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From natural river floodplains to sand pits – the role of primary and secondary habitats in the conservation of the rare tiger beetle *Cylindera arenaria viennensis* (Schrank, 1781) in Poland

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Abstract. Taxa naturally occupying ecosystems spatially restricted by anthropogenic land development sometimes find refuge in secondary habitats, taking advantage of conditions created by human management. One of them is *Cylindera arenaria viennensis* (Schrank, 1781), a rare tiger beetle originally inhabiting natural river valleys, especially open flat banks and dynamic alluvial zones. Today, these habitats across Europe have been heavily transformed, mostly losing their former natural character. Published data as well as those reported in this study indicate that all nine present-day (recorded no more than 30 years ago) localities of this beetle in Poland are found in secondary habitats. These comprise mainly functioning or abandoned opencast extraction sites of mineral deposits (like sand or gravel), which fits the pattern observed in other central European countries. Nevertheless, such sites, due to vegetation succession, drainage or inadequate management following cessation of extraction, are quickly losing their attractiveness for *C. a. viennensis*, ultimately driving local populations to disappear, which is likely to have occurred in one of the reported localities. Thereby, it is crucial to search for and then to protect any sites of this species found in primary habitats, as the long-term survival of populations of this beetle seems best ensured by the protection and restoration of original alluvial habitats found in natural river valleys.

Key words: Coleoptera, Carabidae, riverine biotopes, extraction site, reclamation.

1. Introduction

Initial sandy ecosystems often host specialised and threatened species of flora and fauna typically associated with xeric habitats, such as many vascular plants (Olsson et al., 2009), orthopterans (Hochkirch et al., 2016) or wild bees (Banaszak & Twerd, 2018; Seitz & Leonhardt, 2019). However, certain sand-related taxa utilise both dry as well as wetter habitats, especially those located in the transitional zone between land and water. These include some tiger beetles Cicindelinae Latreille, 1802, a distinct subfamily of ground beetles Carabidae (Putchkov & Matalin, 2003), considered sometimes as a separate family Cicindelidae (Burakowski et al., 1994; Trautner, 1996; Jaskuła, 2011). In Poland, within Cicindelinae there are seven species of beetles grouped in two genera – *Cicindela* L., 1758 and *Cylindera* Westwood, 1831 (Burakowski et al., 1973; BioMap, 2022). One of the tiger beetles associated with shoreline habitats is *Cylindera (Eugrapha) arenaria* (Fuessly, 1775), a Euro-Siberian species whose range extends from France, through

central and southern Europe, to eastern Europe and western Siberia. Within this polytypic taxon, three subspecies are distinguished: *C. a. arenaria* (Fuessly, 1775) inhabiting an area from France through Switzerland to western Austria, *C. a. viennensis* (Schrank, 1781) occurring in the rest of the central European range, the Balkans, eastern Europe and western Siberia, and *C. a. nudoscripta* (W. Horn, 1915) which inhabits southern Russia, Georgia, Azerbaijan, Armenia and Turkey (Trautner, 1996; Putchkov & Matalin, 2003; Jaskuła, 2007; Brigić et al., 2020). In Poland only the subspecies *C. a. viennensis* has been recorded in scattered localities throughout the country. Despite the fact that it is not currently under legal protection, nor is it included as threatened in the national red data book (Głowaciński & Nowacki, 2004) or the national red list (Pawłowski et al., 2002), it belongs to the tiger beetles least frequently observed and with the least known distribution in Poland (Burakowski et al., 1973, 1994; Miłkowski & Sienkiewicz, 2006; BioMap, 2022). Importantly, in some central European countries *C. a. viennensis* is one of the habitat specialists for which secondary habitats play a significant role in maintaining their wild populations (Trautner, 1996; Kästner, 2011; Spitzer et al., 2014).

The present study aims as follows: (1) to present new localities of *C. a. viennensis* in southern Poland, (2) to summarize previous and present knowledge on the geographical distribution and phenology of the occurrence of adult forms of this species in the country, and (3) to analyse the importance of primary (natural) and secondary (associated with opencast mineral extraction sites) habitats in preserving population of this rare tiger beetle in Poland.

2. Material and methods

New records of *C. a. viennensis* were made during entomological surveys of sandy areas, conducted with the naked eye and with the use of 10×42 binoculars. Insects were identified on the basis of photographs taken during searches and no specimens were collected. The study was qualitative in nature, therefore population size was not assessed for individual sites.

Figure 1. Geographical distribution of *C. a viennensis* localities in Poland in UTM grid squares. Black squares – new localities found during this research, grey squares – other localities found over the last thirty years, empty squares – older localities, mainly of historical interest

Distribution maps of *C. a. viennensis* in Poland (Fig. 1) were prepared based on literature data (Burakowski et al., 1973; Cieślak, 2004; Piotrowski, 2004; Miłkowski & Sienkiewicz, 2006; Żurawlew & Markiewicz, 2021), summarized also in the BioMap database (2022). Only data with geographical accuracy at least to the UTM (Universal Transverse Mercator) grid square were used. The central point (centroid) of the UTM grid square from which the species has been reported was assumed as the locality. Sites discovered in the last decade of the 20th century or in the 21st century were considered as recent ones. Other sites mentioned in the literature, older and less defined in terms of geographical location and habitat description, were included separately, considering that they require confirmation whether they are currently occupied by *C. a. viennensis*. The physical-geographical nomenclature of Polish regions applied in the text follow Solon et al. (2018), unless otherwise stated.

On the basis of data from localities considered recent (see above), a graphical distribution of phenology of adult *C. a. viennensis* records in Poland was compiled. A single observation or multiple observations of this species made on a given day (one date) in a single locality were considered a record. Each was assigned to the ten-day period of the month in which it was made, and then the number of records in each period was summed up. If a locality was surveyed more than once during a single ten-day period or over more than one year, the corresponding number of times was included in the graphical distribution.

3. Results

Between 2011 and 2019, two new localities of *C. a. viennensis* have been discovered in southern Poland:

Bukowno: (UTM: CA86; 50.255308°N, 19.438737°E). A fragment of the former "Szczakowa" sand mine (so-called 'Podlesie' reservoir) in Bukowno near Olkusz (the Jaworzno Knolls region of the Silesian Upland; Solon et al., 2018). An extensive (ca. 320 ha) opencast sand mine, now inactive (exploitation ceased in 1998) and recultivated, as part of which the area was afforested, mainly with Scots pine *Pinus sylvestris* L., and to a lesser extent also birch *Betula pendula* Roth, alders *Alnus glutinosa* (L.) Gaertn. and *A. incana* (L.) Moench, larch *Larix decidua* Mill. and black locust *Robinia pseudoacacia* L. (Fig. 2a). Significant parts of the area are also occupied by reeds *Phragmites australis* (Cav.) Trin. ex Steud. The terrain topography is varied, with numerous hills and depressions. The groundwater level in the former mine is high and water is drained from it by a system of drainage ditches and canals (Pucek, 2014). A single individual of *C. a. viennensis* was recorded on 24 VI 2011 on a patch of bare sand in the reclaimed excavation. After 11 years, on 26 VI 2022 r., the sand mine has been surveyed again. After a thorough search of the site, the presence of *C. a. viennensis* has not been recorded.

Brzostowa Góra: (UTM: EA58; 50.394747°N, 21.780408°E). Sand and gravel mine in Brzostowa Góra near Nowa Dęba (the Kolbuszowa Plateau region of the Sandomierz Basin; Solon et al., 2018). An opencast mine (ca. 23 ha), in which mineral deposits are extracted on an area of ca. 5 ha. Nearly 8 ha are occupied by water bodies created after filling in the post-mining excavations. These reservoirs, the largest of which has an area of 6.3 ha, are overgrown by differently developed aquatic and marsh vegetation communities. Rest of the area is covered with dry herbaceous vegetation, reedbeds, single and clumps of bushes, shrubby thickets as well as patches of bare sand and gravel, heaps of sand and sparse initial sandy grasslands (Fig. 2b). *C. a. viennensis* were observed on 24 VI and 9 and 16 VII 2019 in the non-exploited part of the mine, on sandy fragments of initial grasslands and areas almost devoid of vegetation – on patches of bare sand, on the bottom of a dried up temporary water body and on a sandy road. All these sites were placed no more than 40 m from a permanent water body located in the western part of the mine.

In Poland during the last 30 years, 18 observations of *C. a. viennensis* from 9 localities have been reported in the literature, including the present work (Table 1). Data of sufficient precision indicate that adult beetles of this species were observed between 1 June and 1 August (Cieślak, 2004; Piotrowski, 2004; Miłkowski & Sienkiewicz, 2006; BioMap, 2022; Żurawlew & Markiewicz, 2021; this study), although August observations of *C. a. viennensis* (unfortunately without exact dates) are mentioned by Cieślak (2004). The temporal distribution of records shows that the observations mostly took place between the second ten-day period of June and the first ten-day period of July, with the maximum in the latter interval (Fig. 3). Each observation was located in secondary habitats, and almost all of them were associated with opencast mining areas of mineral materials (Table 1). The majority were active or unused sand- and gravel pits in various stages of vegetion sucession and – in one case – also an opencast lignite mine. An interesting, completely artificial habitat, was a watered part of a heap of ash formed as a result of charcoal combustion in an electric power plant. Only one site out of 9 – a dirt road accompanying the drainage canal – was not related to the industrial area. To my best knowledge, in the last three decades no single locality of *C. a. viennensis* located in a non-anthropogenic habitat has been published from the area of Poland.

a

b

Figure 2. Habitat of *C. a viennensis* in Bukowno (a) and Brzostowa Góra (b) in Poland (photo R. Bobrek)

Table 1. Published localities of Cylindera arenaria viennensis (Schrank, 1781) in Poland, recorded in the last decade of the 20th or in the 21st century. For each locality, the UTM grid square code, dates of observation, a brief description of the habitat and the source of the data are provided.

Id	Locality	UTM	Observation dates	Habitat	Source
1.	Babsk	FB49	10 VII 1999	Dirt road next to the drainage canal	Piotrowski 2004
2.	Tarnobrzeg	EB50	1 VI, 10 VI 2002	Unused sand pit	Cieślak 2004
3.	Radom-Wincentów	EC10	17 VI, 3 VII 2003	Sand pit filled with water	Miłkowski & Sienkiewicz 2006
4.	Radom-Wincentów	EC10	1 VIII 2004; 24 VI, 23 VII 2005	Charcoal combustion ash dump of an electric power plant	Miłkowski & Sienkiewicz 2006
5.	Sieniawa	WU20	20 VI, 10 VII 2005	Unused lignite opencast mine	Miłkowski & Sienkiewicz 2006
6.	Bukowno	CA86	24 VI 2011	Unused opencast sand mine, mostly afforested as part of reclamation	this study
7.	Wasilków	FE50	7 VII, 15 VII 2015; 20 VI 2016	Old gravel pit, overgrown with trees	A. Kołodko: BioMap 2022
8.	Brzostowa Góra	EA58	24 VI, 9 VII, 16 VII 2019	Unused part of the active sand and gravel pit	this study
9.	Piła	YT05	4 VIII 2019	Active sand pit	Żurawlew & Markiewicz 2021

4. Discussion

4.1 Distribution in Poland

The actual distribution of *C. a. viennensis* in Poland is poorly known, despite the fact that localities of this species were recorded over a wide area and in different regions of Poland, from the Baltic coastland, through the lakeland and lowland areas of northern and central Poland, to southern uplands and even the Carpathian Mountains (Fig. 1). Moreover, the occurrence of this species was also reported in a general way (with a precision making it impossible to assign them to the UTM grid square) from other regions of the country (sensu Catalogue of the Fauna of Poland; Burakowski et al., 1973), i.e. from the Lower and Upper Silesia and the eastern part of the Sudety Mountains (Burakowski et al., 1973; BioMap, 2022). Unfortunately, most of the literature data on this species comes from several dozen (more than thirty) years ago, so the current status of these formerly recorded localities now needs to be confirmed.

More recent data, dating from the end of the 20th and 21st centuries, concern several localities distributed in the central and north-eastern part of the country (Fig. 1) in only a few regions – the Northern Podlasie Plain (A. Kołodko – BioMap, 2022), Lubuskie Lakeland (Miłkowski & Sienkiewicz, 2006), Southern Wielkopolska Lowland (Żurawlew & Markiewicz, 2021), Southern Masovia Hills (Miłkowski & Sienkiewicz, 2006), Western Polesie (Piotrowski, 2004) and Sandomierz Basin (Cieślak, 2004). From the two localities found in this study – Bukowno and Brzostowa Góra – *C. a. viennensis* has not been reported so far. However, this species has already been reported from these regions of Poland, from locations 15–20 km away (Fig. 1). It is worth noting, however, that the locality in Bukowno is a confirmation of the present occurrence of the species in the Silesia-Kraków Upland (the previous locality in this region was reported several dozen years ago), whereas the one in Brzostowa Góra is only the second present-day locality of this tiger beetle in the Sandomierz Basin. Both new localities given in this paper, which is well illustrated by the map, are the southernmost recent localities of *C. a. viennensis* in Poland (Fig. 1).

4.2 Primary and secondary habitats in the conservation of *C. a. viennensis*

The primary habitat of *C. a. viennensis* in Central Europe comprises mainly dynamic floodplains of medium size to large rivers with open flat banks and alluvial deposits, where a natural spatio-temporal turnover of riverine habitats acts over large area (Trautner, 1996; Gebert, 2007; Jaskuła, 2011). It may also utilise coastal areas, salt flats and lake shores (Trautner, 1996; Kästner, 2011). The species inhabits sun-exposed, relatively wind-sheltered and sparsely vegetated areas with fine-grained, permeable substrate, often with water seeping into the surface layers (Burakowski et al., 1973, 1994; Gebert, 1991; Trautner, 1996; Müller- Kroehling et al., 2000). According to Kästner (2011), *C. a. viennensis* utilise sheltered sites with pronounced small scale relief, numerous alluvia and temporary water bodies, where vegetation cover is optimally less than 20%, and no more than 60%. The nutrient content, acidity and colour of the substrate are of minor importance for this species (Gebert, 1991; Kästner, 2011).

As in other tiger beetles, the larvae of *C. a. viennensis* live in tubular burrows built in the ground (Burakowski et al., 1994; Gebert, 1991; Kästner, 2011). Important parameters

determining the suitability of a substrate as a habitat for larvae include the grain size distribution and cohesiveness (Gebert, 2007; Kästner, 2011). It is beneficial if the soil contains at least 40% clay and very fine sand, but little gravel and coarse sand (Kästner, 2011). Cohesiveness is ensured by a high water table or the proximity of water bodies, and where moisture is lacking, by the presence of marl, clay or silt in the substrate (Trautner, 1996; Gebert, 1991, 2007). The larvae avoid areas covered with loose sand, but are tolerant of high water levels in the ground, which could probably allow them to reduce competition with other tiger beetles such as *Cicindela hybrida* L., 1758 (Kästner, 2011).

Recently, *C. a. viennensis* is most commonly found in the secondary habitats, which are mainly operating or abandoned opencast mining areas of mineral materials (sand, gravel, lignite, clay) in early successional stages. Such sites can resemble riverine floodplains or lakeshores due to the presence of raw soil, sparse vegatation and structures such as temporary water bodies, dunes, sandbanks, mudflats, alluvial fans, shallow and steep slopes, debris cones etc. (Trautner, 1996; Gebert, 2007; Kästner, 2011). It has also been found in inland dune areas in military training ground, where it occupied open ground on tank tracks far away from any water habitats (Gebert, 2007; Kästner, 2011). As *C. a. viennensis* is primarily a species of dynamically changing riverine habitats, it is adapted to an intensive disturbance regime of opencast mining areas while at the same time being negatively affected by vegetation succession (Gebert, 1991, 2007; Kästner, 2011; Růžičková & Hykel, 2019). In secondary habitats, the species has been recorded in many central European countries, e. g. in the Czech Republic (Spitzer et al., 2014; Růžičková & Hykel, 2019), Germany (Gebert, 1991, 2007; Müller-Kroehling et al., 2000; Kästner, 2011), Croatia (Brigić et al., 2020), and Poland (Table 1).

All current localities of *C. a. viennensis* in Poland (Table 1) and Germany (Trautner, 1996; Kästner, 2011) are located in anthropogenic habitats. A similar situation exists in the Czech Republic, where the occurrence of this species is mainly restricted to replacement habitats (Spitzer et al., 2014). This indicates that proper management of opencast mining areas, acting as secondary refuges, is currently crucial for the survival of *C. a. viennensis* populations, both in Poland and in other parts of central Europe (Kästner, 2011; Růžičková & Hykel, 2019; Brigić et al., 2020). These habitats are important for the species not only as refugia, but in view of the scarcity of sites in primary habitats, also regarded as a source of individuals for colonisation of new sites (Kästner, 2011). For the conservation of the species in alternate habitats, it is beneficial to maintain a mosaic of habitats, with an emphasis on the presence of bare sand surfaces and sparse, sandy grasslands (Spitzer et al., 2014; Růžičková & Hykel, 2019; Brigić et al., 2020), as well as appropriate substrate parameters, especially its cohesiveness (Gebert, 2007; Kästner, 2011). Most important is the preservation of disturbance dynamics that guarantee the maintenance of a continuous provision of the initial habitats preferred by this beetle within a given mining site. For the above reasons, both the elimination of the factor generating local disturbances in the habitat (e.g. through abandonment of the mine, resulting in the initiation of vegetation succession) and the technical reclamation of the area (e.g. filling the excavation with water, afforestation or conversion to agricultural use; Ostręga & Uberman, 2010), can quickly lead to the disappearance of *C. a. viennensis* from the occupied site (Trautner, 1996; Müller-Kroehling et al, 2000), as was probably the case at Bukowno locality. A suitable effect may be obtained by continuing (rather small scale and low intensity) mining activities on a fragment of the site or, alternatively, by carrying out measures mimicking these activities, which would guarantee the creation of early successional habitats.

Centuries of modifications introduced in the hydromorphology and land use of river valleys in Europe (use of technical flood protection measures, river channel straightening, damming, agricultural and transport use, disconnection and drainage of floodplains, urbanisation etc.) have led to the current estimates that 60–90% of Europe's floodplains are ecologically degraded, while in some areas of central Europe these values reach almost 100% (EEA, 2019; Globevnik et al., 2020). *C. a. viennensis*, originally inhabiting natural, unaltered river sections, is clearly threatened by their anthropogenic modification, as are other pioneer species specific to the natural riverine habitats (Gröning et al., 2007). And although there are few detailed studies documenting this, as the natural biotopes of most central European rivers have been transformed over past centuries (EEA, 2019; Globevnik et al., 2020), a link between hydrotechnical regulation of rivers and the subsequent decline of *C. a. viennensis* in natural sites has been documented in German Bavaria (Müller-Kroehling et al., 2000). Therefore, there is an urgent need to search for current localities of this species in its natural habitats. Such a highly habitat-specialised beetle as *C. a. viennensis* seems to be a good indicator species for the remnants of natural alluvial floodplain habitats in the highly altered landscape of river valleys in the Central European lowlands. And alluvial habitats associated with riparian zones, such as open, sandy stretches of the banks of large, unaltered rivers, are among highly threatened and disappearing in Europe (Richoux, 2010; EEA, 2019; Brigić et al., 2020; Globevnik et al., 2020), including Poland (Nawrocki et al., 2014; Pawlaczyk, 2017). The discovered riverine localities would be worth protecting in the form of e.g. nature reserves, which has already been suggested for the 'typical' habitats of this species in Poland (Miłkowski & Sienkiewicz, 2006). Of course, this should

take into account the naturally high dynamics (instability) of these habitats in time and space (Ward, 1998; Pawlaczyk, 2017), focusing more on the conservation of processes over a larger spatial scale than the state of the habitat in a given place and time.

When searching for undiscovered sites, it is worth to pay attention to the phenology of occurrence of adult beetles throughout the year. It is best to conduct the search works in the period from the second ten-day period of June to the first ten-day period of July, when these insects are most frequently observed (Fig. 3). Penetration of potential habitats in the appropriate period of the year should result in discovering new localities of *C. a. viennesis*.

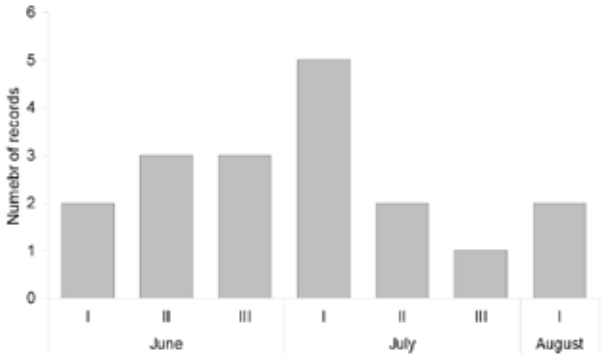

Figure 3. Distribution of *C. a. viennesis* observation dates in Poland published in the last thirty years. The bars represent the number of records of adult beetles in ten-day periods of consecutive months

All sites of this beetle in primary habitats should be protected not only because of their rarity, but also because secondary habitats, due to vegetation succession, disappear quickly (Gröning et al., 2007; Kästner, 2011; Růžičková & Hykel, 2019). Sometimes they are occupied for only a few years and thus can only play a role as a refuge for a species over a relatively short time scale (Trautner, 1996; Gebert, 2007). A good example is the locality in Bukowno, where the species was not found 11 years after its discovery. The reason may be both the progressive succession of vegetation, mainly trees planted as part of reclamation, and the lowering of groundwater table and drying of habitats, symptoms of which were observed during the second field inspection. Therefore, the necessity to preserve the original habitats of species such as *C. a. viennesis* is a further point in favour of the essential need to protect the remnants of natural sandy beaches and riverbanks in central Europe and to carry out appropriate restoration programs. The most efficient way to achieve this is to allow for the renaturalization of anthropogenically altered river stretches, to restore their natural fluvial dynamics and to reconstruct a channel of free lateral migration of the river across its floodplain, which seems the most robust approach to preserve self-renewing early successional riparian habitats in the long term (Ward, 1998; Gröning et al., 2007; Kästner, 2011; Pawlaczyk, 2017; EEA, 2019).

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