

Estimation of feeding history by measuring carbon and nitrogen stable isotope ratios in hair of Asiatic black bears

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Abstract: To investigate feeding habits, carbon and nitrogen stable isotope ratios were measured in hair sampled from Asiatic black bears (*Ursus thibetanus*) inhabiting an alpine area, including the Northern Japanese Alps and the periphery of villages in Nagano Prefecture, in central Japan. Asiatic black bears in the Northern Japanese Alps are subject to little human influence, but in rural areas human encounters with bears seeking food in cornfields and garbage have become an issue that needs to be resolved. We investigated the feeding habits of bears by analyzing the isotopic changes along the entire length of hair samples. Rural bears, including nuisance bears, showed slightly higher $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values than alpine bears, suggesting that rural nuisance bears may have greater access to anthropogenic food resources than their alpine counterparts. Hair samples were further examined by growth section analysis (GSA), in which sectioned samples from the root to the tip are used for isotopic analysis, to estimate feeding history during hair growth. Hairs of alpine bears exhibited low $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values from the root to the tip, and the deviation was small. In contrast, hairs of rural bears, particularly of nuisance bears, showed large deviations in isotope values. One bear captured in a cornfield showed high $\delta^{13}\text{C}$ values at its hair root. Another bear that thrived on garbage showed high $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values at its hair root, similar to those of Japanese people. One captured bear, assumed to be part of nuisance activities, showed low $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values from hair root to tip, suggesting that captured bears are not always the ones causing damage. By comparing and classifying GSA fluctuation patterns, we estimated the dependence of nuisance bears on human-related food sources. We expect these methods to provide relevant information for bear conservation and management programs.

Key words: Asiatic black bear, carbon isotope, feeding history, growth section analysis, hair, nitrogen isotope, stable isotopes, *Ursus thibetanus*

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An estimated 10,000–15,000 Asiatic black bears (*Ursus thibetanus*) inhabit Honshu, Japan's largest and most populated island (Hazumi 1994). However, bear habitat is thought to be decreasing nationwide; bears are extinct in Kyushu and endangered in Shikoku. Further, bear populations in Honshu are becoming isolated, particularly in the western part of the island, where some populations have been labeled as threatened in the Japanese Red Data book published by the Ministry of the Environment (Ministry of the Environment 2002).

Asiatic black bear depredation levels remain high in Japan. Over 1,000 Asiatic black bears are killed each year to control nuisance activity, in addition to the roughly 1,000 bears that are killed during the hunting season (Hazumi 1994). Nuisance activity includes stripping tree bark; raiding crops, orchards, apiaries, and fish farms; feeding from compost heaps and garbage; and attacking humans and livestock (Azuma and Torii 1980, Furubayashi et al. 1980, Watanabe 1980, Hazumi 1994, Huygens and Hayashi 1999, Yoshida 2003). When bear depredation is discovered, local hunters set cage traps to capture and kill the bear. However, the systematic killing of nuisance bears has not reduced overall depredation rates (Huygens and Hayashi 1999,

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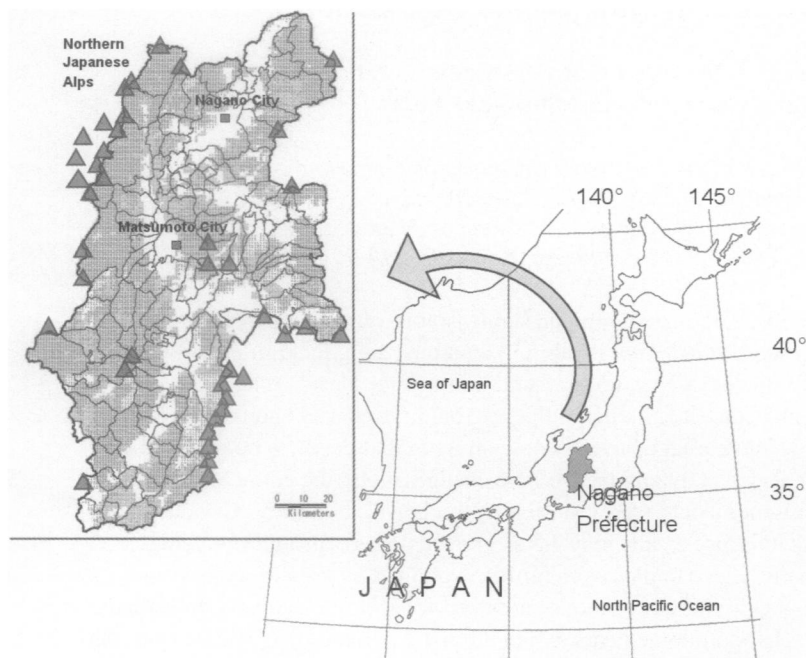


Fig. 1. Study area, Nagano Prefecture, Japan. Shaded area represents distribution of Asiatic black bears in 2000 (Nagano Prefecture, 2002).

Huygens et al. 2004), partly because the killed bears are not always the ones causing the damage. Although the 1999 Wildlife Protection and Hunting Law stipulates that the conservation and management of bears must be conducted on a scientific basis, nuisance bears are systematically killed without any scientific assessment of the efficacy of this method in reducing depredation.

We compared the feeding habits of alpine bears and rural bears including nuisance bears and determined their feeding histories by means of carbon and nitrogen stable isotope analysis. The analysis allowed us to evaluate whether bears that were caught in cage traps were actually nuisance bears.

Obtaining dietary information often depends on direct feeding observations and scat and stomach content analyses, and may be biased by the limited observation time, the absence of soft-bodied prey, or the presence of bony parts from prey that may or may not have been assimilated by wildlife (Hilderbrand et al. 1996, Nakashita 2003, Mizukami et al. in press). The analysis of stable isotopes in animal tissue overcomes some of these disadvantages (Robbins et al. 2004).

Carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotope signatures of animal tissue provide information about diet, and hence the environment in which the animal lived, because carbon and nitrogen stable isotope ratios in

consumer tissues can be related to those in consumers' diets (DeNiro and Epstein 1978, 1981; Minagawa and Wada 1984). The turnover of stable isotopes in tissue is related to the metabolic activity of that tissue (Tieszen et al. 1983), so the isotopic signature of different tissues from the same consumer can provide short- and long-term dietary information (Hobson and Clark 1992, 1993). Hair is particularly useful in analysis of isotopic signatures because, in comparison with tissues such as blood (red blood cells and plasma), bone collagen, skin, muscle, and adipose, it (1) archives temporal (e.g., seasonal) fluctuations in diet isotope composition; (2) can be obtained in a non-invasive manner; and (3) preserves diet information over time excepting quiescent phases (Nakamura et al. 1982; Michael et al. 2003, Nakashita 2003, Mizukami et al. in press). Nakashita (2003) and Mizukami et al. (in press) proposed the growth

section analysis (GSA) method and showed that bear hair may reflect feeding habits and therefore enable the reconstruction of feeding history.

Study area and methods

We conducted our study in Nagano Prefecture, which is located in central Honshu, the main island of Japan (Fig. 1). The prefecture is mountainous, with several peaks above 2,500 m in elevation and the highest over 3,100 m. Large tracts of mountainous areas are uninhabited by humans, and a majority of the 2.2 million people are concentrated on a few plains. Agriculture has historically been an important part of the prefectural economy, but its importance has been decreasing; it represented only 4.7% of the gross prefectural product in 1994 (Huygens and Hayashi 2001a, Huygens et al. 2001).

Approximately 1,300–2,500 Asiatic black bears are distributed throughout the prefecture (Nagano Prefecture 2002), and they are not considered endangered (Sato 2003). Arable land reaching the edge of forested mountains is intensively used for agriculture. Because of this, conflicts between humans and Asiatic black bears are common (Huygens and Hayashi 1999, Nagano Prefecture 2002). Bears debark trees in plantations and raid crops, orchards, apiaries, fish farms, and garbage

Table 1. Asiatic black bears used in the hair growth section analysis (GSA) for a study in the Nagano Prefecture.

Category	Sample	Sampling date	Sex	Weight (kg)	Values of whole hairs		Cutting length in sections (mm)	Site of capture	Reason for capture
					$\delta^{13}\text{C}(\text{‰})$	$\delta^{15}\text{N}(\text{‰})$			
Alpine	bear 1	16 Jun 2002	M	102	-23.4	0.4	5	mountains	for study
	bear 2	11 Jun 2002	M	20	-22.8	2.8	5	mountains	for study
	bear 3	23 Sep 2001	F	51.5	-23.9	1.9	3	mountains	for study
Rural	bear 4	28 Aug 2001	F	77.5	-21.4	3.2	3	in cornfield	nuisance
	bear 5	6 Sep 2001	F	~90	-22.4	3	3	garbage site at hotel	nuisance
	bear 6	14 Sep 2001	M	96.5	-20.1	5.4	3	resort	nuisance
	bear 7	25 Aug 2003	F	60	-23.0	2.8	5	woods near cornfield	suspected nuisance

disposal sites. Raiding cornfields and garbage disposal sites in resort areas is the most serious problem in the study area. Bears living in deep mountain ranges (such as the Northern Japanese Alps) are thought to make little use of anthropogenic food.

The diet of non-nuisance bears shifts from oak (*Quercus* spp.) acorns left over from the previous fall and dwarf bamboo (*Sasa* spp.) leaves and shoots in spring, to succulent forbs and soft mast in summer, to hard mast, including oak acorns, chestnuts (*Castanea crenata*), walnuts (*Juglans mandshurica*), and Korean stone pine (*Pinus koraiensis*) seeds, in autumn. They also consume insects throughout the growing season, particularly in summer, and occasionally scavenge serow (*Naemorhedus crispus*) (Takada 1979, Huygens 2001, Huygens and Hayashi 2001b, Huygens et al. 2003).

Sample collection

Hair was sampled from 22 alpine bears (those that live in the mountains, mainly the Northern Japanese Alps) and 49 rural bears in 2001–03. All bears in this group were confirmed by radiotelemetry to have no access to humans (Izumiyama and Shiraishi 2004). Rural bears lived near humans and included bears that caused nuisance activities. Most of the bears in the present study were captured using barrel traps and anesthetized with a blowgun. The other bears were caught by various means (either captured in traps set for wild boars [*Sus scrofa*] or Japanese macaques [*Macaca fuscata*], killed by hunters due to nuisance activity, or hunted during the hunting season, Nagano Prefecture 2002).

Whole hairs, including hair roots, were plucked from the back and shoulders of captured bears. Hair was stored in plastic bags and transferred to the laboratory without treatment. Permission for capturing Asiatic black bears for academic uses was obtained from Nagano Prefecture.

Sample analyses

Hair samples were rinsed with 2:1 chloroform–methanol solution to remove lipids, then air-dried. Samples were then analyzed in 2 ways. Whole hairs from all samples were analyzed to generate average values of entire hairs. To estimate diet over time with the GSA method, hair samples were cut from root to tip in sections of 3 or 5 mm. The corresponding sections of hairs were gathered to obtain a sufficient amount for analysis and analyzed separately. We used hair samples from 3 alpine bears (bears 1–3), 3 nuisance bears (bears 4–6), and 1 rural bear (bear 7) suspected of nuisance activity (Table 1). The 3 alpine bears confirmed by radiotelemetry to have no access to areas inhabited by humans were selected as typical alpine bears. The 3 nuisance bears were selected as typical nuisance bears because they destroyed a cornfield (bear 4), ate hotel garbage (bear 5), and lived in a resort area (bear 6). The hair of a rural bear (bear 7) that lived near a cornfield was tested by GSA to determine if it was actually depredate crops.

Samples were enclosed in a tin cup and combusted in an elemental analyzer (FlashEA1112; ThermoQuest, Bremen, Germany) interfaced to an isotope ratio mass spectrometer (ThermoQuest Delta Plus, ThermoQuest), in which the carbon and nitrogen isotope ratios were analyzed. The results are reported as parts per thousand of the isotope (‰) relative to a standard $\times(R_{\text{STANDARD}})$ AS FOLLOWS:

$$\delta^{13}\text{C} \text{ or } \delta^{15}\text{N} = [(R_{\text{sample}}/R_{\text{standard}}) - 1] \times 10^3,$$

where R is $^{13}\text{C}/^{12}\text{C}$ or $^{15}\text{N}/^{14}\text{N}$. R_{standard} for $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ was the Pee Dee Belemnite (PDB) standard or atmospheric nitrogen (AIR), respectively. Standard deviations of the isotope analysis were 0.1‰ and 0.2‰ for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$, respectively. GSA was

Table 2. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of whole hair of alpine and rural Asiatic black bears in Nagano Prefecture, central Japan, 2001–03.

	n	$\delta^{13}\text{C}(\text{‰})$			$\delta^{15}\text{N}(\text{‰})$		
		Mean	SD	Range	Mean	SD	Range
Alpine bear	22	-23.2	0.6	-24.0–-21.9	1.9	1	0.4–4.1
Rural bear	49	-22.6	1.3	-24.1–-16.7	2.5	1.2	0.2–5.4

repeated twice for each hair section. The differences in results between duplicate samples were within analytical error.

Results

Analysis of whole hair

The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of alpine bears were -23.2‰ (SD = 0.6‰) and 1.9‰ (SD = 1.0‰), respectively, whereas those of rural bears were -22.6‰ (SD = 1.3‰) and 2.5‰ (SD = 1.2‰), respectively (Table 2 and Fig. 2). Slightly higher $\delta^{13}\text{C}$ values were obtained for rural bears than for alpine bears, but the difference was not statistically significant (Mann-Whitney *U*-test: $U = 387.5$, $P > 0.05$). The $\delta^{15}\text{N}$ values of

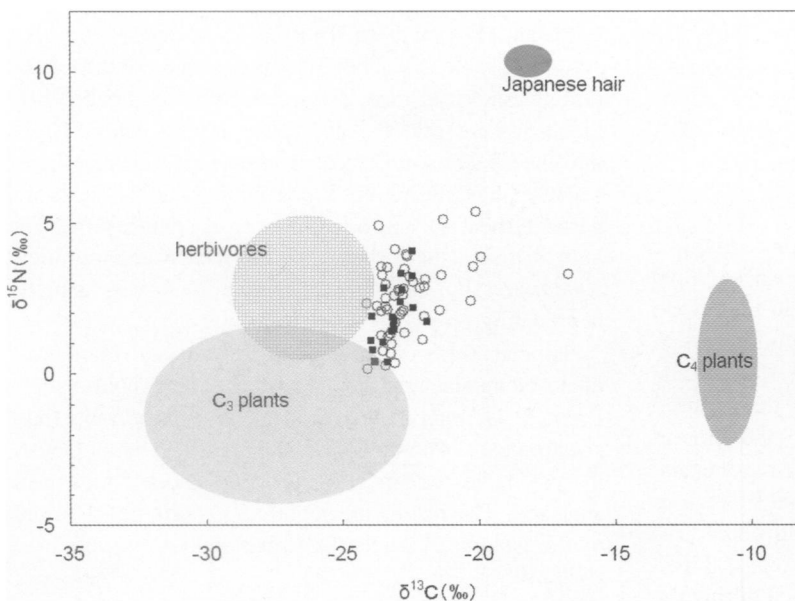


Fig. 2. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ of whole hairs of alpine and rural Asiatic black bears, with literature values of C_3 and C_4 plants, herbivores, and Japanese hair for alpine (■) and rural (○) bears (including nuisance bears). Human hair isotope levels are expected to be close to those of bears that eat garbage. Data on plants, herbivores, and hair from Minagawa and Akazawa (1988), Minagawa et al. (1986), Minagawa (2001) and Nakashita (2003).

rural bears were slightly higher than those of alpine bears ($U = 345.0$, $P < 0.05$). The higher mean $\delta^{15}\text{N}$ value of rural bears may reflect a higher proportion of foods of animal origin in the diet of those bears. Both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of rural bears have larger ranges than those of alpine bears, probably due to the wider diversity of foods of rural bears. The range tends to expand toward the values for Japanese hair, and this probably indicates that rural bears take foods of wider diversity. We speculate that high $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values imply nuisance bears, and that high $\delta^{13}\text{C}$ values show a dependency on corn, a C_4 plant.

Plants are classified as C_3 or C_4 based on metabolic criteria, and the stable isotope signature differs for C_3 and C_4 plants. Corn is one of the few C_4 plants in the region and the only one that is common enough to be an important bear food. Therefore, the stable isotope pattern in hair that matches that of a C_4 plant strongly suggests that the bear eats corn.

Analysis of hair sections

In alpine bears, the deviations of $\delta^{13}\text{C}$ were very small and those of $\delta^{15}\text{N}$ were smaller than those of nuisance bears (Fig. 3). The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of bear 1 ranged from -24.3 – -23.1‰ and from -0.9 – 1.4‰ , respectively. The range of $\delta^{15}\text{N}$ of bear 1 was the narrowest among the 6 bears (Fig. 3), indicating that bear 1 ate similar foods throughout hair growth. The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of bear 2 ranged from -23.5 – -22.1‰ and from 0.3 – 4.3‰ , respectively, and those of bear 3 ranged from -24.1 – -22.9‰ and from -0.5 – 3.4‰ , respectively. Alpine bears showed a tendency for $\delta^{15}\text{N}$ values to be higher at the hair tip than at the root and for the values to decrease with time.

On the other hand, the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of nuisance bears had wide ranges and demonstrated different patterns (Fig. 3b). The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of bear 4 ranged from -23.2 – -14.6‰ and from 0.3 – 4.6‰ , respectively, and those of bear 5 ranged from -23.8 – -20.2‰ and from 0.3 – 7.7‰ , respectively. Bears 4 and 5 showed an increase in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values with hair growth. Bear 6 also had wide ranges ($\delta^{13}\text{C}$: -22.5 – -16.4‰ , $\delta^{15}\text{N}$: 3.0 – 6.8‰), but the

$\delta^{15}\text{N}$ values were high throughout hair growth, whereas the $\delta^{13}\text{C}$ values were low at the root and the tip and high in the middle.

Presumed feeding history of bears by GSA

According to Hilderbrand and Robbins (G. Hilderbrand, Alaska Department of Fish and Game, Anchorage, Alaska, USA, unpublished data), bears molt yearly during summer, and the summer coat is shorter than the fall and winter coat (Jacoby et al. 1999). In our investigations of Asiatic black bears, we found that hair starts to grow in May after hibernation and stops growing before hibernation. The hair that grew in the previous year molts mainly in July (Mizukami unpublished data). Therefore, we assume that the hair tip grew in spring and the hair root in fall (before hibernation) if the hair was collected before molting season, or the hair had just grown if it was collected after the molting season. Although hair during the molting season consisted of short hair grown that year and long hair grown in the previous year, the hair that was sampled before the molting season in this study was all long hair that was grown in the previous year.

In view of the above, we surmised the feeding history of bears (Fig. 4). Hair of alpine bears 1 and 2 collected in June 2002 (Table 1) should have grown the previous year because they were collected before the molting season. In contrast, the hairs of bear 3 collected in September 2002 seemed to have grown that year because they were collected after the molting season. The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of all alpine bears shifted almost vertically (Fig. 4a). The general trend of decreasing with hair growth suggested that those bears consumed only foods of C_3 plant origin throughout the season. Alpine bears seemed to have consumed mainly C_3 plants; the small amount of animal protein detected at the hair tip, which corresponded to spring, suggesting that the ratio of food of animal origin decreased with hair growth. In fall, bears prepared for hibernation by consuming mostly acorns. The pattern of $\delta^{15}\text{N}$ decreasing with time may

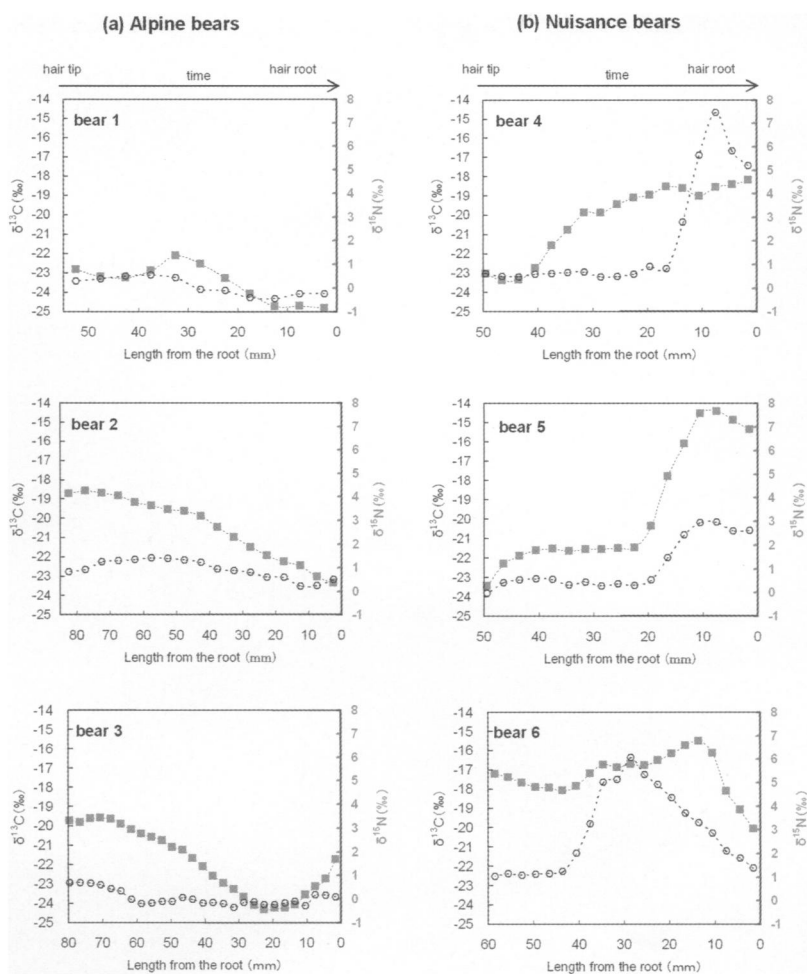


Fig. 3. $\delta^{13}\text{C}$ (○) and $\delta^{15}\text{N}$ (■) for hair sections from root to tip as measured by growth section analysis (GSA) for (a) 3 alpine bears and (b) 3 nuisance bears in Nagano Prefecture, central Japan, 2001–03. Hairs from alpine bears show little variation in $\delta^{13}\text{C}$ and slight variation in $\delta^{15}\text{N}$, whereas those from nuisance bears show large deviations in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$.

reflect a decrease in the consumption of food of animal origin, given such seasonal feeding variation. Bear 1, in particular, seemed to consume mostly C_3 plants.

$\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for nuisance bears were distributed widely (Fig. 4b). Bear 4 was killed in the end of August 2001 because it destroyed cornfields (Table 1). Considering the sampling time, the hair of bear 4 seemed to have grown that year and reflected the feeding history from spring until it was captured. The hair tip showed low $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values that were within the range of C_3 plants. However, $\delta^{15}\text{N}$ gradually increased and $\delta^{13}\text{C}$ abruptly increased to values similar

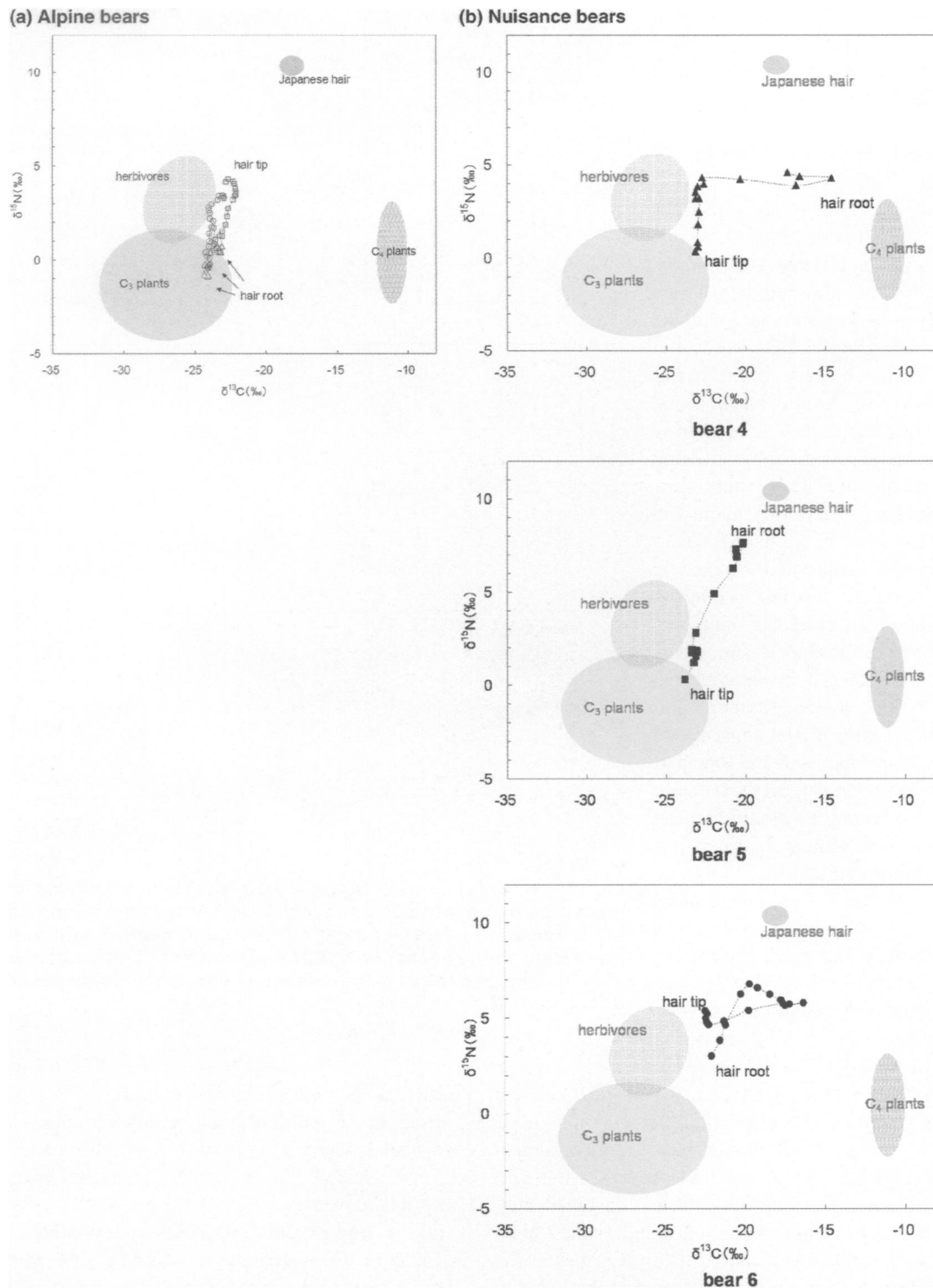


Fig. 4. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ for Asiatic black bears in Nagano Prefecture, central Japan, 2001–03. (a) Hair sections from root to tip as measured by growth section analysis (GSA) for alpine bears (Δ = bear 1, \square = bear 2, and \circ = bear 3). (b) Hair sections from root to tip as measured by GSA for 3 nuisance bears. Values of alpine bears were close to C_3 plants in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ from the root to the tip. In contrast, nuisance bears showed large deviation.

to those of C_4 plants, suggesting that bear 4 fed on mainly C_3 plants (we assume in the mountains in spring) at first, as it has been reported that bears in Japan feed on oak acorns from the previous fall and succulent forbs and grasses in spring (Takada 1979, Huygens 2001). Bear 4 then started to consume more foods of animal origin such as ants and bees, and finally shifted its principal food to corn.

Bear 5 was killed on 6 September 2001, when it was caught scavenging for hotel garbage. Based on the time of sampling, we assume the hair of bear 5 was grown that year. The $\delta^{13}C$ and $\delta^{15}N$ values were low at the hair tip, but increased simultaneously with hair growth to high values at the hair root, approaching those of Japanese people. This suggests that bear 5 fed on mainly plants in the mountains in spring and shifted garbage before it was killed. Bear 6 was killed on 14 September 2001 because it raided a resort area. This bear's hair also seemed to have grown that year as it was collected after the molting season. The $\delta^{13}C$ and $\delta^{15}N$ values of bear 6 were high from hair root to tip, suggesting that it foraged on human-related foods throughout hair growth. In particular, $\delta^{13}C$ and $\delta^{15}N$ values were high in the middle part of the hair (Fig. 3), implying that bear 6 seemed to have eaten corn and garbage in summer. The GSA suggests that bear 6 had access to human activities, consistent with radiotelemetry data from a local hunter (Shinshu black bear research group NPO, Matsumoto, Nagano, Japan, unpublished data).

Bear 7 was a rural bear suspected of nuisance activity that was captured in a trap set near a cornfield. Hairs were collected after molting, which meant that they grew that year (Table 1). Its $\delta^{13}C$ and $\delta^{15}N$ values, ranging from -24.4 – -21.8 ‰ and from 0.6 – 3.7 ‰, respectively, fell within the range of alpine bears. They were low at the hair tip and increased gradually toward the hair root in a manner similar to alpine bears (Fig. 5). It is highly likely that bear 7 was not dependent on corn. This result implies that a captured bear may not always be the one causing damage.

Discussion

The present analysis of feeding habits by measuring nitrogen and carbon stable isotope ratios is useful for revealing putative access of Asiatic black bears to human activities, because $\delta^{13}C$ and $\delta^{15}N$ values differ between native foods in the mountains and anthropogenic foods such as corn (a C_4 plant that is one of the most seriously damaged by bears), as well as garbage in rural areas.

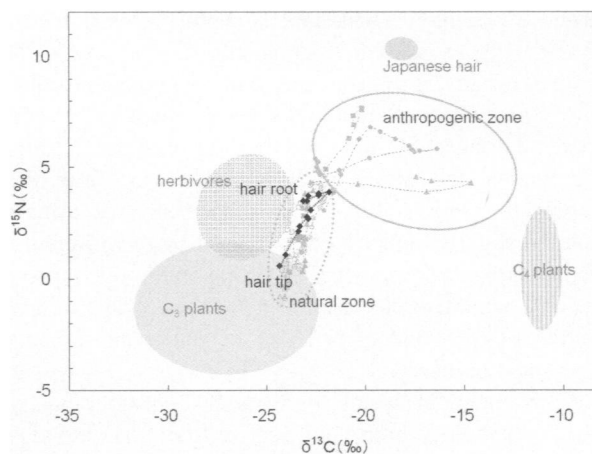


Fig. 5. Stable isotopes for hair from Asiatic black bear 7, Nagano Prefecture, central Japan. This bear was accused of depreeding corn, but the growth section analysis indicates that the bear did not consume corn.

Stable isotope studies to determine animal food habit have generally focused on whole hairs that reflect the average feeding habit during hair growth. From the results of whole hair analysis, indicating that rural bears have slightly higher $\delta^{13}C$ and $\delta^{15}N$ values than alpine bears, we presumed that the feeding habits were slightly different between the two. However, whole hair analysis cannot detect the shift of diet over time. For example, the $\delta^{13}C$ and $\delta^{15}N$ values of bear 2 were very similar to those of bear 5, but the GSA results showed different patterns between alpine and rural bears (Figs. 4 and 5). The GSA result for bear 5 suggested that the bear ate garbage, whereas the result of whole hair analysis cannot prove that bear 5 depended on garbage. Likewise, the GSA for bear 4 showed that it depended on corn only in summer.

The $\delta^{15}N$ values of alpine bears were generally high at the hair tip and decreased toward the hair root (Fig. 3). Conversely, the $\delta^{15}N$ values of rural bears except bear 6 were low at the hair tip and increased with hair growth.

The different patterns of $\delta^{15}N$ observed for the alpine bears can be explained as follows. In spring, alpine bears often eat carcasses of animals (e.g., sika deer [*Cervus nippon*]) which died in winter because of severe conditions in mountain areas. Later, alpine bears climb the mountains in search of buds after thawing in summer, while rural bears at low altitude suffer from food shortages. Alpine bears consume little food of animal

origin in the alpine belt. In fall, alpine bears move to lower altitudes in search of acorns. Decreasing $\delta^{15}\text{N}$ from the hair tip reflects this habit and demonstrates how alpine bears overcome the severe environment and food shortages during summer (Izumiyama 2001, Izumiyama and Shiraishi 2004). However, from the vertical fluctuations (Fig. 4a) for alpine bears, we surmise that the slightly higher $\delta^{15}\text{N}$ is caused by the difference in the C_3 plants consumed, depending on the site of plant growth, habitat, or elevation. We need to conduct further studies of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ levels in plants and animals consumed by bears.

Conversely, in spring rural bears consume mainly plants including, buds and acorns from the previous fall, but suffer from food shortage in summer. In summer, the dependence of bears on insects, including ants and bees, increases (Takada 1979, Ishida 1995, Hashimoto and Takatsuki 1997). This may explain why rural bears showed an increase in $\delta^{15}\text{N}$ with hair growth. Bears that raided cornfields or garbage became nuisance bears.

Based on the GSA patterns, we classified bear habitat into natural and anthropogenic zones (Fig. 5). The natural zone is the isotopic range for bears that have no access to human activities. Because the isotopic range for bear 7 was within the natural zone, we infer that it did not depend on corn. We could not detect its eating other crops from this analysis, because most crops are C_3 plants. However, we can say that bear 7 did not eat anthropogenic foods, because most crops around the foothills in this district are corn in summer. Moreover, we have no information on any other crop damage in this town from the inhabitants. On the other hand, the anthropogenic zone is the isotopic range for nuisance bears, and isotope values are close to human hair and C_4 plants. We surmise that bears distributed in the anthropogenic zone living in this district depended on human activities.

Conclusions

We validated the feeding habits of individual bears by GSA to a considerable extent. From the GSA patterns and the hair growth cycle, further information on bear ecology and its environment was obtained. Furthermore, GSA allowed us to evaluate whether a suspected nuisance bear was actually related to damage. Many bears are killed because of nuisance activity without any scientific evidence. This study provides a scientific method that is applicable to bear conservation and management programs.

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