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An „underrated“ Habitats Directive species: Population status of *Stenobothrus eurasius* Zubovski, 1898 in the Hainburg Hills, Lower Austria (Orthoptera: Acrididae: Gomphocerinae)

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Abstract

Stenobothrus eurasius is one of four Austrian Orthoptera species listed in the annexes of the Habitats Directive (Annexes II and IV). Nationwide it is found exclusively in the Hainburg Hills at Braunsberg and Schlossberg in Lower Austria, where past estimates of the population ranged between 50–100 and 100–500 individuals. From 2021–2024, a single census of individuals in each subarea at the end of June or beginning of July were conducted, so that by 2024 the entire population had been surveyed once. Approximately 1,500 individuals were counted in an area of 4.9 hectares with a sex ratio of 2:1 skewed towards males. Since not all individuals could be recorded, especially due to the difficult terrain, an extrapolation was made, resulting in an estimated total population size of 3,000–4,500 individuals. Contrary to previous views, the highest densities were found on the open lower slopes of the southwestern slope of Braunsberg and in an extensive forest clearing to the east (together accounting for 87 % of the total counted population). This can be explained by the species' need of grass tussocks for oviposition and thin-leaved grasses as diet, which is why the species is rare at the bare rocky areas below the plateau edge at Braunsberg. The habitats are characterized by rocky dry grasslands, gravel grasslands, and sparse dry grasslands with no significant proportion of exposed rock. Although not definitively proven by numbers, the database of ARGE Heuschrecken Österreichs suggests that the population size has likely increased in recent decades. Currently, there is no immediate threat to the total population. However, especially at Schlossberg, grazing is strongly recommended as a management measure as some areas are affected by sward densification.

Keywords: conservation, habitats, individual count, population size, population structure, xerothermophilic species

Zusammenfassung

Stenobothrus eurasius ist eine von vier österreichischen Heuschreckenarten, die in der FFH-Richtlinie geführt werden (Anhänge II und IV). Bundesweit kommt er nur in den Hainburger Bergen am Braunsberg und am Schlossberg in Niederösterreich vor, wo seine Populationsgröße in der Vergangenheit auf insgesamt 50–100 bzw. 100–500 Individuen geschätzt wurde. Zwischen 2021 und 2024 führte der Autor jeweils Ende Juni/Anfang Juli eine einmalige Individuenzählung in den verschiedenen Teilgebieten durch, sodass 2024 das gesamte Vorkommen einmal erhoben war. Dabei zählte er auf 4,9 Hektar Fläche etwa 1.500 Exemplare, das Geschlechterverhältnis betrug 2:1 zugunsten der Männchen. Da vor allem aufgrund des schwierigen Terrains nicht alle Tiere erfasst werden konnten, erfolgte eine Hochrechnung, die eine Zahl von geschätzten 3.000–4.500 Individuen in der Gesamtpopulation ergab. Die größten Dichten wurden – im Gegensatz zur bisherigen Ansicht – an den offenen Unterhängen des Braunsberg-Südwesthangs und in einer ausgedehnten Waldschneise östlich davon registriert (zusammen 87 % des gezählten Gesamtbestandes). Erklärt wird dies durch die Notwendigkeit des Vorhandenseins von Grashorsten für die Eiablage und von dünnblättrigen Gräsern für die Nahrungsaufnahme, weshalb die reinen Felsbereiche unterhalb der Plateaukante am Braunsberg kaum von der Art frequentiert werden. Die Lebensräume präsentieren sich als Felstrockenrasen, Grusrasen sowie lückige Trockenrasen ohne nennenswerten Anteil an anstehendem Felsgestein. Wenngleich sie nicht zweifelsfrei mit Zahlen belegt ist, deuten die in der Datenbank der ARGE Heuschrecken Österreichs enthaltenen Beobachtungsdaten auf eine Zunahme der Populationsgröße in den letzten Jahrzehnten hin. Eine unmittelbare Gefährdung der Gesamtpopulation ist daher aktuell nicht zu sehen, jedoch wird speziell für den Schlossberg aufgrund teils stark verbrachender Bereiche Beweidung als Pflegemaßnahme dringend empfohlen.

Schlüsselwörter: Habitate, Individuenzählung, Populationsgröße, Populationsstruktur, Schutz, xerotherme Arten

Introduction

Background

Stenobothrus eurasius Zubovski, 1898 is a faunal element of the Eurosiberian steppe zone (Holuša & Holuša 2002). Its distributional range extends from the Czech Republic and Austria eastward to China and northern Mongolia. At the western edge of its range, populations are strongly fragmented and relictual, so that the species occurs only in scattered, insular populations in the Balkans, Hungary, Slovakia, Austria, the Czech Republic, and southern Poland (Hochkirch et al. 2016, Kenyeres et al. 2020, 2024). The Austrian populations, which are restricted to the

Hainburg Hills in Lower Austria, represent some of the westernmost occurrences within its distribution range.

Stenobothrus eurasius is strongly xerothermophilic (Ingrisch & Köhler 1998) and, according to the literature, inhabits primary rocky dry grasslands with a high proportion of exposed limestone and their marginal zones in the Hainburg Hills (Berg & Zuna-Kratky 1997, Denner et al. 2006, Berg & Illich 2009, Denner 2009, Karner-Ranner & Ranner 2017). This largely corresponds to the typical habitats of the isolated populations in the Pannonian region (Kenyeres et al. 2020). Kenyeres et al. (2020) found that the western marginal populations of *S. eurasius* thrive particularly well in areas with a high content of coarse sand in the soil and where there is little disturbance from game animals, especially wild boar.

Adult individuals can occasionally be observed as early as the end of May (A. Panrok), while sightings in September are rare (Karner-Ranner & Ranner 2017; Fig. 1). *Stenobothrus eurasius* is therefore a phenologically early grasshopper species with a relatively short embryonic development period.

Currently, five subspecies of *S. eurasius* are recognized (Cigliano et al. 2025), although some of them are subject to debate (Harz 1975, Kenyeres et al. 2024): *S. eurasius eurasius* Zubovski, 1898, *S. eurasius bohemicus* Mařan, 1958, *S. eurasius slovacus* Mařan, 1958, *S. eurasius macedonicus* Willemse, 1974, and *S. eurasius moravicus* Chládek, 2018. Berg & Illich (2009), Denner (2009), and Karner-Ranner & Ranner (2017) provided an overview of the prevailing taxonomic views at the time regarding the Austrian populations; however, *S. eurasius moravicus* was not yet considered, as it was described from southern Moravia (Czech Republic) only a year after the latter publication by Chládek (2018). Referring to the literature, Kenyeres et al. (2024) assign the Austrian populations to *S. eurasius bohemicus*, but based on their own findings, they observed insufficient genetic and morphological differences among the western relict populations to justify subspecies status.

Fig. 1: A phenologically rather late female of *Stenobothrus eurasius* at Braunsberg. 29.8.2014. Photo: Günther Wöss.

In Austria, *Stenobothrus eurasius* is one of four grasshopper species protected by the Habitats Directive (Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora; FFH Directive) and is listed in Annexes II and IV. According to Article 17 of the directive, EU member states are required to submit periodic reports on these species. The reports assess and document the species' conservation status based on several parameters. *Stenobothrus eurasius* has so far been included in Austria's national reports for the periods 2007–2012 and 2013–2018. In both cases, its conservation status was classified as "unfavourable–inadequate" (U1) (Umweltbundesamt 2013, 2020). The report for the period 2019–2024 is currently in preparation.

For the 2007–2012 reporting period, the size of the Austrian populations was estimated at a total of 50–100 individuals (nature-art17.eionet.europa.eu). Karner-Ranner & Ranner (2017) considered this figure to be a significant underestimate, citing a record from the Braunsberg, where on 20 June 2010 "more than 20 singing males and several females were observed in a relatively small area" (A. Panrok & Ch. Roesti). For the 2013–2018 reporting period, population size was not expressed in terms of individual numbers but rather based on occupied 1x1 km grid cells. *S. eurasius* was reported from three grid cells (nature-art17.eionet.europa.eu). At that time, experts revised the population estimate to 100–500 individuals (T. Zuna-Kratky, pers. comm.).

Status in Austria

In Austria the species is currently found exclusively in the Hainburg Hills – specifically on the southern and southwestern slopes of Braunsberg and the approximately 1.2 km distant Schlossberg in Hainburg an der Donau (for simplicity, hereafter referred to as the "southwestern slope"). The Braunsberg represents the hotspot for Orthoptera species listed on the Habitats Directive in Austria: With *S. eurasius*, *Isophya costata*, and *Saga pedo*, three of the four grasshopper species listed under the Habitats Directive are found here.

According to Ebner (1951), *S. eurasius* was first discovered on Braunsberg by the Viennese professor Franz Werner (1867–1939). The corresponding specimens were apparently identified by Willy Ramme (1887–1953), orthopterist at the Zoological Museum Berlin. The year of collection is not recorded, but Ramme probably identified the specimens around 1920. Most of the *S. eurasius* records to date have concerned the transitional area from the summit plateau to the rocky slope of the Braunsberg. This locality will hereafter be referred to as "Plateau Edge". Denner et al. (2006) also discovered the species in the two extensive forest clearings east of the rocky slope. In 2014, a further record was made on a small, less rocky dry grassland island below the slope, about 150 m away from the Pla-teau Edge (M. Sehnal). This finding led Karner-Ranner & Ranner (2017) to hypothesize that the species should be found throughout the entire rocky southwestern slope. In 2020, a single male was found on a small rocky dry grassland on the western slope of Braunsberg just above the Danube (C. Schlosser). The small population on Schlossberg was discovered in 1995 by H.-M. Berg and S. Zelz (database of ARGE

Heuschrecken Österreichs). In the State Collections of Lower Austria, there is also an undated specimen of a female with the locality of collection "Bisamberg" (Ebner 1951, Wöss et al. 2026) – the only indication of a former occurrence in Austria outside the Hainburg Hills. A report of an unconfirmed record on Hundsheimer Berg, which is also part of the Hainburg Hills, on 9 September 1995 by a field trip group from the University of Bonn (Goßmann et al. 1995) was considered a likely case of misidentification (Denner 2009, Karner-Ranner & Ranner 2017). However, surprisingly, on 28 June 2021 the author and a field trip group from the University of Vienna discovered a male of *S. eurasius* on the northwestern slope of Hundsheimer Berg (N 48.13654° / E 16.93630°, 411 m a.s.l.; Fig. 2). The location was a woodland-surrounded, west-northwest-exposed semi-dry grassland, which had very little bare soil and was relatively densely vegetated (Fig. 3). Two days later, a targeted search was conducted on the rock ribs directly below the site, but no further specimens were found. It is likely that this was a stray or displaced individual, which is further supported by the fact that all the relict populations examined at the western edge of the species' overall range are found on slopes with southern exposure (e.g., Kenyeres et al. 2020).

Fig. 2: The first recorded specimen (male) of *Stenobothrus eurasius* from Hundsheimer Berg. Morphologically, it can be distinguished from other Austrian species of the genus *Stenobothrus* by the combination of its characteristics, including the darkened antenna tips with a light apex, the extent of the median field, the position of the wing mark (stigma), and the rather slightly angled lateral carinae of the pronotum. Especially the males have a brightly reddish-orange abdomen tip. 28.6.2021. Photo: Günther Wöss.

Fig. 3: Locality of *Stenobothrus eurasius* at Hundsheimer Berg. 30.6.2021. Photo: Günther Wöss.

The aforementioned record on the western slope of Braunsberg above the Danube in 2020, at an elevation of 169 m, represents the lowest known location in Austria to date. The highest known is the locality on Hundsheimer Berg at 411 m from 2021. All other records from Braunsberg and Schlossberg are between 218 m and 342 m above sea level.

Over the past 30 years, regular data input on *S. eurasius* from grasshopper enthusiasts has only been available from the Plateau Edge of Braunsberg, which can be attributed to the easy accessibility of this site. Nearly no data from the areas below the rocky escarpment on the southwestern slope were available in the database of ARGE Heuschrecken Österreichs prior to the current study. Monitoring of the two eastern clearings has been sporadic since their discovery as a location by Denner et al. (2006), and – according to the data – even the small population on Schlossberg has only been visited in the years 2005 and 2014 after its discovery in 1995.

The first information on the frequency of *S. eurasius* on Braunsberg comes from Ebner (1951), who described the species as "rather rare". Denner et al. (2006) classified it as "moderately common" in the raw data for their report within the LIFE project "Pannonian Steppe and Dry Grasslands" (duration 2004–2008) at the Plateau Edge. In the two eastern clearings and on Schlossberg, they classified the species as "rare" (Denner et al. 2006). In other data contained in the database of ARGE Heuschrecken Österreichs, the semi-quantitative classifications generally

range between "rare" and "moderately common". The species was only classified as "common" in six out of 60 reports with frequency information. It should be noted that these classifications are subjective and not based on standardized allocation rules. Individual counts have been conducted only sporadically and over limited areas. The highest recorded number of individuals, as mentioned above, was "more than 20 singing males and some females in a relatively small area" (A. Panrok & Ch. Roesti, Karner-Ranner & Ranner 2017).

The aim of the present study was to conduct a single census of the Austrian populations of *S. eurasius* to obtain more detailed information about the actual population sizes.

Material and Methods

Since *S. eurasius* is restricted to relatively small areas in the Hainburg Hills and is an important conservation target as a Habitats Directive species, the author decided to conduct a single census of the two populations (Braunsberg and Schlossberg) between 2021 and 2024. Each year, different, previously defined subareas were surveyed to ensure that after four years the entire occupied range would be as completely recorded (Fig. 4 and 5). The four-year survey allowed for partial compensation of any natural population fluctuations. Areas that were inaccessible due to their steepness or other obstacles, or did not provide suitable habitats for *S. eurasius*, were left unexamined. The survey dates were chosen to coincide with the early main development period of the species, from late June to early July (Table 1).

All surveys were conducted at air temperatures between 24 °C and 30 °C. Depending on the date, wind conditions ranged from light to strong. Although strong wind is generally unfavourable for any kind of zoological fieldwork, it was tolerated in this case, as calm conditions are rare at Braunsberg. All safely accessible areas were surveyed as comprehensively as possible in a serpentine pattern. Each observation was recorded with pinpoint accuracy using the app iNaturalist. The geolocation data were downloaded from inaturalist.org on the same day as the survey and then removed from the platform, as no photographic records were made. The detailed data of the survey were later reported to the database of ARGE Heuschrecken Österreichs. Counts were carried out separately for males and females; nymphs were not considered. The focus was placed on visual detection. Singing males were usually only recorded when they were located off the survey route, either in inaccessible terrain or in sections with low individual density. Depending on population density, one or several individuals were recorded per geolocation point. In areas of very high density, observations were grouped at serpentine turning points, where the number of individuals counted along the previous travelled stretch since the last turning point was recorded. This method was particularly necessary in the subarea Braunsberg-South. To ensure traceability, the travelled paths were tracked using the app bergfex/Touren PRO (2021–2024).

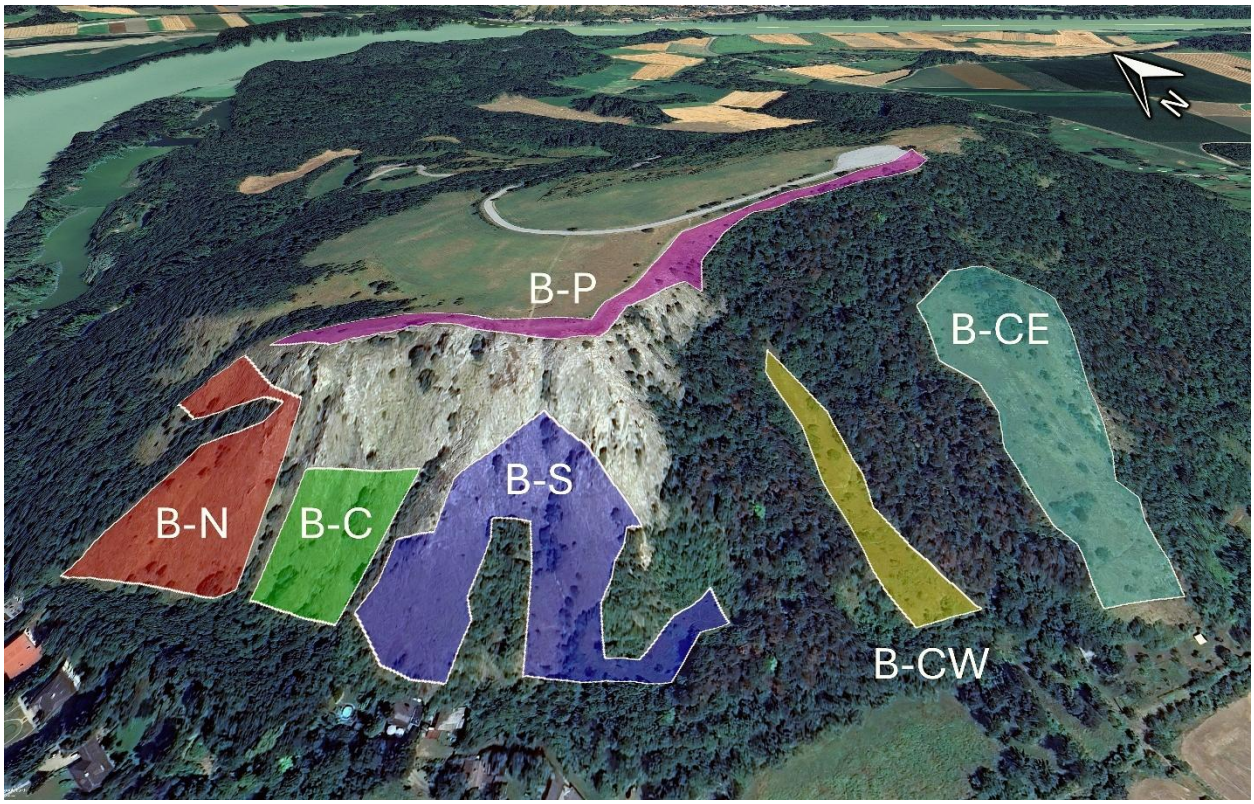

Fig. 4: The subareas surveyed at Braunsberg (roughly outlined). B-N = Braunsberg-North, B-C = Braunsberg-Central, B-S = Braunsberg-South, B-P = Braunsberg-Plateau Edge, B-CW = Braunsberg-Clearing West, B-CE = Braunsberg-Clearing East. Base map: Google Earth.

Fig. 5: The subareas surveyed at Schlossberg (roughly outlined). S = Schlossberg. Base map: Google Earth.

Table 1: Dates, times and target areas of the surveys (see Fig. 4 and 5).

Date	Subarea	Time
27 June 2021	Braunsberg-South	08:15–12:50
27 June 2021	Braunsberg-Plateau Edge	14:30–15:50
28 June 2022	Braunsberg-Clearing East	10:10–14:35
02 July 2022	Braunsberg-Clearing West	12:05–13:25
08 July 2023	Schlossberg	09:20–12:50
23 June 2024	Braunsberg-North	10:35–13:45
24 June 2024	Braunsberg-Central	12:20–13:40

Results

Population status and sex ratios

A total of 1,513 individuals were recorded, with an overall sex ratio of nearly exactly 2:1 (males to females; Table 2). The highest density of individuals was found on the open lower slopes of the Braunsberg southwestern slope and in Clearing East. The total area surveyed covered about 4.9 hectares.

During the field surveys, it became evident that, despite all efforts, not all individuals could be counted for several reasons: (1) Some areas were inaccessible. (2) Even in accessible areas, not all sections could be covered completely due to subjective limitations. (3) Depending on terrain visibility and vegetation density/height, individuals were overlooked. (4) Nymphs were not included in the counts (but they were only relatively numerous during the 2021 survey). These challenges highlight that a realistic estimate of the actual population size can only be achieved by extrapolating from the number of individuals counted. For this purpose, multiplication factors of 2 (minimum) and 3 (maximum) were applied (see discussion, chapter “Population status and sex ratios”). If the total number of recorded individuals (1,513) is rounded to 1,500 and extrapolated using these factors, the estimated total Austrian population size ranges from approximately 3,000 to 4,500 individuals. However, for the subareas “Plateau Edge” and “Schlossberg” a more differentiated approach is required (see chapter “Conditions in the subareas”).

Figures 6–8 show the number of individuals at the geolocation points, categorized by size class, as well as the travelled paths. It is noticeable that some of the points do not align exactly with the path. This is partly due to the tracking app not capturing every small change in direction. This is particularly evident in the upper slope of Clearing West (Fig. 7): As the geolocation points show, the area was walked in a serpentine pattern, but the tracked path is shown as a straight line, which is likely due to fluctuating GPS reception. Furthermore, two different apps were used for the location recording and path tracking, which resulted in slight inconsistencies when compared directly. However, the route tracking served only to make the paths taken traceable, which worked well overall.

Table 2: Results of the individual counts (separated by sex and total) in the subareas and in the entire study area, as well as the sizes of the processed areas and their respective percentage of the total population. Also shown are the extrapolated values (see discussion, chapter “Population status and sex ratios”) as well as the sex ratios (rounded to one decimal place). Regarding the extrapolated values on the Plateau Edge and at Schlossberg, see chapter “Conditions in the subareas”.

	Surveyed area (ha)	Males	Females	Total individuals	% of total population	Ratio m/f
Braunsberg-North	0.72	122	56	178	12 %	2.2/1.0
Braunsberg-Central	0.33	74	28	102	7 %	2.6/1.0
Braunsberg-South	0.83	359	186	545	36 %	1.9/1.0
Braunsberg-Plateau Edge	0.64	81	23	104	7 %	3.5/1.0
Braunsberg-Clearing West	0.33	45	22	67	4 %	2.0/1.0
Braunsberg- Clearing East	1.10	304	178	482	32 %	1.7/1.0
Schlossberg	0.95	20	15	35	2 %	1.3/1.0
TOTAL	**4.90**	**1,005**	**508**	**1,513**	**100 %**	**2.0/1.0**
Minimum estimate (extrapolation factor 2)		2,010	1,016	**3,026**		
Maximum estimate (extrapolation factor 3)		3,015	1,524	**4,539**		

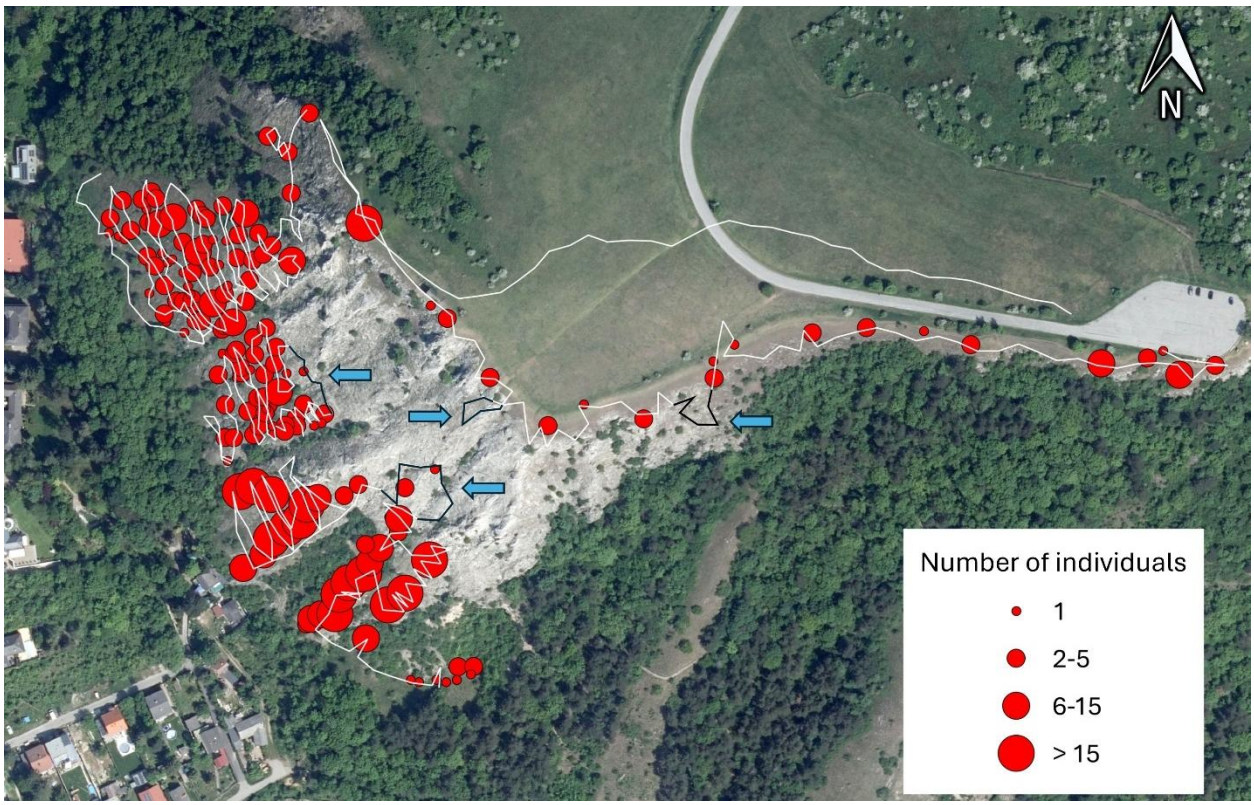

Fig. 6: Locations and recorded size classes of *Stenobothrus eurasius* along the covered routes (white lines) at Braunsberg. The blue arrows and blackened sections mark "excursions" into the steep rock cliff (see text). Base map: basemap.at.

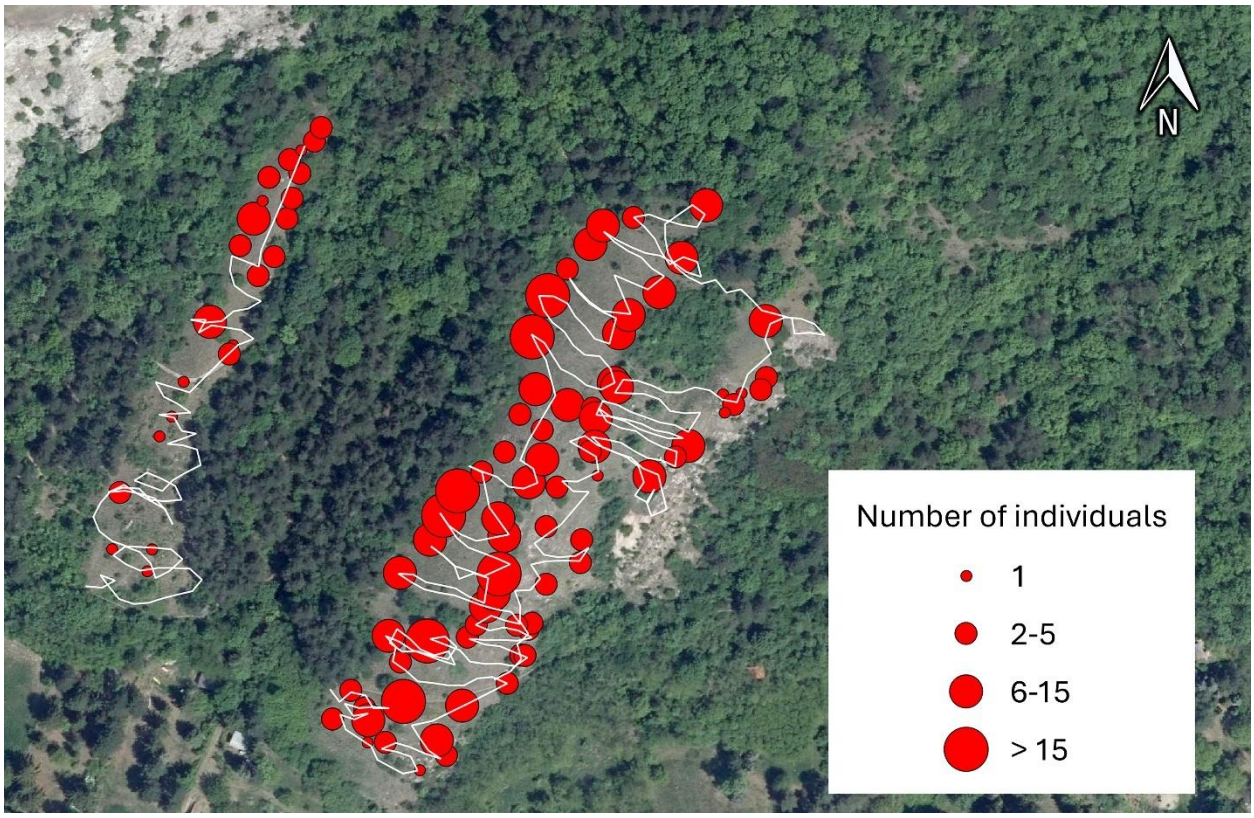

Fig. 7: Locations and recorded size classes of *Stenobothrus eurasius* along the covered routes (white lines) in Clearing West and Clearing East at Braunsberg. Base map: basemap.at.

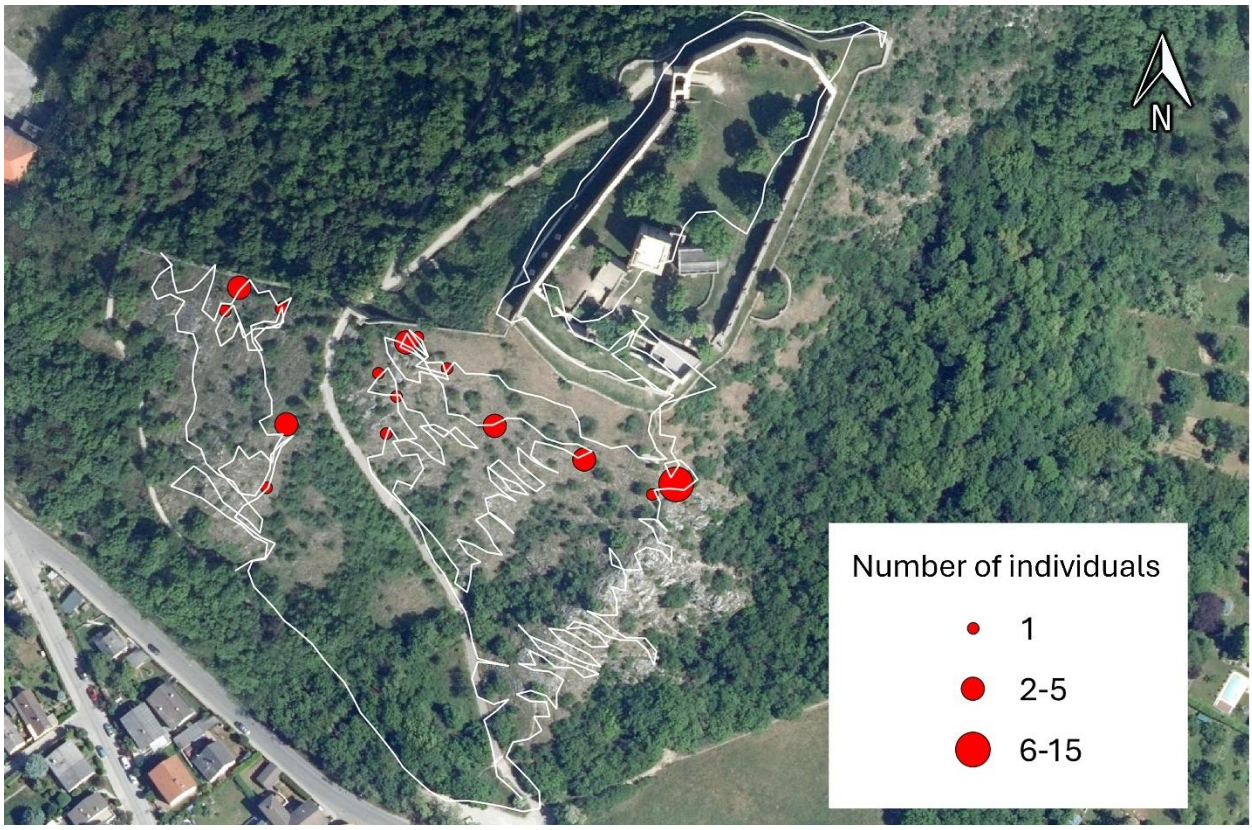

Fig. 8: Locations and recorded size classes of *Stenobothrus eurasius* along the covered route (white line) at Schlossberg. Base map: basemap.at.

Habitats

The highest individual densities were observed in gravel grasslands on the open lower slopes of the southwestern slope of Braunsberg (Fig. 9a); however, the species was also regularly present in open dry grasslands without any significant rocky or sandy component (Fig. 9b). Both habitat types are characterized over large areas by medium-height, loosely structured grass vegetation. Where the terrain permitted, the steep, sparsely vegetated rocky slopes were also checked for the presence of *S. eurasius* at least on a sample basis. In Fig. 6 these surveys are marked by blue arrows and blackened sections of the path. As expected, hardly any individuals were found in these areas (Fig. 9c).

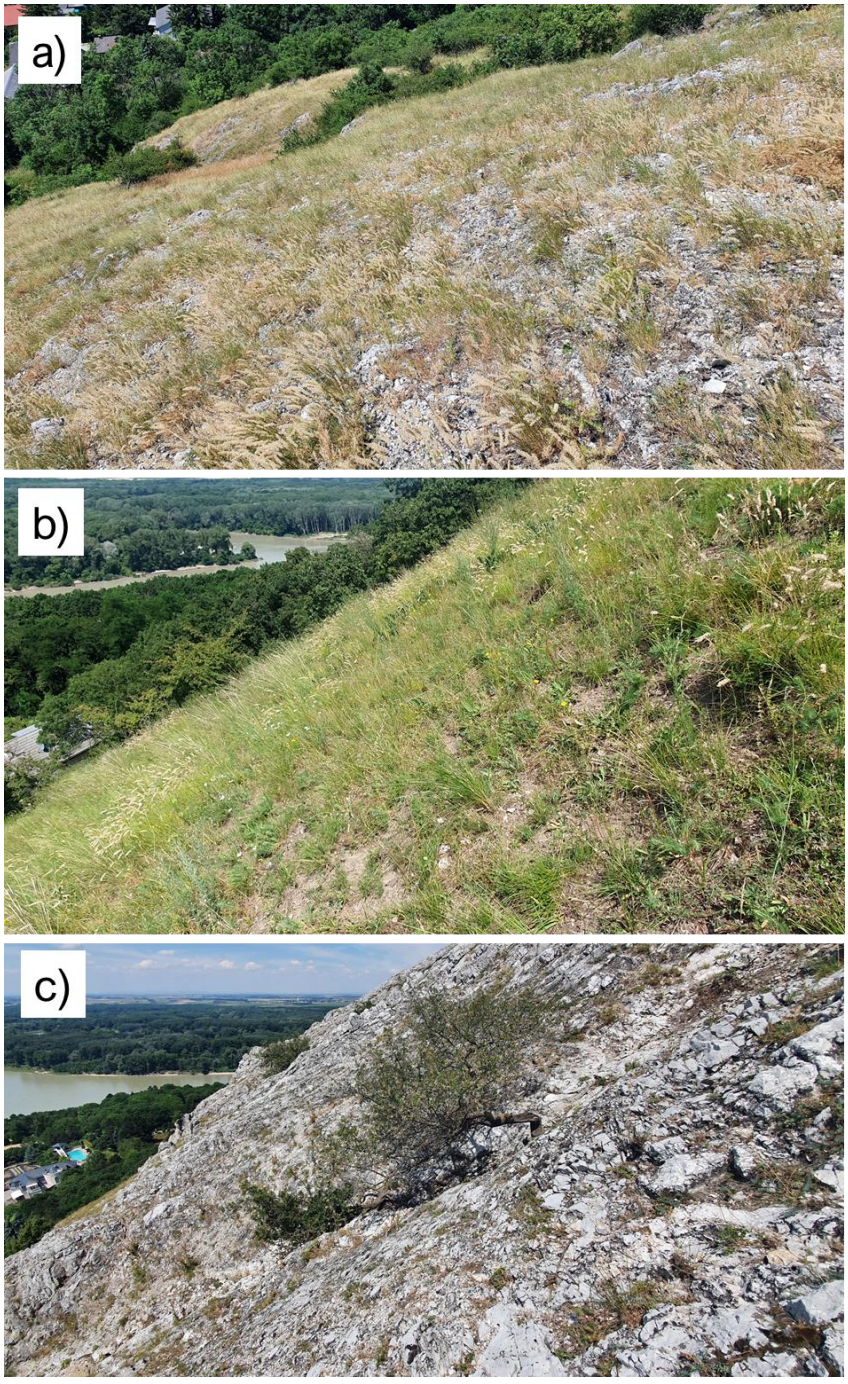

Fig. 9: a) Braunsberg-South. The sparsely grass-covered gravelly lawns on the lower slope are the most frequently used areas by *Stenobothrus eurasius* at Braunsberg (27.6.2021). b) Braunsberg-North. Even patchy dry and semi-dry grasslands without significant rock content are used here by *S. eurasius* (6.7.2024). c) The pure rock steppes below the Plateau Edge are apparently hardly inhabited by *S. eurasius* (27.6.2021). Photos: Günther Wöss.

Conditions in the subareas

Southwestern slope of Braunsberg (Fig. 9)

The highest densities of *S. eurasius* were found in the open dry grasslands with rocky-gravelly or shallow, humus-rich substrates on the lower slopes of the three adjacent subareas Braunsberg-North, Braunsberg-South, and Braunsberg-Central. Together, these areas accounted for more than half (55 %) of the total recorded population – with Braunsberg-South alone comprising over one-third (36 %). Accordingly, the lower slopes of the rocky southwestern flank represent the population's core area. In contrast, the steep rocky escarpment directly below the Plateau Edge appears to be used only minimally by the species.

Braunsberg-Plateau Edge (Fig. 10)

Contrary to earlier assumptions that the Plateau Edge of Braunsberg represented the center of the Austrian populations (e.g., Denner 2009), we now know that it merely hosts a peripheral population (maybe a "sink population", see below) and exhibits a comparatively low individual density. Although previous population size estimates of 50–100 individuals (nature-art17.eionet.europa.eu) or 100–500 individuals (T. Zuna-Kratky, pers. comm.) must now be significantly revised upward, these estimates – referring exclusively to the Plateau Edge, which was previously thought to be the core area of the population – were not far off, as 104 individuals were recorded in this subarea during the survey (7 % of all counted individuals). An extrapolation using factors of 2 and 3 seems excessive here, as the area is relatively compact, easily accessible, and was likely surveyed more completely than other subareas. The population estimate for the Plateau Edge alone is therefore 110–150 individuals.

Fig. 10: Habitat of *Stenobothrus eurasius*, *Oedaleus decorus*, and *Dociostaurus brevicollis* at the Plateau Edge of Braunsberg. The invasive Tree of Heaven (*Ailanthus altissima*) does not even stop at the extremely dry and hot conditions of this site. 27.6.2021. Photo: Günther Wöss.

Braunsberg-Clearing West and Clearing East (Fig. 11)

In Clearing West, large populations of *S. eurasius* were only observed on the upper slope (Fig. 11a). The reason for this is the dense, tall vegetation in the lower slope sections. As Denner et al. (2006) noted, Clearing East is characterized by a very high diversity of habitats – dry and semi-dry grasslands of varying vegetation density, height, and soil depth alternate with rock formations and shrubs (Fig. 11b). *Stenobothrus eurasius* occurs relatively evenly across the entire area of Clearing East, but it prefers the sparse dry and semi-dry grassland areas with exposed rock or other open soil. Together, the two clearings hosted 36 % of the total counted population, with Clearing East standing out with 32 % alone. The habitat restoration measures carried out in the clearings as part of the aforementioned LIFE project (2004–2008) most likely had a positive impact on the population of *S. eurasius*. This is suggested by the frequency comparison: While Denner et al. (2006) previously classified the species here as "rare", high individual numbers were recorded in some areas in 2022. However, it is unclear whether this suspected increase can be attributed solely to these measures. Clearing East and the three subareas on the southwestern slope of Braunsberg together accounted for 87 % of all counted individuals.

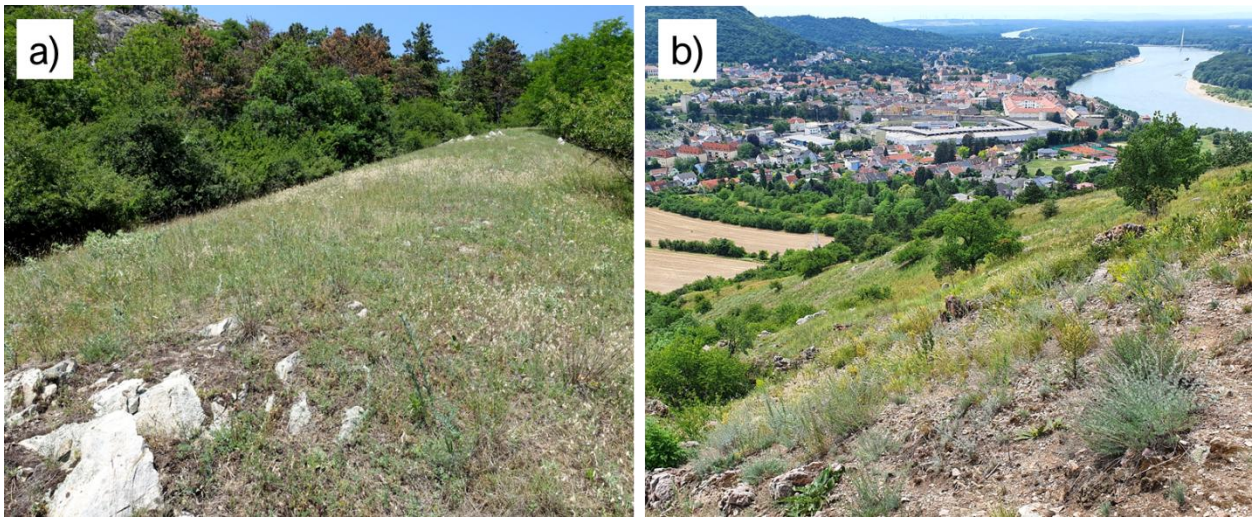

Fig. 11: a) In Clearing West, *Stenobothrus eurasius* occurs mainly in the upper slope areas with low-growing, sparse vegetation (15.6.2025). b) In the diverse Clearing East, *S. eurasius* is widely distributed but, as usual, prefers open dry and semi-dry grasslands with exposed rock and other open soil (28.6.2022). Photos: Günther Wöss.

Schlossberg (Fig. 12)

The population size at Schlossberg was very low, with only 35 individuals, accounting for just about 2 % of all counted individuals. Most of the individuals were recorded directly below the castle portal (Fig. 12a; see Denner et al. 2006). Otherwise, there were only scattered small groups on the southwestern slope of Schlossberg. Similar to the case of the Plateau Edge at Braunsberg, an extrapolation using the factors of 2 (minimum) and 3 (maximum) at Schlossberg tends to be too high. However, this is not justified here by a better visibility of the terrain, but by a smaller

proportion of suitable habitat compared to the southwestern slope of Braunsberg. The number of individuals at Schlossberg is therefore estimated to be 50–70. Of the two Austrian populations of *S. eurasius*, the one at Schlossberg is the most endangered. As shown in Fig. 12b, the areas directly below the castle wall have largely overgrown and are affected by sward densification, so moderate grazing of this area is strongly recommended in order to open it up and make the slope more widely usable for *S. eurasius* and other similarly specialized animal and plant species.

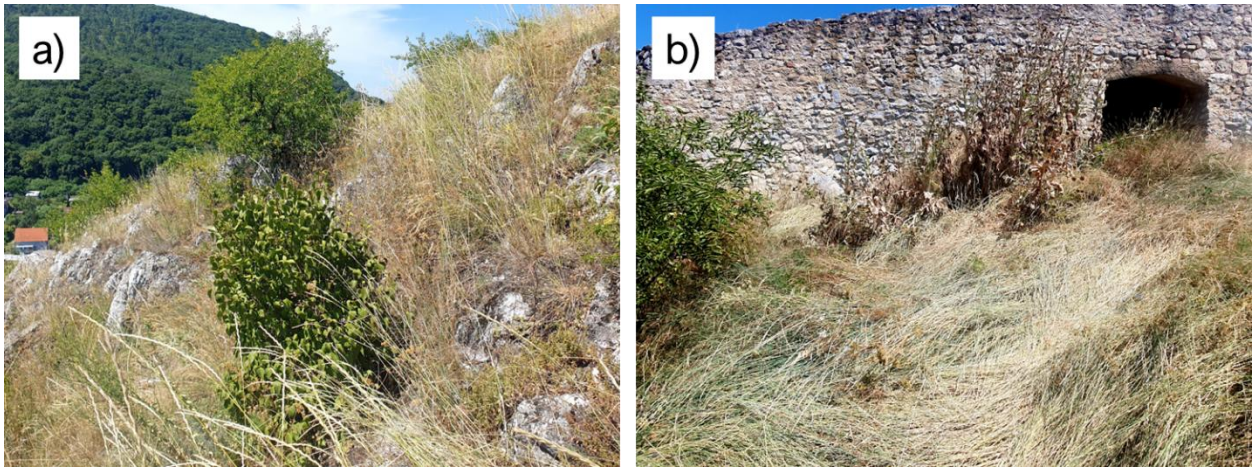

Fig. 12: a) Of all the sites, *Stenobothrus eurasius* is the rarest at Schlossberg, where it is restricted to only a few rocky areas (8.7.2023). b) Grazing is urgently needed at Schlossberg (8.7.2023)! Photos: Günther Wöss.

Accompanying species

Table 3 provides a complete list of grasshopper and mantid species that, besides *S. eurasius*, are currently recorded on the surveyed subareas (database of ARGE Heuschrecken Österreichs). This also includes sympatric species that do not share the exact same habitat as *S. eurasius* but are at least marginally present within the respective areas (e.g., *Pholidoptera griseoaptera* and *Ephippiger ephippiger*). The three sections of the southwestern slope of Braunsberg are combined into one subarea. It should be noted that records from the Plateau Edge are disproportionately represented in the data due to the method of data collection in the past decades (see chapter “Status in Austria”), and only those findings were included in Table 3 that could be reasonably assigned to one of the subareas. This was complicated by the fact that during many field surveys on Braunsberg, often only a single GPS point was recorded, making it difficult to reconstruct the exact location of the actual findings. As a result, some species may have been found just outside the narrow subarea “Plateau Edge” but were still assigned to it in the table.

Accompanying species of *S. eurasius* that have been mentioned in the literature for western relict populations include: *Platycleis grisea*, *Bicolorana bicolor*, *Pholidoptera fallax*, *Ephippiger ephippiger*, *Tetrix bipunctata* or *kraussi*, *Pseudopodisma nagyi* (not present in Austria), *Calliptamus italicus*, *Oedipoda caerulescens*, *Omocestus haemorrhoidalis*, *Stenobothrus lineatus*, *S. nigromaculatus*,

S. crassipes, *Chorthippus apricarius*, *Euchorthippus declivus*, and *E. pulvinatus* (the latter one is now extinct in Austria) (Holuša & Holuša 2002, Kenyeres et al. 2020).

Table 3: Overview of reported sympatric accompanying species (Orthoptera and Mantodea) of *Stenobothrus eurasius* on the examined subareas. Consider the disproportionately high data from the Plateau Edge due to the method of data collection in the past decades (see chapter "Status in Austria"). Species in bold share the immediate habitat with *Stenobothrus eurasius* – in varying density and association intensity. Source of data: ARGE Heuschrecken Österreichs.

	Braunsberg- Southwestern Slope	**Braunsberg-** Plateau Edge	**Braunsberg-** Clearing West	**Braunsberg-** Clearing East	**Schlossberg**
Phaneroptera nana	X	X	X		X
Leptophyes punctatissima		X	X		X
Leptophyes albovittata	X	X	X	X	X
Barbitistes serricauda					X
Isophya costata		X			
Ruspolia nitidula			X		
Tettigonia viridissima	X	X		X	
Decticus verrucivorus	X	X			
Platycleis grisea	X	X	X	X	X
Platycleis affinis		X			
Tessellana veyseli		X	X		X
Bicolorana bicolor	X	X	X	X	X
Pholidoptera griseoaptera		X	X		
Ephippiger ephippiger		X			
Saga pedo	X	X		X	X
Oecanthus pellucens		X	X		
Gryllus campestris		X			
Calliptamus italicus	X	X	X	X	X
Oedaleus decorus		X			
Oedipoda caerulescens	X	X	X	X	X
Euthystira brachyptera	X	X	X		
Dociostaurus brevicollis		X			
Stenobothrus lineatus	X	X	X	X	
Stenobothrus nigromaculatus	X	X			
Chorthippus apricarius		X			
Chorthippus mollis		X			
Chorthippus brunneus	X	X	X	X	X
Chorthippus biguttulus	X	X	X	X	X
Pseudochorthippus parallelus	X	X	X	X	X
Euchorthippus declivus	X	X	X	X	
Mantis religiosa	X		X	X	
Total number of species	**17**	**28**	**18**	**13**	**13**

Discussion

Population status and sex ratios

Due to limited time resources and the difficult accessibility of the terrain, no repeated counts per area or capture–recapture surveys were conducted, although these would have been necessary for a robust population size estimate. The factors 2 and 3 are based solely on the author's subjective assessment during the field surveys. They concern the estimation of the percentage of overlooked individuals of *S. eurasius* depending on the difficult accessibility and observability of the terrain, as well as the sometimes very high numbers of other Orthoptera species present in the areas (which complicates counting). From the author's perspective, these two extrapolation factors provide a realistic population estimate; however, they are not based on any statistically valid foundation. Nevertheless, the estimated numbers are presented for informational purposes in the results table (Table 2), alongside the directly counted individuals.

In many cases, there is a male-biased sex ratio at the beginning of the season in Caelifera. For species of the genus *Stenobothrus*, this has been observed, for example, in *Stenobothrus stigmaticus* and *Stenobothrus nigromaculatus*, as well as in *Myrmeleotettix maculatus* (Behrens & Fartmann 2004, Klatt 2006). In contrast, however, for *Stenobothrus stigmaticus*, it has also been documented that throughout the season, there can be more females present (Landeck et al. 1999). For *S. eurasius*, the present counts showed an overall sex ratio of 2:1 in favour of males. It is likely that this ratio shifts toward more females as the season progresses.

A striking feature at the Plateau Edge is the increased sex ratio of 3.5:1.0 in favour of males (Table 2). This suggests that the Plateau Edge may function as a "sink habitat", into which the more mobile males increasingly immigrate over the course of the season from the densely populated core areas ("source habitat") located further down on the southwestern slope (e.g., see Pulliam 1988, Pulliam & Danielson 1991). Supporting this assumption is an observation made during an early-season survey on 15 June 2025, during which only three males (and no females) were found at the Plateau Edge. But for now, this hypothesis remains speculation.

Habitats

In Austrian literature, the habitat of *S. eurasius* on the southwestern slope of the Braunsberg is described as follows: steep rocky dry grasslands, rocky steppes, primary calcareous dry grasslands, rocky grasslands with large areas of exposed limestone, and "extreme sites that only allow the presence of woody plants in more sheltered spots" (Berg & Zuna-Kratky 1997, Denner et al. 2006, Berg & Illich 2009, Denner 2009, Karner-Ranner & Ranner 2017). Denner et al. (2006) described the area referred to as Clearing West as a "very shallow rocky ridge with many exposed rocks", and attributed the high species richness of grasshoppers recorded in Clearing East to a variety of different habitats, "which, due to their gradual transitions, could hardly be separated from one another." Karner-Ranner & Ranner (2017) summarized the situation in both clearings as "somewhat deeper soils and less

rocky" compared to the southwestern slope. According to Denner et al. (2006), the site at Schlossberg features a "small-scale mosaic of exposed rock interspersed with dry grassland, as found across the entire southern and southwestern flanks of the Schlossberg." Karner-Ranner & Ranner (2017) concur, and, as on the Braunsberg, describe it as "rocky grassland with large areas of exposed limestone."

In this study, the species was also frequently recorded in gravel grasslands and sparse dry grasslands lacking significant sandy or rocky bare ground, often characterized by medium-height, loosely structured grass vegetation. Thus, neither the presence of rock itself nor low vegetation height is decisive, but rather a high proportion of shallow, open soil. This, in combination with strong solar radiation, favourable exposure, and the geographical location of Braunsberg, provides suitable microclimatic conditions for the species. The species was only rarely recorded on predominantly rocky substrates.

For xerothermophilic species, protecting the eggs from desiccation is important (Refsnider & Janzen 2010). Females of *S. eurasius* typically deposit their egg pods in grass tussocks (Knapp & Dvořák 2023), a behavior also characteristic of closely related species such as *S. lineatus* and *S. nigromaculatus* (Harz 1975, Köhler 2009, Knapp & Dvořák 2023). Therefore, a certain proportion of well-developed grass vegetation that provides protection against desiccation is essential for oviposition. In contrast to the pure rocky steppes directly below the Plateau Edge, such vegetation is present on the lower slopes of Braunsberg and in Clearing East – where the highest individual densities of *S. eurasius* were recorded. Since almost no individuals were found on the steep, sparsely vegetated rocky escarpment, it is assumed that the species uses these areas either not at all or only sporadically along the margins. In terms of thermoregulation, more structurally and vegetatively diverse habitats with a high proportion of sun-exposed open soil provide greater flexibility than largely uniform rocky surfaces with limited shelter. Furthermore, current findings suggest that the species primarily feeds on fine-leaved grasses, which should be sufficiently available in its habitat (see Kenyeres et al. 2020).

A habitat degradation along the footpath bordering the Plateau Edge, as feared by Denner et al. (2006), cannot be confirmed, since the reported frequencies in the database of ARGE Heuschrecken Österreichs have generally increased over the years rather than decreased. The widespread impact on vegetation in this area caused by a herd of feral sheep appears to favour the habitat requirements of *S. eurasius*. This is supported by the recent establishment of *Oedaleus decorus* and *Dociostaurus brevicollis* along the Plateau Edge – two further highly xerothermophilic grasshopper species also reaching their western range limits here (see Paces et al. 2025).

Population and habitat development

The observational data from recent decades suggest an increase in the number of individuals of *S. eurasius* and possibly even a range expansion at Braunsberg (database of ARGE Heuschrecken Österreichs; T. Zuna-Kratky, pers. comm.). This

assumption may be supported by the fact that drier and warmer summers, which have become more frequent due to climate change, generally have a positive effect on the populations of many xerothermophilic grasshopper species (e.g., Ingrisch & Köhler 1998). However, this presumed positive population trend of *S. eurasius* at Braunsberg is not confirmed by robust numerical data but is based solely on subjective semi-quantitative frequency assessments reported to the database of ARGE Heuschrecken Österreichs by occasional observers. The fact that Ebner (1951) classified the species as "rather rare" on the southwestern slope of Braunsberg about 75 years ago is merely an indication of a possible increase. One voucher specimen collected by him is held in the Zoological Collection of the Department of Evolutionary Biology at the University of Vienna (Bieringer & Rotter 2001), and another in the State Collections of Lower Austria in St. Pölten (Wöss et al. 2026). Ebner collected both specimens on 18 August 1949 – at a point in time when the emergence period of this phenologically early species was already well advanced, and the number of individuals had presumably already declined. In general, the numerous records in the database of ARGE Heuschrecken Österreichs are too sporadic to allow for conclusions regarding the population development of *S. eurasius*. The present study may now provide the basis for a more precise future evaluation of population trends.

Another question concerns the potential impact of the feral flock of currently 30–40 sheep on the population of *S. eurasius* at the southwestern slope and the Plateau Edge of Braunsberg. A study that examines the spatial use of the area by sheep in relation to the habitat use by *S. eurasius* and tracks both over a longer period would be highly interesting but is hardly feasible due to the difficult terrain and the considerable effort required. It is suspected that sheep grazing may benefit the species by keeping open the areas utilized by *S. eurasius*. However, we currently know far too little about the actual grazing grounds, grazing intensity, herd behavior, and the specific effects on the slope. For the relict populations of *S. eurasius* in northern Bohemia (CZ), Holuša & Holuša (2002) also recommended grazing – combined with shrub clearance – as the most suitable management strategy. Similarly, for the maintenance of a Romanian population, Iorgu & Iorgu (2018) emphasized the necessity of ongoing moderate grazing by sheep and goats. In contrast, Kenyeres et al. (2020), who studied several relict populations of *S. eurasius* in the Pannonian Basin, arrived at different conclusions. They stressed that, besides habitat overgrowth and shrub encroachment, excessive grazing and trampling by livestock represent the most serious threats to the species – and more generally to relict steppe species. According to their findings, many habitats do not require additional grazing due to their specific soil conditions or cannot be grazed at all because of their inaccessibility. They concluded that trampling causes more harm than benefit, particularly in Hungarian areas where *S. eurasius* occurs and where populations of wild boar and mouflon have increased tenfold since 1960 (Csányi et al. 2017, cit. in Kenyeres et al. 2020). In such areas, they call for an urgent reduction of large game populations. In this light, the feral sheep herd at Braunsberg – whose numbers are also increasing (T. Englisch, pers. comm.) – must be monitored. According to the author's observations, the herd seems to remain primarily

in the upper slope areas of the southwestern Braunsberg, which are not as frequently used by *S. eurasius*. Nevertheless, the actual impact of the herd remains unclear for now. Whether grazing activity has a positive or negative effect on relict steppe species like *S. eurasius* at the western edge of its distribution range likely depends on site-specific conditions and grazing intensity and must therefore be evaluated on a case-by-case basis. What is indisputable, however, is the need for at least moderate grazing on Schlossberg, where noticeable fallow development is already occurring in some areas. This will be a future task for the protected area management of the Hainburg Hills.

Considering climate change, the extreme site conditions at Braunsberg, and the fact that all Austrian occurrences of *S. eurasius* are located within the Natura 2000 sites "Donau-Auen östlich von Wien" (Braunsberg) and "Hundsheimer Berge" (Schlossberg), there is currently no indication of an immediate threat to the overall population – despite the small distribution area and the growing sheep herd at Braunsberg. However, the risk of local losses due to overgrowth or shrub encroachment remains at least in Clearing West, and particularly on Schlossberg.

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