) and habitat productivity is more evenly distributed (Mattson et al. 1987), and food availability is unstable in fall (Blanchard and Knight 1991). In this study, the maximum range size in summer corresponds with a wider variety of the diet (Chapter 4). Minmin, however, minimized core areas in late summer and intensively used farmlands, undoubtedly because of concentration of resources (Blanchard and Knight 1991). Minmin's core areas were small and her home range was large in late summer probably because she repeatedly visited and intensively used the farmlands and at the same time she wandered in the forest.

The minimum home range size of Minmin in spring also corresponded with the result of Blanchard and Knight (1991). I could determine her spring home range size only in 2000. In this spring, she had cubs of the year. It is reported that female brown bears with cubs of the year have smallest home ranges among all age- sex classes (Blanchard and Knight 1991). In fact, seasonal home range sizes in 2000 were smaller than that of 1999.

Chapter 6. **Individual identification by a recently developed method: hair root DNA analysis to show range use and abundance**

Introduction

Damage by brown bears is rapidly increasing in Urahoro (Chapter 4). This damage is believed to be related to the population increase and behavioral changes of the bears in throughout Hokkaido (HIES 1995, 1996, 2000). In a forest of Urahoro, however, the bear population decreased over the last 2 decades (Chapter 4) but the bears began to use crops in summer (Chapter 4) and some bears selectively use farmlands (Chapter 5).

Bear-related damage includes crop damage and latent fear of attacks in Urahoro (Chapter 4). Therefore, "problem bears" are defined as those who invade farmlands and villages. What is important for local people is to know how many "problem bears" exist in an area and whether control killing can reduce the number of such "problem bears" or not. For the people, it is not problematic that many bears live in deep forests as long as they are not harmful, whereas it is problematic even one "problem bear" is present around farmlands. Nevertheless, it is unclear how many bears are harmful and whether control killing does reduce the damage or not. It is therefore necessary to determine who are the "problem bears" and to estimate their numbers and their ranges.

Traditionally individual identification has been done by live capturing, and range determination has been done by radio tracking. However, these methods are not only expensive and laborious, particularly when information is needed on many bears, but also dangerous.

In order to get rid of these problems, effective genetic identification using highly variable microsatellite DNA markers has recently become practical (Paetkau et al. 1995), and can be used Ursidae. The analysis is possible from small amounts of DNA by PCR amplification. Techniques to effectively extract DNA from scats and/or hairs in the field without capturing have been developed (hair: Walsh et al. 1991, scat: Hoss et al. 1992, Wasser et al. 1997), and it was confirmed that the extracted DNA could be amplified by the PCR method (Taberlet and Bouvet 1992, Taberlet et al. 1993). Effective methods to collect samples have also been developed (hair trap: Woods et al. 1996, Woods et al. 1999, hair capture from rub tree: Taberlet and Bouvet 1992, scat collection by scat sniff dog: Woods 1998). Population estimates have been done for brown bears using these methods (Mowat and Strobeck 2000, Posillico and Lorenzini 2000).

This chapter aims to evaluate the utility of the new genetic methods for individuality identifying the bears who invade farmlands and to estimate the brown bear population in Urahoro.

Materials and methods

Hair collection

I used 3 methods of hair collection. First, I collected hairs using hair traps. I used a systematic grid design to minimize capture variation. I divided the study area using a 2 km by 2 km grids. This size is smaller than the average size of the home ranges of female brown bears in spring and fall in Hokkaido (Mano 1994a, Chapter 5). I installed 1 hair trap in 70 cells, which covered 38.4 % of Urahoro Town. Each trap site within a cell was subjectively located considering my experiences to maximize capture efficiency.

Baits were suspended approximately 3 m high from a tree in a hair trap, which was surrounded by a barbed wire fence at about 60 cm from the ground following Woods et al. (1999). I used about 3 kg of sika deer meat for bait.

I visited the traps to set new baits and collect hairs for 5 times in 2000; mid May (only setting), late June – early July, late August, mid October, and early November (only collection). At a preliminary session in 1999, the success rate of hair collection was lower (20-30 %) in spite of longer periods (30-60 days) than other studies (74% for 28days: Woods et al. 1999, 73 % for 10 days and 48 % for 14 days: Mowat and Strobeck 2000). In addition, it took 1 week or longer to defrost the frozen deer meat. Thus, I continued to use the same trap site through the year, extended trap duration days to 60 days, and set the traps again immediately after hair collection. Each hair sample was put into a plastic bag, though hair groups trapped by neighboring barbs were considered to be brought by a single bear, and they were put into a plastic bag.

Second, I collected hairs from trees rubbed by bears ("rub tree", hereafter). Brown bears are known to rub their bodies on tree trunks. I found 75 rub trees in the study area during 1998-2000. When I found these trees, I wound barbed wire around them. The snags on the surface of tree were carefully pressed against the tree so as not to injure the bears. I checked 41 to 46 trees for at least once during each session of hair trap collections. All hairs collected on the barbed wire of a tree were put into a small plastic bag.

Third, I collected hairs from deer-proof wire fences ("deer fence", hereafter). They were 2 m high and have extended for longer than 350 km around farmlands to prevent deer invasion since 1997. When bears attempt to invade farmlands, they inevitably pass over the fences or pass through under them. Consequently, the hairs are left on the fence wire. A cooperative researcher (T. Urata, an undergraduate student of Hokkaido University) collected the bear hair along the fence (6,770 m long in total) at 28 farmlands, in the northern part of Urahoro from early June to early November in 2000. All hairs caught at the fence of each invasive trace were put into a small plastic bag.

All the samples collected by these 3 methods were stored at 4 ℃ before analyses.

DNA extraction and fragment analysis

DNA was extracted from hair roots with QIAamp Mini-Kit (QIAGEN) with the QIAamp protocol: isolation of genomic DNA from nails and hairs (QIAGEN, TS-QA05 01/99). I used 1 root in an extraction so as not to contaminate the sample material from more than 2 bears. Each sample was typed at 8 microsatellite loci (Paetkau et al. 1995, Paetkau and Strobeck 1998). The 5' primer of loci G1A, G10C, and G10L were labeled with a fluorescent dye HEX, G1D and G10P with 6-FAM, and G10B, G10M, and G10X with TET. The PCR amplification was performed with 2-10 μl of DNA extracts in a total volume of 20 μl of a reaction mixture containing with 35 μM of each primer, 28 μM of each dNTP, 0.5 U of TaKaRa exTaq polymerase (TaKaRa, Japan) in the buffer consisting of 10 mM Tris-HCL (pH 8.3), 50mM KCL, 1.5mM $MGCL_2$, using TaKaRa PCR thermal cycler personal (TaKaRa, Japan). Amplification of microsatellite DNA was carried out with pre-heating to 94 °C for 2 minutes followed by 42 cycles of a series of reactions for 94 °C for 30 seconds, 50 °C for 20 seconds, and 72 °C for 20 seconds. In order to check DNA amplification, 8 μl of PCR product was electrophoresed on a 2 % agarose gel and stained with ethidium bromide.

PCR products were resolved with the ABI PRISM™ 310 Genetic Analyzer. For each individual, products of G1A, G10B, G10C, and G10X were mixed in 1 tube, and those of G10L, G1D, G10P, and G10M were put together in another tube. One μl of each mixture was loaded on the Performance Optimized Polymer 4 in a formamide loading buffer along with an internal size standard (GeneScan™ 500 TAMRA, ABI). Data were collected using 310 GeneScan™ ver. 2.1.1 software (ABI). Differences of molecular size of PCR products were identified as alleles.

Identification

A difference in genotypes between samples should be taken as evidence that they originate from different individuals at a probability of a match (P_{id}, Paetkau and Strobeck 1998). However, errors in genetic analyses with very low DNA quantities using PCR are inevitable. Errors introduced during genetic analyses can fall into 2 categories (Woods et al. 1999). First, amplification of DNA from very small sources can result in the amplification of "false alleles" or the failure to amplify 1 allele (allelic dropout) in heterozygotes (Taberlet et al. 1996, Gagneux et al. 1997). Second, contamination, labeling, and loading errors, and possibly amplification artifacts, can cause errors (Gagneux et al. 1997). An experimental procedure using multiple separate PCR amplifications from a sample is proposed to obtain reliable genotypes (Taberlet et al. 1996, Gagneux et al. 1997). Nevertheless, less than 10 tubes could be used for PCR amplifications of 8 loci because of a small amount of DNA extract from a sample. Therefore, all of the loci could not be re-analyzed sufficiently.

In this study, I calculated the allele-sharing rate (Bowcock et al. 1994) for all of the combinations of samples. Then, I defined that if the allele-sharing rate is greater than 0.8, the samples are derives from the same individual.

Results

Hair collection

Figure 6-1 shows the locations of 70 hair traps and rub trees in the study area. Figure 6-2 shows the locations of bear invasions through deer-proof fences into farmlands. Hair collections were taken over 4 sessions at 260 traps in total (Table 6-1).

A total of 214 hair samples from 113 hair traps (43%) were collected with a mean of 1.9 samples per a trap (Table 6-1). Sampling success of each session was highest (57.8 %) in late summer while it was lowest in fall (27.3%, Table 6-1, Figure 6-3). This is most likely because deer meat decays easily at high temperature, resulting in a strong smell that attracts bears.

Eighty-five hair samples were collected from 172 rub trees (Table 6-1). They were most abundantly collected in early summer (27 samples, 64.3%), which seemingly reflects the frequent rubbing in this season.

Hairs were also collected from deer fences at 44 points (38.6%) among 114 points where bears passed the fence into farmlands. The samples were most abundant in late summer (Urata 2001). This corresponded with the high frequency of crop damage by the bears.

DNA extraction and identification

Among the samples used in the analysis, those whose alleles of more than 6 loci were confirmed were regarded as genotyping success and used for further analyses. Numbers of samples were; 47 from hair traps, 39 from rub trees, and 19 from deer fences (Table 6-1).

According to the definition of an individual, it was regarded that 26 bears appeared in the study area throughout the study period; 17 bears in spring, 18 bears in early summer, 12 bears in late summer, and 7 bears in fall (Table 6-1). Twenty bears, 14 bears, and 7 bears were identified from hairs collected by hair traps, rub trees, and deer fences, respectively. Newly found bears by hair samples steadily decreased through the sampling period (Figure 6-4).

Genetic diversity

According to the samples whose genotypes were determined, length and frequency of alleles found on each locus are listed in Table 6-2. The number of alleles ranged from 3 to 8. At locus G10C, there were only 3 alleles, one of which (Type 7) occurred at a high frequency of up to 84 %, which resulted in the lowest expected- (H_{exp}) and observed heterozygosity (H_{obs}) among the loci. Even so it was possible to achieve a high probability of identity (Table 6-3). The mean number of allele (A) on 8 loci of microsatellite of the bear population of Urahoro was 6.00 (Table 6-3). The expected- and observed heterozygosity were 0.670 and 0.690, respectively. The probability of individual identification (P_{id}) was 8.5×10^{-7}.

Mapping, ranging, and invading farmlands

The locations of the samples of identified bears are shown in Figure 6-5. Among the 26 identified bears, 15 bears detected in more than 3 locations, which were consequently used to draw home ranges (Figure 6-6). Eight bears detected in 2 locations, and another bear was detected in 2 separate samples from 1 location.

By using the minimum numbers identified in each season, I tried to calculate the crude bear density. As the hairs were collected in the area of 280 km^2 (70 cells of 2 km by 2 km grid), the crude density of each session was calculated as 6.1 / 100 km^2 for spring, 6.4 / 100 km^2 for early summer, 4.3 / 100 km^2 for late summer, and 2.5 / 100 km^2 for fall. Considering the movement through the border of study area, these crude densities would be overestimated. Then, I divided the minimum number identified in total season (26 bears) by continuously ranged area by brown bears including the study area (1,125 km^2, 45 cells of 5 km by 5 km grid, HIES 2000) as the minimum crude density (2.3 / 100 km^2). Thus, the crude density of brown bears in Urahoro was roughly estimated as 2.3 – 6.4 / 100 km^2.

By identifying the samples collected from deer fences, it was shown that 7 bears invaded farmlands in 10 farmland sites (Figure 6-7). More than 3 locations were identified from 5 bears. Their home ranges all included farmlands in the western parts. These locations showed that the bears (Bears A, B, D, and E) ranged through forests in spring and fall, and that they invaded farmlands most frequently in late summer (Bears A, B, C, D, E, Q, and R), followed by early summer (Bears A and B, Figure 6-6). They also showed that Bears A, B, D, E, and R used both farmlands and forests also in late summer.

The hair DNA analyses showed that bears invaded several farmland locations while the farmland being used by several bears (Figure 6-6). Bears A and B used 4 farms, and Bear C visited 2 farms. Hairs were found only at one farm in the cases of Bears D, E, Q, and R. Among 10 farmland sites invaded by bears, one farm was used by at least 3 bears, and 3 farms were used by at least 2 bears (Figure 6-6, 7).

Discussion

Hair collection

Bear hairs were successfully collected by all the three methods: the hair trap, the rub trees, and the deer fences. The efficiency of the hair trap was 43 % on average over 4 sessions, which was lower than the former studies in spite of longer baiting duration time (Woods et al. 1999, Mowat and Strobeck 2000). One reason for this seems that foods are more abundant in the study area than other areas, *e.g.*, western Canada (Mowat and Strobeck 2000), which decreases attraction for the bears. The rates of continuous collection were only 38.7% in spring/early summer, 51.4% in early/late summer, and 50% in late summer/fall. Mowat and Strobeck (2000) used rotten meat while I used defrosted meat that appears to be less attractive. This must explain the lower efficiency in the fall session.

The hair trap method requires experience to judge the place frequented by the bears, and labor in setting baits after the traps have been established. However, it promises nonbiased sampling by even distribution of trap sites. Therefore, this method is effective for population estimation in an area.

The rub tree method showed as high as 49 % success for 4 sessions. The efficiency was highest in early summer, which suggests some relation between reproductive behavior and back rubbing. This method is easy and regular visits are enough for collection after establishment of barbed wire on tree trunks. The bears visit the trees without any particular attractants. However, such trees were not evenly distributed in the study area.

A high efficiency of hair collection during the rut suggests the possibility that the bears that rub their backs may be of a particular age and sex. Therefore, nonbiased sampling by this method alone is difficult. This method is effective as a subsidiary method for estimating home ranges of "problem bears".

The numbers of samples collected by the deer fences were most numerous in summer when damages occurred most frequently. Sampling is easy if the exact place where a bear has invaded farmland is detected. This method does not require the transportation of barbed wire and baits. It is an effective way to identify "problem bears", though it is unable to determine home ranges. This method should be used together with other methods.

Identification

It is inevitable that some errors will occur in microsatellite DNA analysis that uses samples containing small amounts of nuclear DNA. I thought that it was impossible to regard multiple hairs as those of one bear, because several bears using the same rub tree were shot by automatic cameras (Sato and Urata unpublished). This is also the case for the hair samples left on deer fences. For these reasons, I treated each hear as a single sample, though Mowat and Strobeck (2000) used 4 hairs as a sample. It is possible that this strict use resulted in low rate of individual identification, and therefore I did not use "multiple tubes procedure" recommended by Taberlet et al. (1996) and Gagneux et al. (1997), but adopted a conservative method using the allele sharing rate (Bowcock et al. 1994), which inevitably contains some errors. This means that the 26 bears calculated as the minimum number could be an underestimation.

The accuracy of individual identification by the microsatellite DNA is determined by probability (Woods et al. 1999), and the rate of identification depends on the number and frequency of allele. For the population of a low genetic diversity, a large number of loci are required. Taberlet et al. (1997), for example, used 24 loci for identification of European brown bears who experienced bottlenecks in the past. The criterion to judge the genetic diversity is "probability of identity" (Waits et al. 2001). Since it is expected that the hair-trapped samples would include many relatives, as they were intensively collected from small areas, stricter criterion is recommended (Waits et al. 2001). A study using this strict criterion using 6 loci (I used 8 loci including these 6) for a brown bear population in the Canadian Rocky Mountains has shown that it has high genetic diversity (Woods et al. 1999). Their values were: A = 5.63, H_{exp} =0.685, P_{id} = $4.8*10^{-7}$ (Paetkau and Strobeck 1998). These values were almost the same as those of the present study, which suggests that our analysis using 8 loci is appropriate for the target population.

Population estimates

There have been several studies estimating the population of brown bears in Hokkaido. Using interviews with hunters, an estimate of between 1,923-3,119 bears was made in the 1990s (HIES 1995, 1996, 2000). The population on Oshima Peninsula was estimated as being between 522-720 (HIES 2000). It was an estimate made by considering the mortality of radio-equipped bears and the numbers of control kills. The former is less reliable, while the latter cannot be used throughout because radio tracking on many bears is difficult.

One of the traditional methods for estimating the population of brown bears has been the mark-recapture method (Stirling et al. 1997), however it requires many difficult assumptions (Mowat and Strobeck 2000). The hair collection method has some advantages (Woods et al. 1999), *e.g.*, 1) DNA identification cannot be lost, 2) snagged hair may reduce the likelihood of "trap response" because the bear is never physically restrained or surprised, 3) with appropriate analysis procedures, should be rarely misread, and 4) the tags also provide valuable additional resolution in the data, including the sex and genetic relations. Population estimates made with this method were done for a "closed" population where both immigration and emigration did not occur (Mowat and Strobeck 2000). This will be used for an "open" population.

The present study area is located at the end of Shiranuka Hill with brown bears ranging continuously to north and west of the study area (HIES 2000). It is probable that bears pass in and out of study area. In order to estimate the population by using mathematical models, I need to adopt "open" population models such as the Jolly-Seber method (Krebs 1994). In this study, however, the sampling period for setting baits and the collection of hairs took 2-3 weeks, which opposes the assumption of the Jolly-Seber method. Therefore, I did not estimate the population size by using mathematical models, but conservatively estimated the minimum numbers "captured" by the 3 traps. If the sampling time is shortened and repetitions of the hair collection session are increased, hair root DNA identification can be used to adopt the model.

The crude density of brown bears in Urahoro was roughly estimated as 2.3 – 6.4 / 100 km^2. In Oshima Peninsula, southwestern Hokkaido, the population density of brown bears in 1992 was estimated as 9.3 / 100 km^2 (HIES 2000). The population density in Shiretoko Peninsula, eastern Hokkaido, in 1980 was estimated as 13.5 / 100 km^2 (Aoi 1981). The former is known as the area with one of the highest densities of bears (HIES 2000). The latter would also involve many brown bears with a high density, though no comparable data is available because of the inaccessibility of the area. This comparison shows that the bear density in Urahoro is relatively lower than that of other high-density areas. Nevertheless, bear-related damages are occurred constantly, and non-discriminative control killing is performed (Chapter 4). Bear-related damage is not caused by a large bear population but by the presence of "problem bears".

Effect of Identification of "problem bear" on management

Determining the number of the "problem bears" and their home ranges is important for local people and for the managers of the bears, because without it latent fear remains and no effective solution to the bear damage can be found. It is also important in order to evaluate the effect of control killing in reducing the bear damages.

I found that 7 individuals were "problem bears" who invaded a total of 10 farms among the 26 identified bears. The evidence of multiple uses of farms by a bear explain some part of public feeling that the increase in the bear population had caused the increase in bear-related damages. This approach will also be useful for evaluating the nuisance reputation of individual "problem bears". When these bears are caught in the box traps, it would be possible to evaluate whether they were a "problem bear" or not by analyzing their microsatellite DNA and comparing it to that obtained from hairs on deer fences surrounding farmland. Large scale deer fenced are being constructed in many areas of eastern Hokkaido (2200 km long up to 2000, Hokkaido Government 2001b), which provide efficient collection of hairs and consequently DNA analyses to identify "problem bears" will become possible. Moreover, it would be possible to deal with captured bears according to their individual measured nuisance level.

Chapter 7. **Environmental changes in the forest and its surroundings of Urahoro**

Introduction

In earlier chapters I have shown that the bear density in Urahoro has been seems to be decreased in the last 20 years and their food habits have greatly changed (Chapter 4). It has also been seen that some bears use farmlands in summer (Chapters 5 and 6). These results suggest that the human-bear conflicts are caused not because of an increase in the bear population but due to the increased dependence of the bears on farmlands in the summer season.

Such ecological changes in the brown bears are likely to result from environmental changes. The forests of Hokkaido, which are the habitats of the bears, have been greatly reduced since 1871 by human development (Mano and Moll 1999). The broad-leaved forests were turned into coniferous plantation after World War II. That change greatly affected wildlife in Hokkaido (Miura 1999). The distribution of the brown bear throughout Hokkaido was reduced from 60 % in 1978 to 50 % in 1991 (Mano and Moll 1999).

Meanwhile, one of the most marked changes in the Hokkaido ecosystem is the abrupt population increase of sika deer in the 1990s (HIES 1997). After the immigration of Japanese people to Hokkaido, the sika deer population decreased, and by 1925, the distribution was restricted to several small areas in eastern Hokkaido (Kaji et al. 2000). During World War II, the deer population gradually recovered. The elimination of the wolves, the replacement of the native mixed hardwood forests with conifer plantations, and the increased pasture acreage are all likely to have contributed to the expansion in the distribution of deer (Kaji et al. 2000). In particular, large-scale logging and an increase in pasture acreage have brought about an increase in forage for the deer and enhanced population growth. Damage to crops and forests by deer dramatically increased to nearly $15 million (U.S.) in 1990 and to over $30 million (U.S.) in 1996 (Kaji et al. 2000). The total number of culls fluctuated between 2,000 and 3,000 deer during 1970-1989 but increased to 16,134 deer in 1990 and 46,634 deer in 1996 (Kaji et al. 2000). Information on deer eating by brown bears is limited before the 1990s (HIES 2000), and food habit analyses rarely recovered sika deer from bear diets (Aoi 1985, Aoi and Ohdachi 1987, Yamanaka and Aoi 1988). However, recent analyses show an increase in sika deer as a bear food in eastern Hokkaido (Yamanaka 1995, Chapter 3). In Urahoro, in particular, the contribution of sika deer to bear diet are remarkably high, and much greater than any previous analysis (Chapter 4).

The deer increase also affects the vegetation of bear habitats (Kaji 1993, Okada et al. 1997). Undergrowth vegetation is an important food source for brown bears in spring and summer (Aoi 1985, Aoi and Ohdachi 1987, Yamanaka and Ohdachi 1988). Thus it is possible that the deer population increase would affect bear ecology by reducing the amount of herbaceous plants.

Bears in Urahoro use farmlands in summer (Chapters 5 and 6) to eat crops (Chapter 4). Summer crop use is a general tendency for bears in other areas of Hokkaido (Chapter 3). It is therefore plausible that these ecological changes in the brown bears have resulted from the changes in agriculture such as crop changes or changes in the management of agriculture.

In this context, I analyze the environmental factors, in Hokkaido and in

Urahoro, which possibly affect the ecology of brown bear.

Materials and methods

Statistics for forestry in Hokkaido

By using Hokkaido forestry statistics, I examined yearly changes in wood volume, logged areas, and plantation areas for Hokkaido, 1948-1998, and for Tokachi subprefecture, 1953-1998 (Hokkaido 2000b). Woods were divided into coniferous trees and deciduous broad-leaved trees.

Increase of sika deer

In Urahoro, since 1991, spot light censuses of sika deer have been carried out twice a year (late May and late October) by local officers together with the Urahoro hunting group. From 1991-1999, the censuses were taken over 3 consecutive days, while 1-day censuses have been done since 2000. I transformed the data for 3 days (1991-1999) to the mean, so as to show the relative changes in the sika deer population from 1991 to 2000 (Urahoro Town unpublished data). I also surveyed the number of sika deer shot for control killing from 1991-2000 and sport hunting from 1991-1999 in Urahoro (Urahoro Town unpublished data).

I analyzed the site selection of control killing and sport hunting of sika deer. The locations in 1997 were summarized for each 5 km by 5 km cell by HIES (HIES unpublished data). Then, I calculated the proportions of farmlands in each cell by using the Spatial Analyst extension to the ArcView™ (Environmental System Research Institute, Inc., Redlands, California) and grouped them into 10 % categories in the Tokachi- and the Kushiro subprefectures. These 1,140 cells were considered as available cells. Site selection for control killing and sport hunting of deer in 1997 was determined by the method of Neu et al. (1974) using χ^2 goodness for the fit test, and Bonfferoni's *Z*-statistics to control the experiment-wise error by confidence interval on proportion of occurrence (90 % confidence interval).

Controlled killing of sika deer is permitted through the year excluding the sport hunting season from 1 November to 31 January. The seasonal distribution of controlled killing per a permitted day was calculated from the statistics of Urahoro, 1999-2001 (Urahoro Town unpublished data).

Evaluation of the effect of deer grazing on herbaceous plants

I recorded the height of undergrowth (herbaceous plants) inside and outside the deer-proof fences to evaluate the effects of deer grazing. It is known that Hokkaido brown bears prefer large herbaceous plants growing along streams (Aoi 1985, Ohdachi and Aoi 1987, Yamanaka and Aoi 1988, Chapter 3, 4). From 1997 wire fences have been constructed around farmland to prevent the invasion of sika deer. I selected 6 streams, and set 6 2 m by 2 m quadrates inside and outside the fence. The name and height of the herbaceous plants taller than 15 cm were recorded. The height of the plants occurring both inside and outside the fence was compared by randomized block ANOVA and the Mann-Whitney *U*-test.

Statistics of agriculture in Urahoro

Using Urahoro's statistics on agriculture, I examined yearly changes in the acreage of the major crops from 1970-1997 (Urahoro Agricultural Cooperative 1999). I calculated yearly change for the total area of farmlands and the farmland area per farmer.

Results

Changes in forest environment

The volume of logged hard woods and the plantation acreages in the whole of Hokkaido peaked during the 1960s and the early 1970s (Figure 7-1). Both of them began declining in the late 1970s. Though logging of conifers was also intensified in the 1960s, no apparent decline happened thereafter. This is because planted conifers were logged. The volume of standing hardwoods decreased in the late 1970s, while that of conifers increased in the 1980s, which reflects the growth in planted conifers.

Figure 7-2 shows the amounts of logged trees and standing trees in the Tokachi subprefecture. Though the statistics for logging before 1963 are not available, it is likely, that in Hokkaido, that logging of hardwoods was reduced in the late 1970s while the logging of conifers was similar or rather intensified. A difference of the Tokachi subprefecture was that the volume of standing conifers exceeded that of hardwoods after the 1980s.

Increase of sika deer

The numbers of sika deer found by light censuses increased since 1991 when I began counting, and thereafter declined (Urahoro Town Office unpublished data, Figure 7-3). Both the numbers of deer shot for control killing and sport hunting abruptly increased in the late 1990s (Urahoro Town Office unpublished data, Figures 7-4). The number of controlled deer kills exceeded that of hunted deer. In Urahoro alone, the former was as many as about 2000 after 1997.

Sites where control killing and sport hunting of deer occurred in 1997 were significantly selected ($\chi^2 = 163.66$, 9df, $P < 0.0001$ for control killing, $\chi^2 = 42.17$, 9df, $P < 0.0001$ for sport hunting). Deer were controlled quite infrequently in 5 km by 5 km cells in the Tokachi- and Kushiro subprefecture where farmlands covered less than 10 % and 80-90 % in the cells, while they were shot in the many cells where farmlands covered 10-40 % and 50-60 % (Table 7-1). Sport hunting of deer was not common in the cells where farmlands covered 60-90 %, but was common in the cells where farmlands covered 10-30 %.

Except during the hunting season, control killing was done throughout the year. More deer were controlled in fall than in spring (Urahoro Town Office unpublished data, Figure 7-5).

Effects of deer grazing on the vegetation

Herbaceous plants along streams were compared between inside- and outside the deer-proof fences in the study area. More plant species were found inside the fence, though very low growing plants were not listed in the survey. The height of *Petasites japonicus* and *Artemisia montana* whose abundance were "moderate" were compared between inside- and outside the fences. The *Petasites japonicus* inside the fences tended to be taller than that outside ($F = 7.327$, 1df, $P = 0.073$, Figure 7-6). The *Artemisia montana* inside was significantly taller than outside ($P = 0.0014$, Figure 7-7).

Changes in agricultural environment

The acreage of the sugar beets preferred by brown bears was grown the most out of the crops of Urahoro (Urahoro Agricultural Cooperative 1999, Figure 7-8). The acreage had been increasing up to the early 1980s, but is now stabilized. Wheat increased during the 1970s, and is still increasing. Wheat has become the second most important crop following sugar beets. Meanwhile, corn, another preferred crop by brown bears, has been decreasing for the last 20 years. Potatoes have not changed greatly, while the small amount of small beans and soybeans have been decreasing.

Figure 7-9 shows the acreage of farmland and the mean farm size for a farmer of Urahoro (Urahoro Agricultural Cooperative 1999). The total farmland has been linearly increasing until the early 1980s. Since the population of farmers has been declining, the mean farm size for a farmer has been increasing. It is now double that of the 1980s. This means that the time spent working in a unit of farmland for a farmer has become shorter.

Discussion

Changes in the forest environment

Analysis of the statistics has shown that great changes such as logging of hard woods and the planting of conifers occurred 20-30 years ago in Hokkaido. The increase in damage by brown bears does not correspond with these changes. This suggests that the forest change is not directly influence the damages.

In 1978, immediately after large-scale logging, the first bear survey was done.

It is to be expected that the forest change would affect bear food habits. The food analyses showed that the contribution of *Rubus* fruits to the summer diets was large (Chapter 4). In fact it was so as extraordinarily large if compared with other studies on other populations in Hokkaido and other countries. *Rubus* species are typical pioneer plants that rapidly invade forest gaps and cleared areas (Amor 1974, Suzuki and Maeda 1981, Suzuki 1987). Since logging was on a large-scaled in the early 1970s (Miura 1999), it is plausible that *Rubus* species invaded clearings and spread. Aoi (personal communication) remarked that *Rubus* species were so abundant that their berries made slopes appeared red. They suddenly disappeared as forest canopies were closed according to tree growth (Suzuki 1989, 1999). They are rare, growing only in sunny patches along forest paths in Urahoro at present

The above information suggests that with the peak in large-scale logging during the 1960-70s bear food was abundant. This food later disappeared. It is therefore possible that this change resulted in the damage to crops as the alternative food by the brown bears through the changes in food supply including *Rubus* abundance through the last 20 years. Such a time lag in logging and occurrence of damages by wildlife is also known for sika deer and Japanese macaques (*Macaca fuscata*) (Agetsuma 1999).

Sika deer as a food source of brown bears

The food analyses of the brown bears have shown that they use sika deer throughout the year (Chapter 4). It is known world wide that the brown bears use ungulates as foods (Berducou and Barrat 1983, Boertje et al. 1988, McLellan and Hovey 1995, Green et al. 1997, Mattson 1997), and that the amount of ungulates in their diets increases with an increase in the ungulate populations (Cole 1972, Houston 1978, Boertje et al. 1988, French and French 1990, Gunter and Renkin 1990). The sika deer population of Hokkaido increased dramatically in the 1990s (HIES 1997, Kaji et al. 2000). This was also the case in Urahoro. Footprints of sika deer were fewer than those of brown bears in 1978 (Kaji personal communication), whereas it is now difficult to find a place where there are no deer footprints. It is quite possible that the bears in Urahoro increasingly eat sika deer in accordance with the deer population.

It is, however, different from other bear populations in that only Urahoro bears use sika deer throughout the year. Other reports show that the bears eat carcasses of ungulates in spring or offspring of that in summer foods (Berducou and Barrat 1983, Boertje et al. 1988, McLellan and Hovey 1995, Green et al. 1997, Mattson 1997).

An important point is whether or not the bears attack live deer or they eat carcasses. Though very many people visit the forests, there is no information that they attack live deer. For example, many foresters working on behalf of the Hokkaido Government enter the forest, as do many visitors such as wild herb- and mushroom collectors, fishermen, and hunters (permission for forest entry was issued to 3,655 persons in 2000). Therefore, it is to be more possible that bears eat deer carcasses than live deer.

Since most natural mortality of sika deer happens after over-wintering (Takatsuki 1994), it is unlikely that the bears eat naturally dead carcasses. However, many carcasses shot for control killing and sport hunting are available in eastern Hokkaido (HIES 2000). Although it is recommended to process dead deer by asking companies dispose of them or to bury them in the ground, deer wounded by shooting often die later, and many hunters leave them in the field without burying them (Lead Poisoned Eagle Network 1999, 2000, 2001, Ohtaishi 2001). The hunting period is between November 1st to January 31st, and control killing is done from February to October. Therefore, carcasses are available to the bears throughout the year.

Shima, E. (unpublished graduate thesis), a cooperative researcher, walked along the deer-proof fences established in Urahoro in the winter of 2001 and found as many as 2.8 carcasses / km. It is expected that many more carcasses are available in other places and in other seasons. Further, Shima found that carcasses were not eaten between December and April, but 21% of them were eaten by the bears in June. This is because frozen carcasses melted in spring to be utilized by the bears after hibernation.

It was shown that control killing is selectively performed in the cells where farmlands covers 10-40 % and 50-60 %. This means that more carcasses are left near farmlands. Interviews to local farmers confirm this; carcasses left near farmlands are surely brought by the bears. It is therefore possible that the bears visit farmlands to eat deer carcasses.

This situation is problematic in terms of wildlife conservation. That is, the food habits and ranging of the bears are modified by the food resources produced by improper processing of shot sika deer.

Decrease of vegetation

Grazing sika deer would decrease the height of herbaceous plants. They are known as an important spring and summer foods for the brown bears (Aoi 1985, Ohdachi and Aoi 1987, Yamanaka and Aoi 1988). The decline in plant, caused by the population increase in sika deer, is a negative factor with regards to bear food availability.

Changes in agriculture environment

In spite of there not being an increase in acreage of bears' preferred crops, crop damage by the brown bears has been increasing. Many farmers have abandoned agriculture during the last decades. The remaining farmers have enlarged farmlands and have begun large-scaled cultivation. In addition, the total amount of farmland is gradually encroaching into forested areas. All these changes are likely to reduce encounters between brown bears and humans, and increase the chances of bears invading farmlands.

Chapter 8. **Management implications**

Introduction

In Urahoro, and in many towns in Hokkaido, bear-related damage has been increasing, and control killing has been adopted as the only option to reduce human-bear conflicts (Mano and Moll 1999, Yamanaka 2001). Recently, most control killings were conducted by using box traps because of their high efficiency of capture. In Urahoro, over 100 bears have been killed during the last 3 decades (Chapter 4). This causes non-discriminative killing, because captured bears are shot even if they did not cause any problems. It is suggested that the increase in damage is not caused by the increase in the bear population but by the changes in the diet and the selective use of farmlands (Chapters 4, 5, 6). If the present control killing system is continued, it is possible that the local bear population will become extinct.

The conservation of brown bear populations and their habitats is of great public interest worldwide (Servheen 1990, Servheen et al. 1999). In the United States, when a human-bear conflict occurs, non-lethal options such as removal of attractants and translocation of "problem bears" are adopted (Craighead et al. 1995, Gunter et al. 2000). I shall explain these 2 options giving considerations to the practical situations in Hokkaido.

For removal of attractants for the bears, I propose appropriate treatments of deer carcasses that strongly affect bear ecology.

As for translocation, the present status of Hokkaido brown bears is different from that of the United States because the bear density is higher and human-bear conflicts occur more frequently (HIES 1995, 1996, 2000). For example, the bear density in Akan-Shiranuka region including Urahoro is not high but at a medium level relative to bear populations in Hokkaido as a whole (HIES 2000). However, this density is still higher than that of the Yellowstone ecosystem, USA (Chapter 6, Servheen 1999). Crop damage occurs every year in Urahoro (Chapter 4) and most of the local people want to continue the present control killing because of their hatred and fear of the brown bears.

It is therefore impossible to adopt only the non-lethal options as is done in the United States. It is inevitably necessary to shoot the bears. However, an important point is that bear-related damage is not caused by the whole bear population but by the presence of "problem bears". Therefore, elimination of "problem bears" must be the first priority. Based on the results of this study, I propose to establish the extensive monitoring of "problem bears" by using DNA identification to allow discriminate killing of "problem bears".

At the same time, it is also important to judge the intensity in the control killing of bears: it cannot be excessive and must allow for the maintenance of the bear population. I also propose to establish a population monitoring system.

Appropriate treatments of deer carcasses

It is shown that the brown bears in Urahoro eat sika deer throughout the year (Chapter 4). It is likely that the deer carcasses are left after control killing or sport hunting (Chapter 7), which possibly attracts the bears to farmland. This suggests the possibility that controlled killing of the deer, which aims to reduce crop damage, ironically increases damage by brown bears and the frequency of encounters with them. It is reported that when a brown bear possesses a high quality food like deer, it often behaves in a way as to monopolize it and thus may attacks humans (Herrero 1985, Swenson et al. 1999). Therefore, deer carcasses should not be left in the field but should be properly processed.

In Scotland, carcasses and entrails of hunted deer were tagged by hunters and then withdrawn by professional deer managers (Ohtaishi 2001). In Urahoro, the Urahoro Town Office and Urahoro Agricultural Cooperative pay a bounty for the control killing of sika deer. Hunters are supposed to submit parts of deer's body, *e.g.*, ears or noses. This system causes carcasses to be left in situ, and should be changed so that whole deer must be submitted.

At present, many deer carcasses created by sport hunting are left in the forest. It is also expected that they will be left near farmlands because of the following: deer fences being newly built since 1997 (Hokkaido 2001b) are becoming good hunting sites, they interrupt deer migration routes and consequently the deer are concentrated along fences during the winter migration period, the same time as the hunting period begins (Shima unpublished data). Proper processing of deer carcasses will therefore become more necessary in the future. In eastern Hokkaido, 8 towns including Urahoro began to place deer carcasses in dumps during the hunting season of 2000 in order to decrease the lead poisoning of eagles (Lead Poisoned Eagles Network 2001). The bounty used to maintain the dumps and regular collection will be stopped because the use of lead bullets for deer hunting was prohibited in 2000 (Lead Poisoned Eagles Network 2000). However, dumps should be continued so as to reduce the amount of the deer carcasses left in the wild as this will serve to reduce human-bear encounters.

Discriminative killing of "problem bears"

Control killing is and will be necessary since crop damage by bears are frequent and economically serious, in addition there is also the possibility of attacks on humans. There is some doubt as to whether control hunting can be maintained in the future, since there is a serious problem the "aging" of existing hunters and little or no recruitment of young hunters, who are responsible for control killing (Aoi 1990, Yamanaka 2001b). In order to live together with brown bears, human resources and skills are necessary to control "problem bears" in the long run. Therefore, efforts should be done to promote recruitment of young, skilful hunters.

As non-discriminative killing of bears cannot reduce the damage, it is necessary to determine if the bears captured in box traps are "problem bears", and to control only the bears that are identified as being "problem bears". Since the major human-bear conflicts in Urahoro were caused by crop damage and latent fear of bears (Chapter 4), I defined "problem bears" as bears that invade farmlands and villages (Chapter 6). It is then necessary to find the invasion point. Combined methods of live capturing, tagging, and re-capturing at the farmlands or villages were practiced for Asiatic black bear (*Ursus thibetanus japonicus*) in Togouchi, Hiroshima prefecture (Maita 1998, Kurisu 2001). These methods, however, are expensive and laborious. As an alternative method, the individual identification by the hair root DNA collected in the field is a promising method (Chapter 6). It is less expensive than the capturing and tagging of bears (Woods et al. 1999). The deer fence was established and extended for longer than 350 km around farmland in Urahoro (Chapter 6). When bears attempt to invade farmland or villages, hairs are left on the fence wire. By collecting these hairs and analyzing the microsatellite DNA of hairs, it is possible to identify "problem bears". I demonstrated the examples of "problem bears" and "problem ranging", *e.g.*, multiple uses of farmland by a bear, and intensive use of farmlands (Chapter 6). When a bear is captured in a box trap, it is possible to identify whether the bear is a "problem bear" or not by comparison to a reference database of problem bear genotypes. The treatment, death, or respite should be decided by considering the opinions of local people and officers. When "innocent" bears are trapped, they should be released. This method is already used in North America (Gunter et al. 2000, Wieb 2001). In 1999, a bear invaded some campsite and attacked tents in Yellowstone National Park. Hairs were collected and genotyped for 5 loci of microsatellite DNA. At first, a female bear was suspected as the criminal bear because her range included those campsites and she was captured by trapping. However, her genotype did not match that of the criminal bear. Later, a male bear was captured in a trap placed near the campsite. His genotype corresponded with the criminal bear and he was shipped to a captive facility. If the same matter happened in Urahoro, the captured bear would be shot in the trap, and local people and officer would be satisfied even though the criminal bear might be still living. Then the matter would reoccur. I therefore recommend the adoption of the hair root DNA identification method.

Population monitoring

The present permission system for control killing in Japan is actually automatic. Once damage occurs, a local town office submits an application for control permission to the Hokkaido Government. The Hokkaido Government grants permission, and a control killing is performed. There is actually no restriction for the maximum numbers of control killings. The mean annual harvest of brown bears in Urahoro since 1995 is 6.2 bears / year (Chapter 4). It is, however, impossible to judge whether this figure is too high or compatible with conservation. It is also impossible to judge which level of control killing is enough to reduce damage. It is therefore necessary to regularly monitor the population.

I estimated the crude density of bears (2.3-6.4 / 100 km^2) in Urahoro using hair root DNA analysis (Chapter 6). This figure is too rough to use as the basic information of brown bear population in Urahoro. This is mainly because of the small size of the sampling area, which resulted in small sample size of the bear population greatly effected by immigration and emigration from the surrounding areas. More accurate estimates would be possible using the DNA analysis fulfilling several requirements. For example, the sampling area for hairs should be larger. Urahoro is located in the southwestern part of the Shiranuka Hill. The hill covering 1,100 km^2 has been continuously inhabited by brown bears for several decades (HIES 2000). This area seems to be valid to estimate population of bears with confidential variances because of continuous bear distribution.

In order to estimate the population size by using the Jolly-Seber method, it is assumed that "sampling time is negligible in relation to intervals between samples" (Krebs 1994). It requires finishing the entire trap setting and collecting hairs from all traps immediately. Moreover, it is necessary to repeat the sampling process to use this model (Krebs 1994). It took 10-14 days to set the 70 traps or to collect the hairs from the 70 traps by an assistant and I (Chapter 6). It is impossible to expand the study area and to shorten the setting and collecting time without increasing research crews. In order to fulfill these requirements, it is necessary to employ more field crews under the support of an administrative system and the cooperation of local officers, landowners, and people who are familiar with the region.

Long term monitoring study of the bear population should be performed. Based on this, it will be possible to determine the proper intensity of control killings. It will provide the criteria to determine the number of permitted control killings to maintain the bear population.

Summary

I have found the following facts by collecting statistics on forestry and agriculture, and by analyzing the food habits, the home range use, and the hair root DNA of the brown bears in Hokkaido and those in Urahoro.

1. Food habits of brown bears as determined by stomach content analyses (Chapter 3)

The stomach contents included many herbaceous plants in spring and early summer, crops in late summer, and wild fruits in fall. Garbage occurred frequently in the stomach contents of the bears on Oshima Peninsula, southwestern Hokkaido. Sika deer accounted for great portions of the diets of the bears throughout the year in eastern Hokkaido. Use of crops in early summer was also characteristic of them.

2. Crop damages of the bears in Urahoro (Chapter 4)

Crop damage by the bears abruptly increased in Urahoro in the late 1990s. The main damage included; sugar beet from late June to late September, corn from late August to early September. In order to reduce the damage, local people often used box traps to capture and kill them.

3. Changes in the bear density (Chapters 4 and 6)

The densities of field signs of the bears were compared between 1978 and 2000. Though the numbers of the controlled bears were not different between the years, field signs greatly decreased. Thus, it is clear that control has intensified because damage increased, though the actual bear population has not increased. By

using DNA from hair roots of 3 types of traps: hair traps, rub tree, and deer fence, I identified 26 bears as the minimum number living in the study area in 2000. The crude density was roughly estimated as 2.3-6.4 / 100 km^2.

4. Changes of food habits (Chapter 4)

The diet of brown bears in Urahoro has changed greatly during the last 20 years. The bears used crops in both early and late summer, which were not used in 1978. Sika deer occupied great portions throughout the year, which were also not used in 1978. *Rubus* berries were not used at all in 2000, which were used in 1978.

5. Use of farmland (Chapters 5 and 6)

I traced a female brown bear by the radio tracking to determine habitat use in her home range. She stayed in the forest in spring, early summer, and fall, while she selectively used farmland in late summer. The DNA analyses have shown that as many as 7 bears invaded the farmland in the northern part of Urahoro.

6. Environmental changes (Chapter 7)

Logging of hard woods and plantation of conifers in the Tokachi subprefecture of Hokkaido peaked in the 1960s-70s. *Rubus* berries which often grow abundantly in logged areas as pioneer shrubs were important foods for the bears in 1978.

7. Population increase of sika deer (Chapter 7)

Sika deer increased explosively in the 1990s. Field signs of sika were rarer than those of brown bears in the 1970s. Accordingly, agricultural damages by them greatly increased, and therefore intensive control is performed and large-scale deer fences are constructed. Many carcasses of deer shot through control killing and sport hunting are left around farmland as well as in the forests. These carcasses are source of food for the bears. No information is available on deer predation, or bear attack on live sika deer.

8. Decrease of herbaceous plants (Chapter 7)

Herbaceous plants are important spring and early summer forages for the bears, but they tended to be decreased by sika deer grazing.

9. Changes in agricultural environment (Chapter 7)

Acreage of farmland has gradually increased over the last 20 years, but because of a marked decrease in the population of farmers, the farmland size for an individual farmer is greatly increased. Extensive agricultural management means farmers spend less time on farmland than before.

Based on the above-mentioned results, I estimate the history of the brown bears in Urahoro over the last 20 years is as follows. In spite of the bear population decreasing, crop damage by bears increased. This is probably because, 1) *Rubus* shrubs and herbaceous plants in the bear habitats were decreased by forest development, 2) many carcasses of sika deer were left around farmlands, and 3) reduced farmer population permitted the bears to invade the farmland. Heavy control killing is performed, partly because people think the bear population is larger than in reality because bears frequently invade their farmland.

Since non-discriminate killing based on "apparent population increase" is dangerous for the population, I proposed:

1) Sika deer carcasses left in the fields should be reduced by an obligation to submit the whole body and/or constructing carcass dumps.
2) Non-discriminative killing should be stopped, and only "problem bears" should be selectively killed after DNA identification by live-capturing.
3) The population size of the bears must be estimated as precisely as possible, and control killing should be done at a level that will avoid local extinction.

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Table 2-1. Comparison of total percentage volume of brown bear diets based on stomach contents, Hokkaido, Japan, April - December, 1995.

		Total percentage volume			
	n	Point-frame method	Volumetric method	Gravimetric method	*P*-value
Acorn and Nuts	8	5.4 [a]	5.7 [a]	6.3 [b]	0.0237
Berries	21	18.2 [a]	23.0 [b]	24.5 [b]	0.0006
Seeds	6	0.0	0.0	0.0	0.4456
Forbs	27	33.1 [a]	28.9 [a]	26.4 [b]	0.0004
Graminoids	16	2.3	1.4	1.0	0.1253
Symplocarpus renifolius	7	18.0	17.9	17.4	0.3056
Mosses	5	0.0	0.0	0.0	0.0762
Dead leaves (broad leaves and forbs)	26	0.8	0.7	0.9	0.1763
Dead coniferous leaves	19	0.5 [a]	0.2 [b]	0.6 [a]	0.0001
Dead graminoid leaves	13	0.5	0.5	0.6	0.4304
Woody materials	12	0.2 [a]	0.6 [a]	1.2 [b]	0.0088
Insects	10	3.4	2.2	1.8	0.1616
Invertebrates (other than insects)	6	0.1	0.2	0.4	0.2458
Mammalian fur	7	0.3	0.0	0.1	0.1236
Corn	7	17.2	18.6	19.0	0.1492

[a, b] Means with same letters do not differ significantly ($P < 0.05$) between methods using Tukey's multiple comparison.

Table 3-1. Percent frequency of Occurrence (F) and percent volume (V) for each diet category in the brown bear stomach contents collected in the Oshima Peninsula region, Hokkaido, 1991–1998.

	Spring		Early-summer		Late-summer		Fall		Total	
	F% N=50	V% N=46	F% N=20	V% N=19	F% N=65	V% N=61	F% N=88	V% N=83	F% N=223	V% N=209
Plant materials										
Herbaceous plants	94.00	78.07	95.00	53.39	64.62	29.24	59.09	20.00	71.75	38.50
Forbs	70.00	48.57	90.00	48.31	56.92	23.69	52.27	18.00	60.99	29.29
Graminoids	36.00	16.80	10.00	0.85	20.00	1.80	15.91	1.33	21.08	4.71
Synplocarpus renifolius	16.00	12.70	5.00	3.81	4.62	2.85	1.14	0.11	5.83	3.97
Equisetum spp.	2.00	-	5.00	0.42	6.15	0.90	5.68	0.56	4.93	0.52
Roots of forbs	4.00	2.05	-	-	3.08	-	1.14	-	2.24	0.44
Berries	8.00	-	25.00	5.93	32.31	7.20	65.91	25.33	39.46	12.66
Actinidia arguta	-	-	-	-	20.00	4.05	57.95	19.56	28.70	8.86
Actinidia polygama	-	-	-	-	4.62	0.30	3.41	1.22	2.69	0.57
Actinidia kolomikta	-	-	-	-	1.54	0.15	3.41	0.22	1.79	0.13
Vitis coignetiae	-	-	-	-	6.15	0.45	14.77	2.22	7.62	1.00
Aralia spp.	-	-	-	-	4.62	0.45	5.68	0.33	3.59	0.26
Prunus spp.	-	-	5.00	0.42	1.54	1.35	1.14	0.11	1.35	0.48
Swida controversa	-	-	-	-	-	-	4.55	1.44	1.79	0.57
Rubus spp.	-	-	10.00	0.42	-	-	-	-	0.90	0.04
Morus australis	-	-	5.00	2.97	-	-	-	-	0.45	0.31
Others	8.00	-	20.00	2.12	7.69	0.45	3.41	0.22	7.17	0.44
Acorns and nuts	26.00	6.56	-	-	12.31	2.70	28.41	15.67	20.63	8.34
Fagus crenata	12.00	2.87	-	-	-	-	3.41	2.78	4.04	1.70
Quercus crispula	10.00	3.48	-	-	7.69	1.50	14.77	8.89	20.45	4.67
Castanea crenata	-	-	-	-	-	-	3.41	1.56	1.35	0.61
Juglans mandshurica var. *sachalinensis*	-	-	-	-	4.62	1.20	1.14	0.11	1.79	0.39
Others	4.00	0.20	-	-	-	-	5.68	2.33	3.14	0.96
Buds of *Fagus crenata*	22.00	1.84	10.00	0.42	-	-	-	-	5.83	0.44
Fallen leaves and twigs	58.00	5.74	55.00	8.90	36.92	5.55	44.32	3.67	46.19	5.19
Others	18.00	1.64	15.00	0.85	13.85	1.35	11.36	1.00	13.90	1.22
Animal materials										
Mammals	10.00	1.02	-	-	6.15	2.55	9.09	2.33	7.62	1.74
Cervus nippon yezoensis	-	-	-	-	-	-	1.14	1.00	0.45	0.39
Unknown	10.00	1.02	-	-	6.15	2.55	7.95	1.33	7.17	1.35
Insects	14.00	0.41	85.00	19.07	35.38	5.85	15.91	1.00	27.35	4.15
Formicidae	4.00	0.41	85.00	17.80	24.62	4.35	9.09	0.33	19.28	3.32
Vespidae	2.00	-	5.00	0.42	10.77	1.35	2.27	0.22	4.93	0.52
Maggots	-	-	-	-	3.08	-	2.27	0.22	1.79	0.09
Others	12.00	-	15.00	0.85	7.69	0.15	6.82	0.22	8.97	0.22
Invertebrates	6.00	0.41	5.00	0.42	9.23	0.60	12.50	0.78	9.42	0.61
Cambaroides japonicus	4.00	0.41	5.00	0.42	9.23	0.60	10.23	0.78	8.07	0.61
Others	2.00	-	-	-	-	-	2.27	-	1.35	-
Others	2.00	-	5.00	-	3.08	1.35	4.55	1.11	3.59	0.83
Crops										
Crops	-	-	-	-	56.92	37.48	31.82	23.56	29.15	20.17
Corn	-	-	-	-	33.85	23.69	23.86	17.67	19.28	13.84
Rice	-	-	-	-	18.46	13.19	2.27	2.11	6.28	4.67
Pear	-	-	-	-	1.54	-	3.41	1.56	1.79	0.61
Apples	-	-	-	-	-	-	1.14	1.11	0.45	0.44
Sugar beets	-	-	-	-	3.08	0.30	-	-	0.90	0.09
Grass	-	-	-	-	1.54	0.15	-	-	0.45	0.04
Carrots	-	-	-	-	1.54	0.15	1.14	1.11	0.90	0.48
Others										
Anthropogenic waste	8.00	1.23	30.00	8.05	13.85	3.30	18.18	3.44	15.70	3.40
Soil and pebbles	8.00	0.61	40.00	2.97	10.77	0.45	13.64	1.67	13.90	1.22
Others	8.00	0.41	5.00	-	10.77	2.40	20.45	0.44	13.45	0.96

Table 3-2. Percent frequency of Occurrence (F) and percent volume (V) for each diet category in the brown bear stomach contents collected in the Doto-Sohya region, Hokkaido, 1991-1998.

	Spring		Early-summer		Late-summer		Fall		Total	
	F% N=45	V% N=44	F% N=26	V% N=26	F% N=75	V% N=72	F% N=72	V% N=70	F% N=218	V% N=212
Plant materials										
Herbaceous plants	82.22	60.79	92.31	63.57	72.00	31.89	52.78	11.27	70.18	32.19
Forbs	62.22	31.95	88.46	58.21	68.00	28.04	44.44	6.96	61.47	23.56
Graminoids	33.33	6.02	19.23	5.00	28.00	3.85	26.39	4.18	27.52	4.22
Synplocarpus renifolius	28.89	22.82	3.85	0.36	-	-	1.39	0.13	6.88	4.41
Roots of forbs	-	-	-	-	-	-	1.39	-	0.46	-
Berries	2.22	0.21	11.54	3.57	26.67	6.82	25.00	27.72	19.27	11.23
Actinidia arguta	-	-	7.69	2.14	6.67	0.62	54.17	23.54	21.10	7.76
Actinidia polygama	-	-	-	-	1.33	-	-	-	0.46	-
Actinidia kolomikta	-	-	-	-	5.33	0.37	-	-	1.83	0.12
Vitis coignetiae	-	-	-	-	10.67	2.23	13.89	2.53	8.26	1.50
Aralia spp.	-	-	-	-	1.33	0.12	1.39	0.13	0.92	0.08
Prunus spp.	-	-	3.85	1.07	2.67	0.62	5.56	0.51	3.21	0.48
Swida controversa	-	-	-	-	-	-	1.39	-	0.46	-
Sorbus commixta	-	-	-	-	1.33	1.12	4.17	0.89	1.83	0.63
Rubus spp.	-	-	-	-	-	-	-	-	-	-
Others	2.22	0.21	3.85	0.36	5.33	1.74	4.17	0.13	4.13	0.67
Acorns and nuts	13.33	2.49	-	-	2.67	0.62	22.22	8.23	11.01	3.23
Quercus crispula	8.89	3.32	-	-	1.33	0.12	15.28	7.97	7.34	2.88
Juglans mandshurica var. *sachalinensis*	4.44	0.21	-	-	2.67	0.50	2.78	-	2.75	0.20
Others	4.44	0.41	-	-	-	-	4.17	0.25	2.29	0.16
Fallen leaves and twigs	53.33	8.51	26.92	3.21	45.33	6.08	38.89	10.13	46.79	7.05
Others	8.89	0.41	7.69	3.21	8.00	0.62	12.50	0.25	9.63	0.71
Animal materials										
Mammals	42.22	23.86	23.08	4.29	18.67	6.82	56.94	28.86	36.70	15.96
Cervus nippon yezoensis	33.33	18.26	15.38	3.57	9.33	4.59	55.56	28.73	30.28	14.26
Unknown	8.89	5.60	7.69	0.71	9.33	1.61	1.39	0.13	6.42	1.69
Insects	8.89	1.24	57.69	8.21	57.33	13.03	23.61	2.41	36.24	6.03
Formicidae	6.67	1.04	50.00	7.50	45.33	8.31	5.56	0.51	24.77	3.82
Vespidae	-	-	-	-	18.67	3.47	6.94	0.51	8.72	1.26
Maggots	2.22	0.21	3.85	0.36	1.33	0.87	6.94	0.89	3.67	0.63
Others	-	-	3.85	0.36	5.33	0.37	6.94	0.51	4.59	0.32
Invertebrates	6.67	0.62	3.85	0.36	6.67	0.37	3.17	-	5.50	0.28
Cambaroides japonicus	6.67	0.62	3.85	0.36	5.33	0.25	4.17	-	5.05	0.24
Others	-	-	-	-	1.33	0.12	-	-	0.46	0.04
Others	-	-	-	-	2.67	0.62	2.78	0.38	1.83	0.32
Crops										
Crops	-	-	19.23	12.50	48.00	32.26	11.11	7.34	22.48	13.91
Corn	-	-	-	-	30.67	22.08	5.56	4.94	12.39	8.55
Wheat	-	-	3.85	0.36	-	-	-	-	0.46	0.04
Melons	-	-	3.85	0.36	1.33	0.12	-	-	0.92	0.08
Pear	-	-	-	-	-	-	1.39	0.13	0.46	0.04
Sugar beets	-	-	19.23	11.79	4.00	9.68	19.44	2.28	10.09	5.08
Grass	-	-	-	-	1.33	0.37	-	-	0.46	0.12
Others										
Anthropogenic waste	6.67	0.62	11.54	1.07	8.00	0.62	11.11	2.91	9.17	1.34
Soil and pebbles	8.89	1.04	-	-	13.33	0.74	9.72	0.51	9.63	0.59
Others	8.89	0.21	-	-	1.33	0.12	5.56	-	4.13	0.08

Table 3-3. Percent frequency of Occurrence (F) and percent volume (V) for each diet category in the brown bear stomach contents collected in the Hidaka-Yubari region, Hokkaido, 1991-1998.

	Spring		Early-summer		Late-summer		Fall		Total	
	F%	V%	F%	V%	F%	V%	F%	V%	F%	V%
	N=11	N=10	N=3	N=3	N=32	N=32	N=69	N=66	N=115	N=111
Plant materials										
Herbaceous plants	100.00	79.63	100.00	96.77	78.13	26.03	52.17	14.77	65.22	26.08
Forbs	100.00	74.07	100.00	77.42	75.00	20.82	37.68	8.66	55.65	19.95
Graminoids	27.27	1.85	66.67	19.35	28.13	2.19	18.84	1.14	23.48	1.99
Synplocarpus renifolius	18.18	3.70	-	-	12.50	3.01	7.25	4.97	9.56	4.14
Berries	9.09	-	-	-	25.00	5.21	72.46	39.20	51.30	24.42
Actinidia arguta	-	-	-	-	9.38	0.82	56.52	28.69	36.52	16.97
Actinidia polygama	-	-	-	-	3.13	0.82	8.70	2.13	6.09	1.49
Actinidia kolomikta	-	-	-	-	3.13	-	-	-	0.87	-
Vitis coignetiae	-	-	-	-	3.13	0.27	26.09	5.11	16.52	3.06
Aralia spp.	-	-	-	-	12.50	1.92	1.45	-	4.35	0.58
Sorbus commixta	-	-	-	-	-	-	1.45	0.14	0.87	0.08
Rubus spp.	-	-	-	-	3.13	1.37	-	-	0.87	0.41
Others	9.09	-	-	-	3.13	-	5.80	3.13	5.22	1.82
Acorns and nuts	-	-	-	-	3.13	0.27	14.49	9.80	9.57	5.79
Quercus crispula	-	-	33.33	-	-	0.27	13.04	9.09	8.70	5.38
Castanea crenata	-	-	-	-	-	-	1.45	0.71	0.87	0.41
Fallen leaves and twigs	36.36	4.63	33.33	3.23	43.75	4.66	46.38	3.98	45.22	4.22
Others	9.09	-	-	-	9.38	0.55	10.14	0.85	9.57	0.66
Animal materials										
Mammals	-	-	-	-	12.50	3.56	33.33	16.76	23.48	10.84
Cervus nippon yezoensis	-	-	-	-	3.13	1.92	21.74	16.34	13.91	10.10
Unknown	-	-	-	-	9.38	1.64	14.49	0.43	11.30	0.75
Insects	36.36	2.78	33.33	-	50.00	12.33	23.19	2.70	32.17	5.55
Formicidae	36.36	2.78	33.33	-	34.38	4.66	4.35	0.14	16.52	1.74
Vespidae	9.09	-	-	-	18.75	5.75	4.35	-	8.70	1.74
Maggots	-	-	-	-	3.13	0.82	5.80	0.28	4.35	0.41
Others	-	-	-	-	15.63	1.10	10.14	2.27	10.43	1.66
Invertebrates	-	-	-	-	-	-	7.25	0.14	4.35	0.08
Cambaroides japonicus	-	-	-	-	-	-	4.35	0.14	2.61	0.08
Others	-	-	-	-	-	-	2.90	-	1.74	-
Others	-	-	-	-	6.25	-	2.90	-	4.35	-
Crops										
Crops	-	-	-	-	68.75	46.30	18.84	10.37	30.43	20.03
Corn	-	-	-	-	21.88	14.79	11.59	8.24	13.04	9.27
Rice	-	-	-	-	9.38	3.01	2.90	0.57	4.35	1.24
Wheat	-	-	-	-	3.13	1.92	1.45	-	1.74	0.58
Watermelons	-	-	-	-	6.25	5.21	-	-	1.74	1.57
Melons	-	-	-	-	28.13	14.25	1.45	0.71	8.70	4.72
Pear	-	-	-	-	-	-	2.90	0.85	1.74	0.50
Apples	-	-	-	-	3.13	1.37	-	-	0.87	0.41
Grapes	-	-	-	-	3.13	2.47	-	-	0.87	0.75
Sugar beets	-	-	-	-	6.25	3.29	-	-	1.74	0.99
Others										
Anthropogenic waste	9.09	12.96	-	-	3.13	0.27	10.14	0.99	7.83	1.82
Soil and pebbles	-	-	-	-	9.38	0.55	18.84	0.28	13.91	0.33
Others	9.09	-	-	-	9.38	0.27	4.35	0.14	6.09	0.17

Table 4-1. Scat densities of brown bears along routine census roots in Urahoro, Hokkaido, July, August 1978, and July, August, October 2000.

Year	July			August			October		
	Explored distance (km)	Number of scats	Number of scats / km	Explored distance (km)	Number of scats	Number of scats / km	Explored distance (km)	Number of scats	Number of scats / km
1978	33.5	16	0.477	32.5	46	1.415	-	-	-
2000	33.5	1	0.030	32.5	1	0.031	-	-	-
	58	2	0.034	58	2	0.034	58	5	0.086

Table 4-2. Percent frequency of occurrence (F) and percent volume (V) for each diet category in the brown bear scats collected in Urahoro, Hokkaido, 1978.

				July (N=16)				August (N=18)			
				F		V		F		V	
Plant materials	Herbaceous plants		subtotal	100.0		73.5		77.8		42.3	
		Petesites japonicus			93.8		69.8		77.8		42.1
		Other forbs			18.8		2.6		5.6		0.0
		Graminoids			6.3		1.1		5.6		0.2
	Berries		subtotal	-		-		94.4		35.6	
		Rubus spp.			-		-		66.7		16.6
		Actinidia arguta			-		-		16.7		1.0
		Actinidia kolomikta			-		-		50.0		12.5
		Aralia cordata			-		-		16.7		0.4
		Prunus ssiori			-		-		11.1		4.7
		Vitis coignetiae			-		-		5.6		0.3
	Seeds			-		-		16.7		0.0	
	Fallen leaves and twigs			56.3		15.2		22.2		5.2	
	Unknown			12.5		4.3		33.3		4.6	
Animal materials	Insects		subtotal	68.8		4.4		50.0		1.0	
		Formicidae			68.8		3.1		44.4		0.8
		Vespula flaviceps lewisii			-		-		5.6		0.0
		Lucanidae			6.3		1.0		16.7		0.1
		Unknown			12.5		0.2		5.6		0.0
	Cambaroides japonicus			-		-		11.1		0.1	
Others	Soil and pebbles			31.3		1.2		72.2		11.3	
	Hair of *Ursus arctos*			12.5		0.0		-		-	
	Unknown			6.3		1.5		-		-	

Table 4-3. Percent frequency of occurrence (F) and percent volume (V) for each diet category in the brown bear scats collected in Urahoro, Hokkaido, 1998-2000.

			May (N=12)		Jun-Jul (N=30)		Aug-Sep (N=42)		Oct-Nov (N=33)	
			F	V	F	V	F	V	F	V
Plant materials	Herbaceous plants	subtotal	83.3	66.6	70.0	40.4	73.8	27.2	39.4	7.6
	Petesites japonicus		25.0	10.1	36.7	27.3	16.7	13.3	-	-
	Other forbs		75.0	55.6	13.3	9.8	28.6	3.4	36.4	7.5
	Graminoids		16.7	0.9	3.3	3.3	42.9	10.5	3.0	0.2
	Berries	subtotal	-	-	3.3	3.3	26.2	3.5	75.8	55.5
	Actinidia arguta		-	-	-	-	7.1	0.5	54.6	39.0
	Aralia cordata		-	-	-	-	2.4	0.0	23.2	1.4
	Prunus ssiori		-	-	3.3	3.3	7.1	2.9	-	-
	Sorbus commixta		-	-	-		-	-	3.0	-
	Vitis coignetiae		-	-	-	-	2.4	0.0	36.4	15.2
	Others		-	-	-	-	7.1	0.0	3.0	-
	Acorns and nuts	subtotal	-	-	-	-	16.7	2.5	27.3	17.6
	Quercus crispula		-	-	-	-	2.4	0.6	15.2	10.1
	Juglans mandshurica		-	-	-	-	7.1	1.8	9.1	7.4
	Pinaceae		-	-	-	-	7.1	0.1	3.0	0.1
	Seeds		8.3	-	16.7	0.7	2.4	0.1	3.0	0.1
	Fallen leaves and twigs		50.0	1.0	56.7	2.5	45.2	5.3	27.3	1.5
	Mosses		8.3	-	-	-	4.8	0.0	-	-
	Unknown		-	-	3.3	0.1	-	-	-	-
Animal materials	Mammals									
	Cervus nippon		50.0	31.8	46.7	15.5	33.3	14.1	42.4	16.4
	Insects	subtotal	16.7	0.1	63.3	12.2	61.9	15.8	21.2	1.0
	Formicidae		16.7	0.1	53.3	9.5	38.1	14.8	15.2	0.8
	Vespula flaviceps lewisii		-	-	13.3	2.3	2.4	-	-	-
	Lucanidae		-	-	3.3	0.0	9.5	0.2	-	-
	Maggots		-	-	3.3	0.0	16.7	0.6	6.1	0.1
	Unknown		-	-	16.7	0.2	23.8	0.2	9.1	0.1
Crops		subtotal	-	-	23.3	19.0	31.0	25.4	-	-
	Corn		-	-	-	-	11.9	8.0	-	-
	Sugar beets		-	-	20.0	18.7	16.7	12.6	-	-
	Wheats		-	-	3.3	0.3	-	-		
	Meadows		-	-	-	-	4,76	4.7	-	-
Others	Soil and pebbles		8.3	0.5	20.0	6.4	21.4	6.2	3.0	0.3

Table 5-1. Sex, age class, location information, and MCP home range sizes for 3 brown bears in Urahoro, Hokkaido.

Name of bears	Sex	Age class	Weight (kg)	Number of locations obtained	MCP (km^2)	Date of capture	Date of last location
Minmin	F	adult	103	249	61.09	15 Jun 1999	31 Jul 2001
Kanna	F	adult	113	35	51.06	21 Oct 1999	24 Sep 2001
Rocky	M	yearling	37	58	127.36	05 Aug 1999	13 Aug 2000

Table 5-2. Availability of habitat categories and composition of the core area (%) by a female bear in different seasons in Urahoro, Hokkaido, 1999-2000.

		Spring	Early summer		Late summer		Fall	
	availablity	2000	1999	2000	1999	2000	1999	2000
Category	(%)	(20)	(37)	(31)	(43)	(42)	(26)	(28)
Natural Forest	73.1	94.5	87.5	93.6	35.5 -[a]	53.3 -	87.5	87.5
Plantation	19.4	5.5	11.8	6.3	23.7	29.5	12.0	12.5
Farmland	6.4	0.0	0.7	0.0	38.8 +	15.7	0.4	0.0
Riparian community	1.1	0.0	0.0	0.0	1.8	1.4	0.0	0.0

[a] -: aboid, +: select (90 % confidence coeffient).

Table 6-1. Hairs of brown bears captured from hair traps, rub trees, and deer fences in Urahoro, Hokkaido, 2000.

Session	Season	Source	Number of sites sampled	Sites with hair samples	Sampling success (%)	Genotyping success samples	Genotyping success sites	Identified bears	Newly identified bears
1	Spring	Hair trap	61	27	44.3	26	19	13	13
		Rub tree	41	15	36.6	7	7	4	4
		subtotal	*102*	*42*	*41.2*	*33*	*26*	*17*	*17*
2	Early-summer	Hair trap	69	31	44.9	7	6	7	4
		Rub tree	42	27	64.3	20	16	13	7
		Deer fence	21	6	28.6	3	2	2	2
		subtotal	*132*	*64*	*48.5*	*30*	*24*	*18*	*7*
3	Late-summer	Hair trap	64	37	57.8	9	9	5	3
		Rub tree	46	25	54.3	8	8	7	3
		Deer fence	87	33	37.9	16	8	7	5
		subtotal	*197*	*95*	*48.2*	*33*	*26*	*12*	*2*
4	Fall	Hair trap	66	18	27.3	5	5	5	0
		Rub tree	43	18	41.9	4	4	3	0
		Deer fence	6	5	83.3	0	0	0	0
		subtotal	*115*	*41*	*35.7*	*9*	*9*	*7*	*0*

Table 6-2. Observed allele frequency distribution by loci for 26 identified brown bears in Urahoro, Hokkaido, 2000.

Locus	Type	Length	Sample Size	Observed Frequency
G1A	5	178	11	0.212
	6	180	6	0.115
	7	182	22	0.423
	8	184	4	0.077
	9	186	7	0.135
	10	188	1	0.019
	12	192	1	0.019
	Total		52	
G1D	4	172	22	0.423
	5	174	25	0.481
	6	176	1	0.019
	7	178	2	0.038
	8	180	2	0.038
	Total		52	
G10B	4	150	23	0.489
	5	152	13	0.277
	6	154	1	0.021
	7	156	4	0.085
	9	160	4	0.085
	12	166	2	0.043
	Total		47	
G10X	4	132	23	0.442
	6	136	1	0.019
	8	138	26	0.500
	9	142	2	0.038
	Total		52	

Locus	Type	Length	Sample Size	Observed Frequency
G10L	4	149	7	0.135
	6	155	2	0.038
	7	157	3	0.058
	8	159	22	0.423
	9	161	2	0.038
	10	163	10	0.192
	11	165	3	0.058
	12	167	3	0.058
	Total		52	
G10M	4	199	3	0.061
	5	201	1	0.020
	6	203	23	0.469
	7	207	1	0.020
	8	209	1	0.020
	10	211	9	0.184
	11	213	11	0.224
	Total		49	
G10P	2	135	5	0.096
	5	151	25	0.481
	6	153	1	0.019
	7	155	20	0.385
	8	157	1	0.019
	Total		52	
G10C	6	100	1	0.019
	7	102	44	0.846
	8	104	7	0.135
	Total		52	

Table 6-3. Measures of genetic diversity: observed number of alleles, expected heterozygosity, observed heterozygosity, and probability of identity by locus and overall. Overall values are 8-loci means for number of alleles and heterozygosity. The overall value for probability of identity is the product of individual value.

Locus	Number of Alleles	Expected Heterozygosity	Observed Heterozygosity	Probability of identity
G1A	7	0.753	0.692	0.103
G1D	5	0.598	0.731	0.256
G10B	6	0.682	0.783	0.158
G10X	4	0.563	0.538	0.300
G10L	8	0.768	0.808	0.088
G10M	7	0.705	0.625	0.060
G10P	5	0.623	0.654	0.227
G10C	3	0.271	0.308	0.566
Overall	6.00	0.670	0.690	$8.5*10^{-7}$

Table 7-1. Occurrence of control killing, hunting of sika deer, and proportion of total acreage by farmland area for each 5 km by 5 km cell in the Tokachi- and Kushiro subprefecture, 1997[a].

Occupancy of farmland (%)	Number of cells	% of cells	Number of cells where control kill occurred (%)	selection[b]	Number of cells where hunting occurred (%)	selection
< 10%	569	49.912	26.3	-	48.7	
10-20%	133	11.667	18.5	+	14.7	+
20-30%	102	8.947	16.2	+	11.6	+
30-40%	62	5.439	9.7	+	6.8	
40-50%	38	3.333	5.0		3.9	
50-60%	66	5.789	9.0	+	5.7	
60-70%	80	7.018	8.8		5.2	-
70-80%	60	5.263	5.4		3.1	-
80-90%	27	2.368	1.0	-	0.4	-
90-100%	3	0.263	0.2		0.0	
Total	1140		579		796	

[a] Data of location of nuisance control kill and hunting of sika deer were by HIES umpublished data.

[b] -: avoid, +: select (90 % confidence coefficient)

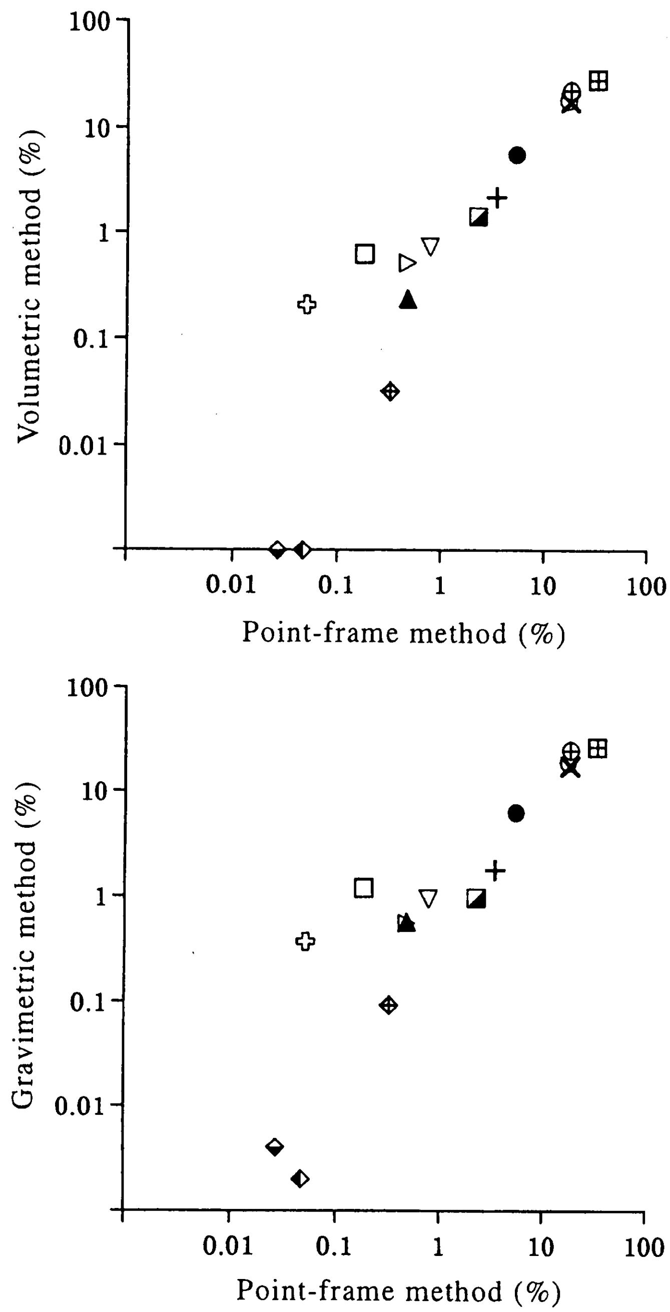


Figure 2-1. Relationship between the percentage volume of brown bear diets estimated by the point-frame method and those estimated by the volumetric method for berries (n = 21, top) and forbs (n = 27, bottom) based on stomach contents of 55 bears, Hokkaido, April - December, 1995. Each point represents percent volume of a given diet category to the total contents of the stomach. Regression equation and coefficient of determination are represented in the graphs.

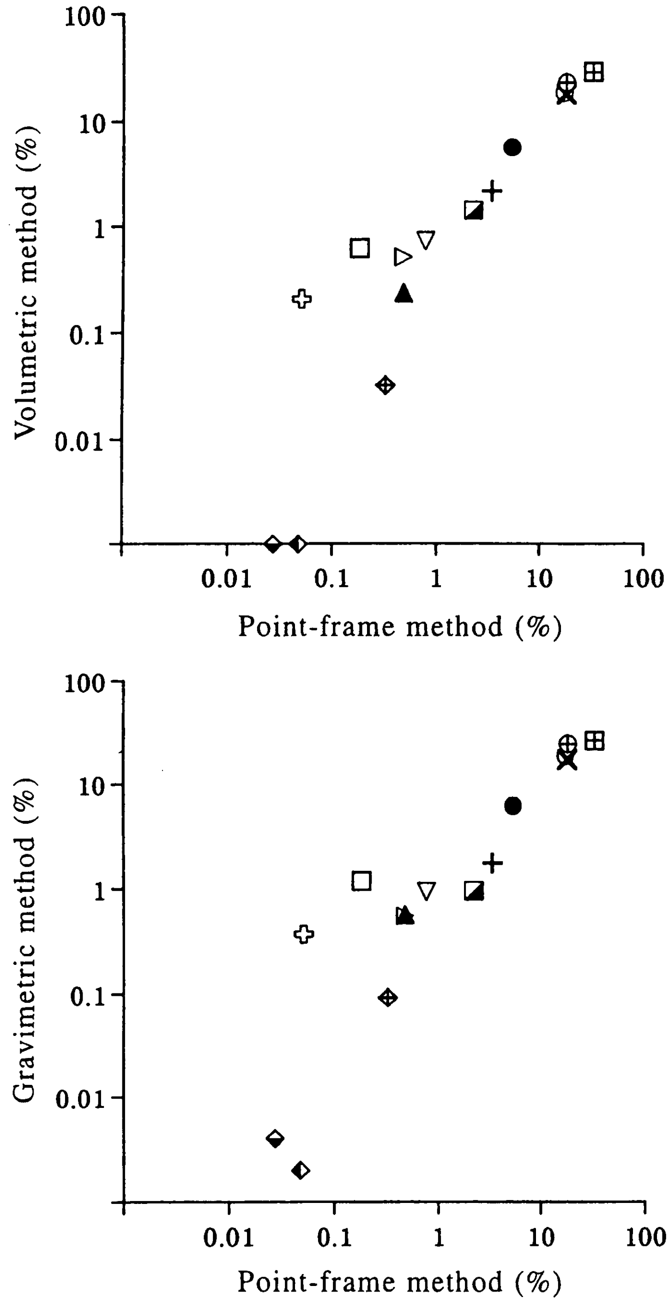


Figure 2-2. Relationship between the percentage volume of brown bear diets estimated by the point-frame method and those estimated by the volumetric method (top) or gravimetric method (bottom) based on stomach contents of 55 bears, Hokkaido, April - December, 1995. The graph is shown by logarithmic axis.

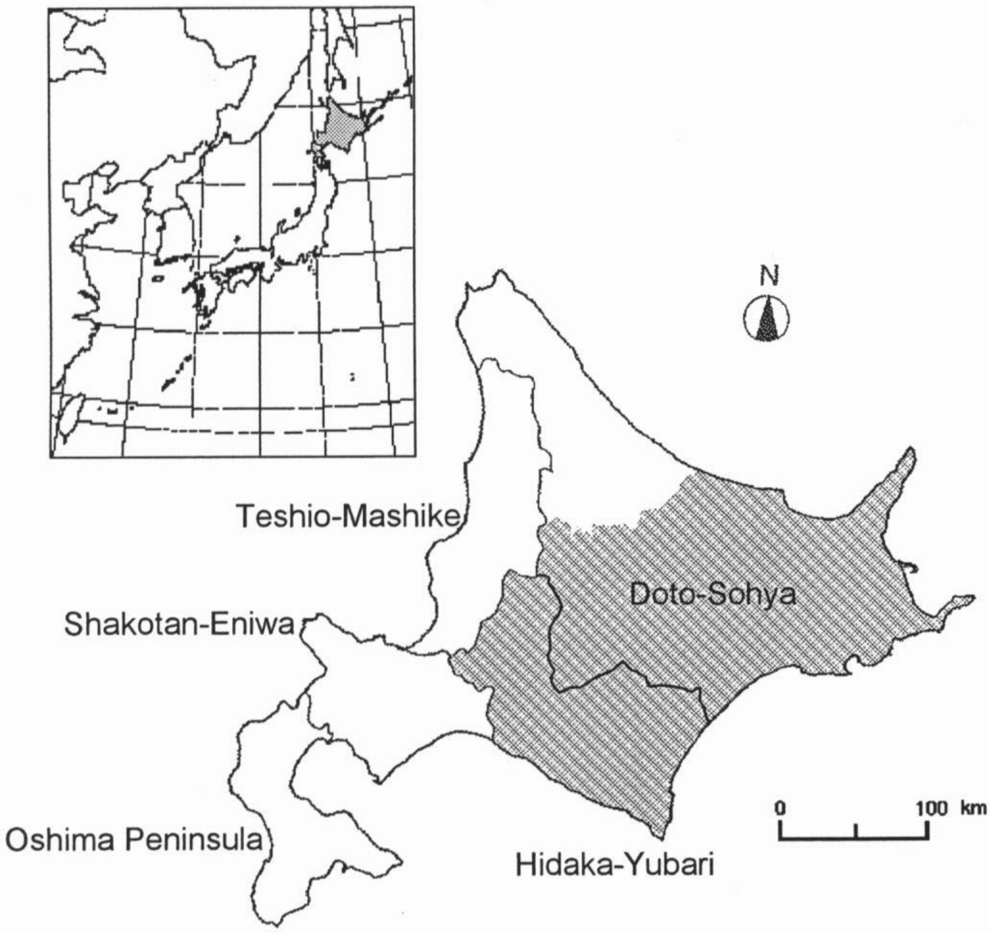


Figure 3-1. Study area in Hokkaido. The shaded area has a high-density of sika deer.

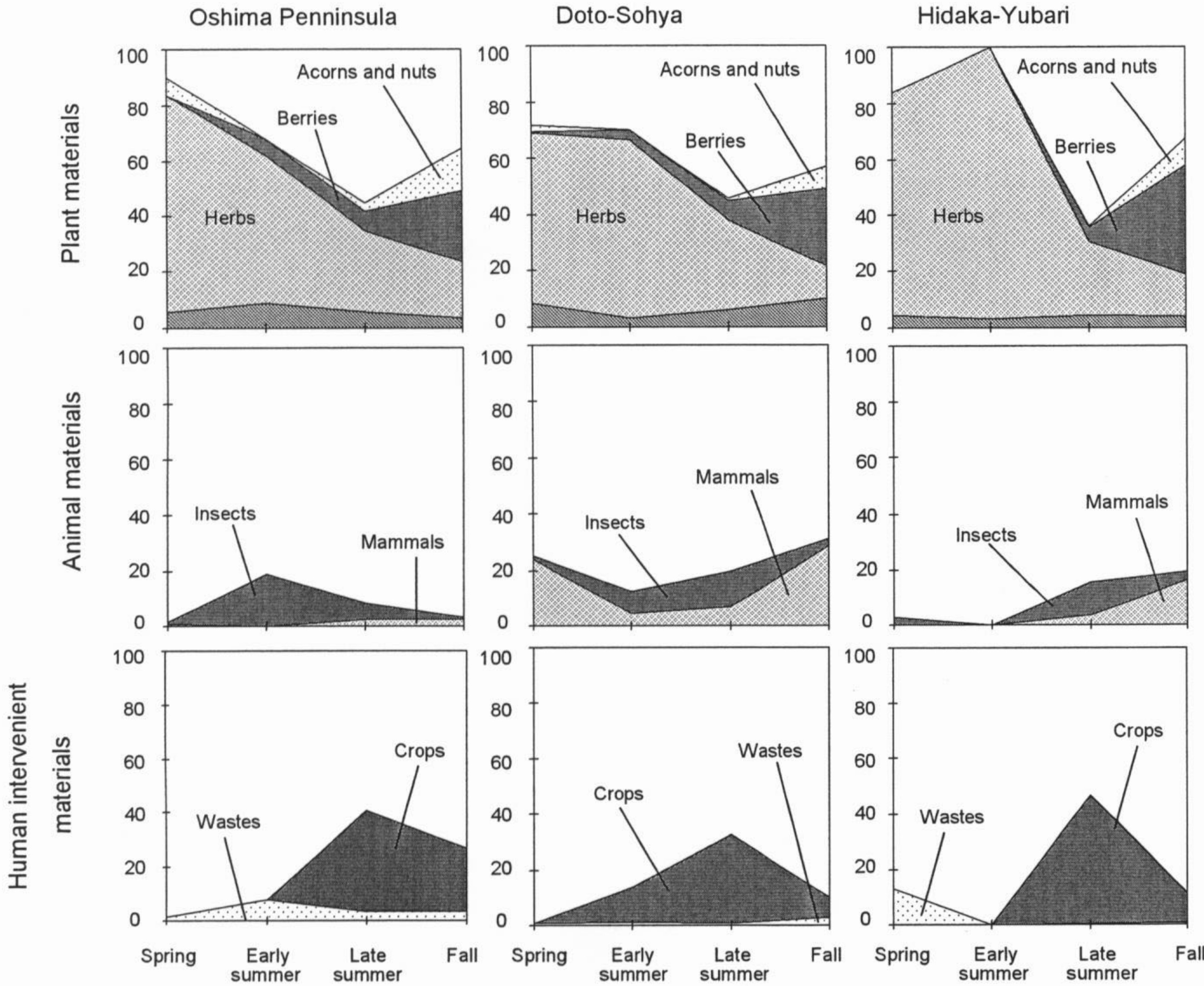


Figure 3-2. A comparison of the percent volumes of the major food categories in the stomach contents of killed brown bears for 3 regions of Hokkaido, 1991-1998.

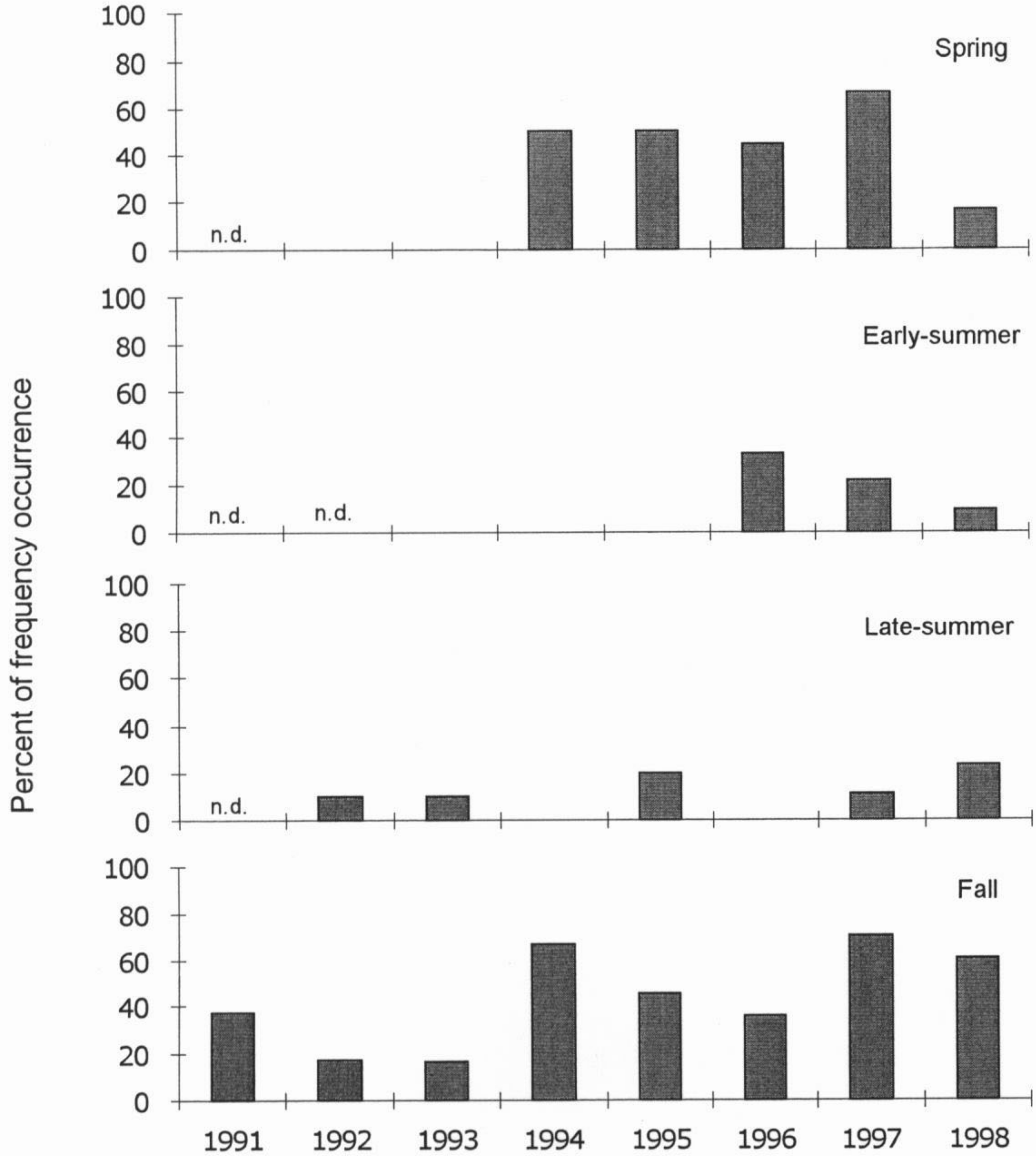


Figure 3-3. Yearly changes in frequency of occurrences of sika deer for each season as shown by the stomach contents of killed brown bears in Hokkaido, 1991-1998. n.d.: no data.

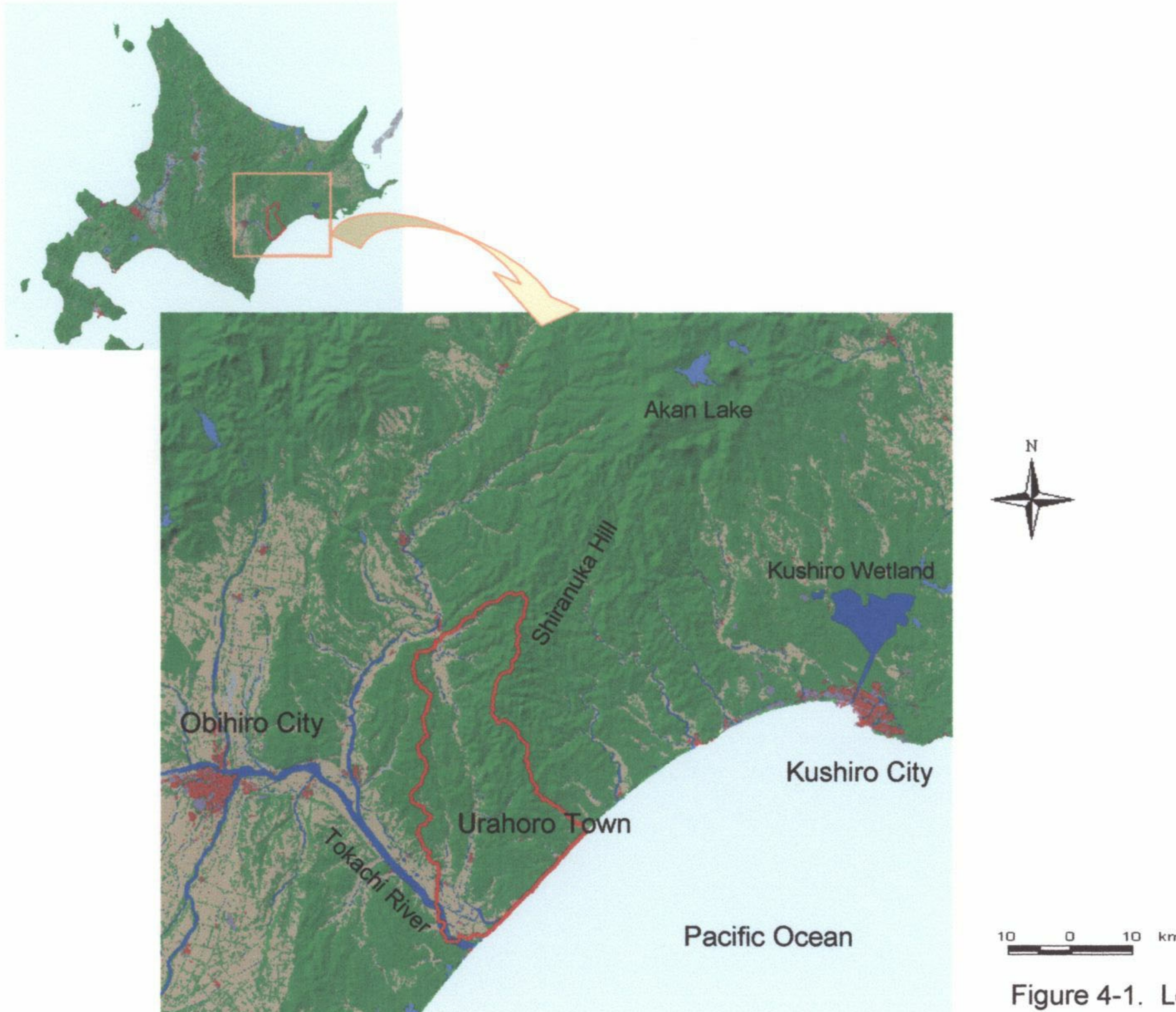


Figure 4-1. Location map of the study area, Urahoro (surrounded by red line).

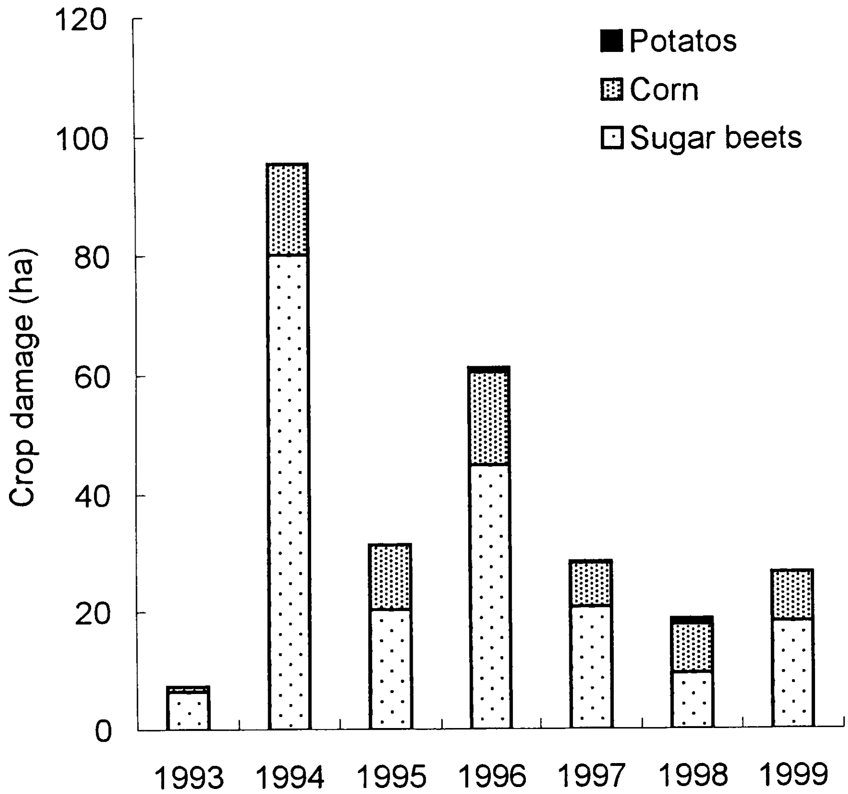
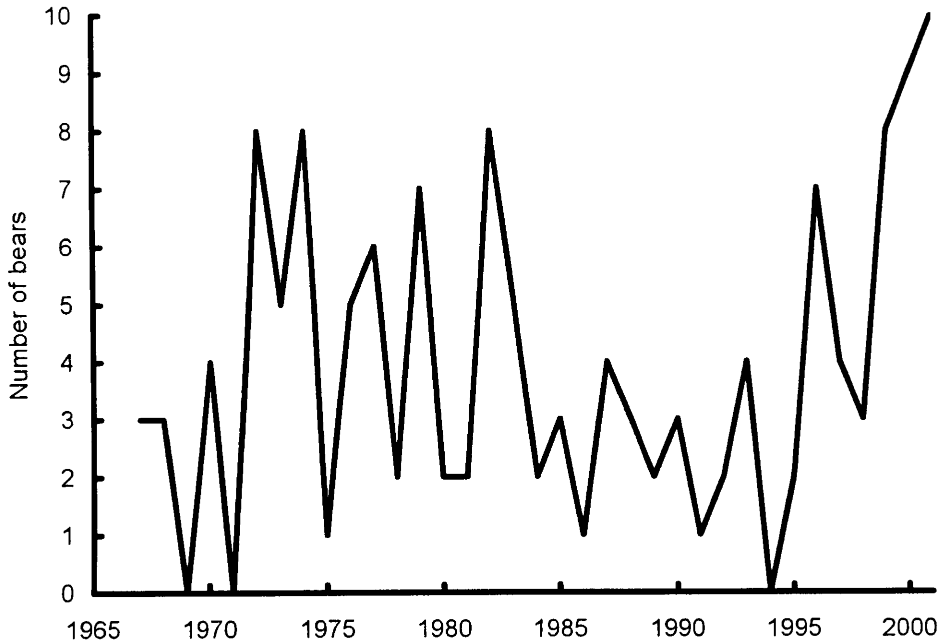


Figure 4-2. Crop damage by brown bears in Urahoro, Hokkaido, 1993-1999 (from Urahoro Agricultural Cooperative unpublished data). Data is only available after 1993.



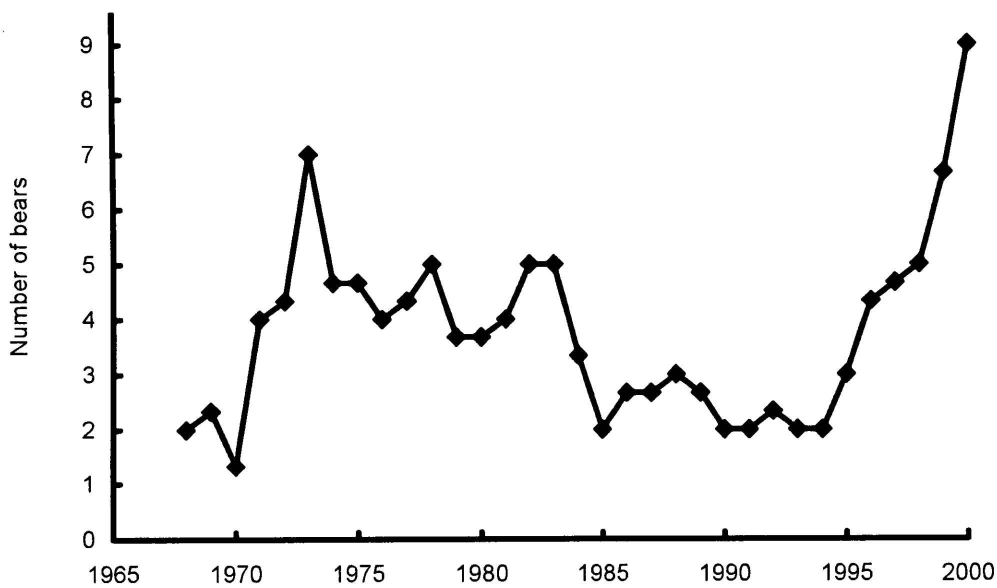


Figure 4-3. Numbers of brown bear shot for control killing and sport hunting in Urahoro, Hokkaido, 1966-2001 (from Urahoro Town Office unpublished data, top). Figures are smoothed by the 3-year moving average (below).

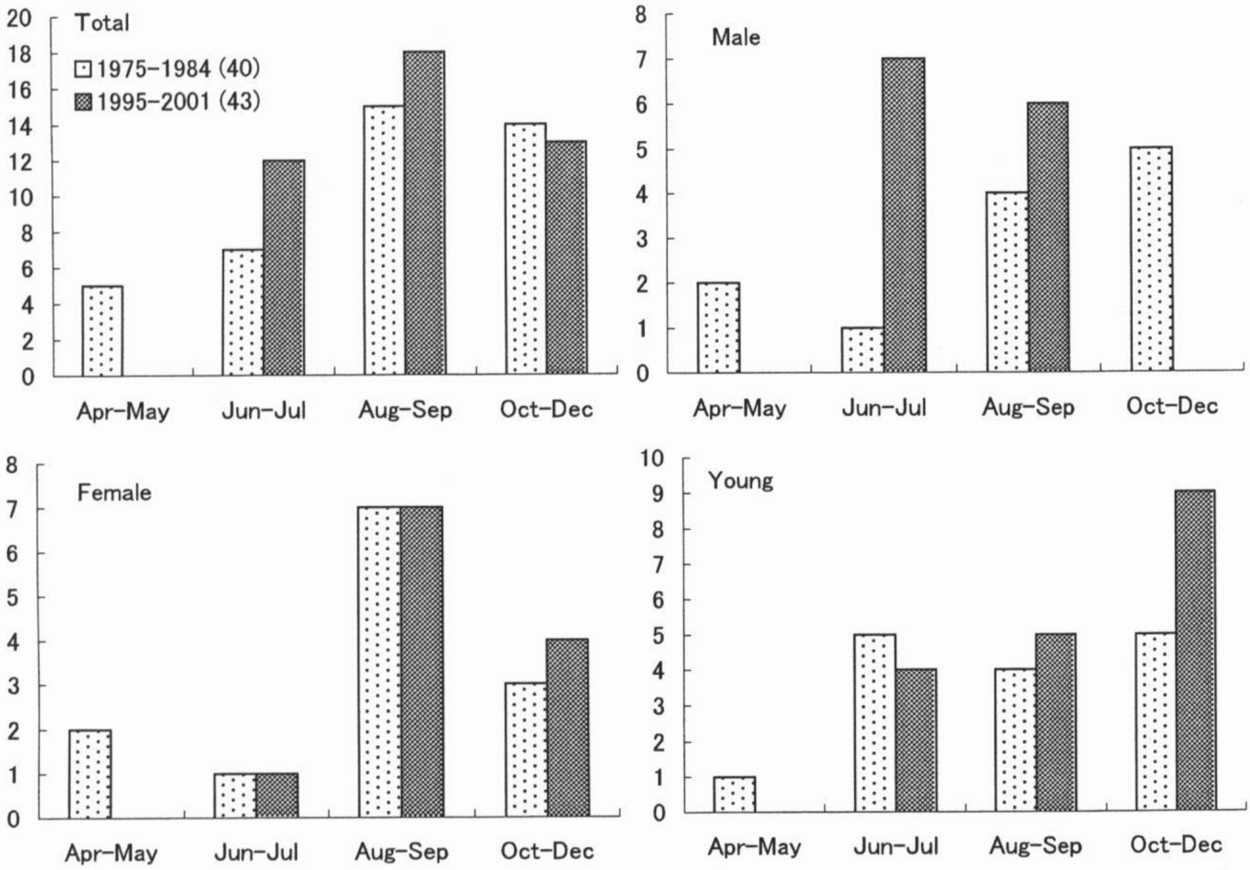


Figure 4-4. Numbers of brown bears shot for control killing and sport hunting in Urahoro, Hokkaido, during 1975-1984 and 1995-2001 (from Urahoro Town unpublished data).

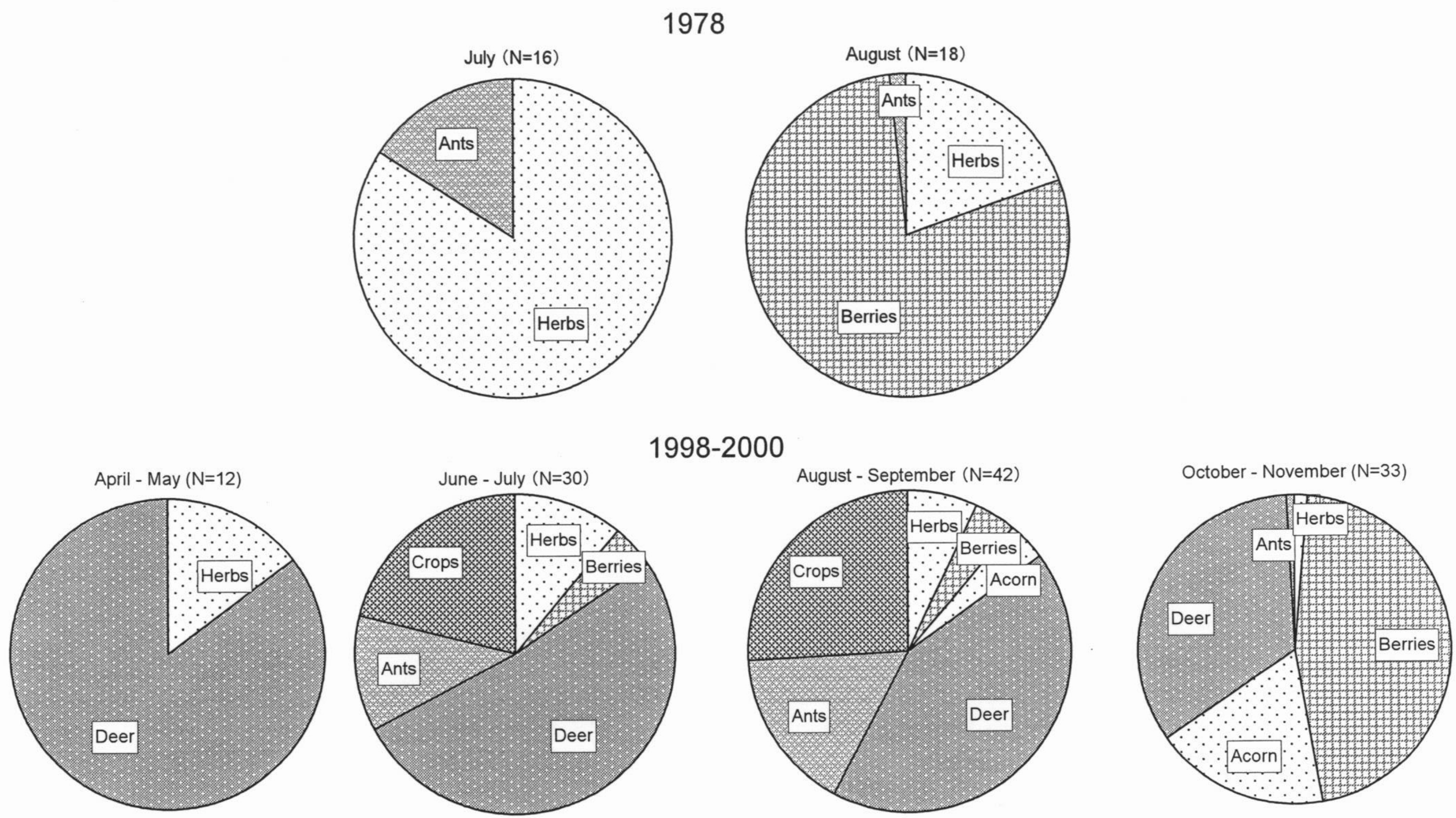


Figure 4-5. Scat composition of brown bears collected in Urahoro Town, Hokkaido, in 1978 (top) and 1998-2000 (below). Data was corrected by the correction factor (Hewitt and Robins 1996).