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# MONITORING OF THE MAMMAL FAUNA BY STUDYING OWL PELLETS: A CASE OF SMALL MAMMALS IN PROTECTED AREAS OF PODILLIA

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Key words

owl pellets, small mammals, fauna monitoring, protected areas, Podillia

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Abstract

Using owl pellets analysis to monitor mammals in protected areas makes it possible to accumulate a unique material to study the distribution and relative abundance of both common and rare species. Due to the ease of collecting and accumulating of pellets, this method helps to quickly obtain a large amount of material to monitor the changes in natural areas and objects during certain time intervals without interfering with the course of natural processes. The proportions of small-mammal species in the diet of most owls are representative of the proportions of species in their groups. Therefore, the pellet method can be used to organise monitoring of mammal species of natural regions. We analysed nearly 2000 pellets of several species of owls collected in Podillia in the course of the study. Pellets are mostly collected within protected areas. Small mammals form the basis of the diet of the studied species of owls. The diet of the long-eared owl is the most diverse, and it includes 18 species of small mammals. The common vole occurs the most often. The diet of other owl species is also diverse, in particular of the little owl, tawny owl, and eagle owl. As in the case of the long-eared owl, the main prey of the little owl and tawny owl is a common species—the common vole. The diet of the eagle owl, unlike others, is dominated by larger small-mammal species—brown rat, white-breasted hedgehog, and European hamster. In addition to common species, the analysis of owl pellets allows us to identify not only the most common, but also rare species, such as the European hamster, bicoloured shrew, lesser white-toothed shrew, and various bats. Therefore, the pellet method of research is highly effective in analysing the composition of the fauna and the structure of communities, of both prey and predator species. Owl pellet analysis is a valuable asset during small-mammal monitoring studies, and is especially useful for sampling of index small-mammal species during environmental impact assessments in protected areas. The method has considerable advantages compared to standard survey methods of small mammals—it does not require the removal of animals from the natural environment, which makes it relevant for use in protected areas.

Cite as

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## Моніторинг теріофауни шляхом вивчення сов'ячих пелеток: приклад з дрібними ссавцями заповідних територій Поділля

**Михайло Дребет**

Резюме. Використання пелеткового методу з метою моніторингу теріофауни на заповідних територіях дозволяє накопичувати унікальний матеріал для аналізу поширення і відносної чисельності як фонових так і рідкісних видів. Завдяки відносній простоті збору та накопичення матеріалу, метод допомагає відносно швидко отримувати масовий матеріал щодо моніторингу змін природних територій та об'єктів за певні проміжки часу не втручаючись у перебіг природних процесів. Пропорції видів дрібних ссавців у раціоні більшості сов, репрезентують пропорції видів у їхніх спільнотах. Отже, пелетковий метод може використовуватися для організації моніторингу теріофауни у регіональних масштабах. У дослідженні проаналізовано близько 2 тис. пелеток кількох видів сов зібраних на Поділлі. Пелетки зібрані здебільшого в межах заповідних територій. Дрібні ссавці становлять основу трофічного раціону досліджених видів сов. Раціон сови вухатої — найрізноманітніший, у ньому представлено 22 види дрібних ссавців. Серед них найчастіше трапляється полівка європейська. Різноманітні спектри живлення інших видів сов, зокрема — сича хатнього, сови сірої та пугача. Як і у сови вухатої, основною здобиччю сича хатнього та сови сірої є фоновий вид — полівка європейська. В раціоні пугача, на відміну від інших, переважають крупніші, ніж мікромаммалії, види — пацюк мандрівний, їжак європейський, хом'як звичайний та заєць сірий Окрім фонових видів аналіз сов'ячих пелеток дозволяє виявляти не лише найпоширеніші, а й рідкісні малодоступні види, серед яких — хом'як звичайний, білозубка білочерева та б. мала, рукокрилі. Таким чином, пелетковий метод дослідження характеризується високою ефективністю при аналізі складу фауни та структури угруповань видів жертв. Аналіз сов'ячих пелеток є дієвим методом під час здійснення програм моніторингу ссавців, а також для виділення індикаторних видів дрібних ссавців, наприклад під час виконання робіт з оцінки впливу на заповідні території. Метод має суттєві переваги у порівнянні зі стандартними методами обліку мікротеріофауни — не потребує вилучення тварин з природного середовища, що робить його актуальним для використання на заповідних територіях.

Ключові слова: пелетки сов, дрібні ссавці, моніторинг фауни, заповідні території, Поділля.

## Introduction

The pellet research method has proved to be the most efficient in analysing the quantitative composition of fauna and the community structure of prey species. The method has decent advan-?ages in comparison with the standard survey methods of small mammals, in particular, it does not require to extract the animals from their natural habitat, which makes it especially relevant for use in protected areas playing the key role in environmental monitoring, especially on population level.

The structure and dynamics of biodiversity remain the main issues in fauna monitoring [Zagorodniuk 2010]. Studying owl pellets aimed at investigating the mammal fauna composition is a popular method of aquaring qualitative data on the composition and structure of small-mammal populations. The advantage of the method is its simplicity due to which the researcher is able to obtain large volumes of information about both background and rare species in a short term [Zsuzsanna & Hegyeli 2009]. Owl pellets are an essential source of information on changes in the numbers of endangered small mammals and their distribution [Kutt *et al.* 2020].

There are different approaches and evaluation methods to estimate the abundance of small mammals. Each of them have their own restrictions and create bias in evaluations of abundance. The heterogeneity of the natural environment within protected areas and specificity of small-mammal habitats complicate the choice of methods for biomonitoring programs [Millán de la Peña 2003]. Owl pellets are an efficient alternative to trapping methods in estimating the composition of small-mammal communities in large geographical areas, because of its relative ease and low cost of collecting and analysing the material. The comparison of the two methods indicate the higher efficiency of the pellet method [Heisler 2015]. The ratio of groups of small mammals in checklists of the mammal fauna compiled based on owl pellets analysis depends on a number of factors, particu-

larly on the foraging strategy of owls. In some cases, the predator's diet demonstrates an explicit opportunistic feature, while in other cases it may be highly selective [Zagorsek & Jugovic 2015].

The pellet research method is successfully used in perennial monitoring programs dealing with studying the specifics of how co-existing owls react to annual abundance fluctuations of small mammals [Ratajc *et al.* 2021]. Small mammals constitute the diet of many predators, not only owls, thus owl pellets are the most convenient material for mammal fauna monitoring [Paci 2020].

Using the pellet method within protected areas contributes to the accumulation of unique materials for analysis of distribution and relative abundance of both background and rare species, allowing studies of relations between the populations of prey and predators, and, due to relative simplicity of collecting and accumulation of prey material, promotes a quick collection of large samples for the monitoring of changes in natural areas within certain periods without interfering with natural processes. This is particularly true for protected areas [Drebet 2017].

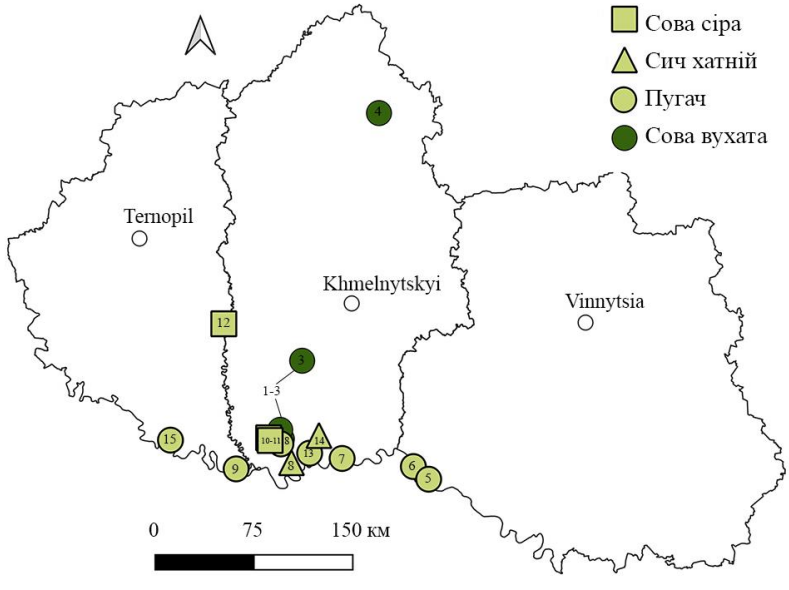
Though some researchers are skeptical about the use of the pellet method for estimations of the small-mammal fauna, the latest results claim the opposite. The share of small mammals in the diet of owls mainly represents the proportion of species in their communities; thus, the pellet method can be used to organise the monitoring of small mammals on a regional scale [Andrade *et al.* 2016].

The goal of the present study was to estimate the possibilities of applying the pellet method for mammal fauna monitoring in natural reserves with the use of abundance and diversity indices on the example of pellets of several owl species.

## Material and Methods

Pellets of four species of owls distributed in the Podillia region (long-eared owl *Asio otus*, little owl *Athene noctua*, tawny owl *Strix aluco* and eagle owl *Bubo bubo*) were used for research. In Podillia, all these owl species (except the eagle owl) are numerous and widespread, which allows their pellets to be collected quite easily and in sufficient amounts.

The main part of the studied material was collected in Podillia in the period of 2000–2014 within protected areas, including sanctuaries, natural monuments, regional landscape parks, and national nature parks. The main collecting localities of pellets are shown in Fig. 1.




*Legend:* (1–3) Podilski Tovtry National Nature Park (Kamyanets-Podilsky); (4) Malyovanka Regional Landscape Park; (5) 'Nahoryany Caves' geological natural monument; (6) vicinities of Bernashivka, Dnistrovsky canyon (Vinnytsia Oblast); (7) Bakotska Bay wetland; (8) 'Smotrych Canyon' geological natural monument; (9) Dzvenygorod Silurian rock exposure; (10–11) Dovzhotsky Botanical Sanctuary; (12) Ivankovetsky Landscape Reserve; (13) Lower Smotrych river wetlands; (14) Sovyi Yar Landscape Reserve; (15) Dnistrovsky Canyon National Nature Park.

Fig. 1. The main collecting localities of owl pellets within protected areas of Podillia.

Рис. 1. Основні місця збору сов'ячих пелеток на заповідних територіях Поділля.

The studied material consists of osteological remnants of small mammals extracted from about 2000 owl pellets. The largest part of the pellets was collected in the period of 2002–2007. Most of the osteological remnants were obtained from pellets of the long-eared owl collected in the Podilski Tovtry National Nature Park. Another part of the pellets was collected in the area surrounding the Malyovanka Regional Landscape Park (Shepetivka Raion, Khmelnytskyi Oblast) (collected and submitted by R. Rabchevsky) [Drebet 2015].

The collection of pellets of the long-eared owl is facilitated by the fact that this species forms groups of a couple of dozens of birds in the same places annually, in the winter period. For example, in Kamyanets-Podilskyi during 2000–2004 a group of approximately 200 long-eared owls spent several winters. A smaller group of 40–60 owls lived in the city suburbs (industrial area), another group of 140–160 owls lived in the central part of the city in the yard of Kamyanets-Podilskyi National University. Since 2005, the number of these winter groups has been declining rapidly. In 2010, their number started to increase again, although due to excessive disturbance factor the number of owls was not renewed.

The eagle owl pellets, besides those which were collected in Podilski Tovtry (in 2006–2012 along the Dnister River and its left tributaries), were obtained from the Dnistrovsky Canyon National Nature Park (collected and submitted by O. Vikyrchak). In the Podilski Tovtry National Nature Park, the pellets were collected on the ledges, overhangs, and grottoes of the canyons of the Dnister, Smotrych (Smotrych canyon, geological natural monument) and Ternava rivers (Chaplia Sanctuary).

Besides the pellets, other food residues were collected additionally (e.g. hedgehog skin, etc.). In 2009, more than 1000 osteological remnants from eagle owl nests were collected in the valley of the Dnister upper stream; most of the remnants belonged to small mammals. A part of the eagle owl pellets was collected in the Dnister valley in Vinnytsia Oblast (including the ones submitted by A. Pirhal and O. Matviychuk).

Pellets of the tawny owl and little owl were collected in the territory of the Podilski Tovtry National Nature Park. Approximately 70 little owl pellets (with 93 osteological remnants) were collected in the Sovyi Yar reserve. The tawny owl pellets were collected in various parts of the Podilski Tovtry National Nature Park, mostly in forested areas, near the nests (Dovzhotsky Botanical Sanctuary) and daytime roost sites of owls (tunnels in the Ivankovetsky Landscape Reserve). In total, 90 pellets were collected containing 306 remnants of small mammals.

In addition to the main collecting localities, pellets and their parts were also collected during the inventory and monitoring of biodiversity in a number of other places.

Bone remains were diagnosed by features of skull fragments, jaws, teeth, and tooth rows using various diagnostic keys [Pucek 1981, 1984]. The osteological material extracted from the pellets was assembled into a collection upon their review and analysis—the osteological collection of small mammals from the Podilski Tovtry National Nature Park. All osteological remnants were processed and prepared for long-term storage; all of them are tagged with indication of place and time of collection, scientific name of the specimen, collector's and researcher's surnames [Drebet 2015].

To describe the similarity and diversity of samples, Sorensen's fauna similarity and Simpson's diversity indices were used. Sorensen's index was calculated as a ratio between the double amount of common species (C) and the sum of species in both lists (A+B).

To describe the diversity of samples, Simpson's index (*D*), Simpson's diversity index (*1-D*) and Inverse Simpson's index (*1/D*) were used. The index is calculated as follows:

$$D = \sum_{i=1}^{R} \left( \frac{n_i(n_i - 1)}{N(N - 1)} \right),$$

where $n_i$ is the number of specimen of *i*-species, and

*N* is a general number of species in the sample.

Fig. 2. The main collecting localities of pellets in Podillia, including the canyon-like valleys of the Dnister River, other rivers, caves, rocks, forest, urban environment; all photos by the author.

Рис. 2. Основні місця збору пелеток на Поділлі — каньйоноподібні долини Дністра, інші річки, гроти, скелі, ліс, міське середовище, усі фото автора.

## Results and Discussion

In general, the mammal fauna of Ukraine comprises 152 species [Zagorodniuk & Emelianov 2012; Zagorodniuk & Kharchuk 2020]. The analysis of owl pellets collected collected in Podillia has revealed 23 species of mammals (15.1% of the mammal fauna in Ukraine). The shares and numbers of remnants of the identified species, including their conservation statuses, are shown in Table 1.

Out of the 23 identified species, 10 species have national or international conservation statuses: 3 are listed in the Red Date Book of Ukraine, 2 in Appendix II and 8 in Appendix III of the Bern Convention, and 1 species is listed in Appendix II of the Bonn Convention [Godlevska & Fesenko 2010].

The reconstructed checklist of the mammal fauna in Podillia for the previous century is known from reference sources [Zagorodniuk & Pirkhal 2013] and it comprises 74 species. During the analysis of the owl pellets, we have identified 1/3 of species out of total mammal fauna in the region (31.1%). The identified share represents over 50% of the small-mammal fauna (54.3%), the taxonomic component of which is typical for several families of small mammals of the orders Eulipotyphla and Rodentia [Zagorodniuk 2002].

Table 1. The list of mammal species of protected areas of Podillia based on the analysis of owl pellets

Таблиця 1. Список теріофауни заповідних територій Поділля за результатами аналізу сов'ячих пелеток

| No. | Scientific name | Common name | Conservation status | Number of osteological remains in the pellets | Share of species in the sample, % |
|---|---|---|---|---|---|
| 1 | *Lepus europaeus* | European hare | Bern 3 | 2 | 0.05% |
| 2 | *Glis glis* | Edible dormouse | Bern 3 | 6 | 0.1% |
| 3 | *Muscardinus avellanarius* | Hazel dormouse | Bern 3 | 4 | 0.1% |
| 4 | *Dryomys nitedula* | Forest dormouse | Bern 3 | 2 | 0.05% |
| 5 | *Micromys minutus* | Harvest mouse | - | 37 | 0.8% |
| 6 | *Apodemus agrarius* | Striped field mouse | - | 59 | 1.3% |
| 7 | *Sylvaemus tauricus* | Yellow-necked wood mouse | - | 72 | 1.6% |
| 8 | *Sylvaemus sylvaticus* | European wood mouse | - | 229 | 5.2% |
| 9 | *Sylvaemus uralensis* | Pygmy wood mouse | - | 13 | 0.3% |
| 10 | *Mus musculus* | House mouse | - | 180 | 4.1% |
| 11 | *Rattus norvegicus* | Brown rat | - | 169 | 3.8% |
| 12 | *Cricetus cricetus* | European hamster | RBU, Bern 2 | 105 | 2.4% |
| 13 | *Myodes glareolus* | Bank vole | - | 51 | 1.2% |
| 14 | *Arvicola amphibius* | European water vole | - | 24 | 0.5% |
| 15 | *Microtus agrestis* | Field vole | - | 87 | 2.0% |
| 16 | *Microtus arvalis* | Common vole | - | 3146 | 71.1% |
| 17 | *Erinaceus roumanicus* | White-breasted hedgehog | - | 79 | 1.8% |
| 18 | *Talpa europaea* | European mole | - | 52 | 1.2% |
| 19 | *Crocidura suaveolens* | Lesser white-toothed shrew | Bern 3 | 19 | 0.4% |
| 20 | *Crocidura leucodon* | Bicoloured shrew | RBU, Bern 3 | 8 | 0.2% |
| 21 | *Sorex araneus* | Common shrew | Bern 3 | 49 | 1.1% |
| 22 | *Nyctalus noctula* | Common noctule | RBU, Bern 2, CMS 2 | 29 | 0.7% |
| 23 | *Mustela nivalis* | Least weasel | Bern 3 | 2 | 0.05% |
| | Total | | | 4424 | 100.0% |

Bern 3—Appendix 3 of the Bern Convention;
Bern 2—Appendix 2 of the Bern Convention;
RBU—Red Data Book of Ukraine;
CMS—Appendix 2 of the Convention on the Conservation of Migratory Species of Wild Animals.

***Characteristics of the owl species and their diet***

Owls are the most convenient group of birds when it comes to the use of pellets for the monitoring of the mammal fauna. Three owl species are the most numerous in protected areas of Podillia. The long-eared owl and the little owl mostly inhabit anthropogenic landscapes, while the tawny owl prefers natural plains or forest-steppe habitats. The mentioned species are evenly widespread across the region and are the most abundant: tawny owl—ca. 5000 pairs, long-eared owl—4000 pairs, and little owl—4500 pairs. The eagle owl is a rare species in Ukraine. These species have a similar way of foraging, mostly in open habitats. Due to their wide distribution, these species play an important role in the energy flow of ecosystems.

***Long-eared owl.*** Among all the owls considered, the long-eared owl's diet has been inves-?igated to the fullest, which is facilitated by its widespread occurrence and large numbers throughout almost the entire territory of Ukraine and its ability to concentrate in a large quantity at winter roost sites [Poluda 2021]. In anthropogenic landscapes of Podillia, the long-eared owl mostly uses the nests of the Eurasian magpie and rook. Its highest nesting density is typical for small towns; the long-eared owls begin nesting quite early in accordance with the season. The main prey of the long-eared owl in protected areas of Podillia are small mammals, mostly voles and mice [Drebet 2009]. Such mammals as squirrels, moles, dormice, shrews, weasels, and bats (mostly *Nyctalus*, *Eptesicus*, and *Pipistrellus*) are rather rarely preyed on by owls, including the long-eared owl [Eremchenko & Toropova 1975]. Birds (Passeridae) and insects (Insecta) are additional and occasional prey items.

In Podillia, the long-eared owl's diet includes 16 species of small mammals, mostly rodents (ca. 99%), among which the common vole prevails (81.6%). Insectivorans comprise less than 1% in the total number of prey (see Table 1). The long-eared owl seems to be specialised on the common vole as prey, although sometimes its feeding plasticity can become compulsory to enable the species to survive under unfavorable feeding conditions. Switching from one prey to another depends on changes in the abundance of the main prey species, and that is why the lack of voles in the long-eared owl's diet can be compensated with mice and additionaly with insectivorans or birds.

In winter, the long-eared owl's diet is characterised with a certain degree of plasticity indirectly influenced by weather conditions, especially by depth of the snow cover. Long-eared owls prey on representatives of murids whereas the share of the main component in their diet—the common vole—decreases. Accordingly, an enduring snow cover in Podillia leads to a decrease in the amount of small-mammal remnants in the pellets from 15% to 9%. Species whose remnants were occasional in the pellets fall out of from the long-eared owl's diet in the winter. The role of sporadic prey items in the diet may change leading to an increased amount of remnants of those items. Bats are quite rarely found in the diet of these owls; on average, the share of bats in the long-eared owl's diet varies between ca. 0.1 to 2% [Zaytseva & Drebet 2007; Zagorodnyi & Shryk 2015]. In some periods of the year, however, bat remnants may occur more often in pellets of the long-eared owl (37.6%) due to its adaptive behaviour in regard of preying on usually occasional feeding items [Drebet 2013].

***Eagle owl.*** The eagle owl belongs to the resident species of birds in Podillia. The landscape, natural and climatic conditions of the studied territory facilitate the spread and efficient nesting of the eagle owl. In general, the territory is characterised by a mosaic microrelief, most rivers have meanders promoting diversity of microhabitats and animal populations nearby to the eagle owl's nesting sites (Fig. 2). These conditions also facilitate the accumulation of pellets. The remnants of small mammals dominate in eagle owl pellets, most of which belong to rodents. Rodents are the main feeding item for the eagle owl and for other owls in the studied area. Insectivorans (mostly the white-breasted hedgehog) are also quite often indicated in the eagle owl's diet.

Mammals in the diet of the eagle owl are represented by 17 species, among which the brown rat prevails (33.2%) followed by the European hamster (21.3%), white-breasted hedgehog (16.0%), and common vole (13.2%) (see Table 1). Unlike the long-eared owl whose diet is clearly dominated by a single species (common vole, 81.6%), the diet of the eagle owl in the same territory is dominated by 3 to 5 species with an average share of 70–80%. Such co-dominance is typical for this species.

Additional prey species in the eagle owl's diet include such mouse-like rodents as the harvest mouse (*Micromys minutus*), striped field mouse (*Apodemus agrarius*), yellow-necked wood mouse (*Sylvaemus tauricus*), European wood mouse (*S. sylvaticus* s. str.), house mouse (*Mus musculus*), and field vole (*Microtus agrestis*). The share of these species comprises over 1%.

The eagle owl's diet also includes occasional feeding items, which are preyed on in the researched area irregularly and in small quantity. These are the European hare (*Lepus europaeus*), least weasel (*Mustela nivalis*), and various muroid rodents whose share is less than 1%.

In addition to pellets, the contents of eagle owl nests were also analysed. The litter of eagle owl nests in the Bakotska Bay wetlands shows a more diverse diet then the analysis of pellets. As in the case of pellets, the dominating feeding items are small mammals. In particular, of the 230 analysed osteological remnants of vertebrate animals only 5 do not belong to mammals. In addition to small mammals, bones of birds and reptiles were also identified, as well as chitin residues of insects. When analysing bone remains extracted from the litter, the eagle owl's diet seems to be dominated by the common vole (57.4%), followd by the white-breasted hedgehog (22.2%). The cumulative share of five muroid species is up to 18.5%. According to the biomass of prey items, the first place in the eagle owl's diet is taken by the white-breasted hedgehog (76.7%) followed by the European hare (18.3%). The share of the common vole by biomass is only 6.2%.

Osteological materials extracted from eagle owl pellets that were collected in the area of the upper section of the Dnister River in 2009 contained 449 cranial remnants (21.4 %), and, in general, 2099 remnants of small mammals (80.3%) and 514 remnants of bird skeletons (19.6%). Elements of fish skeleton (2 specimens) and amphibian remnants (3 specimens) can be found occasionally and thus their share in the eagle owl's diet is insignificant. Residues of insect chitin (6 specimens) appeared in the pellets probably through the stomach content of small mammals.

Among the 449 small-mammal remains, we have identified 12 species, including 1 hedgehog (Erinaceidae), 1 hare (Lagomorpha), 9 rodents (Rodentia), and 1 carnivoran (Carnivora). The family Muridae represented by 6 species is the most widely represented group in the eagle owl's diet.

***Little owl.*** This species is the most widespread and abundant owl. Small mammals are the most typical feeding items in the little owl's diet in Transcarpathia [Drebet 2012], in the east of Ukraine [Zaika 2012], and in the Prut–Dnister interfluve area [Skilsky *et al.* 2007].

***Tawny owl.*** The species usually nests in Podillia in various natural hollows, in mature and stagnant broad-leaved forests. In urban areas, the tawny owl nest in old gardens in the villages and/or parks in the cities (in both cases there must be old hollow trees). The tawny owl's diet in Ukraine is mostly comprised of small mammals (over 90%), among which prevail those that are the most widespread on the owl's hunting grounds. In particular, in forest-steppe habitats (highland oak woods, Homilshansky Lisy National Nature Park), the tawny owl's diet is dominated by the bank vole, and common shrew, yellow-necked wood mouse and striped field mouse are also often found in its pellets [Yatsyuk 2011]. In forest habitats of Polissia in Chernihiv Oblast, the dominant species in the tawny owl's diet are the common shrew and the red squirrel [Zaytseva & Hnatyna 2010]. In both cases the researchers emphasize the tawny owl's plasticity in prey choice and easy switch to the most abundant and most available type of prey.

### *Faunal diversity and similarity of the small mammal samples in the diet of owls*

Despite the substantial similairy of the diet of the analysed owls, there are differences in their foraging methods and habitat selection, which further leads to their trophic specialisation. The data obtained regarding each species were analysed using similarity and diversity indices to understand the feeding features of these owl species.

When analysing the taxonomic composition of the diet of the studied owl species, values of the Sorensen index were the highest in the pair 'little owl—tawny owl' (0.86). It should be noted that most little owl pellets were collected on the attic of the forester's house located on the border of Kamyanets-Podilsky forestry state enterprise (Sovyi Yar Landscape Reserve) within the territory of the Podilski Tovtry National Nature Park. The main part of tawny owl pellets was collected in the

forested area of the Podilski Tovtry National Nature Park (Ivankovetsky Landscape Reserve). There is a notable similarity between the diet of the long-eared owl and the little owl (0.69) and the long-eared owl and the eagle owl (0.67). The lowest level of similarity was observed between the eagle owl and little owl (0.52) and the eagle owl and tawny owl (0.50) (see Table 2).

Simpson's index (D), Simpson's diversity index (1-D) and Inverse Simpson's index (1/D) were used to describe the diversity of samples, which, being closely related, are often described under the same name.

The Inverse Simpson's index (1/D) starts with 1 as an irreducible parameter. One (1) represents a group from 1 species. The higher is the value of the index, the greater is diversity. Respectively, eagle owl pellets has the highest level of diversity of prey species (4.99), while the lowest level characterises the long-eared owl (1.49). Samples dominated by 1–2 species are less diverse compared to those represented by several species having a similar abundance.

The most noticeable differences are clearly related to the size of the owls, which is reflected in the size of their prey. The size of owls from the biggest to the smallest and the respective diversity indices of their prey is as follows: eagle owl (4.99)—tawny owl (3.88)—little owl (2.35). On the other hand, it can also be observed that owls specialise not on the type of their prey but rather on their availability (relative abundance), which, in turn, defines the reduction of the spectrum of prey (long-eared owl—1.49).

***Estimates of species abundance***

To evaluate the abundance of prey species, we have applied the score-based scale of abundance estimates (6-point scale of population abundance of small mammals) arranged in a log-scale where 0 means the absence of species and the mid point is 3 (normal level of abundance) [Zagorodniuk *et al.* 2002].

Thus, approximately 10 species of widespread and abundant small-mammal species can be used for monitoring of protected areas of Podillia: abundant (*Microtus arvalis*), common (*Sylvaemus sylvaticus, Mus musculus*, and *Rattus norvegicus*), and, to a lesser extent, rare species (*Cricetus cricetus, Myodes glareolus, Microtus agrestis, Erinaceus roumanicus, Talpa europaea,* and *Sorex araneus*) (see Table 4).

Among the occasional species (whose shares are small due to their natural rareness or inaccessibility for predators), the following can be used for the monitoring of the mammal fauna in Podillia: *Crocidura suaveolens, Apodemus agrarius,* and *Micromys minutus.*

Table 2. Sorensen's index (SI) of similarity of the diet of owls based on the results of pellet analysis

Таблиця 2. Індекс схожості (подібності) Соренсена раціону сов за результатами пелеткового аналізу

| Owl species | *Asio otus* | *Bubo bubo* | *Athene noctua* | *Strix aluco* |
|---|---|---|---|---|
| *Asio otus* | — | 0.67 | 0.69 | 0.67 |
| *Bubo bubo* | 0.67 | — | 0.52 | 0.50 |
| *Athene noctua* | 0.69 | 0.52 | — | 0.86 |
| *Strix aluco* | 0.67 | 0.50 | 0.86 | — |

Table 3. Simpson index of diversity of the diet of owls based on the results of pellet analysis

Таблиця 3. Індекс різноманітності Сімпсона раціону сов за результатами пелеткового аналізу

| Owl species | Simpson's Index (D) | Simpson's Diversity Index (1-D) | Inverse Simpson's Index (1/D) |
|---|---|---|---|
| *Asio otus* | 0.67 | 0.33 | 1.49 |
| *Bubo bubo* | 0.20 | 0.80 | 4.99 |
| *Athene noctua* | 0.43 | 0.57 | 2.35 |
| *Strix aluco* | 0.26 | 0.74 | 3.88 |

Table 4. Score-based estimates of the abundance of small mammals based on owl pellet analysis
Таблиця 4. Бальні оцінки чисельності дрібних ссавців на основі аналізу сов'ячих пелеток

| No. | Scientific name | Share of species in the sample, % | Scores | Score-based abundance estimates | Status of species in zoocoenoses |
|---|---|---|---|---|---|
| 1 | *Lepus europaeus* | 0.05 | 0–1 | 1 | rare |
| 2 | *Glis glis* | 0.1 | 0–1 | 1 | rare |
| 3 | *Muscardinus avellanarius* | 0.1 | 0–1 | 1 | rare |
| 4 | *Dryomys nitedula* | 0.05 | 0–1 | 1 | rare |
| 5 | *Micromys minutus* | 0.8 | 0–1 | 1 | rare |
| 6 | *Apodemus agrarius* | 1.3 | 0–1 | 1 | rare |
| 7 | *Sylvaemus tauricus* | 1.6 | 0–1 | 1 | rare |
| 8 | *Sylvaemus sylvaticus* | 5.2 | 3–10 | 3 | frequent |
| 9 | *Sylvaemus uralensis* | 0.3 | 0–1 | 1 | rare |
| 10 | *Mus musculus* | 4.1 | 3–10 | 3 | frequent |
| 11 | *Rattus norvegicus* | 3.8 | 3–10 | 3 | frequent |
| 12 | *Cricetus cricetus* | 2.4 | 1–3 | 2 | occasional |
| 13 | *Myodes glareolus* | 1.2 | 1–3 | 2 | occasional |
| 14 | *Arvicola amphibius* | 0.5 | 0–1 | 1 | rare |
| 15 | *Microtus agrestis* | 2.0 | 1–3 | 2 | occasional |
| 16 | *Microtus arvalis* | 71.1 | > 30 | 5 | abundant |
| 17 | *Erinaceus roumanicus* | 1.8 | 1–3 | 2 | occasional |
| 18 | *Talpa europaea* | 1.2 | 1–3 | 2 | occasional |
| 19 | *Crocidura suaveolens* | 0.4 | 0–1 | 1 | rare |
| 20 | *Crocidura leucodon* | 0.2 | 0–1 | 1 | rare |
| 21 | *Sorex araneus* | 1.1 | 1–3 | 2 | occasional |
| 22 | *Nyctalus noctula* | 0.7 | 0–1 | 1 | rare |
| 23 | *Mustela nivalis* | 0.05 | 0–1 | 1 | rare |

### *Feeding features of owls*

The trophic relations of the owls demonstrate that their main feeding items are the most accessible and abunant small-mammal species, among which the common vole (*Microtus arvalis*) is the dominating species. The trophic plasticity of owls is mostly reflected in the seasonal switch to the most abundant and most accessible prey. In the winter diet, the share of murids increases, whereas in most of the cases the share of represntatives of the subfamily Arvicolinae, genus *Microtus* in general dominate.

The trophic plasticity leads to the increased importance of secondary feeding items, which, along with the main feeding items, are quite widespread and abundant.

In addition to the main and the secondary feeding items, the diet of owls may include non-specific (untypical) feeding items, the abundance of which is low in the environment. These items are additional and occasional in the diet. The former, under certain conditions, may have an important role in the feeding of owls in certain periods, while the share of the others remains low.

Due to size of the owls and their prey, various types of prey play the same important role in the diet of owls, whereas the share of the common vole (despite its high level of representation in pellets) tends to decrease.

Bats also occur in the diet of owls, although in a rather small amount (up to 1%), indicating its occasional presence in pellets. In autumn and spring, that is, during the periods of increased activity of bats, such as the common noctule, the long-eared owls can switch to preying on these animals, and thus developing new kinds of foraging behaviour. Besides, the awakening of bats in wintering shelters also contributes to their appearance in the diet of owls.

The use of owl pellet analysis as a method for monitoring mammal fauna in protected areas shows great potential. By determining the distribution and abundance of animal species, monitoring

changes in their populations, and assessing the state of the natural environment, this method allows for the development of strategies to conserve various animal species. Moreover, it can help effectively control the changes occurring in protected ecosystems and promote biodiversity conservation.

According to the Simpson's Diversity Index, the four owl species considered in this study have distinct dietary habits and preferences, which may be attributed to differences in their ecological niches, prey availability, and foraging strategies. The results of this study can provide insights into the dietary preferences of these owl species and inform conservation efforts aimed at protecting their populations and habitats. Additionally, these data can shed light on the understanding of predator-prey relationships and food web dynamics in ecosystems where these owls are part of animal communities, which is crucial for protected areas. The varying degrees of similarity in owl diet, as indicated by the Sorensen's index, can be explained by differences in ecological niches, prey availability, and foraging strategies. The results also highlight the impact of changes in prey availability or habitat conditions on owl populations and their diet.

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