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ANALYSIS OF CHANGES IN DISTRIBUTION OF EURASIAN BEAVER *CASTOR FIBER* FAMILIES BASED ON EVALUATION OF BEAVER ACTIVITY SIGNS IN NORTH-EASTERN SLOVAKIA (2018/2019)

Analiza zmian w rozmieszczeniu rodzin bobrów *Castor fiber* na podstawie oceny śladów bytowania w północno-wschodniej Słowacji (2018/2019)

Abstract: The article presents research on changes in distribution of beaver families based on evaluation of beaver activity signs in the District of Snina on the area of 805 km^2. The goal is to present current knowledge on the local population distribution and dynamics of Eurasian beaver summarizing and comparing data of monitoring period 2018/2019 and previous research conducted in 2014/2015. Using spatial visualisation of beaver activity signs we estimate that there are 34 (±3) beaver families present in study area. It means increase ca. 162% (±129–205%) during the period of 3–4 years. Based on current inventory results one beaver family is distributed over the territory of 23 km^2. The mean length of waterway covered by each beaver family was 3.3 km (in the instance of Water Reservoir Starina we take into account the bank of reservoir), while 0.65 km (±0.49–0.85 km) is actively influenced by beavers within given stretch of stream. In the instance of Water Reservoir Starina the length patrolled by one beaver family is 2.1 km of the bank, while part of 0.79 km (±0.69–0.92 km) is actively influenced by beavers within it. The length of related part of river Cirocha (under the Water Reservoir Starina) for one beaver family is 2.3 km, while 0.95 km (±0.85–1.04 km) is actively influenced by beavers. The length of related part of small streams/tributaries is 4.4 km for one beaver family, while 0.61 km (±0.45–0.83 km) is actively influenced by beavers.

Key words: monitoring, signs of beaver activity, effectivity, families.

Introduction

Beavers (*Castor fiber*) are semi-aquatic, night, social monogamous rodents that live in families, which are composed of one dominant pair, this year and one-year-old kits, exceptionally also non-dominant older individuals (Wilsson 1971; Campbell et al. 2005). Beaver is territorial species, the size of territory is different (Graf et al. 2016), and depends on availability of food and building materials (Campbell et al. 2005). „Castoreum" – adult's castor oil is a product of endocrine glands that serve as odour marked signal and have important role in territory behaviour and demarcation of the territory boundaries (Rosell & Sundsdal 2001). In general, the inputs on territoriality are positively correlated with size of the territory, because bigger territories are harder to defend than smaller (Schoener 1983; Righton et al. 1998). In Norway the beaver population density is 0,24 families of beaver per 1 km^2 – in agricultural land density is higher while in alpine areas markedly lower (Parker & Rosell 2012).

Beaver in Slovakia was negatively perceived in 17th century as an animal causing damage. It could be possible to find beavers as a native species in the Dunaj River and its tributaries in the middle of 19th century (Molnár et al. 1980).

In the western Slovakia the last data of beaver presence are known from 1856. The first information about reappearance in Slovak nature is from 1976 (Valachovič 2013).

The exact credible data about beaver presence in the distant past in the studied area are not known. Also the absence of beavers in the territory of current Bieszczady National Park is estimated on approximately 300 years (Derwich 2000). The restoration of beavers to neighbouring Low Beskidy (Poland) started in 1980–1985 – 5 families with number of 23–26 individuals were released at that time (Zbyryt & Zbyryt 2013). Within the next restoration to the Bieszczady National Park (1991) 182 individuals of beaver in 30 families were released (Derwich 1995; Derwich 2000; Derwich & Mróz 2008). The first records on presence of beavers in adjacent territory of the Carpathians in Ukraine are from 2003 (Bashta & Potish 2012). The first data on beavers' occurrence in Slovak Eastern Carphatians were recorded by Platko (2000) and in the District of Snina by Pčola and Vlasaková (2010).

The increasing number of beaver populations in Europe (Valachovič et al. 2008; Bashta & Potish 2012; Vorel et al. 2012; Borowski 2013; Šimůnková & Vorel 2015), resulted in colonisation of new biotopes. Once a beaver reaches the age of two years it usually leaves the family to find a mate and establish a family of its own. The new adults from previous generation are substituted by individuals of new generation (Doboszyńska & Żurowski 1983). Most of them try to live in close area to their home range (Sun et al. 2000), but some of them migrate over long distances (Hartman 1994; Valachovič 1997; Červený et al. 2000). Beavers within different water bodies manage different part of them with different size of extent (Campbell et al. 2005; Campbell-Palmer 2016).

The goal of this paper is the evaluation, on the basis of signs of activity, the distribution of beaver's families within particular water bodies and to compare the changes in relation to the data from previous research in the District of Snina.

Study area

The study area (District of Snina, 805 km^2) is situated in the eastern part of Slovakia (49.00° N; 22.30° E) (Fig. 1). Monitoring of beavers was focused on collecting data on beavers' signs of activity in District of Snina (in the scope of authority of Administration Office of Poloniny National Park). The northern boundary of study area is the Slovak-Polish state border, while the eastern – Slovak-Ukraine state border, western and southern boundary correspond with the border of the District of Snina. In the orographic classification of Slovakia, the study area comprises following orographic units: Bukovské Hills, part of Ondavská Highland, part of Vihorlatské Hills and part of Beskydské Foothills.

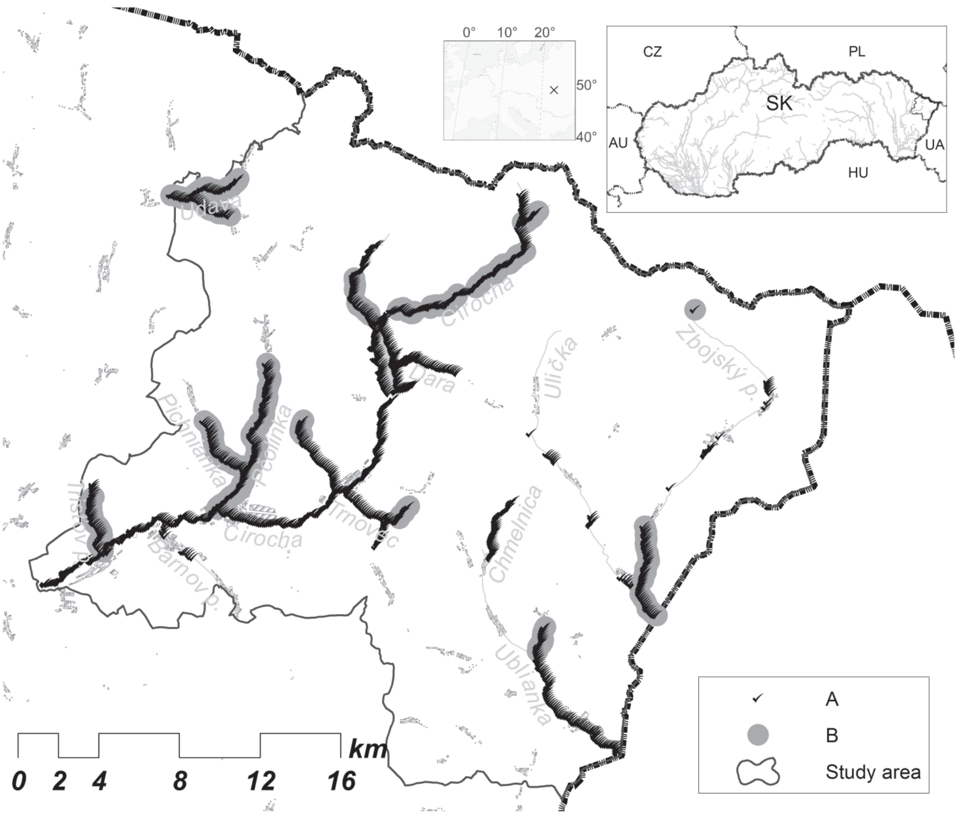

Fig. 1. A – segments of water bodies evaluated in 2018-2019; B – segments of water bodies not evaluated in previous monitoring (Štofík & Bartušová 2016).
Ryc. 1. A – odcinki cieków wodnych badane w latach 2018-2019; B – odcinki cieków wodnych nieprzebadane w poprzednim monitoringu (Štofík & Bartušová 2016).

Monitoring of signs of activity was made from November 2018 till March 2019 in wider area than previous monitoring (Štofík & Bartušová 2016).

Evaluated water bodies were included to three types:

- Water Reservoir Starina – VN
- Larger streams ($Q_m \geq 2.5 m^3 \cdot s^{-1}$; SHMU 2011) – VVT (river Cirocha under VN),
- Smaller streams ($Q_m < 2.5 m^3 \cdot s^{-1}$; SHMU 2011) – MVT.

List of monitored and evaluated water bodies:

- VN – Water Reservoir Starina;
- VVT – river Cirocha under the dam of VN Starina;
- MVT – smaller streams: Ublianka, Chotinka, Dara, Chmelnica, Trnovec, Cirocha/watershed above the VN Starina, Stružnický potok, Ulička, Zbojský potok, Barnov potok, Pichnianka, Pčolinka, Udava, Hostovický potok, Kuzmovský potok and Trsťový potok.

Methodology

In comparison with previous monitoring this research was complemented by additional segments in wider area of District of Snina, which was recommended in the last study (Štofík & Bartušová 2016). In Fig. 1 there are marked all segments studied, where beavers were recorded before or were expected.

The evaluated segments of monitoring (length 100 m ± 10 m) were localised in the field by hand-operated GPS apparatus. Within each segment in width ca. 20 m on the both banks of water body (from the edge of water surface) and also on the water surface the following beavers' signs of activity were recorded:

- foraging signs – gnawed trees or shrubs,
- food cache,
- burrows,
- conical and semi-conical lodges,
- dams and weirs.

The presence of beavers was evaluated on the basis of recording signs of activity. Only fresh signs (see below as "segments with activity signs") were taken into consideration (for example only non-oxidise, non-grey leftovers of woody plant). The signs of activity were defined in relation to the length of particular segment of water body.

By way of map analyses of individual signs of activity the heterogeneity of the following signs of activity was evaluated within particular segment: 1. foraging signs – gnawed trees or shrubs, 2. food cache, 3. lodges, 4. burrows, 5. dams and weirs. Heterogeneity is expressed in the scale 0 till 5 according to number of different types of signs of activity in segment. Quantity of gnawed trees or shrubs was evaluated as number of damaged individuals with minimal diameter of 10 cm at the height of ca 25 cm above the ground (Štofík & Bartušová 2016).

Spatial visualization of signs of activity (Campbell et al. 2012) from evaluated segments was used for estimation of the population distribution and numbers of beaver's families. The key factors used in consideration were: heterogeneity + conical and semi-conical lodges + food cache + quantity of gnawed trees and shrubs (above 11 pieces) in segment.

Results

Monitoring of the signs of beaver activity was realised in 2018/2019 and included 111 km of water bodies and their banks in the study area (Tab. 1).

During the monitoring of beavers 2276 fresh gnawed trees, 35 places with food cache, 141 active burrows, 29 active conical and semi-conical lodges and 74 localities with dams and weirs were registered (Fig. 2).

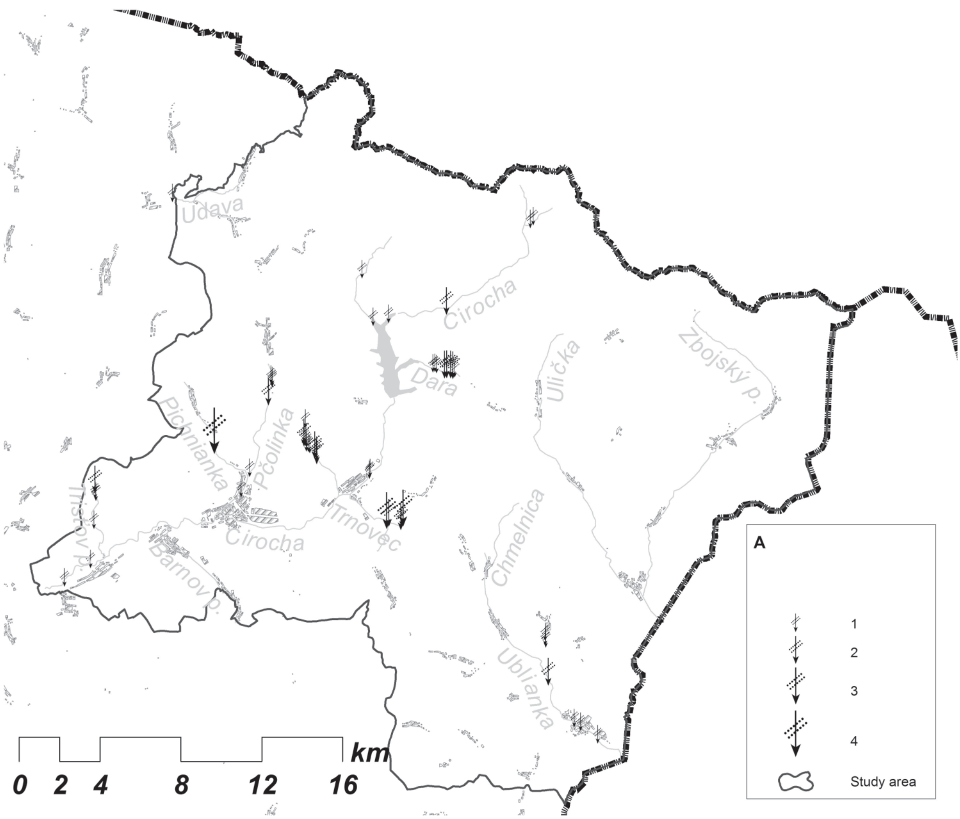

Fig. 2. A – Number of dams and weirs in segments of water course in the study area.
Ryc. 2. A – Liczba tam i jazów na poszczególnych odcinkach cieków na obszarze badań.

Table 1. The evaluated data on signs of beaver activity in the water bodies (1 – the number of evaluated 100 m segments, 2 – the signs of beaver activity – number of 100 m segments with activity signs , 3* – the number of gnawed trees, 4* – the number of beaver's conical and semi-conical lodges, 5* – the number of food cache, 6 – extent of the area with signs of beaver activity expressed in km per 1 family; * – total number for all segments on water course or reservoir).
Tabela 1. Dane szacunkowe dotyczące występowania śladów aktywności bobrów w poszczególnych typach wód (1 – liczba ocenianych 100 m odcinków, 2 – ślady aktywności bobrów – liczba 100 m odcinków ze śladami aktywności, 3* – liczba uszkodzonych drzew, 4* – liczba żeremi, 5* – liczba magazynów pożywienia, 6 – wielkość obszaru ze śladami aktywności bobrów wyrażona w km na rodzinę; * – łączna liczba dla wszystkich segmentów na cieku lub zbiorniku).

Name *Nazwa*	2014-2015								2018/2019							
	(1)	(2)	(3*)	(4*)	(5*)	(6)			(1)	(2)	(3*)	(4*)	(5*)	(6)		
	n	n	n	n	n	mean	max	min	n	n	n	n	n	mean	max	min
VN Starina	148	60	437	9	3	1.00	1.20	0.86	148	55	481	5	7	0.79	0.92	0.69
Cirocha pod VN	253	114	643	8	11	1.63	2.28	1.27	253	104	603	9	13	0.95	1.04	087
Cirocha nad VN	30	7	46	0	0	0.70	0.70	0.70	110	1	32	1	1	0.10	0.10	0.10
Ublianka	77	7	35	0	1	0.70	0.70	0.70	90	17	122	1	2	0.85	1.70	0.57
Chotinka	36	12	94	1	2	1.20	1.20	1.20	44	16	194	1	2	0.80	1.60	0.53
Dara	22	5	17	2	1	0.50	0.50	0.50	22	11	24	1	2	1.10	1.10	0.55
Trnovec & Lieskovec	49	8	25	0	1	0.80	0.80	0.80	59	11	181	2	1	1.10	1.10	0.55
Trsťový	11	4	58	1	1	0.40	0.40	0.40	40	6	158	1	2	0.30	0.60	0.20
Stružnický p.	26	3	71	2	1	0.30	0.30	0.30	48	2	16	1	0	0.20	0.20	0.20
Ulička	22	0	0	0	0	-	-	-	13	5	7	0	0	-	-	-
Zbojský p.	26	0	0	0	0	-	-	-	39	7	47	1	1	0.70	0.70	0.70
Chmelnica	35	0	0	0	0	-	-	-	35	0	0	0	0	-	-	-
Pichnianka	-	-	-	-	-	-	-	-	37	5	132	2	0	0.50	0.50	0.50
Pčolinka	-	-	-	-	-	-	-	-	87	14	200	2	2	0.70	1.40	0.47
Udava & Hostovicky p.	-	-	-	-	-	-	-	-	61	7	45	1	1	0.70	0.70	0.70
Kuzmovsky p.	-	p	p	p	p	-	-	-	11	3	34	1	1	0.30	0.30	0.30
Barnov p.	14	0	0	0	0	-	-	-	14	0	0	0	0	-	-	-
Total ***Razem***	749	220	1426	23	21	0.80	0.90	0.75	1111	264	2276	29	35	0.65	0.85	0.49

Changes

The evaluation of overall recorded signs of beaver activity (Fig. 3.) showed that VN (37%) and VVT (41%) were the most saturated within study area. Relative decreasing of beavers' activity was found in certain areas (VN – 92% resp. VVT – 91%) according to calculations and compared with data from monitoring conducted by Štofík & Bartušová (2016) (Tab. 2). At the same localities also the changes of numbers of gnawed trees and numbers of conical and semi-conical lodges were registered. On the other hand increasing number of families goes together with decline of surface of territory per one family (Tab. 3) and also decreasing active influencing of water body in area of VN, more noticeable in the case of VVT (Tab. 1).

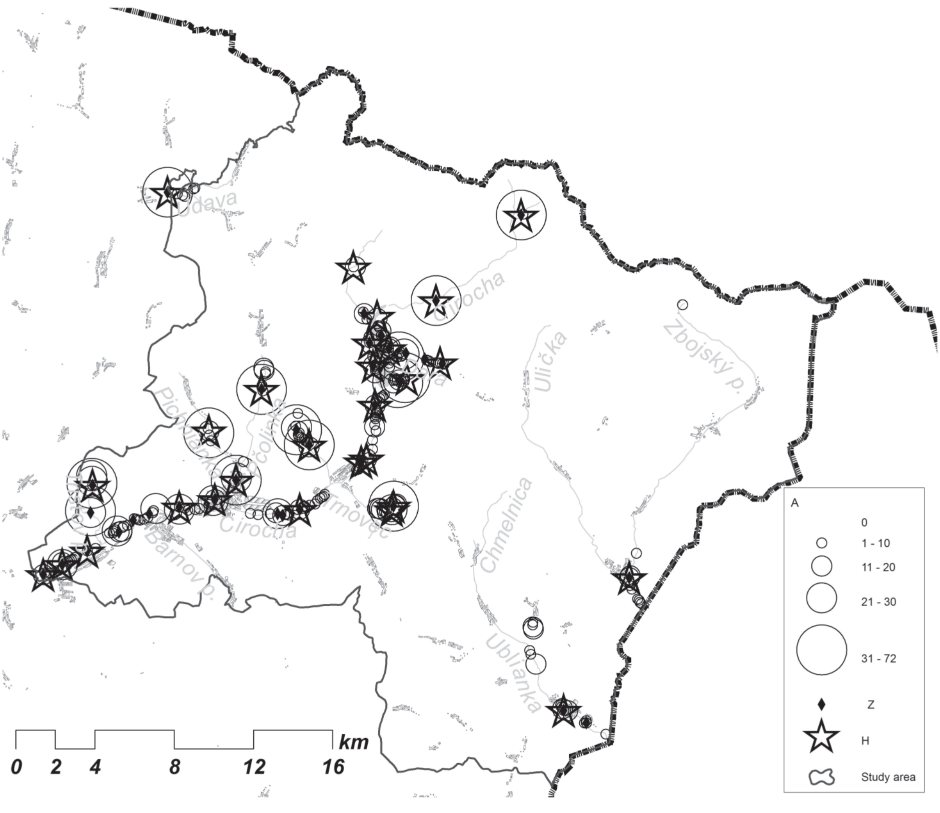

Fig. 3. Signs of beaver activity: A – number of gnawed trees expressed as number per segment; H – conical/semi-conical lodges; Z – food cache.

Ryc. 3. Ślady obecności bobrów: A – liczba ogryzionych drzew w przeliczeniu na jeden odcinek; H – żeremia; Z – magazyny pożywienia.

Table 2. Comparison of the evaluated variables describing the signs of beaver activity according to type of the water bodies (VN – Water Reservoir Starina, VVT – larger streams, MVT – smaller streams) between monitoring in 2014-2015 and 2018/2019 (1 – the number of evaluated 100 m segments, 2 – number of segments where signs of beavers activity were recorded, 3 – the number of gnawed damaged trees, 4 – the number of beaver's conical and semi-conical lodges, 5 – the number of food cache).
Tabela 2. Porównanie ocenianych zmiennych dotyczących obecności bobrów w różnych typach wód (VN – zbiornik wodny Starina, VVT – większe cieki wodne, MVT – mniejsze cieki wodne), między monitoringiem 2014-2015 i 2018/2019 (1 – liczba ocenianych 100 m odcinków, 2 – liczba segmentów, w których stwierdzono ślady aktywności bobrów, 3 – liczba uszkodzonych drzew, 4 – liczba żeremi, 5 – liczba magazynów pożywienia).

Type *Typ*	2014–2015					2018/2019					Changes/*Zmiany*				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
	n	n	n	n	n	n	n	n	n	n	%	%	%	%	%
VN	148	60	437	9	3	148	55	481	5	7	100	92	**110**	56	**233**
VVT	253	114	643	8	11	253	104	603	9	13	100	91	94	**113**	**118**
MVT	348	46	346	6	7	710	105	1192	15	15	**204**	**112**	**169**	**123**	**105**
Total *Razem*	749	220	1426	23	21	1111	264	2276	29	35	-	-	-	-	-

The changes in values in the case of MVT (2-5) were standarised to 100%.
Zmiany wartości w przypadku MVT (2-5) zostały znormalizowane do 100%.

The values of all evaluated attributes of beaver activity signs were increased in the case of MVT compared to previous monitoring, which was probably related to 204% extending of monitored study area by additional segments (Tab. 3., Fig. 1).

Beaver's families

VN (37%) and VVT (41%) were the most inhabited by beavers within study area. In the instance of Water Reservoir Starina we estimate presence of 7 (±1) beaver families and 2.1 km of the bank of water reservoir for one family. In the case of VVT we assume presence of 11 (±1) beaver families and the length for one family is 2.3 km (but in comparison with VN it is even ca. 4.6 km of ligneous vegetation).

In the case of MVT – Ublianka and Chotinka, Trsťov potok and Pčolinka we estimate presence of 2 (±1) beaver families. In the case of MVT – Dara, Trnovec,

Table 3. Changes in number and parameters of beaver' family on different types of water bodies: VN – Starina water reservoir, VVT – larger streams, MVT – smaller streams (1 – number of assessed sections/100 m, 2 – estimation of number of beaver families, 3 – length of watercourse or reservoir occupied by one family, km).
Tabela 3. Zmiany liczby i parametrów opisujących rodziny bobrów w różnych typach wód: VN – zbiornik wodny Starina, VVT – większe cieki wodne, MVT – mniejsze cieki wodne (1 – liczba ocenianych 100 m odcinków, 2 – szacunkowa liczba rodzin bobrów, 3 – długość cieku lub zbiornika zajmowana przez jedną rodzinę, km).

Type *Typ*	2014–2015			2018/2019			Changes / *Zmiany*	
	(1)	(2)	(3)	(1)	(2)	(3)	(2)	(3)
	n	n (±)	km (±)	n	n (±)	km (±)	% (±)	% (±)
VN	148	6 (1)	2.5 (2.1–3.0)	148	7 (1)	2.1 (1.9–2.5)	117% (86%–160%)	84% (63%–119%)
VVT	253	7 (2)	3.6 (2.8–5.1)	253	11 (1)	2.3 (2.1–2.5)	157% (111%–240%)	64% (41%–89%)
MVT	348	8 (2)	4.4 (3.5–5.8)	710	16 (2)	4.4 (3.9–5.1)	98% (69%–147%)	100% (67%–146%)
Total *Razem*	749	21 (3)	3.6 (3.1–4.2)	1111	34 (3)	3.3 (3.0–3.6)	-	92% (71%–116%)

The changes in values in the case of MVT (2) were standarized to 100%.
Zmiany wartości w przypadku MVT (2) zostały znormalizowane do 100%.

Stružnický potok, Zbojský potok, Udava (+ Hostovický potok), Kuzmov potok (Bezmenný p. correction Štofík & Bartušová 2016), Cirocha above VN and Pichnianka we assume occasional or permanent presence of 1 (±1) beaver family. The length for one beaver family is ca. 4.4 km of evaluated smaller watercourse.

Using the spatial visualisation of signs of activity i.e. gnawed trees, conical/semi-conical lodges and food cache (Fig. 3) and on the basis of the most remarkable heterogeneity of signs of activity in the localities (Fig. 4) we assume presence of overall 34 (±3) of beaver families in the study area (Tab. 3).

According to references (Campbell et al. 2005; Valachovič 2013; Graf et al. 2016), relative number of individuals per one family is 4.5. Using this pattern it means ca. 153 (139–167) individuals of beaver in our study area. One beaver family is distributed over the territory of 23 km^2 of evaluated study area, or 1 beaver per 5.26 km^2).

Discussion

According to Valachovič et al. (2008) only sporadic localities of beavers were identified in the eastern Slovakia along the river Cirocha. Nowadays the situation changed and the population has gradually stabilised (Štofík & Bartušová 2016,

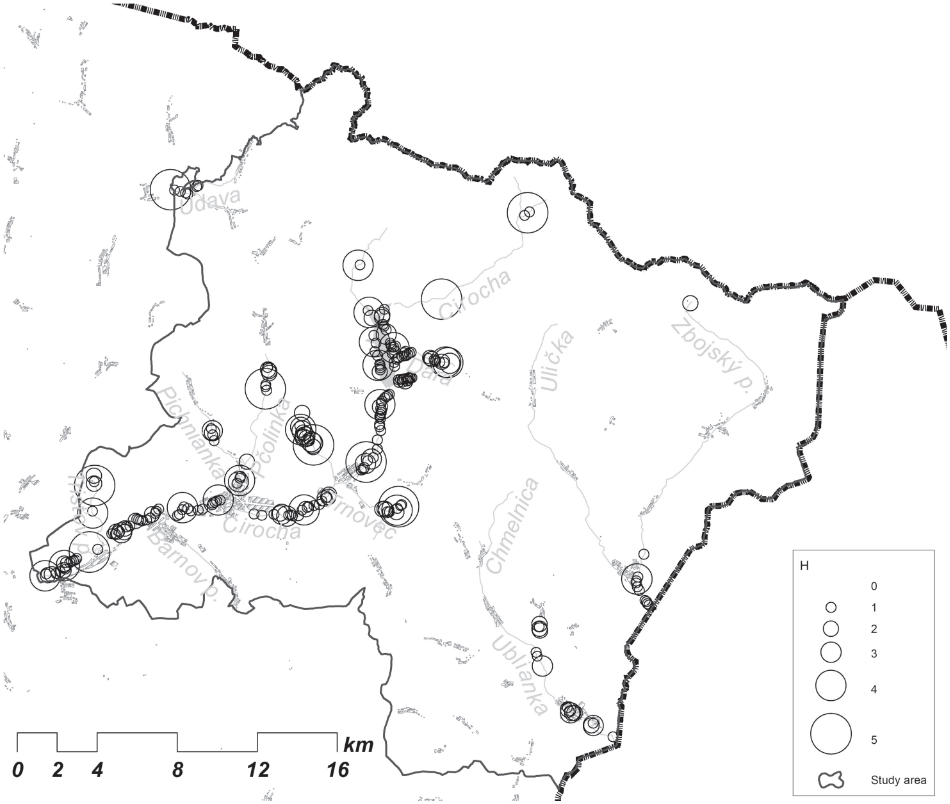

Fig. 4. Heterogeneity of signs of beaver activity expressed as a number (H) of different types of signs of activity in the scale 0 till 5.
Ryc. 4. Różnorodność oznak bytowania bobrów wyrażona jako liczba (H) różnych typów śladów w skali od 0 do 5.

2019 and Fig. 3 and Fig. 4). The method of visual recording of secondary signs of beaver activity such as food cache and conical and semi-conical lodges could not be accurate. Despite this fact it is generally used for the estimation of number of beaver individuals and families and to assess the distribution and state of beaver population (Parker & Rosell 2012).

The surface of territory is also variable parameter, depending on sufficient amount of building materials for lodges and dams, and food cache (Campbell et al. 2005). Beavers are typical territorial animals (Campbell et al. 2005; Busher 2007; Zavyalov et al. 2016), that is why we assume that evaluation of distribution of beavers' families on the basis of spatial visualisation of secondary signs of beaver activity (heterogeneity of activity, conical/semi-conical lodges, food cache and number of gnawed trees) represents effective alternative to assessment of actual state of the population (also distribution of families) and its changes (Parker & Rosell 2012; Štofík & Bartušová 2019). It is necessary to repeat the monitoring each year to improve and actualise the data.

In the case of monitoring in 2018/2019 only fresh signs of beaver activity were evaluated and the signs of activity (Tab. 1) were defined in relation to length of monitored water body (it could be considered as process of stabilisation of permanent monitoring plots from previous monitoring, or repeated monitoring). In previous monitoring in 2014/2015 (Štofík & Bartušová 2016) besides the fresh signs of activity also older ones were evaluated and the signs of beaver activity were defined in relation to segments with presence of particular monitored signs of beaver activity (it could be considered as basic monitoring).

In compliance with increasing trend of beaver expansion in Europe (Valachovič et al. 2008; Vorel et al. 2012; Borowski 2013; Šimůnková & Vorel 2015), the data on beaver local population state have enhanced compared to data from the past (Tab. 3). Despite of data on increasing of population (Tab. 3) we assume that population has stabilised in the localities of VN and VVT as a result of autoregulation (Campbell et al. 2005). The most likely explanation of presented results (Tab. 1) is that they could be influenced by more appropriate period for monitoring on these localities (November and December 2018), that was already described in detail (Štofík & Bartušová 2019).

The data on population density of beaver families in the case of bigger streams (VVT) in study area are similar to data from area with long-term occurrence and monitoring of beavers in Norway (1 family per 2.5 km of water stream) (Parker & Rønning 2007).

The well-marked increase of population density in the area of smaller water stream (MVT) could be result of beaver expansion (Štofík & Bartušová 2019) to these localities (Ublianka, Zbojský potok, Chotinka) and also could arise from extending of monitored study area to 204% during the stabilisation of permanent study plots of repeated monitoring (Štofík & Bartušová 2019).

The data on lower population density of beaver families in the case of smaller streams – tributaries in study area (1 family per 4.4 km of water stream) are not so remarkable as data from Norway (1 family per 25 km of water stream, Parker & Rønning 2007). On the other hand research in Scotland (Campbell-Palmer 2016) registered the similar results (1 family per 1.8–4.7 km of water stream) as in study area.

Discrepancies are resulted from low number (only 2) of monitoring periods (Štofík & Bartušová 2016 and 2019). The further monitoring is needed and it is necessary to repeat monitoring periodically (each year) to improve and actualise the data by their evaluation and comparison with previous ones (Grygoruk & Nowak 2014) in compliance with defined goals and recommendations (Štofík & Bartušová 2016 and 2019).

Conclusions

On the basis of secondary signs of activity the distribution of beaver families in the District of Snina (north-eastern part of Slovakia) was evaluated.

Using the spatial visualisation of signs of activity in 2018/2019 we assume the presence of 34 (±3) beaver families. Using, according to references, relative number of 4.5 individuals per one family it means the presence of ca. 153 (139–167) beavers in our study area.

One beaver family is distributed over the territory of 23 km^2 of evaluated study area.

The length of part of water stream for one beaver family is 3.3 km (in the instance of Water Reservoir Starina we take into account the bank of water reservoir), while part of 0.65 km (±0.49–0.85 km) is actively influenced by beavers within given stretch of water stream.

In the instance of Water Reservoir Starina the length for one beaver family is 2.1 km of the bank of water reservoir, while part of 0.79 km (±0.69–0.92 km) is actively influenced by beavers within it.

The length of related part of big water stream Cirocha (under the Water Reservoir Starina) for one beaver family is 2.3 km, while part of 0.95 km (±0.85–1.04 km) is actively influenced by beavers within given stretch of water stream.

The length of related part of small water streams/tributaries is 4.4 km for one beaver family, while part of 0.61 km (±0.45–0.83 km) is actively influenced by beavers within given stretch of water stream.

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Streszczenie

W pracy oceniono rozmieszczenie rodzin bobrów w okręgu Snina (NE część SK) na podstawie śladów bytowania. Wizualizacja przestrzenna danych, dotyczących bytowania bobrów w sezonie 2018/2019, wykazuje występowanie 34 (± 3) rodzin bobrów, co oznacza, przy założeniu 4,5 osobnika na rodzinę (Štofík i Bartušová 2016), występowanie około 153 (139–167) osobników bobra na badanym obszarze. Jedna rodzina bobrów zajmuje około 23 km^2.

– W obrębie ocenianego obszaru okręgu Snina jedna rodzina bobrów użytkuje 3,3 km wód (lub brzegu w przypadku zbiornika wodnego Starina), z czego aktywnie oddziałuje na 0,65 km (± 0,49–0,85 km).

- W zbiorniku wodnym Starina na 1 rodzinę bobrów przypada 2,1 km brzegu akwenu, przy czym ich aktywny wpływ przejawia się na 0,79 km (± 0,69–0,92 km).
- Na rzece Cirocha (poniżej zbiornika wodnego Starina) na 1 rodzinę bobrów przypada 2,3 km cieku, a ich aktywny wpływ przejawia się na 0,95 km (± 0,85–1,04 km).
- Przy ocenianych małych ciekach/dopływach na 1 rodzinę przypada 4,4 km, w tym aktywny wpływ jest widoczny na 0,61 km (± 0,45–0,83 km).