TAXONOMY OF *EPEORUS FRISONI* (BURKS) AND A KEY TO NEW ENGLAND SPECIES OF *EPEORUS*

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Abstract

Among all of the species of *Epeorus* recorded from New England (i.e., Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island and Vermont), *E. frisoni* (Burks) has been the least studied. Since Burks published the original description of *E. frisoni* in 1946, no other specimens have been found. Thus our knowledge of this species is based on a single specimen (the holotype) and a vague type locality label ("Mt. Katahdin, Roaring Brooks"…Maine). Until recently, further study at the type locality was not possible because of regulations protecting the wilderness nature of the area. However, because of efforts to assess the status of rare or presumably endangered aquatic organisms in Maine by the Maine Department of Inland Fisheries and Wildlife, access to the type locality was granted to search for *E. frisoni*.

Sampling during the summer of 2003 provided the first new specimens of *E. frisoni* since 1939 (when the holotype was collected). Larvae were reared and all life stages were associated. Study of these specimens and the holotype showed *E. frisoni* was distinct from its presumed sister species *E. fragilis* (Morgan) and *E. pleuralis* (Banks). Comparative study of the new *E. frisoni* material has led to the development of new species level keys for male imagos and well developed male larvae. Currently, female imagos and some female larvae can not be reliably determined.

Key words: Ephemeroptera; Heptageniidae; *Epeorus*, *E. frisoni*; taxonomy; key; New England species**.**

Introduction

The focus of this study is what has been called New England's only endemic mayfly, *Epeorus frisoni* (Burks). The original description was based on a single male imago collected in 1939 by T. H. Frison from the "Roaring Brooks" area east of Mt. Katahdin, Baxter State Park, Maine. Over the past 57 years, no other specimens identifiable as *E. frisoni* have been found. This has led to the suggestion that perhaps *E. frisoni* was a variant of one of the other common species of *Epeorus* or that it may have gone extinct. Part of the problem in searching for *E. frisoni* has been in knowing what habitats to search. Certainly flowing water, but not knowing precisely

what microhabitat variables are important, makes looking for an apparently rare species even worse. Therefore, to really understand this species and begin to answer some of the questions concerning its biology and conservation status, it was necessary to start at the type locality.

As part of a larger program to assess rare and presumably endangered aquatic organism in Maine, the Maine Department of Inland Fisheries and Wildlife (MDIFW) in conjunction with officials governing Baxter State Park developed a plan to systematically sample streams in and around the area. The holotype of *E. frisoni* was collected with the following goals: first, verify the existence of *Epeorus frisoni* at or about the presumed type locality; second, rear larvae to associate adult and larval stages; third, collect habitat data necessary to facilitate future searches for *E. frisoni* outside of Baxter State Park; and finally, provide new material for comparative study to develop new keys for the species of *Epeorus* that occur in New England.

Methods

The study area was located in Baxter State Park, Maine, USA and focused on the area of Roaring Brook upstream from Roaring Brook campground and its tributaries along the trail to Chimney Pond. Because Baxter State Park is protected by special regulations to maintain the wilderness nature of the park, sampling was done to minimize effects to aquatic habitats and aquatic insects not the focus of this study. Benthic samples were taken using a 1-m kick net at three sites along Roaring Brook, one site on Pamola Brook and one site on Blacksmith Brook. Larvae were sorted alive and those at or near the final instar were retained for rearing. All rearing was done on site. Aerial nets were used to sweep for adults and a battery-powered blacklight was used at the base camp on Roaring Brook. All specimens were preserved in 95% ETOH. Water temperatures were recorded at each site from June – September 2003 and at the Pamola Brook site dissolved oxygen, pH, specific conductance, velocity and depth were recorded for the 26 August sampling. In addition, substrate composition and changes in channel morphology were qualitatively assessed at each sampling time.

New material of *E. frisoni* was comparatively studied using the holotype of *E. frisoni* and specimens of *E. fragilis*, *E. pleuralis* and *E. vitreus* from New England and adjacent areas. All specimens were observed for morphological characters and body and appendage coloration under stereoscopic and compound light microscopy (up to 1000x magnification. All measurements were made using a calibrated ocular micrometer (nearest 0.01 mm). Larval exuviae were measured with exuviae held as flat as possible without causing excessive distortion. Means and SDs were calculated for all continuous data; medians were estimated by interpolation. Lengths of the foreleg segments of male imagos were compared to the lengths of the fore tibiae and expressed as ratios. Ranges of ratios are given with each ranges median value. Eggs

were dissected in 95% ethanol and slide mounted in CMCP® --10. Eggs were removed from the lower oviducts to minimize differences related to maturation. Egg chorion features were observed under phase contrast microscopy (400 and 1000X). Length measurements were made on 10 eggs chosen haphazardly using an ocular grid.

Material Studied

Holotype of *Epeorus frisoni*: USA, MAINE: Piscataquis Co., Mt. Katahdin, Roaring Brooks, 26.VIII. 1939, T.H. Frison, 1M (INHS), Collection # 16253 and Slide # 20562; Baxter State Park, Pamola Brook [45° 55.263'N/068° 52.570'W], 15.VII.2003, B. Swartz, 1M (NEL); same, 29.VII.2003, P.C. Wick, 4M,1F (NEL); same, 18.VIII.2003, 1SF, 1LEX, 1L (NEL); same, 26.VIII.2003, S.K. Burian and P.C. Wick, 2ML (NEL); Baxter State Park, Blacksmith Brook [45° 55.268'N/068° 52.690'W], 24.IX.2003, P.C. Wick, 1ML (NEL); same, 9.X.2003, P.C. Wick, 1M (NEL); trib. to Abol Stream, Baxter State Park, elevation 1144' (349 m) [45° 51. 6833'N/068° 57.6000'W], 12.VII.1982, A.C. Graham, 1ML (SWRC);VERMONT: Bennington Co., South Fork of Goodman Brook, tributary of the West Branch of the Batten Kill, Elev. 1420' (433m) [43° 17.7833'N/073° 07.1833'W], 14.VII.1982, D.I. Rebuck, 1M, 1F, 2LEX (SWRC).

Other Material Studied: In addition, specimens of *E. fragilis*, *E. pleuralis*, and *E. vitreus* were studied from the following areas:

E. fragilis: USA: MAINE: Piscataquis Co., Nesowadnehunk Stream, Baxter State Park, elevation 1050' (320 m) [45° 54.0333'N\069° 2.3666'W], 28. VI. 1988, D.I. Rebuck and D.H. Funk, 2M (SWRC); same, 14. VII. 1982, A.C.Graham, 2L (SWRC); same, Little Abol Stream (abol trib. #1), Baxter State Park, 27. IX. 1981, D.H. Funk and A.C.Graham, 4L (SWRC); PENNSYLVANIA: Eire Co., Fourmile Creek, trib. site #1, lower section, 6. VI. 1990, E.C.Mastellar, 1M, 1F (NEL); VERMONT: Bennington Co., Gilbert Brook below Daley Brook on West Branch of Batten Kill (River), 0.5 mi. SW of Dorset, elevation 1100' (325 m) [43° 14.4833'N/073° 6.4833'W], 20. VII. 1982, D.I. Rebuck, 58L (SWRC); VIRGINIA: Rappahannock Co., Bearwallow Creek (above bridge), 2.2 mi. W Jct. of CR630 and Hwy. 522 on CR630, elevation 920' (280 m) [38° 47.1166'N/078° 8.9000'W], 18. V. 1980, C.E. Dunn, 1M (SWRC) CANADA: NEW BRUNSWICK: Northumberland Co., Catamaran Brook, 27. VI. 1995, M.Dobrin , 1M (NEL); same, 28.VI.1995, M. Dobrin and D. Giberson, 1M (NEL); QUEBEC: Saguenay Co., Riviere aux Loups Marlins, above Rt. 138, elevation 050' (15 m) [50° 16.7333'N/065° 43.2000'W], 28. VII. 1982, J.A.G., 7L (SWRC).

E. pleuralis: USA: CONNECTICUT: New Haven Co., Bethany, 2. V. 1983, V.A. Nelson, 5M (NEL); Seymour, from swarm over pool on Molsick Rd., 18. IV. 1998, S.K. Burian, 4M (NEL); same, 23. IV. 1998, S.K. Burian, 1F (NEL); MAINE: Franklin Co., Carrabassett River, dwnstr. of 2nd bridge at Sugarloaf Ski Area, 15. VI. 1985, S.K. Burian, 12M, 3F (NEL); same, 21. VI. 1985, S.K. Burian, 1M, 1F (NEL);

small stream flowing through Gondola Village, Sugarloaf Ski Area, 21. VI. 1985, S.K. Burian, 2M, 2F (NEL); Penobscot Co., Crystal Brook, 3.6 mi. N of Patten at Rt. 11, elevation 670' (204 m) [46° 3.2166'N/068° 26.6000'W], 26. V. 1982, A.C. Graham and M.K. Butcher, 7L (SWRC); Piscataquis Co., Nesowadnehunk Stream, Baxter State Park, elevation 1050' (320 m) [45° 54.0333'N/069° 2.3666'W], 2. VI. 1982, A.C. Graham and M.K. Butcher, 1L (SWRC); NEW YORK: Delaware Co., East Fork of Delaware River, 0.8mi. SW of Downsville, elevation 1090' (332 m) [42° 4.3166'N/075° 0.4166'W], 27. IV. 1982, J.W.P. and D.H. Funk, 4M, 2F, 6LEX (SWRC); same, 25. IV. 1982, J.W.P. and D.H. Funk, 1M, 1F, 2LEX (SWRC); same, 19. IV. 1983, P.D., J.D., and D.I. Rebuck, 20L (SWRC); PENNSYLVANIA: Chester Co., Bog Hollow Creek, West Branch of Brandywine Creek, 1.9mi. SE of Mortonville, elevation 330' (100 m) [39° 55.4166'N\075° 45.4500'W], 11. IV. 1978, D.H. Funk, 22L (SWRC); same, 12. IV. 1978, D.H. Funk, 1M, 1LEX (SWRC); same, 14. IV. 1978, D.H. Funk, 1M, 1LEX (SWRC); same, 15. IV. 1978, D.H. Funk, 1M, 1LEX (SWRC); Sesquehanna Co., trib. of Partners Creek, 1.9mi. SW of Harford on Rt. 944, elevation 1360' (414 m) [41° 45.4500'N/075° 44.7666'W], 29. IV. 1980, D.T. Mulvey, 1M, 1LEX (SWRC); same, 15. IV. 1982, D.I. Rebuck, 16L (SWRC); trib. to Wylusing Creek, 3.0mi. W of Montrose, elevation 1220' (372 m) [41° 49.1833'N/075° 56.0000'W], 16. IV. 1980, D.T. Mulvey, 1M (SWRC); same, 26. IV. 1980, D.T. Mulvey, 1M, 1LEX (SWRC); same, 29. IV. 1980, D.T. Mulvey, 1M, 1LEX (SWRC); trib. to Meshoppen Creek, 2.0 mi. E of Dimmock on Rd. T508 at Jct. of Rd. T518, elevation 1060' (323 m) [41° 44.2166'N/075° 51.6000'W], 21. II. 1980, D.H. Funk and P.J. Dodds, 6L (SWRC); same, 27. V. 1980, D.T. Mulvey, IM, 1F (SWRC); same, 4. VI. 1980, D.T. Mulvey, 1M (SWRC); VIRGINA: Bedford Co., unnamed trib. of Sheep Creek, 0.65 mi. NW of Jct. of CR680 and CR614 on CR680, elevation 1250' (381 m) [37° 24.9666'N/079° 38.7666'W], 20. IV. 1980, P.J. Dodds, 1M, 1LEX (SWRC); Sheep Creek, 0.7mi. N of Jct. CR614 and CR680 on CR614, elevation 1240' (378 m) [37° 25.3500'N/079° 38.4000'W], 27. III. 1980, D.H. Funk and P.J. Dodds, 1SM (SWRC); same, 7. IV. 1980, D.H. Funk and P.J. Dodds, 1M (SWRC); Rappahannock Co., Bearwallow Creek (above bridge), 2.2 mi. W of Jct. CR630 and Hwy. 522 on CR630, elevation 920' (280 m) [38° 47.1166'N/078° 8.9000'W], 17. IV. 1980, C.E. Dunn, 5M (SWRC); same, 24. IV. 1980, C.E. Dunn, 2F, 2LEX (SWRC); same, 8. IV. 1981, M.B. Griffith and D.I. Rebuck, 5L (SWRC); same, 8. V. 1981, P.J. Dodds, 12M, 4F (SWRC); Hittles Mill Stream at Jct. of CR630 and CR638, elevation 740' (225 m) [38° 47.6333'N/078° 7.0666'W], 12. IV. 1981, D.I. Rebuck, 2M, 1LEX (SWRC); same, 13. IV. 1981, D.I. Rebuck, 1M, 1LEX (SWRC);CANADA: QUEBEC: Saquenay Co., Ruisseau du Cran Carre, above Rt. 138, elevation 160' (49 m) [50° 17.6000'N/065° 55.5000'W], 13. VI. 1982, A.G., 3M, 2LEX (SWRC); same, 14. VI. 1982, J.A.G., 5L (SWRC); same, 2. III. 1982, J.A.G., 2M, 2LEX (SWRC).

E. vitreus: USA: CONNECTICUT: Litchfield Co., Blackberry River, dwnstr. of Rt. 44 bridge, Norfolk [42° 0.4000'N/073° 14.0833'W], 8. VI. 1997, S.K. Burian, 6L

(NEL); Housatonic River, fly fishing area of Housatonic Meadows State Park, 29. II. 2004, L.M. Rojas, 2L (NEL); MAINE: Hancock Co., Whitten Parritt Stream, T7 SD, Rt. 1, 21. VI. 2004, S.K. Burian, 1F, 1LEX (NEL); Piscataquis Co., Nesowadnehunk Stream, Baxter State Park, elevation 1050' (320 m) [45° 54.0333'N/069° 2.3666'W], 20. VI. 1988, D.H. Funk and D.I. Rebuck, 1M, 1F (SWRC); same, 6. VIII. 1988, A.C. Graham, 2L (SWRC); Washington Co., Narraguagus River, Little Falls National Marine Fisheries Field Station site at Little Falls north of Cherryfield, off of Rt. 193, 23. VI. 2004, S.K. Burian, 12L (NEL); MINNESOTA: Lake Co., West Branch of Splitrock River at Rt. 3 [47° 14.5300'N/091° 28.9116'W], 29. V. 1999, Sk.Burian, 6L (NEL); NORTH CAROLINA: Madison Co., Walnut Creek, Marshall, 6. VI. 1983, S.K. Burian, 4L (NEL); NEW HAMPSHIRE: Hills Co., Souhegan River, 2.5mi. N of Greenville, 11. Vi. 1998, J. Burger and D. Chandler, 1L (NEL); NEW YORK: Delaware Co., East Creek, trib. of Delaware River, 0.8 mi. SW of Downsville, elevation 1090' (332 m) [42° 4.3166'N/075° 0.4166'W], 13. VII. 1982, D.H. Funk and J.W.P., 10L (SWRC); PENNSYLVANIA: Chester Co., East Fork of East Branch of White Clay Creek, 0.6 mi. W of London Grove, 15. V. 1980, D.H. Funk, 1M, 1LEX (SWRC); same, 0.8 mi. WSW of London Grove, elevation 345' (105 m) [39° 51.7833'N/075° 47.1166'W], 14. V. 1981, A.C. Graham, 5L (SWRC); Wet Lab at Stroud Water Research Center, London Grove, elevation 325' (99 m) [39° 51.5333'N/075° 47.0333'W], 27. V. 1979, D.H. Funk, 1M (SWRC); same, 30. V. 1987, D.H. Funk, 1M (SWRC); VERMONT: Bennington Co., West Branch of Batten Kill (river), 2.0 mi. S of South Dorset on Rt. 30, elevation 879' (268 m) [43° 13.1666'N/073° 4.3000'W], 4. VI. 1980, A.C. Graham, 1M, 1LEX (SWRC); CANADA: QUEBEC: Saguenay Co., Riviere Matamec below Beaver Creek, elevation 060' (18 m) [50° 18.3500'N/065° 56.1833'W], 28. VII. 1981, J.A.G., 5L (SWRC); Riviere Pigou above Rt. 138, elevation 075'(23m) [50° 16.9500'N/065° 38.5166'W],8. IX. 1982, D.H. Funk, 2L (SWRC).

Specimen Abbreviations: M= Male imago; F= Female imago; SM= Subimago male; SF= Subimago female; L= Larva; LEX= Larval exuviae. Numbers of specimens studied precede abbreviations. Institution Abbreviations: NEL= Northeast Ephemeroptera Laboratory, at the Department of Biology, Southern Connecticut State University, New Haven, CT USA; SWRC= Stroud Water Research Center, Avondale, PA USA. Deposition of all materials is with the institutions indicated with each record.

Systematic Account and Key

Epeorus frisoni (Burks)

Iron frisoni Burks 1946: 608; Edmunds et al. 1976: 193; Burian and Gibbs 1991: 33.

Male imago (Figs. 5–7 in alcohol): Body Length: 6.83–9.42 mm (8.40±0.80, mean±SD, n=8); Forewing Length: 7.42–9.83 mm (9.02±0.79, n=8); Forewing Width: 2.71–3.93 mm (3.39±0.41, n=7); Caudal Filaments: 15.00–26.00 mm (23.0±3.57, n=7)

Range of ratios and median values of the foreleg segments referenced to the tibia: Femur = 0.44–0.86, Med.= 0.77; Tibia = 1.00; Tarsus 1 = 0.28–0.39, Med. = 0.31; Tarsus 2 = 0.31–0.38, Med. = 0.34; Tarsus 3 = 0.29–0.37, Med. = 0.32; Tarsus 4 = 0.19–0.27, Med. = 0.22; Tarsus 5 = 0.09–0.11, Med. = 0.10.

Head: Pale with bases of ocelli black. Antennae scape and pedicle light brown, flagellum slightly darker. Eyes light grayish brown to kaki colored meeting dorsally.

Thorax: Pronotum mostly pale brown with deep posterior medial notch and dark brown along posterior edge. Mesonotum with dark brown on infrascutellem, medium brown along the medioscutum and on posterior scutal protuberances. Pleural areas mostly pale yellowish brown with heavier sclerotized edges darker amber brown. Metanotum colored similar to mesonotum.

Wings: Forewing and hind wing as in Figs. 1 and 2. All veins pale. No anastomosing of cross veins in stigma. Stigmatic area of wing membrane slightly clouded.

Legs: Mostly pale. Femora with a distinct dark brown medial spot on dorsal surface. Apex of femora slightly shaded brown. Joints of tarsal segments with dark edge, tarsal claws blunt/sharp with dark brown shading in bases of claws.

Abdomen: Segments 2–7 translucent with subcuticular tracheols dark and visible dorsally. Extremely faint brown shading along posterior margins of terga (Fig. 3). Sterna 2–7 completely pale. Segments 8–10 opaque cream colored. Genitalia modified pleuralis-type with a dorsal forked process that merges with the inner apical margins of each pene forming a hook-shaped process (Fig. 5).

Caudal Filaments: Surfaces of annuli with many small setae. Filaments light brown near base becoming paler toward tips.

Female Imago (Figs. 8 and 9 in alcohol): Body Length: 7.08–8.58mm (7.77±0.62, n=4); Forewing Length: 8.58–10.00 mm (9.48±0.62, n=4); Forewing Width:3.25–3.58 mm (3.48±0.16, n=4); Caudal Filaments: 12.50–16.00 mm (14.25±2.47, n=2). Head similar in color to male. Eyes smaller, darker and widely separated. Antennae similar to male in size and color. Thorax similar in color and morphology to male. Legs similar in coloration to male. Abdominal terga mostly pale, but in contrast to

male have a light reddish brown area anteriorly on segments 2–10. Posterior margins of abdominal terga with distinct dark brown edge. Subcuticular tracheols dark and visible dorsally on terga. Caudal filaments with similar setae and color as in male.

Eggs (Fig. 4): Maximum Length: 0.165–0.180 mm (0.172±0.007, n=10); Maximum Width: 0.110–0.130 mm (0.112±0.008, n=10). Eggs oval shaped without any distinct chorionic sculpturing detectible at 1000x phase. Each egg with multiple micropylar devices (Mpd), Mpd positioned around the middle of each egg and somewhat equally spaced out. Mpd as in Fig. 4.

Larva (Figs. 8–17, 19, 22, 24 in alcohol): Body Length [all sexes]: 8.17–10.66 mm (9.16±1.18, n=4); Body Length ♂: 8.17–9.55 mm (8.86±0.97, n=2); Body Length ♀: 8.25–10.66 mm (9.45±1.70, n=2); Head Capsule Width ♂: 2.06–2.40 mm (2.23±0.14, n=3); Head Capsule Width ♀: 2.24 (n=1); Ratio of Head Capsule Width to Distance between Antennae: 2.36–2.73, Med.=2.47, n=7; Head and Thorax Length ♂: 2.96–3.63 mm (3.36±0.35, n=3); Head and Thorax Length ♀: 3.64–3.84 mm (3.74±0.14, n=2).

Head: Broad with anterior portion expanded (Fig. 8). Long hair-like setae present along anterior margin. Coloration as in Fig. 8, distinctive v-shaped mark present on anterior portion. Outer edges of head capsule smoothly curving posteriorly. Outer posterior edges of eyes only slightly extend beyond edge of head capsule (Figs. 8 and 22). Antennae with small brown spot near apical edge of last 10–15 annuli.

Mouthparts: Mouthparts as in Figs. 9–12, 16. Dorsal and ventral aspects of labrum as in Fig. 9. Labrum with shallow anterior median emargination and 2 pairs of setae medially and 1 pair of longer setae lateral to medial group of setae. Lateral edges with several long thick setae. Hypopharynx as in Fig. 10. Left and right mandibles as in Figs. 11 and 12. Right mandible with tuft of setae on anterior margin and row of long setae below molar surface. Left mandible with scattered long setae below molar surface. Incisors of both mandibles with 6–8 teeth long inner edge. Maxillae as in Fig. 13. Galea-lacinia with massive tridentate tip with apical spine tip hooked upward. Dorsal surface with secondary row of about 29 long setae set back from brush of setae along inner margin. Dorsal and ventral aspects of labium as in Fig. 16. Dorsal surfaces of glossa and paraglossa with brush of setae. Labial palps with dense row of long simple setae and large stout pectinate setae on ventral surface of segment 3.

Thorax: Pronotum with broad transverse median ridge margined with setae. Coloration as in Fig. 8 with dark subcuticular tracheols visible. Mesonotum as in Figs. 8 and 22. Pigmented areas strongly contrast with pale regions. Profile of margins of mesonotum from base of wing pads to anterior edge of pronotum not deeply concave (Fig. 22).

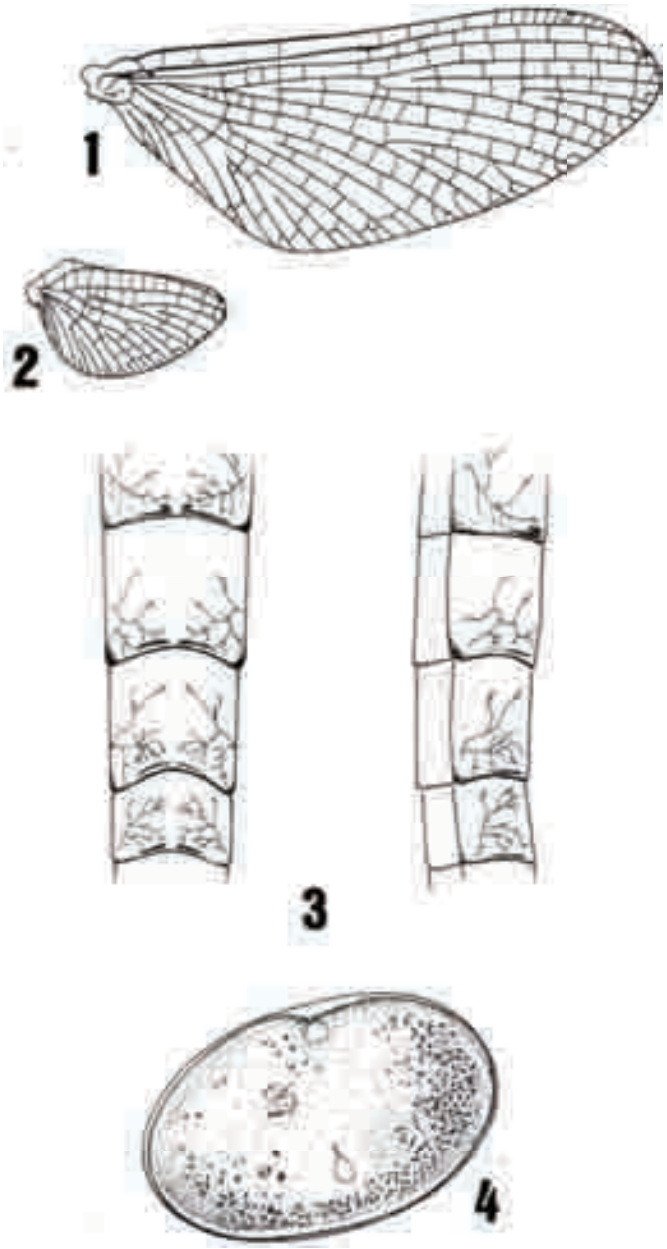
Legs: Legs as in Figs. 8, 14, 15. Femora with basal row of 5–6 large flat setae that can extend to anterior margin (Fig. 14). Dorsal surface of femora with scattered smaller flat setae over middle portion with dark median mark (Fig. 14). Posterior margins of femora with row of long blade-like setae. Tibiae with dorsal row of hair-like setae oriented perpendicular relative to those on the posterior margins of femora. Tarsi with scattered setae. Tarsal claws with 4 small subapical denticles ventrally (Fig. 15).

Abdomen: Abdomen as in Fig. 8. Terga 2–10 with medial longitudinal patch of setae. Terga 2–9 with small denticles along the posterior margin separated medially by area lacking denticles, but marked by a brown spot. Posterolateral projects on segments 2–9 short (Fig. 24).

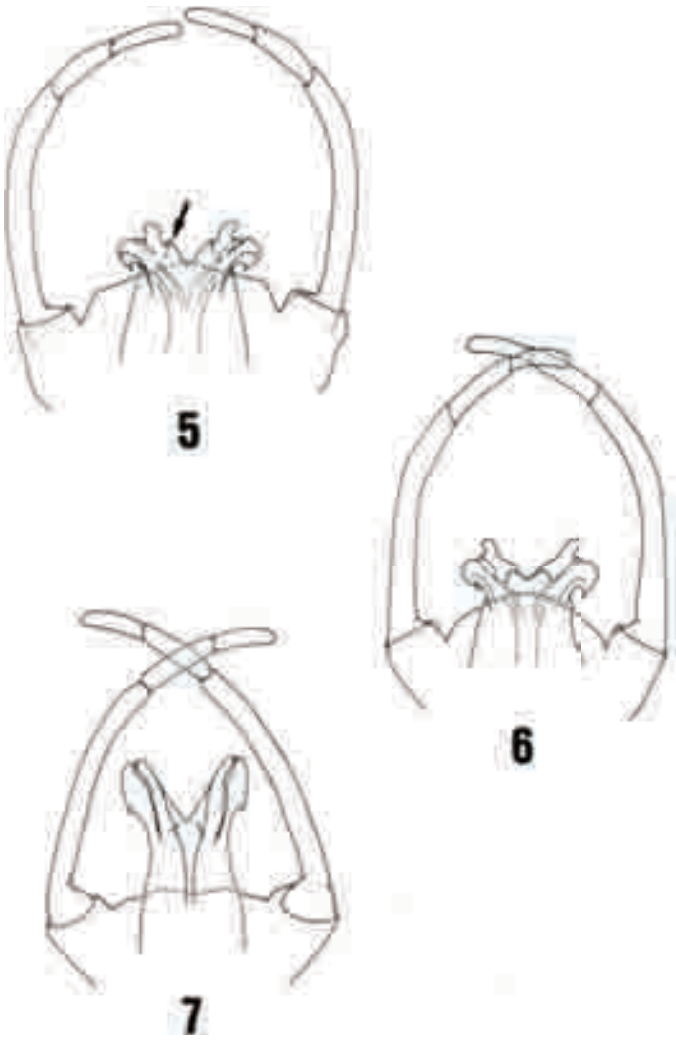
Gills: Gills as in Figs. 8 and 19. Anterior portion of all gills extend beneath the abdomen and except for gill 1 overlap. Anterior portion of gill 1 elongate and broadly rounded (Fig. 19). Elongate anterior portion reaches to about midline of body ventrally, but does not touch or overlap the opposite gill. Medial sclerotized strip of gill 1 angled at about 90° (Fig. 19).

Caudal Filaments: Filaments as in Fig. 8. Two long filaments present and annuli lack long setae, but a few small setae may be present on basal annuli.

Because larva of all the Nearctic species of *Epeorus* have not been studied in detail it is not possible to provide a definitive diagnosis. Therefore, this diagnosis is now restricted to the group of species known for New England.



Figures 1–4. Imago of *Epeorus frisoni* 1—Forewing. 2—Hind wing. 3—Abdominal terga 3–6 of male imago (dorsal and left lateral view). 4—Egg showing micropylar opening.



Figures 5–7. Male genitalia (ventral view). 5—*Epeorus frisoni* (arrow indicates hook-like process on inner apical margin of pene). 6—*E. fragilis*. 7—*E. vitreus*.

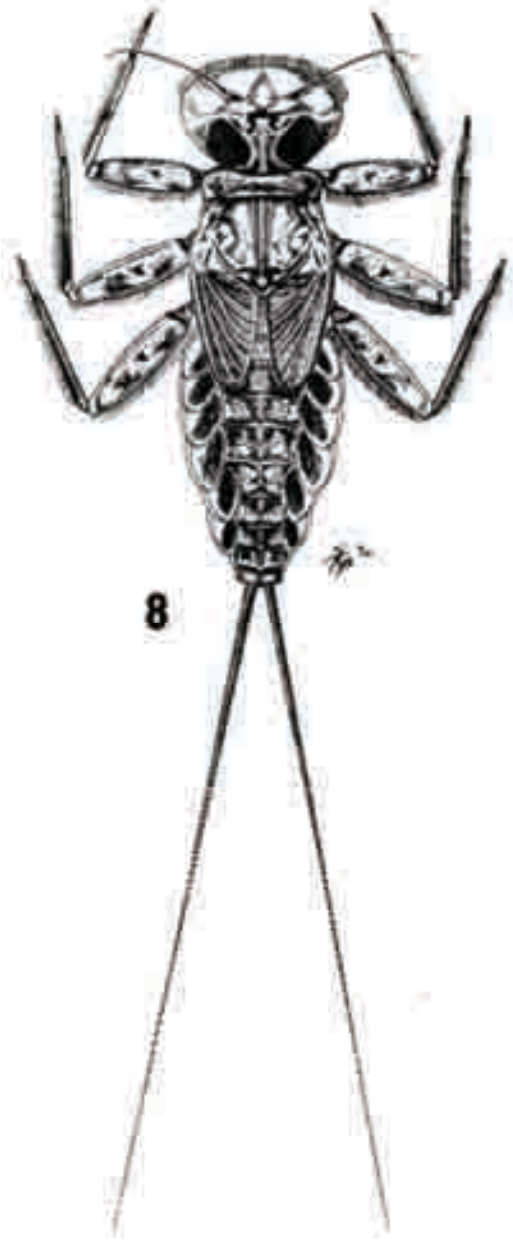
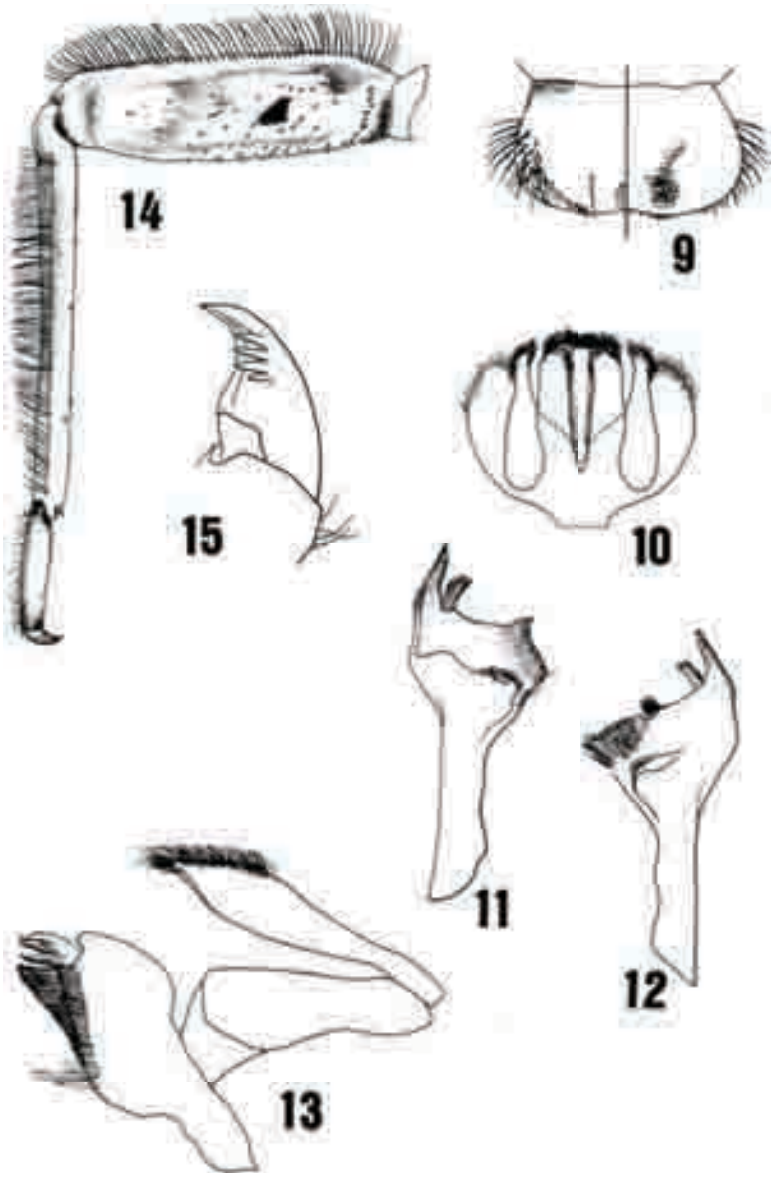
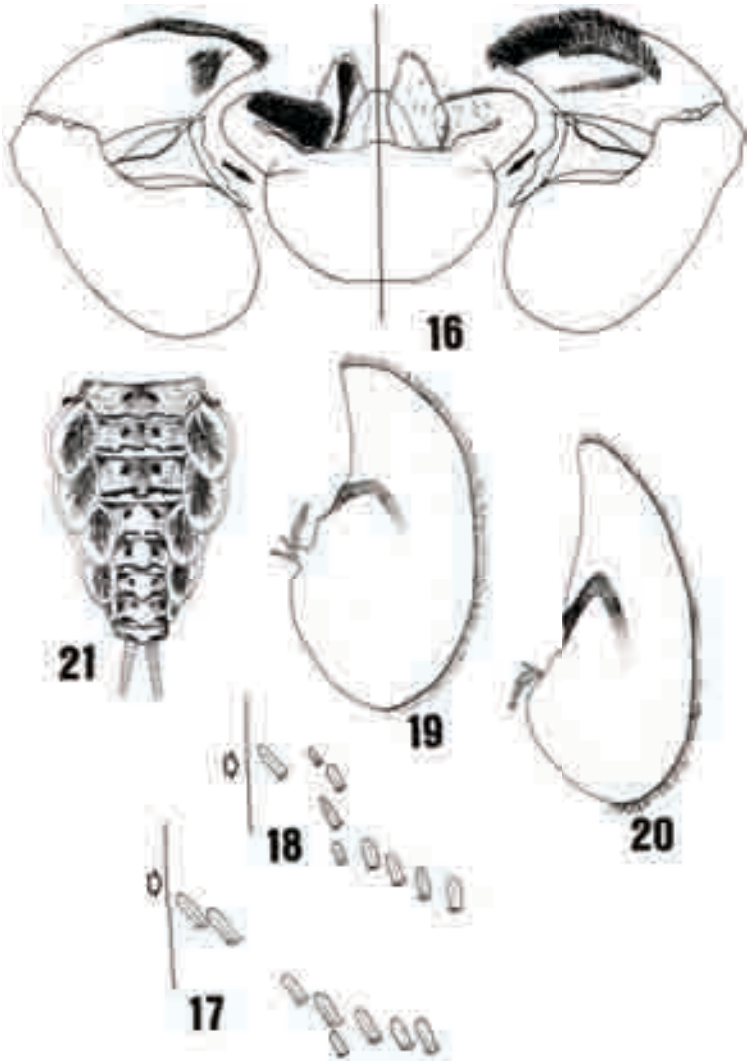


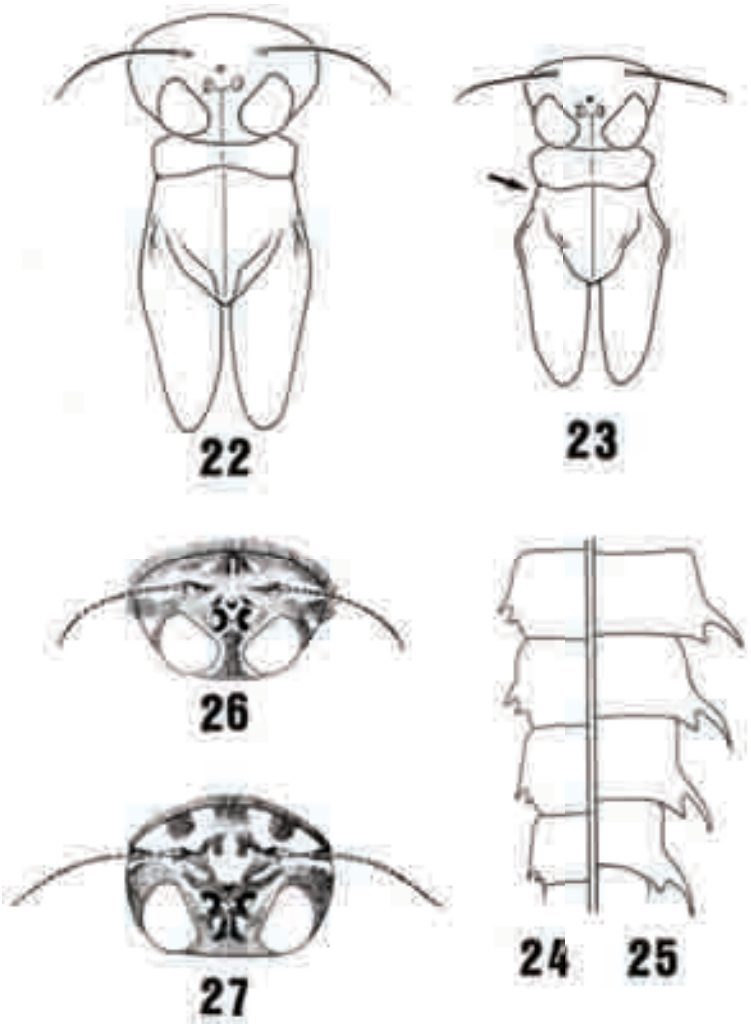
Figure 8. Dorsal view of final instar male larva of *Epeorus frisoni*.



Figures 9–15. Final instar of *Epeorus frisoni*. 9—Labrum with dorsal surface on left and ventral on right. 10— Hypopharynx (dorsal view). 11—Left mandible (dorsal view). 12—Right mandible (dorsal view). 13—Right maxilla (dorsal view). 14—Right foreleg. 15—Right foreclaw (ventral view showing denticles).



Figures 16—21. *Epeorus frisoni*, *E. pleuralis*, and *E. fragilis* larva. 16—Labium of *E. frisoni* (dorsal surface on left and ventral on right).
17—Row of setae on dorsal surface of forefemora of *E. frisoni* (near joint with coax). 18—Row of setae on dorsal surface of forefemora of *E. fragilis* (near joint with coax). 19—Gill 1 of *E. frisoni* (dorsal view). 20—Gill 1 of *E. fragilis* (dorsal view). 21—Abdominal terga 3-10 of *E. pleuralis* (dorsal view).



Figures 22–25. *Epeorus frisoni*, *E. fragilis*, and *E. vitreus* larva.
22— Head and thorax outline of *E. frisoni* (dorsal view). 23—Head and thorax outline of *E. fragilis* (arrow indicates deeply concave area of profile). 24—Posterolateral projections of abdominal sterna 4–7 of *E. frisoni*. 25—Posterolateral projections of abdominal sterna 4–7 of *E. vitreus*. 26—Head capsule of final instar male *E. pleuralis* (dorsal view). 27—Head capsule of final instar male *E. vitreus* (dorsal view).

Diagnosis

In New England, the early emergence of *E. pleuralis* and distinctive morphology of *E. vitreus* allow these species to be easily separated from *E. frisoni*. However, separating larvae of *E. frisoni* from those of *E. fragilis* is more difficult. Several diagnostic characters observed during this study are subtle and with the discovery of a population in VT, suggest the need of additional study. However, the consistent characters of male near final or final instar larvae are: shallowly concave profile of side of the thorax from the base of the wing pads to the anterior edge of the pronotum; ratio of the width of the head capsule to the distance between the antennae bases, 2.36 – 2.73, Med=2.47; head capsule with smoothly curving outer edges; posterior outer edges of compound eyes only slightly extending beyond outer edge of head capsule; anterior portion of gill 1 elongate, but broadly rounded with a sclerotized strip angled at about 90°; medial dark spot on femora not part of a streak or band, spot more vertical in position and sometimes appearing coma-shaped or triangular; and row or 5-6 large flat setae at base of forefemora. The coloration of the femora of *E. fragilis* varies from that of *E. frisoni* in that the medial spot often exists as part of a streak or band and is usually oval in shape.

Male imagos of *E frisoni* can be easily separated from *E. pleuralis* and *E. vitreus* not only by emergence time, but also body size, color and type of genitalia. Male imagos of *E. frisoni*, despite the overlap of emergence time and sympatry with *E. fragilis,* can be easily separated from those of *E. fragilis* by: larger body size (8.17—9.55 mm); pale color of head, thorax and especially abdomen; unique genitalia type with medial apical hook-shaped projections; much lighter grayish brown color of compound eyes after death.

Key to Mature Male Larvae of *Epeorus* of New England

1 Posterolateral projections of abdominal terga long and curving (Fig. 25); abdominal gills not greatly extended under abdomen and anterior portion of gill 1 not elongate; head capsule with outer margin flat curved and distinctive color pattern (Fig. 27) ..... *E. vitreus*.

1' Posterolateral projects of abdominal terga short (Fig. 24); abdominal gills extended under the abdomen and anterior portion of gill 1 elongate so that the apices about meet or exceed the midline of the abdomen; outer margin of head capsule smoothly rounded (Figs. 22, 23, 26) 2

2 Abdominal terga 3–7 with small paired medial dark spots (sometimes these are faint) (Fig. 21); body length ≥ 9.85 mm; anterior portion of head capsule with indistinct v-shaped mark (Fig. 26); final instar larvae collected from May to early June in most areas ..... *E. pleuralis*.

2' Abdominal terga 3–7 without paired dark medial spots (Fig. 8); body length < 9.55 mm; anterior portion of head capsule with distinct or moderately

distinct v-shaped mark (Fig. 8); final instar larvae collected from early July to early October 3

3 Head capsule outer margin with abrupt transition near outer anterior corners of compound eyes; ratio of head capsule width to distance between antennae 2.11–2.45, Med.=2.21; posterior edges of compound eyes hide much of posterolateral edge of head capsule (Fig. 23); profile of thorax deeply concave (Fig. 23); body length ≤ 6.66 mm; anterior portion of gill 1 narrow with sclerotized strip approximating a 45° (Fig. 20); forefemora with 3–4 large flat setae in a row that may extend to anterior edge of femora (Fig. 18) .....*E. fragilis*.

3' Head capsule oval in shape; outer margin smoothly curving posteriorly; ratio of head capsule width to distance between antennae 2.36–2.73, Med.=2.47; outer edge of head capsule visible at posterior edges of compound eyes where eyes extend slightly beyond edge (Figs. 8 and 22); profile of thorax shallowly concave (Fig. 22); body length 8.17–9.55 mm; anterior portion of gill 1 broad with sclerotized strip approximating a 90° (Fig. 19); forefemora with 5--6 large flat setae in a row that may extend to anterior edge of femora (Fig. 17) .....*E. frisoni.*

Key to Male Imagos of *Epeorus* of New England

1 Genitalia as in Fig. 7; abdominal terga mostly pale with median black marks centered on posterior margins of terga 3–5 and 7–9 (rarely abdomen mostly brown) .....*E. vitreus*

1' Genitalia as in Figs. 5 and 6; abdominal terga either brown or pale without dark medial marks 2

2 Genitalia as in Fig. 5 with dorsal process meeting inner apical margins of penes forming small hook-like projections; abdominal terga pale white with only faint yellowish shading along posterior third of terga, small areas of brown along posterior margins and posterolateral areas as in Fig. 3; compound eyes grayish or kaki colored after death.....*E. frisoni*

2' Genitalia as in Fig. 6 without hook-like projections; abdominal terga either mostly medium brown or pale yellowish brown occasionally pale yellowish white; compound eyes after death dark brown to blackish brown 3

3 Body length > 9.00 mm; abdominal terga mostly medium brown with occasional pale areas laterally (rarely with posterior margins of tergites dark brown); emergence May to early June in most areas.....*E. pleuralis*

3' Body length < 6.80 mm; abdominal terga pale yellowish brown to pale yellowish white; abdominal terga with faint dark brown on posterior margins; emergence late June–early August in most areas .....*E. fragilis*

Discussion

Results of this study have greatly increased our understanding of the *Epeorus* of New England and has provided several new directions for future study. After studying the New England subset of the eastern Nearctic species of *Epeorus*, it is now clear that there is much unexplored variation within and among species. Many of the characters studied for larvae and adults of *E. frisoni* are subtle and some are within the range of variation for *E. fragilis* and *E. pleuralis*. Specimens of *E. frisoni* from Vermont, although consistent in adult characters with specimens from the type locality in Maine, had larvae that were more variable compared to those from Maine. This suggests that at least some larval characters presented here as "diagnostic" may need to be modified as more material becomes available for study.

Direct study of the habitats of the type locality has provided much valuable data. We now know the types of clean, cold, higher elevation streams to search for additional populations of *E. frisoni*. Efforts are now under way by some of us to identify these types of habitats in Maine using GIS technologies and these will be the next areas searched.

Lastly, with a much better understanding of the structure of adults and larvae, it is possible to reexamine previously collected material and search for overlooked or misidentified specimens. For example, study of a specimen from New York reported as *E. frisoni* (Jacobus and McCafferty 2001) has showed it to be a misidentified specimen of *E. pleuralis*. Whereas, study of material from the SWRC previously determined to be *E. fragilis* has resulted in one new record for *E. frisoni* for Vermont. With the discovery of *E. frisoni* in Vermont, it is clear the species is not a narrow-endemic. At least one of us believes that a thorough search of suitable higher elevation, cold streams in the White Mountains of New Hampshire, the Adirondacks of New York and the Gaspe area of Quebec should result in the discovery of several new records.

Conclusions

Epeorus frisoni (Burks) is a valid species and is distinctive from its presumed sister species. It is still present at the type locality and there is now no immediate evidence to suggest that its population is not stable or in decline at that site. The habitat association of *E. frisoni* with cold (even in summer) continuously flowing, high gradient, minimally disturbed streams at or above 1200' (~365 m) could be used to identify some of the best high elevation lotic habitats for conservation purposes. Variation among the New England subset of the eastern Nearctic *Epeorus* strongly points to the need for a full revision of this genus.

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