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Distribution of economically important click beetles and the first record of *Agriotes sordidus* Illiger in Hungary

Gazdaságilag jelentős pattanóbogár fajok elterjedése és az *Agriotes sordidus* Illiger első megjelenése Magyarországon

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ABSTRACT

Distribution and abundance of the most harmful click beetles (Coleoptera: Elateridae) were sampled with sex pheromone traps at 11 sites in the Carpathian lowlands in 2022. Samples provided the first Hungarian data on *Agriotes sordidus*, occurring northwest of the country with low abundances. The most abundant species was *A. rufipalpis*, while *A. ustulatus*, *A. lineatus* and *A. sputator* were also common. The reordering of the species rank and the absence of *A. obscurus* from the Transdanubian sites, compared to data collected between 2010 and 2013, may refer to the climatic changes during the last decade.

Keywords: distribution, damage risk assessment, monitoring, Pannonian Lowland, sex pheromone trap

ABSZTRAKT

A gazdaságilag jelentős pattanóbogár (Coleoptera: Elateridae) fajok elterjedését és egyedsűrűségét vizsgáltuk szexferomon csapdákkal 11 magyarországi területen, 2022-ben. A felmérés során elsőként igazoltuk az *Agriotes sordidus* magyarországi előfordulását. A legtömegesebb fajnak az *A. rufipalpis* mutatkozott, de az *A. ustulatus*, *A. lineatus* és az *A. sputator* is gyakori fajoknak bizonyultak. A korábbi (2010–2013) vizsgálatokkal összevetve, mind a fajok abundanciájának változása, mind az *A. obscurus* dunántúli mintákból való eltűnése az elmúlt évtized klimatikus változásainak hatását tükrözhette.

Kulcsszavak: szexferomon csapda, elterjedés, kártételi kockázatbecslés, Alföld

INTRODUCTION

The family of click beetles (Elateridae) is a species-rich taxon of the order Coleoptera, with about 8,000 described species worldwide. In Hungary, 131 species occur, in different habitats, from closed forests through open grasslands to intensively used agricultural areas (Merkl and Mertlik, 2005). Their economic importance depends on the length of their larval development (true wireworms) and their feeding habit, which may be omnivorous, phytophagous, saprophagous, or carnivorous. Species of the *Agriotes* genus are considered the most significant pests of click beetles since their phytophagous feeding habit, 4–5 years long larval development and prevalent occurrence in arable- and horticultural lands. *Agriotes* species are the most abundant within the click beetle assemblages of agricultural areas, with approximately 80–90% relative frequency. They can cause significant economic losses, especially in cultures with low plant densities, such as maize and sunflower, and in the case of high infestations, in winter wheat and horticulture (Tóth, 1990). The damages caused by the most noxious click beetle species have been extensively studied, and their biology considering life cycle, seasonal dynamics and host plant range, are generally well known (Gough and Evans, 1942; Evans, 1944; Furlan, 1996; Parker and Howard, 2002; Furlan, 2004, 2009; Ritter and Richter; 2013). There are also numerous data on their distribution, e.g. in Hungary, by Nagy et al. 2010, 2011, 2012, 2013. However, the control of click beetles must be based on up-to-date distribution and frequency data, contributing significantly to adequate protection (Tóth, 1990).

Using species-specific pheromone traps is the easiest way to study click-beetle species assemblages. These traps help detect a given species' presence and study its seasonal dynamics (Tóth et al., 2002). The quantitative composition of assemblages may also be simultaneously examined using sex pheromone traps of different species. In the case of *Agriotes ustulatus* (Schaller,1783), the economic threshold is between 200–250 adults/trap/year (Furlan et al., 1996). According to Blackshaw et al. (2008), *A. ustulatus*, swarming in July and August, is more vagile than species swarming from spring (from April to June), such as *Agriotes lineatus* (Linnaeus,1767), *Agriotes obscurus* (Linnaeus, 1758) and *Agriotes sputator* (Linnaeus, 1758). Thus, the economic threshold of the latter species is lower: 150 adults/trap/year. Blackshaw and Vernon (2008) and Blackshaw et al. (2008) found that the trap of *A. lineatus* is more efficient than *A. obscurus*, while *A. sputator* is a relatively static species with lower trap efficiency. In a mark-recapture study, Nagy-Szalárdi et al. (2017) and Nagy et al. (2018) found that the sex pheromone traps of *Agriotes rufipalpis* Brullé, 1832, *A. sputator* and *A. ustulatus* have equal efficiency. Thus, their catches may be summarized without correction, and the economic threshold established for *A. ustulatus* can be used for the total catches. Later, Furlan et al. (2020) provided economic thresholds for *Agriotes brevis* Candèze, 1863 and *Agriotes sordidus* (Illiger, 1807) between 200 and 1100 adults/trap/year, depending on the species and the time elapsed since the sampling.

The countrywide distribution of *A. brevis*, *A. sputator*, *A. obscurus*, *A. lineatus*, *A. rufipalpis*, and *A. ustulatus* was intensively studied between 2010 and 2013 (Nagy et al., 2010, 2011, 2012, 2013). During these studies, 76 sites were sampled, and more than 274,000 specimens of the six species were caught. *A. ustulatus* and *A. sputator* occurred at all sampled sites, while the spatial constancy of *A. brevis* (74/76 sites) and *A. lineatus* (74/76 sites) were also high. The less common *A. obscurus* was distributed mainly in the margins of Hungarian mountains and hilly areas of Transdanubia. *A. rufipalpis* showed medium spatial constancy (58/76 sites) with the continuous area and exceptionally high abundances in Eastern Hungary. The most abundant species was *A. ustulatus* (130,395 specimens in total), followed by *A. sputator* (77,576 specimens) and *A. rufipalpis* (47,299 specimens). As non-target catches, further 31 click beetle species were found in the traps (Nagy et al., 2010, 2011, 2012; unpublished data from 2013), including four *Agriotes* species: *Agriotes acuminatus* (Stephens, 1830), *Agriotes modestus* Kiesenwetter, 1858, *Agriotes pilosellus* Schonherr, 1817, *Agriotes proximus* Schwarz, 1891.

Beyond Central Europe, *A. sordidus* is one of the most harmful click beetles in Europe. It is native to the southwestern part of Europe, causing significant damage to herbaceous crops (e.g., maize, sunflower, potato, etc.) in Italy (Rusek, 1972; Platia, 1991; Furlan, 1999, 2004, 2014; Furlan et al., 2000), in Spain (Sánchez-Ruiz et al., 1998) and in Portugal, where it was first described, according to Platia (1991). Its distribution area expanded to the north and appeared in the United Kingdom (Kloet and Hincks, 1977; Mendel and Clarke, 1996), the Netherlands (van Nunen, 2007), Belgium (Jeuniaux, 1996), Switzerland (Lohse, 1979; Zeising, 1984; Furlan, 2004), France (Leseigneur, 1972; Cocquempot et al., 1999), and Germany (Lohse, 1979; Zeising, 1984; Furlan et al., 2007; Lehmhus and Niepold, 2013). It has not reached Hungary, but it has already appeared in Austria, near the Austrian–Hungarian border (Neusiedler See-Seewinkel National Park and Neusiedl am See) (Biologiezentrum, 2023a, 2023b). Although *A. sordidus* was mentioned from Hungary by Szombathy (1910), later this data was revised by Merkl and Mertlik (2005). *A. sordidus* and *A. rufipalpis* are attracted to the same-sex pheromone (Tóth et al., 2002) and appear to be well-separated geographically (Furlan et al., 2021), as instead of *A. sordidus*, *A. rufipalpis* lives in the Balkan Peninsula, and in the Central- and Eastern European countries (Furlan et al., 2007). The appearance and spread of *A. sordidus* in Hungary are presumable but have not been proven until now.

In 2022, studies including sex pheromone traps were repeated in 11 sites in different regions of Hungary. To study the changes in the abundances and relative frequency of the most harmful species, showing the highest abundances and spatial distribution in the former studies, samplings were carried out with *A. ustulatus*, *A. sputator*, and combined *A. lineatus/obscurus* and *A. rufipalpis/sordidus* sex pheromone traps. During the study, special attention was given to the monitoring of *A. sordidus* occurence.

MATERIALS AND METHODS

The spatial distribution and the quantitative composition of the assemblages of the most noxious *Agriotes* species were studied at 11 locations in different regions of Hungary in 2022 (Figure 1, Table 1). In addition, YatlorF (Yf) traps with commercial CSALOMON® (http://www.csalomontraps.com) sex pheromone baits of *A. sputator*, *A. ustulatus*, *A. lineatus/obscurus* and *A. rufipalpis/sordidus* were placed on the margin of maize and cereal fields.

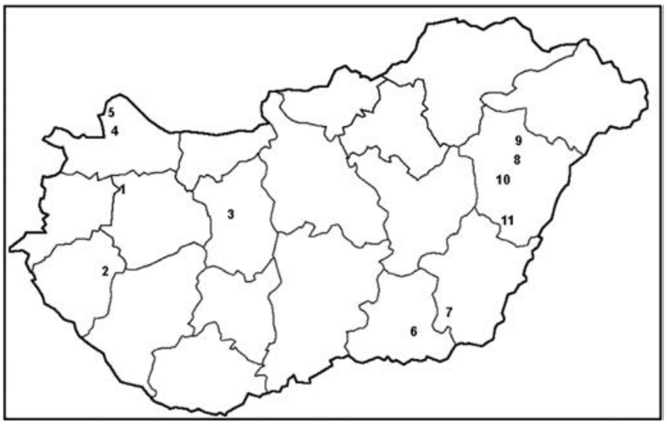

Figure 1. Location of the sampling sites of click beetles (*Agriotes* spp.) in Hungary in 2022 (1 = Vinár, 2 = Sármellék, 3 = Székesfehérvár, 4 = Hanságliget, 5 = Mosonszolnok, 6 = Batida, 7 = Kardoskút, 8 = Debrecen, 9 = Hajdúböszörmény, 10 = Hajdúszoboszló, 11 = Darvas).

Traps were set in blocks, in two or three repetitions at each sampling site. In a block, traps of different species were placed in the same order at a 10–15 m distance. Traps of species swarming in the spring began operating in April, while traps of *A. ustulatus* were set in June, and all of them remained active until August (Table 2). Baits were replaced after four weeks, and insecticide strips killed the insects. The traps were checked, and the samples were collected in 10–14 days, then stored in a refrigerator until count and identification. Dolin's (1991) and Laibner's (2000) keys were followed for identification, and reference specimens of the Plant Protection Institute, University of Debrecen collection were used. In the case of *Agriotes sordidus*, formerly unknown in Hungary, the keys of Platia (1991) and Laibner (2000) and reference specimens collected by Lorenzo Furlan in North Italy were also used.

Table 1. Data of the sampling sites of click beetles (*Agriotes* spp.) in Hungary in 2022, the timing of samplings and the number of sex pheromone traps per species (Trap) (also see Figure 1)

	Location	No. of traps	GPS	Start of sampling		End of sampling
				other species	*A. ustulatus*	
	Transdanubia					
1	Vinár	3	N47.326187 E17.305140	14 April	27 June	31 August
2	Sármellék	2	N46.748575 E17.146963	16 April	27 June	20 August
3	Székesfehérvár	2	N47.178425 E18.465002	22 April	30 June	01 September
4	Hanságliget	2	N47.737826 E17.174314	14 April	27 June	31 August
5	Mosonszolnok	2	N47.854561 E17.133009	28 April	26 May	31 August
	Eastern Hungary					
6	Batida	3	N46.347952 E20.336783	20 April	01 June	28 July
7	Kardoskút	3	N46.496113 E20.707694	20 April	01 June	28 July
8	Debrecen	3	N47.560658 E21.445625	13 April	11 June	13 August
9	Hajdúböszörmény	3	N47.687530 E21.452514	14 April	11 June	13 August
10	Hajdúszoboszló	3	N47.413529 E21.311232	14 April	11 June	13 August
11	Darvas	3	N47.126436 E21.310332	22 April	29 May	31 July

A. sordidus specimens may be easily confused with the morphologically similar *A. rufipalpis*, which was additionally caught by the same traps with a combined bait. Distinguishing the two species is based on the size and morphology of the pronotum, elytra and antennae. Contrasting to the longer-than-wide pronotum of *A. rufipalpis*, the pronotum of *A. sordidus* is at least as wide as long, but in most cases, remarkably wider than long (Figure 2). Moreover, the elytra of the latter species is markedly wider at its midlength than its pronotum, while the elytra of the *A. rufipalpis* is never wider than its pronotum. The length of the antennae of males also differs, since, in the case of *A. sordidus*, these at most reach the apices of posterior pronotal angles. In contrast, the antennae of *A. rufipalpis* males extend beyond those.

A. sordidus specimens were placed into the collection of the Plant Protection Institute, University of Debrecen.

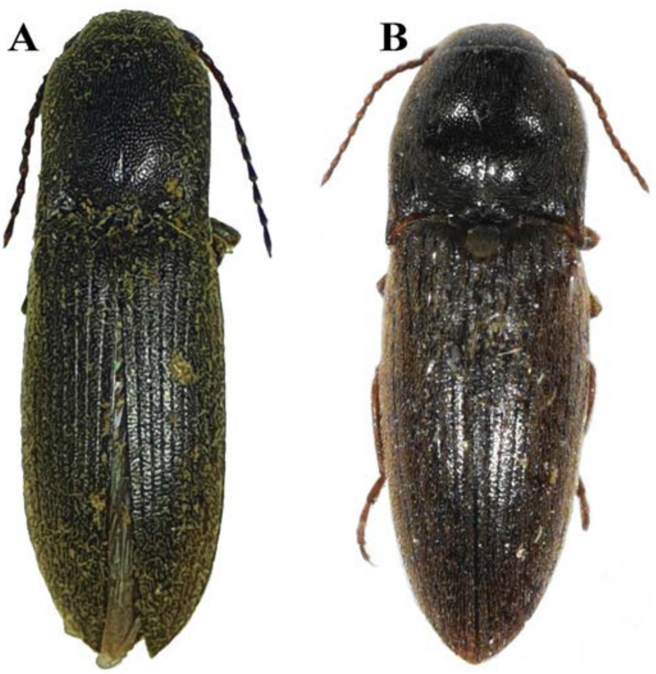

Figure 2. *Agriotes rufipalpis* (A) and *A. sordidus* adults, caught with a combined *A. rufipalpis*/*A. sordidus* sex pheromone traps. *A. rufipalpis*: Székesfehérvár 16/05 2022; *A. soridus*: Pápa–Vinár 19/05 2022 (Photo by Antal Nagy)

Spatial distribution and relative frequency of the studied species were evaluated based on the total number of individuals caught and mean catches per trap (adults/trap/year). To assess the damage risk, the summarized catches of the sampled species were used considering the threshold suggested by Furlan et al. (1996). In addition, changes in the composition of click beetle assemblages during the last decade were evaluated by comparing recent data and results of the former studies between 2010 and 2013 (Nagy et al., 2013). Five traps were used for each species at each site during the former studies. Thus in the comparison, the mean catches per trap were used considering the nearest sampling sites.

RESULTS

In 2022, 10,439 click beetles of five species were caught in 11 sampling sites in Hungary. Among the studied species, *A. obscurus* did not appear in the samples. Contrary, 26 specimens of *A. sordidus* were caught at four sites in Transdanubia, as the first valid records of the species in Hungary. *A. rufipalpis* showed high (90.9%) spatial constancy. In contrast, the other three species, *A. ustulatus*, *A. lineatus* and *A. sputator*, appeared in all sampling sites (Table 2).

The most abundant species was *A. rufipalpis*, followed by *A. sputator*, *A. lineatus*, *A. ustulatus*, and *A. sordidus* with especially low relative frequencies. The abundances were generally higher in Eastern Hungary. *A. rufipalpis* was abundant in eastern areas, while *A. sordidus* appeared only in the northwestern part of the country. *A. lineatus* showed extremely high abundance only in Vinár (1) sampling site (Table 2).

The surroundings of all sites sampled in 2022 were studied between 2010 and 2013 with the same methods, except Hajdúböszörmény (9). The distribution and abundance of the studied species changed in the last decade.

Table 2. Total number of specimens collected (Total no.) by sex pheromone traps in 11 sampling sites studied in Hungary in 2022, with relative frequency (RF%) and spatial constancy (SC%, ratio of occupied sampling sites) of the caught species

	A. rufipalpis	*A. sordidus*	*A. sputator*	*A. lineatus*	*A. ustulatus*	Total
Total no.	4,170	26	2,545	1,919	1,779	10,439
RF (%)	39.9	0.2	24.4	18.4	17.0	
SC (%)	90.9	36.4	100.0	100.0	100.0	
Transdanubia						
	6	19	773	1,246	9	2,053
	0	3	161	50	166	380
	95	2	21	11	35	164
	6	2	48	15	388	459
	4	0	68	3	250	325
Eastern Hungary						
	1,644	0	183	8	254	2,089
	766	0	111	6	102	985
	244	0	546	142	125	1,057
	781	0	246	231	30	1,288
	151	0	19	37	194	401
	473	0	369	170	226	1,238

Table 3. The mean abundances (individuals/trap/year) of *Agriotes* species studied in 2022 (with bold) and sites in their surroundings sampled between 2010 and 2013 with the same methodology

	Year	*A. rufipalpis*	*A. sordidus*	*A. sputator*	*A. lineatus*	*A. obscurus*	*A. ustulatus*	Total
Vinár	**2022**	**2.0**	**6.3**	**257.7***	**415.3***	**0.0**	**3.0**	**684.3***
Nagyacsád	2012	0.0	0.0	173.0	22.0	0.3	105.8	301.1*
Szil	2012	0.0	0.0	7.5	1.8	1.3	151.8	162.3
Sármellék	**2022**	**0.0**	**1.5**	**80.5**	**25.0**	**0.0**	**83.0**	**190.0**
Ordacsehi	2011	0.0	0.0	504.3*	60.8	1.7	2.8	569.5*
Zalaegerszeg	2012	0.0	0.0	132.8	7.0	4.3	85.8	229.8*
Székesfehérvár	**2022**	**47.5**	**1.0**	**10.5**	**5.5**	**0.0**	**17.5**	**82.0**
Kőszárhegy	2010	2.8	0.0	245.5*	15.8	0.0	141.0	405.0*
Székesfehérvár	2011	10.8	0.0	354.8*	27.3	0.0	76.6	469.4*
Hanságliget	**2022**	**3.0**	**1.0**	**24.0**	**7.5**	**0.0**	**194.0**	**229.5**
Mosonszolnok	**2022**	**2.0**	**0.0**	**34.0**	**1.5**	**0.0**	**125.0**	**162.5**
Kóny	2012	0.0	0.0	77.5	164.5	0.0	49.0	291.0*
Batida	**2022**	**548.0***	**0.0**	**61.0**	**2.7**	**0.0**	**84.7**	**696.3***
Szikáncs	2011	14.5	0.0	40.5	0.3	0.0	985.0*	1,040.3*
Kardoskút	**2022**	**255.3***	**0.0**	**37.0**	**2.0**	**0.0**	**34.0**	**328.3***
Orosháza	2010	28.5	0.0	70.5	1.0	0.0	1,491.8*	1,591.8*
Orosháza	2013	13.3	0.0	42.0	1.8	0.0	736.3*	793.3*
Székkutas	2010	6.9	0.0	172.3	1.3	0.0	296.3*	476.6*
Székkutas	2013	10.3	0.0	63.5	1.5	0.0	311.3*	386.5*
Eperjes	2010	80.0	0.0	112.0	1.0	0.0	137.3	330.3*
Pusztaszőlős	2011	11.0	0.0	96.0	1.8	0.0	1,587.3*	1696.0*
Debrecen	**2022**	**81.3**	**0.0**	**182.0**	**47.3**	**0.0**	**41.7**	**352.3***
Debrecen	2010	274.8*	0.0	123.4	2.0	0.0	461.3*	861.4*
Debrecen	2011	11.5	0.0	45.8	6.3	0.0	1,408.0*	1,471.5*
Debrecen	2012	16.8	0.0	186.5	25.0	0.0	726.8*	955.0*
Debrecen	2013	37.5	0.0	169.5	12.3	0.0	415.5*	634.8*
Hajdúböszörmény	**2022**	**260.3***	**0.0**	**82.0**	**77.0**	**0.0**	**10.0**	**429.3***
Hajdúszoboszló	**2022**	**50.3**	**0.0**	**6.3**	**12.3**	**0.0**	**64.7**	**133.7**
Hajdúszoboszló	2011	115.5	0.0	8.5	14.0	0.0	119.5	257.5*
Darvas	**2022**	**157.7**	**0.0**	**123.0**	**56.7**	**0.0**	**75.3**	**412.7***
Biharnagybajom	2010	2,811.0*	0.0	126.5	3.3	0.0	418.5*	3,359.3*
Darvas	2011	2.3	0.0	24.3	4.3	0.0	42.5	73.3
Nagyrábé	2013	338.0	0.0	28.5	41.5	0.0	165.8	573.8*

* Catches (adults/trap/year) above the economic threshold (200–250 adults/trap/year) established by Furlan et al. (1996)

Temporal changes of click beetle assemblages were evaluated by comparing recent (2022) data with results from 2010 and 2013 (Nagy et al., 2010, 2011, 2012, 2013). In Transdanubia, *A. rufipalpis* appeared in the surroundings of Pápa (1), Sármellék (2), Hanságliget (4) and Mosonszolnok (5) and became more abundant in Székesfehérvár (3), while *A. sordidus* also appeared in all sites except Mosonszolnok. Contrarily, *A. obscurus* disappeared from the surroundings of Pápa and Sármellék. The relative frequency of *A. lineatus* increased in Pápa and decreased in the northwestern part of the country around Hanságliget and Mosonszolnok. Contrary, relative frequency of *A. ustulatus* showed a lower value around Pápa and higher in the surroundings of Hanságliget and Mosonszolnok. Only the *A. sputator*, and in one case, *A. lineatus*, could reach the economic threshold in these areas. Still, the summarized catches were above the threshold in Pápa and Hanságliget, while the damage risk decreased in the surroundings of Székesfehérvár and Sármellék (Table 3).

In Batida and Kardoskút, *A. rufipalpis* showed extremely high dominance in 2022. Formerly, in this southeastern part of the Pannonian lowland, *A. ustulatus* was the most abundant species, followed by *A. sputator*. However, around Kardoskút, their abundance decreased simultaneously by 2022, while in Batida, *A. ustulatus* lost its dominance. Formerly, catches of *A. ustulatus* and, in 2022, *A. rufipalpis* were higher than the economic threshold, while the summarized abundances exceed this threshold in each case warns about high damage risk independently of the location and the studied years (Table 3). Larvae of different species cause damage together, and the efficiency of their traps is equal (Nagy et al. 2018), thus their catches may and even should be evaluated together using the economic threshold established for *A. ustulatus* (Furlan et al. 1996).

The relative frequency of *A. ustulatus* also decreased in Debrecen, while *A. rufipalpis*, and even *A. lineatus* and *A. sputator* showed higher frequencies in 2022 than a decade before. In Hajdúszoboszló, the dominant rank structure of click beetles did not show significant changes. At the same time, in the surroundings of Darvas, relative frequencies of *A. lineatus* and *A. sputator* increased parallelly with a decrease in *A. rufipalpis* and *A. ustulatus* abundances. In the eastern part of the lowland, catches of *A. rufipalpis* and/or *A. ustulatus* could also exceed the economic threshold. Still, the summarized catches showed high abundances of Elateridae pests in nearly all cases regardless of location and year (Table 3), which draws the attention of farmers and plant protection engineers to potential risks and the importance of monitoring and protection.

DISCUSSION

Click beetle assemblages of 11 sampling sites in Transdanubia (Western Hungary, 5 sites) and Eastern Hungary (6 sites) were studied in 2022. More than 10,000 specimens of five click beetle species were caught during the study.

Samplings provided the first distribution data of *A. sordidus* in Hungary. This species was first known as a pest in the west Mediterranean countries (Spain, Portugal, and Italy) and has spread to the north through France, Switzerland, and Germany. Although there was data from Austria, near the Hungarian border, former data of the species from Hungary (Szombathy, 1910) was revised by Merkl and Mertlik (2005). The population living in Northeastern Austria may be seen as a source of its expansion in Northwestern Hungary. Since it was not found in intensive studies between 2010 and 2013 (Nagy et al., 2010, 2011, 2012, 2013), its spread has occurred during the last decade. Parallelly, *A. rufipalpis* has also appeared or become more abundant in this region since 2013.

The decrease in the relative frequency of *A. ustulatus* can be explained by the unusual weather of the summer months in 2022 (OMSZ, 2023). Contrary to other click beetles studied, this species overwinters as a pupa and generally swarms from June to August. Therefore, the swarming period's highly arid and warm conditions might have been unsuitable for its development and decreased the abundance of the adults. The absence of *A. obscurus* could also be caused by the same factors since this species prefers humid conditions and is sensitive to extreme heat and aridity, as in May and June of 2022 (Tóth 1990).

The reorder of dominance rank structure was also characteristic in the Eastern Hungarian sites. The increasing dominance of *A. rufipalpis* could be revealed in the southeastern (Batida and Kardoskút) and eastern regions (Debrecen and Darvas). Considering the number of specimens caught behind the increasing relative frequency of *A. rufupalpis*, the extreme decline of *A. ustulatus* abundance may have been caused by climatic factors.

Although real damage risk appeared in all studied regions, the areas' most dangerous species differed. For example, in Western Hungary, the abundance of *A. sputator* and sparsely, *A. lineatus* could reach the economic threshold of 250 individuals/trap/year. In contrast, in eastern counties, *A. rufipalpis* or *A. ustulatus* caused considerable damage risk with heavy infestations.

Considering the summarized catches of the caught-click beetles, the infestation of Western Hungarian regions is lower, on average, than in the eastern counties. Our results suggest that the monitoring of the local click beetle assemblages is necessary, especially when planting as sensitive cultures as maize, sunflower, potato, sugar beet and horticultural plants. Revealing the spread of the newly appeared *A. sordidus* and changes in the dominance rank structure of the click beetle assemblages need further investigation.

CONCLUSIONS

Distribution and relative frequency of the most harmful and abundant click beetle species (Coleoptera: Elateridae, *Agriotes* spp.) were studied in 2022, and the actual data was compared to that collected a decade ago, between 2010 and 2013. The distribution of the studied species did not show significant changes in the past decade, but *A. ustulatus* was less abundant than it formerly was, while *A. lineatus* become locally abundant in the Transdanubian sites. Since the total abundances of the studied click beetle assemblages usually exceed the economic threshold of 250 individuals/trap/year, significant damage risk could be detected at most sampling sites; thus, monitoring of the local click beetle assemblages is necessary.

A new species, *Agriotes sordidus*, formerly unknown in Hungary was caught in the western part of the country close to the Hungarian–Austrian border. It is sporadic and less abundant but has spread during the last ten years through northwestern Transdanubia. Since it is a dangerous pest in some European countries, its spread and population dynamics should be monitored.

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