



LARVAL AND EGG MORPHOLOGY OF *PARAPERLA FRONTALIS* (BANKS, 1902) AND *P. WILSONI* RICKER, 1965 (PLECOPTERA: CHLOROPERLIDAE)

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ABSTRACT

Eggs and larvae of *Paraperla frontalis* (Banks) and *P. wilsoni* Ricker are described from scanning electron micrographs. The eggs of both species are coarsely punctate over the entire chorion except for a narrow ring which surrounds the sessile collar, however, punctations are larger and more conspicuous on *P. frontalis* eggs. Larvae of *P. wilsoni* are similar to those of *P. frontalis*, but lack the lacinial pecten row and vertical cercal fringe found in the latter species.

Keywords: Plecoptera, Chloroperlidae, *Paraperla*, egg morphology, larval identification

INTRODUCTION

The genus *Paraperla* Banks 1906 presently includes two Nearctic species (Ricker 1965). The only proposed Palearctic species, *P. lepnevae* Zhiltzova 1970, formerly placed in the genus (Zhiltzova & Levanidova 1970) was recently transferred to *Utaperla* Ricker 1952 by Zwick (2006). Adults and larvae have traditionally been recognized by their elongate heads with anteriorly located compound eyes, although these are not as extensively developed as in the related genus *Kathroperla* Banks 1920 (Baumann et al. 1977; Stewart & Oswald 2006), and

head length is regarded as “a poor character” by Zwick (2006). Adults of the known Nearctic species, *P. frontalis* (Banks 1902) and *P. wilsoni* Ricker 1965 are usually distinguished by the slightly longer head with more quadrate posterior angles in the former species, but important differences are also apparent in male genitalia, female subgenital plate shape and the pigmentation pattern adjacent to the median pronotal suture (Baumann et al. 1977). Ricker (1965) noted geographic variation in subgenital plate and epiproct shape among some populations of *P. frontalis* which suggests the need for reevaluation of

these populations and a search for additional characters from the egg stage.

The larva of *P. frontalis* was described and illustrated by Claassen (1931) and the description in Stewart & Stark (2002) attributed to that species is actually of the other Nearctic species, *P. wilsoni*. This position is supported by the field association of larval exuviae with adult *P. frontalis* from three sites in Wyoming and Washington and the field association of larval exuviae with adult *P. wilsoni* from three sites in British Columbia and Montana. Larvae of both species are probable inhabitants of the hyporhea (Stewart & Stark 1988), and *P. frontalis* famously passed through the filtration system and entered the water supply of Eureka, Montana in the 1970's (Stanford & Gauvin 1974).

Knight et al. (1965) presented brief descriptions and illustrations based on light microscopy for eggs of 25 western Nearctic stonefly species. Included in this study was the first such description for the egg of *P. frontalis* which was reported to be "honey" colored, "oval" in shape with an average width of 425 microns and an average length of 300 microns. No additional data are available for eggs of this species or *P. wilsoni*, and *Paraperla* eggs appear to be difficult to obtain because few female specimens in museum collections contain developed eggs. However, a few gravid females collected by the authors are available, and eggs were dissected from these and studied with scanning electron microscopy. Unfortunately, the sample is insufficient to address the question of variation within these populations, but we take this opportunity to provide comparative descriptions of the egg capsules for both known species of *Paraperla*.

MATERIALS AND METHODS

Eggs were dissected from gravid females and sonicated with an ultrasonic cleaner for 10-15 seconds. Most eggs were easily fractured and difficult to clean, but after sonication they were transferred to acetone and placed on specimen stubs covered with double stick copper tape using fine tip forceps. Larval mouthparts, abdominal terga and cercal structures were dissected from larvae or exuviae, dehydrated through an ethanol series to 100% and placed in hexamethyldisilazane for 30 minutes before mounting on specimen stubs. Eggs

and larval structures were sputter coated with gold-palladium before examination with a scanning electron microscope. Figures 1-4 were re-coated and images prepared from a stub archived in the Stark Collection in 1982. SEM images were prepared using an Amray 1810D instrument at Mississippi College, Clinton, Mississippi or a Philips XL2 ESEM FEG at Brigham Young University, Provo, Utah. Specimens used in this study were obtained from the following collections:

California Academy of Sciences, San Francisco, California (CASC),

C.P. Gillette Museum of Arthropod Diversity, Colorado State University, Fort Collins, Colorado (CSUC),

K.W. Stewart Collection, University of North Texas, Denton, Texas (KWSC),

Monte L. Bean Life Science Museum, Brigham Young University, Provo, Utah (BYUC)

Stark Collection, Mississippi College, Clinton, Mississippi (BPSC).

Paraperla specimens obtained from the Stewart collection are deposited in the Monte L. Bean Life Science Museum at BYU.

RESULTS AND DISCUSSION

Paraperla frontalis (Banks)

(Figs. 1-4, 7-10, 13-15)

Perlinella frontalis Banks 1902:123. Holotype ♂ (Museum of Comparative Zoology), Beulah, [San Miguel Co., Sapello Canyon] New Mexico

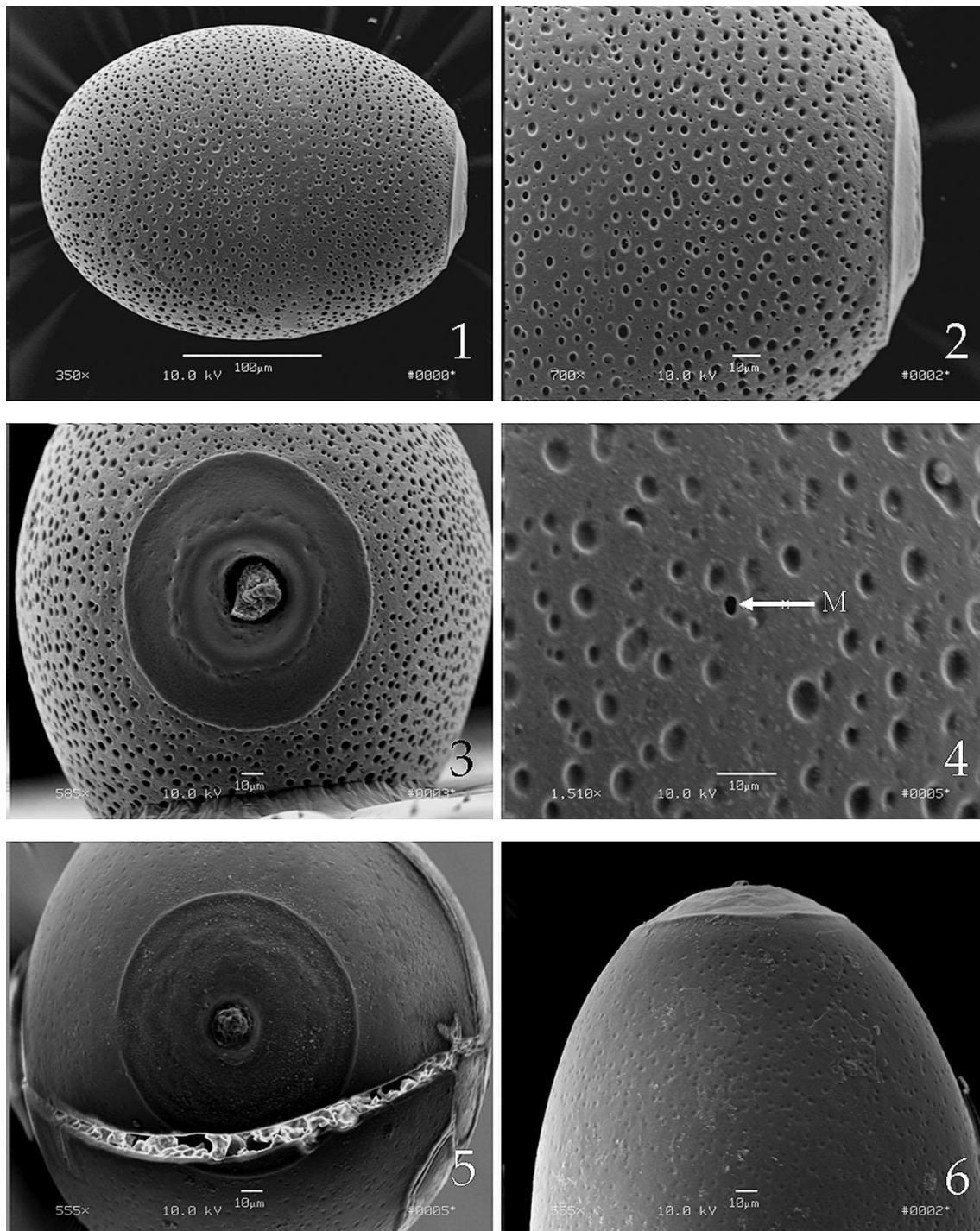
Paraperla frontalis: Claassen, 1931:65. Larval description

Paraperla frontalis: Ricker, 1965:498. Geographic variation of epiproct

Paraperla frontalis: Baumann et al., 1977. Head, pronotum, ♂, ♀ terminalia

Paraperla frontalis: Zwick, 2006:21. Description of lacinial pecten

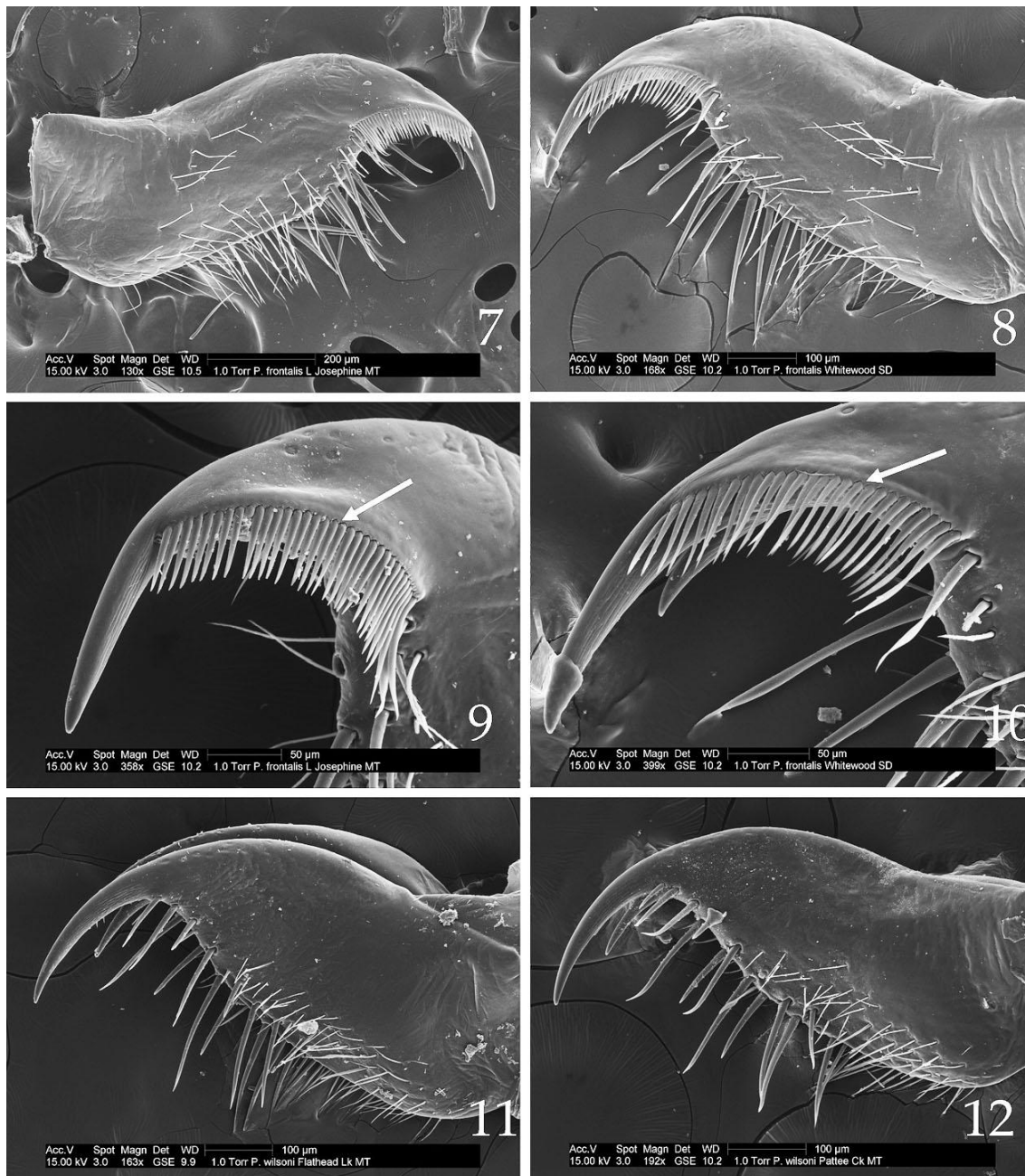
Material examined. (Suitable egg and/or larval/exuvial specimens were examined from the following sites): **CANADA: YUKON:** Bearfield Creek, Hwy 4, 62° 11' 15.03"N, 135° 05' 20.43"W, 25 June 1996, J.C. Abbott, K.W. Stewart, 1 exuvium (KWSC). **UNITED STATES: ALASKA:** West Fork Chena River, below Chena Hot Springs, 2 July 1980, K.S. Stewart, Howe, 1♀ (no eggs), 11 exuvia (KWSC).



Figs. 1-6. *Paraperla* eggs. 1-4. *P. frontalis*, Humboldt Co., California. 1. Egg, lateral. 2. Egg collar, lateral, 3. Egg collar, apical. 4. Chorionic detail (M = putative micropyle). 5-6. *P. wilsoni*, Jewell Basin, Montana. 5. Egg collar, apical (fractured during cleaning). 6. Egg collar, lateral.

North Fork Chena River, Chena Hot Springs Road, 19 July 1986, K.W. Stewart, M. Oswood, 26 exuvia (KWSC). Nations River @ Yukon River jct, near Eagle, 9 July 1982, R. West, 1 larva (KWSC). **CALIFORNIA: Alpine Co.**, West Carson River, Blue Lakes Rd, 27 July 1995, R. Bottorff, 1 ♀ (BPSC). **Humboldt Co.**, Grassy Creek, Fieldbrook, 22 May 1982, B. Stark, D. Ziegler, 1 ♀ (BPSC). Klamath River, Hoopa Reservation, Hwy 96, 1 May 2011, B.C. Kondratieff, J. Sandberg, 5 ♂, 3 ♀, 3 exuviae (CSUC). Klamath River, Aikens Creek Camp Ground, Hwy 96, 1 May 2011, B.C. Kondratieff, J. Sandberg, 1 ♂, 3 ♀ (CSUC). **IDAHO: Lemhi Co.**, Wagonhammer Spring, near North Fork, 22 June 1969, B.R. Oblad, 3 larvae, 3 exuviae (BYUC). **MONTANA: Flathead Co.**, Middle Fork Flathead River, Nyack flood plain, 14 June 2003, B. Reid, 10 ♂, 10 ♀ (1 ♀ with eggs) (CSUC). **Glacier Co.**, Lake Josephine, Glacier National Park, 13 July 1964, A.R. Gaufin, larvae (BYUC). **Lewis & Clark Co.**, Dearborn River, 10 mi west continental divide, Hwy 20, 24 June 1965, A.V. Nebeker, 1 ♀ (BYUC). **Sweet Grass Co.**, American Creek, 10 mi above Hwy 191, 30 June 1966, J.R. Grierson, 1 ♀ (BYUC). **OREGON: Union Co.**, Jordan Creek, 20 mi southwest of La Grande, 30 July 1975, DFTM Project, 1 ♀ (BYUC). **SOUTH DAKOTA: Lawrence Co.**, Whitewood Creek, Lead, 18 March 1981, R.W. Baumann, R.N. Winget, larvae (BYUC). **Pennington Co.**, Pine Creek, Hwy 244, 10 July 1997, R.W. Baumann, B.C. Kondratieff, 1 ♀ (BYUC). **UTAH: Cache Co.**, Franklin Basin, 3 July 1978, G.F. Knowlton, 1 ♀ (BYUC). **Salt Lake Co.**, Thousand Springs, Mill Creek Canyon, 20 July 1982, R.W. Baumann, S. Clark, 1 ♀ (BYUC). Big Cottonwood Creek, below Storm Mountain, 9 June 1965, A.V. Nebeker, 2 ♀, 5 exuviae (no ♀ with eggs) (BYUC). **WASHINGTON: Clallam Co.**, Dungeness River, 15 June 2005, B.C. Kondratieff, R.W. Baumann, 1 ♂, 2 ♀, 4 exuviae (no ♀ with eggs) (CSUC). **Skagit Co.**, tributary Skagit River, South Skagit Hwy, 0.5 mi west of Walberg Rd, 15 April 1967, collector unidentified, 1 ♀ (BYUC). **WYOMING: Fremont Co.**, Middle Popo Agie River, The Sinks State Park, 15 July 1986, R.W. Baumann, B.J. Sargent, 1 larva (BYUC). **Teton Co.**, Snake River, Rt 22, 25 June 1995, B.C. Kondratieff, 17 ♂, 26 ♀, 9 exuviae (2 ♀ with eggs) (CSUC). Cottonwood Creek, near Moose Entrance, Grand Teton National Park, 9 June 1987, B.C.

Kondratieff, 6 ♂, 2 ♀, 14 exuviae (no ♀ with eggs) (CSUC). **Additional specimens examined: UNITED STATES: ALASKA:** Kwethluk River, 16 July 2013, Z. Crete, 4 ♂, 1 ♀ (CSUC). **CALIFORNIA: Alpine Co.**, West Carson River, Blue Lake Rd, 27 July 1995, R. Bottorff, 1 ♀ (BPSC). **El Dorado Co.**, Sopiago Creek, Hwy 88, 3 May 1995, R.L. Bottorff, 1 ♀ (BPSC). South Fork American River, Hwy 49, Coloma, 29 April 2010, B.C. Kondratieff, R.W. Baumann, 1 ♂, 1 ♀ (CSUC). **Humboldt Co.**, Willow Creek, Hwy 299, jct East Fork Willow Creek, 22 June 1985, R.W. Baumann, C.R. Nelson, M.F. Whiting, 1 ♀ (BYUC). East Fork Willow Creek, Willow Creek Campground, 24 April 1987, B. Stark, R.W. Baumann, C.R. Nelson, S. Wells, 2 ♀ (BPSC). **Modoc Co.**, Rush Creek, Upper Rush Creek Camp Ground, 24 May 2007, B.C. Kondratieff, R.W. Baumann, 1 ♀ (CSUC). **COLORADO: Archuleta Co.**, East Fork, FR 667, 11 July 1998, B.C. Kondratieff, 1 ♀ (CSUC). **Boulder Co.**, Middle St. Vrain Creek, FR 114, 17 July 1993, B.C. Kondratieff, Painter, 1 ♀ (CSUC). **Chaffee Co.**, Middle Cottonwood Creek, Cottonwood Pass Rd, 10 July 2003, R.E. Zuellig, 1 ♀ (CSUC). **Hinsdale Co.**, Hensen Creek, 9 mi above lake, 14 July 1962, A. Knight, 1 ♂, 1 ♀ (BYUC). **La Plata Co.**, Los Pinos River, Rt 160, Bayfield, 9 July 1998, B.C. Kondratieff, 1 ♀ (CSUC). **Larimer Co.**, Poudre River, Hwy 14 abv. Tunnel Creek, 4 July 2013, C. Verdone, 1 ♀ (CSUC). **Saguache Co.**, Mendano Creek, Great Sand Dunes Preserve, 23 June 2005, R.E. Zuellig, 1 ♂ (CSUC). **Summit Co.**, Union Creek, Copper Mountain, 6 July 1997, B.C. Kondratieff, 1 ♂ (CSUC). **MONTANA: Flathead Co.**, Logan Creek, Logan Pass, Glacier National Park, 20-22 July 1979, B. Stark, K.W. Stewart, R.W. Baumann, 1 ♀ (BPSC). **Gallatin Co.**, Gallatin River, Bozeman, 17 June 1987, D.L. Gustafson, 5 ♀ (BPSC). New World Gulch Creek, Mount Ellis, abv. trailhead, 14 June 2013, S. Fiance, 1 ♂ (CSUC). **Lake Co.**, Ross Creek, University of Montana Biological Station, Malaise trap, 19 June-10 July 1987, collector unidentified, 6 ♀ (KWSC). **Ravalli Co.**, Bitterroot River, River Park, Hamilton, 14 June 2006, R. Durfee, 3 ♂ (CSUC). Same site, 22 June 2006, R. Durfee, 2 ♂, 2 ♀ (CSUC). Same site, 1 July 2006, R. Durfee, 1 ♂, 2 ♀ (CSUC). Same site, 15 July 2006, 1 ♂ (CSUC). **NEW MEXICO: Lincoln Co.**, Rio Bonito above Bonito Lake, 29 May 1995, B. Stark, C. Massey, 2 ♀ (BPSC). **OREGON: Clatsop Co.**, Big Creek, 16



Figs. 7-12. *Paraperla* laciniae. 7, 9. *P. frontalis*, Lake Josephine, Montana. 8, 10. *P. frontalis*, Whitewood, South Dakota (lacinial pecten row at arrows). 11. *P. wilsoni*, Flathead Lake, Montana. 12. *P. wilsoni*, Pattee Creek, Montana.

April 1949, S.G. Jewett, 4♂, 9♀ (CASC). **Curry Co.**, Brush Creek, Hwy 101, Humbug Mountain State Park, 9 June 2005, B.C. Kondratieff, R.W. Baumann, 1♂, 2♀ (CSUC). **Hood River Co.**, Hermann Creek, 2

April 1940, S.G. Jewett, Jr., 1♀ (CASC). **Union Co.**, Velvet Creek, ca. 8 mi east Medical Springs, DFTM Project, 1♀ (BYU). **UTAH: Uintah Co.**, Jones Creek, Dinosaur National Monument, 21 May 1988, C.E.

Hunter, 1♀ (CSUC). **Utah Co.**, Rock Canyon Creek, Rock Canyon, east of Provo, 16 July 1979, A.T. Christenson, 1♀ (BYUC). **WASHINGTON: Jefferson Co.**, Taft Creek, 1 mi W Hoh Visitor Center, Olympic National Park, 16 July 1979, B. Stark, 1♂ (BPSC). **Skagit Co.**, Hansen Creek, Hwy 20, 2 mi east Sedro Wooley, 30 April 1967, collector unidentified, 1♂, 2♀ (BYUC). **Yakima Co.**, Little Naches River, 2 mi E American River, 11 June 1967, R.W. Baumann, 1♀ (BYUC). **WYOMING: Johnson Co.**, West Fork Clear Creek, Hwy 16, 13 July 2010, B.C. Kondratieff, Mercado, 1♀ (CSUC). **Sublette Co.**, Green River, Daniel, 19 July 1972, B. Stark, 1♀ (BPSC). Pine Creek, Pinedale, 20 July 1972, B. Stark, 2♀ (BPSC).

Egg. Outline oval (Fig. 1). Length ca. 305 µm, equatorial width ca. 227 µm. Collar sessile, surrounded by a smooth circular zone ca. 43 µm wide forming a circular plaque-like structure with diameter of ca. 107 µm (Figs. 2, 3). Chorion covered throughout (except smooth collar zone) with irregularly sized pits; larger pits, ca. 6.5 µm in diameter, give a coarse aspect to chorionic surface. Micropylar row equatorial, orifices without rims (Fig. 4).

Larva. Body length pre-emergent specimens 15-17 mm. General color pale brown without distinctive pigment pattern. Body covered with thin clothing hairs and short, thick setae, usually restricted to posterior segmental fringes and lateral clusters. Posterior fringes of abdominal sterna interrupted mesally except on sternum 10. Lacinia with two teeth, 2nd much smaller than 1st; and not reaching mid length of larger tooth (Figs. 7-8); a prominent row of ca. 30 spine-like pecten comprise a comb-like structure extending from base of 1st lacinial tooth, along midline of tooth to beyond base of 2nd tooth (Figs. 9-10). Basal cercal segments with terminal whorl of setae, but mid and apical segments bear a dense vertical fringe of long, fine swimming hairs (Figs. 13-15).

Paraperla wilsoni Ricker

(Figs. 5-6, 11-12, 16-18)

Paraperla wilsoni Ricker 1965:496. Holotype ♂ (Canadian National Collection), Chiliwack River, Vedder Crossing, British Columbia

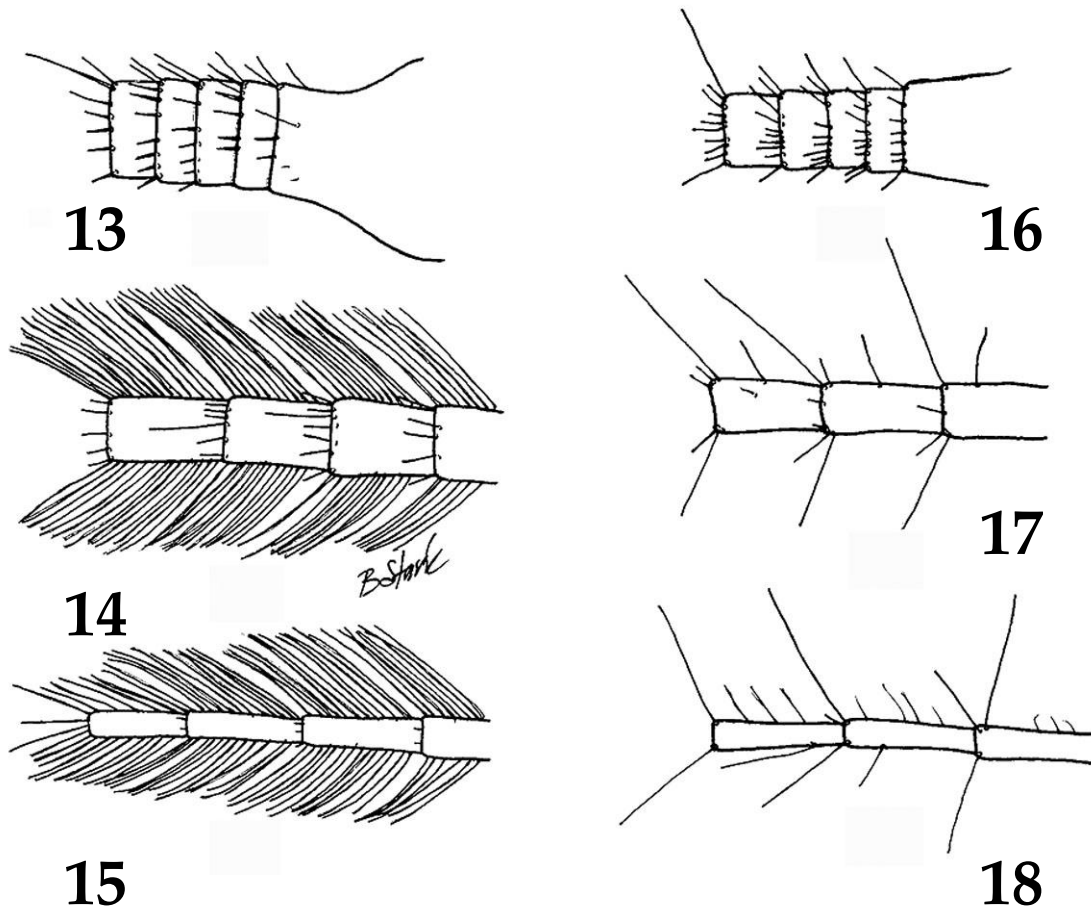
Paraperla wilsoni: Baumann et al., 1977:188. Pronotum

Paraperla frontalis: Stewart & Stark, 2002:266. Larval description

Paraperla wilsoni: Zwick, 2006:21. Notes on male genitalia and larval lacinial structure

Material examined. (Suitable egg and/or larval/exuvial specimens were examined from the following sites): **CANADA: BRITISH COLUMBIA:** Fry Creek, Fry Creek Trail below bridge, Purcell Mountains, Wilderness Park, 18 May 2010, B. Stark, R.W. Baumann, 1♂, 3♀(no eggs), 3 exuviae (BPSC). Davis Creek, Davis Creek Provincial Park, 29 May 2010, B. Stark, R.W. Baumann, 1 exuvium (BPSC). South Salmo River, Lost Creek Reservoir Area, 2 June 2010, B. Stark, R.W. Baumann, 1 exuvium (BPSC). **UNITED STATES: ALASKA:** Kari Creek, Steamer Bay, Etolin Island, 30 August 1977, T.F. Hanson, 1 larva (KWSC). **MONTANA: Flathead Co.**, Jewell Basin, Picnic Lakes outfall, 5 July 1985, K.W. Stewart, B. Poulton, 3♀, 2 larvae, 3 exuviae (KWSC). Same site, 7 July 1989, K.W. Stewart, 3♂, 11♀ (no eggs), 1 larva, 14 exuviae (KWSC). Wounded Buck Creek, west side of Hungry Horse Reservoir, 4 June 1996, C.R. Nelson, R.S. Hanson, B. Ward, 6 exuviae (BYUC). **Lake Co.**, Yellow Bay Creek, Flathead Lake, 6 June 1972, D.S. Potter, exuviae (BYUC). Yellow Bay Well #4, 22 June 2004, R.L. Newell, 1♂, 2♀ (no eggs), 3 exuviae (BYUC). Same site, 15 June 2004, R.L. Newell, 9♂, 7♀ (no eggs), 16 exuviae (KWSC). **Missoula Co.**, Pattee Creek near Missoula, 7 May 1969, M. Poore, A. Dover, exuviae (BYUC).

Additional specimens examined: **CANADA: ALBERTA:** Crows Nest Pass, Kananaskis Highway, 2 August 1971, D.S. Potter, S. Fisher, 1♀ (BYUC). **BRITISH COLUMBIA:** Preacher Creek, Crawford Creek Rd, NE Crawford Bay, 31 May 2010, B. Stark, R.W. Baumann, 1♀ (BPSC). Tam O'Shanter Creek, Riondel Road, Dutch Harbor Camp, 31 May 2010, B. Stark, R.W. Baumann, 1♀ (BPSC). **UNITED STATES: CALIFORNIA: Sierra Co.**, Big Spring, Hwy 49, near Bassetts, 29 May 1991, B. Stark, R.W. Baumann, C. Henderson, 1♀ (BPSC). **IDAHO: Kootenai Co.**, stream into Hayden Lake, Hayden Lake Rd, 26 May 2010, B. Stark, R.W. Baumann, 1♀ (BPSC). **MONTANA: Lincoln Co.**, Ross Creek, FR 398, 27 April 2008, R. Durfee, 1♂ (CSUC). **WASHINGTON: Lewis Co.**, Stevens Creek, below Louise Lake, Mount Rainier National Park, 15 June 1969, R.W. Baumann,



Figs. 13-18. *Paraperla* larval cerci. 13-15. *P. frontalis*, basal, mid and apical segments, Klamath Basin, Oregon. 16-18. *P. wilsoni*, basal, mid and apical segments, Jewell Basin, Montana.

1♀ (BYUC). **Spokane Co.**, Big Spring, Mt. Spokane State Park, 11 June 1991, B. Stark, R.W. Baumann, C. Henderson, 1♀ (BPSC).

Egg. Outline oval. Length ca. 331 μm , equatorial width ca. 241 μm . Collar sessile, surrounded by a smooth circular zone ca. 37 μm wide forming a circular plaque-like structure with diameter of ca. 97 μm (Figs. 5-6). Chorion covered throughout (except smooth collar zone) with shallow, obscure, irregularly sized pits, ca. 2.5 μm in diameter. Micropylar row equatorial.

Larva. Body length pre-emergent specimens 14-16 mm. General color pale brown without distinctive pigment pattern. Body covered with thin clothing

hairs and short, thick setae, usually restricted to posterior segmental fringes and lateral clusters. Posterior fringes of abdominal sterna interrupted mesally, except on sternum 10. Lacinia with two teeth, 2nd much smaller than 1st, and not reaching mid length of larger tooth (Figs. 11-12); lacinial pecten row absent. Basal, mid and apical cercal segments bear terminal whorls of setae (Figs. 16-18); apical setal whorls composed of longer setae but vertical setal fringe absent. Legs with femoral and tibial swimming fringes absent or sparse.

Discussion

Based on the limited available samples, eggs of the two Nearctic species of *Paraperla* are similar in

shape, size, collar form, micropylar placement and chorionic surface detail (Figs. 1-6). The major difference lies in the relative size of the chorionic punctations which are larger in diameter and deeper on eggs of *P. frontalis*. All larvae and exuviae of *P. frontalis* we examined (n=78) have a well developed vertical setal fringe on the cerci (Figs. 14-15) and a well developed pecten row on the lacinia (Figs. 9-10), and these are lacking on all specimens (n = 53) of *P. wilsoni* examined (Figs. 11-12, 16-18). The cercal feature is apparent in Claassen's (1931) habitus figure of *P. frontalis*, presumably from Bozeman, Montana, although he describes the setation as "...each segment terminating in a whorl of hairs", and a "vertical fringe" is not specifically mentioned; the presence of a "...prominent vertical cercal fringe on apical half of cerci..." was noted by Stewart & Stark (1988, 2002) among "some Alaska specimens". The lacinial pecten feature was noted and illustrated by Claassen (1931), who referred to it as a "...comb of stiff hairs", and by Zwick (2006). The vertical cercal fringe and lacinial pecten row are absent from Stewart & Stark's (2002) figures attributed to *P. frontalis* from a larval specimen collected on the Cedar River, King Co., Washington. In our opinion, these figures and the description in Stewart & Stark (2002) represent *P. wilsoni*.

Zwick (2006) raised a fundamental issue about the absence of a single shared apomorphic character for *P. frontalis* and *P. wilsoni* not also shared by *Utaperla*. (e.g. male sternum 7 with hairy lobe; mesosternal Y-stem not forked). We suggest this criterion may be met by the unusual egg collar form of these two species. If this character should prove phylogenetically unacceptable for defining the genus *Paraperla* with only these two species, it might become desirable to place *P. wilsoni* in a separate monotypic genus.

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