Regional concurrence in the number of culled Asiatic black bears, *Ursus thibetanus*

Teruki Oka

*Tohoku Research Center, Forestry and Forest Products Research Institute, Morioka, Iwate 020-0123, Japan*

**Abstract.** Fluctuation in the number of Asiatic black bears, *Ursus thibetanus*, culled in 1993–2004 was analyzed for 25 areas from 23 prefectures in Japan by cluster analysis. The areas were roughly divided into two groups, one consisting of areas west of Toyama, and the other consisting of areas east of Nagano, which was further divided into three clusters. Each cluster was composed of areas (prefectures) that were geographical neighbors except for four areas that were not merged into any clusters. It was likely that the number of culled bears in the residential area was affected by an inter-prefectural factor. These findings kept open the possibility of forecasting the increase of nuisance bears based on hardmast monitoring, although which tree species and how strongly bears depend on them are still unclear. Further monitoring on the number of nuisance bears and hardmast production level is needed.

**Key words:** Asiatic black bear, cluster analysis, hardmast monitoring, nuisance bear, *Ursus thibetanus*.

In autumn of 2004, the frequent invasion of Asiatic black bears, *Ursus thibetanus*, into residential areas constituted a public problem in Japan. In the western part of Honshu Island (11 prefectures located west of Toyama) (Fig. 1), almost 1,000 bears in total were culled because of their nuisance behavior, 5 times more than the previous year. There were 111 incidents involving humans throughout Honshu Island, two of which resulted in human deaths (Japan Wildlife Research Center 2005). However, the incidents in 2004 are not exceptional. The Tohoku district, the northernmost part of Honshu Island (6 prefectures located north of Fukushima) (Fig. 1), encountered similar problems in 2001, resulting in a cull of >900 bears. The number of nuisance bears fluctuates continually, and sharply increases once every several years accompanied by a large-scale culling (Oi 2005).

Hardmast such as nuts and acorns (seeds of *Fagus* spp. and *Quercus* spp., respectively) are the most important autumn food items for bears prior to denning (Hashimoto and Takatsuki 1997). Bears tend to extend their home ranges in years of poor hardmast production (Pelton 1989; Maita 1990), which may bring them close to residential areas. Many researchers have suggested a relationship between bear nuisance behavior in residential areas and hardmast crop failure (Mizoguchi et al. 1996; Nagai 1998; Saito and Oka 2003; Taniguchi and Osaki 2003). Recently, Oka et al. (2004) indicated that the number of nuisance bears culled was linked to fluctuations in beechnut (*F. crenata*) production in five areas of the Tohoku district. Based on this empirical fact, some prefectural governments in the Tohoku district started monitoring beechnut production in 2004 as part of their bear management policies: when a marked increase in out-of-habitat bears is expected, warnings to the public should be issued to minimize human-bear encounters and to reduce incidents involving humans (Oka et al. 2004).

Similar management policies with a bear-warning system have been adopted in other regions since 2005, mainly triggered by a large number of nuisance bear incidents in western Japan, in 2004. The previous studies also showed that a large number of bears were culled (or seen) in years of poor hardmast production in Toyama (Nagai 1998) and Hyogo (Taniguchi and Osaki 2003) prefectures (see Fig. 1). There is a strong possibility that frequent invasions by nuisance bears into residential areas are related to a hardmast crop failure in those years. However, the hypothesis has not been firmly supported.
yet by long-term monitoring on a larger scale.

Fluctuation patterns of the number of bears culled in the Tohoku district that appeared to be linked to those of beechnut production level (Oka et al. 2004) show a major characteristic: the number of bears culled in one prefecture tends to fluctuate with that in other prefectures; that is, in the year when one prefecture is seriously troubled by nuisance bears, neighboring prefectures also experience considerable problems with bears. This is probably related to the synchrony of beechnut production on a certain spatial scale in the area (e.g., Suzuki et al. 2005). Conversely, concurrence in the numbers of culled nuisance bears among prefectures would imply that bears depend on a resource that fluctuates at an interprefectural level, such as hardmast production.

In this study, data on the number of bears culled in all prefectures invaded by nuisance bears was analyzed by clarifying the regional fluctuation patterns in the numbers culled to explore the feasibility of forecasting nuisance behavior in residential areas based on monitoring of hardmast production throughout Japan.

**Methods**

Basic data on the number of nuisance bears culled in each prefecture, was collected from statistics in the yearbook of wildlife compiled by the Nature Conservation Bureau of Ministry of the Environment, Japan. Data sets from all prefectures concerned, from 1993–2004, were used as they were available for some adjustments mentioned below.

In Aomori prefecture, the bear population in the Shimokita Peninsula (hereafter Shimokita) is geographically isolated from that of the rest of the prefecture (Aomori). Similarly, the bear management policy of Iwate prefecture (Iwate Prefecture 2003) has distin-
guished the population in the Kitakami Highland (Kitakami) from that near the Ouu Mountains (Iwate). Hence, these bear populations were treated as distinctive in this study, and data on the number of bears culled were collected from the Nature Preservation Sections of both prefectural governments.

The number of bears culled around agricultural fields following crop damage, or around houses following or prior to accidents with casualties should be an appropriate indicator of how frequently bears invade residential areas (e.g., Oka et al. 2004). However, the number in the statistics in the yearbook of wildlife sometimes includes: 1) bears accidentally caught in traps set for nuisance wild boars, 2) bears culled in forested area to reduce the damage to planted trees (Tori 1989; Hazumi 2003), and 3) bears shot in the forest in early spring to decrease the population and to reduce agricultural damage in the following season (e.g., Akita Prefecture 2002).

Bears culled in boar traps were regarded as bears that invaded residential areas, so they were not excluded from the analysis. Forestry damage by bark stripping behavior is especially severe in central Japan, including Fukui, Gifu, Ishikawa, Kyoto, Nagano, and Shizuoka (Hazumi 2003). The number of bears culled in forested areas should have been subtracted from the total number of culled bears. However, the data sets for some areas were incomplete and included such bears. In contrast, the numbers of bears killed in early spring were subtracted from the total number reported, mainly using data from previous reports (Akita Prefecture 2002; Saito and Oka 2003; Hayashi and Nozaki 2004; Japan Wildlife Research Center 2005).

The relationship between the number of bears culled and the level of hardmast production, if any, will become clear when the numbers of bears culled only from late summer to autumn are extracted. However, monthly data were not completely available for all prefectures, the number of bears culled from July to November accounted for more than 80% of the total culled (e.g., Saito and Oka 2003), and the difference in the number culled during this season was a driving force in changes in the annual number of bears culled (Nagai 1998). Therefore, the numbers of bears culled throughout the year were used for analysis.

Differences in the number of nuisance bears culled from a given year to the next were calculated, followed by the Kolmogorov-Smirnov test for normal distribution. Pearson correlation coefficients \( r \) of those differences among all areas (mostly prefectures) were used for examining the extent of concurrence because the \( r \) calculated by the difference in the time-series data equals the cross correlation coefficient at lag = 0; the greater \( r \) indicates that the number of bears culled in two prefectures fluctuates more concurrently. Patterns of geographic concurrence in the number of bears culled were analyzed by the furthest neighbor (complete linkage) method of hierarchical clustering available in SPSS (1999). Similarity measures for clustering were calculated from Pearson’s \( r \)s mentioned above. Clustering begins by finding the closest pair of areas according to a similarity measure and combining them to form a cluster. In the furthest neighbor method, the distances between clusters are determined by the greatest distance (i.e., the lowest similarity measure) between any two areas in the different clusters.

**Results**

Twenty-nine prefectures in total culled bears owing to their nuisance behavior over 12 years. Data from six prefectures (Mie, Nara, Okayama, Saitama, Tokyo, and Wakayama) were excluded from the analysis because the annual number of bears killed was almost 0 and the maximum was less than 10.

The difference in the number of bears culled in each area was normally distributed \( (P > 0.1) \). Pearson correlation coefficient matrices (Tables 1 and 2) indicated that the areas could be divided into two groups, eastern and western parts of Honshu Island, between Nagano and Toyama. There was no significant positive relationship between any two areas in the eastern and those in western groups \( (Ps > 0.05 \text{ in all cases}) \). Three areas, Gifu, Kitakami, and Shizuoka, had no significant correlation coefficient with any other area \( (Ps > 0.05 \text{ in all cases}) \).

The dendrogram (Fig. 2) can be read from left to right, where the earlier areas grouped together have greater similarity. There was a relative gap in the decrease of similarity (from 0.613 to 0.402) between the 17th and 18th nodes in the order of grouping (Fig. 2). At this point, the patterns in the number of bears culled in 22 areas were divided into four clusters. Cluster A covered nine prefectures, 3 of which (Fukui, Ishikawa, and Toyama) formed a sub-cluster, and 5 of which (Hiroshima, Hyogo, Shimane, Tottori, and Yamaguchi) formed another sub-cluster. Then Shiga was merged into the group containing these two sub-clusters.

Cluster B covered Fukushima and Tochigi and then Miyagi. Cluster C covered two groups: one included Yamagata and Shimokita, and the other Akita, Aomori,
and Iwate. In the last cluster, D, there were also two sub-clusters containing two areas each, that is, Nagano-Yamanashi, and Gunma-Niigata. Four areas of Gifu, Kitakami, Kyoto, and Shizuoka were not grouped.

After the relative gap in the decrease of similarity, Kyoto was grouped together with cluster A at 20th node, and Kitakami, Shizuoka, and Gifu were grouped at the 21st node. The clusters C and D merged into a group at the 19th node, and then with cluster B at the 22nd node.

Although there were some differences in the patterns of fluctuation, the fluctuation was roughly consistent for the areas of any one cluster (Fig. 3). Furthermore, the patterns in the area clustered into B, C, and D, which together formed a larger group, were very similar. However, there was a difference in the whole pattern between cluster A and clusters B-C-D, although the year of the peak was sometimes consistent.

**Discussion**

Fluctuation in the number of culled bears showed regional patterns along a geographical gradient. There is likely to be a gap between Toyama and Nagano (see Fig. 1) in patterns. Cluster A consisted of all the areas

| Table 1. | Pearson correlation coefficient \( (r) \) matrix based on the difference in the number of bears culled from a given year to the next (1993–2004) in 12 areas from 11 prefectures (east of Nagano), Japan. Only significant \( (P < 0.05) \) positive coefficients are listed. |
|---|---|---|
| Aomori | 0.829 |  |
| Akita | 0.692 | 0.948 |
| Iwate | 0.832 | 0.915 | 0.914 |
| Yamagata | 0.917 | 0.862 | 0.718 | 0.753 |
| Miyagi | 0.750 | 0.635 |
| Fukushima | 0.737 | 0.735 | 0.862 |
| Tochigi | 0.649 | 0.616 | 0.841 | 0.944 |
| Gunma | 0.687 | 0.758 | 0.638 | 0.835 | 0.797 |
| Niigata | 0.689 | 0.800 | 0.741 | 0.693 | 0.793 |  |
| Nagano | 0.652 | 0.663 | 0.751 | 0.783 | 0.775 |
| Yamanashi | 0.725 | 0.726 | 0.667 | 0.796 | 0.609 | 0.640 | 0.714 | 0.613 | 0.840 |

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Table 2. Pearson correlation coefficient \( (r) \) matrix based on the difference in the number of bears culled from a given year to the next (1993–2004) in 10 prefectures (west of Toyama), Japan. Only significant \( (P < 0.05) \) positive coefficients are listed.
located west of Toyama (the western part of Honshu Island), and clusters B, C, and D, which formed a larger cluster at a later node, made up the area east of Nagano (the eastern part of Honshu Island) (Fig. 2). In all of the clusters, areas (prefectures) grouped into the same sub-cluster are geographical neighbors (Figs. 1 and 2). Thus, the number of culled bears appears to fluctuate with an inter-prefectural factor.

One of the most likely factors is hardmast production level, but the mast producing trees that influence on bear behavior should differ among regions with a range of the trees. Two major clusters shown in this study (cluster A and clusters B–D) appear to reflect a difference in the species found between western and eastern Japan on which bears mainly rely. Oka et al. (2004) suggested the likelihood that the number of bears culled in 5 areas belonging to cluster C is related to the beechnut production level. It is likely that bears in the eastern part of Japan (clusters B–D) mainly depend on the beech. Bears in the western part of Japan are likely to rely on another species such as Quercus, considering that the distribution of F. crenata is scarce (Ministry of the Environment 2004). In fact, the number of bears observed in residential areas in Hyogo consumed a significant amount of acorns (Q. crispula) but not of beechnuts (Taniguchi and Osaki 2003). However, the hypothesis that bears in the western part of Japan might also depend on the beechnut cannot be denied, when the difference in patterns of the number (Figs. 2 and 3) may be explained by asynchrony in beechnut masting with the eastern part of the Honshu Island. Nagai (1998) pointed out the significance of both F. crenata and Q. crispula to the population in Toyama which is grouped into cluster A. Mizoguchi et al. (1996) reported that bears in the Japan-Sea-side largely depend on F. crenata while Hashimoto et al. (2003) reported that those in the Pacific-side are largely dependent on Q. crispula. It is likely that which species and how strongly bears rely on them may vary along both the North-South and the East-West axes of the Honshu Island.

However, both parts of Japan are much wider (700–800 km) than the synchronous scale of masting trees (10–100 km, Kelly et al. 2000). Suzuki et al. (2005)

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**Fig. 2.** Dendrogram of the grouping of 25 areas from 23 prefectures in Japan in terms of the difference in the number of bears culled from a given year to the next (1993–2004) using the furthest neighbor method in cluster analysis. The number in parenthesis corresponds to the prefecture number in Fig. 1. Numbers (1–23) near nodes indicate the order of grouping. Four groups (A–D) were clustered at the line drawn between the 17th and 18th nodes of grouping.
showed that the production level of *F. crenata* was synchronized at the scale of 60–190 km. Roughly synchronous fluctuations in the number of bears culled between the areas of clusters B and D and those of cluster C (Fig. 3) may not exactly mean that the beechnut production level is strictly synchronized in the whole eastern part of Japan. Further, the Pearson’s *r* used as similarity measures in this study may be rather exaggerated by some concurrent sharp fluctuations. The concurrence of nuisance bears at a larger scale may be caused by years of poor harvest following an abundant harvest. For example, in 2000, when masting was recognized in the whole Tohoku district (Suzuki et al. 2005), a good crop was also observed in central Japan (Sato 2001). Then, the total number of bears culled in Japan markedly increased in 2001, and this peak was explained by the considerable increase in bears culled in the areas of clusters B-C-D (Japan Wildlife Research Center 2005). On the other hand, although acorn production is known to vary greatly amongst areas and amongst individual trees (e.g., Koenig et al. 1994; Greenberg 2000), Koenig and Knops (1997) reported that *Quercus* in California showed a spatial synchrony in seed production within a range of at least 300 km. Unfortunately, information on the synchronous masting scale of *Quercus* in Japan is insufficient (Masaki and Shibata 2005).

Geographically synchronous good and poor harvests in two successive years may cause the fundamental rise and fall in the number of nuisance bears. The fluctuation patterns in the number of culled bears should be arranged by circumstances surrounding the bear population, such as the social consciousness of bears and/or their population size and structure.

Four areas (Kitakami, Shizuoka, Gifu, and Kyoto) were not merged into any clusters by the 18th node in the order of grouping (Fig. 2). Among them, bears in Shizuoka, and Gifu had been culled to reduce forestry damage (Torii 1989; Yoshida et al. 2002). As these areas had no significant correlation coefficient with any other areas, fluctuation patterns in the number of bears culled in areas suffering forestry damage appear to differ from those in residential areas by invaded by bears. Actually, in Kyoto, 41% of bears on average (from 1992 to 2004) were culled in residential areas (Kyoto Prefecture 2004),
and there were significantly positive correlations with Hyogo and Shimane (Table 2), leading to these areas being merged with cluster A at the 20th joint (Fig. 2). On the other hand, the Kitakami area suffered damage only in residential areas. This area has a major problem in that the bears’ habitat may have shifted to residential areas (Oka 2003), and there are no correlations between the number of bears culled and either beech nut production (Oka et al. 2004) or Q. crispula acorn production (the number of culled bears: Oka et al. 2004; acorn production level: Masaki and Shibata 2005).

Several prefectures have started monitoring hardmast production for a bear-warning system after 2004. The regional concurrence in the number of culled bears supports the theory that nuisance behavior in residential areas might be caused by poor hardmast production, and does not eliminate the possibility of forecasting the increase of nuisance bears based on hardmast monitoring. Which species and how strongly bears depend on them should be substantiated by collating the results of monitoring hardmast production level with the record of culled bears in residential areas in the next decade.

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References


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