# Further biting midges (Diptera: Ceratopogonidae) in Canadian Cretaceous amber

**Art Borkent**

**Abstract**—A collection of 55 Canadian amber Ceratopogonidae is described, including two new species, *Protoculicoides ciliatus* Borkent and *Stilobezzia pikei* Borkent. The male of *Protoculicoides depressus* Boesel is newly described and the two males previously identified as members of this species are designated holotype and paratype of *P. ciliatus*. A new key to the species of *Protoculicoides* Boesel is provided. A male genitalia of *Peronehelea chrimikalydia* Borkent is additionally described and a specimen that is possibly a gynandromorph, a female with an associated male genitalia or a new species of *Peronehelea* Borkent is described.

**Résumé**—Nous décrivons une collection de 55 spécimens de Ceratopogonidae du Canada préservés dans l'ambre. Cette collection inclut deux nouvelles espèces, *Protoculicoides ciliatus* Borkent et *Stilobezzia pikei* Borkent. Nous décrivons pour la première fois le mâle de *Protoculicoides depressus* Boesel et deux mâles identifiés originalement comme appartenant à cette dernière espèce et qui sont ici désignés comme holotype et paratype de *P. ciliatus*. Nous proposons une nouvelle clé pour les espèces de *Protoculicoides* Boesel. Sont également décrites les pièces génitales mâles de *Peronehelea chrimikalydia* Borkent, et d'un autre spécimen qui est possiblement un gynandromorphe, une femelle associée avec des pièces génitales mâles attachées à son abdomen, ou une nouvelle espèce du genre *Peronehelea* Borkent.

## Introduction

Biting midges are remarkably abundant and diverse in various ambers of the world (Borkent 2000a). Based on thousands of specimens, 271 fossil species have been described from more than 18 deposits, from 15-million-year-old Dominican Republic amber to 120-million-year-old Lebanon amber. This abundant described material, combined with at least a partial understanding of the species phylogenetic relationships, provides the Ceratopogonidae with perhaps the best-understood fossil record of any diverse insect family.

Canadian Cretaceous amber is dated at 76–80 million years ago and originates in southern Alberta, with some transported eastward by river action into Cedar Lake in Manitoba, where it was found in large quantities before the deposition area was tragically flooded by a dam. The 261 Ceratopogonidae available from this deposit were comprehensively described by Borkent (1995). While that manuscript was being prepared, Ted Pike studied the total insect fauna of the Grassy Lake, Alberta deposit and accumulated a further collection of 76 specimens he identified as Ceratopogonidae (Pike 1995). That collection was deposited in the Royal Tyrrell Museum of Palaeontology (RTMP) and this paper presents the results of my examination of many of these specimens as well as some additional material housed there.

## Materials and methods

This study was based on the examination of 29 males, 23 females, and three specimens of uncertain sex of Ceratopogonidae present in 52 pieces of amber, all housed in the RTMP and collected at Grassy Lake, Alberta, a site more fully described by Borkent (1995) and Pike (1995). All but six of the amber pieces had been previously ground flat, polished, and placed in bioplastic on microscope slides as described

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by Pike (1995). The single male specimen of *Protoculicoides depressus* Boesel, originally in a larger piece of amber, was ground down, polished, examined from different angles in mineral oil, and then mounted on a microscope slide in Canada Balsam as described by Borkent (1995).

Each specimen bears a reference number used by the RTMP. Often other numbers are also present. Those studied by Pike (1995) were written with coloured felt pens and many were given a series of numbers by the RTMP beginning with TMP 91.148. The latter were supplanted with the most recent number series TMP 96.9. Ted Pike prepared all microscope slides that are 46 mm long. I added locality and collector labels to those specimens missing these.

Specimens were examined, measured, and drawn using a Wild M3 dissecting microscope (Wild Heerbrugg, Gais, Switzerland) and a Zeiss Jenaval compound microscope (Carl Zeiss, Jena, Germany). Photomicrographs were taken with a Nikon CoolPix 995 (Nikon Corporation, Natori, Japan) through a Zeiss Jenaval compound microscope.

Terms of structures follow those in the Manual of Central American Diptera (Cumming and Wood 2009) and Borkent (1995) with additional modifications for some wing veins and cells by Szadziewski (1996). The costal ratio (CR) is the length of the costa measured from the arculus divided by wing length. Material studied or reported on here is deposited in the following museums:

CNCI – Canadian National Collection of Insects, Arachnids, and Nematodes, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada.

ROM – Department of Entomology, Royal Ontario Museum, Toronto, Ontario, Canada.

RTMP – Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta, Canada.

## Results

Of the 55 specimens housed at the RTMP, a few were of particular interest and are described more fully and/or discussed below. All material from the RTMP studied here is listed further below.

### *Atriculicoides globosus* (Boesel)

(Figs. 1A–1B)

*Lasiohelea globosa* Boesel, 1937: 47. Cedar Lake, Manitoba, Canada. Upper Cretaceous (ROM).

*Lasiohelea cretea* Boesel, 1937: 46. Cedar Lake, Manitoba, Canada. Upper Cretaceous.

*Atriculicoides globosus*: Borkent (1995: 39).

This species was redescribed by Borkent (1995) and, because 13 males and 31 females were available for study, nearly all taxonomically important features are known. As a supplement to that redescription, I provide two photos of a female (TMP 96.9.549) that depict particularly excellent perspectives of the medially abutting ommatidia, antenna (Fig. 1A), and wing (Fig. 1B).

### *Protoculicoides depressus* Boesel

(Figs. 2A–2C)

*Protoculicoides depressus* Boesel, 1937: 51. Cedar Lake, Manitoba. Upper Cretaceous. Borkent (1995: 34) (in part: female); Szadziewski (1996: 31); Szadziewski and Arillo (1998: 294); Borkent (2000a: 364).

*Diagnosis*. *Male adult*. Only Cretaceous Ceratopogonidae with a CR = 0.80 (all others with CR ≤ 0.62) and without macrotrichia on the wing membrane. *Female adult*. Only species of *Protoculicoides* Boesel with a wing length >1.00 mm (only specimen = 1.6 mm).

*Description*. *Male adult*. Eyes without pubescence. Antennae missing. Palpus (Fig. 2B) elongate, with five segments, pit not visible on segment 3. Male scutum with numerous long setae, pattern not visible. Legs slender, unarmed except for pair of thick bristles at apex of tarsomeres 1–4 of each leg. Midleg tibia without apical spur. Apex of hind leg tibia with 4–5 elongate setae, spur present. Hind leg tarsomere 1 straight, with scattered setae along entire length, without basal thick spine. Claws apically simple. Wing (Fig. 2A) length = 0.97 mm, CR = 0.85, membrane with fine microtrichia, macrotrichia absent, alula with macrotrichia, cells $r_1$, $r_{2+3}$ well defined, elongate, M bifurcating distal to r-m. Genitalia (Fig. 2C): Tergite 9 with well-developed apicolateral process, setae on apicolateral process not visible. Gonocoxite elongate, slightly curved. Gonostylus elongate, slender, evenly curved apically. Paramere elongate, slender, apex rounded. Aedeagus not visible.

*Female adult*. As described by Borkent (1995: 34).

*Distribution and bionomics*. *Protoculicoides depressus* is known from amber collected from the



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**Fig. 1.** (A and B) Female *Atriculicoides globosus*. (A) Head, anterior view and (B) left wing, dorsal view. (C and D) Female *Stilobezzia pikei*. (C) Legs and (D) left midtarsomeres. (E) Habitus of *Peronehelea chrimikalydia*, of uncertain sex. Scale bars = 0.2 mm.

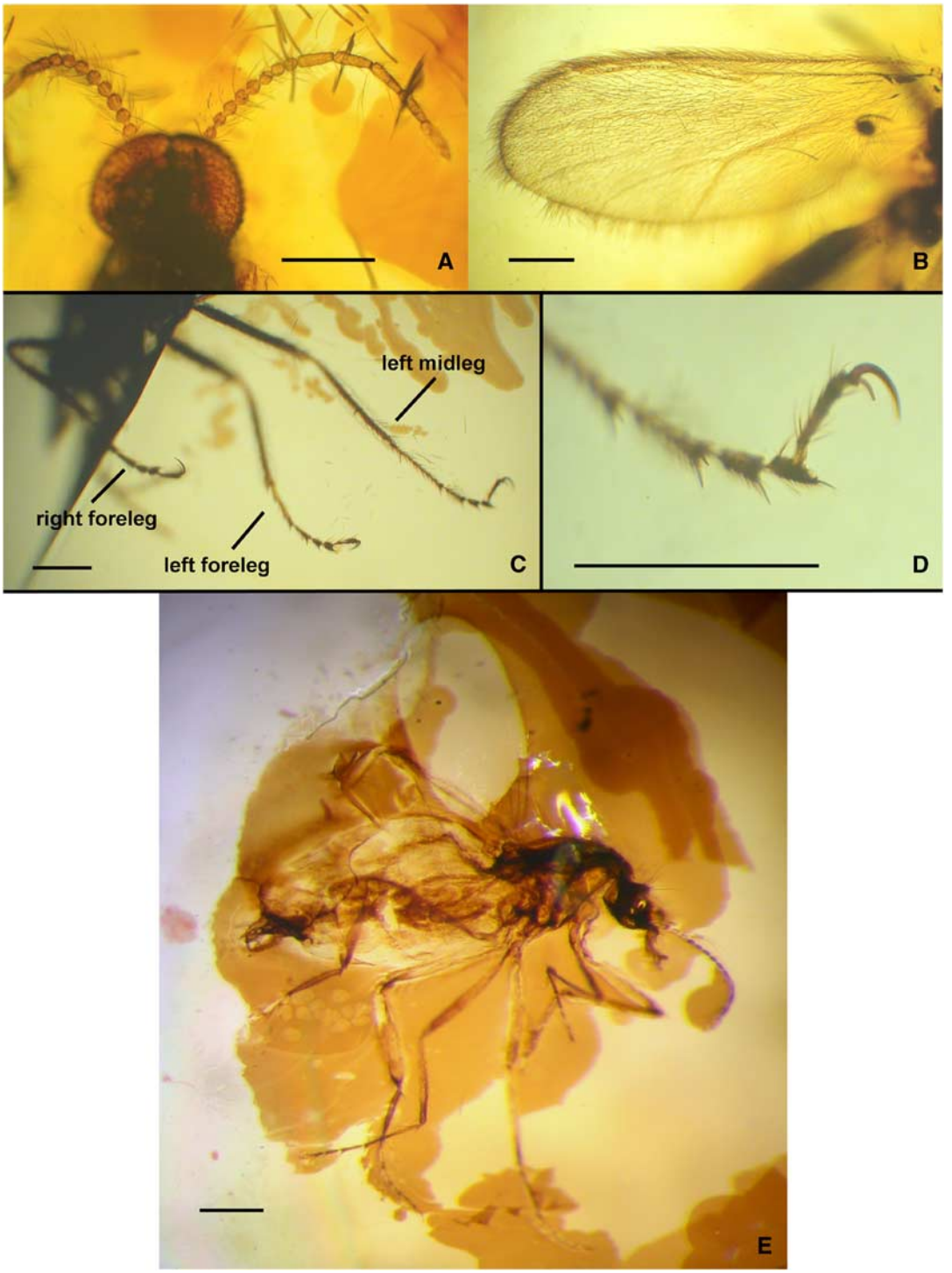




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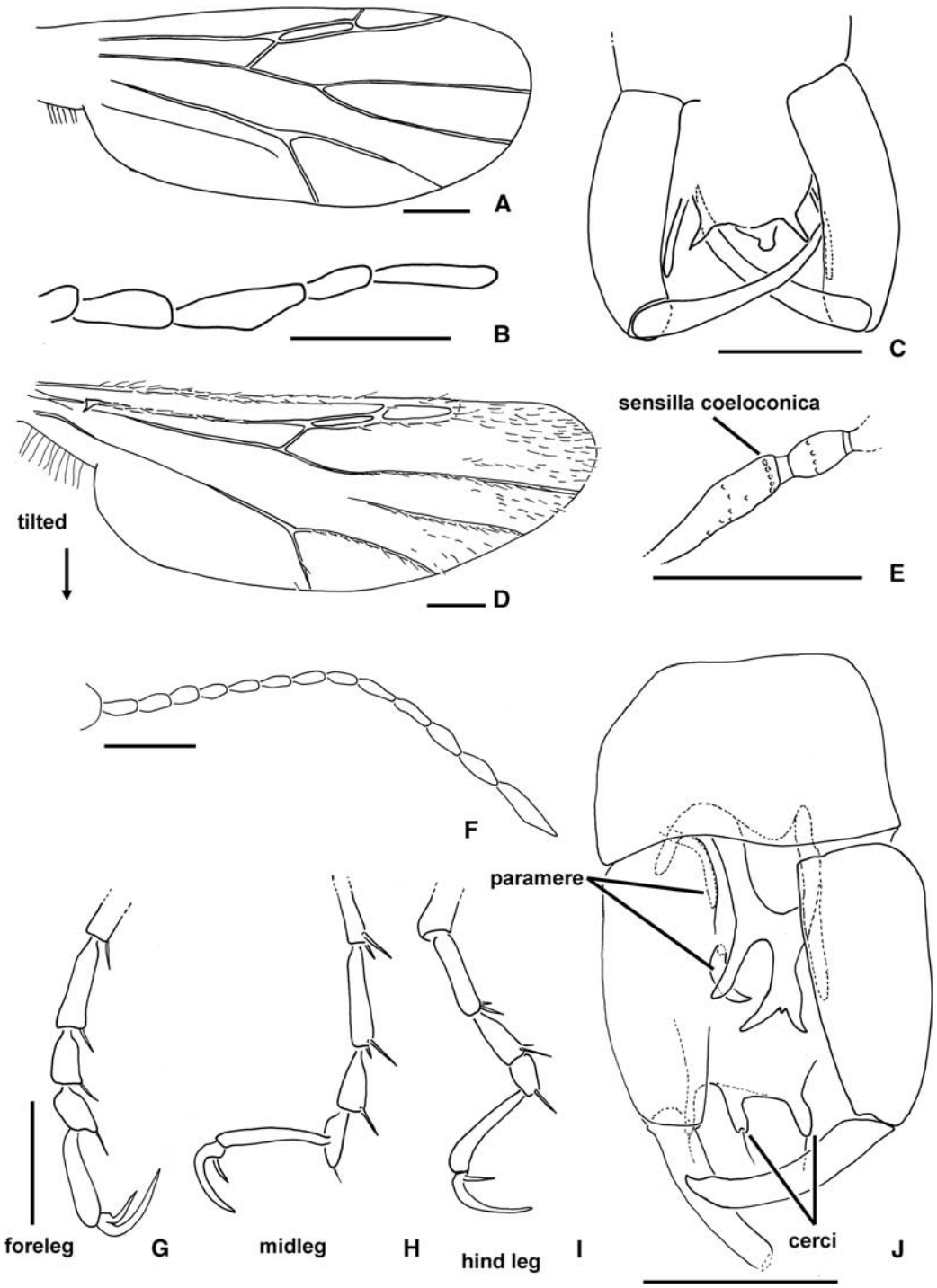
**Fig. 2.** (A–C) Male *Protoculicoides depressus*. (A) Left wing, inverse image; (B) left palpus; and (C) genitalia, dorsal view. (D) *Stilobezzia pikei* right wing. (E) *Peronehelea chrimikalydia*, flagellomeres 1 and 2. (F–I) *S. pikei*. (F) Left antenna; (G) foretarsomeres; (H) midtarsomeres; and (I) hind tarsomeres. (J) *P. chrimikalydia* male genitalia, ventral view. Scale bars = 0.1 mm.



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shore of Cedar Lake, Manitoba, Canada (holotype female) and from 5 km south of Grassy Lake, Alberta, Canada (the male newly described here). The mouthparts of the single known female could not be seen, so its feeding habits are uncertain.

*Taxonomic discussion*. Borkent (1995) associated two male *Protoculicoides* from Grassy Lake (the only males of the genus otherwise then known from Canadian amber) with the previously described female holotype of *P. depressus*. Szadziewski (1996) noted the macrotrichiae on the wing membrane of these males were absent in the female, therefore making the association unlikely (in extant species, females always have more macrotrichiae than males). The male described here also lacks wing membrane macrotrichiae suggesting that it is more likely the male of *P. depressus*. This male, however, has a wing length of 0.97 mm, substantially smaller than that of the female at 1.63 mm. The two males previously associated with the female by Borkent (1995) are here described below as a new species.

*Material examined*. 1 male: Grassy Lake, Alberta, Canada, E.M. Pike, TMP 1996.9.261 (RTMP).

### *Protoculicoides ciliatus* Borkent, new species

*Protoculicoides depressus* Borkent, 1995: 34 (in part: males).

*Diagnosis. Male adult.* Only species of *Protoculicoides* with macrotrichiae on the wing membrane. *Female adult.* Unknown.

*Description. Male adult.* As described as *P. depressus* by Borkent (1995: 34).

*Distribution and bionomics*. This species is known only from the type locality at Grassy Lake, Alberta, Canada. The amber with the paratype male also included a female *Culicoides filipalpis* Remm.

*Taxonomic discussion*. The two males described here as *P. ciliatus* were associated with the female holotype of *P. depressus* by Borkent (1995) but, as noted above, probably incorrectly so. As such, they are recognised as a new species here.

The diagnosis of the genus *Protoculicoides* by Szadziewski and Poinar (2005) notes the absence of macrotrichiae on the wing membrane, whereas *P. ciliatus* bears these at the wing apex. Thus, this feature of the generic diagnosis should be modified to "wing membrane without macrotrichiae or with some at apex".

*Types*. Holotype, male adult in amber, in Canada Balsam on a microscope slide labelled: "HOLOTYPE *Protoculicoides ciliatus* Borkent", "nr. Medicine Hat, Alta., June, 1976, McAlpine, Cooper, Daze, CAS 1231" (CNCI). Paratype, male adult mounted and labelled as for holotype, except CAS 1015 (CNCI).

## Key to species of *Protoculicoides*

With the addition of *P. ciliatus* above and the newly recognised male of *P. depressus*, there are now six species of *Protoculicoides* known and a need to modify the key to species. *Protoculicoides ciliatus* and *P. burmiticus* Szadziewski and Poinar are known only as males and *P. skalskii* Szadziewski and Arillo and *P. succineus* Szadziewski only as females. The following key is based primarily on that by Szadziewski and Poinar (2005).

1. Female with wing length of 1.6 mm . . . . . *P. depressus* Boesel (upper Cretaceous Canadian amber)
— Male or female with wing length <1.0 mm . . . . . 2

2. Wing apex with macrotrichiae on membrane . . . . . *P. ciliatus* Borkent (upper Cretaceous Canadian amber)
— Wing without macrotrichiae on membrane . . . . . 3

3. Palpal segments 4 and 5 almost equal in length . . . . . 4
— Palpal segment 4 much shorter than segment 5 . . . . . 5

4. First and second radial cells similar in length; female CR = 0.73 . . . . . *P. skalskii* Szadziewski and Arillo (lower Cretaceous Spanish amber)
— Second radial cell longer than first radial cell; female CR = 0.94 . . . . . .*P. punctus* Borkent (lower Cretaceous Lebanese amber)



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5. Palpal segment 3 elongate, slender (Fig. 2B); gonostylus slender for nearly entire length . . . . . *P. depressus* Boesel (upper Cretaceous Canadian amber)

— Palpal segment 3 short, squat; gonostylus either tapering or widening from base . . . . . 6

6. Gonocoxite relatively short, tapering from near base to apex; gonostylus tapering from base to pointed apex . . . . . *P. succineus* Szadziewski (lower Cretaceous Lebanese amber)

— Gonocoxite relatively elongate, nearly parallel-sided; gonostylus widening from base to claw-like apex . . . . . *P. burmiticus* Szadziewski and Poinar (lower Cretaceous Burmese amber)

*Derivation of specific epithet*. The name *ciliatus* (hairy) refers to the distinctive (for the genus) setose wings of the male of this species.

### ***Stilobezzia pikei* Borkent, new species**

(Figs. 1C–1D, 2D, 2F–2I)

*Diagnosis*. *Male adult*. Unknown. *Female adult*: Only Cretaceous species of Ceratopogonidae with elongate, unequal-sized claws on each leg and hind tarsomere 1 with a subbasal spine.

*Description*. *Male adult*. Unknown. *Female adult*. Head: Eyes bare. Ommatidia separated medially by width of two ommatidia. Antenna (Fig. 2F) with 13 separate flagellomeres, antennal ratio = 0.93, flagellomeres 9–13 more elongate than preceding flagellomeres, first flagellomere without sensilla coeloconica. Mouthparts moderately elongate, mandible serrate (eight teeth observed on one mandible). Palpus with five segments, further details not visible. Thorax: Most details not visible. Scutum with elongate setae. Wing (Fig. 2D): Length = 0.77–0.84 mm ($n = 3$), CR = 0.58–0.76 ($n = 3$). Membrane with very fine microtrichiae, macrotrichia scattered on apical portion. Alula present. Both radial cells well developed, of equal length. M bifurcating distal to r-m. Legs (Fig. 1C): Femora, tibiae slender. Midleg tibia without apical spur. Foretarsomeres, midtarsomeres, hind tarsomeres 1–4 with pair of apical spines. Foretarsomere 1 with one to two spines along length. Hind leg tarsomere 1 with thick basal spine, with well developed, single row of palisade setae along the entire length. Tarsomeres 4 cordiform. Foreleg, midleg, hind leg claws each with single long talon, single basal slender tooth (Figs. 1C–1D, 2G–2I). Claws on all legs of equal length. Empodium not visible. Genitalia: Most details not visible. Cerci of moderate length.

*Distribution and bionomics*. *Stilobezzia pikei* is known from three specimens from the type locality at Grassy Lake, Alberta, Canada. Among extant taxa, unequal claws and a thick basal spine on hind tarsomere 1 are present only in those species in which females suck blood from other insects, generally those of nearly equal size. This indicates that *S. pikei* was predaceous.

*Taxonomic discussion*. The only other Cretaceous species of *Stilobezzia* Kieffer known is *Stilobezzia kurthi* Borkent from New Jersey amber (Borkent 2000b). It lacks the strong subbasal spine on hind tarsomere 1, which is present in *S. pikei*.

Wirth and Grogan (1988) recognised four subgenera of *Stilobezzia*. *Stilobezzia pikei*, with wing macrotrichiae, two radial cells and cordiform fourth tarsomeres, would be placed in the subgenus *Acanthohelea* Kieffer. However, the entire genus requires a cladistic study to indicate monophyletic groups and, therefore, the proper placement of this fossil.

The holotype was in excellent condition but the body was partially collapsed and situated along a distorting plane within the amber.

*Type*. Holotype, female adult in amber embedded in bioplastic and mounted on a microscope slide, labelled: "HOLOTYPE *Stilobezzia pikei* Borkent", "Grassy Lake, Alberta, E.M. Pike", "TMP 96.9.116" (RTMP). Paratypes: Two females from type locality (TMP 96.9.136, TMP 96.09.772) (RTMP).

*Derivation of specific epithet*. The name *pikei* is proposed to honour Edward (Ted) M. Pike, who collected and prepared, through great effort, most of the specimens examined for this paper.



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### *Peronehelea chrimikalydia* Borkent

*Peronehelea chrimikalydia* Borkent, 1995: 82. Canada (Alberta). Upper Cretaceous.

Five specimens were in the collection: three males, one female, and one of uncertain sex (see below). Male specimen (TMP 96.9.740) showed a particularly fine view of the general features of the male genitalia (Fig. 2J) originally described by Borkent (1995). As noted in that work, there is significant variation in the material at hand (gonostylus shape, female claws) that may indicate the presence of more than one species.

The original description of *P. chrimikalydia* stated that the first flagellomere of the female antenna was "likely with sensilla coeloconica". Specimen 96.9.83 has a female-like antenna (see below) and flagellomere 1 has a row of sensilla coeloconica clearly present, each with fine spicules defining their margins (Fig. 2E).

Specimen 96.9.83 was particularly interesting because I could not be certain of its sex. The specimen was mostly cleared and the head, thorax, and abdomen quite distorted (Fig. 1E). The antennae had the terminal five flagellomeres elongate (as in Borkent 1995: Fig. 17I) and the hind leg claw was elongate (as in Borkent 1995: Fig. 18H). Both mandibles were visible and had large teeth. These features indicate the specimen is a female. The badly distorted apex of the abdomen has a gonocoxite, gonostylus, and aedeagus, suggesting the specimen may be either a feminised male (and perhaps an unnamed species) or a gynandromorph. Equally intriguing is the possibility that this is an example of a female with a postcopulatory, separated male genitalia clinging to the apex of its abdomen, although the posterior direction of the male genitalia would argue against this. In extant taxa of Ceratopogonidae in which the female feeds on the blood of the male during copulation and the male genitalia subsequently breaks off of the dried male abdomen and remains as a mating plug, the male genitalia remain in a mating position, with the apex of the genitalia directed anteriorly. Finally, there remains the possibility that this is a fortuitous association of a separate male genitalia lodged against that of a female (details of which could not be seen) and with the rest of the male body destroyed by an unknown historical process. Unfortunately, the specimen was too distorted to distinguish among these possibilities.

## Specimens from the RTMP studied here

I examined 55 specimens of Ceratopogonidae from the RTMP and these are listed below, in more-or-less phyletic sequence (Borkent 1995, 2000a). Some of those were collected by Pike (1995) who recorded 76 specimens of Ceratopogonidae from 60 pieces of amber and which are purported to be in the RTMP (Pike, personal communication, Calgary, Canada). I examined at least 48 of his specimens, of which seven were actually Chironomidae (96.9.90, 96.9.103, 96.9.107, 96.9.115, 96.9.121, 96.9.122, 96.9.1284) and 41 were identified as Ceratopogonidae.

*Leptoconops primaevus* Borkent: 96.9.748 – 1 male; 96.9.769 – 1 female; 96.9.736 – 1 male.
*Protoculicoides depressus*: 96.9.261 – 1 male.
*Atriculicoides globosus*: 96.9.549 – 1 female; 96.9.774 – 1 male; 96.9.775 – 1 female; 82.15.81 (not slide-mounted, in vial) – 1 male; 96.9.110 – 1 male; 96.9.135 – 1 male.
*Atriculicoides* Remm sp.: 96.9.120 – 1 female, 96.9.754 – 1 female; 92.08.05 – 1 male.
*Adelohelea glabra* Borkent: 96.9.54 – 1 female.
*Heleageron arenatus* Borkent: 96.9.550 – 1 female.
*Culicoides filipalpis*: 96.9.117 – 1 female; 96.9.124 – 1 female; 96.9.98 – 1 female.
*Culicoides* Latreille sp.: 96.9.91 – 1, sex uncertain; 96.9.108 – 1, sex uncertain; 96.9.112 – 1 male; 96.9.119 – 1 male, 1 female; 96.9.118 – 1 male; 96.9.125 – 1 male; 96.9.739 – 1 male; 96.9.747 – 1 male; 96.9.749 – 1 female; 96.9.1095 – 1 female; 92.08.07 – 1 male; 96.9.100 – 1 male; 96.9.138 – 1 male.
*Palaeobrachypogon vetus* Borkent: 96.9.738 – 1 male
*Palaeobrachypogon* Borkent sp.: 96.9.99 – 2 females; 96.9.153 – 1 female; 96.9.1223 – 1 male; 96.9.111 – 1 male; 96.9.146 – 1 male; 96.9.750 – 1 female.
*Stilobezzia pikei*: 96.9.116 – 1 female (holotype); 96.9.136 – 1 female, paratype; 96.9.772 – 1 female, paratype.



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*Peronehelea chrimikalydia*: 96.9.83 – 1, sex uncertain; 96.9.106 – 1 female; 96.9.149 – 1 male; 96.9.740 – 1 male; 96.9.770 – 1 male.

**Genus uncertain:**

*Culicoides* (?): 96.9.157 – 2 males.

*Atriculicoides* or *Culicoides*: 96.9.158 – 1 female; 96.9.741 – 1 male.

*Palaeobrachypogon* (?), possibly *Heleageron* (?) Borkent: 96.9.746 – 1 male.

*Peronehelea* Borkent (?): 96.9.123 – 1 male.

Ceratopogonidae – 82.15.89 (not slide-mounted, in vial) – female.

## Additional observations

Poinar *et al*. (1993) reported the earliest record (at that time) of animal–animal parasitism, based on mites on, or associated with, four Canadian amber midges purported to be members of the subfamily Ceratopogoninae. Re-examination of three of these four specimens revealed that they are a female Chironomidae (TMP 92.8.4), a male *Atriculicoides* (TMP 92.8.5; otherwise in too poor condition to identify to species) and a male *Culicoides* (TMP 92.8.7; probably an unnamed species but with its genitalia in too poor a perspective to adequately describe). Borkent (1995: 42) noted that the fourth specimen, a male shown in a photograph in Poinar *et al*. (1993) is likely an *A. globosus* but its identity will remain uncertain until it is re-examined. The specimen is currently on display and unavailable for loan. The Erythraeidae mites on the Chironomidae and *Atriculicoides* were attached while the trombiid mite (identification by Poinar *et al*. 1993) was well separated from the *Culicoides*. Therefore, confirmed parasitism (attachment) is present only in the subfamily Forcipomyiinae (*Atriculicoides*), with a possible association in the Ceratopogoninae (*Culicoides*).

One female *Palaeobrachypogon* (TMP 96.09.750) likely represents an unnamed species but I do not provide a full description here until further material is available and the genus more comprehensively revised. This female is well preserved and similar to *Palaeobrachypogon aquilonius* (Boesel), with macrotrichiae on the wing apex, a similar head and antennae but with unequal foreleg and midleg claws and short, equal hind claws. The radial cells of the wing are more open than those of other species of *Palaeobrachypogon* (Borkent 1995, 2000b).

Borkent (2000a) demonstrated the value of examining syninclusions in single pieces of amber in estimating community diversity. Nearly, all the specimens here had been previously ground and slide mounted. However, at least for some of this material, Pike (1995: 57–60) recorded syninclusions by using the same last number in the TMP 91.148 series, a numbering system supplanted by the TMP 96.9 series (that reported here). As such, identification of specimens reveal that the following were originally found in the same pieces of amber (with each specimen number given) or were still together in a single piece of amber: (*Culicoides* sp. male, female; TMP 96.9.119), (*Culicoides* sp. male, TMP 96.9.125; *C. filipalpis* female, TMP 96.9.98), (*P. vetus* male, TMP 96.9.738; *P. chrimikalydia* male, TMP 96.9.740), (*Culicoides* sp. male, TMP 96.9.118; *P. chrimikalydia* female, TMP 96.9.106), and (*Palaeobrachypogon* sp., two females, TMP 96.9.99).

## Conclusions

With the addition of two new species described here, there are now 20 species of Ceratopogonidae known from Canadian amber, based on 316 specimens. The sex ratio of Ceratopogonidae in various ambers is strikingly similar to that produced by emergence cages for the modern fauna and strongly suggests that Canadian amber Ceratopogonidae were captured by the resin close to their area of emergence (males tend to disperse so that there are fewer males the farther the species is collected from the site of emergence) (Borkent 2000a). The specimens studied here increases the percentage of males from 43.7% (Borkent 1995) to 45.8%; this does not alter the conclusion that Canadian amber Ceratopogonidae were originally captured by the resin near their site of emergence.

The further records of syninclusions noted above as well as the number of species/100 specimens also do not change the interpretation of Canadian amber Ceratopogonidae by Borkent (2000a) as somewhat less diverse than those in most other amber deposits.



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