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Radioactive contamination of dietary components of the roe deer in the forests of Zhytomirske Polesie of Ukraine

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Abstract. This paper presents a study on radioactive contamination of dietary components of the roe deer (*Capreolus capreolus*) in Zhytomirske Polesie (Ukraine). Studies were conducted on two research plots in forests with similar levels of radioactive contamination, 29 ± 8 kBq/m^2 - 55 ± 17 kBq/m^2, in mixed coniferous forests and mixed broadleaved forests, which are the dominant forest types of the area. The highest level of radionuclide accumulation was observed in young oak seedlings.

The dynamics for oak sprouts indicate that the accumulation coefficient reaches a maximum in September and August in the mixed coniferous and mixed broadleaved forests respectively. A comparison of mean values of the ^{137}Cs accumulation coefficients in the shoots of undergrowth plants confirms that an increase in soil fertility leads to a reduction of radionuclides in plant phytomass. In the mixed broadleaved forests, average values of the coefficient of ^{137}Cs accumulation in phytomass of blackberry was 26% and of raspberries 58% lower compared to mixed coniferous forests. The maximum contamination of phytomass was observed in August for oak, in October for aspen, and in July for birch. The highest specific activity of ^{137}Cs in raspberry shoots occurs during the three summer months, whereas the peak in blackberry occurs from August to September. The dynamics of the specific activity of ^{137}Cs in blueberry, cranberry and heather show an increase in radioactive contamination of phytomass towards the end of the growth period. The maximum concentration of ^{137}Cs in shoots of heather and bilberry was recorded in October and for blueberry in August. Mushrooms in mixed coniferous forests can be ranked as follows according to the degree of ^{137}Cs contamination: *Cantharellus* < *Boletus edulis* < *Russula* < *Leccinum* < *Xerocomus badius* < *Paxillus involutus*. In mixed broadleaved forests the ranking is *Cantharellus* < *Boletus edulis* < *Russula* < *Xerocomus badius* < *Leccinum* < *Paxillus involutus*. Within one habitat type, we observed fairly significant variations in ^{137}Cs accumulation in fruit bodies of fungi species.

Keywords: radioactive contamination, roe deer diet, ^{137}Cs, Zhytomirske Polesie of Ukraine

1. Introduction

After the nuclear accident that occurred in 1986 at the Chernobyl Nuclear Power Plant in Ukraine, the meat of game animals hunted in the areas exposed to radioactivity has become one of the potential sources of radioactive contamination for humans.The threat concerns mainly hunters (poachers as well) and consumers of wild boar and deer meat, who first of all are at risk of accumulation of increased radiation doses. At the same time, game animals as natural components of forest ecosystems have become an important factor in the process of transferring radioactive nuclides in time and space.

Radionuclide contamination of ungulates develops mainly through food consumption (Krasnov et al. 2007). European roe deer diet includes undergrowth and underbrush trees, shrubs and subshrubs, herbaceous plants as well as fungi, lichens and mosses (Krasnov et al. 2007; Krasnov et al., in print). The specificity of radionuclide accumulation expressed by ^{137}Cs contents in plants consumed by forest animals has been studied in several countries.

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For the most part, studies carried out have been focused on ^{137}Cs accumulation in forest plants utilized by humans, and especially that in edible species (e.g. berries) or those used for medicinal purposes (e.g. sprouts, roots, abovegro-und parts, flowers). Several authors paid special attention to a role of particular plant species in radionuclide relocation over forest ecosystems in the countries such as: Belarus (Perevolockij 2006; Bulko et al. 2013), Russia (Ŝeglov, Cvetnova 2001; Mamihin et al. 2005) Ukraine (Shelest 2004; Krasnov et al. 2007; Šitûk et al. 2010; Krasnov et al., in print), Sweden (Fawaris 1995) and Finland (Lehto et al. 2013). The results obtained allow to overview a level of radioactive contamination in plants in diet of the European roe deer – one of the most abundant herbivore in Europe's forests. It was found that heather species (Ericaceae) showed considerably high radionuclide accumulation (Krasnov et al. 2007). Indexes of ^{137}Cs transition into Ericaceae plants show higher values than those observed in the majority of other vascular plants prevailing in northern and eastern Europe (Fawaris 1995; Perevolockij 2006; Lehto et al. 2013). At the same time, the results of the study on radionuclide translocation all through tree organs and tissues showed the highest ^{137}Cs contents in foliage (leaves and needles) and stems of current annual increment – plant parts most readily eaten by the European roe deer (Šelest 2004). Furthermore, fungi hold special radioecological responsibility as they frequently serve as food for forest animals. Their fruit bodies not only accumulate high amounts of ^{137}Cs, but also their contaminated mycelia can pollute plants through mycorrhizal associations with plant roots (Fawaris 1995).

Studies by Krasnov et al. (2007, 20xx in print) confirm considerable variability in contamination of biomass in different phytocenosis components, depending on plant species, growth habitat and development stage. Plants and fungi are most often subject to contamination analyses as parts of forest ecosystems, but not as animal food. The results as such give no basis to evaluate the effects of particular animal diet components on seasonal changes of ^{137}Cs accumulation in animal bodies.

The European roe deer *Capreolus capreolus* (L.) is one of the most common animal species in forests of Ukrainian Central Polesie (Krasnov et al. 2007). The species belongs to Ruminantia taxon and feeds in vegetation zone 0-150 cm up from the soil surface (Prostakov 1989; Sokolov 1992), which is connected with the size of these animals. Roe deer feed most intensely on young parts of plants – those with stem diameter 2–4 mm (maximum: 6 mm) (Drożdż, Osiecki 1973; Sokolov 1992). As a consequence of specific dentition, the European roe deer is not able to damage tree bark (Prostakov 1989). The feeding habits of the European roe deer decide on methodology used for evaluation of ^{137}Cs accumulation in plant components of this animal diet.

The aim of the present study was to determine seasonal changes of the intensity of radionuclide translocation from the soil into plants consumed by the European roe deer.

2. Research methods

Due to partial inaccessibility of the district where the Power Plant is situated, research described below is unique and has not been so far repeated.

Seasonal dynamics of radioactive contamination of European roe deer diet components was observed in the years 1995-1997, on two research plots established in typical roe deer habitats located in Ukrainian Central Polesie forests. The areas (sample plots) No. 1 and No. 2 were situated in north-western and northern parts of Zhytomyr region, respectively.

The plot No. 1 was covered by fresh and wet mixed coniferous forests with characteristic for given ecosystems plant associations, i.e. 30-40 years old stands, with 2 layers: (1) uppergrowth with Scots pine (I class of quality of the standing crop) along with overall 20% share of silver birch and aspen, and (2) - with pedunculate oak (III-IV class). The average level of radioactive contamination of the soil was 29 ±8 kBq/m^2, and average cesium activity was 350 ± 130 Bq/kg. The plot No. 1 was classified as one with relatively low radioactive contamination.

The plot No. 2 was distinctive of a prevailing share of fresh and mixed broadleaved forests. The stand was 30-40 years of age and comprised 3 layers: (1) Scots pine (I class), (2) pedunculate oak (II-III class), silver birch, poplar and aspen and (3) with Norway maple, linden and hornbeam. The average level of radioactive contamination of the soil was almost two-fold higher than that in No. 1 plot and amounted to 55 ± 17 kBq/m^2, whereas average cesium activity in the soil was 855 ± 440 Bq/kg. The plot No. 2 was located in the exclusion zone (people evacuated due to contamination above 37 kBq/m^2).

The choice of plant species for further analyses resulted from their roles in roe deer diet as well as functions in phytocenosis. Taking into account the intensity of roe deer feeding, there were selected:

– undergrowth and underbrush: aspen (*Populus tremula* L.), pedunculate oak (*Quercus robur* L.), silver birch (*Betula verrucosa* L.) and European white birch (*Betula pubescens* Ehrh.). Aspen and pedunculate oak are main roe deer diet components, whereas birch is a seasonal diet constituent (in the fall and winter);

– shrub layer: blackberry (*Rubus nessensis* W. Hall.) and raspberry (*Rubus idaeus* L.). Blackberry is one of the crucial species in the diet of roe deer inhabiting Zhytomyr Polesie region and raspberry is intensely fed on during the fall season;

– herbaceous plant-subshrub layer: dominant and sub-dominant species from the Ericaceae family occurring in mixed coniferous and mixed broadleaved forests in Zhytomyr Polesie, i.e. billberry (*Vaccinium myrtillus* L.) and lingonberry (*Vaccinium vitis-idaea* L.) as typical roe deer diet components in the winter and spring season and common heather (*Calluna vulgaris* (L.) Hill) consumed by the European roe deer in the fall, winter and spring;

– fungi: taken into account due to their noteworthy role in roe deer contamination, despite of rather low fungi consumption by animals in Zhytomyr Polesie forests.

The collection of selected plant species was carried out within the feeding zone of the European roe deer (at the height 0-150 cm above the ground). All the samples were collected 5 times from the area of 1 m^2 (in between 1st and 15th day of each month, there were taken 5 samples, in total 600). Depending on the season of the year, the shoots of tree species (up to 5 mm thick) were collected with or without leaves. Fungal fruit bodies were cut out above the ground and brushed off the litter. Taking into account patchy patterns of radioactive contamination, soil samples were collected together with each plant sample. The soil was sampled with the use of a drill (5 cm diameter) at about 10 cm depth on the area of 1 m^2 around sampled plants or else at the point of fungi and sub-shrubs collection.

Radionuclide activity of ^{137}Cs was measured in air-dried and crushed soil and plant samples (contamination level was calculated per 1 kg). The activity of ^{137}Cs in the samples of crushed fresh fungi was defined using gamma-spectrometer AFORA LP-4900B with the semiconductor detector DG DK-80 B-3. Measurement error ranged from 5.1% to 8.5%. The accumulation coefficient (calculated as the ratio of plant radioactivity and soil radioactivity, Bq/kg) was used for description of ^{137}Cs accumulation characteristics in roe deer food.

The values of ^{137}Cs accumulation coefficients in one-year-old shoots of undergrowth trees (measured in different months) as well as those determined for shrub layer plants were compared using Student's t-test and Fisher's combined probability test. Annual dynamics of ^{137}Cs uptake by underbrush plants was tested using Pearson's correlation coefficient.

3. Results and Discussion

Undergrowth plants

The comparison of mean ^{137}Cs accumulation coefficients showed that generally all plant species samples collected in mixed broadleaved forests indicated lower values than those found in plants collected from mixed coniferous forests (tab.1). This suggests that accumulation of radionuclides in plants decreases with increasing soil fertility. Irrespective of site fertility, annual means of ^{137}Cs accumulation coefficients increased in the following order: aspen > birch > oak. On the sample plot No. 1, ^{137}Cs accumulation by oak was greater by 24% and 20% than that in aspen and birch, respectively. The differences between oak-aspen and oak-birch observed on the sample plot No. 2 were 42% and 30%, respectively. The intensity of ^{137}Cs accumulation by birch and aspen in mixed

Table 1. Dynamics of accumulation indices of ^{137}Cs in yearly shoots of tree undergrowth species during the year (accumulation indices has no units)

Month	Fresh and moist mixed coniferous forests (Sample plot 1)			Fresh and moist mixed broadleaved forests (Sample plot 2)		
	oak	aspen	birch	oak	aspen	birch
February	0.70±0.08	0.56±0.21	0.44±0.11	1.59±0.20	0.53±0.37	0.29±0.01
March	–	–	–	0.93±0.34	0.74±0.18	0.86±0.17
April	1.32±0.26	0.44±0.11	1.16±0.27	–	–	–
May	–	–	–	1.24±0.26	0.55±0.06	0.64±0.13
June	1.19±0.25	1.17±0.09	0.88±0.13	–	–	–
July	–	–	–	0.70±0.16	0.44±0.09	1.57±0.33
August	–	–	–	2.17±0.42	0.35±0.05	0.94±0.17
September	2.24±0.27	2.08±0.34	1.40±0.43	0.58±0.13	0.36±0.03	0.12±0.03
October	0.72±0.10	0.43±0.12	1.04±0.10	0.52±0.03	1.45±0.44	0.59±0.06
November	–	–	–	–	–	–
December	–	–	–	0.53±0.10	0.41±0.09	0.36±.06
Average	1.23±0.10	0.93±0.09	0.8±0.12	1.03±0.08	0.60±0.08	0.72±0.06

broadleaved forests was basically same, whereas in mixed coniferous forests radionuclide accumulation by birch was by 10% greater when compared with aspen.

In undergrowth components of roe deer diet, ^{137}Cs accumulation coefficient values changed depending on tree species and site conditions as well as vegetation season stages. Radionuclide accumulation in oak shoots in mixed coniferous forests was the highest (maximum) in September and in mixed broadleaved forests – in August. When compared to the annual mean, the maximum values in mixed coniferous forests and mixed broadleaved forests were 1.82 and 2.11 times higher, respectively. The analysis of ^{137}Cs accumulation in aspen shoots in mixed coniferous forests showed the maximum value in September (2.24 times higher than the annual mean), and that in mixed broadleaved forests – in October (2.42 higher than the annual mean). The maximum ^{137}Cs accumulation coefficient for birch shoots in mixed coniferous forests were found in September (1.43 times higher than the annual mean), and in mixed broadleaved forests – in July (2.18 times higher than the annual mean).

Underbrush plants

The comparison of ^{137}Cs accumulation coefficient values in the shoots of underbrush plants consumed by the European roe deer proved that radionuclide accumulation in plants decreases with increasing soil fertility (tab 2.). When compared with mixed broadleaved forests, in mixed coniferous forests, the mean values of ^{137}Cs accumulation coefficients for blackberry (*R. nessensis*) and raspberry (*R. idaeus*) were by 26% and 58 % higher, respectively. It should be emphasized, that despite of soil fertility, the intensity of radionuclide accumulation in underbrush plants also relies upon biological and ecological characteristics of a given plant species. In mixed coniferous forests, the value of ^{137}Cs accumulation coefficient in raspberry was higher by 28%, when compared to that of blackberry, in contrast to mixed broadleaved forests where the value of radioactive Cs accumulation in blackberry was by 22% higher when compared to raspberry.

The change of ^{137}Cs uptake from soil into raspberry was steady and its values showed no dramatic fluctuations. The values increased during plant growth stages and started decreasing at the end of the vegetation period. In mixed coniferous forests, changes in ^{137}Cs uptake values in raspberry in April and October were lower when compared to those in the period of May-September ($F_f = 11.22 > F_{(4;19;0.5)} = 2.90$). In mixed broadleaved forests, seasonal changes were not statistically significant. However, monthly differences in accumulation coefficient values in blackberry were statistically significant both on the research area No. 1 ($F_f = 9{,}08 > F_{(4;21;0.5)} = 2.84$) and No. 2 ($F_f = 11.13 > F_{(7;28;0.5)} = 2.36$). The results obtained indicated that in July, radionuclide accumulation in plants growing in mixed broadleaved forests was more than 3-fold higher when compared to the annual mean.

Subshrub plants

^{137}Cs accumulation coefficient values o in Ericaceae subshrubs were higher when compared with those found in undergrowth and underbrush plants (tab. 3). There was also observed a decrease of radionuclide accumulation with increasing soil fertility, which confirmed the results repor-

Table 2. Dynamics of accumulation indices of ^{137}Cs in plant shoots for understorey plants during the year (accumulation indices has no units)

Month	Fresh and moist mixed coniferous forests (Sample plot 1)		Fresh and moist mixed broadleaved forests (Sample plot 2)	
	blackberry	raspberry	blackberry	raspberry
February	0.65±0.25	3.48±0.59	0.71±0.01	0.63±0.23
March	–	–	0.57±0.12	0.57±0.15
April	0.84±0.07	0.79±0.15	–	–
May	–	–	1.03±0.23	1.11±0.28
June	1.01±0.13	1.13±0.33	–	–
July	–	–	2.90±0.59	0.83±0.17
August	–	–	0.86±0.18	0.82±0.17
September	1.50±0.29	2.50±0.59	0.50±0.07	0.46±0.09
October	2.22±0.19	0.71±0.08	0.60±0.08	0.81±0.18
November	–	–	–	–
December	–	–	0.15±0.02	0.51±0.06
Average	1.24±0.10	1.72±0.16	0.92±0.09	0.72±0.06

ted by other authors (Ŝeglov et al. 2001; Perevolockij 2006; Krasnov et al. 2007; Šitûk et al. 2010).

Dynamics of ^{137}Cs uptake by subshrub shoots was tested using Pearson's coefficient. At p = 5%, the measures of the linear correlation were 0.87 and 0.72 for mixed coniferous and mixed broadleaved forests, respectively.

The results for bilberry (*V. myrtillus*) and lingonberry (*V. vitis-idaea*) growing in mixed broadleaved forests (research plot No. 2) showed considerable seasonal fluctuations of ^{137}Cs accumulation coefficient values. At the beginning of active growth (March), there was observed a dramatic increase of cesium accumulation in plants: in bilberry 1.76 times higher when compared to the annual mean, and in lingonberry -1.34 times higher. When compared to the annual mean, the increase of ^{137}Cs accumulation coefficients was observed in bilberry and lingonberry shoots also in August (developed fruit growth stage): 2.05 and 1.37 times, respectively. Similarly, increased radionuclide accumulation was observed at the end of vegetation period (October).When compared to the annual mean, accumulation coefficient values of were 1.38 and 2.22 times higher for bilberry and lingonberry, respectively. Subshrub plant species are comparable in terms of their biological features, and their root systems grow in similar ecological conditions. The differences observed between bilberry and lingonberry, could be a result of their different growth stages at sampling (bilberry shoots were leafless and lingonberry - covered with leaves). In the case of common heather (*C. vulgaris*), the maximum ^{137}Cs accumulation was observed at the end the vegetation season (October). In coniferous mixed forests, radionuclide accumulation was 1.63 times higher when compared to the annual mean and in mixed broadleaved forests – 2.22 times higher.

Based on mean accumulation coefficient values, Ericaceae plants growing in mixed coniferous forests represent the following order: lingonberry > bilberry > common heather, whereas in mixed broadleaved forest: bilberry > lingonberry> common heather. Taking into account not significant differences in cesium accumulation between bilberry and lingonberry in the forests analyzed, there can be concluded that ^{137}Cs accumulation in these species is not reliant upon site fertility. The results obtained for common heather showed that cesium accumulation in this species growing in mixed coniferous forests was 1.18 and 1.23 higher than that in bilberry and lingonberry, respectively, whereas in mixed broadleaved forests cesium accumulation in bilberry and lingonberry was 3.58 and 2.08 higher, respectively.

Fungi

In the fall, European roe diet comprises no more than 1.4% fungal fruit bodies (Krasnov et al. 2007; Krasnov et al. in print). The comparison of ^{137}Cs accumulation coefficient values for fungal species found on the research plots in the present study showed differentiated cesium accumulation depending on site conditions (tab. 4).

In fungi growing in mixed coniferous forests, there was observed the following order of ^{137}Cs accumulation: chanterelle < boletus < russula < rough-stalked boletus < bay boletus < paxillus, and in mixed deciduous forest the order was as such: chanterelle < boletus< russula < bay boletus < rough-stalked boletus < paxillus. Considerable differences in ^{137}Cs accumulation in the fruit bodies of observed fungal species were found even if they occurred in similar habitat

Table 3. Dynamics of ^{137}Cs accumulation indices in the shrubs (accumulation indices has no units)

Month	Fresh and moist mixed coniferous forests (Sample plot 1)			Fresh and moist mixed broadleaved forests (Sample plot 2)		
	bilberry	lingonberry	heather	bilberry	lingonberry	heather
February	3.33±0.38	3.00±0.10	0.85±0.16	1.02±0.31	1.49±0.42	–
March	–	–	–	2.16±0.37	2.84±0.33	5.00±0.93
April	2.06±0.37	1.53±0.09	–	–	–	–
May	–	–	–	0.46±0.07	1.39±0.25	–
June	1.26±0.12	1.83±0.08	1.87±0.35	–	–	–
July	–	–	–	1.08±0.11	1.55±0.21	1.03±0.34
August	–	–	–	2.52±0.44	2.90±0.38	3.08±0.31
September	1.04±0.13	1.14±0.23	2.33±0.96	0.40±0.04	0.32±0.10	4.13±0.77
October	1.38±0.81	1.13±0.15	3.48±0.92	1.70±0.11	4.72±0.82	9.76±0.78
November	–	–	–	–	–	–
December	–	–	–	0.54±0.06	1.75±0.47	3.39±0.59
Average	1.81±0.17	1.73±0.12	2.13±0.35	1.23±0.09	2.12±0.15	4.40±0.26

conditions. ^{137}Cs accumulation in paxillus fruit body was 5.7 and 6. 6 times higher than that in boletus in mixed coniferous forests and mixed broadleaved forests, respectively. In general, accumulation coefficient values obtained for russula, paxillus, and bay boletus were higher (3.4, 3.1 and 8 times, respectively) in coniferous mixed forests when compared with broadleaved mixed forests. Irrespective of habitat conditions, no statistically significant differences were found in radionuclide mean accumulation in chanterelle, boletus and rough-stalked boletus.

Based on the results obtained, it can be concluded that the main factor which determines the value of ^{137}Cs accumulation coefficient in fungal fruit bodies is the habitat type. An increase of site fertility resulted in a decrease of radionuclide uptake by fungi. The species observed can be divided in two groups with different capability of radionuclide accumulation: weakly and intensely cumulative (tab. 4). Fungi from the first group are quite important in roe deer diet and those from the second group occur commonly in Zhytomyr Polesie forests. In any case, the share of fungi in roe deer diet as well as ^{137}Cs accumulation in their fruit bodies can result in substantial radionuclide accumulation in roe deer organs.

Dynamics of cesium activity

The analysis of ^{137}Cs activity in undergrowth and underbrush plant parts of roe deer diet revealed that radionuclide accumulation showed distinct peaks during the vegetation period (fig. 1). The maximum contamination in oak shoots was recorded in August, in aspen – in October, and in birch – in July. The highest accumulation of ^{137}Cs in raspberry shoots was observed in the summer months, and in blackberry – in August and September.

The results obtained indicate that ^{137}Cs accumulation increased in oak, aspen and blackberry parts eaten by roe deer at the end of summer and during the fall. These plant species are of great importance in the diet of roe deer inhabiting forests of Central Ukrainian Polesie. Annual share of oak and aspen shoots in roe deer diet is 13% each, whereas that of blackberry is 12%. During the fall, the share of these species is 13%, 28% and 13%, respectively (Krasnov 2007). The analysis of roe deer rumen contents (carried out on 15 animals in the fall) showed not digested oak shoots (47%), aspen shoots (73%) and raspberry shoots (20%). Intensive consumption of oak, aspen and blackberry by roe deer corresponds with statistically significant increase of ^{137}Cs activity in these plants.

Contradictory to oak and aspen shoots, those of birch and raspberry constitute seasonal roe deer food and lesser amounts of these plants are consumed. The content of birch in roe deer diet is 3.4% in the fall and 10.6% in the winter, and raspberry constitutes 5 % in the fall (Krasnov et al. 2007). The maximum accumulation of ^{137}Cs in birch and raspberry does not correspond with the most intense consumption of these plant species by roe deer. The comparison of European deer diet specifics and those of radionuclide contamination of plant parts eaten by this animal allow for concluding that one of the reasons of increased ^{137}Cs accumulation in roe deer body may be intense consumption of oak, aspen and blackberry shoots (Krasnov et al., in print).

The results of ^{137}Cs activity in bilberry, lingonberry and common heather indicate an increase of radionuclide accumulation at the end of the vegetation period (fig. 2). The maximum content of ^{137}Cs in lingonberry and common heather was observed in October and that in bilberry – in August. Bilberry constitutes basic food for roe deer who feed on it all year round. Earlier studies show that common heather and lingonberry are present in roe deer diet in the fall, spring and winter (Krasnov et al. in print). In the fall, the share of bilberry in roe deer diet is 4.7 %, that of common heather is 2.3 %, whereas lingonberry is rare consumed (Krasnov et al. 2007; Krasnov et al., in print). Even if the furthermost consumption of a given plant species by roe deer takes place in winter, an increase of ^{137}Cs accumulation observed already in the fall can have an effect on overall radioactive contamination in the European roe deer.

Table 4. Accumulation indices of ^{137}Cs in the fruiting bodies of fungi (accumulation indices has no units)

Species of fungus	Accumulation indices		The ability to accumulation
	mixed coniferous forests	mixed broadleaved forests	
Cantharellus spp. Adans. ex Fr.	0.68±0.31	0.29±0.03	weakly cumulative
Boletus edulis Bull.	1.88±0.29	0.52±0.19	
Russula spp. Pers.	3.51±0.40	1.03±0.26	intensively cumulative
Leccinum spp. Gray	4.91±1.14	2.63±0.93	
Xerocomus badius (Fr.) E.-J. Gilbert)	10.54±3.70	1.30±0.50	
Paxillus involutus Fr.	10.63±2.57	3.45±1.82	

4. Conclusions

1. The level of radioactive contamination in plants and fungi that compose European roe deer diet depends on site soil fertility. The highest ^{137}Cs activity in plants and fungi was recorded under the conditions of poor habitats. The intensity of radionuclide uptake by plant and fungi decreases with increasing soil fertility.

2. The highest ^{137}Cs activity in the leaves and one-year shoots of observed in the shoots of undergrowth and underbrush tree species as well as shrubs and sub-shrubs was recorded from the end of the summer to September and October. During this period of time, the European roe deer shows feeding preferences toward the plants examined, and thus the animals can be exposed to increased radioactive contamination.

Conflict of interests

No potential conflicts are declared

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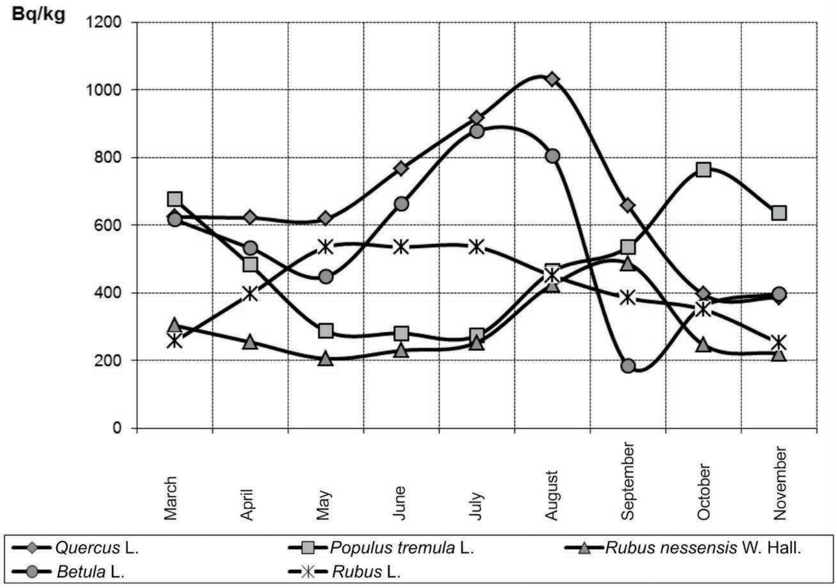

Figure 1. Dynamics of ^{137}Cs activity in the food plant parts of the undergrowth and understorey plants in mixed broadleaved forests

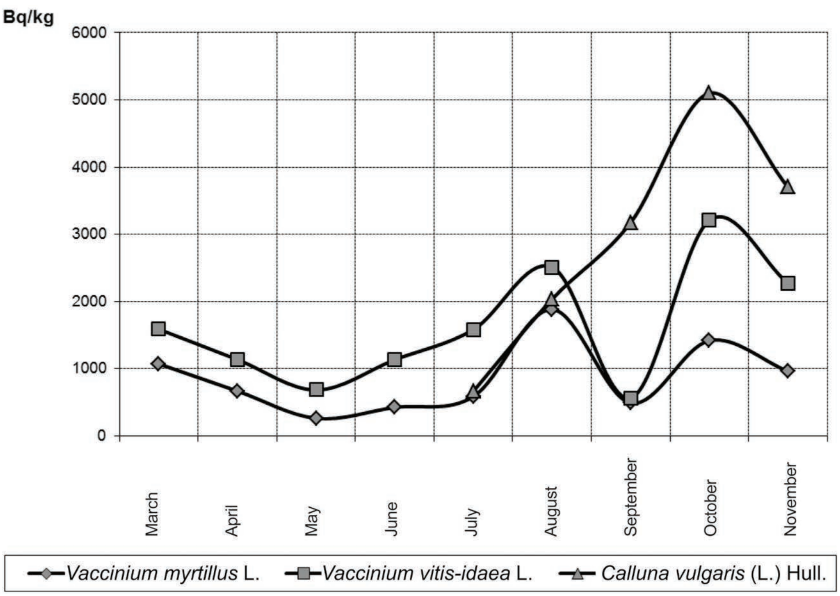

Figure 2. Dynamics of ^{137}Cs activity in the shrubs in mixed broadleaved forests

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Author's contribution

V.K. – conception, result analysis and conclusions; Z.S. – literature review, field work; S.B. – result analysis, discussion and conclusions; I.G. – field work; W.S. – result analysis, discussion and conclusions.

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