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Relationship between diet and occurrence around human settlements in Asiatic black bears

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Abstract: Increased occurrences of bears in human settlements in search of food have led to a high incidence of human–bear interactions in Japan; therefore, a better understanding of bear occurrence in relation to bears' diet is required to establish effective management practices. In this study, we investigated the composition of the diet of Asiatic black bears (*Ursus thibetanus*) and the number of bear sightings in Shirakawa Village, Gifu Prefecture, Japan, during pre- and hyperphagic periods (Aug–Dec) from 2008 to 2016. In years with low numbers of sightings, bears consumed natural foods in natural areas, such as fruits of Japanese bird cherry (*Prunus grayana*), dogwood (*Swida controversa*), oak (*Quercus* spp.), and beech (*Fagus crenata*), which constituted the main part of the bears' diet in our study area. In years with a medium number of sightings, bears consumed both natural and anthropogenic foods in or near human habitations, such as Japanese chestnut (*Castanea crenata*) and kaki (*Diospyros kaki*). In the high-sighting year of 2014, bears exhibited a particularly strong preference for Japanese walnut (*Juglans mandshurica*) and kaki. The number of bear sightings was negatively related to the consumption rates of Japanese bird cherry, dogwood, oak, and beech, and positively related to the consumption rates of Japanese walnut, Japanese chestnut, and kaki. These findings suggest that consumption of fleshy fruits in late summer or hard mast in autumn in or near human settlements has a large effect on the risk of bear–human interactions.

Key words: bear–human conflict, Fagaceae, fleshy fruit, food habits, hyperphagic period, Japan, scat analysis, *Ursus thibetanus*

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Continual conflicts between humans and bears have become a serious problem in North America, Europe, and Asia (Beckmann and Berger 2003, Perveen and Abid 2013, Elfström et al. 2014). In Japan, Asiatic black bears (*Ursus thibetanus*) occupying areas in and around human settlements can damage property and threaten human safety (Yokoyama 2011). Local governments have addressed this issue by killing bears (Ministry of the Environment 2007), which resulted in >2,000 bears being killed annually in 2004, 2006, 2010, 2012, and 2014 (Ministry of the Environment 2015). The estimated population of Asiatic black bears in Japan is only 13,000 to 21,000 (Yoneda and Mano 2011); therefore, these management kills, combined with the conversion of broadleaved forest into coniferous forest, have a large negative impact on the local bear population (Horino and Miura 2000).

Although bears generally avoid humans and human settlements (Takahata et al. 2014, Nemoto et al. 2016), they are believed to roam to search for food close to human settlements in the autumn during years of hard mast failure. In fact, Asiatic black bears come into human settlements more often during years of hard mast failure (Taniguchi and Osaki 2003, Oka et al. 2004, Mizutani et al. 2013). Similarly, grizzly bears (*U. arctos*) and American black bears (*U. americanus*) search for food close to

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human settlements when major natural foods are scarce (Rogers 1987, Mattson et al. 1992). However, it has been reported that bears sometimes come into human settlements in late summer before the production of hard-mast species in autumn (Oka et al. 2004, Maruyama 2006, Izumiyama et al. 2008). In order to develop more sustainable bear management methods, it is essential to improve our knowledge of bears' response to food availability in relation to bear occurrences in human settlements (Oka et al. 2004).

Asiatic black bears in Shirakawa Village, Gifu Prefecture, Japan, switch their major food from fleshy fruits in late summer (Aug–Sep) to hard mast in autumn (from Oct; Mori et al. 2018). Our objective was to determine whether key food sources influence bear occurrence in residential and agricultural land in Shirakawa Village by investigating the composition of the bears' diet. We used bear sightings in Shirakawa Village from 2008 to 2016 as an index of bear occurrences and performed scat sampling during August–December to examine the bears' dietary habits. We predicted that the number of bear sightings would be related to the consumption rates of natural foods, both fleshy fruits and hard mast, because fleshy fruits are also important foods for bears in late summer before they enter hibernation (Mori et al. 2018).

Study area

Shirakawa Village (36°16′N, 136°54′E) is located in northwest Gifu Prefecture, Japan (Fig. 1). The study area covers 356.6 km^2 and has a population of approximately 1,600. The village was declared a United Nations Educational, Scientific and Cultural Organization World Heritage Site in 1995, resulting in >1.5 million tourists visiting the area each year. The Shogawa River flows through the valley, passing through the center of the residential area. The area has a humid continental climate with a mean annual precipitation of 2,522 mm and heavy snowfall in winter. The mean annual temperature in summer and winter is 22.0°C and −0.1°C, respectively (Japan Meteorological Agency 2008–2016). Approximately 96% of the area is dominated by mountain forest, particularly broadleaf forest, and 0.4% is cultivated land (Committee for Compilation of the History of Shirakawa-mura 1998). The vegetation includes beech (*Fagus crenata*), Mongolian oak (*Quercus crispula*), and konara oak (*Q. serrata*) up to an altitude of 1,500 m, with Russian rock birch (*Betula ermanii*) and Marie's fir (*Abies mariesii*) at 1,500–2,400 m and stone pine (*Pinus pumila*) above 2,400 m.

Shirakawa Village and its surroundings include natural areas (mostly forest outside the human area), near-human areas (with a distinct border between the natural and human areas), and a human-dominated area (including human developments such as residential areas, agricultural land, camps, and parks; Fig. 2). Based on a previous study of bear dietary habits (Mori et al. 2018), we categorized their foods into 3 types: natural foods available in the natural area (Japanese bird cherry [*Prunus grayana*], dogwood [*Swida controversa*], Japanese walnut [*Juglans mandshurica*], beech, Mongolian oak, and konara oak), natural foods available in the near-human and human-dominated areas (Japanese chestnut [*Castanea crenata*] and Japanese walnut), and anthropogenic food available only in the near-human and human-dominated areas (kaki [*Diospyros kaki*]).

Methods

Sighting of bears in human habitations

We obtained information on actual bear sightings from 2008 to 2016 from Gifu Prefecture (Gifu Prefecture 2008–2016), which is considered the most reliable evidence of bear occurrence in human habitations. The residents in each municipality of Gifu Prefecture report occurrences of bears, such as actual bear sightings or evidence of bears without sightings (footprints and crop damage), in residential areas and on agricultural land to a city or town office, which collates these reports for the prefecture. The data include date and time, site type (agricultural land, forest, settlement area, or other), and number of bears (adult, adult with cubs, or cubs). We extracted information on actual bear sightings in Shirakawa Village from August to December from this data set and excluded sightings in the forest. No information was available about whether an observation was associated with a conflict between humans and bears.

Scat collection and analysis

To examine the food habits of the bears, we collected 892 scats along 11 survey routes that were 20–25 km in length and included a range of environments and topography from August to December 2008–2016. We conducted the field surveys along each route by foot once or twice per month. For each scat, we recorded the date of collection, estimated deposition date, and Global Positioning System location. We collected few scats in December, so we combined the November and December data in the analyses.

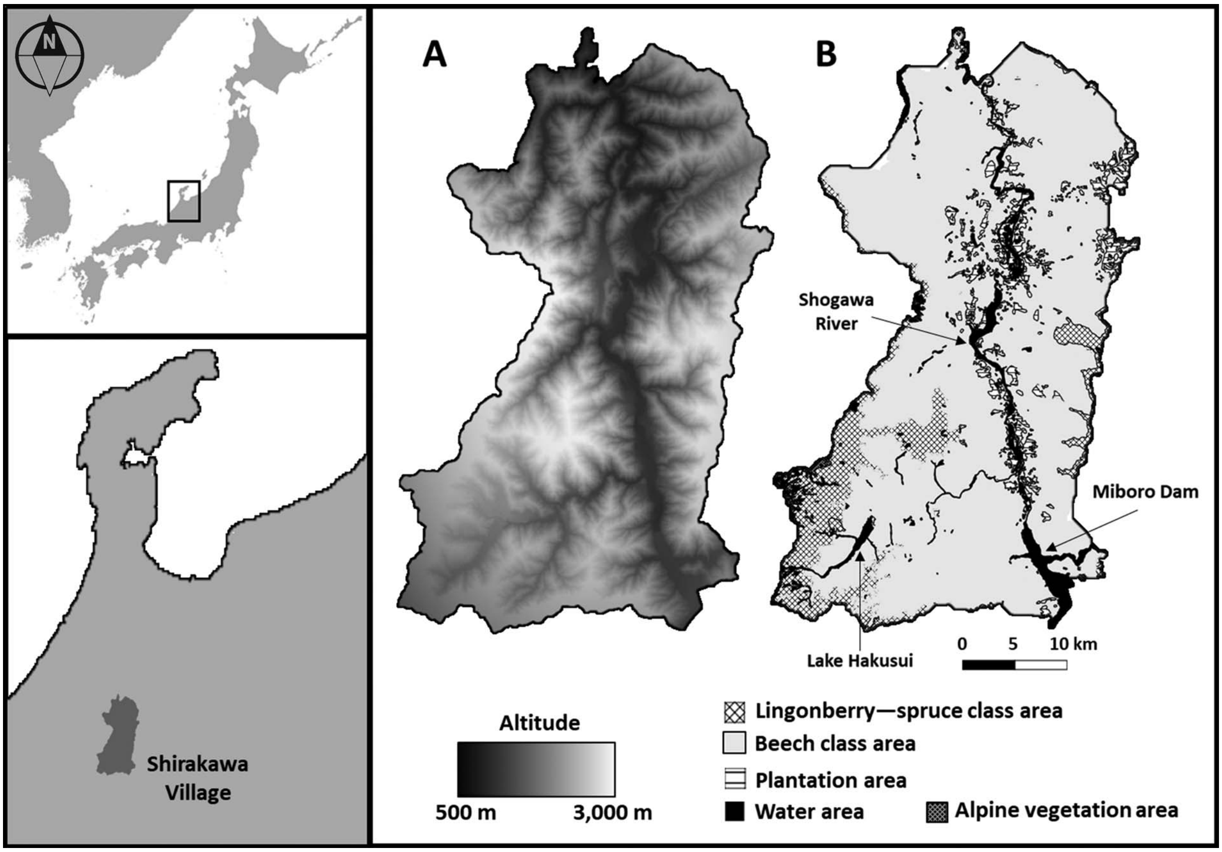

Fig. 1. Graded altitude map (A) and land cover map (B) of the study area in Shirakawa Village, Gifu Prefecture, Japan, where we investigated the composition of the diet of Asiatic black bears (*Ursus thibetanus*) and the number of bear sightings during pre- and hyperphagic periods (Aug–Dec) from 2008 to 2016.

We homogenized each scat sample by mixing and rinsing more than a quarter of the sample with water over a series of sieves (2.0, 1.0, and 0.3 mm in diameter) to extract individual food items. We identified each food item that remained on the sieve to the lowest possible taxon. We used 2 types of scat analysis to evaluate occupancy, which reflects the surface area of the food items. We analyzed scat samples collected in 2008 using a modified version of the technique of Mealey (1980). We separated the scat contents by food items and placed the items on a white plastic tray with a grid of 50 squares and counted the number of squares in which each food item was present. We then divided this number by the total number of squares to obtain a percentage occupancy. We analyzed scat samples collected from 2009 to 2016 using the point frame method (Sato et al. 2000). We spread the food items out on a white plastic tray with 1 × 1-cm gridlines and counted the number of items that intersected with a line until we reached a number >400. We obtained similar results with the 2 methods because they both determine occupancy using the area covered by all food items. We converted the obtained values to volume occupancy values for use in subsequent analyses, following Sato et al. (2000).

We calculated the percentage volume (%V), percentage frequency of occurrence (%F), importance value (IV), and percentage importance value (%IV; Mealey 1980) step by step from the following formulas:

$$\text{Percentage volume } (\%\text{V}i) = \Sigma\text{volume occupancy of food item } i \,/\text{total number of scats}$$

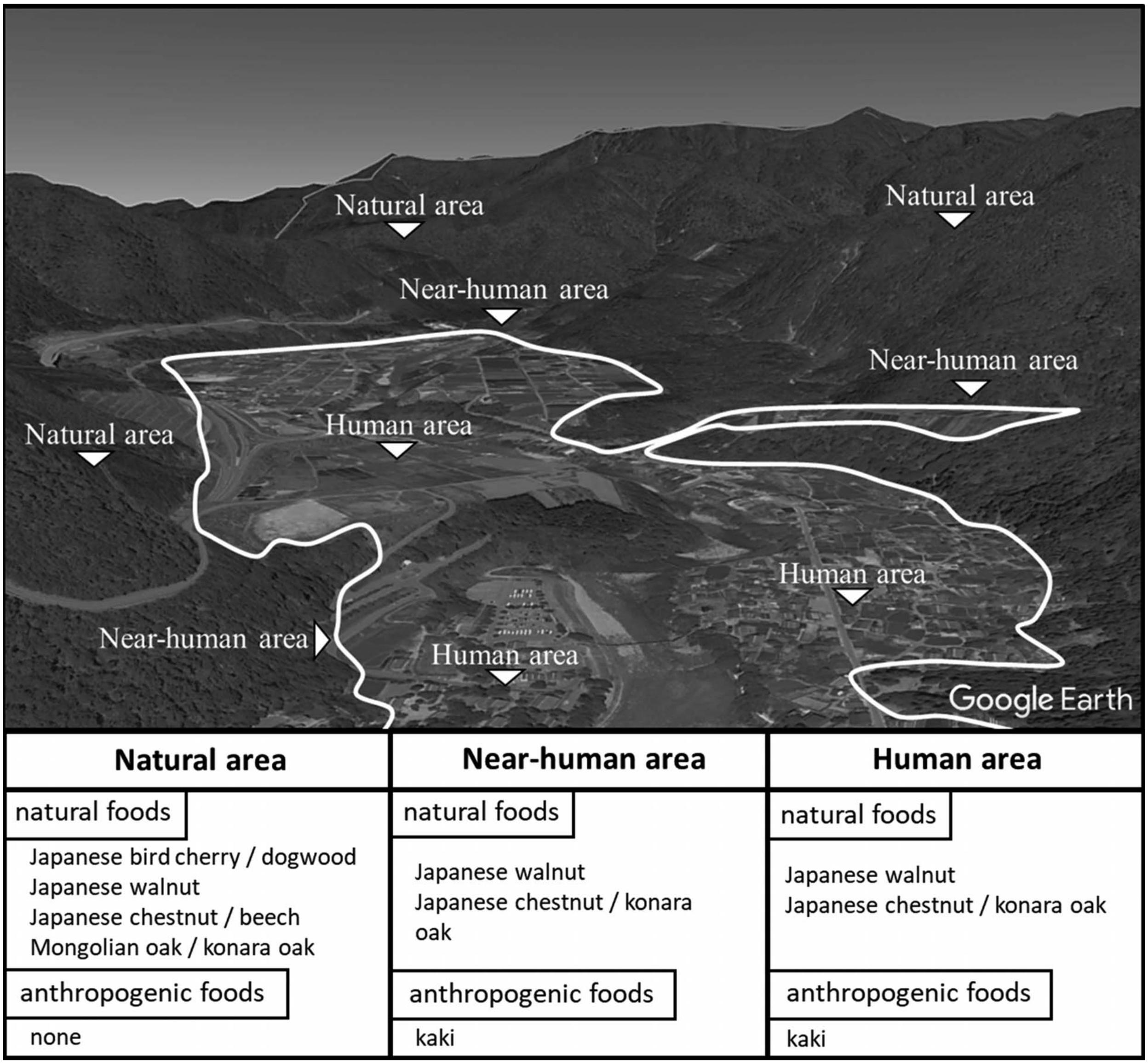

Fig. 2. Geography of Shirakawa Village, Japan, and distribution of Asiatic black bear (*Ursus thibetanus*) food sources, including natural and anthropogenic foods. The area is divided into 3 categories: natural area, near-human area, and human-dominated area. The near-human area is indicated by a distinct border between the natural and human-dominated areas (white line).

$$\text{Percentage frequency of occurrence } (\%\text{F}i) = \text{number of scats containing food item } i \,/\text{total number of scats} \times 100$$

$$\text{Importance value } (\text{IV}i) = \%\text{V}i \times \%\text{F}i/100$$

$$\text{Percentage importance value } (\%\text{IV}i) = \text{IV}i/\Sigma\text{IV} \times 100$$

In this study, we chose %IV as the indicator of the bears' diet because it establishes a relative equilibrium between the quantity and frequency of food intake (Mealey 1980).

We distinguished 11 main categories of food items: green vegetation, Japanese bird cherry, dogwood, Japanese walnut, kaki, other fruits, beech, oak, Japanese chestnut, insects, and vertebrates. When calculating occupancy, we applied the following correction factors to the volume of each food item to account for differences in their digestibility according to Hewitt and Robbins (1996): leaves, stalks, and flowers = 0.26; roots, bulbs, and fruits = 0.93; insects = 1.1; hard mast = 1.5; small mammals consumed whole = 4.0; hair and skin = 15.0.

Data analysis

We calculated the coefficient of variation (CV) for each food item to determine the yearly variability in %IV. To analyze the relationship between dietary composition and the number of bear sightings, we used a generalized linear mixed model (GLMM) with a Poisson distribution and log link function using the package lme4 (Bates 2019) in Program R.3.5.3 (R Core Team 2019). The scat samples were obtained in certain months annually; therefore, we specified month within year as a hierarchical random intercept effect. This model included the number of bear sightings in each month (Aug to Nov–Dec) from 2008 to 2016 as the response variable and the %IV of 7 fruits that accounted for >20%IV in food composition (Japanese bird cherry, dogwood, oak, beech, Japanese chestnut, Japanese walnut, and kaki) as explanatory variables. Fruit production of many trees fluctuates annually (Shibata et al. 2002), so we focused on the consumption rates of fruits in the analysis. We checked for multicollinearity among explanatory variables using variance information factors (VIF) prior to GLMM construction. All VIF values were <5, indicating no collinearity between variables (Zuur et al. 2009). We were unable to collect scat samples in August and November–December 2012, so we excluded these data from the analysis (i.e., $n = 34$). We used Akaike's Information Criterion (AIC) to evaluate the relative suitability of each model as follows: AIC = −2 (log maximum likelihood) + 2 (no. of parameters). We considered models with ΔAIC <2 as equivalent and compared AIC weights to assess the relative support of each model (Burnham and Anderson 2003). Finally, we calculated marginal ($R^2_{\mathrm{GLMM}(m)}$; variance explained by the fixed effects only) and conditional ($R^2_{\mathrm{GLMM}(c)}$; variance explained all the fixed and random effects in the model) pseudo-R^2 proposed by Nakagawa and Schielzeth (2013) for equivalent models using the package r.squaredGLMM function from the package MuMIn (Barton 2019).

Results

The numbers of bear sightings from 2008 to 2016 were 0, 2, 10, 0, 12, 3, 60, 2, and 3, respectively. From these numbers, we categorized bear sighting patterns into 3 groups: low sighting was 0–3 sightings (2008, 2009, 2011, 2013, 2015, and 2016); medium sighting was ≥10 sightings (2010 and 2012); high sighting was ≥60 sightings (2014). In medium- and high-sighting years, the number of sightings peaked in September (Fig. 3A).

The principal food of the bears was Fagaceae hard mast (~70%IV; Table 1). The bears' diet varied among years, particularly for green vegetation, which had a larger CV than did fleshy fruits and hard mast. Among fleshy fruits, the consumption of kuromoji (*Lindera umbellata*), Japanese rowan (*Sorbus commixta*), and kaki varied more than that of other fleshy fruits; whereas, among hard-mast species, the bears showed the greatest variability in consumption of Japanese walnut and Japanese chestnut. Japanese bird cherry, dogwood, oak, and beech had lower CVs than those foods.

Bears consumed natural foods in low-sighting years, and the most important bear foods differed from year to year (Fig. 3B). In 2011 and 2015, which were low-sighting years, beech was a more important bear food than in any other year, and the bears consumed mainly dogwood in August–September and hard mast, such as beech and oak, from October to December (Fig. 3B). In 2008, 2009, 2013, and 2016, which were also low-sighting years, Japanese bird cherry, dogwood, and hard mast were all important, and the bears consumed mainly Japanese bird cherry and/or dogwood in August–September and oak from October to December. In 2010, a medium-sighting year, Japanese bird cherry was an important food source, particularly in August (~90%IV); whereas, hard-mast species, such as Japanese chestnut and oak, were consumed in September and October (~90%IV and 100.0%IV, respectively). In 2012, also a medium-sighting year, the bears consumed mainly Japanese walnuts in September (~70%IV) and oak in October (~100%IV). In 2014, a high-sighting year, the bears were not documented to feed on beech, oak, or Japanese chestnut, but consumed Japanese walnut in August and September (~70%IV and ~60%IV, respectively), other fruits in October (~60%IV), and kaki in November–December (~90%IV).

The model that included Japanese bird cherry, dogwood, oak, and beech was supported as the most parsimonious model, but the second- to seventh-ranked models were also supported as candidates (ΔAIC <2, cumulative Akaike weight = 0.511; Table 2). In all these models, the number of bear sightings was negatively associated with consumption of Japanese bird cherry, dogwood, oak, and beech and positively associated with consumption of Japanese chestnut, Japanese walnut, and kaki. Most of the food items had significant effects (*P*

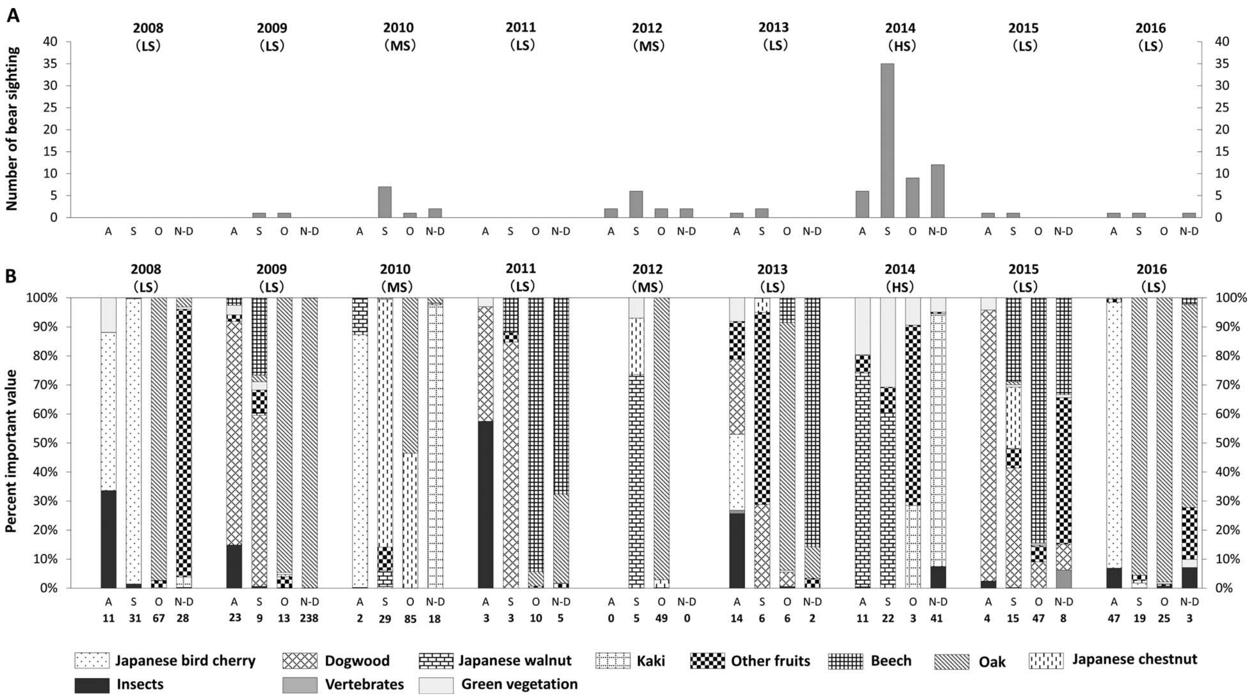

Fig. 3. Seasonal changes in the number of sightings (Panel A) and food items taken (Panel B) by Asiatic black bears (*Ursus thibetanus*) in Shirakawa Village, Japan, from August (x-axis, A), September (x-axis, S), October (x-axis, O), and November–December (x-axis, N-D), 2008–2016. The terms inside parentheses indicate bear sighting patterns: LS, low sightings; MS, medium sightings; HS, high sightings. The numbers below the x-axis represent the numbers of scat samples.

< 0.05). Marginal- and conditional pseudo-R^2 of equivalent models ranged from 0.48 to 0.69 and 0.82 to 0.89, respectively, showing good fit to the data.

Discussion

We found that the number of Asiatic black bear sightings in Shirakawa Village was significantly associated with their consumption of hard mast and fleshy fruits. In some months (e.g., Aug 2010, Aug–Sep 2011, Aug and Nov–Dec 2012, and Nov–Dec 2016), the number of scat samples was insufficient to show a significant association. However, the pattern of the association between diet and the number of bear sightings was consistent between months with a sufficient and insufficient number of samples. In our study area, bear management killing was conducted by the local government in years when the number of bear sightings was high (2010, 2012, and 2014). This may have influenced the bears' diet and the number of bear sightings in the study. We believe that our data reflect actual food consumption, regardless of variation in the number of scat samples. In low-sighting years, bears mainly consumed natural foods in natural areas, such as Japanese bird cherry and/or dogwood in late summer (Aug–Sep) and hard mast in autumn (from Oct). In contrast, in medium- and high-sighting years, the bears tended to consume natural and anthropogenic foods, such as Japanese chestnut and Japanese walnut from August to October and kaki in November, in near-human and human-dominated areas. Bears are opportunistic omnivores, and they can be expected to consume the most accessible foods (Rogers 2011). In poor mast years, Asiatic black bears consume alternative foods, such as kaki, in low-elevation sites near human settlements (Arimoto et al. 2011). Similarly, the bears increase the distance of their movements and move close to human settlements when production of the dominant Fagaceae hard mast is poor (Kozakai et al. 2011, Koike et al. 2012). Fleshy fruits are important foods for bears in late summer before hibernation (Mori et al. 2018); therefore, a shortage of fleshy fruits would lead the bears to increase their movement distance, as in the autumn. Therefore, our results suggest that food sources occurring near human settlements may be key in influencing the occurrence of bears during

Table 1. Percentage importance values, overall average (Mean), and coefficient of variation (CV) for food items in the diet of Asiatic black bears (*Ursus thibetanus*) in Shirakawa Village, Japan, based on scat samples collected from August to November–December 2008–2016. The plus and minus signs indicated the trace amount and no detection, respectively.

Food	2008	2009	2010	2011	2012[a]	2013	2014	2015	2016	Mean	CV
Green vegetation											
	0.6	0.3	0.1	0.1	0.1	4.9	25.5	1.8	0.4	3.8	2.1
Total	0.6	0.3	0.1	0.1	0.1	4.9	25.5	1.8	0.4	3.8	2.1
Fleshy fruits											
Japanese bird cherry	25.3	–	0.2	–	–	13.5	–	+	49.6	22.2	2.1
Dogwood	–	1.0	+	9.2	–	36.4	–	22.5	+	7.7	1.3
Kuromoji	–	–	–	–	–	12.3	–	+	0.0	6.2	3.3
Japanese rowan	0.1	+	+	0.1	–	–	+	0.9	0.1	0.3	2.4
Crimson glory vine	0.0	–	+	0.3	–	0.1	0.3	+	+	0.1	1.4
Tara vine	0.4	+	0.1	+	–	0.1	0.6	1.2	0.0	0.4	1.4
Kaki	0.1	–	3.4	–	–	–	45.5	–	0.0	12.3	2.7
Other	7.9	0.1	0.1	0.7	+	2.0	2.6	1.0	1.2	1.7	1.5
Total	33.8	1.1	3.8	10.3	0.0	64.4	49.0	25.6	50.9	26.5	0.9
Hard mast											
Japanese walnut	0.1	+	0.6	–	0.7	–	21.3	0.0	0.1	2.5	2.6
Japanese chestnut	–	+	61.3	–	3.9	0.5	–	1.8	+	7.5	2.4
Oak	64.3	98.3	34.2	8.4	95.1	15.7	–	+	46.3	36.2	1.1
Beech	–	0.3	–	78.7	–	5.8	–	70.8	+	17.3	1.6
Total	64.4	98.6	96.1	87.1	99.7	22.0	21.3	72.6	46.4	67.6	0.5
Invertebrates											
Formicidae	0.5	0.1	–	2.0	+	1.6	+	+	1.5	1.1	1.3
Vespidae	0.4	+	+	–	+	–	–	–	0.7	0.6	2.7
Others	0.3	+	–	0.5	+	6.6	4.2	+	0.1	2.3	1.9
Total	1.2	0.1	0.0	2.5	0.0	8.2	4.2	0.0	2.3	2.1	1.3
Vertebrates											
	+	+	–	–	0.2	0.5	+	+	0.0	0.2	2.6
Total	0.0	0.0	0.0	0.0	0.2	0.5	0.0	0.0	0.0	0.2	2.6
No. of samples	131	276	136	21	58	28	74	74	94		

[a]We were unable to collect scats in Aug and Nov–Dec 2012.

years of natural food shortage in late summer as well as in autumn.

In the high-sighting year of 2014, a gypsy moth (*Lymantria dispar*) outbreak occurred throughout our study area, resulting in serious defoliation levels in most broadleaf trees from the beginning of May until mid-July (T. Mori, Shinshu University, personal observation). This outbreak may have caused low mast production in many hard mast tree species (Kasbohm et al. 1996, Nakajima 2015) throughout the study area. In fact, beech, Mongolian oak, konara oak, Japanese bird cherry, dogwood, and Japanese chestnut had extremely low mast production levels in 2014 (T. Mori, personal observation), leading bears to increase their consumption of fleshy fruits, kaki, green vegetation, and particularly Japanese walnut compared with other years. In our study area, Japanese walnut grows near the Shogawa River, which flows through the middle of the residential area of Shirakawa Village, and kaki is distributed in areas of human settlements, mostly planted near houses. Japanese chestnuts are distributed in or near areas of human settlements. These foods could attract bears in years of poor natural fruit production, increasing the sighting of bears in human settlements and leading to conflict with humans. Mongolian oak and beech are found at high altitudes; therefore, it is assumed that the number of bear sightings decreased when these species were abundant in 2011 and 2015 (Mori et al. 2018).

Shifting of the diet from natural to anthropogenic foods during periods of natural food shortage has been reported in several other bear species. For example, the diet of American black bears in the Aspen, Colorado, USA, region switches from natural resources to human garbage in years of food shortage (Lewis et al. 2015), and Japanese brown bears use cultivated crops as an alternative food source in years of low acorn production (Sato

Table 2. Results of model selection for evaluating the relationship between the number of Asiatic black bear (*Ursus thibetanus*) sightings and percent important values (%IV) of 7 food items in Shirakawa Village, Japan, based on scat samples collected from August to November–December 2008–2016. Equivalent models and intercept-only model were ordered according to Akaike Information Criteria (AIC) values and Akaike weight (w_i). SE is standard error; SD is standard deviation. Asterisks indicate statistically significant values at $P < 0.05$.

	Jap. bird cherry		Dogwood		Oak		Beech		Jap. chestnut		Jap. walnut		Kaki		Random effect (SD)				
Model no.	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Month:Year	Year	AIC	ΔAIC	w_i
1	−0.039*	0.013	−0.033*	0.012	−0.027*	0.006	−0.056*	0.022							0.62	1.22	113.40	0.00	0.103
2	−0.035*	0.013	−0.028*	0.012	−0.024*	0.007	−0.053*	0.022	0.012	0.008					0.57	0.85	113.63	0.23	0.092
3							−0.032	0.023	0.040*	0.009	0.025*	0.024	0.029*	0.029	0.59	0.65	113.67	0.27	0.090
4	−0.013	0.013					−0.036	0.024	0.037*	0.009	0.022*	0.011	0.027*	0.009	0.53	1.13	114.48	1.08	0.060
5									0.044*	0.009	0.028*	0.011	0.033*	0.009	0.57	1.34	115.04	1.64	0.045
6	−0.032*	0.014	−0.023	0.013	−0.020*	0.008	−0.049*	0.022	0.016	0.010			0.007	0.009	0.54	1.29	115.07	1.67	0.045
7	−0.038*	0.013	−0.033*	0.012	−0.027*	0.008	−0.056*	0.023					0.002	0.013	0.59	1.08	115.38	1.98	0.038
8	−0.039*	0.013	−0.033*	0.012	−0.028*	0.007	−0.056*	0.022			−0.001	0.012			0.53	1.13	115.40	2.00	0.038
9*															0.71	1.54	132.99	19.59	0.000

*Model no. 9 shows the intercept-only model.

and Endo 2006). In our study area, the bears consumed kaki, an anthropogenic food, in near-human and human-dominated areas from October. Anthropogenic foods are a predictable, high-quality food source, and they attract bears to areas of human settlements (Greenleaf et al. 2009, Merkle et al. 2013).

The GLMMs showed that the consumption of 3 species in the family Fagaceae (beech, Mongolian oak, and konara oak) was related to the number of bear sightings, which is similar to previous findings for bears in other parts of the Hokuriku region (Mizutani et al. 2013). Although beech is the dominant species in our study area, there is great variation in its production levels (Mizoguchi et al. 1996, Mori et al. 2018), so that bears can consume it only once every few years. The 2 species of oak (Mongolian oak and konara oak) have lower spatial synchrony in their production than does beech (Shibata et al. 2002), allowing the bears to consume their fruits to some extent in most years (Nemoto et al. 2016). Thus, these 3 species complement each other in supplying food for bears.

Modeling showed that fleshy fruits, such as Japanese bird cherry and dogwood, were negatively associated with bear sightings. The bears used both species as their main food source in late summer (Aug–Sep) in low-sighting years. Asiatic black bears may become emaciated in summer—their kidney fat mass reaches its lowest levels in July–August in Gifu Prefecture (Gifu Prefecture 1995). The bears increase their daily activity level in late summer, which is consistent with the beginning of the hyperphagic period (Kozakai et al. 2013). They then need to forage for food in late summer and autumn to accumulate fat for hibernation (Nelson et al. 1983). If no major fleshy fruits (e.g., Japanese bird cherry and dogwood) are available at the beginning of the hyperphagic period, the bears move into areas of human settlements to seek anthropogenic foods or foods found near human settlements. In fact, the bears exhibited high consumption of Japanese walnut and Japanese chestnut in late summer in the medium- and high-sighting years of 2010, 2012, and 2014. Therefore, our results suggest that the number of bear sightings is related to consumption of fleshy fruits in late summer.

An early warning system that could predict the magnitude of bear occurrences by monitoring key mast production would be important for mitigating the likelihood of human–bear conflicts (Oka et al. 2004). Presently, however, only Fagaceae species are considered in the prediction of the magnitude of bear occurrences (e.g., Taniguchi and Osaki 2003, Mizutani et al. 2013, Fujiki 2018). Here, we demonstrate that bear occurrences in Shirakawa Village are related to the consumption of hard mast and fleshy fruits, particularly in late summer, illustrating the complexity of the effects of various foods in the bears' diet. Furthermore, because Japan has a wide latitudinal range, key plant species relating to bear occurrence are likely to differ among regions (Oka 2006). Therefore, there is a need to identify the key hard mast and fleshy fruit species that bears consume and to evaluate the abundance of these species in order to more accurately predict the likelihood of bear occurrence in areas of human settlement.

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