

The efficiency of landscape management on selected thermophilous land snails – a small-scale case report from the vineyard area in northern Vienna

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Keywords: gastropods, landscape management, grassland, *Zebrina detrita*, *Caucasotachea vindobonensis*

Abstract

Direct implications of landscape management measures, such as clearing and grubbing, on snails are only sparsely published. Thus the impact of management on two xerothermophilous terrestrial gastropod species, *Zebrina detrita* and *Caucasotachea vindobonensis*, and on land snails in general, was evaluated in the vineyard area of northern Vienna. This area belongs to the buffer zone of UNESCO Wienerwald Biosphere Reserve in Austria. A total of 18 sites were investigated, including vineyard embankments and dry meadows with different intensity levels of clearing and grubbing in recent years. Occurrence of both target species and their ability to recolonize newly created habitats were assessed. Snails are able to colonize new areas in direct vicinity of existing populations that are above detection level. Only annually repeated clearing of meadows and embankments with originally strong shrub coverage resulted in a visible effect. Continuous clearing efforts over 10 years were associated with a dense population of *Z. detrita* on a formerly unsuited bush-covered meadow. In contrast, vineyard embankments that were cut free just once within two years before the study harboured only a few specimens of *Z. detrita*. Also the former occurrence of empty shells of grassland species should be taken into consideration when planning landscape management, because they can provide information on the potential success of restoring open grassland.

Profile

Protected area

UNESCO Wienerwald

Biosphere Reserve

Mountain range

Alps

Country

Austria

Introduction

Land use abandonment has been identified as one of the main concerns for biodiversity conservation in traditionally used mountain areas, and subsequent land management is needed to either preserve the local natural and cultural heritage or to speed up reforestation (e.g. Körner 2014). Succession on grasslands leads to substantial changes in vegetational and faunal composition (Lett & Knapp 2003, 2005). Xerothermophilous snails, among others, are extirpated after shrub establishment (Cameron & Morgan-Huows 1975; Labaune & Magnin 2002). This causes a loss of biodiversity, as Central European grassland is known to harbour a high number of organisms, especially plants (Ellenberg 1996; van Diggelen et al. 2005; WallisDeVries et al. 2002), invertebrates (Kirby 2001; Van Swaay 2002; Wiesbauer 2008), and smaller vertebrates like reptiles (Cabela et al. 2000; Wiesbauer 2008) and birds (Vickery et al. 2001; Wiesbauer 2008). Therefore these habitats have a high conservation value (Van Swaay 2002; Cremene et al. 2005; Wiesbauer 2008). Where traditional open habitat structures are to be maintained, the removal of intruding shrubs and trees has been established as an important management tool in Central Europe in recent decades, also in Austria (e.g. Holzner & Säger 1997; Wiesbauer 2008; Waitzbauer et al. 2010; Rabitsch 2013). As these activities are connected with some effort in time and money, some evaluation is necessary to prove their efficiency (Bartel



Figure 1 – Mating couple of *Zebrina detrita*. © Michael Duda

2005; Muller et al. 1998). Mobile taxa seem to have an advantage during recolonization after shrub removal (Tocco et al. 2013). For relatively immobile animals, especially, the question arises whether they are able to respond to this sometimes very sudden improvement of their environment (Knop et al. 2013).

The current case deals with selected vineyard embankments and dry meadows in the northeast of Vi-

enna, where clearing and grubbing of intruding trees and shrubs has taken place with different intentions within the last ten years. As the investigated sites are situated within the buffer zone of the Wienerwald Biosphere Reserve on the very north-eastern margins of the Alps, some management activities are obligatory to keep its character as an old traditional vineyard landscape (Drozdowski & Mrkvicka 2014). Xerothermophilous snails are among the typical biota of vineyard landscapes (e.g. Holtermann 1995). The aim of the current study is to evaluate how and if organisms with limited active dispersal are able to recolonize newly cleared areas, using the example of two snail species. The impact of landscape management on land gastropods has already been documented in several studies, most of them with grazing (e.g. Ausden et al. 2005; Boschi & Baur 2007a, b), some with fire management (Brabetz 1978; Bieringer 1999; Nekola 2002), mowing (Martin & Sommer 2004; Pech et al. 2015), habitat restoration (Knop et al. 2011), and also with shrub removal (Boschi & Baur 2008).

The two selected xerophilous land snail species – *Zebrina detrita* (O.F. Müller 1774) and *Caucasotachea vindobonensis* (C. Pfeiffer 1828) – are listed as species of priority in the environmental protection directive (Wiener Naturschutzverordnung) of the Viennese local government. These are also eligible as flagship species, especially for vineyard landscapes (Bernhard et al. 2005).

Zebrina detrita (Figure 1) is a thermophilous steppe species mainly distributed in Southern Europe with some northern expansion into Austria, Slovakia, the Czech Republic, Germany and Switzerland, plus some introduced populations in England (Welter-Schultes 2012). In Austria it inhabits two distinct main areas: the first one is situated in the northeast (Lower Austria, Vienna, northern Burgenland) where it inhabits mainly dry, sunny hillsides and flatlands, preferably on cultivated thermophilous sites covered with patchy vegetation, but also open thermophilous oak and black pine forests (Tröstl 1997, 1998; Eschner et al. 2014) up to an elevation of 500 m. The second area is found in the southwest of Austria (North and East Tyrol), where it occurs up to 1800 m on very dry mountain sides. On the northern margins of its distribution it is considered a rare species (Boschi 2011; Horsák et al. 2013; Wiese 2014). In Vienna it is known from several distinct locations around the north-eastern end of the Alps separated in three areas: one in the northwest (vineyard areas and abandoned quarries in Döbling), one in the northeast (vineyard areas around the Bisamberg hill) and one single locality in the southeast (an abandoned quarry in Rodaun). As many of its habitats, especially in cultural landscapes, are endangered by abandonment of grazing and arable farming and by reforestation, it is considered *vulnerable* (VU) in the Red Data Book of Austria (Reischütz & Reischütz 2007).

Caucasotachea vindobonensis (Figure 2) inhabits a large area in the eastern half of Europe, from Poland in



Figure 2 – Resting specimen of *Caucasotachea vindobonensis*. © Michael Duda

the north, to the Czech Republic and Austria, down to the southern Ukraine, Bulgaria and northern Greece (Welter-Schultes 2012). Introduced populations can be found in European Russia (Egorov 2014). In Austria it is distributed around the Alps (Klemm 1974). It is less frequently found in open dry areas than *Z. detrita* as it can even more often be found in meadows with dense grass layer, ruderal areas (even in the suburbs and close to the centre of Vienna, see, for instance, Fischer 2002, 2011, 2012) and dry forests with open patches (Tröstl 1997, 1998; Eschner et al. 2014). In the Lobau area in Vienna it can even be found in hardwood forests of former floodplains. Similarly to *Z. detrita*, it is considered to be endangered by reforestation and abandoning of land use. Historical reports for Upper Austria document a steady decline (Klemm 1974), while in the Pannonian regions it is still a frequent species (Fischer 2002). Therefore it is listed as *near threatened* (NT) in the Red Data Book of Austria (Reischütz & Reischütz 2007).

Until recently this species was known as *Cepaea vindobonensis* and it is still listed with this name in the environmental protection directive of Vienna. Recent taxonomic reviews (Nordsieck 2014; Neiber et al. 2015; Neiber et al. 2016) have pointed out that the species shares fewer similarities with other representatives of the genus *Cepaea* than it does with representatives of the western Asian genus *Caucasotachea*.

In our study we addressed these aspects: (1) Current situation of the sites: To what extent do date and intensity of landscape management affect habitat structure and the snail fauna? (2) Do both species occur in areas with removed bushes? What are the conditions for such a distribution? (3) Are management activities also successful for other xerothermophilous land snails?

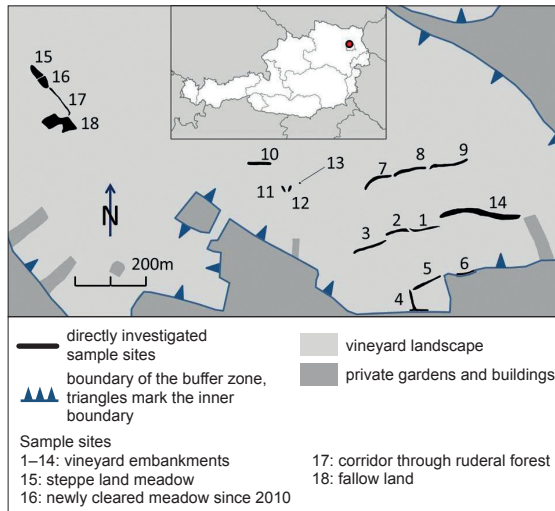


Figure 3 – Investigated area.

Investigated area

The investigated area is situated in the margins of the Vienna Woods in the northwest of Vienna. Geological conditions are characterized by calcareous sand stone and marl belonging to the flysch zone of the Northern Alps (Schnabel 2002). All slopes are exposed to the south. For centuries this area has resembled the traditional vineyard areas of Vienna. Many of the embankments with xerothermophilous life conditions, which used to be cleared regularly, are afflicted by an incursion of shrubs and trees. The area is part of the buffer zone in Wienerwald Biosphere Reserve.

In the south and east it borders on to residential areas with gardens and buildings (Figure 3). The elevation ranges from 240–330 m.

Sampling sites 1–14 consist of several vineyard embankments, which were originally more or less densely covered by shrubs and tall perennial herbs and subjected to clearing measures of different intensity (Table 1, Figure 3). According to information provided by the relevant Viennese municipal authority, MA49, these embankments used to be cleared or mown regularly until the 1980s. In 2012 various management measures were restarted. All embankments border directly on to vineyards. Sampling site 15 is essentially a small fragment of a steep slope, which has been subject to regular removal of bushes in 2002, 2007 and annually since 2012, ideally in autumn and winter. In the year 2010, an adjacent area of about 900 m² that was fully covered by shrubs and therefore not suitable for any kind of xerothermophilous evertbrates was cut free (site 16) and since 2012 has also been subject to landscape management. Sites 15 and 16 are not directly adjacent to vineyards, but separated from them by several metres of ruderal forest. Therefore they are not visible from the adjacent streets and walking paths. Both sampling sites were grazed with sheep in September/October 2012 and September/October 2013. In the southeast a 5 m wide corridor (sampling site 17) was cut free in 2010, which should connect the free-cut area with a fallow one (sampling site 18) situated behind a ruderal forest. The corridor should enable plants and animals to migrate through the forest. The cut material of all management measures is

Table 1 – Methods and intensity of management activities and most important intruding tree, shrub and perennial herb species on the 18 investigated sampling sites. ZdE: empty shells of *Z. detrita* recorded. ZdL: living populations of *Z. detrita* known before the start of the study. CvE: empty shells of *C. vindobonensis* recorded. CvL: living populations of *C. vindobonensis* known before the start of the study

Sample site	Management activities	Intruding trees, shrubs and high perennial herbs	ZdE	ZdL	CvE	CvL
1	Cleared in 2012 & 2013	<i>Clematis vitalba</i> , <i>Urtica dioica</i>	1		1	
2	Cleared in 2012 & 2013	<i>Clematis vitalba</i> , <i>Urtica dioica</i>	1		1	
3	Cleared in 2013	<i>Ailanthus altissima</i> , <i>Clematis vitalba</i> , <i>Urtica dioica</i>	1		1	
4	Cleared in 2012 & 2013	<i>Clematis vitalba</i> , <i>Urtica dioica</i>	1		1	
5	Cleared in 2012 & 2013	<i>Clematis vitalba</i> , <i>Urtica dioica</i>			1	
6	Cleared in 2012 & 2013	<i>Clematis vitalba</i> , <i>Rubus</i> sp., <i>Urtica dioica</i>			1	
7	Cleared in 2012 & 2013	<i>Clematis vitalba</i> , <i>Lycium barbarum</i>				
8	Cleared in 2012 & 2013	<i>Clematis vitalba</i>	1		1	
9	Cleared in 2012 & 2013	<i>Clematis vitalba</i>			1	
10	Cleared in 2012 & 2013	<i>Clematis vitalba</i> , <i>Prunus spinosa</i>				
11	Cleared in 2013	<i>Clematis vitalba</i> , miscellaneous shrubs and trees				
12	Cleared in 2012 & 2013	<i>Clematis vitalba</i> , miscellaneous shrubs and trees				
13	Cleared in 2012	miscellaneous shrubs and trees				
14	None	<i>Clematis vitalba</i>	1	1	1	1
15	Continued cutting of shrubs in 2002, 2007 and continued since 2012	<i>Prunus spinosa</i>	1	1		1
16	Newly created in 2010, since then continued cutting of shrubs, since 2012 continued cutting		1		1	
17	Narrow corridor created in 2010, should connect sampling sites 16 and 18					
18	None: Fallow land since 2010		1		1	

partly removed, partly deposited in ruderal forests downslope, so it will not afflict the habitat by eutrophication. According to the information provided by MA49 (Vienna City Government, municipal department 49, Forestry Office and Urban Agriculture) annual cutting is currently the only feasible method of landscape management. Digging up shrub and tree roots is currently not possible as the sampling sites are too big for manual digging and power shovels cannot reach the area for technical reasons. Moreover, digging would trigger quick erosion because of the steep inclination of the vineyard embankments.

Possible source populations of *Z. detrita* and *C. vindobonensis* were known before the study. The whole area was already investigated for land snails in two unpublished studies (Duda 2002; Duda & Fischer 2007). During these two surveys, living populations of *C. vindobonensis* and *Z. detrita* were only recorded on sampling sites 14 and 15. Adjacent to the north of sampling site 10, a population of *C. vindobonensis* was known in an area which was not part of the current study.

Material and methods

The survey was performed from 2 April to 15 August 2014. Initially we photographed the sites. A follow-up documentation of the vegetation structure was performed during the growth period to illustrate seasonal changes and effects of the management regime.

Both target species are large and have a light-coloured shell that contrasts with the habitat (Figure 1, 2), at least in spring, when sprouting herbs and grass are light green. Hence, detectability during hand search should be high and reliable site occupancy data can be expected, but repetitive sampling was applied to account for detectability biases from withdrawals during phases of inactivity (compare MacKenzie et al. 2005). Empty shells can remain in the litter for decades (e.g. Beinlich & Plachter 1995; Pearce 2008; Řihova et al. 2010). Long-term changes in habitat occupancy, which was used as an indicator of habitat suitability, were thus assessed via the presence or absence of empty shells of the two target species.

Quantitative data of living individuals of the target species were obtained preferably in humid weather by timed sampling. To this end, a visual search was performed for 20 minutes per area. The individuals were separated into adult (with lip) and immature specimens (without lip) and counted to further assess reproductive success. All sites were visited at least once for quantitative purposes. If the search was successful at the first attempt, no additional attempt was made. In sampling sites 1 and 2, a second and a third attempt was made later on, as they still promised suitable conditions for xerothermophilous land snails and, with a potential source population quite near (sampling site 14), it could be not excluded that a recolonization could take place during the vegetation period. The occurrence of other snail species was recorded in the

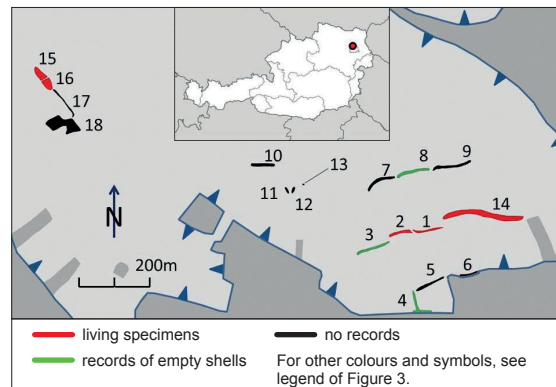


Figure 4 – Occurrence of *Z. detrita* on the sampling sites.

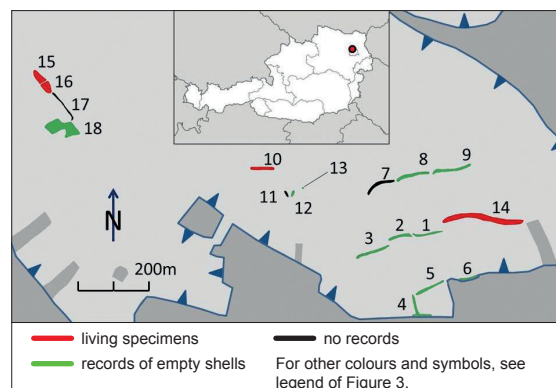


Figure 5 – Occurrence of *C. vindobonensis* on the sampling sites.



Figure 6 – Sample site 5 on 27 April. The patchy vegetation structure apparently provides favourable conditions for thermophilous land snails.



Figure 7 – Sampling site 5 on 20 June. High perennial herbs have overgrown the structures favourable for thermophilous land snails.

Table 2 – Quantitative assessment of *Z. detrita* and *C. vindobonensis*. Absolute numbers and relative abundances during a 20-minute survey. * living specimens only found after a second attempt on a different day. ** living specimens only found after a third attempt on a different day. All other sites just one investigation.

Number of sampling site	1	2	10	14	15	16
<i>Z. detrita</i> juveniles	1/0,33**	3/1,5*		18	194	6
<i>Z. detrita</i> adults		5/2,5*		21	68	3
<i>C. vindobonensis</i> juveniles			1		2	2
<i>C. vindobonensis</i> adults			7	3	7	6

Table 3 – Species list of documented land snails. x: empty shells, l: living specimens. Ecol. group: Ecological main group according to Ložek 1964. 1: pronounced forest dwellers, 2: predominant forest dwellers, 3: forest species requiring high moisture, 4: steppe land species, 5: open land species, 7: euryoecious species. Steppe land and open land species in bold.

		Ecol.	Number of sampling site																	
Genus	Species	Group	1	2	3	4	5	6	7	8	9									
<i>Alinda</i>	<i>biplicata</i>	2		x					x		x									
<i>Arion</i>	<i>vulgaris</i>	*																		
<i>Cepaea</i>	<i>hortensis</i>	2	x	x		x	x		x	x										
<i>Deroceras</i>	<i>reticulatum</i>	7																		
<i>Euomphalia</i>	<i>strigella</i>	5	x	x	l		x	x	l	x	x									
<i>Fruticicola</i>	<i>fruticum</i>	2					x			x	x									
<i>Helicodonta</i>	<i>obvolvata</i>	1		x																
<i>Helix</i>	<i>pomatia</i>	2	x		x		x		x	x	x									
<i>Hygromia</i>	<i>cinctella</i>	*						x												
<i>Monachoides</i>	<i>incarnatus</i>	1		x		x		x												
<i>Oxychilus</i>	<i>cellarius</i>	7	x																	
<i>Oxychilus</i>	<i>draparnaudi</i>	7							x	x										
<i>Zebrina</i>	<i>detrita</i>	4	l	l	x	x				x										
<i>Xerolenta</i>	<i>obvia</i>	4	l	x	l	x		l	l	x										
Number of species			8	9	6	6	5	10	6	8	6									
		Ecol.	Number of sampling site																	
Genus	Species	Group	10	11	12	13	14	15	16	17	18									
<i>Alinda</i>	<i>biplicata</i>	2						x												
<i>Cecilioides</i>	<i>acicula</i>	4					x	x												
<i>Caucasotachea</i>	<i>vindobonensis</i>	4	l		x	x	l	l	l		x									
<i>Cepaea</i>	<i>hortensis</i>	2	x				x													
<i>Euomphalia</i>	<i>strigella</i>	5	x				x	l	l											
<i>Fruticicola</i>	<i>fruticum</i>	2				x														
<i>Helicodonta</i>	<i>obvolvata</i>	1	x																	
<i>Helix</i>	<i>pomatia</i>	2			x		x				x									
<i>Limax</i>	<i>maximus</i>	7																		
<i>Macrogastra</i>	<i>ventricosa</i>	3									x									
<i>Monachoides</i>	<i>incarnatus</i>	1									x									
<i>Oxychilus</i>	<i>cellarius</i>	7			x		x		x	x										
<i>Oxychilus</i>	<i>draparnaudi</i>	7	x																	
<i>Petasina</i>	<i>unidentata</i>	1	x																	
<i>Truncatellina</i>	<i>cylindrica</i>	5					x	x												
<i>Vallonia</i>	<i>costata</i>	5					x	x												
<i>Zebrina</i>	<i>detrita</i>	4					l	l	l											
<i>Xerolenta</i>	<i>obvia</i>	4					x	l	l											
Number of species			8	4	6	6	12	7	6	4	1									

course of quantitative sampling as well as with additional qualitative sampling (sieving, manual examination of the litter layer). As far as possible, documented gastropod species were assigned to ecological groups defined by Ložek 1964. Invasive species not known to Central Europe at the publication time of Ložek in

1964 were classified in a separate *invasive species* category. The sites were assigned to three categories based on the relative ratio of grassland/steppe dwellers to others (>0.75, <0.75–>0.5, <0.5) per sampling site. Results of this assignments and composition of gastropod fauna were used to evaluate the current state of the sampling sites and the efficiency of the landscape management measures.

Results

At the first inspection in early April, all cleared vineyard embankments (sampling sites 1–14) showed an open patchy vegetation structure, which changed to the opposite from the middle of May, where enforced growth of high perennial herbs and new growth of shrubs took place (Figure 6 and 7). After that time, only sampling sites 1, 2, 10 and 14 provided particularly suitable habitats for xerothermophilous snails. A special finding was the occurrence of gutters nearly free of vegetation on the embankments of the eastern investigation area, caused by heavy rainfall from May to June. The vegetation structure on sampling sites 15–18 did not change in such a dramatic way within the next six months (Figure 8 and 9).

Empty shells of *C. vindobonensis* with no living record could be found on sampling sites 1, 2, 3, 4, 5, 6, 8, 9, 12, 13 and 18 (Figure 4). Three of these sites (3, 4, 8) also included empty shells of *Z. detrita* (Figure 5).

Living specimens of *Z. detrita* were recorded on five sites (Table 2, Figure 4). Two of these sites already harboured populations of this species (Duda 2002) before the beginning of any management measures (sampling sites 14 and 15), which indicates that the other three sites must have been newly colonized. Quantitative assessment (Table 2) showed by far the most specimens (262 within 20 minutes) on site 15, followed by sites 14 (39 specimens), 2 and 16 (each 8 specimens) and 1 (1 specimen). In sites 1 and 2 it took two attempts before living specimens could be found, while on all other sites the species could be found at the first inspection (Table 2). Living specimens of *C. vindobonensis* could be found on four sampling sites (Tables 2 and 3, Figure 5). Already known populations are represented by sampling sites 15 and 18, new colonized cleared areas by sites 10 and 15. Most living animals were found on sampling site 15 (9 specimens), followed by sites 10 (8), 16 (7) and 14 (3). At all these sampling sites living specimens were found at the first inspection (Table 2).

In total, 21 species of snail fauna were detected (Table 3). Species richness ranged from 1 to 12 species per site (Table 3). Most species were found in sites 18 (n = 12) and 6 (n = 10). Representatives of the following ecological groups according to Ložek (1964) were found: Group 1 – stenoecious forest dwellers; group 2 – forest-associated species; group 3 – forest species requiring high moisture; group 4 – steppe species; group 5 – open land species; group 7 – euryoecious species (Table 2). Two species (*Arion vulgaris*, *Hygromia*

cinctella, both from site 6) were assigned as *invasive species* not assessed by Ložek (1964), because they have recently spread into Central Europe. In sum, eight of the encountered species are forest dwellers of the first three groups (Table 3), mainly distributed on sampling sites in the east of the investigated area (Figure 10). Typical species for open grasslands or forest steppe were mainly found on sites 1, 3, 4, 14, 15, 16 and 18. Only on the latter three sites did these thermophilous (or xerotolerant) species represent the majority of the recorded species with a relative proportion exceeding 75% (Figure 10). Euryoecious species were occasionally found in sites 1–14 (Table 3).

Discussion

The basic questions addressed in the introduction can now be answered as follows:

Current situation of the sampling sites: Are there differences between the sites in terms of intensity of landscape management?

At the time of the investigation, sampling sites 1–13 already were degenerated ruderal areas rather than steppe areas. Several facts support this statement: The first and most obvious point is the massive regrowth of shrubs and high perennial herbs on most sites of the vineyard embankments, which also display signs of eutrophication. This is proven by the fact that plant and snail societies are closely correlated because of the trophic factors temperature and moisture (Dvořáková & Horsák 2012). This degeneration stems, on the one hand, from the known fact that these sampling sites were not subjected to landscape management from the 1980s to 2012. Empty shells of the two target species found there means that conditions on the slight majority of the sites were in the past more suitable for open grassland dwellers. Empty shell records suggest that a bit more than half of the sites (11 of 18) will have provided suitable conditions for *C. vindobonensis* in the past. On three of these sites (3, 4, 8) empty shells of *Z. detrita* were also documented (Figure 4). Especially for the vineyard embankments, the application of herbicides and fungicides might have afflicted habitats and gastropods, as fungicides in particular have some impact on land gastropods even 20 m away from treated areas (Druart et al. 2011). Another impact, whose influence cannot be exactly quantified, is atmospheric nitrogen deposition, which is known to be high in those parts of the Vienna Woods, which are adjacent to densely populated parts of Vienna (Zechmeister et al. 2014) and might also contribute to the eutrophication of vineyard embankments.

Concerning the two target species, the abundances of *Z. detrita* show a maximum on sampling site 15 with an extremely high rate of juveniles. This can be ascribed to more than ten years of management efforts and the relatively undisturbed steppe land vegetation on this site. The lower abundances and numbers of



Figure 8 – Sample site 15 on 2 April.



Figure 9 – Sample site 15 on 7 May.

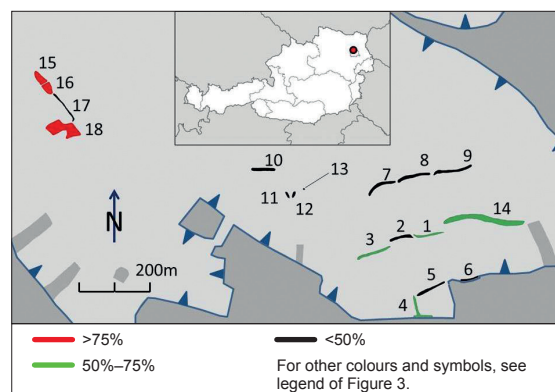


Figure 10 – Proportion of open grassland/steppe species to species with other ecological niches in the assemblages of the sampling sites.

juveniles on the vineyard embankments seem to conform to the fact that these sites in their current stage are more ruderal habitats and therefore not all that suitable for *Z. detrita* as a specialized steppe land species. Moreover, juveniles of *Z. detrita* show their highest abundances by far in late spring/early summer during heavy rainfalls (Kunz & Kobelt-Lamparski 2002), which underlines the explanatory power of the previous interpretation. In *C. vindobonensis* the abundances of living specimens and juveniles seem to be quite balanced (cf. Table 2). The absolute numbers of the species reflect the broader ecological niche of

C. vindobonensis as a species of the forest steppe, which enables it to also inhabit ruderal biotopes within the city of Vienna (see e.g. Fischer 2002, 2011, 2013). The lower number of recorded juveniles might be ascribed to the more difficult detection because of the more hidden lifestyle of juvenile *C. vindobonensis*. Alternatively, it could be caused by the fact that this species reproduces several cohorts of offspring during the vegetation period (Staikou 1998). Concerning the reconstruction of past habitat character, the documentation of empty shells without any record of living animals indicates that the potential habitat suitable for these species must have been much greater in the past. Previously *Z. detrita* occurred on three additional sites and *C. vindobonensis* on 11 of 18 sampling sites (see Table 3, Figure 4 and 5).

In terms of the ecological niche of the recorded species, according to Ložek 1964 a high percentage of woodland species would be indicated. Only sampling sites 15, 16 and 18 present a majority of >75% of open grassland dwellers (Figure 10). On fallow land on sampling site 18, this assessment must be revised as only empty shells of *C. vindobonensis* were found there. This site represents an extreme of a habitat originally not suitable for bigger land snails, as it was for a long time subjected to intensive soil cultivation. Sampling sites 1, 2, 3 and 14 show at least 50–75% of open grassland dwellers, indicating an influx of woodland species. The higher numbers of species in parts also point to beginning forest regrowth on these vineyard embankments as they are caused by the co-existence of a few open land species and intruding forest species. Sampling site 15 with highly specialized steppe land snail fauna returned a comparatively lower number (7 species) than sampling sites 6 (10 species) and 14 (12 species). Similar results for steppe land areas in Europe have already been obtained by previous studies (Cameron & Morgan-Huws 1975; Labaune & Magnin 2002). The occurrence of the non-native *Arion vulgaris* and *Hygromia cinctella* in site 6 can be explained by the adjacent suburban gardens that offers ample opportunities for introductions from human activities.

Do both species occur in areas with removed bushes? What are the conditions for such a distribution?

The results show that both *Z. detrita* and *C. vindobonensis* are generally able to recolonize newly established habitats created by landscape management. Nevertheless there are remarkable differences concerning the degree of management and the location of already existing populations. Obviously the best condition for recolonization is provided if the newly established habitats are directly bordering on already existing populations. In the current study this is evidenced at site 16, where the area cleared in 2010 was recolonized by both species from already existing directly adjacent populations, and at sampling site 10, where *C. vindobonensis* intruded directly from the adjacent embankment

into the new area cleared in 2012/2013. In *Z. detrita* a big quantitative difference (compare Table 1 and 2) between the already existing population on sampling site 15 and the newly colonized one on sampling site 16 indicate that this species has restricted dispersal ability and needs more time to establish a new population. This argument is in line with a 3-year study by Page et al. 2000, where, in a recapture experiment, only 8% of marked individuals of *Z. detrita* had moved more than 20 m. An additional explanation could be that the newly created open area on sampling site 16 needs more time to provide the perfect conditions for the species, as after 3 years the vegetation structure and composition has not yet reached the same state as decades or centuries old steppe meadows.

The quantitative results of *Z. detrita* for sampling sites 1, 2 and 14 point in the same direction. Perhaps the individuals on sampling site 1 and 2 were passively transported by heavy rainfall during May and June, as can be assumed by the finding of an obviously new small population on sampling site 2, situated directly on a gutter. Even so, the active distribution of land snails is also favoured by rainfall (Aubry et al. 2006). Direct immigration from low-density populations in adjacent vineyards (as recorded by Holtermann 1996) is unlikely, as the vineyards themselves are subject to intensive tillage and fertilizing.

As discussed in the previous paragraph, the newly established populations of *C. vindobonensis* on sampling sites 10 and 16 did not differ greatly in numbers from already existing populations located on sampling sites 14 and 15 (Table 2). This might again be explained by the fact that *C. vindobonensis*, as a species of the forest steppe, can occur in a broader range of different habitats and therefore can also get along with a quite newly established habitat. More generalist land snail species often have a more active dispersal ability than stenoecious ones (Dahirel et al. 2014). For the rest of the investigated sampling sites which harbour neither *Z. detrita* nor *C. vindobonensis*, it can be assumed that they are currently out of reach for both species as they are too far away of existing populations.

Are management activities successful for other xerothermophilous land snails as well?

In general, the management activities for land snails can be deemed partly successful, as at least newly created areas near to already existing populations were recolonized. Nevertheless, some facts have to be considered:

The current study underpins the result of Knop et al. 2013 that the existence of an adjacent population is crucial for the colonization of a newly created or restored habitat. The current data suggest that, for the two target species, source populations should be directly adjacent to facilitate (re-)colonization within 1–3 years. At sampling sites 15 and 16 the two grazing sessions in 2012 and 2013 might also have triggered the recolonization of *Z. detrita* and *C. vindobonensis*, as

snails might be translocated by grazing animals (Beinlich & Plachter 1995).

Clearing and grubbing must be repeated over several years to be successful, as documented for sampling site 15. For reasons of time and cost efficiency, management activities should first be focused on those areas where both target species were found in the current study, i. e. sites 14 and 15 as already known core sites and sites 2, 3, 10 and 16 as newly recolonized areas. Special attention needs to be paid to timely response to habitat changes in site 14, where both species are evident but no landscape management has been established yet. It can be assumed that sites 1 and 2 will also be suitable for bigger populations of *Z. detrita* and *C. vindobonensis*, provided that the habitats are cleared from ongoing succession. Therefore landscape management should also be carried out in these areas, especially intensified removal of intruding shrubs. The same applies to sampling site 10, where *C. vindobonensis* has colonized cleared areas. In the longer term, if the populations mentioned above are stabilized, more intense clearance of other embankments could be considered. This also goes for sampling sites 3, 4, 5, 6, 8 and 9, where empty shells of both target species were found. As these shells indicate a former occurrence of the two grassland species and a possibly drier and more open landscape in the past, the survival of newly established populations of *Z. detrita* and *C. vindobonensis* on these sites, combined with the restoration of the formerly open landscape, are therefore very likely. If the active or passive colonization does not work all that fast, the relocation of some specimens from already existing populations could be considered.

The corridor (sampling site 17) obviously does not fulfil its function as connection between the two open land areas of sampling site 15 / 16 and 18. Nevertheless it must be said that this conclusion only applies to xerothermophilous land snails and cannot be applied to more quickly dispersing animals like butterflies or reptiles.

Results and conclusions of this specific study can also be applied more generally. The fact that colonization of newly created habitats by snails succeeds more easily if a viable population is directly connected also applies to other gastropod species and habitats. If a directly adjacent population is not available, the relocation of target species might also be considered. The example of a relocated population of *Helicopsis striata* by Reischütz 1979 in eastern Austria shows that such relocation might be successful if the new location meets the habitat needs of the relocated species. For the selection of areas to be cleared, the potential occurrence of empty shells of grassland species should be taken into consideration. Empty shells give a good overview of former ecological conditions of areas and the potential success of landscape management. Too intensive measures, however, should be avoided. Both too intensive mowing and grazing negatively affect diversity and quantity of land snail fauna (Ausden

et al. 2005; Boschi & Baur 2007a, b; Pech et al. 2015). Nevertheless some landscape management must be provided in man-made steppe land to preserve the open character of the habitat. Therefore a constant but thoughtful replacement of shrubs and perennial herbs, preferably in autumn and winter, when land gastropods are in hibernation, gives good results for land snail fauna, as can be seen on sampling site 15.

Acknowledgements

The project was funded by the state of Austria, the city of Vienna and the European Union with funds of the European Agricultural Fund for Rural Development (EAFRD). Alexander Mrkvicka (MA 49, Vienna City Government, municipal department 49, Forestry Office and Urban Agriculture) provided essential information about past management measures. Three anonymous reviewers made valuable suggestions to improve the quality of this report. Especially the intense recommendations of the third reviewer led to a significant amendment of the manuscript.

References

- Ausden, M., M. Hall, P. Pearson & T. Strudwick 2005. The effects of cattle grazing on tall herb fen vegetation and molluscs. *Biological Conservation* 122: 317–326.
- Aubry, S., C. Labaune, F. Magnin, P. Roche & L. Kiss 2006. Active and passive dispersal of an invading land snail in Mediterranean France. *Journal of Animal Ecology* 75: 802–813.
- Bartel, A. 2005. *Ökologische Infratrakturen – Veränderung landschaftlicher Ausstattung in Acker- Wein- und Obstbaulandschaften. Beitrag zur ÖPUL-Evaluierung Midterm 2005. Studie im Auftrag des Bundesministeriums für land- und Forstwirtschaft, Umwelt und Wasserwirtschaft.* Wien. [In German]
- Beinlich, B. & H. Plachter (eds.) 1995. Schutz und Entwicklung der Kalkmagerrasen der Schwäbischen Alb. *Beibefte zu den Veröffentlichungen für Naturschutz und Landschaftspflege in Baden-Württemberg* 83: 1–520. [In German]
- Bernhardt K.-G., K. Handke, M. Koch, D. Laubhann, H.-M. Berg, M. Duda, H. Höttinger, R. Klepsch, M. Pintar & H. Schedl 2005. Zielartenkonzept in einem niederösterreichischen Weinbaugebiet: Pflege und Erhalt von Weinbergböschungen. *Naturschutz und Landschaftsplanung* 37: 202–211. [In German]
- Bieringer, G. & N. Sauberer 2001. Feuer – Entwertung oder Erneuerung der Großmittler Trockenrasen? *Stapfia* 0077: 243–250. [In German]
- Boschi, C. 2011. *Die Schneckenfauna der Schweiz.* Bern/Stuttgart/Wien. [In German]
- Boschi, C. & B. Baur 2007a. Effects of management intensity on land snails in Swiss nutrient-poor pastures. *Agriculture, Ecosystems and Environment* 120: 243–249.

- Boschi, C. & B. Baur. 2007b. The effect of horse, cattle and sheep grazing on the diversity and abundance of land snails in nutrient-poor calcareous grasslands. *Basic and Applied Ecology* 8: 55–65.
- Boschi, C. & B. Baur. 2008. Past pasture management affects the land snail diversity in nutrient-poor calcareous grasslands, *Basic and Applied Ecology* 9: 752–761.
- Brabetz, R. 1978. Auswirkungen des kontrollierten Brennens auf Spinnen und Schnecken einer Brachfläche bei Rothenbuch im Hochspessart. Ein Beitrag zur Kenntnis der Spinnenfauna des Rhein-Main-Gebietes. *Courier Forschungsinstitut Senckenberg* 29: 1–124. [In German]
- Cabela, A., H. Grillitsch & F. Tiedemann 2001. *Atlas zur Verbreitung und Ökologie der Amphibien und Reptilien in Österreich: Auswertung der Herpetofaunistischen Datenbank der Herpetologischen Sammlung des Naturhistorischen Museums in Wien*. Wien. [In German]
- Cameron, R.A.D. & D.L. Morgan-Huws 1975. Snail faunas in the early stages of a chalk grassland succession. *Biological Journal of the Linnean Society* 7: 215–229.
- Cremene, C., G. Groza, L. Rakosy, A.A. Schileiko, A. Baur, P. Stoll & A. Erhardt 2005. Alterations of steppe-like grasslands in eastern Europe: A threat to regional biodiversity hotspots. *Conservation Biology* 19: 1606–1618.
- Dahirel, M., E. Olivier, A. Guiller, M.-C. Martin, L. Madec & A. Ansar 2014. Movement propensity and ability correlate with ecological specialization in European land snails: comparative analysis of a dispersal syndrome. *Journal of Animal Ecology* 84: 228–238.
- Drozdowski, I. & A. Mrkvička 2014. Der Wienerwald ist UNESCO-Biosphärenpark. *Wissenschaftliche Mitteilungen aus dem Niederösterreichischen Landesmuseum* 25: 9–40. [In German]
- Druart, C., M. Millet, R. Scheifler, O. Delhomme, C. Raeppl & A. Vaufleury 2011. Snails as indicators of pesticide drift, deposit, transfer and effects in the vineyard. *Science of the total environment* 409(20): 4280–4288.
- Duda, M. 2002. *Grundlagenarbeiten zum Artenschutzprogramm Schnecken. Bericht über Nachkartierung und Schutzmaßnahmen-Zebraschnecke (Zebrina detrita) (O.F. MÜLLER 1774) und Wiener Schnirkelschnecke (Cepaea vindobonensis) (FERRUSAC 1821)*. Unveröffentlichte Studie im Auftrag des Magistrats Wien, Abt. 22 Umweltschutz. Wien. [In German]
- Duda, M. & W. Fischer 2007. *Erhebung und Einschätzung des Erhaltungszustandes der in Wien vorkommenden streng geschützten Schnecken-Arten sowie von Musculium lacustre und Sphaerium rivicola*. Unveröffentlichte Studie im Auftrag des Magistrats Wien, Abt. 22 Umweltschutz. Wien. [In German]
- Dvořáková, J. & M. Horsák 2012. Variation of snail assemblages in hay meadows: disentangling predictive power of abiotic environment and vegetation. *Malacologia* 55(1): 151–162.
- Egorov, R. 2014. The first record of *Cepaea vindobonensis* (Pfeiffer, 1828) (Stylommatophora: Helicidae) in the central part of European Russia. *Malacologica Bohemoslovaca* 13: 110–113.
- Ellenberg, H. 1996. *Vegetation Mitteleuropas mit den Alpen in ökologischer, dynamischer und historischer Sicht*. Stuttgart. [In German]
- Eschner, A., K. Jaksch & M. Duda 2014. Biodiversitätsmonitoring und Vergleich der Gastropodengesellschaften auf ausgewählten Flächen des Biosphärenparks Wienerwald. *Wissenschaftliche Mitteilungen aus dem Niederösterreichischen Landesmuseum* 25: 433–452. [In German]
- Fischer, W. 2002. Beiträge zur Kenntnis der Molluskenfauna Österreichs VI. Bemerkungen zu *Cernuela neglecta* (Draparnaud 1805) und *Cepaea vindobonensis* (Ferussac 1821) im südwestlichen Marchfeld (NÖ) sowie in Donaustadt (Wien). *Nachrichtenblatt der Ersten Vorarlberger Malakologischen Gesellschaft* 10: 23–25. [In German]
- Fischer, W. 2011. Beiträge zur Kenntnis der österreichischen Molluskenfauna XXIII. Zwei unterschiedliche Biotope in Wien – Donaustadt als Lebensraum für die streng geschützte *Cepaea vindobonensis* (C. Pfeiffer 1828). *Nachrichtenblatt der Ersten Vorarlberger Malakologischen Gesellschaft* 18: 47–49. [In German]
- Fischer, W. 2013. Beiträge zur Kenntnis der österreichischen Molluskenfauna XXXI. Die Molluskenfauna des St. Marxer Friedhofes in Wien. *Nachrichtenblatt der Ersten Vorarlberger Malakologischen Gesellschaft* 20: 57–59. [In German]
- Holtermann, D. 1995. Die Gehäuseschneckenfauna (Gastropoda) der Technozoenose Weinberg und deren Beziehung zu angrenzenden naturnahen Biotopen im Raum Würzburg. *Abhandlungen des Naturwissenschaftlichen Vereins Würzburg* 35-36: 3–243. [In German]
- Holzner, W. & K. Sänger 1997. *Steppe am Stadtrand. Ein kundiger Begleiter durch das Naturreservat Perchtoldsdorfer Heide*. Graz. [In Czech and English]
- Horsák, M., L. Juříčková & J. Pícka 2013. *Měkkýši České a Slovenské republiky. Molluscs of the Czech and Slovak Republics*. Zlín. [In Czech and English]
- Kirby, P. 2001. *Habitat Management for Invertebrates: a Practical Handbook*. Sandy
- Klemm, W. 1974. Die Verbreitung der rezenten Landgehäuseschnecken in Österreich. *Denkschriften der Österreichischen Akademie der Wissenschaften (mathematisch-naturwissenschaftliche Klasse)* 117: 1–503. [In German]
- Knop, E., F. Herzog & B. Schmid 2011. Effect of Connectivity Between Restoration Meadows on Invertebrates with Contrasting Dispersal Abilities. *Restoration Ecology* 19: 151–159.
- Körner, C. 2014. Mountain ecosystems in a changing environment. *eco.mont* 6(1): 71–77.
- Kunz, F. & A. Kobel-Lamparski 2002. Phenology and population structure of the land pulmonate snail *Zebrina detrita* (Gastropoda: Stylommatophora: Enidae). *Malakologische Abhandlungen* 20(2): 253–262.

- Labaune, C. & F. Magnin 2002. Pastoral management vs. land abandonment in Mediterranean uplands: impact on land snail communities. *Global Ecology & Biogeography* 11: 237–245.
- Lett, M.S. & A.K. Knapp 2003. Consequences of shrub expansion in mesic grassland: Resource alterations and graminoid responses. *Journal of Vegetation Science* 14: 487–496.
- Lett, M.S. & A.K. Knapp 2005. Woody plant encroachment and removal in mesic grassland: production and composition responses of herbaceous vegetation. *American Midland Naturalist* 153(2): 217–231.
- Ložek, V. 1964. Quartärmollusken der Tschechoslowakei. *Rozprawy ústředního ústavu geologického* 31: 1–375. [In German]
- MacKenzie, D., J. Nichols, J. Royle, K. Pollock, L. Bailey & J. Hines 2005. *Occupancy Estimation and Modeling, Inferring Patterns and Dynamics of Species Occurrence*. London/Oxford/Boston/New York/San Diego.
- Muller, S., T. Dutoit, D. Allard & F. Grevilliot 1998. Restoration and rehabilitation of species-rich grassland ecosystems in France: a review. *Restoration Ecology* 6: 94–101.
- Martin, K. & M. Sommer 2004. Effects of soil properties and land management on the structure of grassland snail assemblages in SW Germany. *Pedobiologia* 4: 193–203.
- Nordsieck, H. 2014. Zur Systematik der Gattung *Cepaea* Held 1838 (Gastropoda, Stylommatophora, Helicidae). *Mitteilungen der deutschen malakozoologischen Gesellschaft* 91: 43–52. [In German]
- Neiber, M.T. & B. Hausdorf 2015. Molecular phylogeny reveals the polyphyly of the snail genus *Cepaea* (Gastropoda: Helicidae). *Molecular Phylogenetics and Evolution* 93: 143–149.
- Neiber, M.T., C. Sargony & B. Hausdorf 2016. Increasing the number of molecular markers resolves the phylogenetic relationship of '*Cepaea*' *vindobonensis* (Pfeiffer 1828) with *Caucasotachea* Boettger 1909 (Gastropoda: Pulmonata: Helicidae). *Journal of Zoological Systematics and Evolutionary research* 54(1): 40–45.
- Nekola, J.C. 2002. Effects of fire management on the richness and abundance of central North American grassland snail faunas. *Animal Biodiversity and Conservation* 25(2): 53–66.
- Page, H., L. Rupp, U. Schraml, S. Wießner & J.G. Goldammer 2000. Feuerökologie und Feuer-Management auf ausgewählten Rebböschungen des Kaiserstuhls. Available at: http://www.lel-bw.de/pb/_Lde/644579 (accessed: 06/08/2015) [In German]
- Pech, P., J. Dolanský, R. Hrdlička & J. Lepš 2015. Differential response of communities of plants, snails, ants and spiders to long-term mowing in a small-scale experiment. *Community Ecology* 16(1): 11–124
- Pearce, T.A. 2008. When a snail dies in the forest, how long will the shell persist? *American Malacological Bulletin* 26: 111–117.
- Rabitsch, W. 2013. Die Wanzenfauna (Heteroptera) der Sandberge bei Oberweiden im Marchfeld (Niederösterreich). *Beiträge zur Entomofaunistik* 3: 141–174. [In German]
- Říhová, D., Z. Janovský & L. Juříčková 2010. Land snail shell degradation in temperate forest. *Tropical Natural History, Supplement* 3: 265.
- Reischütz, P.L. 1979. Bericht über einen Umsiedlungsversuch von *Helicopsis striata* (O.F. Müller). *Mitteilungen der zoologischen Gesellschaft Braunau* 3: 233–235. [In German]
- Reischütz, A. & P.L. Reischütz 2007. Rote Liste der Weichtiere (Mollusca) Österreichs. In: K.P. Zulka (ed.), *Rote Liste gefährdeter Tiere Österreichs Teil 2: Kriechtiere, Lurche, Fische, Nachtfalter, Weichtiere*: 363–433. [In German]
- Schnabel, W. 2002. *Geologische Karte von Niederösterreich 1:200 000. Legende und kurze Erläuterung*. Wien. [In German]
- Staikou, A. 1998. Aspects of life cycle, population dynamics and secondary production of the pulmonate snail *Cepaea vindobonensis* (Ferrusac, 1821) in Northern Greece. *Journal of Molluscan Studies* 64: 207–308.
- Tocco, C., M. Probo, M. Lonati, G. Lombardi, M. Negro, B. Nervo, A. Rolando & C. Palestrini 2013. Pastoral practices to reverse shrub encroachment of sub-alpine Grasslands: Dung Beetles (Coleoptera, Scarabaeoidea) respond more quickly than vegetation. *PLoS ONE* 8(12): e83344.
- Tröstl, R. 1997. Faunistisch-ökologische Betrachtungen der Schneckengemeinschaften des Wienerwaldes 1. Gipfel-Eschenwald (*Aceri-Carpinetum* subass. *agopodietosum* KLIKA 1941 em. HUSOVÁ 1982) des Hermannskogels und Linden-Kalkschutthalden-Wald (*Aceri carpinetum* KLIKA 1941 s. I.) des Leopoldsberges. *Verhandlungen der Zoologisch-Botanischen Gesellschaft Österreichs* 134: 71–91. [In German]
- Tröstl, R. 1998. Faunistisch-ökologische Betrachtungen der Schneckengemeinschaften des Wienerwaldes 6. Grenzwaldkomplex des Kalenderberges (Mödlinger Klause). *Verhandlungen der Zoologisch-Botanischen Gesellschaft Österreichs* 135: 259–270. [In German]
- Van Diggelen, R., F.J. Sijtsma, D. Strijker & J. van den Burg 2005. Relating land-use intensity and biodiversity at the regional scale. *Basic and Applied Ecology* 6: 145–159.
- Van Swaay, C.A.M. 2002 The importance of calcareous grasslands for butterflies in Europe. *Biological Conservation* 104: 315–318.
- Vickery, J.A., J.R. Tallowin, R.E. Feber, E.J. Asteraki, P.W. Atkinson, R.J. Fuller & V.K. Brown 2001. The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources. *Journal of Applied Ecology* 38: 647–664.
- Waitzbauer, W., T. Englisch & M. Lampropoulos 2010. Die Laufkäferfauna (Carabidae) des Symposions Lindabrunn (NÖ). *Verhandlungen der Zoologisch-Botanischen Gesellschaft Österreichs* 147: 69–82. [In German]
- WallisDeVries, M.F., P. Poschlod & J.H. Willems 2002. Challenges for the conservation of calcareous grasslands in Northwestern Europe: integrating the

requirements of flora and fauna. *Biological Conservation* 104: 265–273.

Wiesbauer, H. (ed.) 2008. *Die Steppe lebt. Felssteppen und Trockenrasen in Niederösterreich*. St. Pölten. [In German]

Wiese, V. 2014. *Die Landschnecken Deutschlands*. Wiebelsheim. [In German]

Welter-Schultes, F. 2012. *European non-marine molluscs, a guide for species identification*. Göttingen.

Zechmeister, H.G., R. Türk & M. Kropik 2014. Atmosphärische Stickstoffdeposition im Gebiet des Biosphärenparks Wienerwald. *Wissenschaftliche Mitteilungen aus dem Niederösterreichischen Landesmuseum* 25: 237–248. [In German]

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