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Seasonal comparisons of the mosquito fauna in the flood plains of Bohemia and Moravia, Czech Republic

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Abstract

Based on mass collections in spring 2005 and spring / summer 2006, the mosquito fauna of the central Bohemian and south and central Moravian regions of the Czech Republic is reported. Morphological determination of 38,869 larvae and 11,307 adults confirmed the presence of twenty-two species, as follow: *Aedes cinereus* Meigen, *Ae. geminus* Peus, *Ae. rossicus Dolbeskin, Ae. vexans* (Meigen), *Anopheles claviger* (Meigen), *An. maculipennis s.l.* Meigen, *An. plumbeus* Stephens, *Culex pipiens s.l.* Linnaeus, *Cx. territans* Walker, *Culiseta annulata* (Schrank), *Coquillettidia richardii* (Ficalbi), *Ochlerotatus annulipes* (Meigen) , *Oc. cantans* (Meigen), *Oc. cataphylla* (Dyar), *Oc. communis* (De Geer), *Oc. excrucians* (Walker), *Oc. flavescens* (Müller), *Oc. geniculatus (Olivier), Oc. intrudens (Dyar), Oc. leucomelas* (Meigen), *Oc. refiki* (Medschid) and *Oc. sticticus* (Meigen). For the first time, typical flood mosquitoes, *Oc. sticticus* and *Ae. vexans,* were recorded together with snow melt mosquitoes, *Oc. cantans* and *Oc. cataphylla,* in early spring of 2005 and 2006 in the Labe Lowlands (50°17´-22´N). Changes in abundance and seasonality of some other species are discussed.

Introduction

In the Czech Republic, mosquitoes can occur in high densities in innundation zones around the banks of major rivers. This study concentrates on two such regions: (1) The Labe Lowlands of Bohemia (western Czech Republic), where the Labe River meets the Vltava River near the town of Mělník, and upstream towards the city of Kolín, and (2) southern and central Moravia (eastern Czech Republic) along the the Morava and Dyje Rivers, extending from the confluence of the two rivers up to the Nove Mlyny water reservoirs on the Dyje River and on the Morava River up to its source (Figure 1). High density larval populations develop in flood plain forests and meadows with temporary water bodies. The annual appearance of mosquito larvae either begins after the snow thaw which leads to elevation of ground water levels, creating temporary water larval sites in terrain depressions, or as a result of early spring floods which can innundate quite large areas. Occasionally mosquito larvae aappear later in the season, after heavy rains or summer floods. Areas around the Morava and Dyje rivers are more frequently flooded than those near the Labe and Vltava rivers (Table 1). Permanent water bodies such as ox bow lakes, fish ponds or artificial containers are not the major source of mosquitoes in these areas and were therefore not observed in detail in this study.

In August 2002, the Mělník region was devastated by the highest flood in the last 500 years. A few days after the flood peak, massive larval populations of *Ochlerotatus sticticus* and *Aedes vexans* mosquitoes were detected (Rettich, 2004). Due to weather extremes in 2006, four floods resulted in a huge increase in mosquito populations. The first flood, which was almost as catastrophic as that in 2002, was caused by the rapid thaw of unusually deep snow at the end of March. Heavy rainfalls in May, July and August caused three further localised floods.

The mosquito fauna of each of these regions have previously been studied in isolation, but there have been no simultaneous monitoring studies.Twenty-five species have previously been reported in the Labe Lowlands (Rettich 1973; 1979; 1982), and 30 from the Morava / Dyje region (Palička 1967; Minář & Hájková, 1970; Minář, Gelbic & Olejníček, 2003) and upper Morava (Lauterer & Chmela, 1977). The aim of this study is to compare determine the mosquito fauna in the Labe Lowlands and in the Morava and Dyje river basins following flood episodes in 2005 and 2006.

Material and methods

In 2005, mosquito larvae were collected in two areas of the Labe Lowlands: Mělník (localities Hořín, Úpor, Štěpán u Obříství, Tuháň and Červená Píska) and Poděbrady (Poděbrady, Polabec, Kluk, Libice) and in Břeclav (Lanzhot, Soutok, Pohansko, Tvrdonice) in Lower Morava. Collections were carried just after the snow thaw in March and April only (no other floods came later in the spring or summer). As well as those localities samples in 2005, the following additional regions were surveyed in 2006: Kolín in the Labe Lowlands

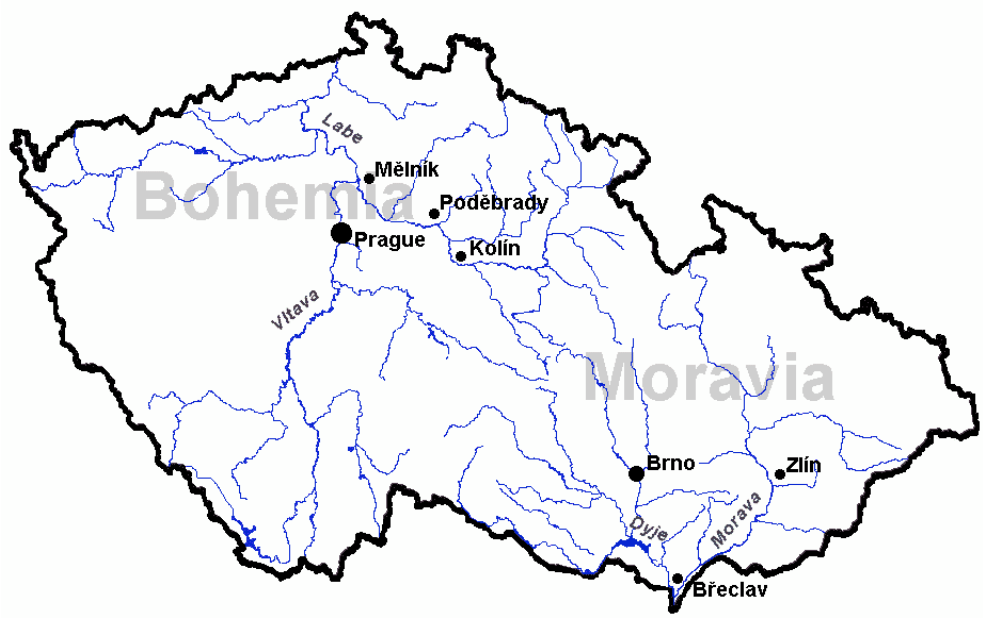

Figure 1: Map of Czech Republic showing the collection sitess in the flood plain areas of Bohemia around the rivers Labe and Vltava (Mělník, Poděbrady & Kolín) and central and southern Moravia around the rivers Dyje and Morava (Břeclav & Zlín).

Region	Bohemia (western Czech Republic) Labe Lowlands		Moravia (eastern Czech Republic) Lower Morava	Central Morava
	Mělník	Poděbrady, Kolín	Břeclav	Zlín
Major rivers	Vltava & Labe	Labe	Morava & Dyje	Morava
Latitude	50°17-22´N	50°06-08´N	48°38-44´ N	48°55-49°10´N
Longitude	14°28-32´E	15°06-10´E	16°55-59´E	17°15-30´E
Altitude (m)	159-161	187-189	151-153	168-180
Spring floods	2000, 2005, 2006*	2000, 2006*	1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006	2006*
Summer floods	1997?, 2002*, 2006	1997?	1997*, 1998, 1999, 2000, 2001, 2002*, 2005, 2006	1997*, 2002*

Table 1: Study areas, with ranges of latitude, longitude and altitude, and details of spring and summer floods between 1997 and 2006. (*indicates catastrophic floods, ? indicates uncertain records).

(Velký Osek and Veltruby) and various sites in central Moravia (Veselí na Moravě, Ostrožská Nová Ves, Nedakonice, Tlumačov and Chropyně and Kroměříž). Figure 1 shows indicates the location of the collection sites and characteristics of the study sites are given in Table 1.

Mosquito larvae were sampled using 10-20 dips per breeding site, using a standard 1,500ml dipper and a wire strainer. Larvae were stored in 80% ethanol prior to identification. Due to the high number of mosquito larvae collected, samples from only one day per month were randomly chosen for analysis, with c.200 larvae per site identified to species. A subsection of immatures caught in the field were also reared through in the laboratory to obtain adults of species difficult to reliably identify as larvae. Where necessary, male hypopygia were dissected and slide-mounted in Swan`s medium.

In 2005, adults were collected at four localities in the Mělník area (Úpor, east Obříství, Tuháň & Červená Píska) from their first appearance in early May, then at 2-3 week intervals until the end of their activity (Table 2). In 2006, adults were collected in the Mělník, Poděbrady and Kolín areas throughout the season, and in the Břeclav area in July only (Table 3). Host-seeking adult females were collected at human bait, using manual aspirators. Three five-minute collections were carried out using one volunteer sitting under flood-plain forest trees at each locality, during the late morning and early afternoon. In the Břeclav area, where density of mosquitoes was intense, adults were also caught by sweeping an insect net around the collector for 1 or 2 minutes. The net was also

	Bohemia (Labe Lowlands)			Moravia
	Mělník		Poděbrady	Břeclav
Species	**April**	**July***	**April**	**April**
Ae. cinereus + rossicus	0.25	3.80	0.13	3.05
Ae. vexans	1.22	78.48	1.07	2.82
An. maculipennis s.l.	-	0.84	-	-
Cx. pipiens s.l.	-	16.88	-	-
Oc .communis	0.01	-	0.03	-
Oc. annulipes + cantans	59.77	-	48.92	27.16
Oc. cataphylla	32.81	-	42.89	5.21
Oc. excrucians	0.01	-	0.02	0.08
Oc. flavescens	-	-	0.03	0.02
Oc. intrudens	-	-	-	9.76
Oc. leucomelas	3.99	-	1.17	0.25
Oc. sticticus	1.95	-	5.74	51.66
Total number of specimens identified	**10,432**	**237**	**5,997**	**5,966**

Table 2: Relative proportions (%) and total numbers of mosquito larvae collected in 3 regions of the Czech Republic in 2005 (Mělník (April and July), Poděbrady (April) and Lanžhot (April)), (*one breeding site only). Note: *Oc. annulipes* and *Oc. cantans*, and *Ae. cinereus* and *Ae. rossicus,* are not differentiated.

used to collect male adults by sweeping the vegetation near breeding sites. Adults were killed using ether, and specimens stored dry prior to morphological identification using the morphological keys of Becker *et al*. (2003).

Results

Relative numbers of mosquito larvae collected in the Labe region and in Lower Morava in the spring of 2005 are summarised in Table 2. In the Mělník and Poděbrady areas of the Labe Lowlands, the early spring (snow melt) species *Oc. cantans* and *Oc. cataphylla* dominated. *Ochlerotatus sticticus* was also dominant in some breeding sites of Úpor near Mělník. A rather early occurrence of *Ae. vexans* was also noted. After the flooding of the Dyje River in the Břeclav area, *Oc. sticticus* dominated, and *Oc. Intrudens* was numerous.

Larval density was recorded in the Labe Lowlands only. Near the confluence of Vltava and Labe rivers, the larval populations were very low (ranging from 0-5.3 larvae per dip). Such low larval densities here in March 2005 could either be attributed to the flood in 2002 (due to egg wash-off), or to a local innundation in mid-March 2005, resulting in wash-off of young larvae. At sites in the Labe Lowlands, larval densities were highest at Tuhan ranging from 26.1-101.8 (mean 61.6) larvae per dip, 15.1-86.4 (mean 51.5) larvae per dip in Cervena Piska and 20.8-80.3 (mean 48.0) larvae per dip in the Poděbrady area. Later in the spring and summer in the Labe Lowlands, the breeding places were dry. The only exception was a meadow site near Mělník where following localised heavy rains and flooding. *Aedes vexans* (78.5%), *Ae. cinereus*, *Cx. pipiens s.l.* and *Anopheles maculipennis s.l.* (0.8%) appeared at the end of June 2005, and again at the end of August (*Ae. vexans,* 76.9%). Some breeding places in the locality of Červená Píska may also have been flooded in August 2005 (not confirmed), as newly hatched females of *Oc. cantans* were caught in rather high quantities.

Numbers of mosquito larvae collected in the Elbe region and in the regions of Lower and Central Morava in the spring and in summer of 2006 are summarized in Table 3. In all three regions, larval development usually begins in mid March, after the snow thaws. At the end of March 2006, a massive flood innundated all mosquito regions in the Czech Republic. During this flood, larval density was recorded in the Labe Lowlands only. Some larvae which had hatched before the flood appeared to have been washed-off or moved downstream with the current. Remaining larval development was slowed down due to the lower temperatures of the flood water. Newly hatched larvae (1^{st}-3^{rd} instars) appeared in most parts of the flooded forests and meadows. In late April, high numbers of mosquito larvae (up to 800 larvae per dip) were concentrated in the flood remnants. A similar situation was observed in Moravia regions in April 2006 before the aerial application of *Bti* larvicides. In in the Zlín and Břeclav areas of the Elbe Lowlands, *Oc. cantans* and *Oc. cataphylla* dominated, alongside *Oc. sticticus*. After a localised flood in the Mělník area (caused by the swelling of the Vltava River), extremely high densities of *Oc. sticticus, Ae. vexans* and *Ae. cinereus* were observed in the beginning of June. Even higher densities (more than 1,000 larvae per dip) were detected in the Břeclav area after two

	Bohemia (Labe Lowlands)					Moravia			
	Kolínsko	Mělník		Poděbrady	Mělník & Poděbrady	Břeclav			Zlín
Month (2006)	**April**	**April**	**May**	**April**	**September**	**April**	**July**	**August**	**April**
Ae. cinereus/ rossicus	0	0.22	0.35	0.05	0	4.24	26.08	7.88	1.90
Ae. vexans	0	0	27.43	0.09	0	8.25	38.16	57.37	7.40
An. maculipennis s.l.	0	0	0.09	0	0	0	0	00	0
Cs .annulata	0	0	0	0	56.60	0	0	0	0
Cx. pipiens s.l.	0	0	0.18	0	28.30	0	0.16	0.05	0
Cx. territans	0	0	0	0	14.15	0	0	0	0
Oc. annulipes/ cantans	77.96	41.94	0	46.85	0	19.63	2.73	0	33.78
Oc . excrucians	0	0	0	0.27	0	0.10	2.09	0.10	0.19
Oc. flavescens	0	0	0	0.18	0	0.03	0.48	0	0.57
Oc. cataphylla	22.04	57.55	0	52.24	0	20.40	0	0	24.86
Oc. communis	0	0	0	0.14	0	1.04	0	0	3.80
Oc. intrudens	0	0	0	0	0	7.10	0	0	0
Oc. leucomelas	0	0.25	0	0.09	0	0.16	0	0	1.71
Oc. refiki	0	0	0	0.05	0	0	0	0	0
Oc. sticticus	0	0.04	71.95	0.05	0.94	39.04	30.27	34.61	25.81
Total specimens identified	**744**	**2,780**	**1,130**	**2,203**	**106**	**6,083**	**621**	**2,043**	**527**

Table 3: Total numbers of mosquito larvae collected in six localities in 2006 (Kolínsko (April), Mělník (April and May), Poděbrady (April), Mělník and Poděbrady (September) and Břeclav (April, July, August) and Zlín (April), showing relative proportions of species identified. Note: *Oc. annulipes* /*Oc. cantans*, and *Ae. cinereus* / *Ae. rossicus,* cannot be reliably differentiated as larvae.

Region	**Labe Lowlands**				**Moravia**	
Locality	**Mělník + Poděbrady**	**Mělník + Poděbrady**	**Mělník + Poděbrady**	**Mělník**	**Břeclav + Zlín**	**Břeclav**
Date	**April 2005**	**April 2006**	**May 2006**	**June 2006**	**April 2006**	**July 2006**
Collection type	**reared**	**reared**	**swept**	**reared**	**reared**	**swept**
Oc. cantans	30.35	15.32	30.77	0	2.87	0
Oc. annulipes	5.06	0.32	64.73	0	0	0
Oc. excrucians	0	0	0.38	0	0	0
Oc. flavescens	0	0	0	0	0	0
Oc. cataphylla	47.42	83.55	2.44	0	48.34	0
Oc. leucomelas	2.42	0	0	0	3.97	0
Oc. intrudens	0	0	0	0	3.35	0
Oc. communis	0	0	0	0	9.49	0
Oc. sticticus	13.75	0.81	0.38	59.01	9.71	77.63
Ae. vexans	0.68	0	0.56	21.51	21.85	13.56
Ae. cinereus	0.11	0	0.19	1.16	0	3.39
Ae. rossicus	0.21	0	0	0	0	4.07
Ae. geminus	0	0	0.56	0.29	0	0.34
An. maculipennis s.l.	0	0	0	0.29	0	0
Culex pipiens s.l.	0	0	0	17.73	0	1.02
Total specimens identified	**1,898**	**620**	**533**	**344**	**453**	**295**

Table 4: Relative proportions (%) of mosquito species in the Labe Lowlands (Mělník + Poděbrady) and Moravia (Břeclav + Zlín) in 2005 and 2006, based on males reared from pupae or collected by sweeping adults on vegetation near breeding sites.

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Area	Mělník	Mělník (*)	Mělník (**)	Poděbrady (*)	Kolín	Břeclav
Date	**May-November 2005**	**May-November 2006**	**May-November 2006**	**May-November 2006**	**May-November 2006**	**July 2006**
Ae. cinereus	0.79	4.67	3.95	3.83	1.00	2.96
Ae. rossicus	0.27	0.01	1.06	0.14	0.12	0.99
Ae. vexans	1.42	1.91	24.28	2.99	2.07	8.13
An. claviger	0.32	0.01	0	0	0.12	0.25
An. plumbeus	0	0.01	0.3	0	0	0
Cq. richiardii	0	0	0	0	0.24	0
Oc. cantans+ Oc. annulipes	83.82	77.46	33,99	81.53	77.80	3.94
Oc. cataphylla	9.71	9.38	1.97	5.76	13.78	1.48
Oc. excrucians	0	0	0	0	0	0.74
Oc. flavescens	0	0	0	0	0	0.25
Oc. sticticus	3.71	6.39	3.,45	5.68	4.88	81.28
Total specimens identified	1,267	2,675	659	1,337	820	406

Table 5: Relative proportions (%) of anthrophophilic mosquitoes in various areas of the LabeLowlands and the Morava / Dyje Lowlands. * flooded in April only; ** flooded in April and June.

floods of the Dyje river in July and August (Table 3).

In the Mělník area, anthropophilic behaviour was first reported on 02 May 2005, peaked at the end of June (mean landing rate = 9.7 per min), and the last biting mosquitoes reported on October 30. In the Labe Lowlands in 2006, the season was similar in length (early May – October 25), but the the peak of activity was recorded slightly later, in mid-July. Owing to localised vector control efforts using larvicides, mosquito density was maintained in bearable numbers, and the maximum landing rate did not exceed 20 mosquitoes per minute; *Oc. cantans / Oc. annulipes* dominated (Table 5). In the area around the confluence of the Vltava and Labe Rivers, almost all larvae were washed away by the rapid currents of the floods in April 2006, and virtually no adults were observed until after the next flood, the following month. From June, *Oc. sticticus* and *Ae. vexans* dominated. Following two localised floods in the Břeclav area, where no control efforts were applied, enormous numbers of attacking females were observed. On July 17, 2006 in Cahov near Břeclav, biting collections around a single volunteer averaged 601 females per minute using net sweeps. *Ochlerotatus sticticus* dominated the collections (Table 5).

Where species were difficult to reliably identify in the larval stages, immatures were reared to adults before dissection and slide-mounting of male hypopygia, i.e. *Oc. annulipes* / *Oc. cantans*, and *Ae. cinereus* / *Ae. rossicus* (see Tables 2 & 3). In 2005, *Oc. cantans* and *Oc. annulipes* comprised 30% and 5% of males identified, respectively. The occurence of both *Ae. cinereus* and *Ae. rossicus* in the Mělník area were reconfirmed using male genitalia. Surprisingly, in April 2006, *Oc. annulipes* was extremely rare (0.3% of the total), whereas *Oc. cataphylla* dominated. However in collections of males swept from vegetation 2-3 weeks after the appearance of the first adults, *Oc. annulipes* dominated and *Oc. cataphylla* was rare. In May 2006, males of *Ae. cinereus* and *Ae. geminus* of the Cinereus Complex were confirmed in the Labe Lowlands using male genitalia. The two species were also found as reared males captured in the Mělník area following a flood in the end of May. In the spring in both Moravia regions, males of *Oc. cataphylla* dominated in reared mosquitoes and no *Oc. annulipes* were found. After a flood in the Břeclav area in July 2006, males of *Oc. sticticus* dominated in material swept from the vegetation near drying pools, and *Ae. cinereus* and *Ae. rossicus* were reported.

Discussion

Previous studies in the Labe basin have reported high mosquito diversity. Twenty-three species were recorded from Poděbrady, sixteen species from Hradec Králové (Eastern Bohemia) and seventeen species from Mělník (Rettich, 1973; 1979; 1982; 2000; 2004). In the Moravia region, the mosquito fauna is even richer than in Labe Lowlands (Palička, 1967; Lauterer & Chmela, 1977; Vaňhara, 1991; Vaňhara & Rettich, 1999). Labuda (1974) found 27 species in the Zahorska Lowlands (southwestern Slovakia), which neighbours the Břeclav area, and Olejníček *et al.* (2003) reported 37 species from central and southern Moravia.

During the study years (2005 & 2006), larvae of seventeen mosquito species were recorded: *Ae.*

vexans, Ae. cinereus, Ae. rossicus, An. maculipennis s.l., Cx. pipiens s.l., Cx. territans, Cs. annulata, Oc. annulipes, Oc. cantans, Oc. cataphylla, Oc. communis, Oc. excrucians, Oc. flavescens, Oc. intrudens, Oc. leucomelas, Oc. refiki and Oc. sticticus. Only one larval specimen of *Oc. refiki* was collected in the Poděbrady area in April 2006. Larvae of *Oc. intrudens* were found in the Moravia regions only. *Aedes geminus* was determined in males captured by sweep netting in the Labe Lowlands and Morava Lowland. Females of another four species (*An. claviger, An. plumbeus, Oc. geniculatus and Coquillettidia richardii)* were captured in human bait collections only.

In the spring of 2005, surprisingly high numbers of *Oc. cataphylla* and *Oc. leucomelas* were found around Mělník. This contrasts with reports from the 1970s when these species comprised only 0.3% and 0.25% of all collected larvae, respectively (Rettich, 1982). The high numbers of *Oc. cataphylla* reported in the Poděbrady area are comparable with previous reports (Rettich, 1973; 2000), however, unexpectedly higher numbers of *Oc. intrudens* larvae were collected in the Břeclav area.

Although common in meadows in Kelské Vinice (Mělník area), *Oc. excrucians* and *Oc. flavescens* were not collected in 2005-2006, possibly as a consequence of egg wash-off during the 2002 flood. *Ochlerotatus communis,* a reportedly rare species in the Labe Lowlands, seems to be further disappearing, with only 2 specimens collected in 2005 and 3 in 2006. *Ochlerotatus punctor* (recorded in Poděbrady in 2000) was not recollected as its regular breeding site was dry in 2005, and polluted by debris during the April flood of 2006. Although Rettich (1973) recorded *Oc. detritus* in Poděbrady in 1969, this was not reconfirmed in this study. *Ochlerotatus caspius,* which was previously found in high numbers in flooded meadows in the Morava and Dyje Basins (Palička, 1967; Lauterer & Chmela, 1977; Labuda, 1994) and in the most eastern part of Labe Lowlands (Rettich, 1979), was not recorded in any of the study sites in 2005 or 2006. Moreover *Oc. caspius* has not been detected in the Morava or Dyje basins in last decade (Minář *at al*., 2001; Olejníček *at al*., 2003), and Chmela (2005) found only one female near Litovel. Similarly *Cs. morsitans,* previously found in high numbers in Poděbrady area in 2000 (Rettich, 2000), was not collected in 2005-2006 nor during regular observations in the springs of 2001-2004 (Rettich, 2004).

In contrast to its regular appearance the early spring in the southern and warmer parts of the Morava and Dyje basins (approx. 48°40´N), studies over the past 35 years have shown that *Oc. stictitus* appears later in the season in the Labe Lowlands (approx. 50°10´N). Surprisingly, in this study, *Oc. sticticus* prevailed in early spring (March – April) in some sites in the Mělník and Poděbrady areas, and was the dominant species in the Břeclav area in our collections in 2005. Hajkova & Minář (1970) and later Minář *et al*. (2001, 2004) observed the appearance of this typically summer species in spring (April) in the lower Morava river regions. Lungström (2005) reported the early appearance of *Oc. sticticus* in Sweden, which he attributed to climate warming. Disappearence of *Cs. alaskaensis* from the Poděbrady area, where the species was common in past (Rettich, 1973), may also be attributed to recent warmer climates. More observations will be needed in future to establish the permanence of our findings.

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