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CONTRIBUTION TO THE MORPHOLOGY AND DESCRIPTIVE BIOLOGY OF *CAURINELLA IDAHOENSIS* (EPHEMEROPTERA: EPHEMERELLIDAE)

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ABSTRACT.—Reared specimens from Bridge Creek, Idaho County, Idaho, provide the bases for the first descriptions of *Caurinella idahoensis* egg and alate stages and redescription of the larval stage. Larvae are distinguished from other Nearctic Ephemerellinae species by the distinctive posterolateral projections on abdominal segment 9. Male adults have a unique combination of characters associated with their genitalia. Larvae were associated with the colonial blue-green alga *Nostoc parmelioides* in a clear, cold headwater stream. Several other Diptera, Ephemeroptera, Plecoptera, and Trichoptera also were found in cohabitation with *C. idahoensis*. Amorphous detritus appears to be a major component of the diet of *C. idahoensis*, and larvae may defend small territories on rock surfaces. Larvae exhibited prolonged preemergence behavior in the laboratory rearing apparatus.

Key words: Caurinella idahoensis, *Ephemeroptera, Ephemerellidae, stage descriptions,* Nostoc parmelioides, *behavior, Bitterroot Mountain Range.*

Caurinella Allen is a monospecific genus (Allen 1984) of the subfamily Ephemerellinae of the Ephemerellidae (McCafferty and Wang 2000). *Caurinella idahoensis* Allen has been known from the larval stage only, and it has been reported from only 2 locales in Idaho (Bushy Creek, tributary of Lochsa River, Idaho County [Allen 1984], and Eggers Creek, tributary of Silver Creek, Valley County [Edmunds and Murvosh 1995]) and 1 locale in far western Montana, near the Idaho border (McCafferty 2001a). Recently, additional *C. idahoensis* larvae were collected from central Idaho (G.T. Lester, Moscow, ID, personal communication). Barbour et al. (1999) inferred that *C. idahoensis* larvae are primary collector-gatherers and that the species is extremely sensitive to pollution, being found only in minimally disturbed streams of high water quality (for discussion of biological indicators and water quality parameters, see Hilsenhoff 1982, 1998, Cummins and Merritt 1996). Edmunds and Waltz (1996) included *Caurinella* in their larval key to North American Ephemeroptera genera.

As part of our studies of poorly known North American Ephemeroptera (e.g., McCafferty 2001a, 2001b, Jacobus and McCafferty 2002) and our revisionary studies of Ephemerellinae, we traveled to the Lochsa River drainage in the Bitterroot Mountain Range to find, study, and rear *C. idahoensis.*

METHODS

On 29 July 2002 we located a population of late instar larvae in Bridge Creek, Idaho County, Idaho, at 1708 m above sea level. We placed a series of these larvae in resealable food container cups with water and stones from their habitat. Aeration was provided by portable aquarium aerators, and each cup was suspended above loose ice in a large, insulated cooler. Temperature in the cooler varied from 7°C to 13°C during the 3 days of our return to Indiana from Idaho. Once in the laboratory, we opened the cooler during the day in an air-conditioned room (20°–23°C, 46%–53% relative humidity) and exposed its contents to ambient light from a south-facing window. Ice changes continued twice a day, and we added small amounts of bottled mineral water to each cup each day to maintain water levels. Subimagos were removed from the rearing apparatus and placed in small plastic cups that contained crumpled tissue paper. We fixed adults in a 70% ethanol solution about 12 hours after emergence from the subimago.

At the study site we measured water temperature and photographed the larval habitat.

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Samples of stone substrate from where the study organisms were found were collected for further study, including the identification of associated epilithic periphyton. Any macroinvertebrates collected with the study organism were fixed in a 90% ethanol solution in the field and later transferred to a 70% ethanol solution for storage. A few specimens of the study organism were fixed in ethanol at the study site for later examination and study. Using stereo and compound light microscopy, we studied in detail the exoskeletal morphologies of mature larvae, larval exuviae, reared male and female adults, and subimagos. A few specimens were dissected for microanatomical analysis and extraction of eggs. We examined and documented eggs from a female adult using scanning electron microscopy and described them following the terminology of Studemann and Landolt (1997). Foregut contents were analyzed following the methodology of McShaffrey (1988).

MORPHOLOGY AND TAXONOMY

Descriptions

EGG (FIG. 1).—One polar cap. Live color yellow; alcohol specimens purple with tan cap. Chorion with geometric macrorelief of juxtaposed hexagonal structures.

MATURE LARVA (FIG. 2).—Length, in millimeters: body 6.8–7.3; caudal filaments 3.0–4.2. General dorsal color light gray to dark khaki, with varied gray to dark brown markings; pale ventrally, without markings. *Head:* brown spot between compound eye and antennal base; other variable brown markings present; vertex smooth with scattered, hairlike setae. Antennal scape khaki, pedicel brown, flagellar segments brown. Genae and frontal ridge slightly produced to form rounded shelf, with numerous, long, hairlike setae. Clypeus produced slightly. Labrum dark brown; margins with dense fringe of short, fine, fimbriate setae. Maxillary palpi reduced, 3-segmented, with apical segment very small. *Thorax:* brown, microscopic excrescences present on dorsal surface; no prominent dorsal tubercles present. Pronotum pale, with smoky tinge at anteromedial margin, 2 pairs prominent dark brown medial spots, and additional variable brown markings; lateral margins and posterior margin dark brown. Mesothorax with variable brown markings; posterior tips of forewing pads dark brown. Legs covered with long, hairlike setae. Femora brown with pale foremargin and pale medial spot; scattered, short, stout, branched setae present on dorsal surface; hind margin with long, stout setae in slightly elevated sockets. Tibiae khaki; inner margin with long, stout setae. Tarsi brown; claws with single row of 3–5 denticles. *Abdomen:* brown, with large, paired, pale spots on terga 1–7; terga 8–9 with large, pale medial areas; small, sublateral pale

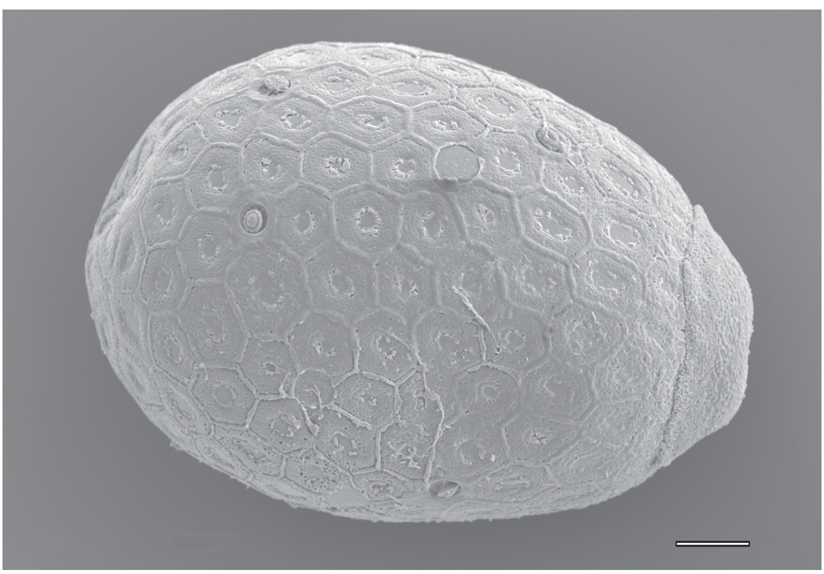


Fig. 1. Scanning electron micrograph of *Caurinella idahoensis* egg (scale bar = 20 µm).

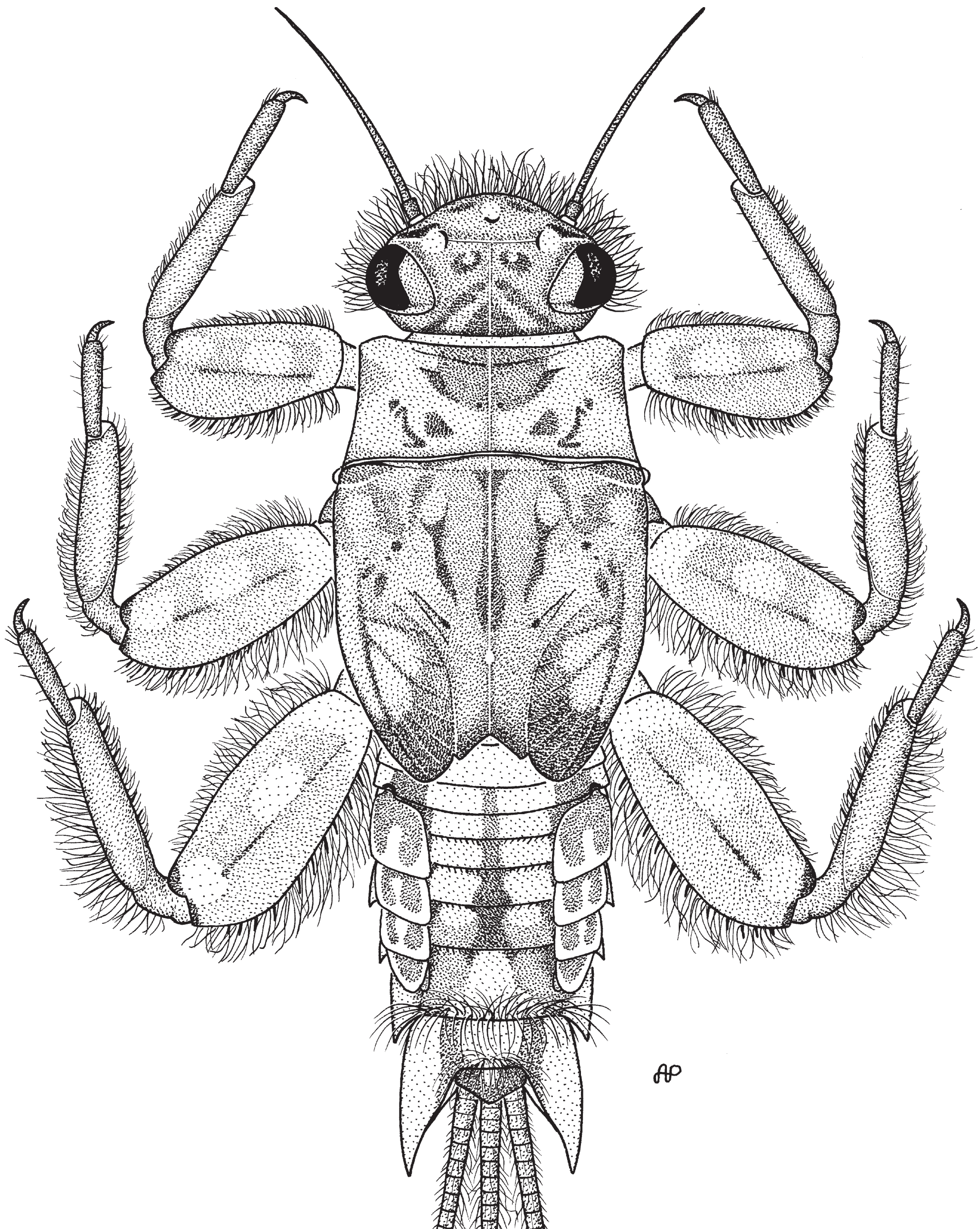


Fig. 2. *Caurinella idahoensis* larval habitus, dorsal view.

spots on terga 1–9; terga pale laterally; tergum 10 mostly brown with anteromedial pale spot; stout setae and hairlike setae present on posterior margins of terga; scattered spicules present on terga sublaterally; pair of posterior, transverse, rounded ridges with dorsally projecting, long, hairlike setae present on terga 8 and 9, more prominent on tergum 8; posterolateral projections present on segments 3 or 4–9; projections pale, with row of short, robust setae laterally and scattered, hairlike setae; projections progressively larger posteriorly; segment 8 projections slightly upturned laterally and distally; segment 9 projections prominent, at least subequal to length of segment at midline, upturned at apices. Gill lamellae on segments 3–7; lamellae 3–6 with median, mitten-shaped, brown region and pale central spot; lamellae 7 reduced, brown. Lower fimbriate portion of gills lamelliform; bifurcate on gills 3–5, integral on gills 6 and 7. Caudal filaments brown, with curved, hairlike setae at apex of each segment and sparse, fine, intrasegmental setae.

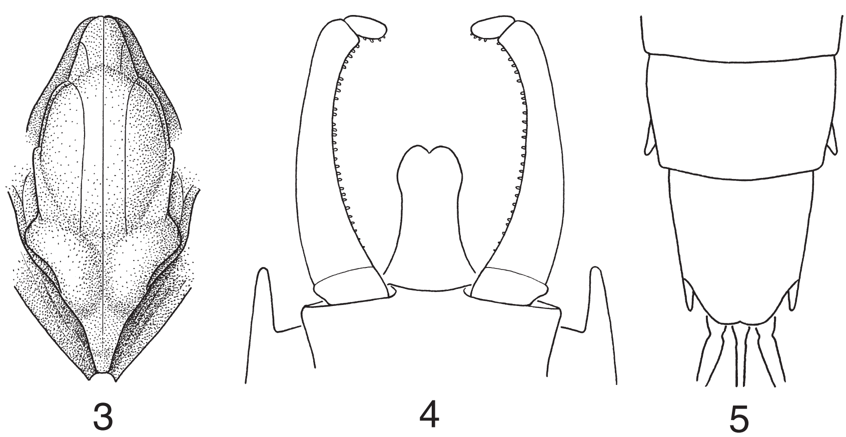
MALE ADULT.—Length, in millimeters: body 8.5, forewings 9.0, caudal filaments 11.2. *Head:* tan. Antennae tan. Ocelli white with reddish brown base. Upper portions of dioptic compound eyes nearly contiguous. *Thorax:* drab olive green in life, light tan in alcohol; prothorax with irregular gray markings and strong median keel; meso- and metathorax (Fig. 3) with sparse, irregular yellow and white markings. Wings hyaline, with all veins, intercalaries, and crossveins pale; stigmatic area lightly clouded with white. All legs pale, each trochanter with white spot. Length of segments of foreleg, in millimeters: trochanter = 0.3, femur = 1.8, tibia = 3.7, tarsus I = 0.1, tarsus II = 1.0, tarsus III = 0.9, tarsus IV = 0.9, tarsus V = 0.4, claws = 0.1. *Abdomen:* ivory white, with segments 1–7 translucent, segments 8–10 opaque; dorsal median areas opaque white on segments 2–10, except for thin, translucent, median stripe; ventral median areas opaque white on segments 6–10; hind margins of terga and sterna opaque white; segments 6–10 with at least part of pleural margins opaque white. Genitalia as in Figure 4; penes with shallow apical notch; forceps segment 2 somewhat dorsoventrally compressed; forceps segment 3 ellipsoidal. Caudal filaments white, relatively densely covered with short, fine setae.

FEMALE ADULT.—Length, in millimeters: body 8.1, forewings 9.8, caudal filaments 9.5, forelegs 6.0. Thorax coloration sometimes much lighter than in male. Wings similar to those in male, except longitudinal veins of forewing variably olive brown. Abdominal segments similar to those of male, except with faint, gray tracheation marks. Subanal plate gently rounded, with very shallow apical notch (Fig. 5).

SUBIMAGOS.—Coloration similar to that of adults, except with dusky, pale blue-gray wings and dull body coloration.

Diagnoses

Larvae may be distinguished from other Nearctic Ephemerellinae species by the distinctive posterolateral projections on abdominal



Figs. 3–5. *Caurinella idahoensis:* 3, male adult meso- and metanotum, dorsal view; 4, male genitalia, ventral view; 5, female adult posterior abdominal segments, ventral view.

segment 9 (Fig. 2). Male adults may be distinguished from other Nearctic Ephemerellinae species by the following combination of characters: penes shaped as in Figure 4 and lack spines, genital forceps segment 3 ellipsoidal, and genital forceps segment 2 somewhat dorsoventrally compressed and not bowed, twisted, or constricted (Fig. 4).

Remarks

Allen (1984) indicated that the maxillary palpi of *C. idahoensis* are 2-segmented. Mature and immature specimens we examined have 3-segmented maxillary palpi. However, immature specimens have maxillary palpi with a very small apical segment that could be overlooked easily.

Material Examined

IDAHO: Idaho Co., Bridge Cr. at Hoodoo Lake Rd. (FR360), 46°21′53″N, 114°38′11″W (WGS84), 1708 m elev., 29-VII-2002, W.P. McCafferty, L.M. Jacobus, 3 male adults, 2 female adults, 1 male subimago, 2 female subimagos, associated exuviae (alates emerged 9-VIII through 17-VIII), 4 larvae (Purdue University Entomological Research Collection, West Lafayette, IN, USA [PERC]); same data, 1 male adult, 1 set larval exuviae (C.P. Gillette Museum of Arthropod Diversity, Colorado State University, Fort Collins, CO, USA).

MONTANA: Missoula Co., 0.6 mi below Lolo Pass, 6-VI-1994, D.L. Gustafson, 2 larvae (PERC).

HABITAT OBSERVATIONS

Bridge Creek is a perennial 2nd-order stream at our study site in the Clearwater National Forest, Idaho County, Idaho. The stream, 15–50 cm deep and 4–5 m wide at our study site, has clear, cold (10°C) water and a moderately swift current. The stream substrate is composed mostly of pale, rough cobble and rocks, 8–30 cm in diameter, and some bedrock. Direct sunlight shone on the stream reach we studied.

Our use of common benthic sampling devices, such as a D-frame dipnet and a kickscreen, yielded only 2 larvae of *C. idahoensis.* However, when we handpicked and examined the cobble and rocks from stream runs, we readily located *C. idahoensis* larvae at the bases of small, earlike or auriform macrocolonies of the blue-green alga *Nostoc parmelioides* Kützing (Nostocales: Nostocaceae; Fig. 6), which occurred on cobble and rock surfaces exposed to the stream current. We collected only 1 specimen of *C. idahoensis* that was not associated with *N. parmelioides,* and it may have been displaced by our activity in the stream. Association of other ephemerellid species with stream macroalgae has been documented previously (Percival and Whitehead 1929, Jones 1950, Hynes 1961, McShaffrey and McCafferty 1991). Just as filamentous algae were found to function as a filter that makes fine detritus available to *Ephemerella needhami* McDunnough (McShaffrey and McCafferty 1990), the dense fields of auriform macrocolonies of *N. parmelioides* may provide a similar benefit to *C. idahoensis.*

Nostoc parmelioides is a relatively well-known and widespread epilithic colonial blue-green alga (Sheath and Cole 1992, Dodds et al. 1995, Potts 2000) that "forms small, olive-green, shelving thalli" on exposed rock surfaces, especially in headwater streams (Prescott 1970). Nearly all *N. parmelioides* colonies that we found in Bridge Creek were the auriform macrocolonies described by Brock (1960), which are known to take on such form when inhabited by a host-specific *Cricotopus* Wulp larva (Diptera: Chironomidae) (Wirth 1957, McCafferty 1981). For additional discussion of the *Nostoc-Cricotopus* association, see Ward et al. (1985), Kleinhaus and Keiser (1988), Dodds (1989), Dodds and Marra (1989), and Sabater and Muñoz (2000). Ward et al. (1985) observed that auriform *N. parmelioides* macrocolonies are found most typically in open-canopied 1st- or 2nd-order streams that are subject to a high-intensity light regime. This is consistent with our study site at Bridge Creek.

Other macroinvertebrates found on larger rocks having patches of auriform *N. parmelioides* macrocolonies and *C. idahoensis* individuals included Diptera larvae of *Micropsectra* sp. (Chironomidae); Ephemeroptera larvae of *Ameletus similior* McDunnough (Ameletidae), *Baetis bicaudatus* Dodds (Baetidae), *Cinygmula* sp. (Heptageniidae), and *Paraleptophlebia* sp. A (Leptophlebiidae); Plecoptera larvae of *Megarcys* sp. (Perlodidae), *Sweltsa* sp. (Chloroperlidae), *Visoka cataractae* (Neave) (Nemouridae), *Yoraperla* sp. (Peltoperlidae), and *Zapada* sp. (Nemouridae); and Trichoptera larvae of *Arctopsyche grandis* (Banks) (Hydropsychidae), *Rhyacophila arcopedes* Banks

Fig. 6. *Nostoc parmelioides,* auriform macrocolonies.

(Rhyacophilidae), *R. tucula* Ross, and *R. vaccua* Milne. Most of these taxa have been associated with cold, high-gradient, 1st- or 2nd-order streams (Smith 1968, Morihara and McCafferty 1979, McCafferty 1981, Stewart and Stark 1988, Stark and Nelson 1994, Wiggins 1996, Zloty and Pritchard 1997). Cooper et al. (1986) and Dudley et al. (1986) previously described the invertebrate fauna of a southern California stream that contained *Nostoc.*

BEHAVIOR OBSERVATIONS

Because our efforts at the study site were focused on collecting specimens for rearing, we had very few field-collected specimens available for dissection and foregut analysis. However, we were able to examine the foregut contents of 1 larva fixed with alcohol at the study site. Amorphous detritus was the largest component of the foregut contents, and this is usually suggestive of a highly specialized feeder (Hawkins 1985). Fragments of 1 chironomid midge larva also were found in the foregut contents examined. It is probable that *C. idahoensis* is merely an opportunistic carnivore, such as has been observed for *E. needhami* (McShaffrey and McCafferty 1990). The structure of *C. idahoensis* mouthparts is typical of species in the mayfly superfamily Ephemerelloidea (McCafferty and Benstead 2002) and also appears well suited for scraping and biting or shredding.

At the study site we observed that small cobble (up to 9 cm in diameter) seldom contained more than a single larva. Our laboratory observations revealed that larvae of *C. idahoensis* possibly defend small territories on rock surfaces. Individual larvae occupying the same rock in the rearing apparatus would approach each other until physical contact with the head and forelegs was made. The 2 remained pressed together, head to head, moving slightly, until 1 individual backed away. Such interaction usually lasted approximately 15 seconds. Further investigation of this behavior is needed.

Subimagos emerged 11–19 days after we collected the larvae from Bridge Creek. Most subimagos emerged during afternoon daylight hours. Emergence behavior was observed in the rearing apparatus as follows. Final instar larvae floated to the water surface, at which point the thoracic terga split along the ecdysial line. Larvae moved to the edge of the rearing cup and grasped a partially submerged strip of paper that we placed along the inside of the cup. Larvae remained on the paper strip for a few minutes just under the water surface and then climbed up the paper so that the head and thorax were exposed to the air and the abdomen was in the water. A film of water remained between the exposed body and the paper. The larvae remained in this position for a few more minutes, and the gills continued beating in the water until immediately before emergence of the subimago. The subimagos then emerged and perched on the exposed portion of the larval exuviae. After less than 1 minute, the subimago wings unfurled completely and the subimagos flew away from the larval exuviae. Elapsed time from when the larvae floated until the subimagos flew from the rearing cup was approximately 40 minutes. Subimagos molted to the adult stage approximately 30 hours after emergence from the larval exuviae.

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