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Description of last instar larva of *Cordulegaster kalkmani* (Odonata: Cordulegastridae)

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Abstract. The final instar larva of *Cordulegaster kalkmani* Schneider, Vierstraete, Müller, van Pelt, Caspers, Ikemeyer, Snegovaya & Dumont 2021 is described and illustrated based on one female exuvia collected in Alakabük, Bitlis province, Turkey, in July 2022. The exuvia of *Cordulegaster kalkmani* is compared with the exuviae of members of the "*boltonii* group" in the eastern part of the Western Palaearctic: *C. vanbrinkae, C. picta,* and *C. heros.* The exuvia of *C. kalkmani* shows no clear distinction in comparison to the other members of the eastern "*boltonii* group".

Key words. Exuviae, habitat, Turkey

Research Article

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Data Availability Statement:
All relevant data are within the paper.

Introduction

Cordulegaster kalkmani was recently described as a Western Palaearctic *Cordulegaster* species (Schneider et al., 2021). The main morphological characters were confirmed by 16 additional males recently collected in Eastern Turkey (Schneider et al., 2022). The special feature of the inferior appendage, which is broader than long so that the distal pointed lobes are visible from above, is unique in the genus. This makes it easy to identify male imagines of this species. *C. kalkmani* belongs to the "*boltonii* group" of *Cordulegaster* species of the Western Palaearctic. This "*boltonii* group" of the Western Palaearctic includes three western distributed species: *C. boltonii, C. trinacriae*, and *C. princeps*, whereas *C. heros, C. picta, C. kalkmani*, and C*. vanbrinkae* are distributed in the east. The exuviae of the "*boltonii* group" are all very similar (Holuša, 2022; Seidenbusch et al., 2015; Verschuren, 1989). The larval stages of *C. kalkmani* are not known so far. In this paper the exuvia of *C. kalkmani* based on a specimen collected in Eastern Turkey in Bitlis province is described. In this region no other member of the "*boltonii* group" occurs (Schneider et al., 2022). We compare it with the characteristics of the exuviae of other related eastern species of the group from different geographical regions (*C. heros, C. picta*, and *C. vanbrinkae*).

Methods

Throughout the paper the term 'exuviae' is used to refer to the final instar exuviae and not to any earlier instar.

Examined material

One exuvia was found during a field trip in Eastern Turkey which took place from 14.vii. to 26.vii.2022 (Schneider et al., 2022). The exuvia was found on a brook (38°21'47.9'' N, 42°45'36.7'' E, 1,988 m a.s.l.) on July 25th, 1 km SE of Alakabük, Bitlis province.

We did not observe any hatching imagines. We assigned the exuvia to *C. kalkmani* based on the fact that the only adults of *Cordulegaster* flying along the brook belonged to this species. Several patrolling males of *C. kalkmani* were caught and determined. One female was observed during oviposition under the shelter of a bush of *Salix* spec.

Sampling

The exuvia was collected on a root of a willow (*Salix* spec.) about 40 cm above the waterline of a little pool where the current velocity was lower. See below for more information on the habitat.

Measurements

For the description and the comparison of the species different measurements were carried out. As all measurements were carried out on one single exuvia of a female larva, we used measurements of sections of intact body parts and those that were only slightly deformed. These included the width and length of the labium and the abdomen. The absolute length of the body and the width of the head, however, cannot be determined accurately from this exuvia. Measurements were done with a sliding gauge (1/100 mm accuracy). Microscopic photographs were taken for measurements of the labium by using a CMEX 5000 (Euromex) camera. The measurement distances in the photos were measured with ImageFotov3 (1/100 mm accuracy).

Description of the larva

General. The larva of *C. kalkmani* has the typical appearance of cordulegastrid larvae (Fig. 1). The total length of the female exuvia is about 47 mm, the color of the body is brown, with no distinct color patterns, the entire body is covered with fine hairs, between the hairs, sediment particles from the habitat adhere to the body. Longer hairs and setae are present at the posterior edge of thorax, abdominal tergites, anterior border of sternites and legs.

Head. Nearly rectangular in dorsal view (Fig. 2A), maximum width about 8 mm, clypeus brown in color, anterior margin of frons with a row of short hairs, compound eyes large, forming antero-lateral angles, interior parts of compound eyes dark brown, segments 5–7 of both antennae are missing in the specimen, length of antennae segments (AS1 = 0.31; AS2 = 0.69; AS3 = 0.33; AS4 = 0.38 mm).

The labium has the general shape of a cordulegastrid (Figs 2B, C, E). Prementum elongated. Length : width ratio of prementum 6.23 : 5.93 = 1.05. Anterior margin of ligula with a row of dense and very short setae, in medial view with two humped protuberances slightly different in shape (Fig. 2D). The lateral margins of prementum with a row of short, regularly arranged setae. The mesial margins of palpal lobes with prominent irregularly pointed teeth (Figs 2B, C, E). Tips of all teeth strongly sclerotized, indicated by a strong brown color. Moveable hooks long and stout with dark brown apex. Prementum in dorsal view with five long setae at the right side, and four short setae medially placed, parts of the left side are missing (Fig. 2E, gray-shaded area). Palpal lobes with five palpal setae, outer margins of palpal lobes with two rows of dense setae (details Fig. 2E).

Thorax. Wing cases nearly parallel, forewings 10.3 mm, hindwings 9.3 mm, sparsely setosed. The anterior margin of forewings extending up to the posterior margin of S3, margin of hindwings almost extends to the anterior margin of S4 (Fig. 1). All legs with rows of setae interrupted by bare areas. Hindlegs extending to 7th abdominal segment, all tarsi with long curved claws, tarsal formula: 3–3–3 (Figs 1, 3B).

Abdomen. The abdomen is enlarged in the middle (Figs 3A, D), maximum width on S5; all tergites with very short setae beside some single longer setae, lateral margins of abdominal segments with rows of some longer setae, no dorsal spines at all (Fig. 3F), posterolateral spines at S9 (Figs 3D, E), only a hump-shaped lateral protuberance on S8, hidden between setae of segment's margin.

The caudal appendages form a cone shaped pyramid in dorsal view (Figs 3A, C). Epiproct (2.49 mm) approximately as long as paraprocts (2.57 mm), cerci (0.89 mm) are less than half as long as epi- and paraprocts. In lateral view, the paraprocts curve slightly ventrally (Fig. 3F).

The ovipositor at S9 curved in a crescent shape does not reach S10, maximum length 2.36 mm (Figs 3D, F).

Habitat

In Bitlis province *C. kalkmani* was found at three localities (Schneider et al., 2022). In the mountainous region south of the highway D 300 (Van Bitlis Yolu) between the Kuskunkiran tunnel at the Bitlis-Van border and westward to Güntepe there are a number of brooks. These brooks feed a stream which runs parallel to the highway and flows near Güntepe into the Kesan River. The brook, where the exuvia was found (Fig. 4), is 70–110 cm broad and about 10–40 cm deep with a stony streambed without submerged vegetation but partially

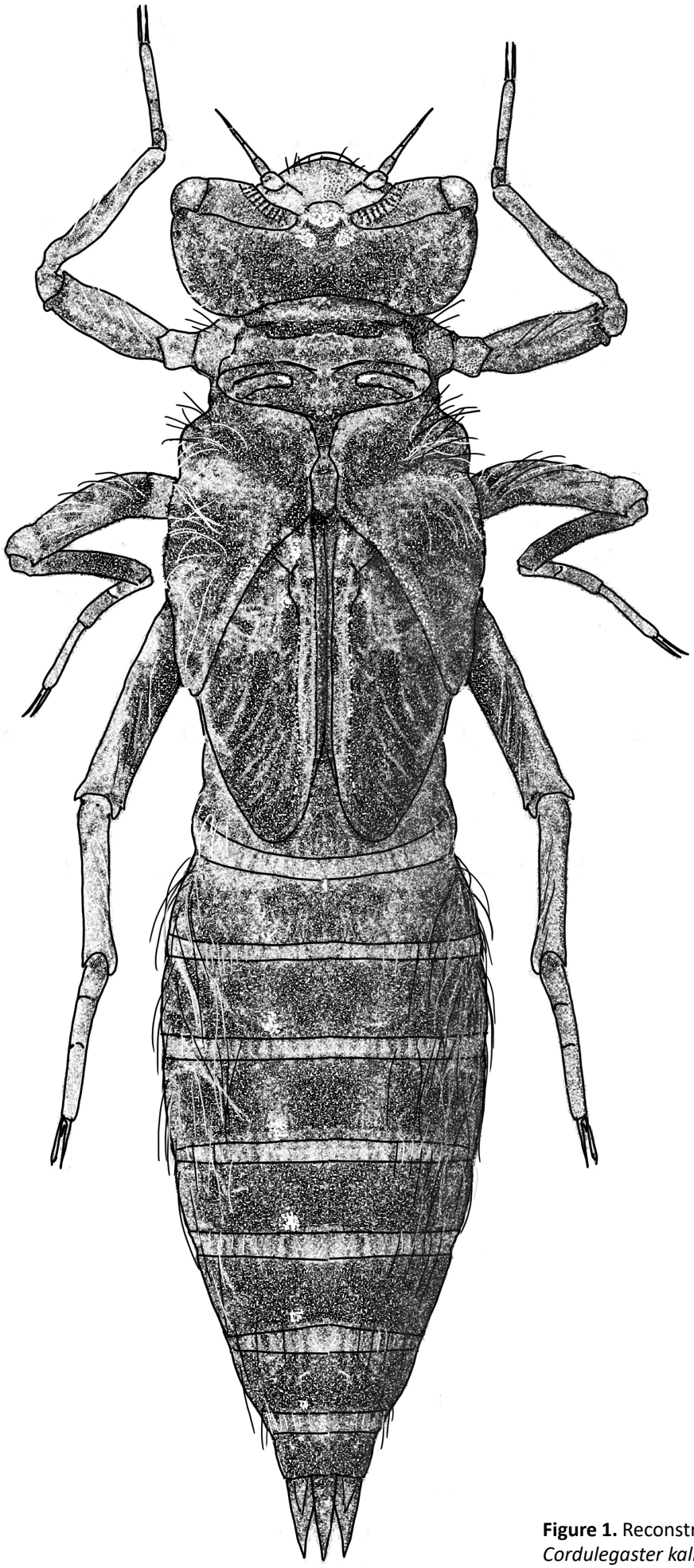

Figure 1. Reconstruction of the last instar of a female larva of *Cordulegaster kalkmani*. Drawing OM

Table 1. Comparison of measurements of different *Cordulegaster* species (*Holuša 2022).

species	*Cordulegaster kalkmani*	*Cordulegaster heros**	*Cordulegaster picta**	*Cordulegaster vanbrinkae**
N	1	30	30	30
Length of spine on segment 8	0	0.3–0.5	0–0.25	0
Length of spine on segment 9	0,23	0.4–0.6	0.15–0.35	0.05–0.3
Ratio lateral spine 9/segment 9	0,10	0.20–0.32	0.12–0.22	0.03–0.15
Number of palpal setae	5	5	5	5
Number of long premental setae	5	5	6 (rarely 7)	5 (rarely 6)
Number of short premental setae	4	2–3	3–4	1–3

shaded by bushes and trees (*Salix* spec.). Its flow velocity was about 2–3 km/h. Sections with ripples alternated with low-flow calm water with sandy sediments or detritus. Pools caused by larger stones created a mosaic with variable flow conditions and substrate patches. The habitat is shown in Figure 4.

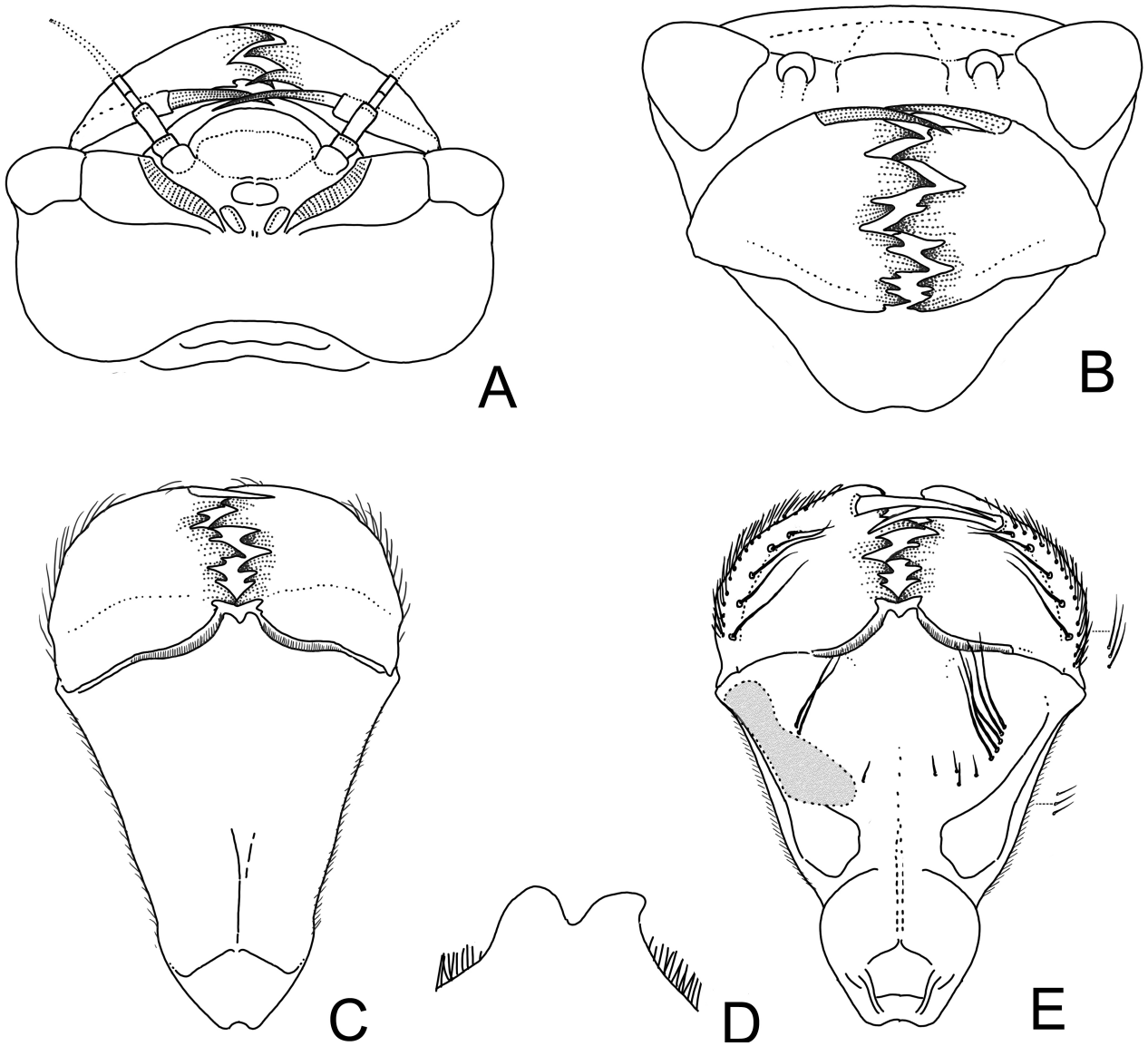

Figure 2. Head of larva of *Cordulegaster kalkmani.* A – head, dorsal view (dotted lines indicate missing antennae segments); B – head, frontal view; C – labium, ventral view; D – anterior margin of ligula in ventral view; E – labium, dorsal view (missing structures indicated with gray-shaded area). Drawing OM

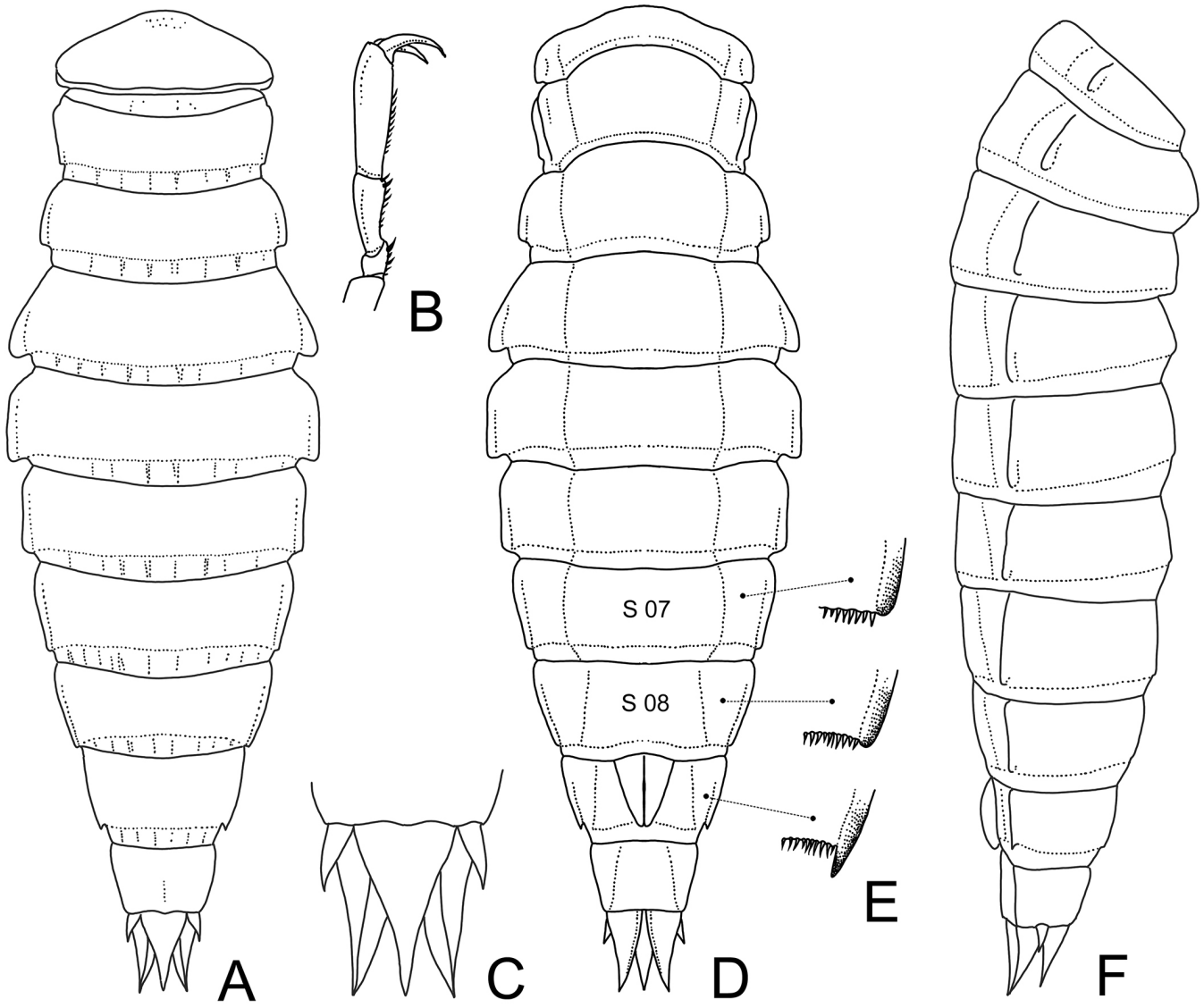

Figure 3. Details of the abdomen and the thorax of the larva of *Cordulegaster kalkmani.* A – abdomen, dorsal view; B – tarsus, hindleg; C – anal pyramid, dorsal view; D – abdomen, ventral view; E – details of lateral spines or protuberances, lateral view; F – abdomen lateral view. Drawing OM

Figure 4. Habitat of *Cordulegaster kalkmani* where the exuvia was collected. Two sections of the same brook are shown, 38°21’47.9’’ N, 42°45’36.7’’ E, 1,988 m a.s.l., East Turkey, Bitlis province.

Discussion and conclusions

Cordulegaster kalkmani is a recently described Western Palaearctic *Cordulegaster* species (Schneider et al., 2021, 2022). It belongs to the "*boltonii* group" and is the only member of this group in the Western Armenian Highlands (Schneider et al., 2022). The exuviae of *C. picta* (*pictus*) and *C. heros* were already described by Verschuren (1989), the exuvia of *C. vanbrinkae* was first described by Seidenbusch et al. (2015) and then again together with the larvae by Holuša (2022). The exuvia of *C. kalkmani* is described here for the first time and is compared to the other eastern members of the West Palaearctic "*boltonii* goup". In the region where the exuvia was found no other member of the "*boltonii* group" occurs (Schneider et al., 2021, 2022).

The rather slender and elongated prementum, and five or fewer premental setae is in line with the eastern members of the *boltonii* clade-(group) already recognized by Verschuren (1989). Seidenbusch et al. (2015) worked out several differential criteria in the morphology of exuviae between *C. vanbrinkae* and *C. picta*, for example, shorter epiproct and paraprocts in comparison with length of mentum, length of supraanalis and length of tergite 10 and sternite 10. *Cordulegaster kalkmani* clearly fits within the proportions of the other three species of this group. All the species show the same number of palpal setae: five. On the prementum *C. picta* mostly has six long premental setae while the other species have five (rarely six in *C. vanbrinkae*). The number of short premental setae varies among different species and within the same species. *Cordulegaster heros* and *C. vanbrinkae* have no more than three short premental setae, *C. picta* vary between three and four and *C. kalkmani* has four. On the abdomen, *C. heros* has lateral spines on S8, *C. picta* shows variation in this criterion whereas *C. vanbrinkae* has no lateral spine on S8. The exuvia of *C. kalkmani* doesn't have lateral spines on segment 8. *Cordulegaster heros* has stronger lateral spines on segment 9 than *C. kalkmani*, *C. picta*, and *C. vanbrinkae*.

Holuša (2022) compares the length of the cerci in relation to the length of S10. His data suggest that cerci are longer than S10 in all compared species. However, examination of his figure of *C. vanbrinkae*, does not support this view. Furthermore, our own data of exuviae of *C. vanbrinkae* and the published data by Seidenbusch et al. (2015) do not support either this assumption. Indeed, the cerci of exuviae of *C. vanbrinkae* are shorter than S10.

Using our morphological data plus credible published characters a first attempt of a dichotomic key that summarizes the main differences between these four species is made. As already stressed, with only one exuvia of *C. kalkmani* it is not possible to confirm intraspecific morphological differences. Nevertheless, a start has been made:

1 Number of short premental setae ≥ 4 2
..... (*C. picta* & *C. kalkmani*)
1' Number of short premental setae < 4 3
..... (*C. heros, C. vanbrinkae* & *C. picta*)
2 Number of long premental setae 6 to 7 ..... *C. picta*
2' Number of long premental setae 5 ..... *C. kalkmani*
3 Length of spine on segment 9 ≥ 0.40 mm ... *C. heros*
3' Length of spine on segment 9 < 0.40 mm .....
..... (*C. vanbrinkae* & *C. picta*)
4 Anal pyramid short; length of tergite 10 : length of epiproct = 1 : < 2.1 .....
or length of sternite 10 : length of paraprocts = 1 : < 1.4 ..... *C. vanbrinkae*
4' Anal pyramid long; length of tergite 10 : length of epiproct = 1 : > 2.1 .....
or length of sternite 10 : length of paraprocts = 1 : ≥ 1.5 ..... *C. picta*

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