

# THE NYMPH AND MALE OF *CENTROPTILUM INFREQUENS* MCD (BAETIDAE)

Robert G. Lowen and John F. Flannagan

*Freshwater Institute, 501 University Crescent, Winnipeg, Manitoba, Canada*

## ABSTRACT

*Centroptilum infrequens* was described from a single female specimen taken at Winnipeg Beach, Manitoba. This description was based on colour and size characteristics which we have found to be variable. The species was rediscovered along the Manitoba escarpment. The male imago is described for the first time. Wings, genitalia, legs, body segments and the overall morphology are illustrated and taxonomically evaluated. The female imago is redescribed using structural characteristics. The nymph is also described for the first time. Mouth parts, antennae, wing pads, legs, paraprocts, and colour pattern are illustrated and evaluated. *C. infrequens* belongs to the *C. pennulatum* Eaton species group.

## INTRODUCTION

*Centroptilum infrequens* was described from a single female imago caught at Winnipeg Beach, Manitoba (McDunnough 1924). McDunnough wrote that he was hesitant to describe a new species on the basis of a single female but that he felt that this species was distinctive enough to warrant specific status. Criddle (1925) recorded the species as occurring in Winnipeg and McDunnough (1931) recorded the species from near Lethbridge, Alberta. Since 1931 no new reports of this species have been published and the male of the species and the nymph have never been described.

Prior to this study, *C. infrequens* was rediscovered in small spring fed streams in the Duck Mountains Provincial Park and Riding Mountains National Park, Manitoba (Flannagan *et al.* this volume). These parks are part of the Manitoba escarpment (Fig. 1) which is a bench separating the low altitude Manitoba prairies from the higher Saskatchewan prairies. The bench is composed of Cretaceous shales covered

by a layer of glacial till. The escarpment is liberally supplied with cool, ground water fed, springs and streams. Sampling of these water bodies showed *C. infrequens* nymphs to be widespread and abundant.

The following first description of the male and nymph and redescription of the female follow

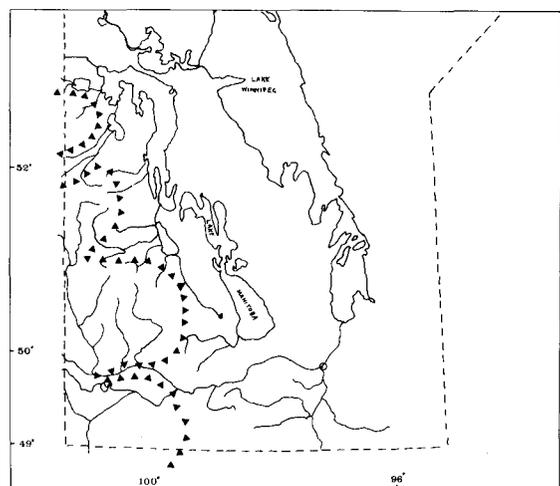


Fig. 1. Southern Manitoba showing the Manitoba escarpment.

Müller-Liebenau's (1969) system. The original description was based on colour and size characteristics which have been found to be too variable for accurate evaluation. It is hoped that the greater detail in the species description will aid our understanding of this genus.

## MATERIALS AND METHODS

Nymphs were collected from the streams with a rectangular dip-net. "Kick-samples" yielded poor results. Sweeping the net rapidly through the water over the substrate and through submerged vegetation yielded good catches. Nymphs were sorted out in the field and transported back to the laboratory in stream water. Mortalities were lower if the nymphs were kept cool. The nymphs were reared singly in one litre jars, half filled with stream water, and containing a stone or a few pebbles. Vegetable based "Nutra Fin" fish food was provided initially and the water was aerated. Each jar was covered with Nylar mesh upon which the emerged subimago could land. Subimagines were placed in dry jars for final moulting. Imagines were allowed to mature for 24 h so that colour would be fully developed before preservation in either 70% ethanol or Kahle's solution. Before dissection specimens were dehydrated through an alcohol series and cleared in cedarwood oil, they were then mounted on slides in Canada Balsam. Specimens for SEM were first hardened in xylene and desiccated.

## RESULTS

### Male imago

Unless otherwise stated, measurements were made on 24 specimens ( $n = 24$ ), and are given in mm as a mean followed by a range in parentheses. Total body length 8.5 (7.3–10.0); cerci length 14.0 (11–17) ( $n = 19$ ); forewings 9.0 (8.1–10.3) always equal to or longer than body length.

*Head.* Turbinate eyes bright orange, slightly divergent, disc broadly oval, width  $2/3$  length,

stem much paler, 0.4–0.5 mm tall; non-turbinate eyes and ocelli black; antennae smoky at base, translucent distally; remainder yellow-white to yellow-brown, occasionally red in vestigial mouth parts.

*Thorax.* Pronotum creamy-tan, unmarked; mesonotum light brown laterally, paler dorsally, sometimes with opaque white mid-dorsal stripe; metanotum with similar pattern; entire thorax often with sclerites reddish along lateral margins; thoracic sternites pale tan to opaque white, coxae slightly darker.

*Legs.* Hyaline white distally, yellowish proximally; large variation in individual measurements (Table 1); forelegs 7.0–7.5 mm long, tibia equal to or longer than femur; tibia usually  $1/3$  length of tarsus; tarsus usually 5 segmented, segment 1  $< 1/10 \times$  segment 2 and each subsequent segment being  $2/3$  length of its precursor; mid and hindlegs with similar proportions, both about 4 mm, tibia  $2/3 - 3/4$  femur, tarsus  $1/3 - 2/5$  of tibia + tarsus, tarsus 4 segmented with segment 1  $5/6$  length of rest combined, segment 2 1.8 to 2.5 times length of segment 3, segment 4 equal to or longer than segment 2; claws similar on all legs.

Table 1. Mean length ( $\bar{x}$ ) and observed ranges (r) in mm of leg segments in imagines. Forelegs are separated by sex of specimen

		Male foreleg	Female foreleg	Midleg	Hindleg
Femur	$\bar{x}$	2.14	2.06	1.72	1.83
	r	1.88–2.40	1.80–2.24	1.36–2.16	1.44–2.28
Tibia	$\bar{x}$	2.19	1.45	1.23	1.29
	r	2.00–2.36	1.20–1.74	1.12–1.30	1.14–1.52
1	$\bar{x}$	0.10	0.60	0.51	0.50
	r	0.08–0.12	0.50–0.72	0.46–0.62	0.44–0.60
2	$\bar{x}$	1.24	0.32	0.22	0.21
	r	0.90–1.80	0.28–0.36	0.18–0.26	0.19–0.24
Tarsi	$\bar{x}$	0.90	0.15	0.10	0.09
	r	0.84–0.96	0.10–0.16	0.08–0.12	0.06–0.10
4	$\bar{x}$	0.48	0.32	0.27	0.28
	r	0.44–0.56	0.28–0.40	0.24–0.30	0.24–0.36
5	$\bar{x}$	0.31	–	–	–
	r	0.28–0.34	–	–	–

**Wings.** Forewings (Fig. 2a) hyaline, yellow basally, pterostigma translucent white without clearing on crossveins, length 3 times width, crossvein number variable, 4–16 between C and Sc with 6–8 most common, 1–4 between Sc and R1 with an occasional intercalary present, 2–4 between R1 and R2 with intercalary occasionally absent, MA2 reaching at least MA1/MP1 crossvein and often further, MP2 longer than IMP, MP2 and IMP may be extended as folds to the CuA/Mp1 crossvein, individuals with these folds tend to have MA2 extend past the MA1/MP1 crossveins in the pterostigmal area, a small intercalary occasionally present basad to A1; hindwings (Fig 2b) with mean length 0.95 mm (0.70–1.30), width less variable so length ranges from 5.0–8.5 times width, processus costalis long, curved, beginning after basal third of wing length, two veins present which may be entirely separate or fused up to processus costalis.

**Abdomen.** Abdominal tergites 1–8 edged posteriorly with solid red-brown line, tergites 1–6 semi-hyaline, tergite 1 with red markings dorso-posteriorly, tergites 7–10 and sometimes half of 6 tan to light brown with a dorsal scarlet stripe or series of red wedges widest posteriorly, colour variable and red colour may be entirely absent or present only as a ruddy wash, when present red colour is an infusion rather than a pattern, broken black spiracular line present in some individuals, sternites 1–6 semi-hyaline and unmarked, sternites 7–9 opaque tan to opaque white sometimes with reddish markings laterally, cerci hyaline white.

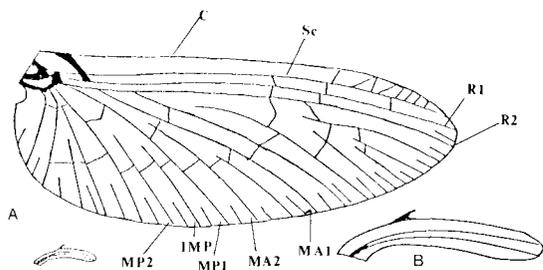


Fig. 2. Generalized drawing of wings, a) fore and hind wings drawn to the same scale b) hindwing detail. See text for symbols.

**Genitalia:** basal segments of forceps (Fig. 12) tan, broader than long, inner segments of basal segments contiguous basally but diverging distally, forceps segments I, II and III hyaline white, segment I as long as basal segment but half as wide, weakly separated from segment II but with a distinct shelf between them, segment II 3 times length of segment I, narrowest basally and expanding slightly distally, curving inwards, segment II heavily sculptured distally (Fig. 13) less sculpturing but more hair basally (possibly not visible with a light microscope), segment III about 1/2 length of segment I, drop shaped and clearly separate from segment II, penile plate opaque tan with a red-brown posterior edge, truncated with rounded edges.

#### Female imago

Unless otherwise stated measurements made on 25 specimens, and presented as for males above. Body length 9.46 (7.7–10.9), forewing length 10.0 (9.5–11.0), hindwing length 1.1 (0.8–1.4) (n = 17).

**Head and thorax.** Head colouration similar to male but often marked in red, sometimes two red stripes posteriorly from ocelli, thorax light brown to tan, pronotum sometimes marked with red dorsally, opaque white on edges of sclerites on meso and metathorax, posterior edge of metathorax opaque white with red anterior to the white, all three pairs of legs resemble mid and hind legs of male (Table 1), wing venation as in male.

**Abdomen.** Distinctly different than male, tergites tan or light brown, 1–7 edged with black posteriorly, with a bright red dorsal stripe or a series of unconnected red wedges, wider posteriorly, tergites 8–10 with bright scarlet overlay, sometimes with with hyaline spots lying in sub-dorsal pairs, as in the male the red colour may be absent or present only as a ruddy wash and forms an infusion rather than a pattern, sternites 1–7 hyaline, unmarked with eggs clearly visible, sternites 8 and 9 translucent white with rosy tinges and sometimes marked with opaque white.

## Male subimago

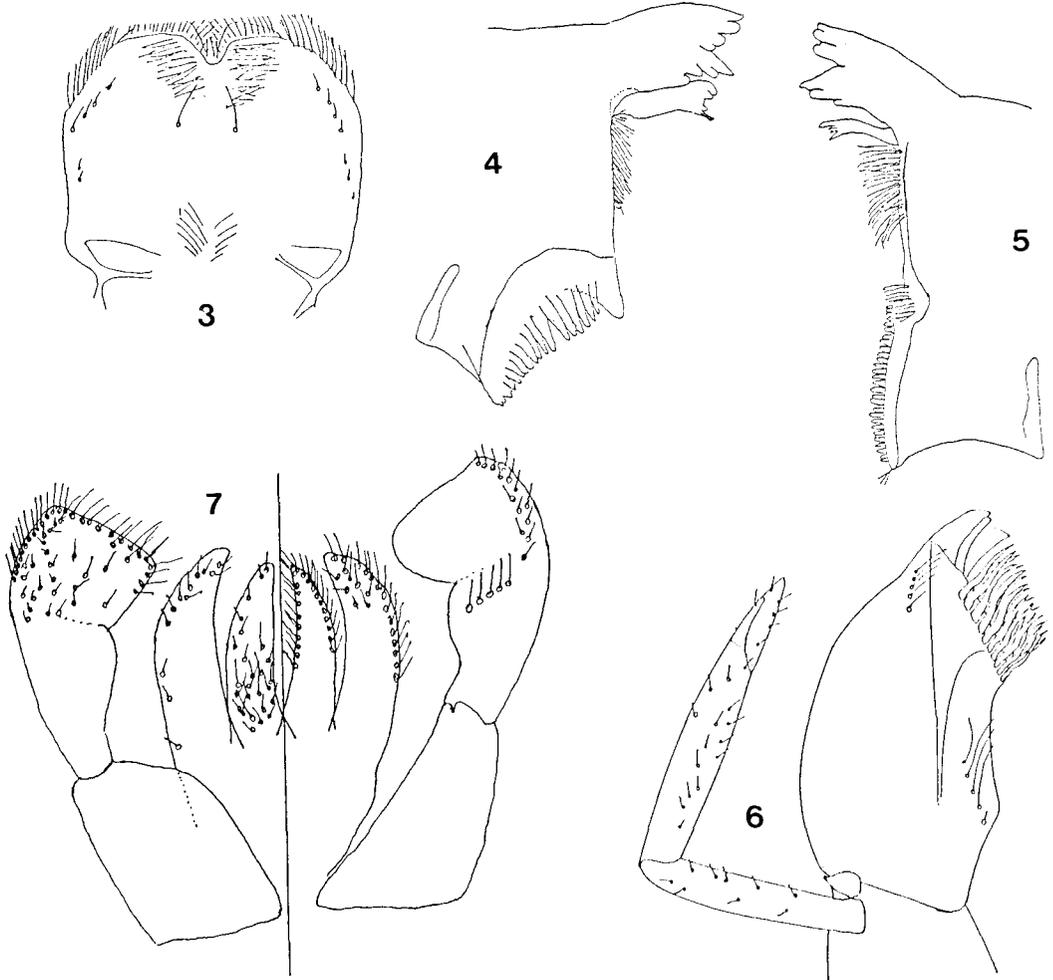
Ten specimens were measured. Measurements as in imago except for the forelegs which are about 4.5-mm long. Mean lengths and ranges of foreleg segments in mm are: femur 1.92 (1.80–2.05), tibia 1.27 (1.00–1.52), first tarsal segment 0.07 (0.06–0.08), second tarsal segment 0.49 (0.38–0.58), third tarsal segment 0.39 (0.22–0.48), fourth tarsal segment 0.21 (0.12–0.28), fifth tarsal segment 0.30 (0.28–0.34), cerci 10.0–15.0.

Turbinate eyes globular and only partly raised above the rest of the eye, colours of head and

thorax similar to imago but hyaline areas in imago are semi-hyaline or opaque white in subimago, wings translucent steely grey with marginal fringe of hair shorter than the intercalaries, tergites edged with black posteriorly, tergites 1–6 opaque light brown or dark tan with slight or no red markings, sternites 1–9 opaque white with no other markings, cerci and forceps white.

## Female subimago

Sixteen female subimagines were examined. As in imago except hyaline and sub-hyaline areas in imago opaque white, red abdominal stripe may be



*Figs 3–7.* Generalized nymphal mouthparts. 3, labrum. 4, left mandible. 5, right mandible. 6, maxilla. 7, labium, left half dorsal, right half ventral.

completely absent, wings and cerci similar to male subimago.

### Nymph

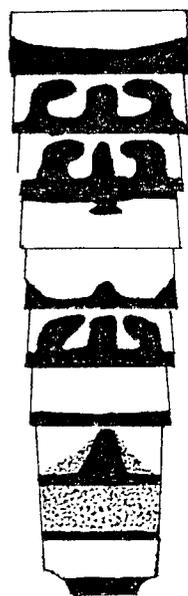
Body length of nymphs with black wingpads 8.0–10.5 mm (n = 26).

**Head.** Light brown in colour, dark band bordering dorsal half of compound eyes, turbinate eyes of males clearly visible, antennae semi-hyaline, 2.0–2.5 mm long, basal segments longest declining to segment 4 then lengthening, arc of numerous short hairs surrounding the dorso-anterior half of the antenna base (Fig. 11); Mouthparts with labrum edged basally with black, anterior

surface with many short hairs and sometimes several long ones but the distribution of these is variable (Fig. 3), distal half of both mandibles orange-brown fading basally to semi-hyaline, canines of the left mandible almost totally fused (Fig. 4), four projecting denticles on each canine, prosthema well developed with five denticles and width equal to 1/4 width of fused canines, tuft of hairs running for 1/2 distance from base of canines to molar area, large “thumb” present on molar area, plane of molar area depressed 50 degrees below level of distal edge of mandibles excluding canines, canines of right mandible slightly divided, fused for 3/4 length (Fig. 5), three denticles per canine, prosthema more slender, 1/8 width of fused canines, with four denticles, tuft of



A

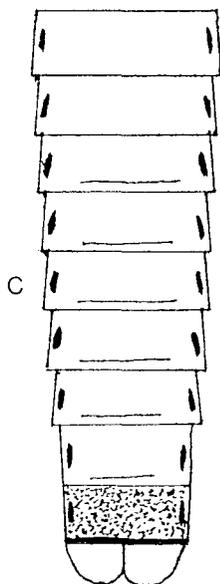


B

VII



8

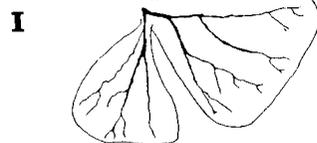


C

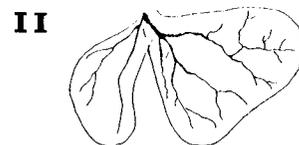
VI



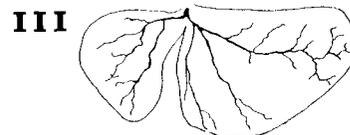
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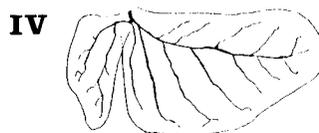
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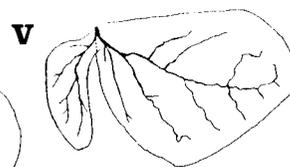
II



III



IV



V

Figs 8–9. 8, stylized pattern on nymphal abdomen and pronotum. A) pronotum, b) dorsal abdomen, c) ventral abdomen. 9, gills from segments I-VII. Exact drawings of a particular nymph showing typical form.

hairs extending 1/2 distance from base of canines to molar area, plane of molar area parallel to but slightly raised above level of distal edge of mandibles, secondary tuft of hairs present around edge of molar area closest to canines, two or three hairs present on other end of molar area; maxillae (Fig. 6) with four widely spaced biting teeth and a double row of hairs along distal edge, two rows of five hairs each along anterior face of maxillae, one row distal below level of biting teeth, the other proximal opposite the palpus, maxillary palpus slightly longer than maxillae, three segmented, covered with spines, segments 1 and 2 sub-equal length, segment 3 1/2 length segment 2, broadly to sharply pointed (Fig. 14) and partially fused to segment 2; Hypopharynx hyaline, delicate, without distinguishing features; labium (Fig. 7) very hairy especially on glossae and paraglossae, glossae slightly shorter than paraglossae, palpi three segmented but segments 2 and 3 partially fused, segment 2 narrowest at base, expanding distally, straight row of five short hairs present distally on segment 2, segment 3 truncate, not broadly expanded and only slightly excavated.

*Thorax.* Tergites light brown or tan with dark brown or black markings (Fig. 8), sternites white to pale brown, wingpads off-white to light brown becoming black in last instar, legs all similarly coloured, coxae dark brown or black, femora light tan with dorsal dark patch near each end and a poorly defined subapical row of long fine setae, tibiae and tarsi brown with a pale patch at the junction, tibiae with a subproximal row and a dorsal row of long setae (Fig. 15), tarsus subtended by a small unornamented spine (Fig. 16), claws brown with a dark patch at connection with tarsi, bearing double row of extremely small spines visible only under high magnification, a ribbed pad near base and a few scattered hairs on the surface (Figs 14–15), comparative lengths of fore, mid and hind leg segments highly variable (Table 2), within-leg ratios also highly variable.

*Abdomen.* Tergites tan to light brown, edged posteriorly with black, patterned dorsally with dark brown or black (Fig. 8), pattern darkest on seg-

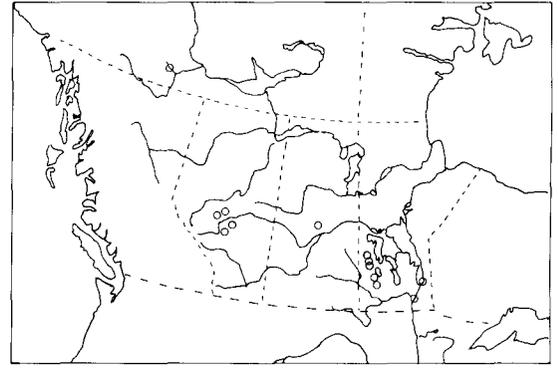
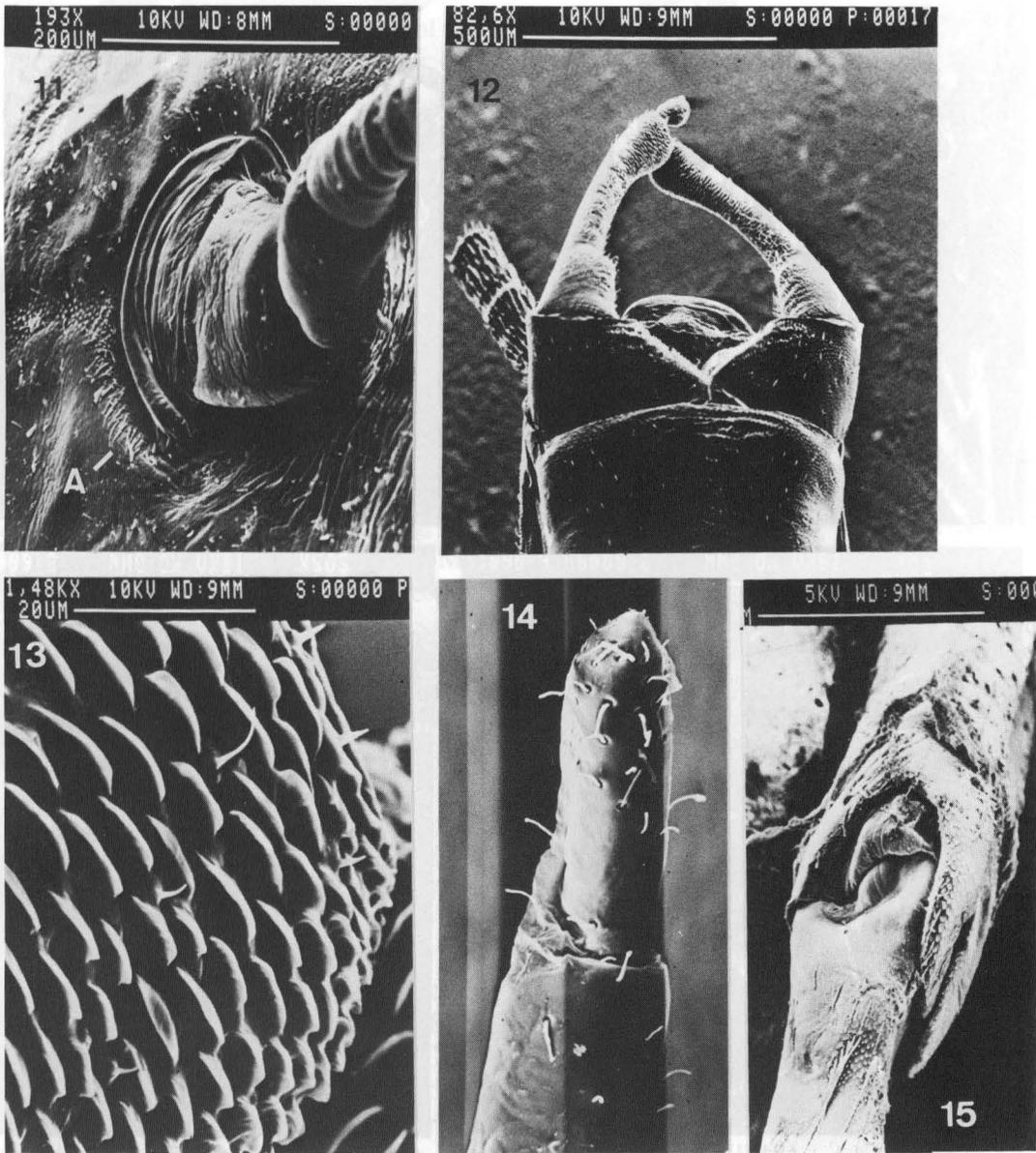


Fig. 10. Known range of *Centropitulum infrequens*.

ments II, III, V and VI, posterior edge and surface of terga as in fig. 16, one lateral spine at base of gills on segments I–VII, segment VIII with 2–5 lateral spines, segment IX with 5–7 lateral spines, segment X with 0–5 spines; sternites white to light tan with lateral patches of light brown, sternite IX evenly brown, brown stripe along anterior edge of sternites III–VIII or at least VI–VIII, genital forceps of males visible in mature nymphs as two small rounded projections on the posterior edge of sternite IX; gills on segments I–VII (Fig. 9), hyaline white with dark brown or black veins and having recurved dorsal flap on segments I–VI, absent on segment VII, flap largest on segment I and decreasing in size posteriorly; paraprocts tan with dark spines (Fig. 20), median terminal filament 3.5–4.0 mm long, cerci 3.7–4.5 mm, all three similarly patterned (Figs 19–20) tan to light brown with dark brown every fourth segment, a band of dark segments across middle of the three, lateral fringes of hair light brown in basal half, dark brown distally.

Table 2. Mean length ( $\bar{x}$ ) and observed ranges (r) of leg segments mature nymphs (n = 26)

		Foreleg	Midleg	Hindleg
Femur	$\bar{x}$	2.17	2.03	2.05
	r	2.04–2.36	1.74–2.32	1.88–2.20
Tibia	$\bar{x}$	0.95	0.99	0.92
	r	0.85–1.14	0.90–1.08	0.84–0.98
Tarsus	$\bar{x}$	1.04	0.97	0.87
	r	0.96–1.08	0.92–1.00	0.78–0.94
Claw	$\bar{x}$	0.49	0.53	0.56
	r	0.42–0.56	0.40–0.64	0.48–0.62



Figs 11–15. Scanning electron micrographs. 11, detail of nymphal antenna, A = arc of hairs. 12, genitalia, dorsal view. 13, genitalia, detail of sculpturing on segment II. 14, tip of maxillary palp. 15, femora-tibia joint of nymph.

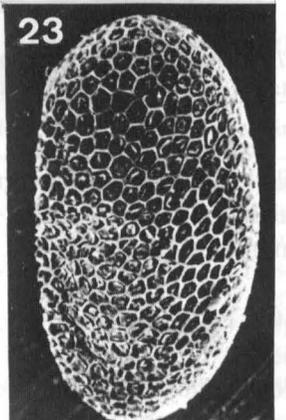
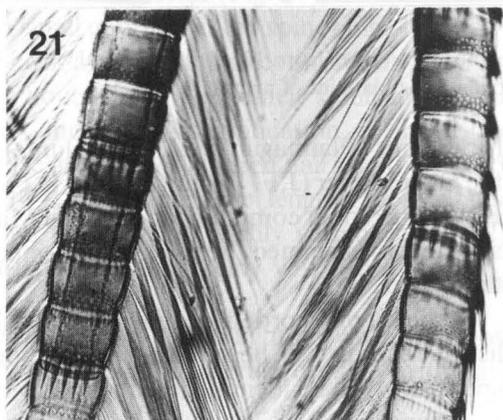
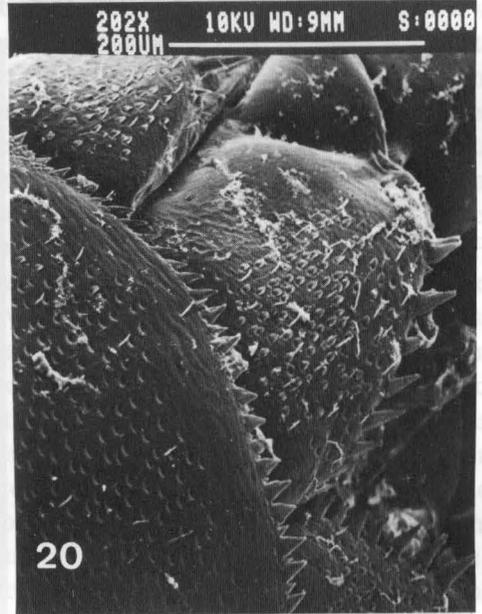
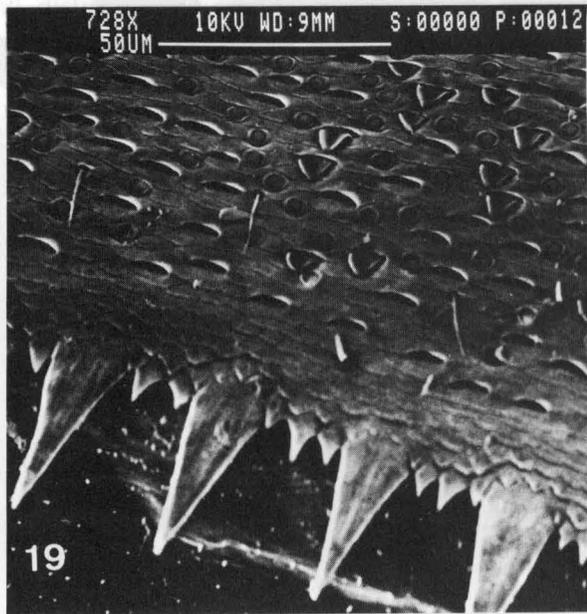
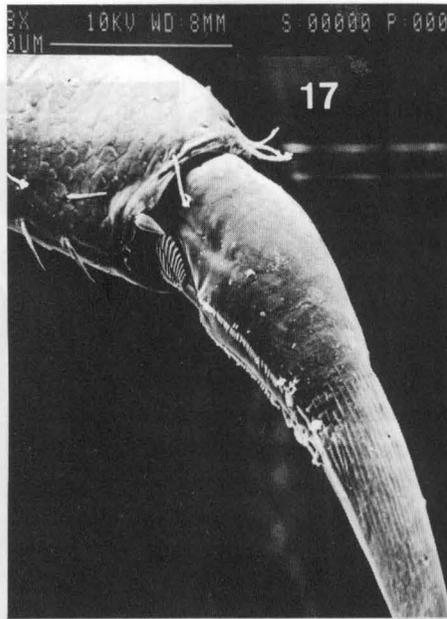
**Egg.** Eggs elongate ovals (Fig. 23), chorion heavily sculptured into irregular hexagons each containing a raised papilla, no obvious sign of sperm guides or micropyles.

#### RANGE

Previous collecting in the province of Manitoba has extended the known range to the Duck

Mountains (Flannagan *et al.*, this volume) and to the Ochre River (J.F. Flannagan and D.G. Cobb, F.W.I., personal communication). The Manitoba specimens examined here were collected from these sites.

In the list of recorded localities, previously published records will be referenced and borrowed specimens will be identified by the following abbreviations.



ACIB Alberta specimens in the collection of Dr. J. Ciborowski, University of Windsor, Department of Biology, Windsor, Ont.

NPBS Nahanni National Park Biological Survey, invertebrate specimens collected by R. Wickstrom and deposited at the Freshwater Institute, Winnipeg, Manitoba.

ROM Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario. CNIC Canadian National Insect Collection, Agriculture Canada, Ottawa, Ontario.

Records not identified with a reference or an abbreviation were collected as part of this study and specimens will be deposited at the J.B. Wallis Museum, University of Manitoba, Winnipeg, Manitoba, The Freshwater Institute, Winnipeg, Manitoba, or in the Canadian National Collection, Ottawa, Ontario.

The following records represent the known range of *C. infrequens* (see Fig. 10). Dates for adults are the dates the nymphs were caught and laboratory rearing commenced.

*Holotype*. Imago, Winnipeg Beach, Manitoba, 50 × 30 N 97 × 57 W, J. Hunter coll., 10VII1923, No. 695 (CNIC).

ALBERTA: Battle River, Hwy 21 at campground north of New Norway, 52°57'N 112°58'W, 15VI1979, L.D. Corkum coll., 5 nymphs (ACIB); Medicine River, Hwy 766 just north of Eckville, 52°57'N 114°22'W, 14VI1979, L.D. Corkum coll., 5 nymphs (ACIB); Pembina River, just north of lodgepole, 53°08'N 115°19'W, 3 nymphs (ACIB); Pembina River, at Pembina River Provincial Park, Entwistle, 22 nymphs 28VI1979 (ACIB), 1 ♂ subimago, 2 ♀ subimagines, 3 nymphal exuviae 14VII1979 (ACIB); Lethbridge, 8VII and 15IX 2 (McDunnough 1931).

MANITOBA: Cowan Creek 51°51'N 100°40'W, 25 nymphs, 2 ♂ imagines with exuviae 6 imagines with exuviae, 2 subimagines with exuviae, gynandromorph imago with exuvium 24VI1986-30VII1986; Little Ochre River, just inside boundary of Riding Mountain National Park, 50°56'N 99°47'W, 40 nymphs, 9 ♂ imagines with exuviae, 3 ♂♂ subimagines with exuviae, 10 imagines with exuviae, 6 subimagines with exuviae, 15VII1985-6VIII1985 and 2VII1986; North Pine River, by Hwy 10 bridge, 51°48'N, 100°34'W, 5 nymphs 9VII1986-30VII1986; Ochre River, 2 sites 51°07'N, 99°46'W and 51°05'N 99°47'W, 16 nymphs, 1 imago with exuvium, 10VI86-29VII1986; South Duck River, 4 sites 51°52'N 100°40'W, 51°52'N 100°37'W, 51°53'N 100°37'W, and 51°53'N 100°36'W, 174 nymphs, 17 ♂♂ imagines with exuviae, 6 ♂♂ subimagines with exuviae, 8 imagines with exuviae, 6 subimagines with exuviae. 30VII1985 and 19VI1986-7VIII1986; Wilson Creek, just inside Riding Mountain National Park, 50°43'N 99°33'W, 1 nymph, 1 ♂ imago with exuvium, 3 ♂♂ imagines with exuviae 24VII1985-7VIII1985; Winnipeg, (Criddle 1925); Winnipeg Beach, 1 ♀ imago, 10VII1924 (McDunnough 1924).

Saskatchewan: Prince Albert National Park, Lavallee Lake, 54°18'N 106°34'W, 30VII1929 1 imago (ROM).

Northwest Territories: Nahanni National Park, Nahanni River, 61°35'N 125°20'W, no date, 1 ♀ subimago, (NNPBS).

United States: there is as yet no record of this species in the United States, several localities occur close to the Canadian Border, this species probably occurs in the North Central U.S.A..

All records are areas that drain into either the Churchill, Lake Winnipeg-Nelson, or Mackenzie

◀ Figs 16–23. Figs 16–20 & 23 scanning electron micrographs, 21 & 22 photographs. 16, spine subtending foreleg tarsus of nymph. 17, base of nymphal claw. 18, detail of tip of nymphal claw. 19, detail of posterior end of an abdominal tergite. 20, detail of left paraproct. 21, median terminal filament and cerci of nymph. 22, Detail of Fig. 21. 23, egg dissected from imago.

River systems. Due to the glacial history of Canada, these areas were once linked to waterways that no longer exist (Elson 1967, Flint 1971). The currently known distribution, therefore, presents no surprises and is similar to several other Manitoban aquatic insects (Flannagan and Flannagan 1982).

## BIONOMICS

*C. infrequens* is found in streams ranging from spring-fed headwaters to medium-sized silt-laden rivers. It has not been found in large rivers in Manitoba. In small streams it is usually found in quiet backwaters or on the downstream face of large boulders. In medium-sized rivers it is found most often in the shallows on submerged vegetation. *C. infrequens* seems to be associated with the same areas of a stream where members of the hemipteran family Gerridae congregate, and these provide good indicators to the habitat of the mayfly. The digestive tracts of nymphs contained algae and detritus, no animal remains were observed.

In Manitoba streams, *C. infrequens* emerges from mid-July until mid-September. It is suspected that it overwinters in the egg stage since nymphs were collected as early instars one month prior to the start of emergence and nymphs were not found after the last emergence in winter or in spring.

## DISCUSSION

Previous to this paper, *C. infrequens* was one of the least well known species of the genus. However, few other species are well known so that comparisons with other Nearctic species are difficult. Needham, Traver and Hsu (1935, p 705) provided a key that may lead to mis-identification. The females will usually key out correctly but some imagines and almost all sub-imagines will be too pale to make identification using colour characters possible. The males can be keyed out correctly if the first two couplets are changed to the following:

1. – Dorsum of abdomen largely bright red, or at least tergites 7-10 red...2
  - Dorsum of abdomen not as above, tergites 7 to 10 brown or white, tergites 1 to 6 may be shaded red but never over most of the tergite...3
2. – Males, abdominal tergites 1 to 6 semi-hyaline, edged posteriorly with black or brown, tergites 7 to 10 bright red or scarlet. Females with red or scarlet dorsal stripe or a series of red wedges.....*infrequens*
  - Abdominal tergites of male bright red, except for a pale narrow lateral area: of females, pale yellowish tinged with brown posteriorly.....*quaesitum*

The most complete description of European species of *Centropilum* is that of Keffermuller and Sowa (1984). In their keys, both the imago and nymph of *C. infrequens* will key out to *C. pennulatum* Eat. and *C. nemorale* Eat.. The keys do not differentiate the two European species. Colour descriptions given for these two species both fall within the range observed for *C. infrequens*. Egg descriptions of *C. pennulatum* fit the eggs of *C. infrequens*. Illustrations of male genitalia, nymphal legs, and gills closely resemble *C. infrequens*. The illustrations of mandibular canines however, show more projecting denticles than observed in *C. infrequens*. The observed size range of *C. infrequens* is closer to that reported for *C. pennulatum* than for *C. nemorale* but the hindwings and labial hairs of *C. infrequens* more closely resemble the descriptions given for *C. nemorale*. It is possible that *C. infrequens* is a junior synonym of either *C. pennulatum* or *C. nemorale*. It is also possible that *C. infrequens* is an intermediary form and that *C. infrequens* and *C. nemorale* are both junior synonyms of *C. pennulatum*. At the very least *C. infrequens*, *C. pennulatum* and *C. nemorale* represent a single very tight species group.

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## REFERENCES

- Criddle, N. (1925). The entomological record, 1924. *Ann. Rep. Ent. Soc. Ont., Toronto* 55: 89-108.
- Elson, J.A. (1967) Geology of glacial Lake Agassiz. In W.J. Mayer-Oakes (ed.) *Life, Land and Water*. University of Manitoba Press, Winnipeg.
- Flannagan, J.F., D.J. Cobb and M.K. Friesen (1989) The relationship between some physical factors and mayflies emerging from South Duck River and Cowan Creek, Manitoba. In Campbell, I.C. (ed.) *Mayflies and Stoneflies, life histories and biology*. Dr. W. Junk, Netherlands.
- Flannagan, P.M. and J.F. Flannagan (1982). Present distribution and the post-glacial origin of the Ephemeroptera, Plecoptera and Trichoptera of Manitoba. Manitoba Dept Natural Resources, Fisheries. Tech. Rept No. 82-1.
- Flint, R.F. (1971). *Glacial and Quaternary Geology*. J. Wiley and Sons, Inc., New York.
- Keffermuller, M. and R. Sowa (1984). Survey of Central European species of the genera *Centroptilum* Eaton and *Pseudocentroptilum* Bogoescu (Ephemeroptera: Baetidae). *Polskie Pismo Ent.* 54: 309-340.
- McDunnough, J. (1924). New Canadian Ephemeroptera with notes, 11. *Can. Ent.* 56: 90-98.
- McDunnough, J. (1931). New Species of North American Ephemeroptera. *Can. Ent.* 63: 82-93.
- Müller-Liebenau, I. (1969). Revision der europäischen Arten der Gattung *Baetis* Leach, 1815 (Insecta, Ephemeroptera). *Gewässer und Abwässer* 48/49: 1-214.
- Needham, J.G., J.R. Traver and Y. Hsu (1935). *The Biology of Mayflies*. Comstock Publishing Company, Inc., Ithaca.