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TWO INTRODUCED *CEPAEA* SPECIES (GASTROPODA, HELICIDAE) IN TERNOPIL, WESTERN UKRAINE, AND SPECIFICS OF THEIR PHENOTYPIC COMPOSITION

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Two Introduced *Cepaea* Species (Gastropoda, Helicidae) in Ternopil, Western Ukraine, and Specifics of Their Phenotypic Composition. Gural-Sverlova, N. V., Gural, R. I. — The shell colour and banding polymorphism of *Cepaea* was studied at 6 sites of Ternopil. *Cepaea hortensis* was found at all sites, its cohabitation with *C. nemoralis* was recorded in three cases. Phenotypes were determined in 1166 adult snails or empty shells with well-preserved colouration (830 *C. hortensis*, 336 *C. nemoralis*). It was found that part of the areas in Ternopil, as well as in the neighbouring Lviv Region, is inhabited by descendants of the primary introduction of *C. hortensis* to Western Ukraine with reduced variability in the shell colouration and only with a light body. At four studied sites, colouration traits indicating the presence of later introductions of *C. hortensis* were found: yellow banded shells, less often pink ones and well-expressed variability in body colouration. The phenotype 10305 in *C. hortensis*, previously unknown from Ukraine was shown. A significant negative correlation between the yellow shell colour and the band presence in *C. nemoralis* was found at one site, which is not typical for Western Ukraine and also rare in other introduced Eastern European populations of this species. The potential significance of the results for documenting the introduction history of two *Cepaea* species into Ukraine is discussed.
Key words: land snails, *Cepaea hortensis*, *Cepaea nemoralis*, polymorphism, Ukraine.

Introduction

Recently, there have been more and more reports about the occurrence of two introduced species of land snails, *Cepaea nemoralis* (Linnaeus, 1758) and *C. hortensis* (O. F. Müller, 1774) in different parts of Ukraine (Balashov & Markova, 2021; Gural-Sverlova & Gural, 2021 a, Gural-Sverlova et al., 2020, 2021 a, b; iNaturalist, 2023; UkrBIN, 2023, etc.). Numerous garden centres importing seedlings from other European countries play an important role in the spread of both species (Gural-Sverlova & Gural, 2022 b, Gural-Sverlova et al., 2021 a). Despite the more intensive spread of *C. nemoralis* from such garden centres, *C. hortensis* remains more widespread in Western Ukraine, especially in the Lviv Region. This is due to the primary introduction of *C. hortensis* into Western Ukraine in the second half of the 20th century and the subsequent spread of this species during the planned landscaping of settlements with ornamental shrubs (Gural-Sverlova et al., 2021 a).

The common origin of most currently known Western Ukrainian populations of *C. hortensis* is evidenced by their reduced and unusual phenotypic composition. Their most reliable phenotypic marker is the presence of dark spiral bands only on shells with a white ground colour (Gural-Sverlova et al., 2021 a), which is not typical of other parts of the present range of *C. hortensis* (Gural-Sverlova & Gural, 2022 a). Only recently (beginning in 2015) other variants of shell colouration began to be found in Western Ukraine (Gural-Sverlova et al., 2021 a), indicating later introductions of this species, independent of the primary one (Gural-Sverlova & Gural, 2022 a). Unlike the descendants of the primary introduction, such specimens are so far found very locally, which was clearly shown by the example of Lviv (Gural-Sverlova & Gural, 2022 b: fig. 3), often at sites whose length does not exceed several tens of meters.

Despite the proximity of Lviv Region, where the study of possible dispersal routes (Sverlova, 2002) and shell colour and banding polymorphism of *C. hortensis* (Gural-Sverlova & Gural, 2022 b; Sverlova, 2001) began as early as the late 1990s, Ternopil Region remained until recently the only administrative region in the western part of Ukraine where no records of this species were known (Gural-Sverlova & Gural, 2022 b: 252). It was only in early 2023, thanks to Facebook and regional press reports, that we learned the location of two sites in Ternopil inhabited by *C. hortensis* (referred to as sites 1 and 5 in this publication). During several one-day trips to Ternopil, we also found other sites inhabited only by *C. hortensis* or by both introduced *Cepaea* species. A month and a half after our research, at the end of June 2023, photographs of several specimens of *C. hortensis* taken in Ternopil appeared for the first time in the citizen science database iNaturalist (2023).

Cepaea nemoralis was first recorded in the Ternopil Region in 2017 from Chortkiv (UkrBIN, 2023), this finding was then described in a separate publication (Gural-Sverlova & Lyzhechka, 2021). An original feature of the found population was the presence of unevenly pigmented (so-called spotted or interrupted) bands in some specimens (Gural-Sverlova et al., 2021 a: fig. 5). This character, which is known to occur in the natural range of *C. nemoralis* and is hereditary (Murray, 1975: table 2; Richards et al., 2013: fig. 1), has not yet been found in other introduced Eastern European populations of the species (Gural-Sverlova & Gural, 2021 b; Gural-Sverlova et al., 2021 a). Prior to our study in Ternopil, there were no other reports on the presence of *C. nemoralis* in Ternopil Region, either in publications or databases we analysed (iNaturalist, 2023; UkrBIN, 2023).

In contrast to the primary introduction of *C. hortensis* into Western Ukraine (see above), subsequent introductions of both this species and *C. nemoralis* occur through different garden centres and may therefore have different origins even in the same administrative region or its centre, such as Lviv (Gural-Sverlova & Gural, 2022 a, b). Comparative data from different administrative regions may be of even greater interest for documenting the history of introduction and subsequent spread of both *Cepaea* species. Therefore, the main aim of this publication was not only to describe the phenotypic composition of *C. hortensis* and *C. nemoralis* at the studied sites in Ternopil, but also to elucidate their possible specific features.

Material and Methods

In April and May 2023, the phenotypic composition of *Cepaea* was studied at 6 sites of the city of Ternopil (fig. 1), Ternopil Region of Ukraine. Most of the collected material, except for damaged empty shells, is stored in the malacological collection of the State Museum of Natural History of the National Academy of Sciences of Ukraine in Lviv. The corresponding inventory numbers are given in parentheses after the site descriptions. The collected material (live snails and shells) is also partially shown in the illustrated database "Land molluscs of Ukraine" (Gural-Sverlova & Gural, 2012–2023).

Site No. 1. Academician Korolov Street, Nos. 2–8. Coordinates: between 49.554231, 25.647828 and 49.557095, 25.649362. Low trimmed (no more than 1 m high) hedges along the street, most often shaded by tall trees, but there are also open places. In the centre of the site, both species were found, with *C. hortensis* predominating. In the northern part, empty shells of *C. nemoralis* with well-preserved colouration, which remained on the soil surface after winter, were collected in large numbers. There were also a few living specimens

Fig. 1. Location of the studied sites. The dashed line shows the administrative boundaries of Ternopil. Squares — two species of *Cepaea*, circles — only *C. hortensis*, black — the presence of colouration variants that are absent in the descendants of the primary introduction of *C. hortensis* to Western Ukraine, white — no such colouration variants.

of this species on the bushes. Only *C. hortensis* was present in the southern part of the site. The total length of the studied site was about 250 m. *C. hortensis* was collected over a length of up to 200 m, *C. nemoralis*, about 100 m (Inv. No. 5117 — *C. nemoralis*, Nos. 5113 and 5118 — *C. hortensis*).

Site No. 2a. Park of National Revival, southwestern part of the park, bordering Stepan Bandera Avenue. Coordinates: between 49.549705, 25.628889; 49.551965, 25.630362 and 49.548876, 25.630931. Sparse tree plantations with rather large open lawns and groups of ornamental shrubs, under which live snails and their empty shells, whole or pecked by birds, were concentrated. The size of the studied area: about 100 m along the avenue and up to 150 m towards the park centre (Inv. No. 5125 — *C. nemoralis*, No. 5124 — *C. hortensis*).

Site No. 2b. A tree-shaded slope immediately adjacent to the Park of National Revival. Coordinates: 49.549222, 25.627444. The site was about 20 m long (Inv. No. 5123 — *C. hortensis*).

Site No. 3. Stepan Bandera Avenue, Nos. 72–88. Coordinates: between 49.549953, 25.622509 and 49.549036, 25.626608. Low trimmed (about 0.5–0.7 m high) hedges along the carriageway, well exposed and only in some places shaded by taller bushes or young trees. The site length was about 200 m (Inv. No. 5114 — *C. hortensis*).

Site No. 4. Stepan Bandera Avenue, Nos. 44–46. Coordinates: 49.551315, 25.616097. The remains of an old hedge (height no more than 1 m), partially shaded by young trees growing behind the fence of a household plot. Nearby is a building bordered by thujas planted no more than 10 years ago (the age was determined from the photo in Google maps). The site was about 15 m long (Inv. No. 5112 — *C. hortensis*).

Site No. 5. Taras Shevchenko Boulevard, No. 17, near the former premises of the central television and radio company. Coordinates: 49.554324, 25.595459. Low trimmed (height no more than 1 m) hedges of evergreen (boxwood, heavily damaged by box tree moth) and deciduous ornamental shrubs, well exposed, in places shaded by a few trees. The site is about 30 m long (Inv. No. 5115 — *C. hortensis*).

For quantitative analysis of the phenotypic composition, only mature live snails or their empty shells with well-preserved colouration were used. In total, phenotypes were determined in 830 adult specimens of *C. hortensis* and 336 of *C. nemoralis*.

Phenotypes were scored according to the standard method (Clarke, 1960), taking into account the ground colour of the shells and the banding pattern of their ultimate whorl. Spiral dark bands were designated by Arabic numerals from 1 to 5, counting them from the apex to the base of the shell. The absence of band(s) was indicated as “0” in place of the corresponding numeral(s). The fusion of adjacent bands was indicated with parentheses. The bands were considered to be fused if they were fully or partially merged for no less than a quarter of a whorl before the aperture. Phenotype formulas did not take into account weak, blure, additional (split) bands. The shell ground colour was designated as A — white, Y — yellow, P — pink, B — brown.

Y-0 — yellow unbanded;
Y-1 — yellow mid-banded (with one central band);
Y-3 — yellow three-banded (with three lower bands);
Y-5 — yellow five-banded;
P-0, P-1, P-3, P-5 — similar for pink shells;
B-0, B-1 — similar for brown shells.

In *C. hortensis*, special attention was paid to the presence of such colouration traits that are absent in the descendants of the primary introduction of this species to Western Ukraine (Gural-Sverlova & Gural, 2021 a, 2022 a). The latter are characterised by only three main shell colouration variants (yellow unbanded, white unbanded, white banded) and a light body (Gural-Sverlova & Gural, 2022 a: fig. 1).

Results

At three of the 6 studied sites, the cohabitation of two introduced *Cepaea* species was recorded (indicated by squares in figure 1). At site No. 4, only one adult *C. nemoralis* was observed, which had a yellow shell with three lower bands. Data on the phenotypic composition of the samples of *C. nemoralis* collected at sites Nos. 1 and 2 a are summarised in table 1. In both cases, the samples were polymorphic both in the shell ground colour and in the shell banding. In general, all three main ground colours (yellow, pink, and brown) and all four main banding variants (unbanded, with one central band, with three lower bands, and five-banded) were recorded in Ternopil. At site No. 2 a, pink and three-banded shells were not found (which could also be due to the small sample size), and at site No. 1, brown shells were not found.

Table 1. Phenotypic composition of *C. nemoralis* samples from Ternopil

Banding vertically, ground colour horizontally	Sites			
	No. 1		No. 2a	
	Yellow	Pink	Yellow	Brown
00000	79	85	–	2
00300	14	104	1	–
00345	1	4	–	–
003(45)	1	18	–	–
12345	*	5	8	–
123(45)	1	3	3	–
(12)3(45)		5	*	–
(123)(45)		1		–
1(23)45		1		–
Yellow, %	29.8		85.7	
Pink, %	70.2		0	
Brown, %	0		14.3	
Unbanded, %	50.9		14.3	
Mid-banded, %	36.6		7.1	
Three-banded, %	7.4		0	
Five-banded, %	5.0		78.6	
Live snails	4		5	
Empty shells	318		9	
Total	322		14	

*Phenotype noted only in juveniles. The table does not include one specimen from site No. 4, which had a yellow shell with three lower bands (see Results).

Table 2. Phenotypic composition of *C. hortensis* samples from Ternopil

Phenotypes	Sites					
	No. 1	No. 2a	No. 2b	No. 3	No. 4	No. 5
A00000	50	11	13	34	1	6
A12345	5	2	–	–	8	–
A(12)345	–	1	–	–	1	–
Y00000	185	125	95	125	52	69
Y10305	–	3	6	–	–	–
Y12345	–	1	*	–	9	7
Y(12)345	–	1	8	–	–	–
Y(12)3(45)	–	1	4	–	–	–
Y(123)(45)	–	1	1	–	–	–
Y1(23)(45)	–	–	1	–	–	–
Y12045	–	–	1	–	–	–
P00000	–	1	–	–	–	2
Unbanded, %	97.9	93.2	83.7	100	74.6	91.7
Yellow unbanded, %	77.1	85.0	73.6	78.6	73.2	82.1
**Untypical, %	0	5.4	16.3	0	12.7	10.7
Live snails	134	92	123	159	70	84
Empty shells	106	55	6	–	1	–
Total	240	147	129	159	71	84

*Phenotype noted only in juveniles. **Colouration variants, not typical for Western Ukraine (yellow banded, pink, 10305).

For *C. hortensis*, unbanded shells clearly predominated at all sites studied (table 2). Their share varied from 75 to 100 %. Most of the unbanded specimens were of the Y00000 phenotype (from 73 to 85 % of the total number of collected snails and empty shells). The shell colouration variants not typical for the descendants of the primary introduction of *C. hortensis* into Western Ukraine, see Material and methods, were found at four sites marked in black in figure 1. Mostly these were yellow banded shells, less often pink ones (tables 2, 3), which are currently also known for some other administrative regions of Ukraine (table 3). With the exception of site 4, the presence of such atypical forms of shell colouration was accompanied by a pronounced variability in the intensity of body pigmentation (table 3).

At the edge of the Park of National Revival (site No. 2 a) and the slope adjacent to it (site No. 2 b), the phenotype 10305, previously unknown from Ukraine, was recorded (fig. 2, A, B). Two specimens of *C. hortensis* with the same phenotype but with dark lip (fig. 2, C, D) were also found by us in June 2023 near a large garden centre in Horodok, Lviv Region (coordinates 49.790401, 23.715062).

Unlike Lviv Region (table 3, figs 2, C, D), no specimens of *C. hortensis* with dark lip resembling *C. nemoralis* were found in Ternopil. Although at different sites there were shells with a pinkish tint on the lip fragment adjacent to the columella and on the parietal wall of aperture, expressed to varying degrees. This pinkishness was most clearly seen at site No. 5 (Gural-Sverlova & Gural, 2012–2023), where it was visible in at least half of the shells of the phenotype Y00000. A similar colouration of this part of the shell, sometimes present also in the descendants of the primary introduction, is shown in one of our previous publications (Gural-Sverlova & Gural, 2021 a: fig. 5, B). Subsequently, this colouration trait was not considered as a phenotypic marker of later independent introductions of *C. hortensis* to Ukraine, in contrast to the true dark lip (table 3).

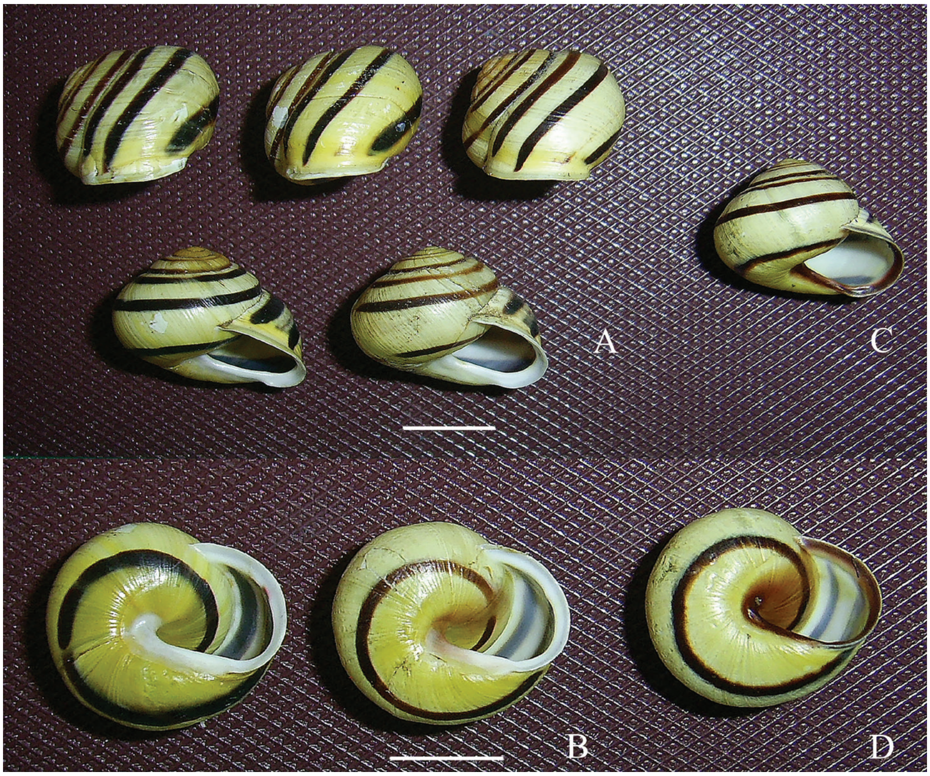

Fig. 2. Shells of *C. hortensis* with phenotype 10305 from Ternopil (A, B) and Horodok, Lviv Region (C, D). Scale bar 1 cm.

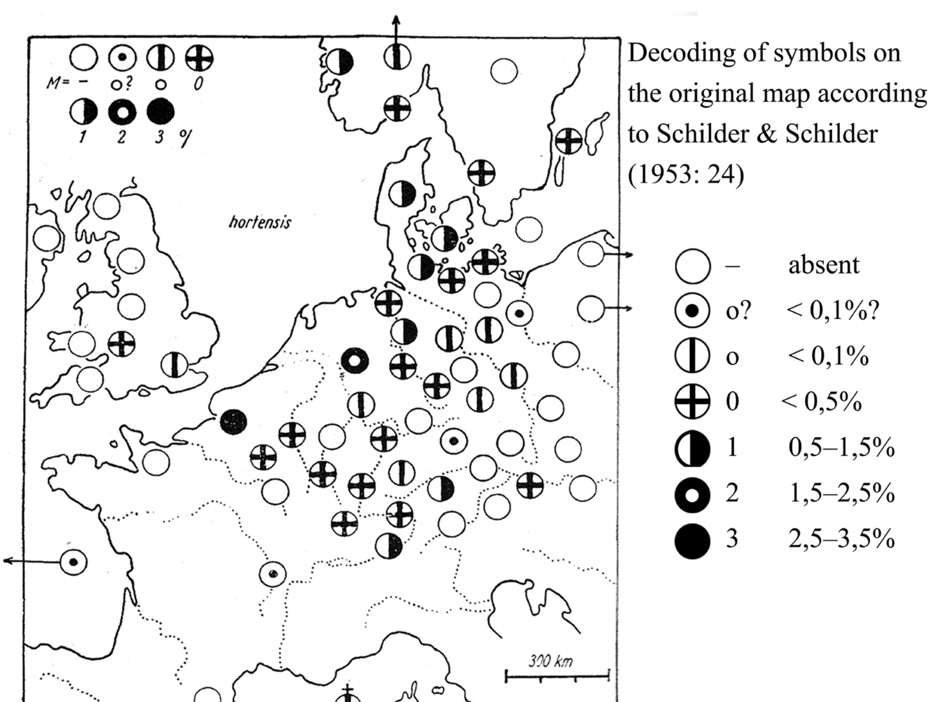

Fig. 3. Occurrence scheme of the phenotype 10305 in *C. hortensis* in Europe according to the monograph by Schilder & Schilder (1957: 186, map 62).

Table 3. Colouration traits absent in the descendants of the primary introduction of *C. hortensis* to Ukraine

Sites or regions	Shell				Lip	Body
	banded yellow	pink	brown	10305	dark	dark (grey)
Studied sites in Ternopil						
Site No. 2a	+	+	–	+	–	+
Site No. 2b	+	–	–	+	–	+
Site No. 4	+	–	–	–	–	–
Site No. 5	+	+	–	–	–	+
Number of sites	4	2	0	2	0	3
Administrative regions of Western Ukraine						
Lviv	+	+	+	+	+	+
Ternopil	+	+	–	+	–	+
Transcarpathian	–	+	–	–	–	+
Other administrative regions of Ukraine						
Kharkiv	+	+	–	–	–	–
Kirovohrad	–	+	–	–	–	–
Kyiv	+	+	–	–	–	+
Zhytomyr	+	–	–	–	–	+
Number of regions	5	6	1	2	1	5

When compiling the table, personal observations (Lviv and Lviv Region, Ternopil and Uzhhorod) and photographs from two citizen science databases (iNaturalist, 2023; UkrBIN, 2023) were used.

Discussion

Although the first evidence for the presence of *C. hortensis* in Ternopil appeared only very recently (see Introduction), there are good reasons to assume that this species was introduced to the city in the second half or at the end of the 20th century. In this case, its late discovery may be due to the fact that no special study of the urban land mollusc fauna of Ternopil has been carried out, in contrast to Lviv, which was well studied in this respect.

At two sites of Ternopil studied by us (Nos. 1 and 3), no shell colouration variants (yellow banded, pink) and snails with well-expressed gray pigmentation of the body were found, which are absent in the descendants of the primary introduction of *C. hortensis* to Western Ukraine, but are quite common not only in the natural range, but also in other introduced Eastern European populations of the species (Gural-Sverlova & Gural, 2021 a, 2022 a). The absence of banded shells with a non-white ground colour (Gural-Sverlova & Gural, 2022 a) at site No. 1 can be considered especially indicative in this respect.

At site No. 3, banded specimens were not found among both adults and juveniles of *C. hortensis* (table 2). This may be due either to the complete absence of the corresponding recessive allele, or to its relatively low frequency, when most of its carriers are heterozygotes and have unbanded shells (Gural-Sverlova & Gural, 2022 b: fig. 4). In this case, the main attention was paid to the body colouration, which was light not only in all collected adults (table 2), but also in all juveniles observed at the site.

At both sites mentioned above, low hedges were present, which played an important role in the spreading of descendants of the primary introduction of *C. hortensis* throughout Lviv (Sverlova, 2002) and Lviv Region (Gural-Sverlova & Gural, 2021 a). These hedges looked quite old and could well have been planted along the streets in the second half of the 20th century. At least part of the ornamental shrubs in the Park of National Revival (site No. 2 a), established in 1978, could also have remained here since the end of the 20th century.

It is significant that the not typically coloured shells and dark body in *C. hortensis*, as well as some specimens of *C. nemoralis*, were found by us only at the very edge of the park, where it borders on buildings. It is quite probable that descendants of the primary and later introduction of *C. hortensis* mixed in this place. In the latter case, there could have been a joint introduction of two *Cepaea* species, which has recently been observed quite often in Lviv and its immediate environs (Gural-Sverlova & Gural 2022 b). A similar process could have taken place at site No. 4, where both *Cepaea* species were also found, snails were collected on the remains of an old hedge, all specimens of *C. hortensis* had a light body, and half of the banded shells had a white ground colour (tables 2, 3).

Until now, populations of *C. hortensis* formed by the descendants of the primary introduction have been recorded mainly in the Lviv Region, and only in several cases in other administrative regions of Western Ukraine (Gural-Sverlova & Gural, 2021 a). And cases of the mixing of the descendants of the primary introduction and later importations of this species to Ukraine can be observed in Lviv and some other settlements of the Lviv Region (Gural-Sverlova & Gural, 2022 b). Thus, the obtained results expand the available data on the scale of unintentional settling of *C. hortensis* in the Western part of Ukraine in the second half of the 20th century.

We noted earlier that most Western Ukrainian populations of *C. hortensis* are characterised by an atypically high proportion of unbanded shells, predominantly of the phenotype Y00000, which is often observed even in habitats heavily shaded by trees or buildings (Gural-Sverlova & Gural, 2021 a). The average frequency of unbanded shells in *C. hortensis* in Western Ukraine usually exceeds 80 % (Gural-Sverlova & Gural, 2022 b), which is higher than in any part of the natural range of this species (Cameron, 2013: table 6). If this is not related to a common origin, it may indicate a selective advantage of lighter variants of the shell colouration in a more continental climate compared to the natural range (Gural-Sverlova & Gural, 2022 b).

At the studied sites of Ternopil, the trend towards the predominance of unbanded shells was even somewhat stronger than in Lviv (Gural-Sverlova & Gural, 2022 b: table 1), they averaged about 90 % (table 2). A distinct predominance of unbanded shells was observed both at sites inhabited by descendants of the primary introduction of *C. hortensis* into Western Ukraine (Nos. 1 and 3, see above), and in areas where there is clear evidence of a later introduction (other sites).

Colouration traits that are absent in the descendants of the primary introduction, but recorded in Ukraine in recent years (table 3), can be divided into two groups: 1) common in different parts of the natural range of *C. hortensis* and therefore with a high probability enter the introduced populations (yellow banded shells, pink ground colour, well-expressed gray pigmentation of the body); 2) locally occurring even within the natural range (dark lip, brown shell, phenotype 10305).

The first of them can evidence only the presence of later introductions, independent of the primary one, but do not provide any information about their possible origin. The latter may indicate, for example, the spreading of their carriers from certain garden centers (Gural-Sverlova & Gural, 2022 a, b). Therefore, they are much more valuable for documenting the history of introductions and subsequent dispersal of *C. hortensis* in Western Ukraine, and prospectively, in other parts of the country. In previous publications (Gural-Sverlova & Gural, 2021 a, 2022 a), we have elaborated on one of these traits (dark lip) in introduced Eastern European populations of *C. hortensis*.

The most detailed information about the phenotype 10305 in *C. hortensis* and its occurrence in different parts of Europe (fig. 3) can be found in the monograph by well-known

German researchers on the shell colour and banding polymorphism in *Cepaea*, Schilder & Schilder (1957). Moreover, they considered this phenotype as one of the main inherited variants of the shell colouration in *C. hortensis* ("consubspecies"), along with unbanded, five-banded, and mid-banded shells (Schilder & Schilder, 1957), and in an earlier publication (Schilder & Schilder, 1953: 21), also with the phenotype (123)(45). This form of colouration was given the letter designation "M" from the word "moulinsia". Among more than 145 thousand specimens of *C. hortensis* from different parts of the species range, but mainly from Germany, 2.2 % of the total number and 4.0 % of the banded shells were assigned to this form (Schilder & Schilder, 1957: table 13). For comparison, the proportion of shells with one central band was approximately 10 times less.

Comparing the distribution of the phenotype 10305 in Europe with that of mid-banded shells in *C. hortensis*, Schilder & Schilder (1957: 185) wrote: "Auch M erscheint noch lokalisierbar, obgleich die M-freie Zone ringsum (Westengland–Pyrenäen–Bayern–Polen) schmaler ist: wir vermuten ihren Ursprung in Dänemark, von wo aus sie bis Norwegen, England, zu den Alpen und bis Sachsen vordringen konnte; vielleicht aber sind die M von Bayern bis Frankreich hier unabhängig entstanden, da an Main und Mosel eine gewisse M-Armut zu beobachten ist" (M also seems to be localizable, although the M-free zone around is narrower (Western England–Pyrenees –Bavaria–Poland): we suspect its origin in Denmark, from where it could penetrate into Norway, England, the Alps and Saxony; but perhaps M from Bavaria to France arose independently, since on the Main and Moselle one can observe some poverty of M). According to Taylor (1914: 339), the phenotype 10305 is "not so common" in Great Britain, but "has been quoted from Germany, France, Belgium, Switzerland and Norway".

In later publications, we found few references to the phenotype 10305 in *C. hortensis*. In three samples collected near Bergen in the west of Norway, its frequency ranged from 3.4 to 9.2 % of the total (Andreassen, 1978: table 2) or from 4.6 to 37.8 % of banded shells. Like phenotypes 12345 and 10345, this was one of the most common colouration variants of banded shells in samples.

Among nearly 75 thousand of *C. hortensis* collected throughout France, more than 1.5 thousand had the phenotype 10305 (Lamotte & Guerrucci, 1970: table 1). This is 2.1 % of the total number and 6.4 % of the banded shells. Out of a hundred samples of *C. hortensis* (Lamotte & Guerrucci, 1970: table 3), the phenotype 10305 was present in 33. In general, 10305 was found to be one of the five most common phenotypes in France, behind only (in descending order) 00000, 12345 and 00300, and slightly ahead of 10345 (Lamotte & Guerrucci, 1970: table 1).

Even in those parts of the natural range of *C. hortensis* where the phenotype 10305 occurs more often than usual, its spatial distribution can be quite mosaic. In addition to the data from France mentioned above, this can be shown on the example of the German island of Rügen. Among 25 large (more than one hundred specimens) samples, information about which we received from the archive of the spouses Schilder, stored in the Museum of Natural History of the Humboldt University of Berlin (Sverlova, 2004), this phenotype was present only in 10. On the other hand, in three cases its share among banded shells exceeded 20 %. Rensch (1932: 100) gives the phenotypic composition of two samples from Rügen, in which there were even more shells with the phenotype 10305. Their share was 23–26 % of the total and 37–38 % of the banded shells.

The phenotype 10305 is only rare and locally found in England (Taylor, 1914; Schider & Schilder, 1957), see also figure 3. Therefore, it is often completely absent in samples (Clarke, 1960: tables 1, 2; Wall et al., 1980: table 1) or may not be listed separately in the publications of British researchers (Cameron, 1992; Cameron & Dillon, 1984; Cameron & Pokryszko, 2008). It is not surprising that even in the generalizing publication by Cameron (2013), which analysed the geographic variability of the phenotypic composition of *C. hortensis* in most of the present European range of the species, this colouration variant is not mentioned. It is possible that some neglect of this phenotype was also influenced by the fact that it does not correspond to the main variants of shell colouration in the more studied related species *Cepaea nemoralis* (unbanded, one central band, three lower bands, five bands). The nature of its inheritance is also not known (Murray, 1975: table 3), although the heritability of this phenotype is not in doubt.

Some additional data on the current presence of the phenotype 10305 in different European countries can be found in the citizen science database iNaruralist (2023). Among more than 10 thousand photographs identified (though not always correctly) as *C. hortensis*, we selected several dozen images of this form, mainly from Finland (Turku) and Germany, but also from Denmark, France, Norway, Slovakia, Switzerland and possibly Belgium, England and the Czech Republic.

Except for our records in Ternopil and Horodok (fig. 2) made in 2023, the phenotype 10305 has not yet been found not only in Ukraine (table 3), but also in other introduced Eastern European populations of *C. hortensis*: in Belarus (Kruglova & Kolesnik, 2017; iNaturalist, 2023) or in the central part of European Russia (Egorov, 2015, 2018; Gural-Sverlova & Gural, 2021 a; iNaturalist, 2023). There is also no data on the presence of this form in introduced populations of *C. hortensis* in North America (Cockerell, 1890, 1899; iNaturalist, 2023; Johnson, 1906).

The records of the phenotype 10305 in Ternopil and Horodok are not related to each other. Near the garden centre in Horodok, an atypical (dark) lip colour was recorded in all pink and some yellow banded shells of *C. hortensis*, including both specimens with the phenotype Y10305 found by us. The dark lip is a rare hereditary trait locally found in the natural range of *C. hortensis* (Schider & Schilder, 1957; Ożgo, 2010) and occasionally observed in introduced populations of the species (Egorov, 2018; Gural-Sverlova & Gural, 2021 a). In Ukraine, shells of *C. hortensis* with a dark lip are known so far only from Lviv Region (table 3). At present, carriers of this trait are spreading in Lviv and its immediate environs from two garden centres at once: "Club of Plants" in Pidbirtsi (Gural-Sverlova & Gural, 2022 a, b) and "ElitFlora" in Horodok (new data).

Unlike *C. hortensis*, the set of main colouration variants in introduced populations of *C. nemoralis* (table 4) is quite similar not only in different administrative regions in the west of Ukraine or in different parts of Ukraine, but also when comparing different Eastern European countries (Egorov, 2018; Gural-Sverlova & Egorov, 2021; Gural-Sverlova & Gural, 2021 b; Gural-Sverlova & Kruglova, 2022; Gural-Sverlova et al., 2021a, etc.). Regional differences may rather be expressed in the ratio of different phenotypes or phenotype groups (Gural-Sverlova & Gural, 2021 b; Gural-Sverlova & Kruglova, 2022), and for five-banded shells, also in the relative frequencies of fusion of different band pairs as well as in an increased proportion of some rare phenotypes with fused bands (Gural-Sverlova & Kruglova, 2022: table 7; Gural-Sverlova et al., 2020: table 3).

Despite the fact that we have so far been able to collect and analyse only two samples of *C. nemoralis* from Ternopil, almost all the main shell colouration variants recorded in introduced Eastern European populations of the species (Gural-Sverlova et al., 2021a: table 1) are already known for this city. The only exceptions are brown banded shells (table 4), which are extremely rare in the compared countries (Gural-Sverlova & Egorov, 2021; Gural-Sverlova & Kruglova, 2022).

Table 4. Composition of the samples and correlation of yellow ground colour and band presence in Eastern European populations of the introduced species *C. nemoralis*

Settlements	N	Percentages										Y0/b	Correlation	
		Y-0	Y-1	Y-3	Y-5	P-0	P-1	P-3	P-5	B-0	B-1		D	r
Ukraine, Ternopil Region, new data														
Ternopil (No. 1)	322	24.5	4.3	0.6	0.3	26.4	32.3	6.8	4.7	–	–	4.65	-0.09	-0.41**
Ukraine, Ternopil Region (Gural-Sverlova & Gural, 2021 b; Gural-Sverlova & Lyzhechka, 2021)														
Chortkiv	224	1.3	2.7	15.2	12.5	0.9	2.2	34.4	30.8	–	–	0.04	-0.01	-0.09
Ukraine, Ivano-Frankivsk Region (Gural-Sverlova & Gural, 2021 b; Gural-Sverlova et al., 2020)														
Bohorodchany	95	–	–	–	30.5	69.5	–	–	–	–	–	0	0.21	1.00**
–"–	359	–	0.8	–	16.2	27.0	1.4	–	54.6	–	–	0	0.05	0.28**
Ukraine, Lviv Region (Gural-Sverlova & Kruglova, 2022)														
Lviv	1167	0.3	24.2	5.7	–	50.6	15.9	3.3	–	–	–	0.01	0.15	0.65**
–"–	388	–	1.0	–	4.9	75.8	4.9	–	13.4	–	–	0	0.04	0.44**
–"–	95	1.0	29.5	–	17.9	38.9	5.3	–	7.4	–	–	0.02	0.18	0.75**
–"–	82	34.1	–	24.4	28.0	1.2	–	3.7	8.5	–	–	0.65	-0.04	-0.22*
–"–	51	–	2.0	13.7	23.5	37.2	2.0	7.8	13.7	–	–	0	0.15	0.62**
–"–	62	22.6	8.1	1.6	25.8	3.2	3.2	1.6	–	33.9	–	0.64	0.12	0.50**
–"–	103	–	3.9	12.6	23.3	32.0	4.8	6.8	13.6	2.9	–	0	0.14	0.60**
–"–	65	–	–	–	15.4	73.8	–	–	10.8	–	–	0	0.11	0.72**
–"–	60	21.7	11.7	6.7	10.0	10.0	15.0	11.7	13.3	–	–	0.76	-0.06	-0.25
–"–	732	0.7	16.4	3.1	39.7	10.0	9.0	3.7	17.3	–	–	0.01	0.06	0.38**
–"–	107	–	58.9	4.7	–	–	16.8	7.5	–	12.1	–	0	0.08	0.49**
–"–	92	–	4.3	–	45.6	16.3	6.5	–	27.2	–	–	0	0.08	0.44**
–"–	53	–	–	1.9	5.7	32.1	–	17.0	43.4	–	–	0	0.02	0.20
Zubra	53	43.4	17.0	–	34.0	1.9	–	–	3.8	–	–	0.85	-0.01	-0.06
Ukraine, Lviv Region, unpublished data, 2023														
Horodok	85	16.5	8.2	3.5	23.5	17.6	9.4	–	8.2	12.9	–	0.47	0.08	0.32**
Belarus, Minsk Region (Gural-Sverlova & Kruglova, 2022)														
Minsk	1264	–	23.5	0.2	5.0	0.2	65.3	0.1	5.5	0.2	–	0	0.001	0.04
–"–	66	3.0	90.9	–	1.5	–	3.0	–	1.5	–	–	0.03	-0.001	-0.04
–"–	76	1.3	67.1	1.3	1.3	–	18.4	–	1.3	9.2	–	0.02	0.06	0.44**
–"–	73	1.4	47.9	–	45.2	–	5.5	–	–	–	–	0.01	-0.001	-0.03
–"–	267	2.2	24.7	1.5	3.0	0.7	58.4	8.2	1.1	–	–	0.08	-0.01	-0.16**
–"–	124	0.8	35.5	4.0	–	–	54.0	4.8	0.8	–	–	0.02	-0.005	-0.11
–"–	219	22.4	15.1	–	48.9	3.6	0.9	–	3.6	5.5	–	0.35	0.05	0.30**
–"–	739	24.5	4.7	1.2	27.2	6.2	4.9	0.5	15.4	15.3	–	0.74	0.02	0.08*
–"–	331	24.2	47.1	1.8	11.5	2.7	11.8	0.3	0.3	0.3	–	0.40	-0.01	-0.07
–"–	73	38.4	2.7	2.7	2.7	27.4	9.6	1.4	9.6	5.5	–	4.67	-0.05	-0.23*
–"–	167	18.6	41.3	1.8	32.3	0.6	3.6	0.6	0.6	0.6	–	0.25	<0.001	0.002
–"–	50	12.0	12.0	–	10.0	2.0	28.0	–	12.0	24.0	–	0.55	0.01	0.04
–"–	99	12.1	6.1	9.1	8.1	12.1	11.1	25.2	16.2	–	–	0.52	-0.04	-0.17
–"–	81	22.2	2.5	9.9	7.4	11.1	8.6	17.3	12.3	8.6	–	1.13	-0.05	-0.19
Belarus, Mahiloŭ Region (Ostrovsky & Prokofieva, 2017)														
Babrujsk	280	–	5.0	2.1	10.0	30.4	28.2	4.6	14.3	5.4	–	0	0.06	0.34**
Russia, Moscow Region (Gural-Sverlova & Gural, 2021b)														
Moscow	447	0.2	21.0	–	21.5	14.8	19.5	0.2	22.8	–	–	0.01	0.06	0.35**
–"–	51	21.6	2.0	–	2.0	27.4	2.0	–	19.6	25.5	–	5.50	-0.03	-0.14
Dmitrov	160	–	1.9	–	–	16.2	71.2	–	10.6	–	–	0	0.003	0.06
Dolgoprudnyi	246	1.2	4.1	2.4	40.6	8.5	6.5	7.3	29.3	–	–	0.03	0.03	0.24**
Malakhovka	66	–	3.0	–	4.5	–	21.2	–	37.9	33.3	–	0	0.03	0.20
Mytishchi	228	–	16.2	3.5	17.1	41.2	9.2	0.9	11.4	0.4	–	0	0.15	0.65**
Nakhabino	568	–	1.2	17.4	25.3	56.0	–	–	–	–	–	0	0.25	1.00**
–"–	112	–	7.1	1.8	16.1	25.0	3.6	8.0	8.0	30.4	–	0	0.14	0.64**
Zagoryansky	152	0.7	0.7	–	0.7	2.0	14.5	–	23.0	57.9	0.7	0.50	0.01	0.08

D — coeffcient of linkage disequilibrium, N — sample size, r — correlation coefficient, Y0/b — ratio of unbanded to banded among yellows. Asterisks indicate r values significant at p = 0.01 (**) or 0.05 (*). For other designations, see Material and methods. Samples of less than 50 specimens or with a complete absence of unbanded shells were not taken into account.

The only specific colouration trait of *C. nemoralis* for the Ternopil Region is the uneven pigmentation of bands recorded in Chortkiv (Gural-Sverlova et al., 2021 a: fig. 5; Gural-Sverlova & Lyzhechka, 2021) and mentioned in the Introduction. However, this feature has not yet been found in Ternopil itself. The origin of the Chortkiv population is also not known. This would probably help clarify a malacological study of local garden centres or their immediate surroundings, as for *C. hortensis* in Lviv (Gural-Sverlova et al., 2022 a, b).

The only large sample of *C. nemoralis* that we collected so far in Ternopil shows a significant negative correlation between the yellow shell ground colour and the band presence (table 4). Most of the studied introduced Eastern European populations of this species are characterised rather by a opposite trend (table 4), often expressed in a greatly increased proportion of pink unbanded shells, and in some cases even in the complete absence of pink banded and yellow unbanded ones (Gural-Sverlova & Egorov, 2021; Gural-Sverlova et al., 2020, 2021 b). Even in samples with an increased proportion of yellow unbanded shells, their number is usually inferior to that of yellow banded ones (compare Y0/b values in table 4).

As is known, the shell ground colour and the band presence in *Cepaea* are inherited linked (Murray, 1975; Richards et al., 2013). When crossing, recombinations are rare or, according to Gonzalez et al. (2019) do not occur at all. The latter is indirectly confirmed by our long-term observations of Western Ukrainian populations of *C. hortensis* formed by the descendants of the primary introduction, see above. These populations have no yellow banded shells at all, despite a large number of yellow unbanded ones, and in some cases also no white unbanded shells, despite the presence of white banded and yellow unbanded ones (Gural-Sverlova & Gural, 2022 a).

In Poland, a shift in linkage disequilibrium between shell colour and band presence in *C. nemoralis* was found from "pink unbanded/yellow banded" in the north to "yellow unbanded/pink banded" in the south. The latter was described as "unusual". It has been suggested that this is due to the different origins of the Polish populations (Ożgo et al., 2019). An unusual ratio of phenotypes in a single site may be due to random causes, primarily the founder effect. Therefore, in the future, it is desirable to analyse the correlation between yellow colour and band presence at different sites in Ternopil where *C. nemoralis* is found. This is especially the case for local garden centres, from which *C. nemoralis* may be spread.

Conclusions

Our study has significantly expanded the data on the current distribution, shell colour and banding polymorphism, and introduction history of both *Cepaea* species in the Ternopil Region and in Western Ukraine in general. The analysis of the variability in the shell and body colouration of *C. hortensis* allows us to assume with a high probability that the colonisation of Ternopil by this species began already in the second half of the 20th century.

In addition to areas inhabited exclusively by descendants of the primary introduction of *C. hortensis* into Western Ukraine, there is reliable evidence of subsequent introduction(s) of this species in Ternopil. Among the phenotypic markers of such repeated introduction(s), the most interesting is the phenotype 10305, which occurs locally in the natural range of *C. hortensis* and was not previously known for the introduced Eastern European populations of the species.

In contrast to *C. hortensis*, the samples of *C. nemoralis* collected in Ternopil were represented only by colouration variants found in different Eastern European countries. Of some interest is the statistically significant negative correlation between yellow shell colour and band presence at one site, which is not typical for most Eastern European populations of *C. nemoralis* studied to date.

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