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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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...
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://glsf. 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: tRNA*Glu* — 5’-ATC GTT ATT CAA TTA GAA CTA TAA GAA C-3’ and cytb_403R — 5’-YCC YCA RAA TGA TAT TGG YCC TCA-3’; cytb_389F — 5’-GTT AGC GCC ACT GCC TTT ATAG-3’ and cytb_746R — 5’-TAA TTG GCC GGG TCT CCG AGT A-3’; cytb_614F — 5’-TWT TCC TYC ATG AAA CAG GAT C-3’ and tRNA*Thr* — 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 MgCl2, 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)).

**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, Psyl, 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 Dauгava (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.

**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) (Białowieża, Poland), the Zoological Museum of the Zaporozh'ke State University (ZMPSU) (Penza, Russia), the Zoological Museum of the Moscow State University (ZMGMU) (Moscow, Russia).
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 & Quadaccr, 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.
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) (Dehn, 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 | 16–19 (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) (Dehn, 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 western and eastern 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 mokrcezki* 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 (Bobrinskii 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 Bobrinsky’s checklist; however, there is a dot in the Brest region shown on the map. The mammal identification guide of Gromov & Baranova, 1981 almost repeats information from the previous checklist (Bobrinskii 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 Dmitrivskiy 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 Seversky 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 (Ioroki 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 Vyra 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 Brovaryskiy and Yagotinsky of the Kyiv region (Abelentsiev & Pidoplichko, 1956) and near Poltava City (Gavrilenko, 1946 (1947)). Later, four specimens of *N. anomalus* were collected in the valley of the Seversky Donets River in the summer of 1961 (Kremsensky District, Lugansk Region) (Abelentsiev, 1966, 1967).

After the 1980s, the 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 (Kashatalyan, 1999; Kashatalyan & Springer, 2012; Igra 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 Sunny 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 & Gatina, 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 Dniproprotskov 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 (Abelentsv & 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 (Dzerzhinskii District) and Berezichskoe (Ulyanovskiy District) forests 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 Khvostovichskiy District in 2011 (Koryavchenkov, 2017) and in Ferzikovsky 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 “Bryanskis 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-Sevnyi” 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 Voronzhsky 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 Lyargas 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-
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, Berezinskii, Bryanskii les, Voronezhskii, Kaluzhskie zaseki, Mordovskii), National Parks (Desnyansko-Starogutskiy, Ugra), natural monuments (Neruso-SEvniy, Lovatyanka, Vytebet and Obelna Rivers, green area of Khvostovichy settlement), other traditional field stations (Pershiniskaya station of MOIP, Vlasovskoye peatland near Tambov, biological centre of Voronezh State University “Venevitino”, vicinities of Alexandrovka village in Zemetchinskii 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 ***.

| 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 Larerevka Village, sandbar of Usozha River | 34.3892 | 52.414 | 23.07.2004 | Mishta, 2005; Sitnikova & Mishta, 2006, 2008 * |
| Bryansk Region, Suzemsky District, Bryanskii Les Zapovednik, quarter 111 | 33.8797 | 52.4429 | 18.07.2003 | Mishta, 2005; Sitnikova & Mishta, 2006, 2008 ** |
| Bryansk Region, Suzemsky District, Bryanskii Les Zapovednik, quarter 111 | 33.8776 | 52.4417 | 01.01.2004 | Mishta, 2005; Sitnikova & Mishta, 2006, 2008 ** |
| Bryansk Region, Suzemsky District, Bryanskii Les Zapovednik, vicinity of Chukhrai | 33.8608 | 52.4623 | 13.06.2004 | Mishta, 2005; Sitnikova & Mishta, 2006, 2008 * |
| Bryansk Region, Suzemsky District, Bryanskii 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, Bryanskii Les Zapovednik, vicinity of Proletarsky cordon | 34.0555 | 52.5385 | 06.10.2004 | Mishta, 2005; Sitnikova & Mishta, 2006, 2008 * |
| Bryansk Region, Trubchevsk District, Bryanskii 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 Ferzikovo Village, Mshakovka ravine | 36.5763 | 54.4492 | 15.07.2014 | Alekseev S.K. * |
| Kaluga Region, Khvastovichsky District, Natural monument “Vytebet River and its floodplain” | 35.5957 | 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 * |
### Place, Longitude, Latitude, Date, Reference

| 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, Kozezk District, Ugra National Park, Berezichsky Forestry | 35.8558   | 53.9567  | 01.06.2004 | Alekseev & Rogulenko, 2014 |
| Kaluga Region, Ulyanovsky District, Kaluzhskiy 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 Sniza Village | 35.1711   | 52.1281  | 16.08.1927 | ZMMU                    |
| Kursk Region, Kursky District, Linevo Lake | 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   | 52.1222  | 27.07.1927 | ZMMU                    |
| Kursk Region, vicinity of Lgov | 35.2479   | 51.6726  | 03.09.1926 | ZMMU                    |
| Mordovia, Temnikov District, Mordovskski Zapovednik, “Inorka” area | 43.1289   | 54.729   | 03.09.1936 | Borodin, 2013            |
| Mordovia, Temnikov District, Mordovskski Zapovednik, quarter 358 | 43.1887   | 54.7652  | 01.01.2013 | Ruchin et al., 2018     |
| Mordovia, Temnikov District, Mordovskski Zapovednik, quarter 358 | 43.1887   | 54.7652  | 01.01.2013 | Ruchin et al., 2018     |
| Mordovia, Temnikov District, Mordovskski Zapovednik, quarter 377 | 43.1015   | 54.7542  | 29.04.1929 | Borodin, 2013            |
| Mordovia, Temnikov District, Mordovskski Zapovednik, quarter 408 | 43.2011   | 54.7487  | 01.01.2013 | Ruchin et al., 2018     |
| Mordovia, Temnikov District, Mordovskski 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, Prigorodnobe 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, Bakheysarai District, Prokhladnoe Village | 33.9925   | 44.7461  | 25.07.1987 | rusmam.ru               |
### Appendix 1 (continued)

| Place                                                                 | Longitude | Latitude | Date           | Reference         |
|-----------------------------------------------------------------------|-----------|----------|----------------|-------------------|
| Crimea, Bakchysarai District, Shelkovichnoe Village                    | 34.1011   | 44.635   | 15.10.1999     | rusmam.ru         |
| Crimea, Bakchysarai District, Shelkovichnoe Village                    | 34.1011   | 44.635   | 15.10.1999     | rusmam.ru         |
| Crimea, Bakchysarai District, Trudolubovka Village                     | 33.9914   | 44.7739  | 15.09.1998     | rusmam.ru         |
| Crimea, Bakchysarai District, Trudolubovka Village                     | 33.9914   | 44.7739  | 15.09.1998     | rusmam.ru         |
| Crimea, Bakchysarai District, Zalesnoe Village                         | 33.7789   | 44.5786  | 15.11.2008     | ZM NUK            |
| Crimea, Beshyyskoe Forestry, Kohlodnaya Voda Tract, vicinity of Chatyr-Dag | 34.2007   | 44.7149  | 08.09.1918     | ZIN RAS           |
| Crimea, Boldshaya Chuchel Mountain                                    | 34.1618   | 44.6568  | 16.07.1967     | SMNH (Lviv)       |
| 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, Kholodnaya Voda Tract, Alma River         | 34.2717   | 44.6935  | 27.06.1975     | Shevchenko & Zolotukhina, 2005 |
| Crimea, Crimean Zapovednik, Kholodnaya Voda Tract, Savlyk-Su River    | 34.2697   | 44.664   | 11.10.1973     | Shevchenko & Zolotukhina, 2005 |
| Crimea, Crimean Zapovednik, Sodov cordon                              | 34.3017   | 44.6959  | 28.10.1967     | Shevchenko & Zolotukhina, 2005 |
| Crimea, Crimean Zapovednik, Kotolnaya Voda Tract, Alma 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    | 09.09.1973     | ZM NUK            |
| Crimea, Kuybyshesky 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, Shchepetrovka Village                      | 35.1536   | 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, Miliev Village, Vilshanka River                      | 31.4879   | 49.3141  | 06.1926; 30.07.1927 | Pidoplichko, 1932 |
| Cherkasy Region, Mohny 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 Katerynopol                               | 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 |

* Neomys anomalus in the eastern part of the range
| Place                                                                 | Longitude | Latitude | Date       | Reference               |
|----------------------------------------------------------------------|-----------|----------|------------|-------------------------|
| Cherkasy Region, Zvenyhorodka District, Kozatskoe                     | 31.1469   | 49.1006  | 17.11.1930 | Pidoplichko, 1937      |
| Chernivtsi Region, vicinity of Lenkovtsy, Sursha River               | 31.1469   | 49.1006  | 02.05.2018 | Gikhazali M. (UKRBIN)   |
| Chernivtsi Region, Khotyn District, Klishkovtsy                       | 31.1469   | 49.1006  | 25.05.1950 | Sokur, 1963             |
| Chernivtsi Region, on road between Kitsman and Dubovtsy               | 31.1469   | 49.1006  | 01.01.2009 | Smirnov & Skilskiy, 2010|
| Chernivtsi Region, Sadhora District, Toporivtsi                       | 31.1469   | 49.1006  | 31.05.1950 | Sokur, 1963             |
| Dnepropetrovsk Region, vicinity of Kryvyi Rih, Northern Red gully Landscape Reserve | 31.1469   | 49.1006  | 02.10.2017 | Sevidov V. (UKRBIN)     |
| Ivano-Frankivs Region, Carpathian National Park                      | 24.5018   | 49.1006  | 19.06.1959 | SMNH (Lviv)             |
| Ivano-Frankivs Region, Dniester River Bank                           | 24.7534   | 49.1006  | 28.06.1959 | Sokur, 1963             |
| Ivano-Frankivs Region, Galich                                        | 24.7451   | 49.1006  | 10.06.1950 | Sokur, 1963             |
| Ivano-Frankivs Region, Gorodenka                                      | 25.4824   | 48.1006  | 15.06.1950 | Sokur, 1963             |
| Ivano-Frankivs Region, Kolonya                                        | 25.0374   | 48.1006  | 01.06.1950 | Sokur, 1963             |
| Ivano-Frankivs Region, Nadvirna District, Polonyna Pozhizhevskaja    | 24.5327   | 48.1006  | 30.07.1958 | SMNH (Lviv)             |
| Ivano-Frankivs Region, Nadvirna District, Rogatin                    | 24.6201   | 49.1006  | 21.06.1950 | Sokur, 1963             |
| Ivano-Frankivs Region, Nadvirna District, Zabolotov                   | 25.292    | 48.1006  | 03.06.1950 | Sokur, 1963             |
| Kherson Region, Bilozerkza District, Kizomys Village, Bobrovka Lake   | 32.5558   | 46.5448  | 02.11.2005 | NMNH                    |
| Kherson Region, Hola Prystan, Danube overflow land                    | 32.5221   | 46.5448  | 10.07.1996 | Mishta, 2008            |
| Kherson Region, Hola Prystan District, 7 km South-East of Malye Kopani Village, Burkuty Tract | 32.7777   | 46.4046  | 01.01.1967 | Abelentsev, 1967       |
| Kherson Region, Hola Prystan District, 7 km South-East of Malye Kopani Village, Burkuty Tract | 32.7777   | 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                    |
| Khmelnytsky Region, Derazhnia District, Kalnya                        | 27.5394   | 49.27    | 1928       | Pidoplichko, 1932      |
| Khmelnytsky Region, Izzyaslav                                        | 26.8254   | 50.1174  | 08.06.1949 | Sokur, 1963             |
| Khmelnytsky Region, Kamanets-Podilskyi                                | 26.5789   | 48.679   | 12.05.1952 | Sokur, 1963             |
| Khmelnytsky Region, Kamanets-Podilskyi District, Kulchievtsy Village  | 26.7297   | 48.6534  | 14.08.2004 | Mishita, 2008           |
| Khmelnytsky Region, Krasilov                                         | 26.9691   | 49.6488  | 29.07.1929 | Pidoplichko, 1937      |
| Khmelnytsky Region, Starokonstantinov                                 | 27.253    | 49.7669  | 10.08.1928 | Pidoplichko, 1937      |
| Khmelnytsky Region, vicinity of Kamanets-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 |
**Neomys anomalus** in the eastern part of the range

### 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, Lesniki Tract | 30.5585 | 50.2818 | 01.10.1957 | ZM NUK ** |
| Kyiv Region, Kyiv-Sviatoshyn District, Romanovskoe swamp, Bank of Kubka 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 Krenychy and Gvodaz | 30.3029 | 50.2459 | 01.04.2015 | Mishta et al., 2018 ** |
| Kyiv Region, Slupsky Village | 30.144 | 50.4129 | 25.08.1929 | Pidoplichko, 1937 *** |
| Kyiv Region, Zhukov Village | 30.5687 | 50.3061 | 01.01.1937 | Pidoplichko, 1937 ** |
| Lugansk Region, Kremenskoy District, Serebryansky Forestry, floodplain of Seversky Donets, Cheremkova Lake | 38.1316 | 48.9457 | 01.01.1961 | Abelentsev, 1966; Abelentsev & Pidoplichko, 1967 * |
| Lviv Region, Drohobych District, Gai Village | 24.2625 | 49.7557 | 29.06.1950 | Sokur, 1963 ** |
| Lviv Region, Glimiansky District, Yasenewka 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, Lisimichy 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, Pomornyany | 24.939 | 49.6396 | 09.07.1950 | Sokur, 1963 ** |
| Lviv Region, Pustomytyovskiy 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 Sambr District now), Verkhny Luhok | 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, Pleshchany Island             | 29.6828   | 45.3837    | 15.08.1991    | Chronicle of nature DBZ ** |
| Odessa Region, Danube Biosphere Reserve, Pleshchany 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); 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    | Podoprignora & Merzlikin, 2003 * |
| Sumy Region, Romny District, Anddriashchevsko-Gudymovsky Hydrological Reserve of National Importance, Ostrov Tract | 33.3384   | 50.558     | 01.01.1984    | Podoprignora & Merzlikin, 2003 * |
| Sumy Region, Seredyno-Buds'kyi District, Desna-Starohutsky 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-Starohutsky National Nature Park (vicinity of Staraya Guta Village) | 33.6711   | 52.308     | 26.09.1999    | Gavris, 2007 ** |
| Sumy Region, Seredyno-Buds'kyi District, Desna-Starohutsky National Nature Park, vicinity of Ochkinovo Village | 33.3288   | 52.2619    | 07.08.2007    | Mishta et al., 2018 * |
| Sumy Region, Sumy and Lebedynsky 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 & Sheverdulova, 2010 * |
| Sumy Region, Vorozhbas'kyi 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, Zborov                                                | 25.1659   | 49.668     | 07.08.1995    | 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    | 08.09.1927    | Pidoplichko, 1932 *** |
| Vinnitsa Region, Komarginorod Village                                  | 28.6119   | 48.5305    | 20.08.1929    | Pidoplichko, 1937 * |
| Vinnitsa Region, Kopaigorodsky District, Khrenovka (now Chernomivsky District, Privetnoe) | 27.8182   | 48.7935    | 27.10.1928    | Pidoplichko, 1937 * |
| Vinnitsa Region, Luninet District, Populukhi Village                   | 28.9907   | 48.2254    | 28.11.1928    | Pidoplichko, 1932 *** |
| Vinnitsa Region, Martinovka                                            | 28.0204   | 49.0892    | 02.05.1928    | Pidoplichko, 1937 *** |
### Neomys anomalus in the eastern part of the range

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, Vinnytsky District, Vedmezhe Ushko Village | 28.313    | 49.1896  | 06.05.1989      | Mishta, 2008         |
| Vinnitsa Region, Vinnytsky 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      | Pidoplichko, 1932;  |
| 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  | 13.03.1928      | Sokur, 1963          |
| Vitebsk Region, Ushachsky District, Vashkovo Village, Borkovschina Lake | 28.6004  | 55.1058  | 11.07.1905      | Savarin, 2019 a, b, c |
| Vitebsk Region, Ushachsky District, Borkovschina Lake | 28.6009   | 55.1094  | 11.07.1905      | Savarin, 2019 a, b, c |
| Vitebsk Region, Ushachsky District, Vashkovo Village, Dolzhina Lake | 28.6103   | 55.1321  | 11.07.1905      | Savarin, 2019 a, b, c |
| Volyn Region, Kamin-Kashyrskiy                | 24.9933   | 51.6368  | 27.06.1949      | Sokur, 1963          |
| Volyn Region, Klevan                         | 25.97     | 50.75    | 14.06.1949      | Sokur, 1963          |
| Volyn Region, Lubomi                         | 24.0483   | 51.2275  | 21.06.1949      | Sokur, 1963          |
| Volyn Region, Manychy 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   | 51.4037  | 01.01.1987      | Zagorodyuk et al., 1997 |
| Zakarpattia Region, Carpathian Biosphere Reserve, Chernogorka | 24.4798   | 48.1121  | 01.01.1987      | Zagorodyuk et al., 1997 |
| Zakarpattia Region, Carpathian Biosphere Reserve, Kaziysky area | 24.1598   | 48.0001  | 1987–1994       | Zagorodyuk et al., 1997, 1997 |
| Zakarpattia Region, Carpathian Biosphere Reserve, Marmorosky area | 24.45     | 48.1     | 1987–1994       | Zagorodyuk et al., 1997, 1997 |
| Zakarpattia Region, Carpathian Biosphere Reserve, Shirokoluzhansky area | 23.7722   | 48.2328  | 1987–1994       | Zagorodyuk 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, Maly Bereznyi             | 22.5767   | 48.3988  | 28.05.1948      | Sokur, 1963          |
| Zakarpattia Region, Mal'te Pastil             | 22.541    | 48.5922  | 28.05.1948      | Sokur, 1963          |
| Zakarpattia Region, Mal’t Bereznyi            | 22.4511   | 48.8628  | 01.09.1948      | Sokur, 1963          |
| 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 Yasyna 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    | ZIN RAS                          |
| Zakarpattia Region, Tiachiv District                                 | 23.7101    | 48.3079   | 25.06.1954 | ZM NUK                           |
| 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 Berezny                   | 22.4514    | 48.8672   | 09.11.1955 | ZIN RAS                          |
| Zakarpattia Region, Velykyi Berezny                                  | 22.4611    | 48.8863   | 29.08.1948 | Sokur, 1963                      |
| Zakarpattia Region, Vynohradiv District, Bolshe Komaty               | 22.9809    | 48.2464   | 03.06.1948 | Sokur, 1963                      |
| Zhytomyr Region, Borushkovtsi                                         | 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 | 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 | Mishra, 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, Berezynski Biosphere Reserve (Test site “Sinichen”, 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, Vaskhovo 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 | * |