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Soil characteristics at *Spermophilus citellus* localities in the Czech Republic (Rodentia: Sciuridae)

Charakteristika půd na lokalitách sysla obecného (*Spermophilus citellus*) v České republice (Rodentia: Sciuridae)

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Abstract. Many rodent species, including ground squirrels, inhabit underground burrows used as a shelter for night, protection from predators and adverse weather, for reproduction or hibernation. Although soil is an important part of environment of the critically endangered *Spermophilus citellus*, almost no data on this habitat component are available. In 2008 and 2009, basic pedological survey was carried out at 34 extant and four recently extinct localities of *S. citellus* in the Czech Republic. Altogether 43 test pits were excavated at the study localities. Basic soil characteristics were described, such as taxonomic affiliation – soil group with qualifiers order, suborder or variety, thickness, colour, structure, presence and type of soil skeleton and moisture. In the samples taken, soil texture and basic physical characteristics (maximum capillary water capacity, minimum and actual air capacity, bulk density and porosity) were determined and vulnerability of the soil towards pedocompaction was assessed. Most often, deep soils free of skeleton originating from loess and loess soils loam (39% of test pits), but also shallow soils with a high content of skeleton were recorded. Mean soil depth was 70 cm. No semi-hydromorphic and hydromorphic soils were recorded. Soils with medium and light texture (65% of test pits) prevailed at the study localities, however, rather heavy soils were also represented. Very light and very heavy soils were recorded only marginally. Most of the soils showed good water retention and usually medium aeration. Vulnerability of the soils towards pedocompaction was evaluated as medium in most cases. In summary, *S. citellus* is quite adaptable to soil conditions, avoiding only soils affected by water. Current distribution of the species in the Czech Republic is thus probably not directly determined by soil conditions.

Key words. Soil, habitat, endangered species, environmental conditions, Rodentia.

INTRODUCTION

The European ground squirrel *Spermophilus citellus* (Linnaeus, 1766) is an endemic to central and southeastern Europe, ranging from the Czech Republic, Austria and Slovakia in the northwest to Greece, Bulgaria and western Ukraine in the southeast (Kryštufek 1999). At present the species is classified as vulnerable and is the object of conservation efforts throughout Europe (IUCN 2011). In the Czech Republic, an action plan for conservation of *S. citellus* has been implemented since 2008 (Matějů et al. 2010). Among others, the aims of this action plan include an ambition to complete information about *S. citellus* habitat requirements. Our attention in this study was thus focused on soil, representing the environment of *S. citellus* burrows.

Subterranean burrows are created and/or used by a variety of mammals including numerous rodent species and among them also ground squirrels. Burrows protect ground squirrels against predators (Blumstein 1998). They are used as a shelter for night, for rearing of the young and even for mating (Grulich 1960, Nowak 1999). Burrows provide stable and relatively secure microenvironment during the periods of winter inactivity – hibernation (King 1984). The rise of soil temperature is known to be a trigger of ground squirrels emergence from hibernation (Wade 1950, Grulich 1960). In some marmot species (*Marmota* sp.), soil geomorphology is even a key factor enabling expression of their sociality (Hare & Murie 2007 and references therein).

S. citellus is usually referred to occur in light, well-drained soils (Ružić 1978, Kryštufek 1999, Spitzenberger 2002) where it can excavate its burrows. Nevertheless, original information about *S. citellus* relation to soil environment is scarce, probably due to former commonness of this species (Grulich 1960, 1980, Koshev & Kocheva 2007).

The aim of this study is to describe basic characteristic of soils recently occupied by *S. citellus* colonies in the Czech Republic and possibly ascertain factors limiting its occurrence.

METHODS

Pedological survey was carried out at all 34 extant and four recently extinct localities of *S. citellus* in the Czech Republic in 2008 and 2009 (for details see Table 1).

Soil characteristics were obtained using dug test pits, approximately 60×120–150 cm in size. Depth of the test pits varied according to depth of soil at the particular site. Test pits could not be dug at the localities "Karlovy Vary – golf course" and "Karlovy Vary – airfield", basic data were thus obtained using a drilled test pit. At most sites only one test pit was made, however, 2–3 test pits were dug at three larger and more heterogeneous sites. Altogether 43 test pits were excavated (Table 1).

For each test pit, morphology of soil profile was described, i.e. sequence and thickness of the particular diagnostic soil horizons and the character of their transition (Janderková et al. 2010). Based on the presence and sequence of the horizons, the soil was classified into the particular soil order, suborder or variety following Němeček et al. (2001). Moreover, morphological characteristics of the horizons detectable in the field were taken, especially thickness, structure, and moisture. Presence of soil skeleton (gravels, stones, artefacts) was classified in following categories: none (0–5 volume percent), admixture of skeleton (5–10 volume percent), sligthly skeletal (10–25 volume percent), medium skeletal (25–50 volume percent), strongly skeletal (50–80 volume percent) and skeletal (>80 volume percent). Depth of soil and – where appropriate – occurrence of continuous bedrock, continuous layer of soil skeleton or increased level of groundwater were also recorded. Occurrence of soil hydromorphism (formation of soil under anaerobic conditions due to periodic or permanent flooding or saturation – stagnic and gleyic processes) was also identified.

For the laboratory analysis of soil texture, a disturbed soil sample about 500 g in weight was taken from the test pits about 40–50 cm underground. Soil texture was determined using the pipette method (ISO

11277). In order to determine soil type based on soil texture, international classification using the triangle diagram developed by NRCS USDA (FAO 2006) was used.

For the analysis of selected physical characteristics of the soil, undisturbed samples were taken using the so-called Kopecký's cylinders 100 cm^3 in volume. The samples were taken from the dug test pits only, vertically from the small platform created by cutting a part of the pit wall about 40 cm underground. The soil samples were analysed in a standard way, the following parameters were measured: actual soil moisture, maximum capillary water capacity, volumetric weight, bulk density, porosity, minimum and actual air capacity, and absorption. For further assessment, mainly the maximum capillary water capacity, minimum and actual air capacity, bulk density and porosity were used as the parameters which best characterise the water regime in soil and its vulnerability towards pedocompaction. Maximum water capacity characterises the ability of soil to retain water, i.e. it determines the percentage of pores filled with capillary water. Its values enable to quantify maximum water retention of the soil, i.e. the highest level of moisture which can be contained by the soil without overwatering of the given horizon. The highest values are usually found in clayish soils, while the low values are typical of sandy soils. On the other hand, minimum air capacity informs about the amount of air in the same moment, i.e. when all capillary pores are filled with water. It is the opposite situation than in water capacity – the highest values are typical of sandy soils.

Bulk density together with porosity are basic indicators of the level of pedocompaction, i.e. thickening of the soil. This degradation process is also interesting considering penetrability of the soil for animals living in it – it is more difficult to dig burrows in a compacted soil, however, the burrows are not so prone to collapse. Based on the recorded values of the above parameters, the so-called packing density (Novák & Valla 2002) was calculated and vulnerability of the soil towards pedocompaction was assessed according to Novák & Valla (l.c.).

RESULTS

Soil groups and soils according to parent material

Altogether eight soil groups were found at the *S. citellus* localities (Fig. 1). Regosols were the most frequent (10 test pits, 23%), followed by cambisols (9 test pits, 21%) and leptosol (six test pits, 14%; see Fig. 1, Table 1). Considering the relation to parent material, soils originating from loess sediments – black (chernozem), grey and brown earth soils or carbonate regosols – were identified most often (17 test pits, 39%), followed by soils from weathered crystalline rocks (11 test pits, 26%) and soils from sand and gravel (8 test pits, 19%). Soils originating from clay, clay stone, marl and marl stone were recorded in four test pits, soil of anthropogenous origin in two test pits, while limestone was a parent material in one case.

Semi-hydromorphic and hydromorphic soils were recorded at none of the studied localities or more precisely, in none of the test pits. The only exception is the locality Lomy, where a reductomorphic horizon was determined, however, as deep as over 85 cm underground. It is a well-preserved horizon of original soil, which was overlaid with a strong layer of soil material showing no significant tendency to wetting. Even at the localities with soils heavier in texture (Jamolice, Raná), no apparent morphological evidence of hydromorphism was found in the soil profile.

Soil skeleton and soil depth

Soils without skeleton were recorded in 16 test pits (36%), soils with admixture of skeleton in nine test pits (21%) and slightly skeletal soils in five test pits (12%). In eight cases (19%) the soil in the test pits was classified as medium and in five cases (12%) as strongly skeletal.

Table 1. List of studied European ground squirrel localities and their basic soil characteristics (names of localities shortened according to Matějů et al. 2008; extinct sites indicated in *italics*)

Tab. 1. Přehled zkoumaných lokalit sysla obecného a základní charakteristiky jejich půd (jména lokalit zkrácena podle Matějů et al. 2008, zaniklé lokality uvedeny *kurzívou*)

Legend / vysvětlivky: SD – soil depth / hloubka půdy; STC – soil textural classes / druh půdy: c – clay, cl – clay loam / jílovitohlinitá, l – loam / hlinitá, ls – loamy sand, s – sandy / písčitá, sl – sandy loam / písčitohlinitá; MTC – main textural categories / druh půdy: h – heavy / těžká, l – light / lehká, m – medium / střední, vh – very heavy / velmi těžká; PD – packing density / hustota záznamu; PcV – pedocompaction vulnerability / zranitelnost pedokompakcí: c – compacted / zhutněno, h – high / vysoké, l – low / nízké, m – medium / střední

site (n. of test pit) / lokalita (č. sondy)	coordinates of test pit / souřadnice sondy °N	°S	soil group with qualifiers / půdní typ a subtyp	SD [cm]	STC	MTC	PD [g×cm^{-3}]	PcV
Albeř	49.0266	15.1481	cambisol (dystric) / kambizem dystrická	75	sl	m	1.47	m
Bezděčín	50.4006	14.8957	regosol (arenic) / regozem arenická	60	s	l	1.79	m
Biskoupky	49.0947	16.2897	regosol (calcaric, siltic) / regozem karbonátová	150	l	m	1.51	m
Bořitov	49.4321	16.5922	haplic luvisol (siltic) / hnědozem modální	130	l	m	1.71	m
Brno-Medlánky	49.2407	16.5589	haplic luvisol (siltic) / hnědozem modální	100	l	h	1.90	c
Břeclav-Ladná	48.7893	16.8861	chernozem (arenic) / černozem arenická	65	sl	l–m	1.84	m
Čejč	48.9588	16.9645	haplic chernozem (siltic) / černozem modální	80	l	h	1.81	m–h
Černovice	49.1788	16.6626	haplic chernozem (siltic) / černozem modální	63	cl	h	1.80	m–h
Hodkovice n. Mohelkou	50.6531	15.0759	regosol (arenic) / regozem arenická	50	s	l	1.67	l
Hrádek	50.4047	13.7468	regosol (arenic) / regozem arenická	42	sl	vh	1.77	m
Hrubšice, PR Nad řekami	49.0942	16.2935	cambisol (siltic) / kambizem luvická	75	cl	h	1.88	c
Hrušovany u Brna (1)	49.0326	16.5869	colluvial soil / koluvizem modální	135	ls	l-m	1.78	m
Hrušovany u Brna (2)	49.0287	16.5850	regosol (skeletic) / regozem psefitická	25	sl	m	1.66	m
Chramosty	49.6700	14.3231	haplic cambisol / kambizem modální	53	ls	l–m	1.67	l
Ivančice	49.0936	16.3752	regosol (skeletic) / regozem psefitická	33	ls	l-m	1.56	l
Jamolice	49.0829	16.2501	luvisol (clayic) / hnědozem pelická	80	c	vh	1.93	c
Jaroslavice	48.7423	16.2085	haplic chernozem (siltic) / černozem modální	95	l	h	1.64	m
Karlovy Vary, airport	50.2051	12.9049	haplic cambisol / kambizem modální	60	–	l–m	–	–
Karlovy Vary, golf range	50.2121	12.9284	haplic cambisol / kambizem modální	70	–	l–m	–	–
Kolín	50.0048	15.1740	greyic phaeozem (siltic) / šedozem modální	85	l	h	1.76	m–h
Kyjov-Milotice	48.9825	17.1239	greyic phaeozem (siltic) / šedozem modální	80	sl	m	1.89	m
Letňany	50.1316	14.5338	haplic chernozem (siltic) / černozem modální	100	l	h	1.69	m
Líchovy, *hotel Mana*	49.6781	14.2974	haplic cambisol / kambizem modální	50	ls	l–m	1.69	l–m

Table 1. (continued)
Tab. 1. (pokračování)

site (n. of test pit) / lokalita (č. sondy)	coordinates of test pit / souřadnice sondy °N	°S	soil group with qualifiers / půdní typ a subtyp	SD [cm]	STC	MTC	PD [g×cm^{-3}]	PcV
Loděnice	49.9849	14.1642	leptosol (calcaric) / pararendzina modální	20	sl	m	1.54	m
Lomy	49.1105	15.1657	anthrosol / antropozem terasovaná	85	ls	l–m	1.58	l
Milešov: Trhovky	49.5839	14.1739	cambisol (skeletic) /ranker kambický	25	ls	m	1.63	l
Milešov: Trhovky-Bor	49.5830	14.1764	haplic cambisol / kambizem modální	55	s	l	1.61	l
Milešov: Trhovky-Loužek	49.5881	14.1783	technosol (skeletic)/ antropozem urbická	16	ls	l–m	1.42	l–m
Miroslav	48.9335	16.2992	colluvial soil /koluvizem karbonátová	170	sl	m	1.69	m
Mladá Boleslav-Radouč	50.4332	14.9042	regosol (arenic) / regozem arenická	62	ls	l–m	1.79	m
Mohelno	49.1100	16.1803	haplic leptosol / ranker modální	30	l	m	1.51	m
Raná (1)	50.4063	13.7787	leptosol (calcaric) / pararendzina pelická	53	c	vh	1.63	h
Raná (2)	50.4042	13.7738	leptosol (calcaric) / pararendzina pelická	58	c	h	1.63	h
Raná (3)	50.4025	13.7719	leptosol (calcaric) / pararendzina pelická	32	cl	l–m	1.89	c
Roudnice n. Labem	50.4049	14.2330	regosol (skeletic) / regozem psefitická	30	sl	m	1.89	m
Rozdrojovice, hotel Atlantis	49.2480	16.51624	haplic luvisol (siltic) / hnědozem modální	100	cl	vh	1.97	c
Strakonice	49.2550	13.8941	cambisol (episkeletic) / kambizem rankerová	18	sl	m	1.62	m
Svatobořice-Mistřín	48.9832	17.0695	hortic anthrosol / kultizem rigolovaná	100	sl	m	1.73	m
Újezd u Brna	49.1095	16.7635	regosol (calcaric, siltic) / regozem karbonátová	70	cl	h	1.66	h
Velká Dobrá	50.1112	14.0907	haplic luvisol (siltic) / hnědozem modální	110	l	h	1.79	m–h
Velké Pavlovice	48.9158	16.8138	regosol (calcaric, siltic) / regozem karbonátová	70	sl	m	1.66	m
Vítkův vrch	50.2046	12.8929	haplic cambisol / kambizem modální	60	ls	l–m	1.52	l–m
Vyškov	49.2994	17.0220	greyic phaeozem (siltic) / šedozem modální	85	l	vh	1.65	m

The mean soil depth was 70 cm (median 65 cm), however, both very deep soils (170 cm, Miroslav) and shallow soils on gravely and/or stony bedrock (18 cm, Strakonice) or on scree (16 cm, Loužek; Fig. 2, Table 1) were recorded.

Soil texture and soil types

Considering soil texture, *S. citellus* localities are situated on a wide range of soil types, from light incoherent sandy soils to very heavy clayish soils (Fig. 3, Table 1). Light soils were recorded in three test pits (7%), light to medium soils in 12 test pits (28%) and medium in 13 test pits (30%). In eleven cases (26%) the soil in the test pits was classified as heavy and in four cases (9%) as very heavy.

Physical characteristics of the soils

The recorded values of bulk density range between 1.1 and 1.8 g×cm^{-3} (mean and median 1.5 g×cm^{-3}) depending on soil texture (Table 2), most often between 1.6 and 1.7 g×cm^{-3}. These values indicate strongly compacted dense soils. Lower values of bulk density are typical of soils heavier in texture but uncompacted (Raná), higher values for soils with a higher proportion of sand (Bezděčín) or moderately and heavily compacted soils (Roudnice). The overall porosity

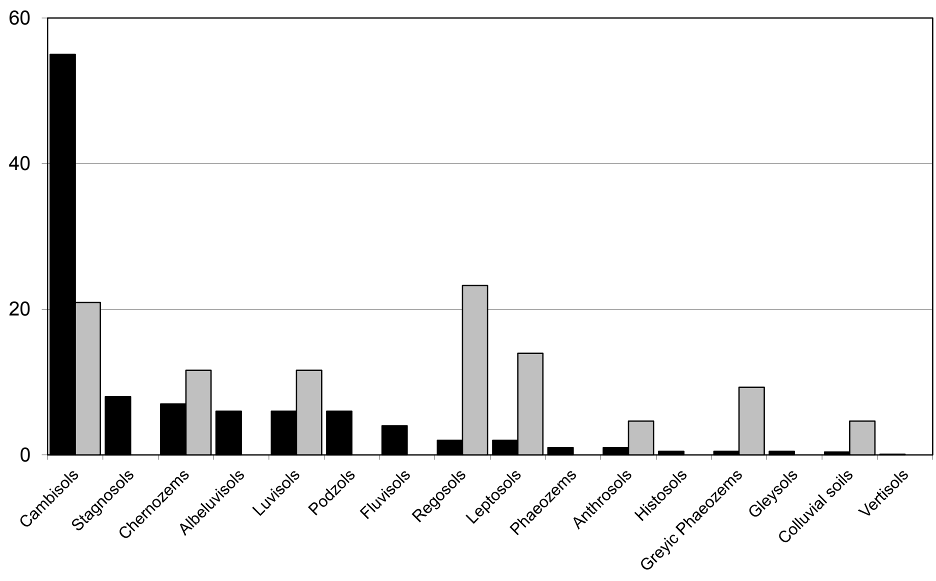

Fig. 1. Soil groups recorded in 43 tests pits at 38 studied localities of *Spermophilus citellus* in the Czech Republic (grey columns). Reference ratio of soil groups in the Czech Republic (black columns) according to Sedláček et al. (2009).
Obr. 1. Půdní typy zaznamenané ve 43 sondách na 38 studovaných lokalitách sysla obecného (*Spermophilus citellus*) v ČR (šedé sloupce). Pro srovnání je uvedeno zastoupení jednotlivých typů půd v ČR (černé sloupce) podle Sedláček et al. (2009).

Table 2. Basic physical soil characteristic of the studied European ground squirrel localities (names of localities shortened according to Matějů et al. 2008; extinct sites indicated in *italics*)
Tab. 2. Základní fyzikální charakteristiky půd na zkoumaných lokalitách sysla obecného (jména lokalit zkrácena podle Matějů et al. 2008, zaniklé lokality uvedeny *kurzívou*)
Legend / Vysvětlivky: AM – actual soil moisture / momentální vlhkost (% vol. / obj.), MC – maximum capillary water capacity / maximální kapilární vodní kapacita (% vol. / obj.), D – density / hustota (g/cm^3), BD – bulk density / objemová hmotnost redukovaná (g/cm^3), P – porosity / pórovitost (% vol. / obj.), ACA – actual air capacity / momentální vzdušná kapacita (% vol. / obj.), ACM – minimum air capacity / minimální vzdušná kapacita (% vol. / obj.), WA – water absorption / nasáklivost (% vol. / obj.)

site / lokalita	AM	MC	D	BD	P	ACA	ACM	WA
Albeř	28.69	34.50	2.65	1.36	48.73	20.03	14.23	42.89
Bezděčín	0.77	16.03	2.66	1.75	34.22	33.44	18.18	30.31
Biskoupky	5.15	43.33	2.75	1.32	52.18	47.03	8.85	51.40
Bořitov	9.95	35.68	2.69	1.49	44.33	34.38	8.65	43.57
Brno-Medlánky	10.06	35.81	2.72	1.59	41.74	31.68	5.93	45.24
Břeclav-Ladná	3.10	29.25	2.67	1.67	37.39	34.29	8.14	35.55
Čejč	8.00	39.67	2.66	1.56	41.49	33.49	1.82	46.25
Černovice	18.20	39.07	2.70	1.49	44.83	26.63	5.76	48.35
Hodkovice n. Mohelkou	7.15	19.88	2.66	1.61	39.19	32.04	19.31	26.94
Hrádek	13.59	33.81	2.68	1.61	39.99	26.40	6.18	43.82
Hrubšice, PR N. řekami	16.04	41.07	2.75	1.52	44.83	28.79	3.76	48.53
Hrušovany u Brna I	12.53	28.02	2.67	1.64	38.72	26.19	10.71	34.45
Hrušovany u Brna II	10.47	26.92	2.66	1.49	44.13	33.67	17.22	38.14
Chramosty	11.52	24.37	2.69	1.61	40.06	28.54	15.68	31.56
Ivančice	12.63	24.83	2.68	1.43	46.72	34.09	21.89	33.49
Jamolice	28.99	58.32	2.80	1.46	48.11	19.13	<0.10	63.32
Jaroslavice	5.93	37.62	2.68	1.37	49.07	43.15	11.46	46.93
Kolín	17.24	41.44	2.71	1.46	45.93	28.70	4.50	48.32
Kyjov-Milotice	5.50	32.77	2.68	1.70	36.71	31.21	3.94	38.55
Letňany	26.31	35.55	2.68	1.38	48.57	22.26	13.02	44.85
Líchovy, hotel Mana	15.70	24.34	2.71	1.61	40.58	24.88	16.24	32.32
Loděnice	20.86	37.44	2.73	1.41	48.60	27.74	11.16	46.37
Lomy	18.82	26.15	2.64	1.51	42.76	23.94	16.61	35.36
Milešov: Trhovky	11.48	28.35	2.73	1.56	42.80	31.33	14.45	39.46
Milešov: Trhovky-Bor	7.39	19.61	2.70	1.55	42.52	35.13	22.91	26.76
Milešov: Trhovky-L.	9.45	24.37	2.70	1.33	50.54	41.09	26.17	34.58
Miroslav	2.07	31.38	2.70	1.52	44.03	41.96	12.65	39.03
Mladá Boleslav-Radouč	1.77	21.73	2.66	1.65	38.17	36.39	16.44	31.26
Mohelno	23.68	33.90	2.71	1.27	53.10	29.42	19.20	41.96
Raná I	42.69	57.31	2.74	1.11	59.28	16.59	3.06	62.36
Raná II	24.60	45.23	2.71	1.18	56.35	31.75	11.12	54.39
Raná III	18.10	37.33	2.73	1.55	43.21	25.12	5.88	45.73
Roudnice n. Labem	14.27	28.82	2.66	1.70	36.10	21.83	7.29	38.04
Rozdrojovice, h. Atlantis	18.49	41.00	2.74	1.58	42.50	24.01	1.50	47.31
Strakonice	24.53	36.52	2.66	1.52	42.63	18.10	6.11	42.02
Svatobořice-Mistřín	3.99	37.68	2.69	1.51	43.78	39.79	6.10	44.11
Újezd u Brna	9.09	45.90	2.73	1.33	51.42	42.34	5.53	52.73
Velká Dobrá	22.11	36.56	2.71	1.50	44.56	22.45	8.00	44.50
Velké Pavlovice	2.21	42.24	2.73	1.46	46.72	44.52	4.48	46.92
Vítkův vrch	4.08	15.57	2.70	1.45	46.13	42.04	30.55	24.57
Vyškov	13.57	36.49	2.71	1.35	49.99	36.42	13.50	46.78

ranged between approx. 34 and 59 volume percent, most often between 40 and 50 volume percent (mean and median 44 volume percent; Table 2). Considering values of the packing density, in most cases (27 test pits) the soil showed medium vulnerability towards pedocompaction. Low vulnerability was found in two test pits only, on the other hand, an obviously compacted soil with heavier texture was recorded in five test pits. High or medium to high vulnerability towards pedocompaction was found in seven test pits (Table 1).

Values of maximum capillary water capacity were in a wide range of 16 to 58 volume percent (mean 33.8, median 35.6 volume percent), depending mostly on soil texture and structure. The lowest values are shown by sandy soils or soils with a high content of granite grus, while the highest values by soils with a higher content of dust silt and especially clay (Table 2). All studied soils, including the soils from substrates with lighter texture, belong to the so-called water-retaining soils. Of them, soils with water retention (maximum water capacity >10 volume percent) were found in 15 test pits, soils with strong water retention (max. water capacity >30 volume percent) in 24 test pits, and soils with very strong water retention (max. water capacity >50 volume percent) in two test pits. However, all of them show good infiltration and, due to their position, grass vegetation cover with high evapotranspiration, content of soil skeleton and absence of hardly permeable layers, there is no stagnation of rainfall water in the profile.

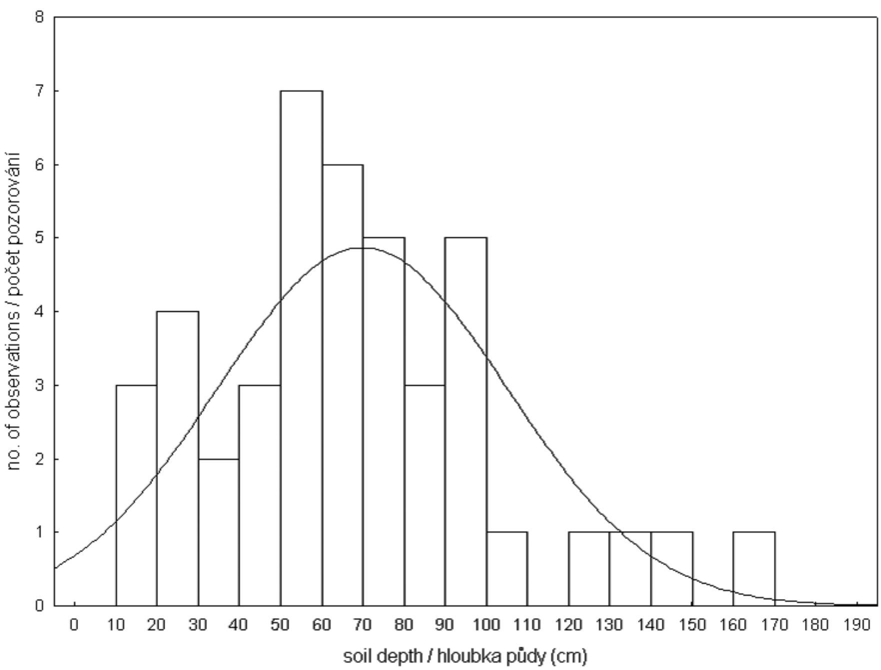

Fig. 2. Depth of soil recorded in 43 tests pits at 38 studied localities of *Spermophilus citellus* in the Czech Republic.
Obr. 2. Hloubka půdy zaznamená ve 43 sondách na 38 studovaných lokalitách sysla obecného (*Spermophilus citellus*) v ČR.

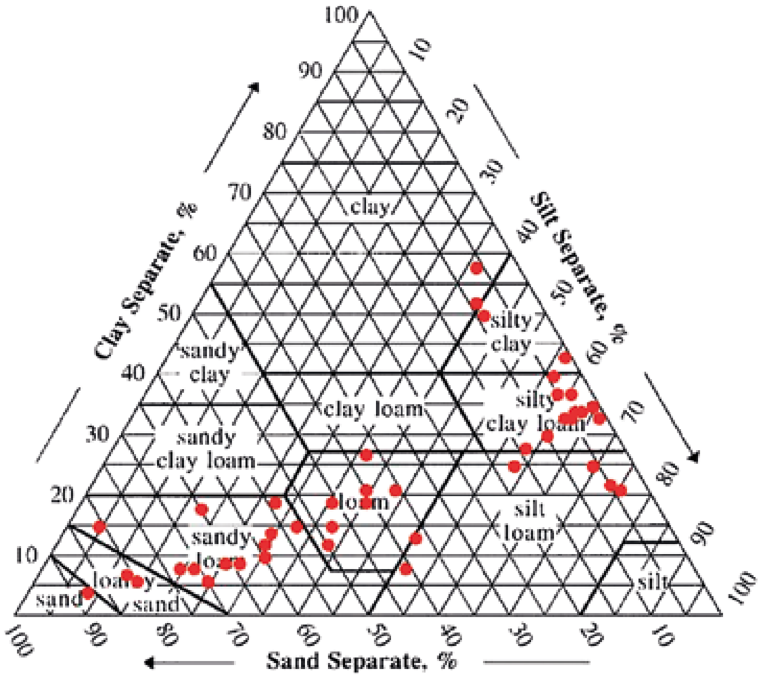

Fig. 3. Distribution of soil textural classes recorded in 43 tests pits at 38 studied localities of *Spermophilus citellus* in the Czech Republic. Triangle diagram according to NRCS USDA, FAO (2006).
Obr. 3. Distribuce zrnitostních tříd zjištěných v 43 sondách na 38 studovaných lokalitách sysla obecného (*Spermophilus citellus*) v ČR. Trojúhelníkový diagram podle NRCS USDA, FAO (2006). Vysvětlivky: clay – jíl, jílovitý, loam – hlína, loamy – hlinitý, sand – písek, sandy – písčitý, silt – prach, silty – prachovitý.

Also the values of minimum air capacity were highly variable, ranging from 0.1 to 30.6 volume percent (mean 11.2, median 10.7 volume percent; Table 2). In almost a half of the test pits (20), very low or low minimum air capacity was recorded (less than 5 or less than 10 volume percent, respectively), while in 21 cases the minimum air capacity was medium or high (more than 10 or more than 20 volume percent, respectively). The recorded actual air capacity was significantly higher (16.6 to 47.0 volume percent, mean 31.0, median 31.3 volume percent).

DISCUSSION

Soil is an important component of the ground squirrel environment. Our study provides the first detailed description, including physical parameters, of this part of environment of *S. citellus* in the Czech Republic. We have found that the current localities of the species in the Czech Republic are found both on deep soils free of skeleton originating from loess and loess loam, and on shallow soils with a high content of skeleton. Soils affected by water – semi-hydromorphic and hydromorphic were not recorded. Soils with medium and light texture were found in most of the studied *S. citellus* localities, however, there also was an important proportion of heavy soils. Very light or very heavy soils were represented only marginally. Most of the soils showed good water retention and usually medium aeration. Vulnerability of the soils towards pedocompaction was evaluated as medium in most cases.

Practically no comparable, sufficiently detailed data are available for *S. citellus* or other closely related species. In Bulgaria, Koshev & Kocheva (2007) found 30.4% of the known *S. citellus* colonies on chernozem, 25.3% on fluvisols and 15.7% on luvisols. However, the information may be misleading as Koshev & Kocheva (2007) did not provide information about soil type proportion in the studied area.

Earlier papers by Grulich (1960, 1980) are restricted to the statement that *S. citellus* in the Czech and Slovak Republics are found on all light cohesive soils with low groundwater level and lower capillarity. According to Grulich (l.c.), occurrence of *S. citellus* is not related to bedrock, chemical composition of soil or presence of soil skeleton, but to the type of bedrock weathering. Unfortunately, neither the methods used nor primary data for the mentioned statements are specified. Contrary to this study, we recorded *S. citellus* occurrence also on heavy and even very heavy soils. Similarly as Grulich (l.c.), we did not find *S. citellus* occurrence on soils with periodical or permanent overwetting of the profile, i.e. on semi-hydromorphic and hydromorphic soils.

It is rather difficult to draw general biological conclusions from our data, especially for two reasons. First, as shown by similar ecological studies aimed at environment parameters affecting species distribution (e.g. Betts 1990), it is not clear whether the tested parameters are always the essential and key parameters for the existence of a given species. We tried to compensate for this flaw by a large number of measured parameters, working on the assumption that the key parameters could be identified retrospectively. In our case, water influence on the soil is probably the key factor. Periodically or permanently wet soils were not recorded even at the localities Břeclav and Ivančice, which are situated close to large rivers, only some 2–3 m above their water surface. The latter two localities lie on permeable sandy gravel terraces and are not affected by stagnating groundwater. The only manifestation of soil hydromorphism recorded at the locality Lomy was found as deep as 85 cm underground, which is probably beyond the usual depth of occurrence of *S. citellus* burrows (up to 80 cm, usually 50–70 cm; Grulich 1960).

Second, it is not known whether all studied localities represent optimal habitat of *S. citellus* or whether, considering the current "relic" occurrence of the species in the Czech Republic (Matějů et al. 2008), some of them could be sites with suboptimal soil conditions. Occurrence of *S. citellus* on very shallow soils at the localities Loděnice, Strakonice, Trhovky can be mentioned as an example. *S. citellus* populations at all three latter localities were negatively affected by rainfall water in the past (Matějů et al. 2010, Uhlíková, Schnitzerová & Matějů unpubl. data), which can be related to temporary accumulation of water in shallow soil. Occurrence of *S. citellus* at such localities may be enabled by presence of other extraordinarily favourable factors, such as vegetation height or better food availability.

Regarding the former more widespread occurrence of *S. citellus* in Europe (Jacobi 1902, Werth 1936) as well as in the Czech Republic (Grulich 1960), we can assume that our study covers only a part of variability of soil characteristics which could be recorded at *S. citellus* localities. This fact may e.g. explain the occurrence of *S. citellus* on podzols reported by Grulich (1960), which was not confirmed in our study (see Fig. 1). Similarly, the prevailing *S. citellus* occurrence on soils originating from loess recorded in our study could be quite different at the times of widespread distribution of the species.

CONCLUSIONS

Our study brings basic information about soil conditions at current localities of *S. citellus* in the Czech Republic. The species seems to be quite adaptable to soil conditions at the site, being able to inhabit a wide range of soil types – light as well as heavy soils, shallow as well as deep soils, regardless of the presence of soil skeleton and potential soil compaction. It only avoids semi-hydromorphic and hydromorphic soils. The current pattern of *S. citellus* distribution in the Czech Republic is thus probably not directly determined by soil conditions.

The results of this study can be used e.g. for selection of sites suitable for *S. citellus* reintroduction as a part of implementation of the species action plan – such sites should be situated on rather deep soils, not affected by water. At the same time, it would be highly beneficial to carry out similar studies in other parts of *S. citellus* distribution range and to compare the obtained data.

SOUHRN

Řada druhů hlodavců, mezi nimi i sysel obecný (*Spermophilus citellus*), je vázaná na podzemní nory, které jim slouží jako noční úkryt, úkryt před predátory a nepříznivým počasím, k rozmnožování či zimnímu spánku. I přesto, že půda tvoří významnou složku životního prostředí sysla obecného, neexistují téměř žádné informace, které by tuto část prostředí popisovaly či dokonce řešily možné vazby mezi rozšířením sysla a vlastnostmi půdy. V rámci přípravy a realizace záchranného programu byl proto v letech 2008 a 2009 proveden základní pedologický průzkum 34 lokalit současného a čtyř lokalit nedávného výskytu sysla obecného v ČR, na kterých bylo realizováno celkem 43 půdních sond. Na plochách přímo osídlených syslem byly popsány základní charakteristiky půdy jako: taxonomická příslušnost – půdní typ, subtyp popř. varieta, mocnost, barva, struktura, skeletovitost a vlhkost. Z odebraných vzorků byla stanovena zrnitost a základní fyzikální charakteristiky: maximální kapilární vodní kapacita, minimální a momentální vzdušná kapacita, objemová hmotnost redukovaná a pórovitost půdy. Také byla stanovena míra ohrožení půdy pedokompakcí (utužením). Výsledky ukázaly, že na území České republiky se v současné době sysel obecný vyskytuje nejčastěji na hlubokých a bezskeletových půdách vzniklých ze spraší a sprašových hlín, zjištěn byl ale i v půdách mělkých s vysokým obsahem skeletu. Půdy ovlivněné vodou – semihydromorfní a hydromorfní na lokalitách s výskytem sysla zaznamenány nebyly. Na studovaných lokalitách převažovaly půdy střední a lehčí střední zrnitosti, zastoupeny však byly i půdy těžší. Vysloveně lehké či velmi těžké půdy byly zaznamenány jen okrajově. Většina půd vykazovala dobrou vododržnost a zpravidla střední provzdušněnost. Zranitelnost půd pedokompakcí byla ve většině případů hodnocena jako střední. Souhrnně lze říci, že ve vztahu k půdním podmínkám je sysel obecný značně přizpůsobivý a vyhýbá se pouze půdám ovlivněným vodou. Stávající rozšíření sysla v ČR tak pravděpodobně není přímo určeno půdními podmínkami. Dosažené výsledky je možné využít například pro výběr lokalit vhodných pro reintrodukce sysla v rámci realizace jeho záchranného programu – takové lokality by měly být situovány na hlubších vodou neovlivněných půdách.

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REFERENCES

Betts B. J., 1990: Geographic distribution and habitat preferences of Washington ground squirrels (*Spermophilus washingtoni*). *Northwestern Naturalist*, **71**: 27–37.

Blumstein D. T., 1998: Quantifying predation risk for refuging animals: A case study with golden marmots. *Ethology*, **104**: 501–16.

FAO, 2006: *Guidelines for Soil Description. 4th Edition*. FAO, Rome, 108 pp.

Grulich I., 1960: Sysel obecný *Citellus citellus* L. v ČSSR [European ground squirrel *Citellus citellus* L. in Czechoslovakia]. *Práce Brněnské Základny Československé Akademie Věd*, **32**(11): 473–563 (in Czech, with a summary in English).

Grulich I., 1980: Savci a zemní stavby v kulturocenózách [Mammals and earth works in culturocoenoses]. *Questiones Geobiologicae*, **24–25**: 1–204 (in Czech, with summaries in English, German, French and Russian).

Hare J. F. & Murie J. O., 2007: Ecology, kinship, and ground squirrel sociality: Insights from comparative analyses. Pp.: 345–355. In: Wolff J. O. & Sherman P. W. (eds.): *Rodent Societes: an Ecological and Evolutionary Perspective.* The University of Chicago Press, Chicago & London, 610 pp.

ISO 11 277, 2002: *Soil quality – Determination of Particle Size Distribution in Mineral Soil Material – Method by Sieving and Sedimentation*. Beuth-Verlag, Berlin, 38 pp.

IUCN, 2011: *IUCN Red List of Threatened Species. Version 2011.2.* URL: http://www.iucnredlist.org.

Jacobi A., 1902: Der Ziesel in Deutschland. *Arbeiten aus der Biologischen Abteilung für Land- und Forstwirtschaft am Kaiserlichen Gesundheitsamte*, **2**(4): 506–511.

Janderková J., Petruš J., Sedláček J. & Uhlíková J., 2010: Příloha 1: Pedologická studie vybraných charakteristik. (celkem 122 str.) [Annex 1: Paedological study of selected characters. (altogether 122 pp.)]. Pp.: 11–134. In: Vohralík V., Hulva P., Kvičerová J., Matějů J., Růžička J., Schneiderová I., Schnitzerová P. & Uhlíková J. (eds.): *Projekt VaV č. SP/2d4/61/08 – Výzkum biologie*, *ekologie a rozšíření sysla obecného* (*Spermophilus citellus*) *v kontextu jeho Záchranného programu v ČR* (*2008–2010*). *Průběžná zpráva o realizaci projektu v roce 2010*. *Kontrolní den 14. 6. 2010* [*Project VaV No. SP/2d4/61/08 – Research of the Biology*, *Ecology and Distribution of the European Ground Squirrel* (*Spermophilus citellus*) *in Context of its Action Plan in the Czech Republic* (*2008–2010*). *Interim Report on Implementation of the Project in 2010. Check Day 14 June 2010*]. Unpubl. Report. Ministry of the Environment of the Czech Republic, 153 pp (in Czech).

King J. A., 1984: Historical ventilations on a prairie dog town. Pp.: 447–456. In: Murie J. O. & Michener G. R. (eds.): *The Biology of Ground-dwelling Squirrels.* University of Nebraska Press, Lincoln, 459 pp.

Koshev Y. S. & Kocheva M., 2007: Environmental factors and distribution of European ground squirrel (*Spermophilus citellus*) in Bulgaria. *Journal "Ecology & Safety. International Scientific Publications",* **1**: 276–287.

Kryštufek B., 1999: *Spermophilus citellus*. Pp.: 190–191. In: Mitchell-Jones A. J., Amori G., Bogdanowicz W., Kryštufek B., Reijnders P. J. H., Spitzenberger F., Stubbe M., Thissen J. B. M., Vohralík V. & Zima J. (eds.): *The Atlas of European Mammals*. Academic Press, London, 484 pp.

Matějů J., Hulová Š., Nová P., Cepáková E., Marhoul P., Uhlíková J., 2010: *Záchranný program sysla obecného* (*Spermophilus citellus*) *v České republice* [*Action Plan for the European Ground Squirrel* (*Spermophilus citellus*) *in the Czech Republic.* Univerzita Karlova v Praze & AOPK ČR, Praha, 80 pp (in Czech and English).

Matějů J., Nová P., Uhlíková J., Hulová Š. & Cepáková E., 2008: Distribution of the European ground squirrel (*Spermophilus citellus*) in the Czech Republic in 2002–2008. *Lynx*, *n. s.*, **39**: 277–294.

Němeček J., Macků J., Vokoun J., Vavříček D. & Novák P., 2001: *Taxonomický klasifikační systém půd České republiky*. [*Taxonomic Classification System of Soils of the Czech Republic*]. ČZU, Praha, 78 pp (in Czech).

Novák P. & Valla M., 2002: Jiné formy degradace půdy [Other forms of soil degradation]. Pp.: 137–124. In: Borůvka L. (ed.): *Pedologické dny 2002. Sborník z konference* "*Degradace půdy*" [*Paedological*

Days 2002. Proceedings of Conference "*Soil Degradation*"]. ČZÚ, Praha, 216 pp (in Czech, with a summary in English).
Nowak R. M., 1999: *Walker's Mammals of the World.* The Johns Hopkins University Press, Baltimore & London, 1936 pp.
Ružić A., 1978: *Citellus citellus* (Linnaeus, 1766) – Der oder das Europäische Ziesel. Pp.: 123–144. In: Niethammer J. & Krapp F. (eds.): *Handbuch der Säugetiere Europas. Band 1. Rodentia I* (*Sciuridae*, *Castoridae*, *Gliridae*, *Muridae*). Akademische Verlagsgesellschaft, Wiesbaden, 476 pp.
Sedláček J., Janderková J. & Šefrna L., 2009: *Půdní asociace* [Soil associations]. Pp.: 134–135. In: Hrnčiarová T., Mackovčin P. & Zvara I. (eds.): *Atlas krajiny České republiky* [*Atlas of Landscape of the Czech Republic*]. MŽP, VÚKOZ, Praha, 352 pp (in Czech).
Spitzenberger F., 2001: *Die Säugetierfauna Österreichs*. Bundesministerium für Land- und Fortswirtschaft, Umwelt und Wasserwirtschaft, Graz, 896 pp.
Wade O., 1950: Soil temperatures, weather conditions, and emergence of ground squirrels from hibernation. *Journal of Mammalogy*, **31**: 158–161.
Werth E., 1932: Zur Verbreitung und Geschichte des Ziesels. *Arbeiten aus der Biologischen Reichsanstalt für Land- und Forstwirtschaft*, **21**: 255–267; 637.