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Does the Mediterranean water shrew *Neomys anomalus* (Soricidae, Eulipotyphla) expand the eastern part of the distribution range?

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ABSTRACT. The Mediterranean water shrew *Neomys anomalus* is sparsely distributed across the major part of Eastern Europe. There is a large amount of new information about the enlargement of the distribution range of the species during last 2 to 3 decades. We analysed species distribution, variation of cytochrome *b* gene and character of appearance of new records on species distribution. We suggest that the "expansion" of the Mediterranean water shrew is rather a result of more thorough faunal studies than of a natural expansion of the species range.

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KEY WORDS: *Neomys anomalus*, distribution, cytochrome *b*, species distribution modelling, Eastern Europe.

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Расширяет ли малая кутора *Neomys anomalus* (Soricidae, Eulipotyphla) восточную часть своего ареала?

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РЕЗЮМЕ. Малая кутора *Neomys anomalus* спорадично распространена по большей части Восточной Европы. В течение последних 2–3 десятилетий появился большой объем новой информации о расширении ареала этого вида. Мы проанализировали распространение вида, изменчивость гена цитохром *b* и характер появления данных о новых находках вида. Мы предполагаем, что "расширение" ареала малой куторы скорее является результатом интенсификации фаунистических исследований, чем следствием действительного расширения ареала этого вида.

КЛЮЧЕВЫЕ СЛОВА: *Neomys anomalus*, распространение, цитохром *b*, экологическое моделирование, Восточная Европа.

Introduction

The range of the Mediterranean water shrew (*Neomys anomalus* Cabrera, 1907) extends from Europe to Asia Minor (Hutterer *et al*., 2010). It is sparsely distributed across the major part of Eastern Europe. New information about the enlargement of the distribution range in the southern, northern and eastern directions began to arrive during last 2 to 3 decades. The Mediterranean water shrew was captured in south-western Iran, which is about 1000 km to the south from known distribution limits (Esmaeili *et al.*, 2008), and was also found in Estonia (Balčiauskas *et al.*, 2016), 700 km to the north

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of the most northern locality for this species in Poland. In Russia, during last decades the species was found in several regions for the first time: Mordovia Republic, Kaluga, Tambov and Penza Regions (Lada & Sokolov, 2000, 2012; Sokolov & Lada, 2007; Borodin, 2013; Ruchin *et al.*, 2018; our data), far outside its known distribution.

This poses the question of the reasons for these new reports. Is this a consequence of species distribution change or a result of increased native populations, which were so sparse previously that it was not possible to capture animals using traditional trapping methods? It should be noted that some "new" findings of the shrew are the result of the analysis of museum collections; animals were captured and stored in a museum with incorrect species identification. In such cases, the Mediterranean water shrew was mixed up with the Eurasian water shrew (*N. fodiens* Pennant, 1771), although these two species have notable morphological differences (Zaitsev *et al.*, 2014).

In this study, we used species distribution modelling as well as analysis of mitochondrial cytochrome *b* sequence variation for the comparison of two alternate hypotheses on the reasons of the "expansion" of the distribution range of *N. anomalus*: actual range shifts vs. previous mistakes in species identification, along with increasing success of species detection using more effective methods.

Material and methods

Species distribution modelling

We analysed all occurrence records of the Mediterranean water shrew in Eastern Europe, available from literature, museum collections, and our field data. The whole dataset consisted of 239 records (Appendix 1), some of which were made from territory that suffered from anthropogenic transformation during the time passed from the date of capture or were obtained from pellets analysis (no geographical coordinates of animal occurrence). Such records were excluded from the analysis. The remaining dataset had irregular spatial distribution, including spatial aggregations. Therefore, we filtered the dataset, selecting one observation locality per 50 × 50-km square. The resulting dataset, which was used in the species distribution modelling, contained 69 localities.

The spatial frame of the analysis included a grid with a resolution of 0.02° in geographic longitude/latitude WGS84-based projection. We used 86 environmental variables: WorldClim 19 "bioclimatic" variables (http://www.worldclim.org; Hijmans *et al.*, 2005), elevation, maximum snow depth, slopes curvature and steepness and 63 MODIS generalised average monthly data layers (9 months of 2004 per seven spectral bands; http://glcf.umiacs.umd.edu/data, Eastern Hemisphere only) as environmental descriptors. To correct for the non-random spatial distribution of locations and to control the set of background points, we prepared a Maxent bias file that describes the spatial distribution of sampling efforts. Specifically, we selected all available records (1149 points) of representatives of Soricidae from the studied region and constructed a 5-km buffer around each. The bias file had the value "1" across the studied region, but "10" under the buffers. The same dataset was used for reducing the number of environmental variables: we learnt principal components analysis (PCA) on the set of raster cells that intersect the 5-km buffers mentioned above and projected the result on the entire raster extent. Thus, principal components explain the variation in the environment around all sampled localities. Overall, 23 PCs, explaining 95% of variance, were selected for further analysis.

Species distribution modelling was carried out in MaxEnt version 3.4.1 (Phillips *et al.*, 2019). To prevent over-parameterisation of the species distribution model, we compared the AICc values across the set of models with different values of regularisation multiplier (0.75, 1, 2, 3, 5) and different sets of feature types ("LQ", "LQH", "LQP", "LQHP") (Muscarella *et al.*, 2014).

Molecular analysis

We sampled DNA from two museum specimens of the Mediterranean water shrew, originated from the most eastern part of the range (Tambov 52.7216 N, 41.5267 E, and Penza 53.6804 N, 42.2019 E regions). The DNA was extracted according to a standard procedure, including treatment with sodium dodecyl sulphate and proteinase K and subsequent phenol-chloroform extraction (Sambrook *et al.*, 1989).To deal with degraded DNA from old museum samples, we used three overlapping primer pairs specific to *Neomys* in gene cyt *b* (1140 bp) amplification: tRNAGlu — 5'-ATC GTT GTT ATT CAA CTA TAA GAA C-3' and cytb_403R — 5'-YCC YCA RAA TGA TAT TTG YCC TCA-3'; cytb_389F — 5'-GTT ATA GCC ACT GCC TTT ATA G-3' and cytb_746R — 5'-TAA TTG TCC GGG TCT CCG AGT A-3'; cytb_614F — 5'-TWT TCC TYC ATG AAA CAG GAT C-3' and tRNAThr — 5'-TTT TGG TTT ACA AGA CCA GTG TAT-3' (Igea *et al.*, 2015). Each PCR reaction contained 50 mM Tris-HCl (pH 8.9), 20 mM ammonium sulphate, 20 μM EDTA, 150 μg/ml bovine serum albumin, dNTPs (200 μM of each), 2 mM $MgCl_2$, 15 pmol of each primer, 2 units of *Taq* polymerase and 0.1 to 0.2 μg DNA in a final volume of 25 μl. The reaction conditions were an initial denaturation of 3 min at 95°C, followed by 32 cycles of denaturation (30 s at 95°C), annealing (30 s at 54°C) and extension (40 s at 72°C). The PCR products were analysed using electrophoresis in 6% PAAG with subsequent staining with ethidium bromide and visualisation under UV light. Sequencing was done on an ABI 3500 automated capillary sequencer (Applied Biosystems) with the ABI Prism Big Dye Terminator Cycle Sequencing Ready Reaction Kit3.1, using the same primers. Sequences were aligned manually and checked for unexpected stop codons using BioEdit 7.0 (Hall, 1999). The genetic distance matrices (*p*-distances) between haplogroups were calculated in the MEGA7 software (Kumar *et al.*, 2016). Haplotype networks were constructed using the median

joining method in the PopART software (Leigh & Bryant, 2015). The obtained sequences were deposited in GenBank (MT855469, MT855470). Additionally, we used 22 sequences downloaded from GenBank (AB175099–100 (Ohdachi *et al.*, 2006); DQ991049–55 (Castiglia *et al.*, 2007); LK936659–71 (Igea *et al.*, 2015)).

Morphology

Measurements of the body, tail and feet of Mediterranean and Eurasian water shrews was taken from museum labels. All specimens were identified using a complex of external and cranial features (Pucek, 1984). We used specimens from collections of the following institutions: the National Museum of Natural History at the National Academy of Sciences of Ukraine (NMNH, Ukraine), the Zoological Museum of Taras Shevchenko National University of Kyiv (KNU, Ukraine), the theriological collection of the Department of Monitoring and Animal Conservation of I.I. Schmalhausen Institute of Zoology (IZAN, Ukraine), the Zoological Museum of Ivan Franko National University of Lviv (LNU, Ukraine), the National Museum of Natural History (Lviv, LNHM, Ukraine), the Zoological Museum of the National University of Uzhhorod (UzhNU) (Uzhhorod, Ukraine), the zoological collection of Mykola Hohol State University of Nizhyn (NU) (Nizhyn, Ukraine), the theriological collection of the Mammal Research Institute Polish Academy of Sciences (MRIPAS) (Bialowieza, Poland), the Zoological Museum of the Penza State University (ZMPSU) (Penza, Russia), the Zoological Museum of the Moscow State University (ZMMU) (Moscow, Russia).

Results

Distribution model

The optimal model selected had a regularisation multiplier of 0.75 and linear and quadratic features only. Algorithm converged after 1100 iterations; AUC was 0.927. The predicted distribution of suitable habitats for the Mediterranean water shrew did not form a continuous area and rather consisted of a set of small patches of suitable habitats. These patches mostly forested areas in river valleys, were separated by bands of unsuitable or less suitable habitats (Fig. 1). The largest agglomerations of suitable habitats were confined to forests in the basin of the middle Oder River, valleys of the Vistula River and its tributaries: Kamienna and Narew, in the Carpathian Mountains (Danube basin: Tisza and Prut Rivers valleys), forests of the Neman River and its tributary Viliya valleys, the middle Dniester basin, tributaries of the Dnieper River (Samara, Vorskla, Psyol, Sula, Teteriv, Irpin, Desna, Sozh, Prypiat), forests of the Seversky Donets River and the tributary Oskol and in mountainous Crimea. The patch of suitable habitats was situated in the basin of the Ushacha River, tributary of Daugava (Zapadnaya Dvina). Habitat suitability decreased in an eastern direction; the main agglomerations of suitable habitats were situated in forests of the Voronezh River basin (Don River tributary) and the Moksha River basin (Oka tributary, Volga basin).

The Mediterranean water shrew was never found in two areas predicted by our modelling, namely the area in Northern Caucasus and Taman Peninsula as well as the Trans-Volga region near Samara Bend.

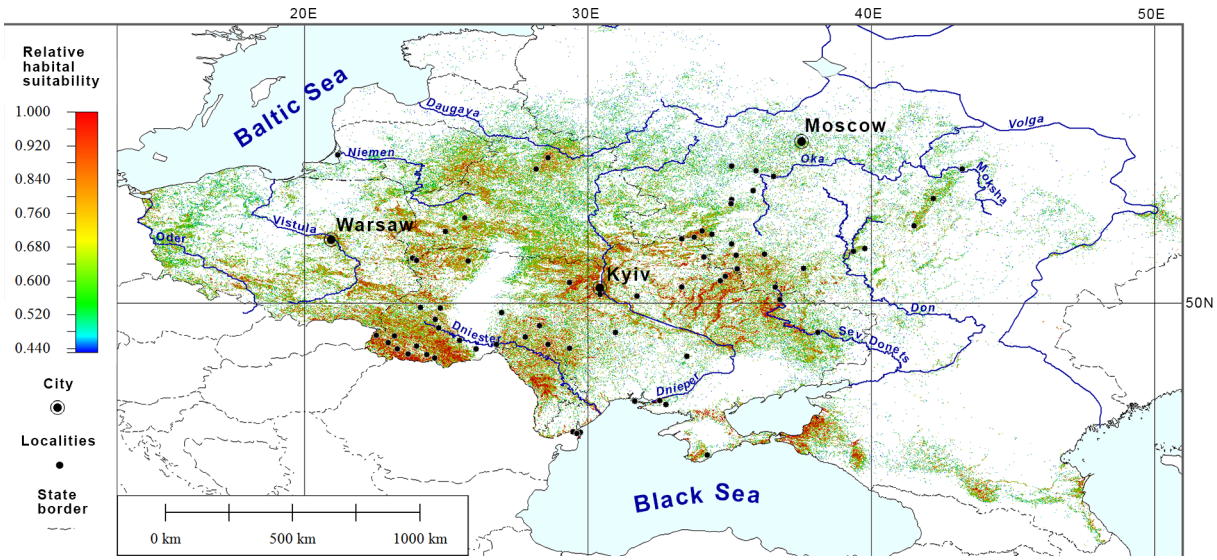

Fig. 1. Model of habitats suitable for *Neomys anomalus* after analysis of environmental predictors using Maxent. Relative suitability is shown by colour gradient. Areas of low habitat suitability are masked using the Maxent maximum training sensitivity plus specificity threshold. Localities, included in the analysis are shown.

Mitochondrial variation

Both studied specimens of Mediterranean water shrew from the Penza and Tambov regions had the same haplotype, similar (difference 0.3%) to the haplotypes from Belgorod region and Belorussia from GenBank. There are three major haplogroups in the network of *N. anomalus* haplotypes (Fig. 2), all of which have a distinct geographic distribution. The first consisted of Iberian specimens and thus corresponded to *N. a. anomalus*. The remaining two consisted of non-Iberian specimens and therefore represented *N. a. milleri*. One of the haplogroups within *N. a. milleri* included Eastern European samples, while the second included samples from the rest of Europe, excluding the Iberian Peninsula. The difference (*p*-distance) between subspecies was 6.9 ± 0.6%, while that between haplogroups of *N. a. milleri* was 3.7 ± 0.5%. The average distance within "*milleri*" haplotypes (2.4 ± 0.3%) was about 2.5 times larger than average distance within "*anomalus*" (0.9 ± 0.2%).

Sample from Estonia

The northernmost localities for which the occurrence of the Mediterranean water shrew was found are situated on the territory of Estonia (Balčiauskas *et al.*, 2016). Three *N. anomalus* specimens were found during the revision of collection of the University of Tartu Museum (UTM). Our species distribution modelling did not confirm the existence of suitable habitats for *N. anomalus* in the territory of Estonia (Fig. 1). Keeping in mind the theoretical possibility of mixing up of *N. anomalus* and *N. fodiens*, we compared body measurements of the Estonian sample with those of water shrews from the rest of Eastern Europe. According to our data, values for foot length do not overlap in samples of two *Neomys* species collected from one geographical region (Table). Therefore, the length of the hind foot could serve as a rough diagnostic tool for these two species in sympatry. We suggest that all body measurements (including foot length) of specimens described by Balčiauskas *et al.* (2016) as *N. anomalus* from Estonia lie completely within the variation of *N. fodiens* from this country and adjacent territories. Besides, there is a negative correlation of body size with latitude (Kryštufek & Quadracci, 2008); northern populations should be smaller in size. This rule is true for *N. fodiens* (Balčiauskas *et al*., 2014). Estonian *N. anomalus* (more northern) specimens were larger than those from Lithuania (more southern) (Balčiauskas *et al*., 2016). Consequently, we suggest a thorough additional investigation of specimens of *N. anomalus* from the UTM collection.

Discussion

The Mediterranean water shrew has a wide but fragmented distribution range from Western Europe to the Volga region and Asia Minor (Zaitsev *et al.*, 2014). Our modelling results confirm that the range in Eastern Europe consists of a number of fragments of various sizes, with different habitat suitability. The largest patches of suitable habitats are located at least in the basins of nine larger rivers. Taking into account the ecological relation of water shrews to water (Spitzenberger, 1990), disconnection of the distribution range into patches in different large river basins, together with low density across the range (Zaitsev *et al.*, 2014), could indicate real distribution fragmentation at present. The high parameterisation of our optimal model (regularisation coefficient of 0.75) suggests regional ecological peculiarity and weak general ecological trends.

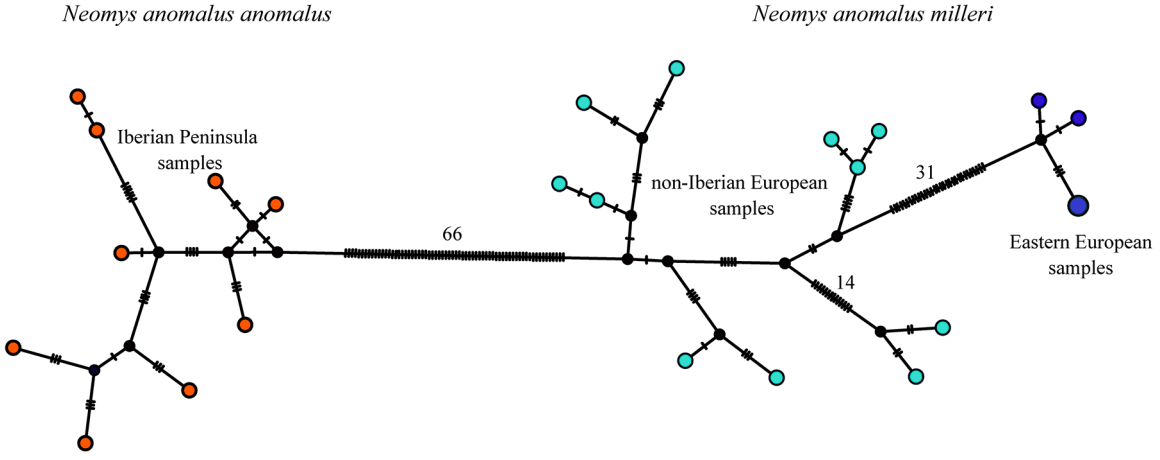

Fig. 2. Haplotype network of Iberian, non-Iberian and Eastern European specimens of *Neomys anomalus*, based on analysis of the mitochondrial cytochrome *b* gene (1140 bp). Hash marks reflect the number of mutational differences between haplotypes separated by more than one mutation.

Table. Body measurements (mm) of *Neomys anomalus* and *N. fodiens* from Estonia, Lithuania, Poland, Belarus, Ukraine and Russia. Data are from labels of museum collections and publications.

Region	Body length min–max (avg)	Tail length min–max (avg)	Foot length min–max (avg)
Neomys anomalus from Estonia			
Estonia (Balčiauskas *et al.*, 2016)	70–84 (78) n=3	51–58 (54.6) n=3	16.5–17 (16.8) n=3
N. anomalus			
Belarus (our data, Savarin & Savarina, 2019; Savarin, 2020)	59.1–77 (67.68) n=19	41–51.3 (45.5) n=19	13–15 (14.25) n=19
Kyiv region (Ukraine)	66–74.5 (71.2) n=9	39.5–49.5 (44.53) n=9	13.8–15.2 (14.29) n=9
Zakarpattia region (Ukraine)	57–88 (74.48) n=21	42–52 (47.67) n=21	14–15.7 (15.16) n=21
Lviv region (Ukraine)	63–79 (70.9) n=20	46–56 (51.05) n=20	13–16 (14.88) n=20
Odessa region (Ukraine)	64–79 (72.1) n=5	44.5–54 (50.68) n=5	14.5–15.4 (14.98) n=5
Sumy region (Ukraine)	67.8–75 (70.86) n=5	38.8–44 (43.4) n=5	13.6–14.7 (14.1) n=5
Lugansk region (Ukraine) (Abelentsev, 1967)	71–76.1 (73.07) n=4	43–53 (47.65) n=4	13.2–15 (14.38) n=4
Crimea	60–89.4 (76.14) n=21	44.5–58.3 (51.9) n=21	15–18 (16.28) n=23
Bryansk region (Russia)	63–74 (69.28) n=9	42–55 (48.33) n=9	13.8–15 (14.14) n=9
Kursk region (Russia)	68–75.2 (72.52) n=11	45–51.5 (48.39) n=11	13.7–15 (14.45) n=11
Mordovia (Russia) (Borodin, 2103)	67–76 (72.8) n=15	44.7–54.1 (50.32) n=15	13.4–15.4 (14.51) n=15
Penza region (Russia)	69 n=1	45 n=1	14 n=1
Białowieża (Poland)	65–83.2 (75.0) n=28	39–49.1 (43.4) n=28	14–16.5 (14.92) n=28
Białowieża (Poland) (Dehnel, 1950)	67–85 n=65	42–52 n=65	14–15.4 n=65
Lithuania (Balčiauskas *et al.*, 2012)	–	41–48.2 (44.7) n=3	14–15.2 (4.0) n=3
N. fodiens			
Belarus (our data; Savarin, 2020)	70.5–102 (78.93) n=7	54–65 (58.57) n=7	16–19 (17.79) n=7
Kyiv region (Ukraine)	78–85 (81.37) n=7	61–69 (63.44) n=7	16.5–19 (18.06) n=8
Zakarpattia region (Ukraine)	63–105 (79.62) n=90	53–68 (61.09) n=90	16–21 (18.08) n=90
Lviv region (Ukraine)	63–87 (77.36) n=22	53–67 (60.02) n=22	16.5–19 (17.62) n=22
Sumy region (Ukraine)	82.5–94.2 (87.9) n=6	59–66.5 (61.18) n=6	17–19.8 (18.15) n=6
Lugansk region (Ukraine) (our data; Abelentsev, 1967)	66.1–87 (79) n=7	60–69.6 (63.44) n=7	18.7–22 (19.79) n=7
Bryansk region (Russia)	71.5–86 (79.52) n=12	53.5–62 (58.77) n=12	17.1–19 (18.08) n=12
Kursk region (Russia)	81.7–90 (83.11) n=9	62.5–78 (68.24) n=9	17.3–19.4 (18.94) n=9
Białowieża (Poland)	71–93 (81.05) n=78	54–69.2 (61.62) n=78	17.2–19.5 (18.43) n=78
Białowieża (Poland) (Dehnel, 1950)	70–96	52–72	16–19.5
Lithuania (Balčiauskas *et al.*, 2012)	–	50.5–73.1 (61.78) n=84	16.3–19.6 (18.0) n=84
Estonia (Balčiauskas *et al.*, 2014)	–	48–68 (59.31) n=18	16–19 (17. 53) n=18

Genetic data also support the long-standing formation of the Mediterranean water shrew population in Eastern Europe. According to Igea *et al.* (2015), the divergence between *N. a. anomalus* and *N. a. milleri* took place about 400000 years ago and, most probably, was related to one of the Middle Pleistocene glaciations. The ancestral population of *N. anomalus* became isolated in the Iberian Peninsula, while the remaining population (*milleri*) could occupy Eastern Europe and Asia Minor during interglacials. Since all known haplotypes from Eastern Europe belong to a separate haplogroup, we can hypothesise that the eastern and western populations of *N. a. milleri* diverged later than the split between *N. a. anomalus* and *N. a. milleri*. The long history of formation of *N. a. milleri* is supported by high genetic distances within this taxon — 2.4% on average, with a maximum of 4.2%.

Turning back to the main task of this study, it would be interesting to describe the dynamics of the accumulation of data on *N. anomalus* distribution. The species was described at the beginning of the 20th century on the basis of a specimen from Spain (Cabrera, 1907). The same year, but later, another species, *N. milleri* (Mottaz, 1907), was described from the territory of Switzerland; this name was considered as a synonym of *N. anomalus* for a long time. Recently, Igea *et al.* (2015) suggested the separation of Iberian water shrews (*N. a. anomalus*) and animals from the rest of Europe (*N. a. milleri*) into two independent species. The subspecies of the Eurasian water shrew was described from the southern Crimea in 1917 — *N. fodiens mokrzeckii* Martino, 1917 (Martino & Martino, 1917); later, this subspecies was considered as a taxon within the Mediterranean water shrew. The author Ognev (1928) listed the Mediterranean water shrew (as *N. soricoides*) in Eastern Europe for the first time; Ognev's checklist contains two localities: Białowieża and Kyiv Province (I.G. Pidoplichko collection). Around this time, *N. anomalus* was found in Belarus not only in Białowieża (1913), but in the Gomel (1929 and 1930) region (Turov, 1955; Serzhanin, 1961; Serzhanin *et al*., 1967). The checklist from 1944 (Bobrinskiy *et al.*, 1944) expanded the list of the Mediterranean water shrew records in Eastern Europe by two items only: Southern Bessarabia and Voronezhskiy Zapovednik (Lavrov & Lavrov, 1938). There is no mention of this species from Belarus in the text of Bobrinskiy' checklist; however, there is a dot in the Brest region shown on the map. The mammal identification guide of Gromov *et al*. (1963) contains almost the same localities for the Mediterranean water shrew in Eastern Europe comparing to that of Bobrinskiy *et al.* (1944). The minor difference included new information about the occurrence of the species in Transcarpathia, the suggestion of this species' presence in Belarus as well as doubts on the correct species identification of the specimens from Voronezhskiy Zapovednik, mentioned above. Two years later, Bobrinskiy *et al*. (1965) notably enlarged our knowledge on the distribution of *N. anomalus*. Changes concerned the territory of Ukraine and Belarus, while the Russian range was still restricted to records from Voronezhskiy Zapovednik. The catalogue of mammals of the USSR (Gromov & Baranova, 1981) almost repeats information from the previous checklist (Bobrinskiy *et al.*, 1965), with exception of the absence of a mention of the Mediterranean water shrew from Russia.

Thus, in 1981, at least some Russian zoologists doubted the existence of *N. anomalus* in Russia, while museum specimens with incorrect species identification were kept in collections for a long time. The author E.S. Ptushenko found the Mediterranean water shrew in the Kursk Region in 1926–27. The shrew was collected in five localities of Dmitrievskiy District as well is in the districts Lgovskiy and Sudzhanskiy. These specimens were kept in the Zoological Museum of Moscow State University (ZMMU) and later identified by M.V. Zaitsev. Further, E.S. Ptushenko collected the Mediterranean water shrew near Belgorod in the valley of the Severs-ky Donets River in 1926; the specimen was passed to the ZMMU. In 1936, L.G. Morozova-Turova captured *N. anomalus* in the territory of Mordovskiy Zapovednik (Inorki plot) (Borodin, 2013). Later, 15 specimens were collected by L.P. Borodin and P.L. Borodin in a water meadow of the Pushta River in 1975, 1979–1981; two of them are kept in the ZMMU.

The data set from the Ukraine territory was also notably larger than it was reflected in published checklists. The first data on the Mediterranean water shrew were indeed collected in 1926 (Ognev, 1928; Pidoplichko, 1929) — ten skulls from pellets of barn owls were collected by E. Kititsyn in the Vyrva River valley near Radomyslska station in Kyiv Province (Korostensky District of Zhytomyr Region now). The adult female of the Mediterranean water shrew was collected by E. Kititsyn in the same locality in autumn 1926, and this material was analysed by I. Pidoplichko. Another specimen, collected by S. Ivanov near Uman (Cherkassy Region) in 1925, was handed to I. Pidoplichko. A large data set on the distribution and density of the Mediterranean water shrew in Right-bank Ukraine and Western Ukraine was generated after analysis of pellets of birds of prey, mainly in the first half of the 20th century (Pidoplichko, 1927, 1929, 1932, 1937, 1963; Sokur, 1963). More than 600 localities of 24 regions were investigated; *N. anomalus* was found in 75 localities of 12 regions. The knowledge on *N. anomalus* distribution in Western Ukraine was extended by Tatarynov (1956). In the territory of Left-bank Ukraine, single Mediterranean water shrews were revealed in the districts Brovarsky and Yagotinsky of the Kyiv region (Abelentsev & Pidoplichko, 1956) and near Poltava City (Gavrilenko, 1946 (1947)). Later, four specimens of *N. anomalus* were collected in the valley of the Severs-ky Donets River in the summer of 1961 (Kremenskoy District, Lugansk Region) (Abelentsev, 1966, 1967).

After the 1980s, information on the Mediterranean water shrew distribution in Eastern Europe grew rapidly (Appendix I). Three localities were found in Lithuania. One specimen was collected in 2009 in the Neman River delta, and two specimens were found during the examination of museum collections (Balčiauskas & Balčiauskiene, 2012).

Several specimens of *N. anomalus* were collected in the Vitebsk region of Belarus, in the territory of Berezinsky Zapovednik (Kashtalyan, 1999; Kashtalyan & Springer, 2012; Igea *et al.*, 2015). In the 20th century, new localities in Brest (Bereza Town vicinities) and Vitebsk (Ushachskiy District) were found (Savarin, Molosh, 2017; Savarin, 2019 a, b, c).

After 1997, in Ukraine, the species was found across Sumy region in the districts Seredina-Budsky, Gluhivsky, Romensky, Sumsky and Lebedinsky (Merzlikin, 1999; Mishta, 1999, 2003; Mishta & Shevchenko, 2003; Podoprigora & Merzlikin, 2003; Gavris *et al*., 2007; Merzlikin & Sheverdyukova, 2008; Mishta, 2008; Merzlikin & Sheverdyukova, 2010). A single specimen was collected in the valley of the Seversky Donets River near Verkhniy Saltov Village, Kharkiv region, in October 2005 (Zorya, 2008; Tokarskiy & Zorya, 2013). The first record of the Mediterranean water shrew from the Chernigiv region came from the analysis of pellets of tawny owls in 2008 (Zaitseva & Gnatina, 2010). The species was found in the south of the regions Kherson and Nikolaev (Gizenko, 1967; Selyunina, 2005) in the Danube delta Reserve of Odessa (Fedorchenko, 1992; Mishta, 2018). The most recent record from the Dnepropetrovsk region (right bank of the Dnieper River) near Kryvyi Rih was uploaded by V. Sevidov to the UkrBin database (http://ukrbin.com/show_image.php?imageid=52354).

The Mediterranean water shrew has always been a rare species in Ukraine, with an unstable abundance over time. According to data came from the first half of the 20th century, in Right-bank Ukraine, this species was less common in pellets of birds of prey than other shrews such as the common shrew, the Eurasian pygmy shrew, the bicolored white-toothed shrew and the Eurasian water shrew (Abelentsev & Pidoplichko, 1956). In the last 50 years, notable parts of habitats suitable for *N. anomalus* were destroyed or transformed by human activity (swamp drainage, dam construction, deforestation, development and ploughing up of the wetlands). The species was included in the Red Data Book of Ukraine (1994, 2009). Its density in suitable habitats is maintained at a fairly low level — relative density is no more than one to two individuals per 100 traps/days; usually below 0.5 individuals. The percentage of the total catch for this species is usually below 1.5%. There is a tendency to an even greater decline in the number of the species over the last 30 years (Mishta, 2009).

In Russia, the species was registered in the Kaluga region in "Ugra" National Park in 2004 for the first time. Later, single specimens of the Mediterranean water shrew were captured in Belyaevskoe, Yugorskoe (Yukhnovskiy District), Galkinskoe (Dzerzhinskiy District) and Berezichskoe (Ulyanovskiy District) forestries of this National Park as well as in "Kaluzhskie Zaseki" Zapovednik (Ulyanovskiy District) (Alekseev *et al.*, 2006, 2011, 2014; Koryavchenkov, 2017).

The species was registered in four localities of Khvastovicheskiy District in 2011 (Koryavchenkov, 2017) and in Ferzikovskiy District in 2014 (S. Alekseev, personal communication).

The Mediterranean water shrew was registered in the south-eastern part of the Bryansk Region, within the districts Trubchevskiy, Suzemskiy and Komarichskiy. The major part of these observations was made in the territory of "Bryanskiy Les" Zapovednik (Mishta, 2005; Sitnikova & Mishta, 2006, 2008). Outside the Zapovednik borders, the Mediterranean water shrew was found in Komarichskiy District in 2004 and in the regional natural monument "Nerusso-Sevniy" in 2005 (Mishta, 2005; Sitnikova & Mishta, 2008).

Recently, the Mediterranean water shrew from the districts Korenevskiy and Kurskiy, Kursk region, was mentioned in several publications (Zherdeva *et al.*, 2009; Zherdeva, 2017), but unfortunately there is no information on species identification in these publications. Inaccurate information about the presence of *N. anomalus* in the Oryol region was published in the Mammals of Russia checklist (Bannikova & Lebedev, 2012); the Dmitrievskiy District of the Kursk region and the neighbouring Dmitrovskiy District of the Oryol region were mixed up when citing specimens collected by E. Ptushenko.

In the Belgorod region, the single recent registration was made by Yu.M. Kovalskaya in the "Belogorye" Zapovednik, "Yamskaya step" plot in 2007 (Igea *et al.*, 2015; Shapovalov, 2019). The occurrence of *N. anomalus* in Lipetsk and Voronezh regions was established within "Usmanskiy Bor" (forest). Most records were from the territory of Voronezhskiy Zapovednik, which occupies the northern part of this forest. The last case took place in July 2014 (Sapelnikov & Sapelnikova, 2015). The only specimen registered outside of the Zapovednik was a dead female found during summer 1991 at the south-western edge of Usmanskiy Bor (Klimov & Khitsova, 1996; Klimov, 2011, 2013, 2018). There is additional information about a wider distribution of *N. anomalus* in the Lipetsk region (Nedosekin *et al.*, 1996; Parshina, 1997); however, the data source is unknown. In 1995, one specimen was supposedly collected by M.V. Ushakov in a water meadow of the Don River in the territory of "Galichya Gora" Zapovednik (Sarychev *et al.*, 1995; Klimov & Khitsova, 1996). Nevertheless, this report was recognised as erroneous (Klimov, 2011). The very author of this "finding", M.V. Ushakov (2009), considers the Mediterranean water shrew as "probably extinct in the region". This species was not included in later editions of the Red Data Book of Lipetsk region (Konstantinov, 2006; Alexandrov, 2014). The Mediterranean water shrew is known from the Tambov region by the single finding in Vlasovskoye peatland near Tambov (Lada & Sokolov, 2000, 2012; Sokolov & Lada, 2007). Two specimens were collected (1993 and 1997) in the Lyangas River valley, in the vicinity of Alexandrovka village in Zemetchinskiy District of the Penza region (our data). In the Mordovia Republic, the Mediterranean water shrew continues to live in Mordovskiy Zapovednik (Ruchin *et al.*, 2018).

Recently, *N. anomalus* was found in 21 regions of Ukraine and in Crimea: four of these regions were added to the list during 1997–2019 (Chernigov, Sumy, Khar-

kov, Dnepropetrovsk Regions), as well as eight regions of central Russia. The species was found after 1980 for the first time in four of these regions, namely Bryansk, Kaluga, Tambov and Penza. The species was found and kept in museum collections, but it was misidentified as *N. fodiens* in three regions: Kursk, Belgorod and Mordovia Republic (Borodin, 2013).

It is significant that for most cases of *N. anomalus* registration on the periphery of the range, the species was found during long studies in field stations. Such studies use various kinds of traps, including pitfalls. The stations belong to Nature Reserves (Białowieża Forest, Belogorye, Berezinskiy, Bryanskiy les, Voronezhskiy, Kaluzhskie zaseki, Mordovskiy), National Parks (Desnyansko-Starogutskiy, Ugra), natural monuments (Nerusso-Sevniy, Lovatyanka, Vytebet and Obelna Rivers, green area of Khvastovichi settlement), other traditional field stations (Pershinskaya station of MOIP, Vlasovskoye peatland near Tambov, biological centre of Voronezh State University "Venevitinovo", vicinities of Alexandrovka village in Zemetchinskiy District of Penza Region). No increasing numbers of the Mediterranean water shrew were registered somewhere in Eastern Europe. Thus, there was no reason for a dispersion of animals from zone of higher density to the periphery of the distribution range.

In summary, all studied animals belong to one compact haplogroup that was registered only in Eastern Europe. Consequently, if dispersion of water shrews is taking place, one can expect such dispersion within Eastern Europe only. The highly fragmented structure of *N. anomalus* distribution in this region makes the recent expansion of this rare species to the periphery of the range through large areas of unsuitable habitats less possible. The major part of new registrations of the Mediterranean water shrew is confined to places where long-term observations, focused on the investigation of the faunal composition, take place. This indicates a change in the thoroughness of faunal studies rather than a natural expansion of the species range. We hypothesise that one of the reasons of the "rarity" of *N. anomalus* during the 20th century was rather a social phenomenon: zoologists did not expect to find this species because of its extremely low density. As a result, specimens were not transferred to museums or were misidentified due to the lack of thorough attention.

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Appendix 1. Checklist of occurrence localities of *Neomys anomalus* in Lithuania, Belarus, Ukraine and Russia. Localities included in the spatial analysis are marked with *; localities filtered out during spatial aggregations removal are marked with **; localities from the territory that suffered from anthropogenic transformation during the time passed from the date of capture or obtained from pellets analysis are marked with ***.

ZM NUK — Zoological museum of Taras Shevchenko National University of Kyiv; NMNH (Kyiv) — National Museum of Natural History at the National Academy of Sciences of Ukraine; IZAN — collection of the Department of Monitoring and Animal Conservation, Schmalhausen Institute of Zoology, Kyiv; ZMMU — Zoological Museum of Moscow State University; ZIN RAS — Zoological Institute of Russian Academy of Sciences; ZM PSU — Zoological museum of Penza State University; SMNH (Lviv) — State Museum of Natural History NAS of Ukraine (Lviv); ZM UzhNU — Zoological museum of Uzhhorod National University; ZM LNU — Ivan Franko National University of Lviv; rusmam — Portal "Mammals of Russia" (http://rusmam.ru/)

Place	Longitude	Latitude	Date	Reference	
Belgorod Region, Belogorye Zapovednik, “Yamskaya steppe” area, gully of Sura River	37.6363	51.2035	22.06.2007	Shapovalov, 2019	*
Belgorod Region, vicinity of Belgorod, floodplain of Seversky Donets River	36.6207	50.5586	31.08.1926	ZMMU	*
Bryansk Region, Komarichsky District, vicinity of Lagerevka Village, sandbar of Usozha River	34.3892	52.414	23.07.2004	Mishta, 2005; Sitnikova & Mishta, 2006, 2008	*
Bryansk Region, Suzemsky District, Bryanskiy Les Zapovednik, quarter 111	33.8797	52.4429	18.07.2003	Mishta, 2005; Sitnikova & Mishta, 2006, 2008	**
Bryansk Region, Suzemsky District, Bryanskiy Les Zapovednik, quarter 111	33.8776	52.4417	01.01.2004	Mishta, 2005; Sitnikova & Mishta, 2006, 2008	**
Bryansk Region, Suzemsky District, Bryanskiy Les Zapovednik, vicinity of Chukhrai	33.8608	52.4623	13.06.2004	Mishta, 2005; Sitnikova & Mishta, 2006, 2008	*
Bryansk Region, Suzemsky District, Bryanskiy Les Zapovednik, vicinity of Chukhrai	33.8617	52.4625	01.06.2005	Mishta, 2005	**
Bryansk Region, Suzemsky District, Natural monument “Nerusso-Sevny”	34.126	52.3973	01.01.2005	Mishta, 2005; Sitnikova & Mishta, 2006	**
Bryansk Region, Trubchevsk District, Bryanskiy Les Zapovednik, vicinity of Proletarsky cordon	34.0555	52.5385	06.10.2004	Mishta, 2005; Sitnikova & Mishta, 2006, 2008	*
Bryansk Region, Trubchevsky District, Bryanskiy Les Zapovednik, vicinity of Staroe Yamnoe cordon	33.8664	52.4497	01.07.2007	IZAN	**
Kaluga Region, Dzerzhinsky District, Ugra National Park, Galkinskoe Forestry	35.805	54.7144	01.06.2004	Alekseev *et al*., 2006	*
Kaluga Region, Dzerzhinsky District, Ugra National Park, vicinity of Sabelnikovo Village	35.9396	54.6616	27.06.2004	Alekseev *et al*., 2006	**
Kaluga Region, Dzerzhinsky District, Ugra National Park, vicinity of Sabelnikovo Village	35.9396	54.6616	27.06.2005	Alekseev *et al*., 2006	**
Kaluga Region, Ferzikovsky District, 13 km South of Ferziko Village, Mshakovka ravine	36.5763	54.4492	15.07.2014	Alekseev S.K.	*
Kaluga Region, Khvastovichsky District, Natural monument “Vytebet River and its floodplain”	35.5597	53.4611	01.06.2011	Koryavchenkov, 2017	**
Kaluga Region, Khvastovichsky District, Natural monument “Green zone of Khvastovichsky settlement”	35.0654	53.4835	01.06.2011	Koryavchenkov, 2017	**
Kaluga Region, Khvastovichsky District, Natural monument “Lovotyanka River and its floodplain”	35.0867	53.6231	01.06.2011	Koryavchenkov, 2017	*

Appendix 1 (continued)

Place	Longitude	Latitude	Date	Reference	
Kaluga Region, Khvastovichsky District, Natural monument "Obelnya River and its floodplain"	35.1307	53.2997	01.06.2011	Koryavchenkov, 2017	*
Kaluga Region, Kozeksk District, Ugra National Park, Berezichsky Forestry	35.8558	53.9567	01.06.2004	Alekseev & Rogulenko, 2014	**
Kaluga Region, Ulyanovsky District, Kaluzhskiye Zaseki Zapovednik	35.739	53.568	01.06.2004	Koryavchenkov, 2017	*
Kaluga Region, Yukhnovsky District, Ugra National Park, Belyaevsky Forestry	35.0851	54.8036	01.06.2004	Alekseev & Rogulenko, 2014	**
Kaluga Region, Yukhnovsky District, Ugra National Park, Ugra Forestry	35.0405	54.7682	01.06.2004	Koryavchenkov, 2017	*
Kursk Region, Dmitriyevsky District, Pershino biological station	35.1317	52.1022	08.08.1926	ZMMU	**
Kursk Region, Dmitriyevsky District, Pershino biological station	35.1317	52.1022	17.09.1926	ZMMU	**
Kursk Region, Dmitriyevsky District, Pershino biological station	35.1268	52.1041	15.08.1927	ZMMU	**
Kursk Region, Dmitriyevsky District, Pershino biological station	35.1317	52.1022	18.08.1927	ZMMU	**
Kursk Region, Dmitriyevsky District, Pershino biological station	35.1317	52.1022	19.08.1927	ZMMU	**
Kursk Region, Dmitriyevsky District, vicinity of Rogozna Village	35.0878	52.0817	17.08.1927	ZMMU	**
Kursk Region, Dmitriyevsky District, vicinity of Snizha Village	35.1711	52.1281	16.08.1927	ZMMU	*
Kursk Region, Kursky District, Linevo Lake	36.2445	51.7104	06.06.2006	Zherdeva, 2017	*
Kursk Region, Sudzhansky District, vicinity of Sudzha	35.2926	51.2009	28.08.1926	ZMMU	*
Kursk Region, vicinity of Dmitriyev	35.0921	52.1229	25.07.1927	ZMMU	**
Kursk Region, vicinity of Dmitriyev	35.0873	52.122	27.07.1927	ZMMU	**
Kursk Region, vicinity of Lgov	35.2479	51.6726	03.09.1926	ZMMU	*
Mordovia, Temnikov District, Mordovski Zapovednik, "Inorka" area	43.1289	54.729	03.09.1936	Borodin, 2013	**
Mordovia, Temnikov District, Mordovski Zapovednik, quarter 358	43.1887	54.7652	01.01.2013	Ruchin *et al.*, 2018	*
Mordovia, Temnikov District, Mordovski Zapovednik, quarter 358	43.1887	54.7652	01.01.2013	Ruchin *et al.*, 2018	**
Mordovia, Temnikov District, Mordovski Zapovednik, quarter 377	43.1015	54.7542	29.08.1979	Borodin, 2013	**
Mordovia, Temnikov District, Mordovski Zapovednik, quarter 408	43.2011	54.7487	01.01.2013	Ruchin *et al.*, 2018	**
Mordovia, Temnikov District, Mordovski Zapovednik, quarter 449	43.2197	54.7111	29.04.1975	Borodin, 2013	**
Penza Region, Zemetchinsky District, vicinity of Aleksandrovka	42.2019	53.6804	02.08.1993	ZM PSU	**
Penza Region, Zemetchinsky District, vicinity of Aleksandrovka	42.2019	53.6804	11.08.1997	ZM PSU	*
Tambov Region, vicinity of Tambov, Prigorodnoe Forestry, northwest of Vlasovskoe peatland	41.5267	52.7216	22.04.1982	Lada & Sokolov, 2000	*
Voronezh Region, Usmansky Bor, South-Western outskirts, vicinity Biological Educational and Scientific Center of Voronezh State University "Venevitinovo" Samara Swamp	39.384	51.8111	01.07.1991	Klimov, 2011	*
Voronezh Region, Verkhnekhavsky District, vicinity of Belovka Village.	39.7934	51.8999	25.07.2014	Sapelnikov & Sapelnikova, 2015	*
Crimea, Alma River	34.2671	44.668	03.05.1935	ZMMU	**
Crimea, Bakhchysarai District, Prokhladnoe Village	33.9925	44.7461	25.07.1987	rusmam.ru	**

Appendix 1 (continued)

Place	Longitude	Latitude	Date	Reference	
Crimea, Bakhchysarai District, Shelkovichnoe Village	34.1011	44.635	15.10.1999	rusmam.ru	**
Crimea, Bakhchysarai District, Shelkovichnoe Village	34.1011	44.635	15.10.1999	rusmam.ru	**
Crimea, Bakhchysarai District, Trudolubovka Village	33.9914	44.7739	15.09.1998	rusmam.ru	**
Crimea, Bakhchysarai District, Trudolubovka Village	33.9914	44.7739	15.09.1998	rusmam.ru	**
Crimea, Bakhchysarai District, Zalesnoe Village	33.7789	44.5786	15.11.2008	ZM NUK	*
Crimea, Beshuyskoe Forestry, Kholodnaya Voda Tract, vicinity of Chatyr-Dag	34.2007	44.7149	08.09.1918	ZIN RAS	**
Crimea, Bolshaya Chuchel Mountain	34.1618	44.6568	16.07.1967	SMNH (Lviv)	**
Crimea, Crimean Zapovednik and Hunting Farm	34.2697	44.664	16.08.1936	ZMMU	**
Crimea, Crimean Zapovednik and Hunting Farm, Kacha River	34.0117	44.66	27.08.1969	Shevchenko & Zolotukhina, 2005	**
Crimea, Crimean Zapovednik, Alabach cordon	34.22	44.6177	16.07.1975	Shevchenko & Zolotukhina, 2005	**
Crimea, Crimean Zapovednik, Bazarchik place, Alma River (now Pochtovoe)	33.942	44.8373	20.10.1923	ZMMU	**
Crimea, Crimean Zapovednik, Chernaya River	34.2717	44.6935	27.06.1975	Shevchenko & Zolotukhina, 2005	**
Crimea, Crimean Zapovednik, Kholodnaya Voda Tract, Alma River	34.2007	44.7149	16.10.1923	ZMMU	**
Crimea, Crimean Zapovednik, mouth of Savlyk-Su River	34.2697	44.664	11.10.1973	Shevchenko & Zolotukhina, 2005	**
Crimea, Crimean Zapovednik, Sodovy cordon	34.3017	44.6959	28.10.1967	Shevchenko & Zolotukhina, 2005	**
Crimea, Crimean Zapovednik, source of Kachi River	34.2367	44.6315	24.04.1967	ZMMU	**
Crimea, Greater Yalta District, Krasnokamenka Village	34.2931	44.5703	25.10.1985	rusmam.ru	**
Crimea, Kurortnoe Village	35.18	44.92	09.1973	ZM NUK	***
Crimea, Kuybyshevsky District, Sokolinoe Village	33.9576	44.5543	20.06.1957	Shevchenko & Zolotukhina, 2005	**
Crimea, Nikita Village	34.2285	44.514	03.06.1979	Shevchenko & Zolotukhina, 2005	**
Crimea, rock outcrops at foot of mount Syuryu-Kaya, Bank of Sara-Uzen River	33.9683	44.5104	01.01.1983	Tovpinets & Evstafiev, 2005	**
Crimea, Simferopol District, Perevalnoe Village	34.2924	44.8365	01.01.2007	Tovpinets & Evstafiev, 2005	**
Crimea, Simferopol District, Perevalnoe Village	34.3117	44.9114	15.09.1998	rusmam.ru	**
Crimea, Simferopol District, Perevalnoe Village	34.3383	44.7778	05.04.1999	rusmam.ru	**
Crimea, Sudaksky District, Shchebetovka Village	35.1356	44.9242	25.09.1998	Tovpinets & Evstafiev, 2005	*
Crimea, vicinity of Grand Canyon	34.0028	44.5226	08.06.1986	Dulitsky, 2001	**
Crimea, vicinity of Krasnolesye Village	34.2357	44.811	02.07.2009	Mishta, 2008	*
Cherkasy Region, Kozatskoe	31.1469	49.1	1926–1928	Pidoplichko, 1932	***
Cherkasy Region, Mliev Village, Vilshanka River	31.4879	49.3141	06.1926; 30.07.1927	Pidoplichko, 1932	***
Cherkasy Region, Moshny District, Irdyn Swamp	31.7084	49.4033	01.07.1927	Pidoplichko, 1932	***
Cherkasy Region, Uman	30.1752	48.7206	1925	Pidoplichko, 1929	***
Cherkasy Region, vicinity of Katerynopil	30.9704	48.9294	22.08.1928	Pidoplichko, 1932	***
Cherkasy Region, vicinity of Katerynopol	30.9806	48.9595	01.01.1928	NMNH (Kyiv)	*
Cherkasy Region, vicinity of Yablunivka, Ros River	31.2635	49.4086	09.05.1926	Pidoplichko, 1932	***

Appendix 1 (continued)

Place	Longitude	Latitude	Date	Reference	
Cherkasy Region, Zvenyhorodka District, Kozatskoe	31.1469	49.1006	17.11.1930	Pidoplichko, 1937	***
Chernivitsi Region, vicinity of Lenkovtsy, Sursha River	26.7854	48.5237	02.05.2018	Gkhazali M. (UKRBIN)	*
Chernivtsi Region, Khotyn District, Klishkovtsy	26.2925	48.4535	25.05.1950	Sokur, 1963	***
Chernivtsi Region, on road between Kitsman and Dubovtsy	25.7204	48.3893	01.01.2009	Smirnov & Skilskiy, 2010	*
Chernivtsi Region, Sadhora District, Toporivtsi	26.0752	48.3741	31.05.1950	Sokur, 1963	**
Dnepropetrovsk Region, vicinity of Kryvyi Rih, Northern Red gully Landscape Reserve	33.5131	48.1051	02.10.2017	Sevidov V. (UKRBIN)	*
Ivano-Frankivsk Region, Carpathian National Nature Park	24.5018	48.3909	1986–1999	Kyselyuk, 2002	***
Ivano-Frankivsk Region, Dniester River Bank	24.7534	49.1119	28.06.1959	SMNH (Lviv)	*
Ivano-Frankivsk Region, Galich	24.7451	49.1154	10.06.1950	Sokur, 1963	***
Ivano-Frankivsk Region, Gorodenka	25.4824	48.6772	15.06.1950	Sokur, 1963	*
Ivano-Frankivsk Region, Kolomya	25.0374	48.5387	01.06.1950	Sokur, 1963	***
Ivano-Frankivsk Region, Nadvirna District, Polonyna Pozhizhevskaja	24.5327	48.156	30.07.1958	SMNH (Lviv)	**
Ivano-Frankivsk Region, Nadvirna District, Rogatin	24.6201	49.41	21.06.1950	Sokur, 1963	**
Ivano-Frankivsk Region, Nadvirna District, Zabolotov	25.292	48.4747	03.06.1950	Sokur, 1963	**
Kharkov Region, Volchansk District, Verkhniy Saltov Village	36.791	50.1057	01.01.2005	Zorya, 2008	*
Kherson Region, Bilozerka District, Kizomys Village, Bobrovka Lake	32.5558	46.5448	02.11.2005	NMNH	**
Kherson Region, Hola Prystan, Danube overflow land	32.5221	46.5394	10.07.1996	Mishta, 2008	**
Kherson Region, Hola Prystan District, 7 km South-East of Malye Kopani Village, Burkuty Tract	32.7748	46.4047	01.01.1967	Abelentsev, 1967	*
Kherson Region, Hola Prystan District, 7 km South-East of Malye Kopani Village, Burkuty Tract	32.777	46.4046	1967	Abelentsev, 1967	***
Kherson Region, Hola Prystan District, vicinity of Hola Prystan	32.5003	46.5328	13.11.1963	Abelentsev, 1967	**
Kherson Region, Hola Prystan District, West side of Black Sea Biosphere Reserve	32.1464	46.4692	01.01.1967	Gizenko, 1967	**
Kherson Region, vicinity of Gopri, Bobrovka Lake	32.5487	46.5425	01.01.1963	NMNH	*
Khmelnitsky Region, Derazhnia District, Kalnya	27.5394	49.27	1928	Pidoplichko, 1932	***
Khmelnitsky Region, Izyzslav	26.8254	50.1174	8.06.1949	Sokur, 1963	***
Khmelnitsky Region, Kamianets-Podilskyi	26.5789	48.679	12.05.1952	Sokur, 1963	**
Khmelnitsky Region, Kamianets-Podilskyi District, Kulchievtsy Village	26.7297	48.6534	14.08.2004	Mishta, 2008	***
Khmelnitsky Region, Krasilov	26.9691	49.6488	29.07.1929	Pidoplichko, 1937	*
Khmelnitsky Region, Starokonstantinov	27.253	49.7669	10.08.1928	Pidoplichko, 1937	***
Khmelnitsky Region, vicinity of Kamianets-Podilskyi, Muksha River	26.6013	48.713	25.09.1927	Pidoplichko, 1932	***
Kirovohrad Region, Kirovohrad (Kropyvnytsky)	32.2355	48.5518	1928	NMNH (Kyiv)	***
Kyiv, Kyiv-Sviatoshyn District, left Bank of Lubka River	30.3006	50.4981	10.07.2017	Tsvelykh, 2018	**
Kyiv Region, Koncha Zaspa reserve	30.5683	50.2994	03.10.1930–25.06.1931	Isotiv, 1932; Popov, 1932; Sharleman, 1933	***

Appendix 1 (continued)

Place	Longitude	Latitude	Date	Reference	
Kyiv Region, Bila Tserkva District, Shkvarivka	30.1847	49.7412	26.06.1927	Pidoplichko, 1932	***
Kyiv Region, Bila Tserkva, Ros River	30.0576	49.803	25.06.1927	Pidoplichko, 1932	***
Kyiv Region, Boryspil District, Bortnishi	30.7304	50.3885	27.10.1957	ZM NUK	**
Kyiv Region, former Berezansky District (now Yagotinsky District), Supoy River	31.758	50.238	01.01.1956	Abelentsev & Pidoplichko, 1956	*
Kyiv Region, Kyiv, Holosiivsky District, Pirogovo urban residential	30.5087	50.3466	10.03.1988	Tsvelykh, 2018	**
Kyiv Region, Kyiv-Sviatoshyn District, Holosiivskyi National Nature Park	30.5585	50.2818	03.10.2009	Mishta *et al.*, 2018	**
Kyiv Region, Kyiv-Sviatoshyn District, Lesniki Tract	30.55	50.2801	28.09.2005	Mishta, 2008	*
Kyiv Region, Kyiv-Sviatoshyn District, vicinity of Kruglik Village	30.4382	50.3027	01.10.2005	Mishta, 2008	**
Kyiv Region, Kyiv-Sviatoshyn District, vicinity of Podgortsy railway station	30.5533	50.2703	16.11.2004	Mishta, 2008	**
Kyiv Region, Kyiv-Sviatoshyn District., Romanovskoe swamp, Bank of Lubka River	30.2718	50.5015	10.07.2017	Tsvelykh, 2018	**
Kyiv Region, Obolon	30.5211	50.5298	19.10.1963	ZM NUK	**
Kyiv Region, Obukhiv District, between Villages of Krenychi and Gvozdov	30.501	50.242	01.04.2014	Mishta *et al.*, 2018	**
Kyiv Region, Obukhiv District, between Villages of Krenychi and Gvozdov	30.5029	50.2459	01.04.2015	Mishta *et al.*, 2018	**
Kyiv Region, Shpitky Village	30.144	50.4129	25.08.1929	Pidoplichko, 1937	***
Kyiv Region, Zhukov Island	30.5687	50.3601	01.01.1937	Pidoplichko, 1937	**
Lugansk Region, Kremenskoy District, Serebryansky Forestry, floodplain of Seversky Donets, Chernikova Lake	38.1316	48.9457	01.01.1961	Abelentsev, 1966; Abelentsev & Pidoplichko, 1967	*
Lviv Region, Drohobych District, Gai	24.2625	49.7557	29.06.1950	Sokur, 1963	**
Lviv Region, Glinyansky District, Yasenevka Village	24.8163	49.8184	01.11.1951	Tatarynov, 1956; ZM LNU	*
Lviv Region, Gorodok	23.6505	49.7812	07.07.1950	Sokur, 1963	**
Lviv Region, Ivano-Frankivsk	23.7436	49.9008	07.07.1948	Sokur, 1963	**
Lviv Region, Khodorov	24.3225	49.4145	24.05.1950	Sokur, 1963	***
Lviv Region, Kimets Village	23.1766	48.8346	01.01.1960	ZM LNU	**
Lviv Region, Lisinichi Village, vicinity of Lviv	24.1089	49.8339	01.01.1957	SMNH (Lviv)	**
Lviv Region, Nesterovo (Zhovkva)	23.9676	50.0534	08.07.1950	Sokur, 1963	**
Lviv Region, Pomoryany	24.939	49.6396	09.07.1950	Sokur, 1963	**
Lviv Region, Pustomytovsky District, Davydov Village	24.1195	49.7533	27.07.1956	SMNH (Lviv)	*
Lviv Region, Roztochchia Biosphere Reserve	23.6575	49.9642	01.01.2004	Kyjko *et al.*, 2005	**
Lviv Region, Strelkovsky District, (Staryi Sambir District now), Verkhny Luzhok	23.0212	49.3678	5.08.1950	Sokur, 1963	***
Lviv Region, Turka District, Volche Village	22.8626	49.2268	30.07.1959	SMNH (Lviv)	***
Lviv Region, Turka Village	23.0366	49.1443	5.07.1950	Sokur, 1963	***
Lviv Region, Zolochev	24.8706	49.8279	9.07.1950	Sokur, 1963	***
Lviv, Eastern outskirts	24.1089	49.8339	21.06.1951	Tatarynov, 1956; SMNH (Lviv)	**
Mykolaiv Region, Ochakiv District, Black Sea Biosphere Reserve, Volozhin area	31.6727	46.5367	01.01.1967	Gizenko, 1967	**
Odessa Region, Bobrik, Kodyma River	30.1685	47.91	10.08.1928	Pidoplichko, 1932	***
Odessa Region, Danube Biosphere Reserve, Gneushev Island	29.7547	45.442	23.11.1986	Chronicle of nature DBZ	*
Odessa Region, Danube Biosphere Reserve, Kubansky Island	29.7338	45.3399	01.07.1985	Chronicle of nature DBZ	**

Appendix 1 (continued)

Place	Longitude	Latitude	Date	Reference	
Odessa Region, Danube Biosphere Reserve, Kubansky Island	29.757	45.3086	23.09.1992	Chronicle of nature DBZ	**
Odessa Region, Danube Biosphere Reserve, Ochakiv Island	29.6707	45.4306	16.12.1989	Chronicle of nature DBZ	**
Odessa Region, Danube Biosphere Reserve, Ochakiv Island	29.6806	45.4299	18.07.1986	Chronicle of nature DBZ	**
Odessa Region, Danube Biosphere Reserve, Peshchany Island	29.6828	45.3837	15.08.1991	Chronicle of nature DBZ	**
Odessa Region, Danube Biosphere Reserve, Peshchany Island	29.6192	45.3829	01.01.1992	Chronicle of nature DBZ	**
Odessa Region, Kiliya District, vicinity of Vilkovo	29.5785	45.4206	26.08.2009	Mishta A.V. (unpublished data)	*
Odessa Region, Limansky District, Leski Village	29.4883	45.4564	01.01.2008	Mishta A.V. (unpublished data)	**
Odessa Region, South-Eastern outskirts of Vilkovo	29.5682	45.4332	19.07.1996	Mishta, 2008 IZAN	**
Poltava Region, vicinity of Poltava	34.5786	49.592	25.05.1944	Gavrilenko, 1946 (1947)8; Abelentsev & Pidoplichko, 1956 ZMMU	***
Rivne Region, Rivne Zapovednik, Bilozerske Forestry	25.79	51.4784	29.06.2019	Mishta A.V. (unpublished data)	*
Sumy Region, Glukhovsky District, floodplain of Abesta River, Shalyginsky Landscape Reserve of National Importance	34.11	51.61	01.01.1990	Podoprigora & Merzlikin, 2003	*
Sumy Region, Romny District, Anddriyashevsko-Gudymovsky Hydrological Reserve of National Importance,Ostrov Tract	33.3384	50.558	01.01.1984	Podoprigora & Merzlikin, 2003	*
Sumy Region, Seredyno-Buds'kyi District, Desna-Starohutskyi National Nature Park (Staraya Guta area, 121 quarter)	33.7	52.32	02.03.2002	Gavris, 2007; IZAN	**
Sumy Region, Seredyno-Buds'kyi District, Desna-Starohutskyi National Nature Park (vicinity of Staraya Guta Village)	33.6711	52.308	26.09.1999	Gavris, 2007	**
Sumy Region, Seredyno-Budskyi District, Desnyansko-Starogutsky National Nature Park, vicinity of Ochkino Village	33.3288	52.2619	07.08.2007	Mishta *et al.*, 2018	*
Sumy Region, Sumy and Lebedynskyi Districts, vicinity of Petrenkovo Village	34.6913	50.7711	25.07.1997	Merzlikin, 1999	**
Sumy Region, Sumy, vicinity of Tokary Village	34.874	50.9246	19.12.2009	Merzlikin & Sheverdukova, 2010	*
Sumy Region, Vorozhbansky Hydrological Reserve	34.6947	50.7668	03.07.2004	Mishta, 2008	*
Ternopil Region, Berezhany	24.9417	49.4489	10.05.1950	Sokur, 1963	*
Ternopil Region, Chortkiv District, Uryn	25.8287	48.971	15.05.1950	Sokur, 1963	***
Ternopil Region, Zoborov	25.1659	49.668	9.07.1950	Sokur, 1963	***
Vinnitsa Region, Bar District, Garmaki, Rovets River	27.5487	49.1032	29.09.1927	Pidoplichko, 1932	***
Vinnitsa Region, Bershad District, Florino	29.4986	48.3431	17.05.1952	Sokur, 1963	**
Vinnitsa Region, Borovka Village, Bushka River	28.259	48.4991	8.09.1927	Pidoplichko, 1932	***
Vinnitsa Region, Komargorod Village	28.6119	48.5305	20.08.1929	Pidoplichko, 1937	*
Vinnitsa Region, Kopaigorodsky District, Khrenovka (now Chernovitsky District, Privetnoe)	27.8182	48.7935	27.10.1928	Pidoplichko, 1937	*
Vinnitsa Region, Luninets District, Popelukhi Village	28.9907	48.2254	28.11.1928	Pidoplichko, 1932	***
Vinnitsa Region, Martinovka	28.0204	49.0892	02.05.1928	Pidoplichko, 1937	***

Appendix 1 (continued)

Place	Longitude	Latitude	Date	Reference	
Vinnitsa Region, Murafa	28.2067	48.7826	15.03.1927	Pidoplichko, 1929	***
Vinnitsa Region, Nemercha	27.7227	48.6701	18.07.1927	Pidoplichko, 1932	***
Vinnitsa Region, Obodovsky District, Balanovka Village	29.3734	48.3932	15.05.1952	Sokur, 1963	*
Vinnitsa Region, Oratov settlement	29.5239	49.1856	1927	Pidoplichko, 1927	***
Vinnitsa Region, Stefanovka	28.7736	49.1291	21.08.1929	Pidoplichko, 1937	***
Vinnitsa Region, Vinnitsky District, Vedmezhe Ushko Village	28.313	49.1896	06.05.1989	Mishta, 2008	*
Vinnitsa Region, Vinnitsky District, vicinity of Peshchanka	28.8896	48.2081	13.03.1988	Mishta, 2008	***
Vinnitsa Region, Yakushintsy	28.3763	49.2525	12.08.1930	Pidoplichko, 1937	***
Vinnitsa Region, Yampil District, Dzygivka	28.3249	48.3706	22.09.1927 02.09.1928	Pidoplichko, 1932; Pidoplichko, 1937	***
Vinnitsa Region, Zhmerynka District, Severinovka	27.9468	49.0557	18.04.1928	Sokur, 1963	**
Vinnitsa Region, Zhmerynka District, Severinovka, Rov River	27.9473	49.0561	18.07.1927	Pidoplichko, 1929	***
Vitebsk Region, Ushachsky District, Vashkovo Village, Borkovschina Lake	28.6004	55.1058	11.07.1905	Savarin, 2019 a, b, c	**
Vitebsk Region, Ushachsky District, Vashkovo Village, Dolzhina Lake	28.6009	55.1094	11.07.1905	Savarin, 2019 a, b, c	**
Vitebsk Region, Ushachsky District, Vashkovo Village, Vechelye Lake	28.6103	55.1321	11.07.1905	Savarin, 2019 a, b, c	**
Volyn Region, Kamin-Kashyrskyi	24.9933	51.6368	27.06.1949	Sokur, 1963	***
Volyn Region, Klevan	25.97	50.75	14.06.1949	Sokur, 1963	***
Volyn Region, Luboml	24.0483	51.2275	21.06.1949	Sokur, 1963	*
Volyn Region, Manevychi District, Povorsk	25.1588	51.2703	28.06.1949	Sokur, 1963	***
Volyn Region, Shatsk	23.9602	51.4888	24.06.1949	Sokur, 1963	**
Volyn Region, Shatsky District, Zatishye Village, Northern shore of Luky Lake	23.8366	51.5824	22.06.2004	Zatushevskiy *et al*., 2010	*
Zakarpattia Region, Beregi	22.7826	48.2529	29.08.1946	Sokur, 1963	***
Zakarpattia Region, Beskidy, Volonets Village	23.1975	48.6979	05.08.1950	Tatarynov, 1956; SMNH (Lviv)	*
Zakarpattia Region, Byerazino District, Uzhok Village	22.9299	48.9893	01.07.1961	ZM UzhNU	**
Zakarpattia Region, Carpathian Biosphere Reserve, central office	24.2229	48.0437	01.01.1987	Zagorodnyuk *et al.*, 1997	**
Zakarpattia Region, Carpathian Biosphere Reserve, Chernogorka	24.4798	48.1121	01.01.1987	Zagorodnyuk *et al.*, 1997, 1997	**
Zakarpattia Region, Carpathian Biosphere Reserve, Kuziysky area	24.1598	48.0001	1987–1994	Zagorodnyuk *et al.*, 1997, 1997	***
Zakarpattia Region, Carpathian Biosphere Reserve, Marmorossky area	24.45	48.1	1987–1994	Zagorodnyuk *et al.*, 1997, 1997	***
Zakarpattia Region, Carpathian Biosphere Reserve, Shirokoluzhansky area	23.772	48.2328	1987–1994	Zagorodnyuk *et al.*, 1997, 1997	***
Zakarpattia Region, Carpathian Biosphere Reserve, Ugolsky area	23.6102	48.2127	01.01.1987	Sokur, 1963	*
Zakarpattia Region, Chornogora	24.6108	48.0541	19.08.1961	NMNH	*
Zakarpattia Region, Irshavsky District, vicinity of Dolgoe Village	23.2946	48.3834	08.09.1990	Zatushevskiy *et al*., 2010	*
Zakarpattia Region, Irshavsky District, Zagate	22.9567	48.3988	28.05.1948	Sokur, 1963	*
Zakarpattia Region, Kosteva Pastil	22.541	48.8522	31.08.1948	Sokur, 1963	*
Zakarpattia Region, Maly Bereznyi	22.4511	48.8628	01.09.1948	Sokur, 1963	**
Zakarpattia Region, Menchil	23.6605	48.31	02.06.1963	NMNH (Kyiv)	**

Appendix 1 (continued)

Place	Longitude	Latitude	Date	Reference	
Zakarpattia Region, Mukachevo	22.6797	48.4393	11.12.1947	Sokur, 1963	**
Zakarpattia Region, Mukachevo District, Sinyak Village	22.8523	48.5799	10.06.1965	ZM NUK	**
Zakarpattia Region, Perechyn District, Turi Remety	22.5988	48.7012	02.05.1948	Sokur, 1963	***
Zakarpattia Region, Rakhovsky District, Kvasovy Menchul	24.3278	48.1732	01.09.1972	ZM UzhNU	*
Zakarpattia Region, Rakhovsky District, vicinity of Yasynya Village, Lopushanka River, Portoshi Tract	24.3898	48.2298	01.08.1986	ZM UzhNU	*
Zakarpattia Region, Sheshul, Baskul Tract	24.3732	48.1529	01.01.1950	NMNH (Kyiv), SMNH (Lviv)	**
Zakarpattia Region, Svaliava District, Vilchy Village	23.1039	48.5952	07.1965	ZM UzhNU	***
Zakarpattia Region, Tiachiv District	23.7101	48.3079	25.06.1954	ZIN RAS	**
Zakarpattia Region, Tiachiv District, Bradul Tract	23.9663	48.4633	01.09.1963	ZM NUK	**
Zakarpattia Region, Tiachiv District, Goverlyanka River	24.4699	48.1404	01.05.1963	ZM NUK	**
Zakarpattia Region, Tiachiv District, Grushevo	23.7689	48.0104	28.05.1948	Sokur, 1963	**
Zakarpattia Region, Tiachiv District, Uglya	23.6288	48.1487	14.05.1948	Sokur, 1963	**
Zakarpattia Region, Tiachiv District, vicinity of Bolshaya Ugolka Village	23.67	48.2	01.08.1978	ZM UzhNU	**
Zakarpattia Region, Tyachev	23.5969	48.0083	28.05.1948	Sokur, 1963	***
Zakarpattia Region, Uzhhorod District, Maly Bereznyi	22.4514	48.8672	09.11.1955	ZIN RAS	**
Zakarpattia Region, Velykyi Bereznyi	22.4611	48.8863	29.08.1948	Sokur, 1963	**
Zakarpattia Region, Vynohradiv District, Bolshie Komyaty	22.9809	48.2464	03.06.1948	Sokur, 1963	**
Zhytomyr Region, Borushkovtsy	27.656	49.9746	02.05.1928	Pidoplichko, 1932	***
Zhytomyr Region, Liubar District, Glezno	27.7067	49.9794	24.07.1929	Pidoplichko, 1937	***
Zhytomyr Region, Liubar District, Korostki	27.7434	49.9954	06.09.1926	Pidoplichko, 1932	***
Zhytomyr Region, Malinsky District, Fedorovka	29.3694	50.7053	07.09.1926 07.1927 01.06.1930	Pidoplichko, 1932, 1937	*
Zhytomyr Region, Mala Tsvilka	27.549	50.7427	31.07.1929	Pidoplichko, 1932	***
Belarus, Brest Region, Baranovichi District, wet alder forest on River Bank	25.6649	52.9898	20.08.1997	Mishta, 2011	*
Belarus, Brest Region, Kamenets District, Bialowieza Forest	24.9958	52.5181	15.08.2015	Savarin & Molosh, 2017; Savarin, 2019 a, b,c	*
Belarus, Vitebsk Region, Lepelsky District, Berezinsky Biosphere Reserve (Test site “Sinicheno”, forest quarter 444 and test site “Savsky Bor”, forest quarter 401)	28.1908	54.7147	15.07.1998	Kashtalyan, 1999; Kashtalyan & Springer, 2012	*
Belarus, Vitebsk Region, Ushachsky District, Vashkovo Village, Borkovschina Lake	28.6013	55.1051	11.07.1905	Savarin, 2019 a, b,c	*
Lithuania, Delta of Neman River	21.2851	55.2477	01.01.2009	Balčiauskas & Balčiauskiene, 2012; Balčiauskas *et al.*, 2016	*