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A PROPOSAL OF MONITORING OF THE BANK VOLE (*MYODES GLAREOLU*, SCHREBER 1780)

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Abstract. There are many reasons why it might be necessary to monitor the bank voles. It causes damage to trees and eats seeds in orchards and tree plantations, and the determination of its presence as well as the effectiveness of the measures taken to minimize losses is very important in the activity of the above-mentioned. The rodent is also the main for central Europe reservoir of the Puumala virus, which is dangerous to humans, so observing the trends in the number of voles may be crucial. The small number of the species may indicate environmental poisoning, especially with copper. And finally, it is a very important species for the environment, both transformed by man and natural, so it is very important to preserve it despite the climate changes. The bank vole is a small mammal from the Cricetidae family. It occurs all over Europe. It lives mainly in deciduous forests of medium density and rich undergrowth, although it is also found in other areas, including anthropogenic ones. The proposed monitoring is based on catching with the use of wooden box traps and the analysis of pellets. The indicators used would be: the number of individuals caught per 100 trap-nights, the percentage of the species in total number of small mammals and the age structure of the population. In the first method one should remember about practices that will reduce or eliminate the mortality of captured animals – the appropriate setting of traps and selection of weather conditions. Also collecting pellets, one should bear in mind the limitations of this method and the differences between the spring-summer and autumn-winter material. The determination of the condition of the habitat may be based on the percentage of deciduous trees, density of trees and the appearance of the undergrowth.

Key words: bank vole, species protection, species monitoring, human-wildlife conflict, zoonoses, indicator species, small mammals.

INTRODUCTION

The bank vole (*Myodes glareolus*), both in Poland and throughout Europe, is a numerous species with a wide range of occurrence. It is not protected under national (Journal of Laws from 2016, pos. 2183) or European (Council Directive 92/43/EEC) regulations, and the International Union for Conservation of Nature classifies it as a Least concern species (Hutterer et al. 2021). Moreover, many of us have dealt with it in a more or less direct way, whether by encountering it in nature or just hearing about it in various – positive or negative – contexts. Due to this commonness, the bank vole is taken as a kind of obviousness, and therefore it is disregarded in some respects. This also applies to the need to monitor it, which does not seem to exist. However, it is not so.

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The bank vole causing damage to orchards and tree plantations, where it gnaws the bark of trees, making them wither, and also eats the seeds planted and sown (Birkedal et al. 2009). The most often attacked by it are soft-barked deciduous species, including sycamore maple (*Acer pseudoplatanus*), warty birch (*Betula pendula*) or common beech (*Fagus sylvatica*) (Pigott 1985), and among the trees grown in orchards, for example, various species of apple trees (*Malus* spp.) (Stirkė et al. 2021). There are many methods that can be used to reduce the impact of the species (Villalobos 2019). However, when selecting appropriate measures and monitoring their effectiveness, as well as planning the location and structure of new plantings, it is very important to determine the occurrence and number of voles.

Another major challenge connected with bank voles is the Puumala virus (PUUV). It is a pathogen dangerous for humans; the most important representative of the hantavirus group in northern, central and western Europe. It leads to nephropathia epidemica disease, i.e. mild to moderate Hemorrhagic fever with renal syndrome, causing renal failure or dysfunction. Its main, and in central Europe the only reservoir is the bank vole (Reil et al. 2017). The knowledge of the abundance of this rodent may therefore become very important in the context of preventing PUUV, which may become a very important pathogen.

On the other hand, the bank vole is a useful species. It is an important indicator of the condition of the environment. In areas where human activity has left a strong mark, both the population and density of voles are lower than in wild ones (Mukhacheva 2007). Contamination of the environment with copper in industrial districts makes males less attractive to females due to the disturbance of olfactory communication (Miska-Schramm et al. 2018), but also causes a decrease in the amount and quality of sperm, and uterine development disorders among females (Miska-Schramm et al. 2014). This leads to a reduction in the success of reproduction, and thus limitation of the species occurrence in the contaminated area.

It should also be remembered that the present good population status of the described animal cannot dull our vigilance. Just like others, this species, under certain conditions, may become a victim of changes taking place in the environment with increasing intensity. Forest loss, the introduction of alien species, fires and epidemics are just some of the events that may cause the voles' population to shrink. Meanwhile, its disappearance may pose a threat to the environment – both transformed by human and the natural one. The bank vole and similar animals play an important role on crops, eating undesirable plants and their seeds (Fischer et al. 2018). It is also an important part of the diet of birds of prey, in some areas being one of the main sources of food for some of them (Gryz and Krauze 2007). Therefore, the preservation of this species is very important, while people should constantly analyze its numbers in order to be able to act in the event of a catastrophe.

These are just some of the factors that make monitoring of the bank voles essential. Meanwhile, it is not subject to such activities, and none have been planned. However, there are guides for similar species of animals – the most important here are the monitoring of the southern birch mouse and the Tatra vole (Makomaska-Juchiewicz and Bonk 2015), which is a close relative of the bank vole. These guidelines can be the basis on which, taking into account the biology of describing species, it is possible to create an adequate plan. This paper addresses this challenge, as the goal is both to fill the existing gap in monitoring programs, as well as to lay stronger ground for further work on monitoring small rodents and other mammals of similar size.

MONITORING

I. Information about the species

1. Description of the species

The bank vole is a small mammal from Rodentia order, Cricetidae family and Arvicolinae subfamily (Abramson et al. 2009). Its body weight varies between 10.1 and 38.5 g. Length of its body is 66–115 mm, and tail 35–63 mm. Hind foot length is between 14.6 and 19.5 mm, and ear length between 10 and 15 mm. Coloration on the sides is grey, with white abdominal side. The back is ginger, which is characteristic feature for the species. Coloration can vary slightly, depending on the habitat, from gray-, by yellowish-, to reddish ginger. Albinistic and melanistic forms have been observed. The mountains populations are slightly darker and bigger than the lowlands ones. The animals from the vicinity of Kraków are clearly brighter and more ginger than those from the mountains and Białowieża. The eyes are big and protruding. There are 6 calluses on the hind foot (Kowalski and Pucek 1984).

The species similar to the bank voles are rodents of the *Microtus* genus: Tatra vole (*Microtus tatricus*), European pine vole (*Microtus subterraneus*), common vole (*Microtus arvalis*), field vole (*Microtus agrestis*) and others. The Eurasian harvest mouse (*Micromys minutus*) is also similar. All of them, however, have a unique set of features, shown in Table 1.

Table 1. Comparison of the features of the bank voles (*Myodes glareolus*) and similar species (Buchalczyk 1964; Serafiński 1965; Kowalski and Pucek 1984)

Trait\Species	Tatra pine vole	European pine vole	Common vole	Short-tailed field vole	Bank vole	Eurasian harvest mouse
The color of the fur	light gray back, slightly yellowish, without a red tinge	gray-brown back, lighter sides, gray underside	fawn back, silvery grayish belly; the colors turns gently	gray-brown back, silvery white underside	red back, gray sides, white belly	red, reddish-grey, reddish-brown or yellowish-brown back; cream, white or gray body underside
Body size	93–120 mm	73–115 mm	80–120 mm	92–135 mm	66–115 mm	45–60 mm
Body weight	19–27 g	10–14 g	20–30 g	20–40 g	10.1–38.5 g	4–10 g
The look of the eyes	very small	very small	little	little	big	big
The look of the ears	slightly protruding from the fur	slightly protruding from the fur	clearly protruding from the fur	clearly protruding from the fur	clearly protruding from the fur	slightly protruding from the fur
The length of the hind foot	15.5–21 mm	12–17 mm	15–18 mm	16–19 mm	14.6–19.5 mm	13–16 mm
The length of the tail	31–46 mm	20–33 mm	30–45 mm	25–42 mm	35–63 mm	43–60 mm
The number of calluses on the hind limb	5 big and 1 small	5	6	6	6	6
Habitat	alpine tundra, meadows, the edge of mountain forests	fields, meadows, forests	fields, meadows	fields, meadows, forests	mainly forests	fields, meadows, parks

Many subspecies of the bank vole are distinguished, in Poland however there are one or two. *M. g. glareolus* is the nominative subspecies and is distributed most widely in Eurasia. Various authors believe that in the country it may form population from the Białowieża Primeval Forest or most of the lowlands and mountains populations. *M. g. istericus*, inhabiting mainly the eastern Carpathians, may, in turn, form a group of larger individuals found near Kraków (Kowalski and Pucek 1984).

The range of bank voles covers forests from the north of Spain, through Continental Europe and the British Isles, to most of Scandinavia in the north. On the east its territory almost reaches Lake Baikal. Isolated sites are found in Asia Minor as well as in the Italian mountains. In Poland, it is one of the most popular rodents. It lives in the whole country, in the mountains up to the upper limit of the compact occurrence of the mountain pine (Kowalski and Pucek 1984).

2. The biology of the species

The bank vole is an animal active all day, but mainly at night. Its activity decreases in case of unfavorable weather conditions – it is a warm- and dry-loving species. It climbs and jumps well. In humus soil, it digs extensive paths, using its forelimbs and incisors. The bank vole do not hibernate (Kowalski and Pucek 1984).

The homeranges of the males are between 1200 and 11 000 m^2 (average 4120 m^2), while females ones are between 150 and 4850 m^2 (average 1280 m^2) (Korn 1986). In the autumn these divisions disappears almost completely, which probably is the result of decrease of the aggression and may be the outcome of merging into larger groups in winter, the purpose of which is to facilitate the maintenance of warmth (Gliwicz and Rajska-Jurgiel 1983).

The bank vole builds nests using shredded herbaceous plants, mosses and fallen leaves, lining them with a phloem and a grass (Serafiński 1965). The animal places them primarily in rotten tree trunks (Kowalski and Pucek 1984), between rocks, in low-lying tree holes or under the ground. Sometimes it puts them on the ground, among shrubs – then they have the shape of a sphere with a diameter of 20–30 cm (Serafiński 1965). The breeding season lasts from April to October. There are 3–4 litters per year with 2 to 8 pups, but usually 3 to 5 (Kowalski and Pucek 1984).

The composition of the diet of the bank voles varies slightly depending on the region inhabited by given population. It can be noticed, however, that the clearly dominant role is played by the green parts of herbaceous plants, which are 49.6% of the food in the population of Białowieża. The examples of plants consumed by that species are a common nettle (*Urtica dioica*), plants of the *Lamium* genus, a lesser celandine (*Ficaria verna*) or a red raspberry (*Rubus idaeus*) (Gębczyńska 1983).

This species feeds also on grains and fruits of trees (18.5%), seeds and the berries of herbaceous plants (10.2%), and to a small extent also on roots, mosses, tree leaves, flowers parts and a bark. Apart from a plant food, voles also eat fungi and animal food – insects and other invertebrates (16.4%). During the winter, it eats young tree shoots and the bark (Gębczyńska 1983).

The main enemies of the bank voles are red foxes, badgers, martens, polecats, stoats, birds of the Corvidae family and owls (Kowalski and Pucek 1984). Its remains were found in pellets of tawny owls (*Strix aluco*) (Gryz et al. 2012; Żmihorski et al. 2012; Romanowski et al. 2016), long-eared owls (*Asio otus*) (Żmihorski et al. 2012; Romanowski et al. 2017; Stolarz et al. 2018) and barn owl (*Tyto alba*) (Żmihorski et al. 2012). It lives up to 2 years in the wild (Serafiński 1965).

3. Habitat requirements

The bank vole inhabits mainly deciduous forests and mixed coniferous forests with rich groundcover and undergrowth and soft, humus soil, in which the animal can easily dig corridors and nests. It also appears in coniferous forests, and in northern Europe and Russia in boreal forests. It also occurs in wooded river valleys and in the mid-field thickets. In result of progressive urbanization, it can be found in other areas, including anthropogenic ones – parks, gardens or cemeteries, shrubbery slopes and embankments, in hedges, as well as in places covered by grass and shrubs (Haitlinger 1983; Kowalski and Pucek 1984).

4. Distribution of the species in Poland

At the moment 1,354 sightings of the species in 833 squares have been reported (state for the January 2022) (Atlas ssaków Polski, 2021). Considering places of the reports, it may seem that the western part of the country is characterized by a little less density of occurrence. Moreover, there are places, where observations wasn't reported on a big areas. A similar situation occurs in the vicinity of Ostrołęka, Radom and Tarnów (Fig. 1). However, reduction or even lacks of the population on these places may be a result of not conducting observations or not reporting them. Generally, it should be assumed that the species inhabits the entire country.

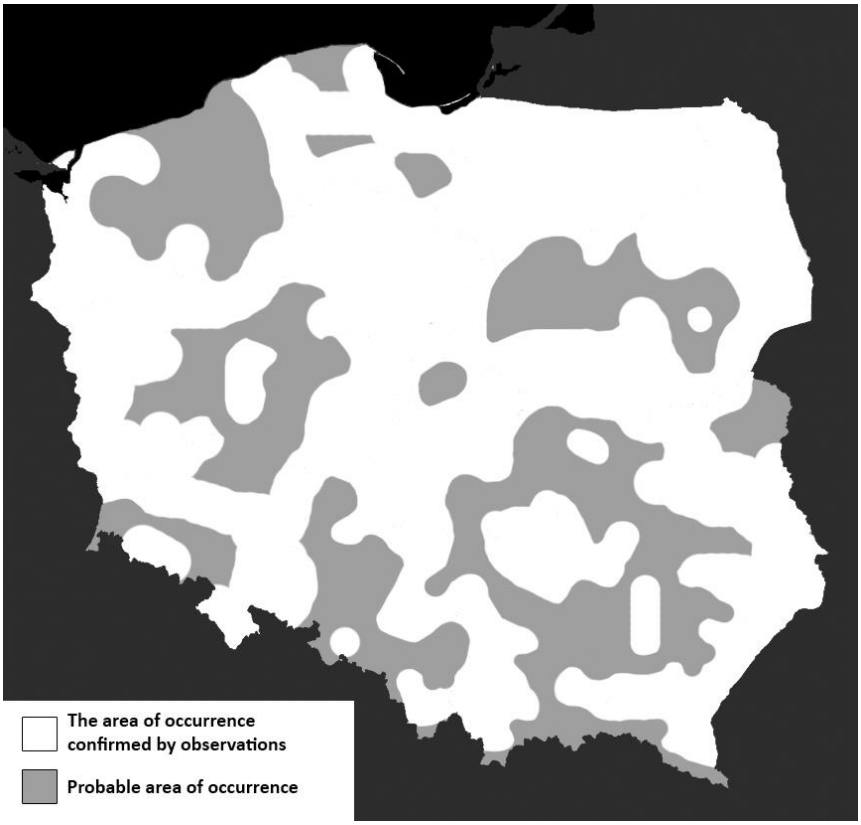

Fig. 1. Distribution of the bank voles (own graphics, basing on Atlas ssaków Polski, 2021; map of Poland: https://upload.wikimedia.org/wikipedia/commons/thumb/e/ea/Poland_location_map_white.svg/1234px-Poland_location_map_white.svg.png)

II. METHODOLOGY

1. The concept of species monitoring

The standard method of monitoring of small mammals is capture-mark-recapture (CMR), consisting in catching individuals from nature, marking them and then – releasing (Chełkowska and Goszczyński 1983). Marking, preventing from counting the same individuals several times, consists in trimming a small piece of hair on the back (Powell and Proulx 2003). This method is non-invasive, therefore does not require permits from the local Ethics Committee for Animal Experiments (Resolution No. 14/2016). The bank vole is not a protected species, so its catching does not require permits from Regional Director for Environmental Protection (Journal of Laws from 2016, pos. 2183).

Considering that the bank vole is a species of country-wide range, this type of monitoring is possible to do in whole country. However, to be sure of the results, it is good to pick areas where its presence was confirmed by observations or where it is found in pellets of owls. The suggested sites are Kraśnicza Wola (Romanowski et al. 2016) and Miechowicki Forest (Lesiński and Beuch 2016), where the bank vole has been found repeatedly in pellets of tawny owl, and Lower Odra Valley Landscape Park, in which the mammal was present in pellets of tawny owl, as well as the barn owl (Żmihorski et al. 2012). Moreover, important habitats seems to be those described by authours like Kowalski and Pucek (1984) – Białowieża Primeval Forest, Bieszczady, Karkonosze and the vicinity of Wrocław. Kraków seems to be a particularly interesting habitat, where *M. g. istericus* may occur.

It should be remember that the size of the population of small mammals is strongly related to the availability of food in a given area. Researches has shown that in the so-called mast seeding years, when seeds are bring forth synchronously by a given plant species that does not bloom annually (Bogdziewicz and Wróbel 2012), the number of caught voles was many times higher than in the following years (over the four consecutive years of measurements it was correspondingly 59.3, 3.2, 1.0 and 1.7 individual per 100 trap-nights) (Pucek 1983). Information on the appearance of mast seeding years sometimes occurs on the websites of the State Forests. However, due to their limited availability, to counteract the illusion of a high abundance of voles, it is advisable to conduct the study for several years (at least 3).

Apart of CMR method, independently from it, in monitoring of vole it is worthwhile to use searching of its remains in owls pellets. This method makes it possible to identify the presence of the mammal in an easy, non-invasive (and not causing accidental death of animals) and inexpensive way (Gryz and Krauze 2007). Moreover, in case of choosing a species such as the tawny owl (*Strix aluco*), which is an food opportunist, received percentage of bank vole in general number of catched animals should be approximately a percentage of number of its individuals relative to the number of individuals of all small mammals occurring in the hunting area (Lesiński and Beuch 2016). At the same time, however, if the environment inside the hunting area of a given individual of the owl is not homogeneous, the analyses of pellet do not allow the identification, and therefore monitoring of specific habitats preferred by the bank vole in specific area (Andrade et al. 2016). This is limiting for ability of receiving valuable information about the biology of the species and a given population, but also translates into the impossibility of applying possible protective measures. Additionally, it is difficult to conclude about the abundance on the area, and therefore to control its changes.

The third component of the bank voles monitoring, albeit based on the above two, should be the determination of the age of the individuals. It may indicate whether individuals inhabiting a given territory are successful in reproduction, and whether the survival in age groups is appropriate. As a result, it can bring detailed insight into the state of the population and complement the previous two components. This assessment can be performed during trapping by CMR method, based on visual features, as well as using pellets by measuring the roots of the M1 molars (Zalewski 1996).

In the case of the first method, the colour of the fur is assessed. The specimens can be divided into 2 groups – adults and young. The fur of the former is rusty brown on the back, often with a reddish tinge. The sides are brighter, slightly grayish, while the belly is silvery-gray, sometimes even whitish with a yellow tinge. The border between the coloration of the back and the abdomen is clearly outlined. Meanwhile, the fur of juvenille individuals is more grayish and less contrasting (Raczyński 1983). The method is simple, but has relatively low accuracy. Bank voles are animals with a short maturation period, lasting about 1 month in females and about 2 months in males (Bujalska 1990). Because of that, the percentage of juveniles in the entire population throughout the year is very low, in some part of the year close to 0% (Zalewski 1996).

The second method of determining the age of the individuals is based on the teeth found in the pellets of owls, for example the tawny owl (*Strix aluco*). In this case, the length of the roots of the first molars in the collected material should be measured (Zalewski 1996). The method is the most accurate due to the greater number of age groups that can be distinguished compared to the visual assessment. Therefore, it is the recommended method for determining the age structure of the population. The relationship between the measurements and age is presented in Table 2.

Table 2. The relationship between the age expressed in months and the length of the roots of the first molars (M1) expressed in millimetres (Zalewski 1996)

Age (months)	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	>16
Length of the M1 teeth (mm)	absent	to 0.15	0.16–0.45	0.46–0.75	0.76–1.05	1.06–1.35	1.36–1.65	1.66–1.95	>1.95

For convenience, individuals with roots above 0.75 mm can be considered as one age group: >8 months.

A very important factor is the cyclical changes in the age structure, which results from the breeding period from April to October (Kowalski and Pucek 1984). In spring, the predominate group in the population are individuals older than 8 months. In summer, this situation changes significantly and individuals aged 2–4 months constitute the largest percentage of voles. The same trend, but even more clearly outlined, can be observed in the fall (Zalewski 1996).

2. Indicators and assessment of the species conservation condition

Indicators of population condition

An appropriate indicator for evaluation the condition of the bank vole population is a number of individuals caught at the site per 100 trap-nights (Chełkowska and Goszczyński 1983). This indicator has been widely used for years in the studies of the small mammal populations, both

in Poland and abroad. Importantly, it include the duration of the measurement and number of traps used, which may be an important part of the results received. For this reason, it is better than the population density index, which omits these two variables.

It is obtained as follows (Cunningham and Moors 1996):

$$\frac{\textit{number of animals caught x 100}}{\textit{number of days x number of traps used}}$$

Another important indicator is the percentage of the bank vole in the total number of identified small mammals. It is a very important complement to the above, allowing to determine whether the number of bank voles observed is appropriate for environments suitable for the species. Additionally, it can help to better visualize the habitats preferred by the vole. Its valorization was developed on the studies of the Tawny Owl pellets and researches conducted by other authors (Goszczyński 1983; Gryz et al. 2012; Żmihorski et al. 2012; Lesiński and Beuch 2016; Romanowski et al. 2016).

Knowing the age of the individuals may allow for the determination of the age structure of the population, i.e. percentage share of specific age groups in the total of the animals. Valorisation of the indicator was prepared both for the age structure of individuals caught with the use of traps and for the age groups found in the pellets of owls. In both cases, the above-mentioned seasonal changes are clearly reflected and therefore have been taken into account. The valorisation is based on the percentage of the most present age group (Zalewski 1996). Its too low or too high values may indicate an increased mortality of individuals in particular age groups or disorders of reproductive success.

The population and environment indicators (Table 3) are assessed on a 3-degree scale (Table 4) – the same as that adopted by the European Commission for the purposes of reporting on the conservation status of habitats and species. This will facilitate the fulfillment of the reporting obligation included in Article 17 of Council Directive 92/43/EEC of 21 May 1992 on the protection of natural habitats and wild fauna and flora. According to this scale, the FV rating is the favourable condition, containing the most desirable values. The U1 assessment is an inadequate condition. U2 is a bad condition. The general assessment for the population condition is the lowest assessment of its components (Explanatory Notes and Guidelines, 2017). It is possible to give a grade of XX for parameters that could not be determined. For the accuracy of the results, only one XX assessment for population parameters is allowed. In this case, the XX assessment is not included in the final results.

Table 3. Population condition indicators

Indicator	Measure	Method of measurement/determination
Abundance	number of individuals/100 trap-nights	catching by capture-mark-recapture (CMR) method
The contribution of the species in the structure of small mammals	%	counting the number of individuals of various species of small mammals caught by the CMR method and found in pellets
Age structure	%	calculation of the percentage of juveniles and adults during catching or age classes based on the root length of M1 teeth

Table 4. Valorization of the condition of the population

Indicator	Measure		
	FV	U1	U2
Abundance	>5	5–1	<1
The contribution of the species in the structure of small mammals	>10	10–5	<5
Age structure	Visual assessment Spring and summer: >7% are juveniles Autumn: >1.5% are juveniles Assessment based on pellets Spring: 45–65% are >8 months Summer: 25–40% are 2–4 months Autumn: 35–55% are 2–4 months Winter: 35–50% are 4–8 months; 35–55% are >8 months	Visual assessment Spring and summer: 4–7% are juveniles Autumn: 1–1.5% are juveniles Assessment based on pellets Spring: 30–45% or 65–75% are >8 mos. Summer: 10–25% or 40–60% are 2–4 months Autumn: 20–35% or 55–70% are 2–4 months Winter: 15–35% or 50–65% are 4–8 mos.; 20–35% or 55–70% are >8 months	Visual assessment Spring and summer: <4% are juveniles Autumn: <1% are juveniles Assessment based on pellets Spring: <30% or >75% are >8 months Summer: <10% or >60% are 2–4 months Autumn: <20% or >70% are 2–4 months Winter: <15% or >65% are 4–8 months; <20% or >70% are >8 months

FV – favourable condition, U1 – inadequate condition, U2 – bad condition, XX – condition unknown.

Cardinal indicators

Not distinguished

Indicators of habitat condition

The bank vole is a species connected primarily with deciduous forests (Kowalski and Pucek 1984). This type of forest provide the proper structure of the undergrowth and the groundcover, and the trees themselves are a food source for described mammal (fruits, seeds, bark). For these reasons, defining the percentage of deciduous trees in total trees on the site is an important indicator of the voles' environment.

As is also known, the species prefers forests of medium density (Pucek 1983). It is the factor that largely, though indirectly, influences the appearance of the forest – the crown density determines the illumination of its lower parts, which affects the formation of the undergrowth and groundcover vegetation, as well as the trees themselves (Szymański 2000), which has a significant impact on the food base.

Another important factor is the appearance of the undergrowth and the groundcover. These are materials, which voles can use to build its shelters, i.e. mosses and other small plants, fallen leaves or dry grasses, but also other types of elements, which may constitute a hiding places for voles – fallen logs, branches or stones aggregations.

The assessment of the environmental condition indicators (Table 5) is carried out on the same 3-degree scale as the population condition assessment (FV – favourable condition, U1 – inadequate condition, U2 – bad condition) (Table 6). It is possible to give a grade of XX for parameters that could not be determined. For the accuracy of the assessment, one results of XX for environmental parameters is allowed.

Table 5. Habitat condition indicators

Indicator	Measure	Method of measurement/determination
Percentage of deciduous trees	%	Determination of the percentage of deciduous trees using the phytosociological survey method
The appearance of the undergrowth and groundcover	descriptive characteristics	Undergrowth and groundcover assessment in terms of the amount of building materials for the bank vole
Density of the trees	numerical scale	Calculation of the ratio of the crown area to the stand area using aerial photos or orthophotomaps

Table 6. Valorization of the condition of the habitat

Indicator	Measure		
	FV	U1	U2
Percentage of deciduous trees	>60% of deciduous trees	60–40% of deciduous trees	<40% of deciduous trees
The appearance of the undergrowth and groundcover	a wealth of mosses, small plants, fallen leaves, dry grasses and branches	average amount of mosses, small plants, fallen leaves, dry grasses and branches	little or no mosses, small plants, fallen leaves, dry grasses and branches
Density of the trees	0.5–0.8	0.3–0.4 or 0.9–1.0	<0.3 or >1.0

FV – favourable condition, U1 – inadequate condition, U2 – bad condition, XX – condition unknown.

Cardinal indicators

Not distinguished

Assessment of the condition of the population

The assessment of the condition of the population in the habitat is determined by the lowest measure of the three indicators. One XX assessment is allowed. The XX assessment is not included in the final population assessment.

Assessment of the condition of the habitat

The assessment of the condition of the habitat in the area is determined by the lowest measure of the three indicators. One XX assessment is allowed. The XX assessment is not included in the final habitat assessment.

Conservation perspectives

Evaluation of perspectives of the conservation covers the evaluation of condition of the population and habitat on given area within next 10–15 years. The evaluation of the perspectives should take into account the current state of the population (the abundance of the species, its percentage in the total number of caught/found small mammals and the age structure), but also the current environmental conditions.

Predicted threats, which may lead to the deterioration of the population condition, are also important. Its own impact may have a pressure from the other species occupying a similar ecological niche in a given area, as well as a predatory pressure, in case of an increase in the number of animals hunting for the voles.

In the context of the environment, despite of a certain flexibility of the bank voles, it is a predominantly forest species, especially of deciduous forests, therefore the degradation of this type of environment will be a threat to its population. For this reason, an important factor in the conservation prospects is wood management, including the removal of trees damaged by the European spruce bark beetle, as well as investments influencing the appearance of the forest. Changes in the tree density are also important, as they will have a direct impact on the species composition of the undergrowth and groundcover, which may limit the food base of these animals.

Overall assessment

The overall assessment is the lowest of the parameters of the species conservation condition (population condition, habitat condition and conservation perspectives).

3. Description of monitoring research

Selection of the monitoring areas and its suggested size

In case of the bank vole, the monitoring area is the area where the catchings are conducted. It should be preserved as good as possible, not necessarily protected, but characterized by (if, based on previous studies, such an assessment is possible before monitoring) a consistent occurrence of the species. Depending on the size of the monitoring area, the condition of the environment should be determined for it all or for its representative majority. If no researches have been conducted in a given area so far, before starting the monitoring, it is worth to collect and analyze pellets of owls, especially the tawny owl, to determine the presence of the bank voles.

Studies conducted on small mammals have shown that placing traps in one transect is a more effective method than in several (Pearson and Ruggiero 2003). Assuming that one trap should be set on the area of each individual (Powell and Proulx 2003), due to the relatively large area of it, the traps should be placed at a distance of about 25 meters from each other. Such a density will ensure adequate accuracy while reducing costs. As a minimum, 16 traps should be considered, which – assuming the effectiveness of the traps within a radius of 25 m – translates into monitoring of 1 ha. If there are logistical and financial possibilities, the number of traps should be increased to cover the largest possible area, which will lead to more meaningful results. At the same time, however, taking into account the efficiency of their checking, the monitoring area should not exceed 25 ha.

The method of performing of the research

Determination of population condition indicators – catches

Monitoring of the bank voles is based on the CMR method – catching, marking (by cutting off a fragment of fur on the back) and releasing the animals. The most appropriate will be box livestock traps, especially made of wood. This is due to the fact that this material provides

insulation against too high and too low temperatures, ensuring animals greater thermal comfort, which is an important factor influencing the survival of captured individuals. Traps should be hidden in places such as burrows, trees or bushes, which will increase the success of catching (Powell and Proulx 2003).

Another effective type of traps are containers with smooth walls, that are buried in the ground (Powell and Proulx 2003), such as rolled up PVC sheets or plastic/metal buckets (Petit and Waudby 2012). It should be 20 to 40 cm in diameter and at least 40 cm deep. To attract animals to them, it may have a bait, be installed on voles' migration routes, or be fitted with fences to guide animals into the trap (Powell and Proulx 2003). Using it, researcher should remember to cut holes in the bottom of the container and to protect it with a roof as a preventive measure against the ingress of rainwater. Roofs can be also used as sun protection. However, it should be remembered that their installation will affect the speed of checking the traps, while releasing of the animal is the best protection against its death, especially in bad weather conditions (Petit and Waudby 2012). In addition, this type of the traps is a much more labor-intensive method, and in the case of using it in protected areas, it requires an additional permit.

Regardless of the type of traps used, one should remember to mark them with e.g. flags and save the coordinates on a GPS device, as the ability to find them quickly is crucial for their efficient control (Petit and Waudby 2012).

To increase the effectiveness, it is recommended to leave the bait in open traps for 2 days before the start of catching. Such baits can be pieces of carrot or parsley (Cichocki et al. 2012). During trapping, animals must be provided with the same food due to their high metabolism (Powell and Proulx 2003).

The traps should be checked at least twice a day – in the morning (5.00–6.00 am) and in the evening (after 8.00 pm) (Cichocki et al. 2012). In case of hot, cold or rainy weather, this should be done more often (Powell and Proulx 2003). A higher frequency is also recommended for buried traps, regardless of the weather. Conducting the monitoring during the day, it is best to place the traps in the shadow so that the temperature inside them does not rise too much (Petit and Waudby 2012). In addition, in the case of extremely high temperatures, monitoring should be abandoned (limiting it to night-time could have a negative impact on the results, as the bank voles are animals with 24-hour activity). Also at too low temperatures (below 0°C), catching should be abandoned due to the greater mortality of animals (Montgomery 1980). Monitoring should be conducted for a minimum of 5 days – shortening this period may have a negative impact on the quality of data (Cichocki et al. 2012).

If, while setting up the traps, one comes across a nest with young individuals, the traps should not be placed in the area. If a new nest has been established in the vicinity of a previously set trap, it must be deactivated. This will reduce the chance of catching young voles, which are less resistant to detention, or nursing mothers, which could lead to the death of her offspring, deprived of a food source. The nest should be left in order not to disturb the specimens. Under no circumstances one should touch the young with bare hands, so as not to transfer own scent to the growing voles, which could lead to the female not recognizing the litter and abandoning it.

In case of trapping juvenile, particular care should be taken not to cause damage. If it is possible, a piece of fur should be cut as for any other specimen. However, if the chance of causing damage to the animal is too great, a try of marking should be abandoned and the vole should be released as soon as possible.

Even more delicacy should be shown in the case of pregnant females. They should be grab very gently and released as soon as possible, even at the expense of marking, in order to minimize the stress on the animal, which could adversely affect the viability of the fetuses. If the female uses a given trap as a nest, the object should be deactivated and excluded from further monitoring, while the female should be allowed to raise an offspring; due to the rapid growth of voles, this situation will not be long-term. If the female in the trap is lactating, should not touch it with bare hands, so as not to transfer own scent to it, which could affect the recognition of her by the offspring.

If an injured individual is found, it should be released as soon as possible. If an individual in a trap is dead, it should be placed on the ground, but at a distance from the trap site, so as not to discourage other voles from exploring the area nearby. At the same time, it should be very carefully analyzed whether the death of the individual was caused by the actions of the person conducting the monitoring, and if so, how to prevent further such events.

All the above-mentioned cases should be recorded as accurately as possible, as they can provide important information on a given population of bank voles, as well as the correctness of the monitoring activities carried out.

Determination of population condition indicators – pellets analysis

The search sites for pellets of owls should be in the areas of the bank voles occurrence, i.e. in deciduous and mixed forests. When looking for places to collect pellets, one should rely on information collected primarily from local ornithologists, supplementing it with information provided by local residents. The most appropriate species to assess the occurrence of the bank voles is the tawny owl (*Strix aluco*).

Pellets should be collected regularly, at least twice a year; otherwise, they will partially decompose, making it difficult to identify victims. The material should be examined as soon as possible after the finding it; alternatively frozen or dried (in the latter case, it should be sprayed with an insecticide first). Before analysis the pellets, it should be soaked for twelve hours (Gryz and Krauze 2007) and rinsed on a sieve with the addition of dishwashing liquid. Recognizing the collected remains, one can use the keys for recognizing the mammals of Poland, e.g. “Keys to vertebrates of Poland: mammals” by Pucek et al. (1981) (for polish-language researchers suggested is 1984’s “Klucz do oznaczania ssaków Polski” by Pucek) (Lesiński and Beuch 2016).

Determination of population condition indicators – age of the individuals

The age of the individuals in the population can be determined in two ways. The first is to determine the age based on the color of the fur. This assessment should be carried out with the release of individuals caught by the trap. It is advisable to carry out the assessment on a sunny day so that the color perception is not disturbed. In the hours before sunrise, it is a good idea to have a good light source that preferably mimics natural light as much as possible. A useful practice may be additional photographing of each captured individual and re-analysis of the photos on an electronic device, which can largely eliminate the error and allow to compare individuals with each other and with the source materials, if available (especially recommended for people inexperienced in determining the maturity of bank voles based on the color of the fur). Determining the age structure with this method is worthwhile throughout the entire duration of monitoring activities.

Another method is to classify the age of voles based on the root length of M1 molars. They should be obtained from previously prepared and selected material from pellets. Finding the right teeth is possible on the basis of their morphology – M1 molars of the bank voles are characterized by 5 lobes and an additional front lobe, and a different outline of the lobes than in the tundra vole (*Microtus oeconomus*) (Kowalski and Pucek 1984). Measurements of the length of the root, i.e. the fragment of the tooth without lobes, can be taken with a ruler or caliper and the results recorded for later comparison with tabular values (Table 2).

Determination of habitat condition indicators

Percentage of deciduous trees. Using phytosociological survey method, the number of deciduous and coniferous trees is determined and on this basis the percentage share of the former among the total trees in the monitoring area is calculated.

The appearance of the undergrowth and groundcover. The assessment is made of the amount of material that the bank voles can potentially use for nest building. It is a parameter determined visually and is the average score from the entire monitoring area.

Density of the trees. It is the ratio of the crown area to the stand area. To determine these parameters one can use specialized devices measuring the projection of crowns onto the ground, aerial photographs or orthophotomaps (Szymański 2000).

Term and frequency of the research

Due to changes in behavior in the annual cycle, trapping should be providing between early spring (April) and fall (September) (Gliwicz and Rajska-Jurgiel 1983). These dates should not be exceeded, because in the period between October and March, the mortality of bank voles increases significantly compared to the reproductive period (Montgomery 1980). During this period the main limiters are weather conditions – voles should not be caught at too low or too high temperatures due to the possible mortality of the individuals. Due to the significant impact of mast seeding years, it is advisable to providing monitoring for at least 3 consecutive years. Monitoring should last at least 5 days once (Cichocki et al. 2012).

Pellets should be collected regularly, at least twice a year. When doing so, it is necessary to take into account differences in species composition between pellets from spring or summer and autumn or winter (Gryz and Krauze 2007). Pellets should not be collected in the winter, as, unlike bank voles, some small mammals, such as dormice, hibernate, which will undoubtedly distort the percentage of species. An exception is the collection of pellets to determine the age structure, which can also be carried out in winter.

It is advisable that the determination of the percentage of deciduous trees takes place in late spring or summer, when all species are fully developed, which will facilitate the determination of their species identity.

The appearance of the undergrowth and groundcover should be monitored between April and October, when the voles are reproducing, which is associated with the need to build nests. It is recommended to conduct it once a month, which will allow to obtain full knowledge about the species occurring in these layers of the forest.

In the case of on-site measurements of crown projection, without the use of aerial photos or orthophotomaps, the measurement of tree cover density should be carried out in late spring or summer, with full foliage of trees.

Required equipment and material

- 10 m metal measuring tapes (for determining catching points on transects);
- stakes (for marking catching points on transects);
- compass (useful when marking out transects);
- camera (to keep documentation of the stand and photograph the voles);
- GPS receiver;
- maps or orthophotos, preferably with marked site boundaries;
- wooden livestock box traps;
- laboratory scissors for marking animals by cutting their hair;
- cards for writing information on observations or a notebook;
- mammals identification keys (e.g. Pucek et al. 1981: *Keys to vertebrates of Poland: mammals*);
- an off-road car with a spacious trunk;
- in case of conducting the research after dark, a good source of light;
- in case of collecting pellets, paper envelopes and a pen/marker that allows for their accurate description.

4. An example of a completed species observation card for a site (catching area)

(all data are theoretical, used just for the example).

Species observation card for a site	
Code and species name	*Species code according to the Habitat Directive; English, Latin name, author according to currently valid nomenclature*: *xxxx* Bank vole *Myodes glareolus* (Schreber, 1780)
Name of the site	*Name of the monitored site*: Podcerkwy 01
Type of the site	*Research site/reference site*: research site
Protected areas where the site is located	*Natura 2000, nature reserves, national and landscape parks, ecological sites, documentation sites etc.*: PLC 200004 Białowieża Primeval Forest
Geographical coordinates	*Type the GPS coordinates of the site*: N XX°XX'XX.X"; E XX°XX'XX.X"
Altitude above sea level	*Altitude of the site above sea level* (*specify the range from… to…*): 160 m above the sea level
Site area	*Type the size of the catching area in ha*: 8 ha
Description of the site	*The description is to facilitate the identification of the site. The location and nature of the site should be described.* The site is located in the Białowieża Primeval Forest, near the settlement of Podcerkwy, between the town of Gródek and the Polish-Belarusian border. Geographical coordinates of the extreme points of the catching area: 1. N XX°XX'XX''; E XX°XX'XX'' 2. N XX°XX'XX''; E XX°XX'XX'' 3. N XX°XX'XX''; E XX°XX'XX'' 4. N XX°XX'XX''; E XX°XX'XX''
Characteristics of the species habitat on the site	*Brief description including habitat type, vegetation, abiotic conditions*: Mixed forest with a slight predominance of conifer trees. The groundcover is rich, with many herbaceous plants.
Information about the species on the site	*Synthetic information about the species occurrence on the site* (*has it been studied for the first time?*), *research to date and other important facts; research results from previous years*: The species was previously found on this site.
Observer	*Name and surname of the monitoring contractor*: Jan Kowalski
Date of observation	*Dates of all observations*: 5–10.05.2020

The conservation status of the species at the site				
parameter/indicators		indicator value and comment	grade	
Population	abundance	*Number of individuals caught per 100 trap-nights*: During the 5 days of studies, 6 bank voles were caught using 32 traps 3.75 individuals/100 trap-nights	**U1**	**U1**
	the percentage of species in the structure of small mammals	*The percentage of the bank voles in the total number of small mammals caught on the site*: 22%	**FV**	
	age structure	*The percentage of the most numerous age class*: 50% of individuals was >8 months	**FV**	
Habitat	the percentage of deciduous trees	*The percentage of deciduous trees on the site*: 41%	**U1**	**U1**
	the appearance of the under-growth and groundcover	*Undergrowth and groundcover assessment in terms of the amount of building materials for the bank voles*: Rich in small plants, fallen leaves, dry grasses and branches	**FV**	
	density of the trees	*The ratio of the crown area to the stand area*: 0.9	**U1**	
Conservation prospects		*Brief forecast of the state of the population and habitat of the species on the site in the perspective of 10–15 years in relation to their current condition and observed processes occurring in the habitat, taking into account all activities and plans that may affect the species and his habitat*: Prospects unknown	**XX**	
Overall grade			**U1**	

FV – favourable condition, U1 – inadequate condition, U2 – bad condition, XX – condition unknown.

List of the most important current and anticipated impacts (*threats*) *on the species and its habitat at the site* (*including the current use, planned investments, planned changes in management and use*)*; impact/threat coding in accordance with Annex E to the Standard Data Form for Natura 2000 sites; impact influence: "+" – positive, "–" – negative, "0" – neutral; intensity of influence: A – strong, B – moderate, C – weak.*

Current impacts				
Code	Impact name	Intensity	Impact	Synthetic description
B03	forest exploitation without replanting or natural regrowth	C	–	the forest exploitation slightly exceeding the area of new plantings
I01	invasive non-native species	B	–	the presence of American mink

Future impacts				
Code	Impact name	Intensity	Impact	Synthetic description
B.02. 01.01	forest replanting (native trees)	C	+	the excessive use is to be compensated in the following years

Other informations	
Other natural values	*Other species of animals and plants observed during the monitoring, included in the appendices of the Habitats and Birds Directives: endangered and rare species* (*Red Book*)*, protected species* (*type the number on a scale: numerous, medium-numerous, rare*) Animals: European edible dormouse (numerous) Plants: *Botrychium matricariifolium* (rare)
Alien and invasive species of animals	*Observed alien and invasive species of animals* American mink
Methodological notes	*Information important for further planning of monitoring (method of conducting works, indicators that should be tested in monitoring and their valorization, regionally optimal time of conducting research, etc.*) None
Other comments	*Any information that is helpful for the interpretation of the results, e.g. weather anomalies* There was no mast seeding year during the monitoring.
Photographic and cartographic documentation	*Attachments to the database (in electronic version):* *At least 2 photos per site (species, habitat), the boundaries of the research area marked on the appropriate cartographic background* Attachments 1–6: photos of captured bank voles Attachments 7–14: photos of the monitoring area Attachment 15: Map with the monitoring boundaries All attachments were submitted with the observation card for a site

5. Species with a similar ecological requirements for which the developed methodology can be adapted

The methodology used for the condition of the population of the bank vole can be applied to all small mammals.

6. Protection of the species

The bank vole is not under species protection in Poland and the condition of its population does not require any forms of it.

CONCLUSIONS

It seems that the bank voles are completely common and very well known species. In fact, however, we know little about it, and information on various aspects of its biology has not been supplemented for a long time. While new research is emerging, it usually focuses on narrow bits of knowledge without going back to what was once established. It may seem that the world of science completely forgot about the basics in the context of the bank voles. One of these basics is monitoring of the species.

Monitoring of the bank voles can be performed relatively easily, with the use of two complementary methods – the most traditional one, with the use of livestock traps, and the gaining its popularity one, which is the analysis of owl pellets. They can provide very accurate information about the increase and decrease in the number of individuals of this species, both in general and in relation to other small mammals. They also provide a chance to learn about the age structure of the surveyed population. The assessment of the condition of the environment is slightly more difficult, as indicators are not always easy to measure and must be based on expert visual analysis. However, if carried out right, it is possible to properly assess the environmental context of a given population, and thus determine how it may develop in the future.

The importance of monitoring of the bank voles is very broad. It allows for the proper planning and checking the success of activities minimizing the losses caused by the described species in orchards and tree plantations. Provides tools to counteract a potential Puumala virus epidemic. Allows the detection of environmental poisoning. And finally, or perhaps most importantly, it offers the possibility of controlling the stability of the population of the species that is important for the natural environment and whose situation, although good at the moment, can change very quickly. The current pace of climate changes, as well as other threats for which humans are directly or indirectly responsible (e.g. the introduction of alien species) are factors of unpredictable course and strength. As a result, a stable animal population may begin to shrink in a relatively short period of time. In such a situation, it will be necessary to act as soon as possible, preferably on the basis of already existing tools, the use of which may turn out to be crucial for the preservation of the species. Prepared monitoring is one of such tools.

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PROPOZYCJA MONITORINGU NORNICY RUDEJ (*MYODES GLAREOLU,* SCHREBER 1780)

Streszczenie. Istnieje wiele powodów, dla których objęcie nornicy rudej monitoringiem może być konieczne. Jest to gatunek konfliktowy, powodujący uszkodzenia drzew i zjadający nasiona w sadach i hodowlach, a określenie jego obecności, jak też skuteczności podejmowanych działań minimalizujących straty jest bardzo istotne w działalności takich upraw. Gryzoń jest również głównym dla centralnej Europy rezerwuarem groźnego dla człowieka wirusa Puumala, dlatego obserwacja trendów liczebności nornicy może być kluczowa. Niewielka liczebność gatunku może wskazywać na zatrucie środowiska, zwłaszcza miedzią. A wreszcie, jest to gatunek bardzo istotny dla środowiska, zarówno przekształconego przez człowieka, jak i naturalnego, dlatego bardzo ważne jest zachowanie go pomimo zmian klimatycznych. Nornica ruda jest drobnym ssakiem z rodziny chomikowatych. Występuje w całej Europie, a na terenie Polski jest liczna. Zamieszkuje przede wszystkim lasy liściaste o średnim zwarciu oraz bogatym runie, choć spotykana jest również na innych terenach, w tym antropogenicznych. Proponowany monitoring opiera się na dwu filarach – odłowach z wykorzystaniem żywołownych pułapek drewnianych oraz analizie wypluwek. Użytymi wskaźnikami byłyby: liczba odłowionych osobników na 100 pułapko-nocy, procentowy udział gatunku w ogóle drobnych ssaków oraz struktura wiekowa populacji. W przypadku pierwszej z metod należy pamiętać o dobrych praktykach, które ograniczą albo wyeliminują śmiertelność zwierząt pochwyconych – odpowiednim ustawieniu pułapek oraz właściwym doborze warunków pogodowych. W przypadku zbierania wypluwek należy z kolei mieć na względzie ograniczenia tej metody oraz różnice między materiałem wiosenno-letnim oraz jesienno-zimowym. Biorąc pod uwagę wymagania nornicy rudej, określenie stanu siedliska opierać się może na wskaźnikach procentowego udziału drzew liściastych, zwarcia zadrzewienia oraz wyglądu runa.

Słowa kluczowe: nornica ruda, ochrona gatunków, monitoring gatunków, gatunek konfliktowy, choroby odzwierzęce, gatunek wskaźnikowy, drobne ssaki.