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BAETIS (EPHEMEROPTERA: BAETIDAE) OF WISCONSIN¹Edward A. Bergman and William L. Hilsenhoff²

Data on life histories and environmental requirements for species in many mayfly genera remains sketchy at best. This is certainly true of *Baetis*, which is one of the most common components of Wisconsin's lotic fauna. Most Wisconsin streams that are not grossly polluted contain one or more species of the minnow-like nymphs, which are usually found clinging to surfaces of rocks or aquatic plants. Biological studies of *Baetis* in North America have been neglected primarily because of their enigmatic taxonomy. Even keys of Needham et al. (1935) and Burks (1953), which are considered standard references, are either incomplete or difficult to use when identifying *Baetis*.

Before a study of the biology of *Baetis* in Wisconsin could be completed, a study of their taxonomy was necessary, and numerous unexpected problems were encountered. Most significant were the occurrence of maleless parthenogenetic species, seasonal size and color variations in male imagoes of several species, difficulties in associating reared specimens with existing descriptions, and physical deterioration of important nymphal specimens collected by early taxonomists. Despite these problems, we collected valuable data on *Baetis* and this paper reports our knowledge of *Baetis* in Wisconsin today.

In Wisconsin, 14 species of *Baetis* have been collected. Adult males and mature nymphs can be separated using keys that follow. Supplemental characters useful in identification and synonymies are presented in a discussion of each species, and developmental cycles, ecology, and known distribution of Wisconsin *Baetis* are summarized in Table 1.

KEY TO WISCONSIN BAETIS—ADULT MALES³

1. Hind wing with 3 longitudinal veins and with a costal projection near base . . . 2
- 1'. Hind wing with 2 longitudinal veins, with or without a costal projection . . . 3
- 2(1). Second vein of hind wing simple . . . 6
- 2'. Second vein of hind wing forked (males and females). *hageni*
- 3(1'). Costal projection of hind wing absent; first segment of genital forceps with a prominent apicomeral tubercle (Fig. 1B) *propinquus*
- 3'. Costal projection present, although sometimes reduced 4
- 4(3'). A spine between bases of genital forceps (Figs. 1D,E); costal projection reduced 5
- 4'. No spine between bases of genital forceps; first segment of forceps approximately 1/3 as long as second, third segment about 2-1/2 times longer than wide (Fig. 1C); costal projection relatively well developed *pygmaeus*
- 5(4). First segment of genital forceps with a prominent, pointed mesal projection (Fig. 1D) *spinus*
- 5'. First segment of genital forceps cylindrical (Fig. 1E) *frondalis*
- 6(2). First segment of genital forceps cylindrical (Fig. 1F), no tubercle on inner apical margin of basal segment *vagans*
- 6'. First segment of genital forceps conical (Fig. 1G, H, I, J), a tubercle present on inner apical margin of basal segment 7
- 7(6'). Tubercle on apical margin of basal segment of genital forceps poorly developed (Fig. 1G); eyes (live) lemon yellow *levitans*

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³Male *B. macdunnoughi* unknown, females difficult to separate from female *B. pygmaeus* and not included in this key.

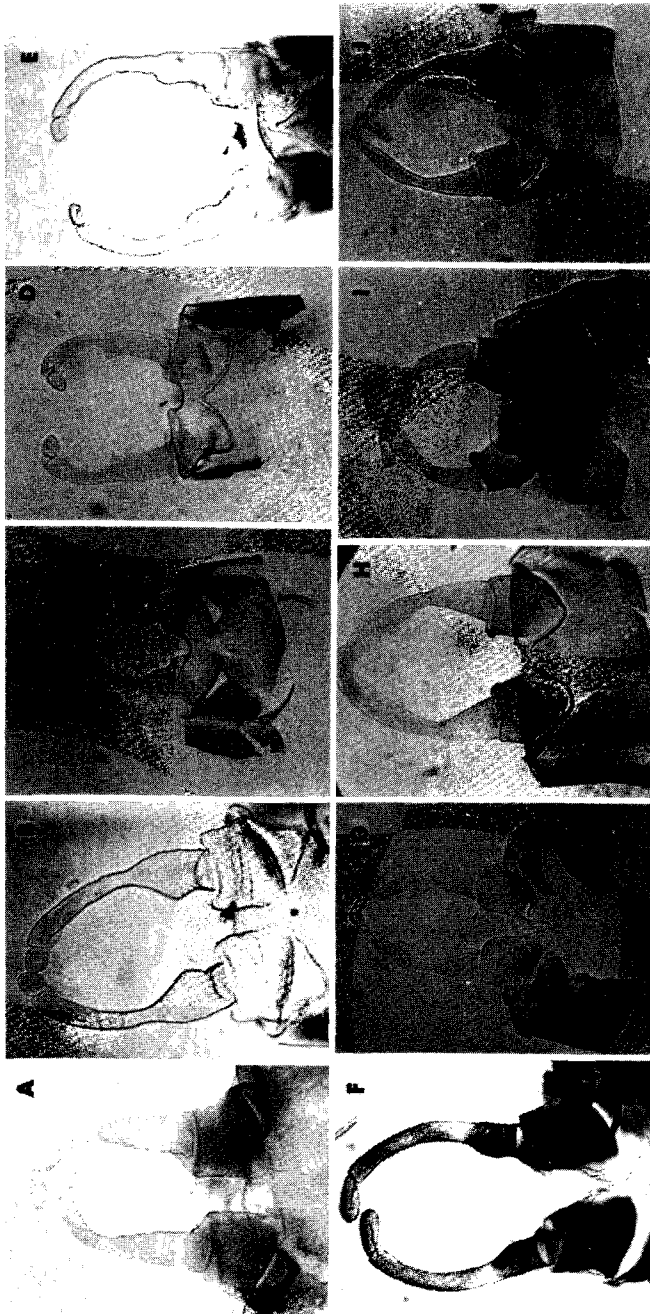


Fig. 1. Male genitalia of *Baetis*: A—*hageni*; B—*propinquus*; C—*pygmaeus*; D—*spinosus*; E—*frondalis*; F—*vagus*; G—*levitans*; H—*brunnei-*
color; I—*intercalaris*; J—*phoebus*.

- 7'. Tubercle on apical margin of basal segment of genital forceps well developed . 8
 8(7'). Abdominal terga 2-6 brown (amount variable) *brunneicolor*
 8'. Abdominal terga 2-6 hyaline-white or yellowish-white, often with a narrow reddish-orange transverse stripe (variable) 9
 9(8'). Thorax shiny black; abdominal terga 2-6 hyaline-white; turbinate eyes reddish-brown (live) *intercalaris*
 9'. Thorax olive-brown, never shiny black; abdominal terga 2-6 yellow-white, often with a reddish-orange transverse stripe (intensity of stripe variable); turbinate eyes reddish-orange (live) *phoebus*

KEY TO WISCONSIN *BAETIS*-MATURE NYMPHS

1. Two tails *Baetis* sp. B
 1'. Three tails 2
 2(1'). Tails without crossbands at or near middle 3
 2'. Tails with dark crossbands at or near middle 6
 3(2). Tails without crossbands 4
 3'. Tails with white or dark apical crossbands 5
 4(3). Abdominal terga brown, often with a pale median stripe (Fig. 2A); abdominal terga 10 and 5 sometimes paler than other terga *brunneicolor*
 4'. Abdominal terga without a pale median stripe; abdominal tergum 9 paler than other terga, 5 also usually pale (Fig. 2B) *vagans*
 5(3'). Tails tan, with a dark brown apical band on cerci *hageni*
 5'. Tails dark brown, with a white apical band *Baetis* sp. C
 6(2'). Abdominal terga 1, 4-7, and 10 mostly white (Fig. 2E,F) *Baetis* sp. A
 6'. Abdominal terga predominantly brown, sometimes with white segments, but not in the above combination 7
 7(6'). Tibia with a wide, dark band at middle; gills on abdominal segment 7 lanceolate 8
 7'. Tibia unbanded or banded only at apex; gills on abdominal segment 7 rounded 9
 8(7). Gill on segment 7 sharply pointed at apex, very narrow (Fig. 2S) *pygmaeus*
 8'. Gills on segment 7 elongate, but not sharply pointed (Fig. 2T) *macdunnoughi*
 9(7'). Abdominal terga uniformly dark, each with an interior and posterior median white dash forming an interrupted median line on abdomen (Fig. 2I) *frondalis*
 9'. Abdomen usually with some pale terga, if uniformly dark, without a pale interrupted median line on abdomen 10
 10(9'). Cerci banded at or near apex; tarsi and tibiae with a band at apex 11
 10'. Cerci not banded near apex; tarsi and tibiae without dark marks 13
 11(10). Abdominal terga with distinct mid-anterior paired, pale, oblique dashes and dots, often obscure in terga 1,9, and 10; abdominal tergum 10 often pale *intercalaris*
 11'. Abdominal tergum 9 usually pale; mid-anterior paired, pale, oblique dashes and dots indistinct or absent; when present a faint longitudinal line often between paired dashes and dots; banding on tails distinct, never obscure 12
 12(11'). Gills weakly tracheated, usually without branching; abdominal tergum 5 usually pale with 2 black spots; line between dashes and dots usually very faint and limited to anterior terga (Fig. 2M) *phoebus*
 12'. Gills strongly tracheated, with many branches; abdominal tergum 5 usually not pale; line between dashes and dots often present, usually more distinct than in above species (Fig. 2N,O) *levitans*
 13(10'). Abdominal terga uniformly dark, 10 sometimes pale; large, paired, pale dashes and dots in basal half of each tergum and usually a darkened area in between; gills tracheated with some branching (Fig. 2P,Q) *spinousus*
 13'. Abdominal tergum 7 often pale like segment 10; only very tiny pale dashes and dots in basal half of each abdominal tergum, with a median pale spot at

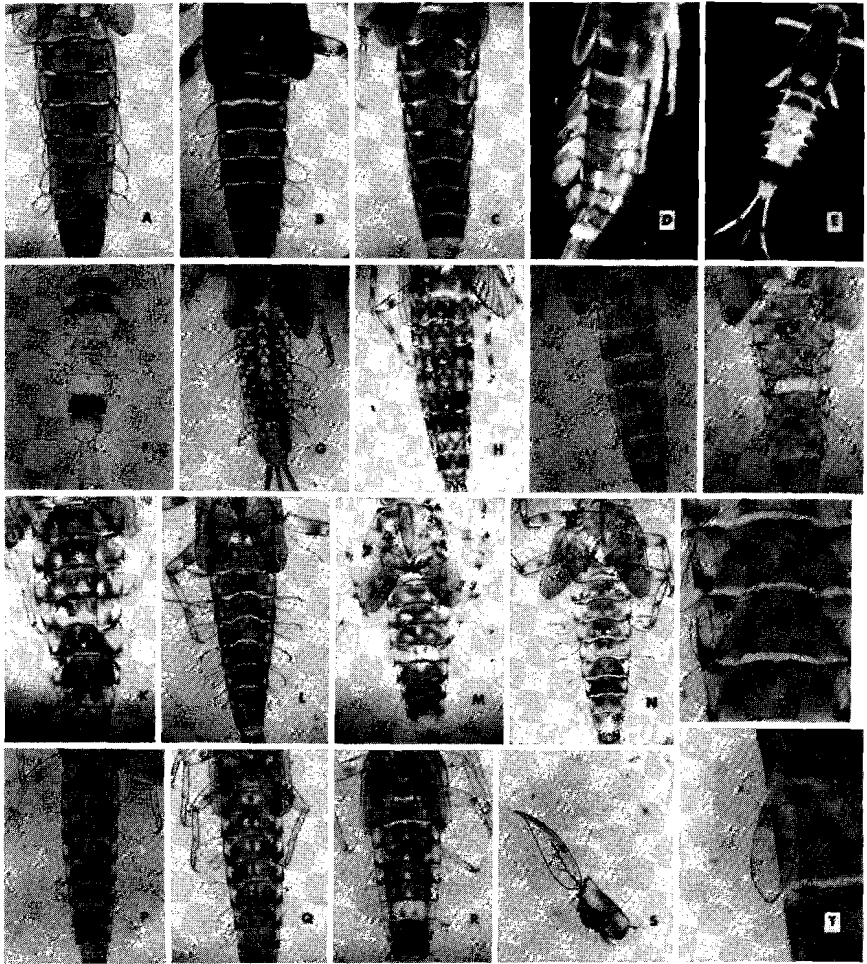


Fig. 2. Exuviae of *Baetis* nymphs: A-*brunneicolor*; B-*vagans*; C-*hageni*; D-sp. C; E, F-sp. A; G-*pygmaeus*; H-*macdunnoughi*; I-*frondalis*; J,K,L,-*intercalaris*; M-*phoebus*; N,O,-*levitans*; P,Q-*spinus*; R-*propinquus*; 7th gill of: S-*pygmaeus*; T-*macdunnoughi*.

posterior margin; gills without trachea or with only a hint of tracheation (Fig. 2R) *propinquus*

Baetis brunneicolor McDunnough

Adult description: McDunnough (1925a:113)
 Nymphal description: Ide (1937:221)

Male imagoes can be easily separated from known Wisconsin species by characters in the key. The color of abdominal terga, especially 2-6, varies seasonally, being less brown in the summer than spring. *B. brunneicolor* nymphs can be confused with those of *vagans*, especially mature winter generation nymphs. Usually abdominal terga 5 and 9 in *vagans* nymphs are pale, but in spring the paleness is less apparent. Abdominal terga of nymphs of *brunneicolor* vary from light brown to almost black. When light brown, terga 5 and 10 are sometimes pale, but when the terga are black, 5 and 10 are uniformly dark. Both light and dark nymphs usually retain a median longitudinal stripe, which often is less distinct in the dark forms. This stripe is absent in *vagans*.

Baetis frondalis McDunnough

Synonymy: *Baetis baeticatus* Burks (1953:129)

Adult description: McDunnough (1925a:173)

Nymphal description: Ide (1937:229)

Adult males can be separated from other *Baetis* in Wisconsin by their distinctive genitalia. Nymphs are most easily confused with *spinus*, but have light tan abdominal terga with an indefinite pale median line. *B. baeticatus* is a synonym. Burks (1953) separated adults of *baeticatus* from *frondalis* primarily by the color of abdominal terga 2-6. Nymphs that were identical to *frondalis* nymphs in collections of McDunnough and Ide were reared and produced male imagoes with abdominal terga that varied in color. Terga 2-6 of male imagoes reared in late spring or early summer were typical dark brown *frondalis* and those reared from the same stream in summer were light brown with a reddish-brown transverse stripe at the posterior margins as described for *baeticatus*.

Baetis hageni Eaton

Synonymy: *Baetis unicolor* Hagen (1861:54); *Baetis herodes* Burks (1953:130)

Adult description: Hagen (1861:54); Burks (1953:130)

Nymphal description: Burks (1953:130)

Only parthenogenetic females are known from Wisconsin. Female imagoes were identified by their distinctively forked second vein of the hind wing. Nymphs (Fig. 2C) fit the brief description of a female nymph by Burks (1953). We speculated earlier (Bergman and Hilsenhoff, 1978) that these parthenogenetic forms may be a sibling species and not *hageni*. Further study is needed to make this determination. Genitalia of a male imago collected in Indiana and identified by Burks are shown in Fig. 1A.

Baetis intercalaris McDunnough

Synonymy: *Baetis lasallei* Banks (1924:425)

Adult description: McDunnough (1921:118)

Nymphal description: Ide (1937:227)

In addition to characters in the key, the shape of labial palps and conspicuous tracheation of gills are helpful in identifying nymphs. Pigmentation of the abdominal terga is useful, but unfortunately color patterns vary from stream to stream. In some populations, especially those in the dark water streams of northern Wisconsin, abdominal terga are mostly brown (Fig. 2L). In many populations abdominal terga have distinct pale markings (Fig. 2K), typical of nymphs described by Ide (1937). Nymphs with color patterns intermediate between the above forms have been collected throughout the state (Fig. 2J). Nymphs with variations in color were reared and no differences in male imagoes were observed.

Table 1. Summary of life cycles and ecology of *Baetis* known to occur in Wisconsin.

Species	Seasonal Occurrence		No. of Generations	Life Cycle ^a	Abundance & Distribution	Occurrence of Nymphs		
	Nymphs	Adults				No. of Streams ^b	Preferred Habitat	Substrate
<i>brunneicolor</i>	early May-Dec.	late May-mid-Nov.	1 or 2	B	abundant; state-wide	36	2-73m (10) .09-.79m/sec (.40)	aquatic plants and debris
<i>frondalis</i>	late May-mid-Nov.	June-early July; late July-early Nov.	2	D	common; scattered throughout state	8	3-91m (29) .15-.51m/sec (.30)	aquatic plants
<i>hageni</i>	Apr., May?	late Apr., May?	2 ^c	C	rare; southeast	1	5m .51m/sec	moss covered gravel and rubble
<i>intercalaris</i>	May-Oct.	June-early Oct.	1	A	common; scattered throughout state	16	7-27m (17) .15-.66m/sec (.48)	gravel and rubble
<i>levitans</i>	May-Oct.	late May-mid-Oct.	1 or 2	B	common; scattered throughout state	16	5-24m (11) .15-.73m/sec (.39)	gravel and rubble
<i>macdunnoughi</i>	Nov.-early June; late June-Oct.	May-early June; late June-Oct.	2	C	uncommon; northern 2/3's of state	6	2-27m (10) .09-.46m/sec (.31)	aquatic plants gravel and rubble
<i>phoebus</i>	May-Dec.	late May-Nov.	1 or 2	B	abundant; statewide	31	2-91m (11) .17-.79m/sec (.39)	gravel and rubble

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<i>propinquus</i>	mid-June- mid-Sept.	late June- mid-Sept.	1	A	uncommon; Wis. R. southern 1/3 of state	1	320m .30m/sec	rubble and submerged logs
<i>pygmaeus</i>	Oct.-early June; late June-Oct.	May-June; June-Oct.	2	C	common; northern 3/4's of state	9	8-24m (15) .14-.45m/sec (.31)	gravel and aquatic plants
<i>spinus</i>	June-mid- Nov.	mid-June- mid-Nov.	2	D	common; scattered throughout state	9	4-91m (22) .14-.48m/sec (.29)	aquatic plants and debris
<i>vagans</i>	Nov.-May; late June- Oct.	Apr.-May; late June- mid-Oct.	2	C	abundant; statewide	23	2-18m (7) .17-.79m/sec (.45)	gravel and rubble
sp. A	June-Oct. ^d	late June- mid-Oct.?	1?	A?	rare; southern 1/3 of state	2	15-320m (168) .14-.31m/sec (.22)	gravel and rubble
sp. B	d	d	d	d	very rare; west central	1	11m .39m/sec	gravel and rubble
sp. C	d	d	d	d	very rare; Wis. R. southern 1/3 of state	1	320m .30m/sec	rubble and submerged logs

^aTypes of Life Cycles: A: univoltine, eggs diapause through winter until spring or early summer; B: univoltine or bivoltine, eggs diapause through winter to late spring; species either have one generation with a long hatching period or two generations which overlap; C: bivoltine, eggs hatch in fall with emergence in spring and from early summer through fall; D: bivoltine, eggs diapause through winter until early summer, followed by two rapid overlapping summer generations.

^bData summarized from Hilsenhoff (1977) and Bergman (1977).

^cColeman and Hynes (1970) found *B. hageni* (as *herodes*) bivoltine in Ontario.

^dInsufficient data; ? = scanty data.

Baetis levitans McDunnough

Adult description: McDunnough (1925b:216)

Nymphal description: Ide (1937:225)

Brilliant lemon-yellow eyes of live or recently killed male imagoes distinguish this species from other Wisconsin *Baetis*. Adult males remain teneral for several hours before attaining adult coloration. These teneral males can be confusing because they are considerably lighter, especially in the thorax. Nymphs are difficult to separate from *phoebus* and both species may occur in the same stream. Mature *levitans* nymphs usually have strongly tracheated gills, while gill tracheation in *phoebus* is usually weak or lacking. Abdominal pigmentation is similar, but usually colors are more contrasting in *phoebus*, although both species show considerable variation in color intensity from stream to stream. Abdominal markings described in the key are useful in separating *levitans* from *phoebus*.

Baetis macdunnoughi Ide

Adult and nymphal description: Ide (1937:230)

Only females are known from Wisconsin, and they cannot be separated from *pygmaeus*. *B. macdunnoughi* (Fig. 2H) and *pygmaeus* (Fig. 2G) nymphs have distinctive labial palps, with the thumb-shaped inner lobe of the second segment approximately twice as long as wide. They are easily separated from each other by the shape of the seventh pair of gills.

Baetis phoebus McDunnough

Synonymy: *Baetis quebecensis* (= *B. cingulatus*) McDunnough (1925b:216), *Baetis pallidulus* McDunnough (1924:8)

Adult description: McDunnough (1923:41)

Nymphal description: Ide (1937:224)

Seasonal changes in color patterns on abdominal terga make male imagoes difficult to identify. At certain times of the year, usually spring and autumn, males often have a reddish-brown or orange transverse stripe at the posterior margin of terga 2-6. In summer this stripe frequently becomes light orange or is lost entirely. Terga 2-6 vary from light orange-tan to semi-translucent white and like *levitans*, male imagoes of *phoebus* remain teneral for several hours during which time the thorax is light yellow-tan before changing to olive-brown. After rearing numerous imagoes we concluded that *B. phoebus*, *B. quebecensis* and *B. pallidulus* are synonymous. *B. quebecensis* was probably described from imagoes with reddish-orange bands on abdominal terga 2-6 and *pallidulus* from teneral imagoes. Laboratory rearing of adults in controlled environments is needed to determine the exact cause of these color changes, which appear to be related to seasonal changes in stream temperatures. Pigment variations tend to occur more frequently in northern latitudes. Many *Baetis* were described from male imagoes collected in the midwest and Canada and synonymies have resulted because color often was used as the distinguishing character. Nymphs (Fig. 2M) may be confused with *levitans* and differences are discussed under *levitans*.

Baetis propinquus (Walsh)

Synonymy: *Cloe propinqua* Walsh (1863:207); *Acentralla propinqua* (Walsh) Traver (1937:83); *Baetis dardanus* McDunnough (1923:41)

Adult description: Walsh (1863:207); Burks (1953:126)

Nymphal description: Edmunds (1952:259 as *dardanus*), not *propinquus*

Burks (1953) studied a lectotype of *dardanus* and after finding no specific differences from *propinquus*, synonymized the two species and redescribed the imagoes. The description of a nymph of *propinquus* (as *dardanus*) by Edmunds (1952) does not agree with nymphs collected in Wisconsin. *B. propinquus* nymphs have unique labial palps. The second segment lacks a lobe on the inner margin giving the apical portion of the palp a distinctive cone-shaped appearance. Since *propinquus* was originally described from Illinois and imagoes reared from Wisconsin agree with the description of a male by Burks (1953), the Utah nymph described by Edmunds is undoubtedly a different species. A redescription of the nymph was deemed necessary and follows:

Length of body 6.9 mm; cerci 4.2 mm, median caudal filament 1.5 mm. Head light brown; antennae white. Thorax brown with white median area forming a white stripe. Thoracic sterna tan. Legs mostly white with brown shading on coxae and at base, middle and apex of each femur. Forelegs with numerous short spines on ventral surface of femur and tibia. Abdominal terga (male) 1, 7 and 10 mostly white; tergum 7 often with median and lateral brown shading. Terga 2-6 mostly medium brown; a pair of minute pale spots near middle of each tergum, anterior to these spots a pair of short oblique dashes (median spots and dashes often absent). Terga 3-6 with a pale median-posterior spot (often diffuse to form a median white stripe). Lateral margins of terga 2-6 white. Submarginal white blotches often present on 2-6, sometimes forming two diffuse longitudinal stripes. Terga 8 and 9 chocolate brown with a pair of median pale dots. Abdominal terga of female similar to males, except terga with fewer pale areas than males, especially tergum 7. Abdominal sterna 1-7 and 10 dirty white; 8 and 9 dark brown in males, paler in females. Gills mostly hyaline with a single partially pigmented median trachea; gill margins dark basally. Cerci of male and female nymphs pale, each with a dark brown median band. Median caudal filament white to hyaline with a brown median band.

Baetis pygmaeus (Hagen)

Synonymy: *Cloe pygmaea* Hagen (1861:54)

Adult description: Hagen (1861:54); Needham (1901:421); McDunnough (1925a:172)

Nymphal description: Needham (1901:421); Ide (1937:230)

Male imagoes and nymphs can be easily separated from other Wisconsin *Baetis* by characters in the keys and those presented in the discussion of *macdunnoughi*.

Baetis spinosus McDunnough

Adult description: McDunnough (1925a:174)

Nymphal description: Berner (1940:50)

Male imagoes are easily recognized by their distinctive genitalia. The absence of an interrupted median longitudinal line separates the nymphs from *frondalis*. The mid-anterior oblique dashes and dots on terga 2-9 are often diffuse, especially on terga 2-6, often forming two large mid-anterior spots (Fig. 2Q).

Baetis vagans McDunnough

Synonymy: *Baetis incertans* McDunnough (1925b:220)

Adult description: McDunnough (1925b:219); Burks (1953:131)

Nymphal description: Ide (1937:221)

Needham et al. (1935) and Ide (1937) were undoubtedly correct when they synonymized *incertans* with *vagans*. Summer generation imagoes are smaller and lighter in

color. Abdominal terga 2-6 are opaque with a yellow tinge and have a narrow reddish-brown transverse line at the posterior of each tergum, agreeing with McDunnough's (1925b) description of *incertans*. Male imagoes emerging in spring have abdominal terga 2-6 olive-brown to chestnut brown with the anterior fourth of each tergum light yellow. Summer generation nymphs have terga 5, 9 and 10 pale to white, while these same terga in the nymphs of the winter generation are usually only partially pale (Fig. 2B).

Baetis sp. A

This species was not identified because male imagoes were not successfully reared in the laboratory. Nymphs can be distinguished from other species by the extensive pale areas on abdominal terga 1, 4-7 and 10 (Figs. 2E,F). The following description is from a mature male nymph preserved in 70% ethanol.

Length of body 5.5 mm; cerci 2.5 mm, median caudal filament 1.5 mm. Head and thorax brown with pale areas. Legs white with brown shading on coxae and at base, middle and apex of each femur. Terga 1, 4-7 and 10 mostly white; terga 4-7 with variable brown shading (5 often with a dark brown W-shaped pattern). A pair of pale median spots on terga 2 and 3; anterior to these a pair of short oblique dashes. Sterna 1-7 and 10 white, 8 and 9 mostly brown, 8 with a pair of anterior-median pale spots. Caudal filaments white to hyaline with a median brown band. Gills hyaline, each having a black median trachea with one or two short branches.

Baetis sp. B

A single nymph of this two-tailed *Baetis* was collected in Wisconsin. Although evidence is scanty, it appears likely that it could be *B. elachistus*, which Burks (1953) described from adults collected in Illinois. He noted that this species was similar to *B. amplus* (Traver), which was described from North Carolina. Nymphs of *amplus* (Traver, 1932) have two tails and it seems likely that *elachistus* nymphs may also be two-tailed. Unfortunately, Burks did not describe the nymph of *elachistus* and the two-tailed *Baetis* from Wisconsin does not agree with the nymphal description of *amplus*. The female nymph collected in Wisconsin was not mature and also lost some of its coloration during preservation in alcohol. Its description follows:

Thorax light brown dorsally with scattered pale areas. Abdominal terga 5, 9 and 10 mostly pale, tergum 5 with a pair of median brown spots; terga 1-4 and 6-8 mostly brown. Lateral margins of terga under gills white. Sterna tan. Gills hyaline and ovate, tracheae 4-5 branched and hyaline. Tails two and pale to tan.

Baetis sp. C

One specimen (Fig. 2D) was collected in Wisconsin and presently cannot be associated with known adults. Nymphs can be identified by white apical bands at the end of each caudal filament. The following description is from a mature male nymph preserved in 70% ethanol.

Length of body 6.8 mm; cerci 3.2 mm, median caudal filament 2.1 mm. Thorax mostly brown dorsally, with a narrow pale median longitudinal stripe. Thoracic sterna pale. Legs white with brown shading on coxae and at base, middle and apex of femur. Abdominal terga mostly medium brown with a narrow, pale, indefinite median line; on terga 2-6 and 8-10 this line widens to form a pale spot at anterior and posterior margins; posterior spot on tergum 1 larger than on terga 2-6 and 8-10; pale line on tergum 7 distinctly wider than on other terga and extending entire length of tergum.

Terga 2-6 with two pairs of median spots, anterior pair being slightly oblique and dash-like. Terga 7-10 with one pair of median spots anteriorly. Abdominal sterna 1-4 light brown with a diffuse median pale area. Sterna 5-8 with two pairs of spots, anterior pair on 5-7 dash-like and slightly oblique. Gills hyaline, except for margins which are brown (most prominent at base); tracheae hyaline with 2-3 indistinct hyaline branches. Tails with basal two thirds brown and apical third white.

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