

# Relationships between Asiatic black bear kills and depredation costs in Nagano Prefecture, Japan

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**Abstract:** Over 1,000 Asiatic black bears (*Ursus thibetanus*) are killed each year in Japan to control depredation activity. Our objective was to determine if killing bears reduces depredation costs. We focused our study on Nagano Prefecture, where 2,562 nuisance bears were reported killed and where reported depredation cost exceeded ¥1,430 million between 1979 and 1999. We used mixed models with repeated measures to determine if annual depredation costs were associated with the number of bears killed. Our data set included 15 years (1985–99) of kill and cost data for 122 municipal jurisdictions within 10 regions. We performed analyses at the regional level based on combined harvest and nuisance kill data, and at the municipal level based only on nuisance kill data. We classified the number of kills into 3 classes (low, medium, high). Analyses were repeated using prior-year kills to examine whether a possible time-lag existed. Annual depredation costs were positively associated with the kill data at the regional level ( $F = 5.51$ ; 2, 72.3 df;  $P = 0.006$ ) during the same year. However, we observed no association based on prior-year kill data ( $F = 0.96$ ; 2, 65.1 df;  $P = 0.390$ ), suggesting that depredation costs and bear kills are a function of nuisance bear numbers rather than reflecting a causal relationship between the 2 measures. Nuisance bear numbers may in turn be affected either by the availability of natural foods or by general population trends. At the municipal level, depredation costs were not associated with the number of nuisance bears killed during the same year ( $F = 1.36$ ; 2, 466 df;  $P = 0.258$ ) or the prior year ( $F = 0.42$ ; 2, 459 df;  $P = 0.656$ ). Our results suggest that systematically killing Asiatic bears may not be an effective tool for mitigating nuisance costs. In municipalities where nuisance costs remain high, we recommend that alternative methods be tested for their efficacy in mitigating costs. Such methods may include public education, changing or removing financial incentives to kill bears, changing crop rotations to crops that are not attractive to bears in risk areas, promoting natural food production, using electric fences, and applying aversive conditioning techniques.

**Key words:** Asiatic black bear, depredation, Japan, Nagano Prefecture, nuisance kill, *Ursus thibetanus*

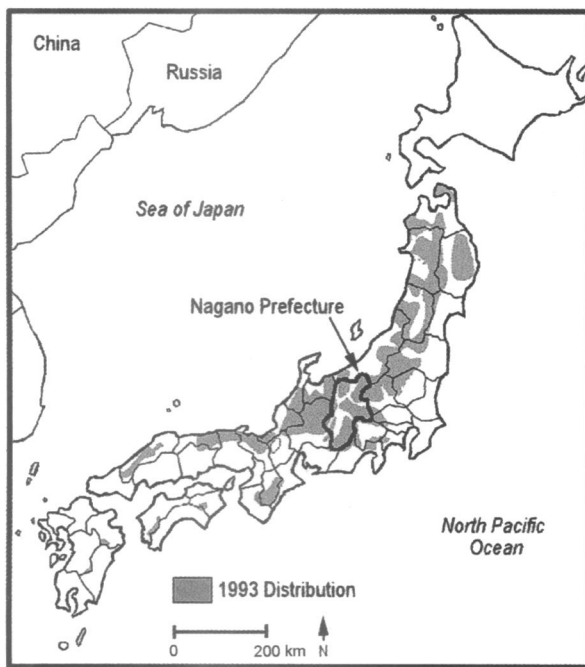
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In Japan, nuisance activities by Asiatic black bears include stripping bark from trees; raiding crops, orchards, apiaries, and fish farms; feeding from compost heaps and garbage bins; and attacking livestock and

humans (Azuma and Torii 1980; Furubayashi et al. 1980; Watanabe 1980; Hazumi 1994, 1999; Angeli 2000). The primary response to bear depredation is for hunters to set cage traps to capture and kill nuisance bears. Hunters legally sell the parts of bears they kill (Mills and Servheen 1991, 1994), and they usually receive monetary compensation from municipal offices or local agricultural cooperatives for killing nuisance bears. During 1985–99, depredation levels remained high despite the killing of over 1,000 nuisance bears

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**Fig. 1. Location of Nagano Prefecture, Japan. Shaded area represents 1993 distribution of Asiatic black bears (modified from Hazumi 1999).**

annually (Hanai 1990; Hazumi 1994, 1999). To our knowledge, the effectiveness of killing Asiatic black bears as a method to reduce depredation levels in Japan has not been tested. Therefore, the objective of our study was to determine if a relationship exists between the number of bears killed and bear depredation costs. We tested 2 null hypotheses: (1) the number of bears killed annually through legal harvest and nuisance control is not correlated with depredation cost, and (2) the number of bears killed annually for nuisance control only is not correlated with depredation cost.

### Study area

We focused our study in Nagano Prefecture, on Honshu, Japan's largest island (Fig. 1). Nagano is landlocked and the climate is greatly influenced by seasonal monsoons. Rain is more common in the south of the Prefecture (265 cm annually) than the east (88 cm annually). However, the pattern is reversed in winter due to changing seasonal winds: 10 m of snow is common in the north, whereas the south receives about 0.6 m of snow. Agriculture traditionally has played an important role in the prefectural economy, though in recent times Nagano has diversified into various industries such as

the machinery and metal industries, precision-machinery, and food-processing industry. The economic importance of agriculture has sharply decreased in recent years, and in 1994 agriculture represented 4.7% of the gross prefectural product. Yet Nagano still has more farms (149,000) than any other prefecture in Japan.

Asiatic black bears occur in approximately 60% of the Prefecture (8,000 km<sup>2</sup> of 13,585 km<sup>2</sup>; Fig. 1), and Nagano's human population (2.2 million) is concentrated in the remaining 40% of land. The Prefecture is divided into 122 municipal jurisdictions, which are grouped into 10 administrative regions. In Nagano Prefecture, decisions to kill nuisance bears are made at the municipal level, as stipulated by a regulation signed by the prefectural governor in 1980 and reinforced by an ordinance passed by the prefectural assembly in 1999 (Nagano Prefecture 1980, 1999). Between 1979 and 1999, average reported estimates of bear depredation costs exceeded ¥ 68 million per year (\$1 US ≈ 115 ¥ in 1999) and number of bears killed annually as nuisances and as legal harvest averaged 122 and 69, respectively (total of 4,002 bears; Nagano Prefecture 1995; Nagano Prefecture, unpublished data).

### Methods

No direct measure of depredation incidents was available. Therefore, we assumed that depredation costs were an adequate measure of depredation levels. Depredation costs were the visual cost estimates of crop, orchard, tree plantation, and other depredations reported to the prefectural office by the 122 municipal jurisdictions. We obtained kill and depredation cost data for the 15 years from 1985 to 1999 from the central prefectural office (Nagano Prefecture, Nagano City, Japan). Depredation cost and nuisance kill data were available for municipal and regional levels. However, harvest data for the general hunting season (15 Nov to 14 Feb) were only available at the regional level. Therefore, for hypothesis 1 we summarized cost and kill (legal harvest and nuisance kill) data by region, whereas we summarized cost and kill (nuisance kill only) data by municipality to test hypothesis 2.

For the analyses, we corrected cost data to account for inflation. However, inflation data were not available for all commodities, and the breakdown of the commodities damaged by bears was available only for 1997–99. Therefore, we averaged available data to generate a consistent basket of commodities damaged by bears each year. We used domestic wholesale prices of hinoki cypress (*Chamaecyparis obtusa*) for all trees because hinoki cypress represented the majority of the cost of

trees damaged by bears in plantations. Consumer price indices were used for all other commodities.

We used mixed modeling procedures with a repeated measures design (Proc MIXED; SAS Institute 2000) to determine if annual depredation costs were associated with the number of bears killed. We normalized all depredation cost data by using log-transformations. We calculated the effective degrees of freedom for each model by using the Kenward-Roger approximation (Kenward and Roger 1997). Because municipalities sometimes reported no depredation kills in a given year, we reduced bias due to zero entries by classifying the number of bears killed as a categorical variable: low (0–1 bear killed), medium (2–5 bears killed), and high (>5 bears killed). For the regional-level analysis, we changed these criteria to 0–10, 11–25, and >25 bears killed, respectively. Some regions and municipalities had no reported depredation costs in some years, resulting in skewed cost distributions. Therefore, we excluded those observations from analysis because we were primarily interested in examining relationships with the number of bear nuisance kills when depredation damage actually occurred. For the first hypothesis, we used region as the experimental unit and combined legal harvest and nuisance kills to examine associations of depredation costs with the kill data, region, year, and their interactions. Because information was collected on the same experimental units over 15 years, we used a repeated measures design. We tested the second hypothesis using repeated measures as well, treating municipalities within regions as the experimental units.

We modeled covariances using a combination structure that specified both between-experimental unit effects and a correlation structure within experimental units that decreases with increasing time lag (Littell et al. 1998). As with the regional analysis, we included region, year, and interaction terms in the model. For both the regional- and municipal-level analyses, we accounted for a possible time lag between killing bears and the effects on depredation cost by repeating our analyses with kill data from the previous year (i.e., 1-year time lag; 1986–99 data only).

## Results

During 1985–99, a mean of 16.4 bears were killed annually (legal harvest and nuisance kills) per region (SE = 1.1; range = 1–73) and annual depredation costs averaged ¥6,280,526 (SE = 1,049,688; range = 0–83,040,000) per region. During that same period, the mean number of bears killed annually (nuisance kills

only) at the municipal level was 0.9 bears (SE = 0.05; range = 0–33); annual depredation costs averaged ¥528,097 per municipality (SE = 56,035; range = 0–41,501,000).

Parameter estimates for region indicated that depredation cost differed among the 10 regions ( $F = 21.59$ ; 9, 27.7 df;  $P < 0.001$ ) and, to a lesser degree, years ( $F = 1.84$ ; 14, 62.9 df;  $P = 0.051$ ). That is, much of the variability in bear depredation costs was explained by region, likely because some regions had consistently greater nuisance activity than others. Bear depredation costs were positively associated with category of bear kills (low, medium or high;  $F = 5.51$ ; 2, 72.3 df;  $P = 0.006$ ), and the interaction terms indicated that these relationships varied by region ( $F = 3.48$ ; 14, 68.3 df;  $P < 0.001$ ) but not by year ( $F = 0.75$ ; 22, 62.7 df;  $P = 0.773$ ). The model based on prior-year kill data did not indicate any relationships with the number of bear kills ( $F = 0.96$ ; 2, 65.1 df;  $P = 0.390$ ) or its interaction with region or year.

We found no evidence at the municipal level that depredation costs were associated with the number of nuisance bears killed during the same year ( $F = 1.36$ ; 2, 466 df;  $P = 0.258$ ) or the prior year ( $F = 0.42$ ; 2, 459 df;  $P = 0.656$ ). Similarly, no significant interactions with region or year were evident (all  $P > 0.283$ ). Reported depredation costs varied among the 10 regions (current-year kill:  $F = 2.69$ ; 9, 156 df;  $P = 0.006$ ; prior-year kill:  $F = 3.54$ ; 9, 85 df;  $P = 0.001$ ) and among years (current-year kill:  $F = 1.94$ ; 14, 462 df;  $P = 0.021$ ; prior-year kill:  $F = 2.68$ ; 13, 459 df;  $P = 0.001$ ).

## Discussion

The longitudinal data set we compiled for Nagano Prefecture provided a unique opportunity to examine whether bear depredation costs may be reduced through harvest management or targeted killing of nuisance bears. However, the data we used contained some inaccuracies, which should be considered in the interpretation of our results. For example, we discovered several errors in the data we received from the Prefecture, and more errors may remain. Also, under- and over-reporting of harvested bears occurs (Hazumi 1992, Moll 1994), and our data do not include poaching incidents, although they occur throughout Japan (Hazumi 1992, Moll 1994) and Nagano (Huygens et al. 2001, Huygens and Hayashi 2001). Inaccuracies also may exist in depredation cost data. Visual depredation cost estimates are subjective, and crops may be more valuable in some areas than others (e.g., timber versus

corn) and, as such, the same level of depredation (e.g., 1 bear-night) may result in different monetary losses. Finally, landowners receive no compensation for bear damage, removing incentives to report bear damage or to accurately estimate costs.

Despite the existence of data inaccuracies, we believe that our observations regarding the associations between depredation costs and the number of bear kills are reliable. For example, even if the harvest data were somewhat under- or over-reported, the results would have been similar because we categorized the kill data in 3 classes. Furthermore, different definitions of those 3 kill categories did not distinctly change the model parameters. Effects due to any inaccuracies among the depredation cost data likely were limited as well because our goal was to examine associations, rather than predicting depredation costs. Also, we have no reason to believe that the degree of inaccuracy in the reporting of depredation costs differed substantially among years, regions, or municipalities.

The regional kill data included both harvest and nuisance kills, with harvest kills typically representing approximately one third of the total kill. Regionally, annual depredation costs were associated with the number of Asiatic black bears killed through legal harvest and nuisance kills. Although this relationship varied somewhat among the 10 regions, the parameter estimates indicated that annual depredation costs increased, rather than decreased, with the total number of kills during the same year. However, we did not find such a relationship based on prior-year kill data, suggesting that higher depredation costs at the regional level may simply reflect a greater number of nuisance bears, which, in turn, would lead to more nuisance bear kills. These results provide evidence that increased harvest and nuisance kills do not necessarily result in reduced depredation costs, either in the current or subsequent year. We suggest that changes in all 3 measures (i.e., depredation cost, nuisance kill, and harvest) may simply be a consequence of temporal variation in the availability of natural foods and regional fluctuations in population abundance.

Our municipal analyses may provide additional evidence for this interpretation: targeted killing of bears that cause depredation was not correlated with the cost of depredation in the current or subsequent year. These results suggest that the current system of killing bears after depredation events may not help reduce depredation costs. When municipalities approve the killing of nuisance bears, non-target bears also may be killed because hunters can set traps to control nuisance activity

for extended periods (>1 month) near depredation sites and along bear approach routes. Furthermore, areas where bears have been sighted and where they are thought to present a threat to human safety, even if no financial losses have been incurred (e.g., schools, houses, hotels, garbage disposal sites), may be trapped for extended periods as well. The killing of non-target bears and bears that do not generate monetary losses would not directly affect depredation costs, which may explain why we failed to find significant associations between depredation costs and nuisance kills at the municipal level.

### Management implications

Local factors likely play an important role in depredation incidents, including agricultural and forestry practices, availability of natural bear foods, landscape settings, changes in land use practices, local bear densities, and effects of developments (such as golf courses, second homes, and hotels). Unique local conditions require local coordination of management responses to bear depredation. Such a system essentially is in place in Nagano Prefecture, but this method has not effectively reduced conflicts to acceptable levels. We speculate that the inaccessible mountains act as *de facto* refugia that are perpetual sources of nuisance bears, possibly reducing the effectiveness of reactive management responses, such as trapping and killing of nuisance bears. Consequently, the image of bears in rural areas of the Prefecture remains largely negative (Huygens et al. 2001). Methods that failed to reduce bear depredation to acceptable levels also led to landowner dissatisfaction and frustration and generated negative attitudes toward bears and bear conservation in other areas of Japan (Roy 1998) and in the U.S. (Ambrose and Sanders 1978, Brady and Maehr 1982).

The reduction of bear depredation remains an important issue in Nagano Prefecture. We suggest that current management plans should be adapted to better respond to locally varying levels of bear depredation. We also propose that studies be conducted to compare the effectiveness of the current management approach with alternative approaches. Proactive approaches may be more successful in the long term than reactive management responses. The lack of landowner and public interest has been cited as a major impediment to the evolution of bear management in Japan (Kellert 1991, Roy 1998, Hazumi 1999, Huygens et al. 2001). Farmers in Nagano Prefecture often are unconcerned or unaware that planting crops near forests attracts bears and may

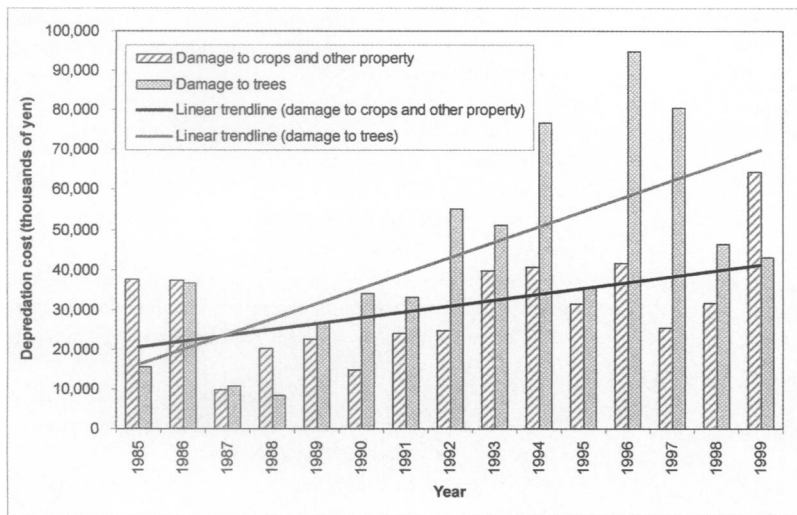


Fig. 2. Depredation cost (¥) of Asiatic black bear damage to crops and other property compared with bear damage to trees, Nagano Prefecture, Japan, 1985–99. Costs were adjusted for inflation.

lead to nuisance activity. For example, farmers are defensive about their right to plant sweet corn near forested areas in Nagano, and this leads to depredation and to bears being captured and killed (Huygens et al. 2001). Furthermore, landowners harvest some crops (e.g., fruits and sweet corn) by hand, selecting only items suitable for sale and leaving the rest to decompose in the field. Many landowners may not be aware that bear use of those crop remains can result in future depredation (Goto 2000). We suggest selecting control areas where the current management approach would be continued, and treatment areas in which a combination of proactive actions would be used, including landowner and public education, electric fences, and aversive conditioning of nuisance bears. In treatment areas, particularly problematic bears would be killed only as a last resort. The potential efficacy of such an approach was first described by Huygens and Hayashi (1999), who observed a 45% reduction in depredation costs in a Nagano village where farmers and managers made extensive use of electric fences and aversive conditioning.

Our data differentiated between damage to tree plantations and damage to other property, but not between bears killed to protect tree plantations or other property. Thirty-three (27%) municipalities in Nagano Prefecture reported damage to trees during 1985–99, but such damage represented almost 59% of all cost estimates. Although the number of bears killed to protect trees during 1985–99 is unknown, municipalities where damage to trees occurred killed more nuisance

bears ( $n = 681$ ,  $\bar{x} = 20.6$ ) than other municipalities ( $n = 872$ ,  $\bar{x} = 9.7$ ), suggesting that a substantial number of bears were killed to protect trees. Yet from 1985 to 1999, damage to trees seems to have increased more than damage to other property (Fig. 2). Supplemental feeding programs successfully reduced damage to coniferous trees in the states of Washington and Oregon, USA (Ziegeltrum 1998), and we suggest such a feeding program be tested in Nagano as well.

Finally, the legal market for bear parts and the compensation paid by village offices or agricultural cooperatives provide hunters with financial incentives for the continued taking of bears (Servheen 1990; Mills and Servheen 1991, 1994; Huygens et al. 2001). Consequently, landowner in-

centives to protect their property may be diminished because hunters offer an easy and inexpensive alternative (Huygens et al. 2001). Not surprisingly, hunters in Nagano are among the strongest opponents to proactive nuisance bear management programs (Huygens et al. 2001). Ultimately, effective reduction of bear depredation costs in Nagano may require changing hunter financial incentives and encouraging landowners to take more responsibility for the protection of their property (Huygens et al. 2001).

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