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The Diet of Asian Badger, *Meles leucurus* Hodgson, 1847, in Samarovskii Chugas Nature Park, Western Siberia

O. S. Zagainova and N. I. Markov

Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, ul. Vos'mogo Marta 202, Yekaterinburg, 620144 Russia
e-mail: zagainova_o@mail.ru

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Abstract—The diet structure of Asian badgers (*Meles leucurus* Hodgson, 1847) on Bol'shoi Chukhtinskii Island (Samarovskii Chugas Nature Park, Khanty–Mansi Autonomous Area) was studied by means of coprological analysis. Ten diet components were identified, including Siberian stone pine seeds (pine nuts), berries, earthworms, larval and adult insects, fishes, amphibians, reptiles, and mammals. The proportion of pine nuts was especially large. Seasonal fluctuations in the occurrence frequency and abundance of different foods were insignificant, but some of them were found to markedly vary between years.

Keywords: Asian badger (*Meles leucurus*), diet, Western Siberia, middle taiga.

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Badgers are typical polyphages, which consume practically all kinds of animal and vegetable food available to them (Geptner, Naumov, and Yurgenson, 1967). Eurasia is inhabited by two species of badgers, European (*Meles meles* L., 1758) and Asian (*Meles leucurus* Hodgson, 1847) (Abramov et al., 2003; Rossolimo et al., 2004). They are similar in feeding pattern and foraging activity, but their diets have been studied to different extents.

The majority of relevant publications deal with the diet of the European badger, which has been studied in more detail in Western Europe (Kruuk and Parish, 1981; Goszczyński, Jędrzejewska, and Jędrzejewski, 2000; Revilla and Palomares, 2002; Balestrieri, Remonti, and Prigioni, 2004; Rosalino et al., 2005; Fischer, Ferrari, and Weber, 2005). In Russia, similar studies have been performed in Tula, Leningrad, Pskov, Yaroslavl, Vologda, and Voronezh oblasts, Tatarstan, and Karelia (for review, see Tumanov, 2009).

Data on the diet of the Asian badger are less extensive. In the Middle Urals, these animals are known to feed mainly on insects, amphibians, and mammals, with the proportions of other kinds of food varying from year to year (Markov and Zagainova, 2005; Zagainova, 2009). In the Southern Urals, Chashchin (2002) has noted a high occurrence frequency of earthworms in their diet (on average, 72%). In Kazakhstan, the prevailing diet components, depending on habitat type, include fruits, insects, mammals, reptiles, mollusks, and earthworms (Afanas'ev, Sludskii, and Bekenov, 1982). Knowledge of the Asian badger diet in the north of Western Siberia is limited to general information on the variety of foods consumed by the animals. According to Yanushevich and Blagoveshchenskii (1952; cited from Laptev, 1958), badgers in this region feed on insects, earthworms, mammals, birds, frogs, lizards, snakes, berries, Siberian stone pine seeds (pine nuts), and plant roots and rhizomes. However, these authors provide no quantitative data allowing one to estimate the significance of particular foods for the species. On the whole, the diet of the Asian badger has been studied mainly in the central and eastern parts of its range, remaining poorly known in the north. Meanwhile, more such data are necessary for gaining a deeper insight into the adaptation of the species at the northern boundary of its range.

The purpose of this study was to reveal specific features of the Asian badger diet in the Samarovskii Chugas Nature Park. In particular, attention was focused on the range of food objects, their relative significance, and changes in the structure of the diet according to data over four years.

STUDY REGION

Studies were performed on Bol'shoi Chukhtinskii Island, a part of the Samarovskii Chugas Nature Park located in the Ob River floodplain about 25 km north of the city of Khanty-Mansiisk, the Khanty-Mansi Autonomous Area (61°13′N, 69°4′E). This relatively small island (865 ha) harbors a historically developed complex of natural communities characteristic of the middle taiga subzone of Western Siberia, which has suffered no significant disturbances and differs considerably from that described in other parts of the badger

range. Therefore, the spectrum of foods available to these animals is also different.

Monthly average temperatures on the island are −9.8°C in January and 17.5°C in July, with the snow-cover period being about 187 days. Its central part is covered by forests with dominance of fir (*Abies* sp.), spruce (*Picea* sp.), and Siberian stone pine (*Pinus sibirica* Du Tour); there is also a sedge bog. As a result of pyrogenic succession in the northeastern part of the island, forests in this area are represented by young deciduous, mainly birch (*Betula* sp.) stands. The herbaceous layer in conifer forests is dominated by bilberry and true mosses; in deciduous stands, cowberry is dominant, and mosses are also abundant. Old-growth birch (*Betula* sp.) and aspen (*Populus tremula* L.) with a poorly developed herbaceous layer grow on the shores. The floodplain in the study area is an expanse of meadows dominated by sedges (*Carex* sp.).

MATERIAL AND METHODS

Fecal samples were collected during the last 10 days of May and in September to October (below, there periods are referred to as spring and autumn). According to data from Khanty-Mansiisk weather stations, the long-term average air temperatures in May and late summer were about 6.6 and 13°C, respectively. Spring sampling coincided with the onset of the growing season after complete snow melt in the forest and the Ob floodplain. In late summer, the main phenological phenomenon characteristic of the sampling period was fruiting in bilberry, cowberry, and Siberian stone pine.

Before sampling, badger latrines (located previously) were cleaned of excrements, and then the material (whole fecal passages) was collected at intervals of 1–2 days. Each sample was placed in an individual plastic bag with a label indicating its number and the date and place of sampling. The numbers of samples taken in spring and autumn were as follows: 21 and 29 in 2006, 32 and 31 in 2007, 23 and 26 in 2008, and 24 and 18 in 2009.

In the laboratory, the material was washed and checked for the presence of oligochaete bristles using the standard procedure (Kruuk and Parish, 1981), excluding treatment with formalin and staining with picric acid. Undigested food remains were sorted by types and identified by comparing them with reference collections. Plant remains (pine nut shells, berry seeds, etc.) were weighed on an electron balance to an accuracy of 0.1 g. The quantities of animal foods were estimated by the "minimum number principle." The numbers of insects were determined by counting the elytra, pronota, and heads; the numbers of amphibians reptiles, and mammals, by counting skeletal elements (for mammals, including teeth).

The high diversity of badger diet and technical difficulties of field studies on the island did not allow us to collect sufficient data on the accessibility of different foods in nature. Hence, their relative significance for the species was estimated by analyzing general indices characterizing the occurrence frequency and abundance of different food remains over several years of observation.

Each kind of food was characterized with respect to *occurrence frequency* (the percentage of samples containing its remains relative to the total number of samples) and *the abundance of remains in the samples* (the weight of pine nut shells and the numbers of berry seeds, insects and vertebrates, and oligochaete bristles). In addition, we introduced and calculated the following indices: *the total number of individuals in the general sample set* (GN_i), or the sum of their numbers counted in all samples; *the average number of individuals per sample* (AN_i), or the arithmetic mean for the set of samples where this number was above zero; *the average index per season* (AI_s), or the arithmetic mean of values recorded in every spring or autumn season over the study period (for the weight of pine nut shells and the occurrence frequencies of foods); *the average index per year* (AI_y), or the arithmetic mean of values recorded in the spring and autumn of a given year (for the occurrence frequencies of foods); and *the average index over the study period* (AI_g), or the arithmetic mean of values recorded in all seasons throughout the study period (for the weight of pine nut shells and the occurrence frequencies of foods).

The magnitude of seasonal and interannual differences in food consumption was estimated by means of ANOVA. Data on the numbers of insects and the weight of pine nut shells were processed using parametric ANOVA followed by Bonferroni's test for significance. The former set of data were expressed in logarithmic form: $f(x) = \ln(x + 1)$, where x is the number of insects per sample. The year and season were regarded as independent factors, with the respective confidence levels being 0.008 and 0.05. A similar analysis for the numbers of amphibians and mammals was performed by means of Kruskal–Wallis nonparametric ANOVA. The significance of different foods was estimated by their occurrence frequency (AI_y), using pairwise comparisons of samples. As the sample size in our case was small ($n = 4$, the number of observation years), comparisons were made using the nonparametric Mann–Whitney test, with the null hypothesis being rejected at $p < 0.05$. Statistical data processing was performed with the Statistica 6.0 program package (StatSoft Inc., 2001).

RESULTS

The badger feces proved to contain undigested remains of plant foods (pine nuts and berries), invertebrates (earthworms, adult and larval insects), and vertebrates (fishes, amphibians, reptiles, birds, and mammals). In addition, some samples included the remains of small mollusks (no more than 5 mm in size), with their shells being usually unbroken. In our opinion,

Table 1. Occurrence frequencies (%) of different foods in the diet of Asian badger in spring (above the line) and autumn (below the line)

Food	2006	2007	2008	2009	$AI_g \pm$ standard deviation
Pine nuts	100.0/100.0	100.0/100.0	100.0/100.0	95.8/100.0	99.5 ± 0.52
Berries	33.3/20.7	50.0/83.9	13.0/26.9	37.5/33.3	37.3 ± 7.72
Earthworms	85.7/72.4	96.9/90.3	78.3/61.5	25.0/33.3	67.9 ± 9.32
Adult insects	81.0/72.4	90.6/87.1	73.9/80.8	100.0/77.8	83.0 ± 3.26
Insect larvae	42.9/13.8	15.6/9.7	8.7/26.9	70.8/16.7	25.6 ± 7.56
Fishes	14.3/20.7	–/–	–/3.8	4.2/16.7	7.5 ± 4.04
Amphibians	19.0/10.3	28.1/29.0	30.4/7.7	16.7/0.0	17.7 ± 3.93
Reptiles	4.8/–	–/–	–/3.8	–/–	1.1 ± 0.71
Birds	33.3/17.2	18.8/16.1	8.7/3.8	4.2/16.7	14.9 ± 3.4
Mammals	42.9/31.0	6.3/3.2	34.8/38.5	79.2/27.8	33.0 ± 8.34

they were consumed accidentally, together with other foods or substrate. Thus, badgers on Bol'shoi Chukhtinskii Island were found to consume ten kinds of food (Table 1).

The occurrence frequency of pine nuts and adult insects remained high in all seasons; the highest variation in this parameter was observed for berries, earthworms, and mammals (Table 1, Fig. 1). The Mann–Whitney test revealed no significant interseasonal differences in the occurrence frequencies (AI_s) of individual foods.

Pine nut shells occurred in almost all fecal samples taken either in spring or in autumn. Their average weight per sample varied between years (Fig. 2), and the average value over the observation period (AI_g) was 18.6 ± 3.68 g. No significant differences were revealed between the average weights of pine nuts shells per sample in spring and autumn: AI_s = 17.7 ± 5.37 g. 19.5 ± 5.82 g, respectively.

The seeds of bilberry (*Vaccinium myrtillus* L.) and raspberry (*Rubus idaeus* L.). occurred in almost all samples either in spring or in autumn. Most samples with the remains of raspberry (81.8%) contained one or two seeds, and their maximum number was no more than 15. The numbers of bilberry seeds per sample in 2006, 2008, and 2009 were generally low, with only one to three samples containing more than 100 seeds. The highest abundance (10–2300 seeds per sample) and occurrence frequency (58.1%) of bilberry seeds were recorded in August 2007. The occurrence frequency of berries (AI_s) was slightly lower in spring than in autumn (Fig. 1). but the difference lacked statistical significance (Mann–Whitney test: U = 5.5, $p > 0.4$) even when taking into account the samples where the number of seeds exceeded 10 or their weight was more than 0.1 g.

The average occurrence frequency (AI_g) of earthworms (Lumbricidae) was about 70%, being slightly lower in spring than in autumn (Table 1). The number of earthworm bristles per sample, estimated according to Kruuk and Parish (1981), averaged 0.6 ± 0.18, indicating that this prey was consumed in small amounts.

The taxonomic composition of the remains of adult insects found in badger feces was as follows. With respect to the number of species and genera and the total abundance, the best represented groups were the orders Coleoptera and Hymenoptera: among all insects recorded over the study period, their proportions were 84.3% (835 ind.) and 13.9% (138 ind.), respectively. Insects of other orders were scarce: Hemiptera, 6 ind.; Odonata, 2 ind.; Homoptera, 2 ind.; and Orthoptera, 8 ind. (their total proportion was only 1.8%). Badgers were found to feed mainly on epigeic insects, hymenopterans, riparian insects, and, to a lesser extent, inhabitants of the herb–shrub layer. The remains most frequently occurring in the samples belonged to ground beetles *Pelophila borealis* Payk. and *Carabus aeruginosus* F.-W., the carrion beetle *Silpha carinata* Hbst., bumblebees (*Bombus* sp.), and diving beetles (*Rhantus* sp.).

The maximum number of insects per sample proved to vary widely, from 6 to 67 ind. (Table 2). However, their number per sample averaged over the study period (AN_i) was only 5.8 ± 0.82 ind., indicating

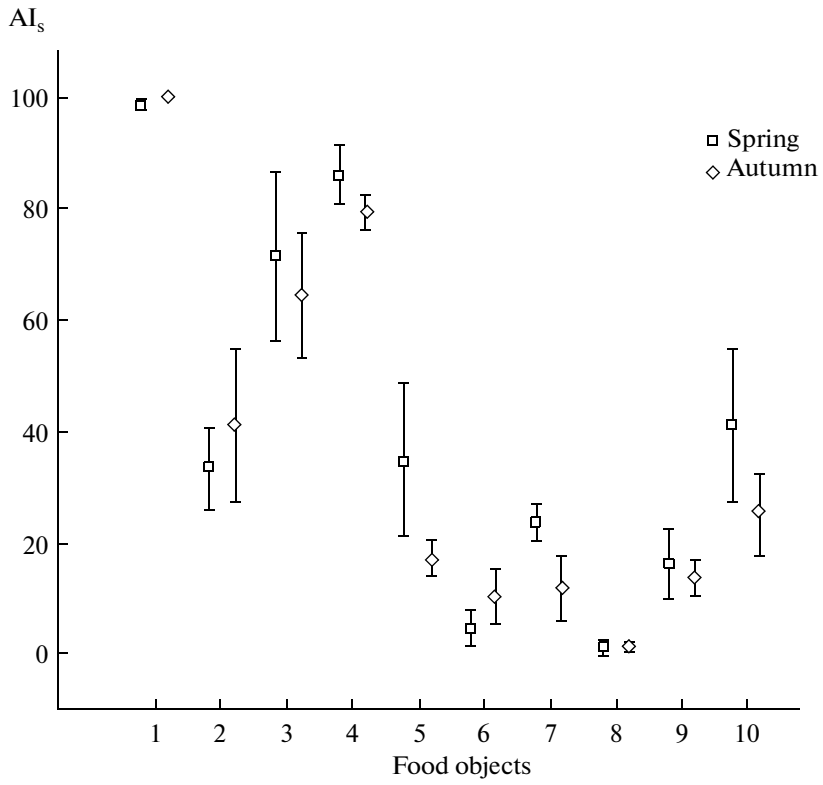

Fig. 1. Occurrence frequencies of food remains (AI_s) in badger feces, 2006–2009: (1) pine nuts, (2) berries, (3) earthworms, (4) adult insects, (5) insect larvae, (6) fishes, (7) amphibians, (8) reptiles, (9) birds, (10) mammals.

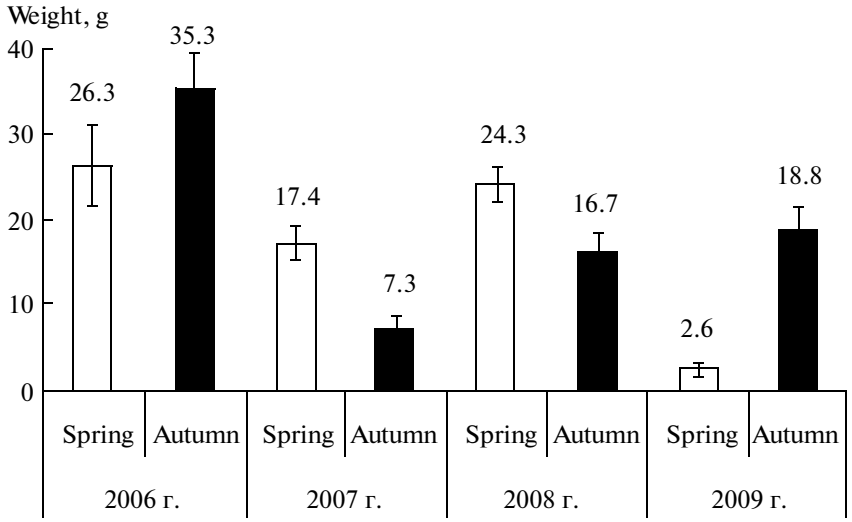

Fig. 2. Average weight of pine nut shells in fecal samples (vertical lines show standard deviation).

that badgers consumed relatively small amounts of insects. Analysis of the roles of factors "season" and "year" in the dynamics of insect number per sample showed that factor "year" and the interaction of both factors have a significant effect on this parameter (in both cases, $p < 0.001$). Seasonal differences lack statistical significance when evaluated without regard to its annual dynamics.

In addition to adult insects, badger feces contained the larvae of beetles and moths. In 2006, 2008, and 2009, fish remains (scales and skeletal bones) were

Table 2. Numbers of insects in fecal samples in spring (numerator) and autumn (denominator)

Number of insects per sample	2006	2007	2008	2009
Maximum	67/10	15/27	6/48	18/16
Average	9.5 ± 3.88/3.6 ± 0.51	4.9 ± 0.75/7.3 ± 1.37	2.5 ± 0.45/7.9 ± 2.76	5.8 ± 0.85/4.8 ± 1.33

Table 3. Changes in the numbers of amphibians (numerator) and mammals (denominator) in fecal samples

Year	Spring		Autumn	
	GN_i	AN_i	GN_i	AN_i
2006	4/12	1.0 ± 0.0/1.3 ± 0.17	4/4	1.3 ± 0.33/1.1 ± 0.11
2007	17/2	1.8 ± 0.68/1.0 ± 0.0	10/1	1.1 ± 0.11/1.0 ± 0.0
2008	7/12	1.0 ± 0.0/1.5 ± 0.33	2/19	1.0 ± 0.0/1.9 ± 0.69
2009	4/20	1.0 ± 0.0/1.2 ± 0.18	–/15	–/3.0 ± 1.55

found in fecal samples, which indicated that badgers probably fed on dead fish.

The average occurrence frequency (AI_g) of the remains of amphibians was below 20% (Table 1). The number of individuals per sample varied from one to seven, with most such samples (89.5% over the study period) containing the remains of only one animal. Changes in this parameter between years are shown in Table 3. The effect of factors "year" and "season" on its dynamics lacked statistical significance ($p = 0.058$ and $p = 0.059$, respectively). In May 2006 and August 2008, skeletal remains of lizards (one animal per sample) were found in single cases. Taking into account the species composition of herpetofauna on Bol'shoi Chukhtinskii Island (Starikov et al., 2005), it appears that badgers fed mainly on brown frogs (*Rana arvalis* Nilsson and common lizards (*Zootoca vivipara* Jacquin).

The diet of badgers also included passerine birds (Passeriformes), mainly their eggs and chicks. Fecal samples collected in May 2006 and in May and August 2007 contained feathers, bone remains, and egg shells; in 2008 and 2009, only feathers and bones were found.

The remains of mammals in fecal samples included hair, skeletal components, and teeth. Their taxonomic identification was possible in the samples that contained teeth (60.3%). The composition of mammals in the diet varied by years. In 2006 and 2008, they were represented mainly by northern red-backed voles (*Clethrionomys rutilus* Pall.) and shrews (*Sorex* sp.); in single cases, field voles (*Microtus* sp.) and harvest mice (*Micromys minutus* Pall.) were found. In 2009, root voles (*Microtus oeconomus* Pall.) prevailed. Both adult and juvenile animals occurred in the samples. Their number per sample varied from one to nine, with the average over the study period (AN_i) being 1.5 ± 0.24 Table 3). This parameter proved to vary significantly between years ($p < 0.001$) but not between seasons ($p > 0.05$).

A comparative assessment of the significance of different foods based on their occurrence frequencies (index AI_y; detailed information is not presented here) allowed us to discriminate pine nuts into a special category, as they occurred in the samples significantly more frequently than other food objects. Adult insects were the second most frequent food. The above index for reptiles and fishes was significantly lower, and, therefore, we classified them as occasional foods. Berries, earthworms, insect larvae, amphibians, birds, and mammals differed in occurrence frequency but could not be definitely classified with respect to their significance. We included them into the category of secondary foods.

Estimating relationships between occurrence frequencies of different food objects and between parameters of abundance of food remains (pine nuts, insects, amphibians, and mammals) in fecal samples, we revealed no correlation in the level of their consumption. The only exception was an inverse correlation between the occurrence frequencies of amphibians and mammals ($R_s = -1$, $p < 0.001$).

DISCUSSION

The composition and ratio of food objects in the diet of badgers depends both on their feeding preferences, which are manifested in specialization on certain kinds of prey (Kruuk and Parish, 1981; Revilla and, Palomares, 2002), and on the relative accessibility of foods in nature, which accounts for the seasonal and interannual dynamics of diet composition (Pigozzi, 1991; Rosalino et al., 2005). In the study region, badgers retreat to their setts for winter sleep in late October to early November and emerge again beginning in April (Geptner, Naumov, and Yurgenson, 1967). Thus, the period of their activity largely coincides with the period when various foods are available to them.

Considering the qualitative composition of the badger diet in the study region, we can note several distinctive features. First, the diet includes pine nuts, which are its main component. In our opinion, the Asian badger is specialized in feeding on pine nuts, as is the European badger is specialized in feeding on earthworms in Scotland (Kruuk and Parish, 1981) or on rabbits in Spain (Revilla and Palomares, 2002). Second, Asian badgers do not eat cowberries, even though they are highly abundant on the island in autumn. We cannot explain such selectivity in feeding, the more so that badgers in Tatarstan readily consume these berries (Gorshkov, 1997). Third, Asian badgers in the study region preyed mainly on forest voles of the genus *Clethrionomys*, whereas the majority of publications on the diet of European badgers (Goszczyński, Jędrzejewska, and Jędrzejewski, 2000; Fisher, Ferrari, and Weber, 2005) and our data obtained in the forest–steppe zone of the Middle Urals (Markov, Zagainova, and Zinovjev, 2005b) provide evidence that voles of the genus *Microtus* prevail in their diet. This is probably explained by the small proportion of open habitats on the island (only about 3% of its total area) and, therefore, low relative abundance of *Microtus* voles, which prefer forest–free areas (Bol'shakov, Berdyugin, and Kuznetsova, 2006). Fourth, the island is not inhabited by the insects most frequently eaten by badgers in other parts of their range, such as the forest dung beetle *Geotrupes stercorosus* Scriba and scarab beetle *Melolontha hippocastani* Fabricius (Geptner, Naumov, and Yurgenson, 1967; Gorshkov, 1997); hence, these animals feed mainly on abundant and easily accessible ground beetles *Pelophila borealis* Payk. and *Carabus aeruginosus* F.-W. (Zinovjev, 2004).

The range of foods consumed by badgers appears to remain relatively constant in spring and summer, since we have revealed no significant differences in the qualitative and quantitative composition of their diet between the seasons. However, this can be explained by a relatively short observation period (4 years). Thus, as follows from Fig. 1, the occurrence frequency of adult and larval insects markedly decreases in autumn, compared to spring, but the differences lack statistical significance. At the same time, the occurrence frequencies in spring and autumn for most kinds of food overlap considerably. Therefore, we consider that the majority of foods are almost equally accessible to badgers in spring and autumn. In particular, the sources of pine nuts in spring include both the remains of the last year's yield (the seed productivity of Siberian stone pine on the island reaches 200 kg/ha) (Smolonogov, 1990) and the stores made by nutcrackers (*Nucifraga caryocatactes* L.) or chipmunks (*Eutamias sibiricus* Laxmann) (Talantsev, 1981).

The yield of bilberries in the middle taiga zone of Western Siberia varies from 90 to 180 kg/ha (*Ekologiya...*, 1997). Their accessibility is different in spring and autumn, but no significant seasonal differences in their occurrence frequency have been revealed. We consider that the role of bilberries in the badger diet does not change appreciably and that the level of their consumption in autumn is lower than the level of their accessibility.

Significant interannual dynamics of occurrence frequency and abundance in fecal samples have been revealed for insects and mammals. This may be explained by differences in their accessibility resulting from random changes in environmental conditions or related to the natural cyclicity of prey populations. The latter applies primarily to mammals: as noted above, badgers in the study region prey mainly on voles, and changes in the occurrence frequency of these rodents and their numbers in fecal samples conform to the four-year pattern characteristic of vole population cycle (Bobretsov, 2009). The occurrence frequency of amphibian remains in fecal samples shows a significant inverse correlation with that of mammals. It appears that badgers eat more amphibians in years of vole population depression, thereby maintaining the normal level of animal food consumption. Since no data on distinct population cycles of amphibian on the island are available, we consider that the abundance of mammals has an effect on the consumption of amphibians by badgers, and not vice versa.

Thus, Asian badgers on Bol'shoi Chukhtinskii Island are specialized in feeding on pine nuts, and the composition of their diet shows no distinct seasonal dynamics. The absence of detailed information on the diet of this species in the middle taiga zone precludes any definite conclusions as to whether the above features are characteristic of badgers throughout this zone or only in the study region. To resolve this issue, it is necessary to study the feeding of badgers in other regions of Western Siberia.

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