

A MULTI-SCALE ASSESSMENT OF HABITAT USE BY ASIATIC BLACK BEARS IN CENTRAL JAPAN

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Abstract: Japan may have >20% of the world's population of Asiatic black bears (*Ursus thibetanus*), but local extinctions may result in decreasing populations of the Japanese subspecies (*U. t. japonicus*). Apparent decreases seem to be related to loss and fragmentation of habitat, a liberal permit system for depredation kills, and a lack of ecological data to develop management guidelines. From 1996 to 1999, we studied bear habitat relationships at 2 spatial scales in the central mountain region of Japan. We used classification and regression tree analysis (CART) to determine the hierarchical structure of bear use of available habitats. The landscape analysis focused on Nagano Prefecture (approximately 13,585 km²), of which bears occupy 60%. Land-cover and land-use data were summarized and compared with the percent of occupied bear habitat within each of the 120 municipalities within the prefecture. The greatest distribution of bears occurred in municipalities with relatively little (<16%) agricultural land use. In areas with >16% agriculture, the presence of national park land and limited human development (<9%) characterized areas occupied by bears. At the local scale within Nagano Prefecture, we determined habitat preference with locations of 13 radiocollared bears. Bears used oak (*Quercus* spp.)-dominated deciduous and planted, mixed forests in the montane zone (<1,460 m) more than expected. Habitat use at the local scale appeared related to the distribution of natural food resources, particularly hard mast, whereas our landscape analysis indicated that municipalities with abundant bear habitat were primarily associated with areas where agriculture was limited. Because of the complex topography in Nagano Prefecture, agricultural and developed areas often are directly adjacent to bear habitat. Recent patterns of human development have been more diffuse, which may negatively affect resource use on a local scale and bear distribution on a landscape scale.

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Despite the extensive range of Asiatic black bears, <50,000 are estimated to exist worldwide and all populations seem to be declining (Servheen 1990, Servheen et al. 1999). The population of the Japanese subspecies of Asiatic black bears, *U. t. japonicus*, is estimated to number 10,000–15,000 bears (Hazumi 1999). Numerous local extinctions are suspected of causing an overall decrease in numbers (Hazumi 1999). Hunting and depredation kills account for >2,000 bear mortalities each year, representing 7–20% of the Japanese population (Huygens 1998, Roy 1998). Habitat protection and management are crucial to reduce threats to the species worldwide (Servheen 1990, Chestin and Yudin 1999, Hazumi 1999, Ma and Li 1999, Sam 1999, Sathyakumar 1999, Wang 1999). Long-term threats to black bears in Japan include habitat loss and fragmentation, poaching, and, indirectly, limited science-based wildlife management (Hazumi 1994, 1999; Roy 1998). Successful conservation of Asiatic black bears in Japan is critically dependent on proper management

and protection of bear habitat. However, very little is known about bear–habitat relationships in Japan and how they may vary depending on scale. Therefore, we examined the habitat relationships of Asiatic black bears at the local and landscape scale.

STUDY AREA

Our study was conducted within Nagano Prefecture (36°20'N, 137°48'E), which is centrally located on Honshu, the main island of Japan (Fig. 1). The landscape study included the entire prefecture; the local-scale study focused on a population in the west-central section of the same prefecture.

Nagano Prefecture is 13,585 km² and had a human population of 2.2 million. Most (60%) of the prefecture consisted of mountainous terrain with elevations of 286–3,190 m (Huygens 1998). Average annual temperature and precipitation were 11.5°C and 980 mm, respectively (Yomiuri Shimbun 1999). Approximately 10% of the land base was used for agricultural purposes. Asiatic black bears were distributed throughout approximately 60% of Nagano Prefecture, with an estimated bear population of

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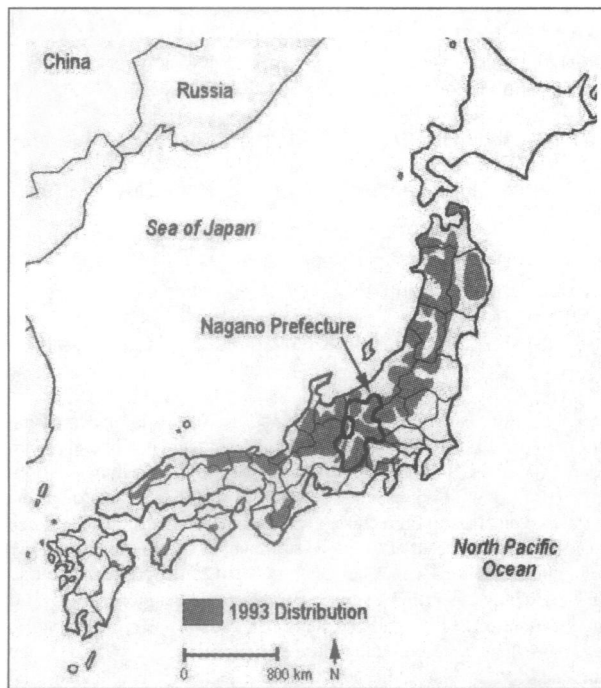


Fig. 1. Study areas for a 2-scale assessment of habitat relationships of Asiatic black bears in Nagano Prefecture, Japan, 1996–99. Nagano Prefecture was the study area for the landscape-scale analysis. The circled area on the western border of the prefecture indicates the study area for local-scale analysis. Shaded area represents 1993 distribution of Asiatic black bears from Hazumi (1999).

1,362 animals (Nagano Prefecture 1995). One or more bear attacks on humans occur annually, and bear damage to forestry and agriculture costs an average of >70 million yen per year, equal to approximately US \$600,000 (1999; Nagano Prefecture 1995, Huygens and Hayashi 1999). An average of 216 bears were hunted or killed in depredation hunts annually within the prefecture during 1975–93 (Nagano Prefecture 1995).

Local-scale data were collected within approximately 220 km² of a southeastern section of the Central Japanese Alps. Approximately half of this study area was within Chûbu-Sangaku National Park. Elevation varied from 700 m to 2,900 m. Average monthly temperatures varied from 7°C to 24°C during the research season (from June to November), and total yearly precipitation was 967 mm. Snow fell mainly from December to March and annual accumulation averaged 910 mm (Matsumoto Weather Bureau, Matsumoto, Japan, unpublished data).

Three vegetation zones existed within the local-scale study area (Numata 1974, Huygens 1998). The montane zone was found from the lowest elevations to 1,500 m, with oak (*Quercus* spp.) often dominating the forest canopy. Bamboo grass (*Sasa* spp.) was the main understory component and often prevented forest regeneration in disturbed areas (Taylor et al. 1991, Taylor and Qin

1993). The subalpine zone occurred from 1,500 m to 2,500 m, where fir (*Abies* spp.) was the dominant canopy species. Japanese stone pine (*Pinus pumila*) was the main species in the alpine zone (>2,500 m; Huygens 1998).

METHODS

Landscape-scale Analysis

All data for the landscape analyses were collected from government statistics and published reports and summarized for all municipalities in Nagano prefecture ($n = 120$; 17 cities, 36 towns, and 67 villages). We used the most recent bear distribution published in the Japanese Black Bear Survey (Nagano Prefecture 1994) to determine the proportion of occupied habitat in each municipality. As part of this survey, occupied bear range was mapped based on observations of bears and bear sign from field surveys (sign observations in 1992, fixed point observations in 1993, transect surveys in the southern portion of the prefecture in 1992 and 1993). Additional information on locations of bear observations (e.g., depredations, nuisance bear captures, hunting kills, depredation kills) were obtained from questionnaires (1992) and interviews (1993). All 3 data sources were then synthesized to map the entire bear distribution in Nagano Prefecture using 1-km² cells; records of bear observations (e.g., hunter observations, nuisance activity, captures, mortalities) within a particular cell were used to classify that cell as occupied bear habitat. We converted the distribution map to a digital raster image and combined this information in ArcView[®] GIS (ESRI, Redlands, California, USA) with the boundaries of the municipalities. We then calculated the number of 1-km² cells classified as occupied bear habitat for each municipality. We used digitized maps of land-cover and public land data to calculate the total area of forested, agricultural, developed, and national park lands within each municipality (Table 1). Because the municipalities varied in size, all area measurements were converted to percentages for standardization.

We used SPSS AnswerTree[®] software (SPSS Inc. 1998) to perform a classification and regression tree (CART) analysis. This statistical technique uncovers the structure inherent in a dataset by partitioning the multidimensional space into increasingly homogenous groups (nodes) using the predictive capabilities of the independent variables (Anderson et al. 2000). At each step, CART evaluates all possible splits for all variables and selects the variable that best separates the data into 2 homogeneous nodes. This separation is made at a particular value of the independent variable. With successive splits, model complexity increases and sample size decreases. If necessary, “pruning” methods can be used to eliminate superfluous

Table 1. Variables used in classification and regression tree analysis of Asiatic black bear distribution in Nagano Prefecture, 1996–99. Land-cover data were from Japanese Environmental Agency (1988).

Variable ^a	Category	Description
Bear distribution		1-km ² grid cells mapped as bear range from observations of bears or bear sign from field surveys (1992–93), questionnaires (1992), and interviews (1993) (Nagano Prefecture 1994)
Land cover	Agriculture	Agricultural areas
	Developed	Developed areas
	Natural broadleaf	Natural forest with broadleaf trees as dominant canopy species
	Natural conifer	Natural forest with only coniferous trees as dominant canopy species
	Unmanaged cut	Logged; regeneration not managed; often colonized by bamboo grass
	Broadleaf plantation	Logged; regenerated mainly with broadleaf trees
	Conifer plantation	Logged; regenerated mainly with conifers
	Bamboo	Areas dominated by bamboo grass; no overstory
National park	Barren	Undeveloped areas lacking vegetation
	No data	Land-cover data not available
		Areas designated as national park

^a Area of each variable or variable category was calculated for each municipality and converted to percentages for standardization.

nodes and reduce tree complexity while minimizing classification errors (Breiman et al. 1984). The result of the analysis is a binary decision tree, similar to a taxonomic key. These trees can then be used to classify or predict new observations. For example, O'Connor et al. (1996) developed CART models with Breeding Bird Survey data to predict bird species richness in the United States from a suite of environmental correlates.

We used the percent of occupied bear habitat in each municipality as the dependent variable and the percent area of national park lands and 10 land-cover classes as independent variables (Table 1). Because different combinations of variables and tree structures may depict the same dataset, we compared competing models by assessing the reduction of overall variance of the dependent variable (risk estimate) for all nodes in the model (SPSS Inc. 1998). The fit of the selected CART model was tested by estimating a risk parameter based on within-node variance around the mean of the node (Clark and Pregibon 1991).

Local-scale Analysis

We captured bears with culvert traps during summer and fall of 1996–99 and used a blowgun to administer an intramuscular injection of ketamine hydrochloride (Park Davis, Tokyo, Japan) at a dosage of 15 mg/kg and xylazine hydrochloride (Bayer, Tokyo, Japan) at a dosage of 1 mg/kg. Bears >20 kg were fitted with radiocollars (Advanced Telemetry Systems, Minnesota, USA; Lotek, Ontario, Canada). Various modifications were made to allow expansion or detachment of the collar over time.

We used a citizen's band radio receiver (FT-290mkII, Yaesu, Tokyo, Japan) with 4- or 6-element, hand-held Yagi antennas (AF Antronics, Inc., Urbana, Illinois, USA) to locate radiocollared bears. Bears were located every 3–5 days between 0800 and 1600 hours. We marked telem-

etry stations onto 1:25,000 topographic maps (Kokutouchi Ri-in/Japan Map Center, Tokyo, Japan). Azimuths from ≥ 2 stations were used to estimate bear locations by triangulation (Nams and Boutin 1991). We reduced location error by eliminating locations whose azimuths were collected >30 minutes apart or whose azimuth angles were $<45^\circ$ or $>135^\circ$ (White and Garrott 1990, Saltz 1994). Azimuth sets ($n = 1,469$) and visual locations ($n = 10$) from 21 different bears were entered into program TELEM 88 (Coleman and Jones 1986) to estimate universal transverse mercator (UTM) coordinates of locations. Because we only used data from bears with >14 locations, the resulting database consisted of 507 location estimates of 13 bears (1 subadult and 4 adult females; 1 subadult and 7 adult males). The analyses we performed at the local scale were similar to those at the landscape scale. However, the dependent variable was binomial (bear telemetry locations and randomly generated locations). We generated the random locations with the Animal Movement extension (Hooge et al. 1999) in ArcView[®] GIS to measure available habitat within the local study area. The number of random locations was equal to the number of actual locations of each bear; we assigned associated data, such as ID, sex, age, month, year, and season to the random locations. Because initial CART models showed no differences in habitat use among individual bears, we pooled the data and defined the local study area as the minimum convex polygon home range of all locations combined (Michener 1979).

We used Arc/Info[®] GRID (ESRI, Redlands, California, USA) and ArcView[®] GIS to sample 9 independent variables for the bear and random locations (Table 2). We used these 9 variables in a CART analysis to partition the data using the relative concentrations of the random and actual bear locations. Whereas the landscape-scale analysis evaluated percent of bear range, the local-scale analy-

Table 2. Independent variables used in classification and regression tree analyses of habitat use of 13 radiocollared Asiatic black bears in the Japanese Alps, Nagano Prefecture, Japan, 1996–99. The vegetation data were from Japanese Environmental Agency (1988).

Variable	Category	Description/value range
Vegetation type ^{a,b}	Natural deciduous	Natural forest, deciduous dominant canopy species
	Natural mixed	Natural forest, coniferous and deciduous
	Unmanaged cut	Logged; regeneration not managed; often colonized by bamboo grass
	Mixed plantation	Logged; regenerated as deciduous and coniferous
	Conifer plantation	Logged; regenerated as coniferous
	Other	Included all other vegetation types, such as alpine meadows, agriculture, and developed areas
Age		Age of captured bear; range = 0.75–18.75 years
Sex		Sex of captured bear
Month		Month of bear location; May–Dec
Season		Season of bear locations; summer or fall
Year		Year of bear location; 1997–99
Elevation		Elevation: 687–2,778 m
Slope		Slope; 3–58°
Aspect		Aspect transformation (Beers et al. 1966); 0.0–2.0

^a Vegetation types were classified based on the 2 dominant plant species.

^b Natural forest categories comprised mostly disturbed or exploited forests that were not managed after regeneration; old growth forest was rare; unmanaged forests were not managed after harvest; plantations represented planted forests that were managed for timber value.

sis was used to determine which independent variables would best distinguish the bear and random locations. Because the dependent variable was binomial, we determined model fit by calculating the correct prediction rate of the actual and random locations from the model parameters (SPSS Inc. 1998).

RESULTS

Landscape-scale Analysis

Four CART models had similar risk estimates and composition of variables. We chose the simplest of these 4 models as the operating model (Fig. 2), which included the proportion of area of each municipality in agricultural land, developed area, national park area, and unmanaged cut areas. This model explained 53.1% of the variation in occupied bear range in Nagano Prefecture.

The results indicated distinct differences in the bear distribution. Municipalities with relatively little agricultural land ($\leq 16\%$) tended to have the largest proportion of predicted bear range ($>68\%$ occupied range). Within those municipalities, the amount of unmanaged cut areas ($>0.1\%$, not including subsequently planted areas) seemed to be an important factor to further define optimal bear range; model predictions indicated that those regions supported the greatest proportion of occupied bear range ($>75\%$). Municipalities with $>13\%$ of their land designated as national park land tended to have more bear range, even when the proportion of agricultural land was relatively high ($>55\%$). Municipalities with $\leq 13\%$ national park area still had approximately one-third of their land area (32%) occupied by bears if the region had little development ($\leq 9\%$). With more developed areas ($>9\%$),

the predicted bear range decreased to 18%.

Local-scale Analysis

We selected the model with one of the lowest levels for risk of misclassification ($<25\%$) from 38 CART models developed from the pooled dataset (Fig. 3). Of the 507 bear locations, 473 locations were at elevations $<1,459$ m. Below this elevation, 73% of bear locations were in 4 forest types: deciduous, planted mixed, unmanaged cut, and planted coniferous forests (Fig. 3). Because unmanaged cut and planted coniferous forests each accounted for $<3\%$ of the study area, most bear locations were concentrated in deciduous and planted mixed forests. These 2 forest types were used in greater proportions than expected. Among bears concentrated in the deciduous and planted mixed forests, the final split showed a slightly greater frequency of bear locations at elevations $\leq 1,224$ m (Fig. 3).

DISCUSSION

The purpose of our research was to explore and identify potentially important bear habitat use patterns at 2 spatial scales using multivariate datasets. The CART analyses were appropriate because the hierarchical structure of the data could easily be explored and interpreted (Clark and Pregibon 1991). Use of CART models has many advantages over other techniques, such as logistic regression, because interpretation often is easier and treatment of missing variables is more satisfactory (Clark and Pregibon 1991). CART is a non-parametric technique and, unlike parametric models, can distinguish multiple structures within the data (Vayssières et al. 2000). Moreover, this technique is robust regarding the effects of outliers

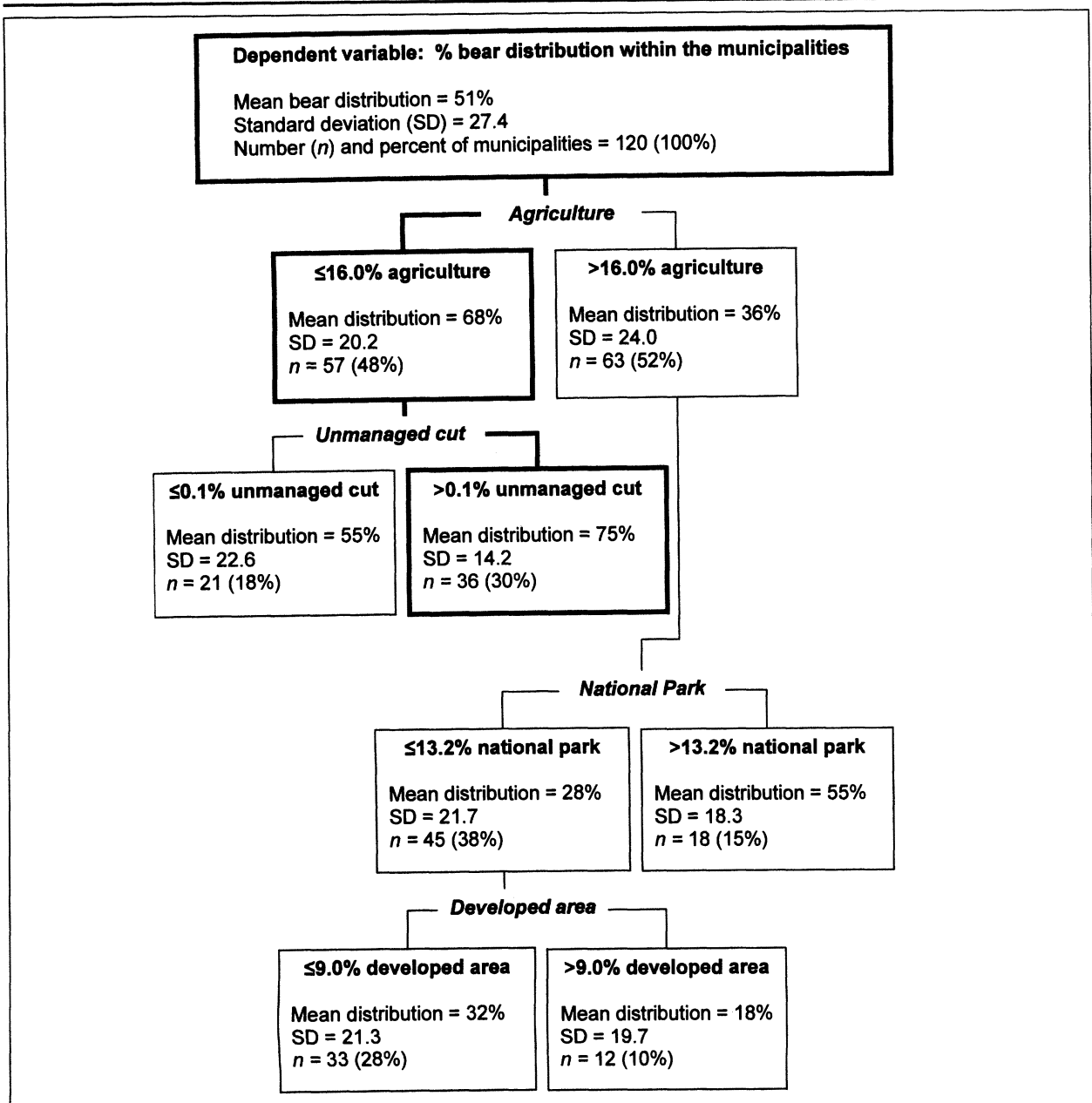


Fig. 2. Classification and regression tree model for a landscape-scale study of habitat use of Asiatic black bears in Nagano Prefecture, Japan. Each box contains the mean percent of bear distribution (mean distribution), its standard deviation (SD), and the number of municipalities (*n*) involved. The dominant branch (thick lines) indicates the higher bear distribution at each split.

(Vayssières et al. 2000).

The landscape analysis was performed with existing datasets. The effect of measurement error likely was small because the scale of analysis was relatively coarse. The results of the landscape analysis indicated that the greatest amount of occupied bear range (68%) occurred in municipalities with relatively little agricultural land (≤16%). In Nagano Prefecture, bear conflicts typically occur at the forest–agriculture interface, often resulting in depredation kills. Thus, a threshold for occupied bear range may be reached even when agriculture is not a domi-

nant land use. Where agriculture is more dominant, however, bear range may be maintained if national parks are present to provide protection. This protection likely is a combination of the inaccessible mountainous terrain that is typical of national parks in Nagano Prefecture and the lack of bear hunting.

The amount of occupied bear range in municipalities with ≤16% agricultural land further increased when >0.1% of the land was used for timber extraction then left unmanaged. Forest management areas typically are small (<45 ha) and usually are interspersed among unmanaged

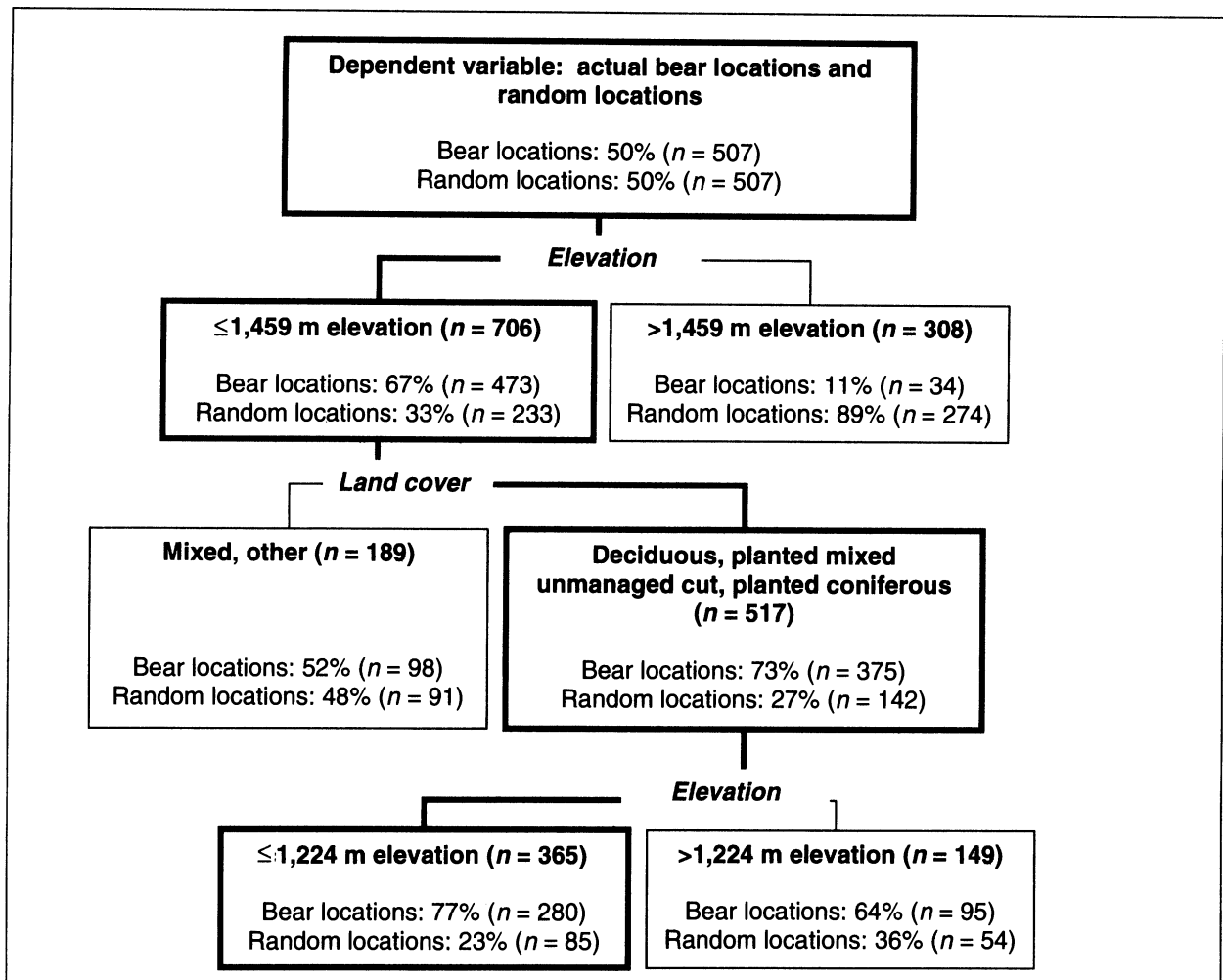


Fig. 3. Classification and regression tree model for a local-scale study of habitat use of 13 radiocollared Asiatic black bears in Nagano Prefecture, Japan, 1996–99. The dominant branch (thick lines) contains nodes with the largest percent of bear locations at each split.

forest areas. Stands not managed for forest regeneration after timber harvest provide ideal conditions for bamboo growth (Taylor et al. 1991, Taylor and Qin 1993). Although these areas make up a small percent of the land base, their inclusion in the analysis may indicate that bamboo establishment in these previously cut areas could influence bear distribution. We speculate that fresh bamboo shoots provide bears with important nutrition during early to mid spring, when food resources are relatively scarce in other forest types. Furthermore, the dense bamboo may also provide important protective cover for bears.

The bears we used for our local-scale analysis in the Central Alps were captured in poorly accessible terrain with complex topography and dense patches of bamboo grass. Although we did not achieve an optimal sample of the resident bear population, study bears included sub-adult and adult bears of both sexes. Poor access also restricted collection of radiotelemetry data. Approximately a third of the telemetry stations were accessible only by

foot, limiting data collection at night. However, early morning (0600 to 0730) and late evening (1800 to 2030) observations occasionally were made, and they indicate that bears did not exhibit wide-ranging movements at night.

We reduced the effects of telemetry error by using strict selection criteria for the telemetry azimuths. Using these criteria, we eliminated approximately 1,000 of >1,500 locations. Our mean telemetry error from the locations was 373 m ($n = 50$, $SD = 424$); when we generated a new set of locations incorporating this error, 11.4% of the locations were in polygons with a different vegetation type. Using this same set of error locations, we also determined that the difference in elevation compared with the original set was only 104 m. Therefore, the effect of telemetry error on the habitat analysis was relatively small, which we attribute in part to the large sizes of the vegetation polygons ($\bar{x} = 1.2\text{ km}^2$) and the relatively coarse resolution of the topographic data (50 m).

Fall was best represented in our dataset because all radiocollared bears moved to the montane zone during this season and locations were more attainable there. Because of the inaccessible terrain, locations also were more obtainable during daytime hours. Thus, the local-scale analysis best represents fall and daytime habitat use and interpretations regarding other seasons and times should be made with caution. The Central Alps was an ideal area to determine bear use of natural resources because our study of bears had limited access to agricultural resources. A telemetry study on Asiatic black bears elsewhere in Nagano Prefecture included bears that used agricultural areas (M. Gotoh, Shinshû University, Matsumoto, Japan, personal communication, 1999). This study may provide a valuable comparison to determine differences in home ranges and habitat use.

Bear use of the montane zone was greater than expected. Although this finding may have been biased because of greater access, the potential importance of this zone became evident when all radiocollared bears moved to this zone during the fall. The importance of the montane zone is likely related to the use of acorns as a primary food source (O.C. Huygens, Shinshû University, unpublished data). In contrast, the subalpine zone may not provide adequate food resources. Research in Nikko National Park (Hazumi and Maruyama 1987) also indicated that bears spend little time in the subalpine zone. Further studies need to be conducted to determine the importance of the alpine zone.

The importance of planted, mixed forests was shown by the concentration of bear locations; although this type of forest covered only 19% of the area, 33% of the locations were found there. Ohsako (1995) and Hazumi and Maruyama (1986) also observed that bears made extensive use of plantations. Hazumi and Maruyama (1986) speculated that forest plantations were used for cover. However, in another study in the same area as our study, researchers observed that most scats in mixed forest plantations during fall were composed of hard mast (O.C. Huygens, Shinshû University, unpublished data), suggesting that these plantations may also be important for fall food resources. Planted, coniferous forests were relatively uncommon in the study area (2%) and received infrequent use by bears. In other areas, however, plantations provided important sources of soft mast (*Prunus* spp., *Rubus* spp., *Cornus* spp., *Vitis* spp.; O.C. Huygens, Shinshû University, unpublished data) and cambium. Consumption of cambium by bears has led to substantial tree damage and losses to the forest products industry (Furubayashi et al. 1980). The low use of conifer plantations and lack of tree damage in the Central Alps may indicate that food resources there are adequate for bears.

Historically, the complex topography of Japan has re-

sulted in land-use patterns characterized by a concentration of agricultural fields and developed areas immediately adjacent to bear habitat (Huygens and Hayashi 1999). Therefore, seasonal movements by Asiatic black bears in response to food shortages increase the probability of encountering developed areas, particularly as development moves further into the montane zone (Roy 1998). At the forest–agriculture interface, bears often exploit agricultural food resources. The number of depredation kills has increased in recent years, surpassing the number of bears harvested by hunters in many areas (Roy 1998). Although future expansion of agricultural areas in Nagano is unlikely because most areas with appropriate terrain already are in use, recent development patterns (e.g., hydroelectricity, golf courses, second homes) have been more diffuse. This dispersed development may ultimately affect bear habitat use on a local scale and the extent of bear range throughout Nagano Prefecture. Bear management should focus on those areas where agriculture and forests are adjacent and particularly where development progresses further into the montane zone. Finally, our study suggests that national parks and other protected areas may be important to maintain bear range where land use is more intensive. Given the potential impacts of depredation kills on local populations, the role of those protected areas in maintaining a regionally stable metapopulation should be examined.

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