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A COMPENDIUM OF DISTRIBUTIONAL RECORDS FOR *OROPERLA BARBARA* NEEDHAM, 1933 (PLECOPTERA: PERLODIDAE), WITH ADDITIONAL DOCUMENTATION OF REPRODUCTIVE MORPHOLOGY AND BIOLOGY

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ABSTRACT

A summary of distributional records from 19 California counties and a single Nevada county are presented for the poorly known stonefly *Oroperla barbara* Needham, 1933. The adult stages, egg, early larval instars, and habitat are described or redescribed, larval growth is documented for populations at four elevations in the Cosumnes River and a preliminary analysis of larval diet is presented.

Keywords: Plecoptera, Perlodidae, *Oroperla barbara* Needham, 1933, North American distribution, reproductive morphology, larval growth, hatching, and food habits

INTRODUCTION

Needham (1933) recognized the unique features of this perlodid stonefly and proposed the new genus, *Oroperla* and species, *barbara,* based on a single larval specimen collected from the Rubicon River near Lake Tahoe. Needham's description included a habitus drawing, the only illustration for this species until Ricker (1952) presented figures of the mandible and maxilla, prepared from the holotype specimen. In the systematic history of the species, Ricker (1952) also placed *Oroperla* as a subgenus of *Arcynopteryx* where it remained until

Figs. 1-2. *Oroperla barbara* adult habitus and typical habitat. California, El Dorado Co., South Fork American River, Camp Sacramento, Hwy 50. 1. Habitus of adult female. 2. Typical habitat. (Images by R.L. Bottorff).

Illies (1966) reestablished *Oroperla* as a valid genus. Jewett (1960) reported the 1954 collection of the species by S.W. Hitchcock from the South Fork American River in El Dorado County, California, and Jewett (1966) described the adult male from two male specimens he collected from the Yuba River (Nevada County, CA) and the Upper Truckee River (El Dorado County, CA). Siegfried et al. (1977) reared ten male and four female specimens from the Yuba River. Adults were kept

alive up to two weeks after emergence, and mating was observed for some individuals. The first descriptions of the female and egg are based on this material, and a redescription of the male includes an observation of variation in the apex of the male epiproct from that shown by Jewett (1966). Stark & Szczytko (1984, 1988) provided the first scanning electron micrographs of the egg, and Shepard & Stewart (1983) illustrated the distribution of gills on the larval submentum, thorax and abdomen. Subsequently, Stewart & Stark (1984, 1988, 2002) presented descriptions that detail the larval color pattern, distinctive setation, gill placement, maxillary lacinia, mandible and developing male and female abdominal apices, and Stark et al. (1998) provided a color image of the adult female. However, basic biological and morphological data are still lacking 84 years after the species was described, and even the distribution is poorly documented beyond recognition that the species is found in rivers of the Sierra Nevada Mountains of California (Boiano et al. 2005, Brown & Short 1999, Jewett 1960, 1966, Needham 1933, Siegfried et al. 1977), and Nevada (Baumann et al. 2017). In this study we bring together all known distributional records for this species and provide descriptive notes for incompletely documented structures and larval growth.

MATERIALS AND METHODS

We collected *Oroperla barbara* adults from streamside vegetation primarily by using beating sheets (size about 74 cm x 74 cm), however, some adults were found close to the stream by searching rock faces and crevices, organic debris piles, and the surface of bridge abutments. Despite considerable time in the field pursuing this species, we have never seen flying adults or its oviposition behavior. We collected larvae using either a kick net (width 36-76 cm, mesh opening about 1 mm) or D-frame net.

Oroperla barbara exuviae were routinely included in specimen collections because they are easily identified to species. Their identification is facilitated by the distinctive gill remnants on abdominal segments 1-7, mesosternal Y-arms connecting to posterior ends of furcal pits, the shape of the lacinia, and large body size (20-30 mm) for a stonefly (Stewart & Stark 2002).

Specimen records were obtained from our own collections along with other private and public collections. Codens for most institutional collections were obtained from the Global Registry of Biodiversity Repositories (http://grbio.org). Specimens were provided from the following sources.

(BPSC) Bill P. Stark Collection, Mississippi College, Clinton, MS

(BYU) Monte L. Bean Life Science Collection, Brigham Young University, Provo, UT, Shawn M. Clark

(CAS) California Academy of Sciences, San Francisco, CA, Christopher C. Grinter

(CNC) Canadian National Collection of Insects, Arachnids, and Nematodes, Ottawa, ON, Owen Lonsdale

(CSUIC) C.P. Gillette Museum of Arthropod Diversity, Colorado State University, Fort Collins, CO, Boris C. Kondratieff

(CSUS) California State University Sacramento Collection, Sacramento, CA, Jimmy Bruce Pitzer, Jr.

(EMEC) Essig Museum of Entomology, University of California, Berkeley, CA, Cheryl Barr

(INHS) Illinois Natural History Survey, Champaign, IL, R. Edward DeWalt

(JBSC) John B. Sandberg Collection, Paradise, CA

(JJLC) Jonathan J. Lee Collection, Eureka, CA

(LESC) Larry E. Serpa Collection, Fairfax, CA

(RLBC) Richard L. Bottorff Collection, South Lake Tahoe, CA

(USGS NWQL) U.S. Geological Survey, National Water Quality Laboratory, Lakewood, CO, Robert Hood.

(USNM) Smithsonian Institution, National Museum of Natural History, Washington, DC, Oliver S. Flint, Jr.

(WDSC) William D. Shepard Collection, Pinole, CA.

Many larval records came from the California Environmental Data Exchange Network (CEDEN)

database. Those contributing data to the CEDEN database include (1) California State Water Resources Control Board, (2) California Regional Water Quality Control Boards, (3) Surface Water Ambient Monitoring Program, (4) U.S. Environmental Protection Agency, (5) Central Valley Regional Data Center, (6) Moss Landing Marine Laboratories, (7) San Francisco Estuary Institute, and (8) Southern California Coastal Water Research Project. CEDEN specimens lack permanent repositories.

Most latitude-longitude coordinates in the text are presented in decimal degree format, with north latitudes being positive numbers and west longitudes being negative numbers. Some *O. barbara* records, particularly in older collections, lacked coordinate data, provided them in different formats, or presented the location as a text string only. In the text, we retained the original collection label format, but in the linked internet accessible Excel spreadsheet we have provided coordinates in decimal degrees for all records (Oroperla_barbara_database.csv). For records lacking coordinates, we estimated latitude-longitude as closely as possible using label information and Google Earth.

Eggs were dissected from gravid females collected in the South Fork American River at Kyburz and placed in an ultrasonic cleaner for 15 seconds to remove the external membrane. Eggs were placed in acetone for two minutes and transferred to specimen stubs covered with double stick copper tape. Stubs were coated with gold-palladium in a Hummer sputter coater before examination with an Amray 1810 scanning electron microscope. Male and female external reproductive structures were cleared with hot 10% KOH and examined with a Wild M5 microscope equipped with camera lucida.

Male aedeagus images were prepared from a single male of *O. barbara* by C. Riley Nelson at Brigham Young University using an Olympus MVX10 monocular microscope and Olympus DP 74 camera equipped with cellSens Standard 1.17 Full software. We employed the cellSens extended focal imaging (EFI) routine to stack manually focused images using an Olympus SZX-MDCU microscope controller. As we focused through the specimen the software used those parts of each layer that were in focus to make the composite images we present below.

Larval head capsule widths and body lengths were measured using an optical micrometer in a Bausch and Lomb StereoZoom 4 dissecting microscope.

Biological data for *O. barbara* were obtained from a study of the Cosumnes River drainage, which flows 123 km from Sierra Nevada crest to Central Valley lowlands in California. In particular, the study focused on the North Fork Cosumnes River (elevations, 241-2249 m) and main Cosumnes River (elevations, 27-241 m). This major, western-slope, drainage basin is located in the central Sierra Nevada 30-110 km east of Sacramento, California (Fig. 30).

RESULTS AND DISCUSSION

Oroperla barbara Needham, 1933

http://lsid.speciesfile.org/urn:lsid:Plecoptera.speciesfile.org:TaxonName:1067

(Figs. 1-29)

Oroperla barbara Needham, 1933:17. Holotype larva (Cornell University Insect Collection), Rubicon River, [Placer Co.], near Lake Tahoe, California
Arcynopteryx (*Oroperla*) *barbara*: Ricker, 1952:78
Oroperla barbara: Illies, 1966:372

Published records. USA
CALIFORNIA:
El Dorado Co.
Cosumnes River, 4 September 1980, A.W. Knight, 1 larva (BYU).
South Fork American River, near Kyburz, 7 September 1954, S.W. Hitchcock, 1 larva (CAS), 1 larva (BYU).
Upper Truckee River, Hwy 50, 1 mile SW Meyers, 22 May 1964, S.G. Jewett, Jr., 1♂ (repository unknown).
Mariposa Co.
Merced River, Happy Isle Bridge, Yosemite Valley, Yosemite National Park, 13 September 1994, L.R. Brown, 1 larva (USGS NWQL).
Nevada Co.

South Yuba River, Hwy 80, uppermost bridge, 6000', 8 June 1965, S.G. Jewett, Jr., 2♂ (CAS).

South Yuba River, T17N: R12E: S24, 10 April-15 May 1974, C.A. Siegfried, P.J. Sheehan, A.W. Knight, 10♂, 4♀ reared (repository unknown).

Placer Co.

Miller Creek, near Miller Lake, 5-7 September 1954, S.W. Hitchcock, 2 larvae (USNM).

Rubicon River, 5-7 September 1954, S.W. Hitchcock, 4 larvae (USNM).

Rubicon River, ~6000', 1 September 1932, P.R. Needham, 1 larva (Holotype, Cornell University Insect Collection).

Shasta Co.

Roaring Creek, 20 March 1976, D.R. Lauck, 1♀ (BYU).

Tulare Co.

Kaweah River drainage, Sequoia National Park (repository unknown).

NEVADA:

Douglas Co.

East Fork Carson River, near Dresslerville, 30 August 1993, U.S. Geological Survey sample, S. Lawrence, 1 larva (USGS NWQL).

New records. USA

CALIFORNIA

Alpine Co.

Arnot Creek 1, 38.407354°, -119.799361724°, 16 June 2015, CEDEN, 1 larva. Same site, 12 July 2016, CEDEN, 1 larva.

Arnot Creek, above Clark Fork, 38.40244°, -119.8°, 17 June 2015, CEDEN, 1 larva.

Blue Creek, 25 August 2015, I. Chan, 4 larvae (JJLC).

Charity Valley Creek, ~2.5 mi above Charity Valley, 38.69578°, -119.87532°, 27 June 2002, CEDEN, 5 larvae.

Clark Fork Stanislaus River, 38°24'26.3"N, 119°46'10.6"W, 6298', 11 September 2004, L.E. Serpa, 9 larvae (LESC).

Disaster Creek, above Clark Fork, 38.41833333°, -119.7513889°, 24 August 2004, CEDEN, 3 larvae. Same site, 29 August 2012, CEDEN, 2 larvae.

Forestdale Creek, above Blue Lakes Rd, 38.6789°, -119.9608°, 4 September 2012, CEDEN, 1 larva.

Hot Springs Creek, 38°41'57"N, 119°50'44"W, 5875', 4 September 2005, L.E. Serpa, 1 larva (LESC).

North Fork Mokelumne River, 38°32'15.3"N, 119°53"57.1"W, 7064', 3 September 2004, L.E. Serpa, 11 larvae (LESC).

North Fork Mokelumne River, 38°32'14.5"N, 119°49'28.7"W, 7821', 26 July 2014, L.E. Serpa, 2 larvae.

Pacific Creek, below Marshall Creek, 38.49611111°, -119.8938889°, 28 July 2004, CEDEN, 1 larva.

Shay Creek, 4 miles W Markleeville, 5 November 1983, J. Devorak, 1 larva (CSUS).

Silver Creek, tributary East Carson River, 12 September 1934, P.R. Needham (?), 3 larvae (BYU), 2 larvae (INHS), 1 larva (USNM).

Silver Creek, 38°36'10"N, 119°46'17.8"W, 6425', 3 September 2004, L.E. Serpa, 4 larvae (LESC).

Silver Creek, 38°37'12.9"N, 119°44'31.6"W, 6138', 26 July 2014, L.E. Serpa, 4 larvae (LESC).

Silver King Creek, 38.53281°, -119.59393°, 23 July 2008, CEDEN, 1 larva.

West Carson River, Hwy 89, Snowshoe Campground, 9 May 1986, R.W. Baumann, 1♂ (BYU).

West Fork Carson River, ~1.6 miles up Blue Lakes Rd, 38.73217°, -119.92824°, 26 June 2002, CEDEN, 11 larvae. Same site, 1 August 2002, CEDEN, 7 larvae. Same site, 14 July 2003, CEDEN, 9 larvae. Same site, 10 September 2003, CEDEN, 1 larva.

Wolf Creek, above Wolf Creek Meadows, 9 May 1986, R.W. Baumann, 1♀ (BYU).

Wolf Creek, ~0.7 mi above East Fork Carson River, 38.60621528°, -119.6904003°, 15 August 2011, CEDEN, 7 larvae.

Woods Creek, 18 October 2011, I. Chan, 1 larva (JJLC). Same site, 15 August 2016, I. Chan, 4 larvae (JJLC).

Amador Co.

Bear River, 27 August 2015, I. Chan, 3 larvae (JJLC).

Cole Creek, 26 August 2015, I. Chan, 1 larva (JJLC).

North Fork Mokelumne River, above Salt Springs Reservoir, 25 September 1999, W.C. Fields, 2 larvae (BYU).

Butte Co.

Big Chico Creek, Soda Springs Campground, near Butte Meadows, 40.087778°, -121.584444°, 11 September 1998, J. May, 3 larvae (USGS NWQL).

Butte Creek, Butte Meadows Campground, Humboldt Rd, 40.07861°, -121.55967°, 30 March 2007, J.B. Sandberg, 1♂, 1♀ (JBSC), 1♂ (CSUIC). Same site, 21 April 2007, 1♂ (JBSC).

Butte Creek, at Butte Meadows Campground. 40.07833°, -121.56°, 9 July 2009, CEDEN, 2 larvae.

Butte Creek, Cherry Hill Campground, 2.3 mi SW Jonesville, 40.1025°, -121.496389°, 15 September 1997, J. May, 1 larva (USGS NWQL).

Butte Creek, Cherry Hill Campground, Humboldt Rd, 40.10221°, -121.49911°, 10 December 2006, J.B. Sandberg, D.P. Pickard, 1 larva (JBSC). Same site, 9 March 2007, J.B. Sandberg, 1♂ (CSUIC). Same site, 2 November 2007, J.B. Sandberg, 1 larva (CSUIC).

Butte Creek, Doe Mill Road, 39.90889°, -121.61836°, 4 October 1998, CEDEN, 2 larvae.

Butte Creek, 40˚6′3.5″N, 121˚30′3.7″W, 4630′, 18 September 2006, L.E. Serpa, 1 larva (LESC).

Middle Fork Feather River, Milsap Bar, 2 November 2010, I. Chan, 2 larvae (JJLC).

North Fork Feather River, Lower Cresta, 18 October 2010, I. Chan, 1 larva (JJLC).

South Branch Middle Fork Feather River, 39.70612°, -121.20361°, 19 August 2008, CEDEN, 2 larvae.

El Dorado Co.

Alder Creek, 19 October 2011, I. Chan, 2 larvae (JJLC). Same site, 5 November 2012, I. Chan, 1 larva (JJLC).

Big Silver Creek, 38.88056°, -120.35861°, 18 September 2006, CEDEN, 1 larva.

Camp Creek, 38°40′49.2″N, 120°25′0.5″W, 4642′, 16 August 2008, L.E. Serpa, 8 larvae (LESC).

Camp Creek, ~2 miles below North/South Road crossing, 38.68333°, -120.44083°, 6 October 1995, CEDEN, 1 larva.

Camp Creek, near headwaters, 38.65833°, -120.29778°, 4 October 1995, CEDEN, 2 larvae.

Gaddis Creek, Blodgett Forest, 6 October 1996, R. Leach, 2 larvae (EMEC).

Meeks Creek, Lake Tahoe Basin, 9 September 2003, Lake Tahoe Regional Planning Agency, 1 larva (BYU). Same site, 27 October 2003, Lake Tahoe Regional Planning Agency, 1 larva (BYU).

Middle Fork Cosumnes River, 38°34′0.1″N, 120°26′29.9″W, 3870′, 16 August 2008, L.E. Serpa, 3 larvae (LESC).

Middle Fork Cosumnes River, 1 mi above Dogtown Creek confluence, 38.58556°, -120.53139°, 18 October 1995, CEDEN, 1 larva.

Middle Fork Cosumnes River, above PiPi Campground, 38.5975°, -120.4275°, 6 October 1995, CEDEN, 1 larva.

North Fork Cosumnes River, Capps Crossing, 6 miles E Grizzly Flat, 38.65045°, -120.40741°, 22 April to 17 May 1981 trap, R.L. Bottorff, 1♂, 3 exuviae (RLBC). Same site, 17 May 1983, R.L. Bottorff, 64 exuviae [35♂, 29♀] (RLBC). Same site, 21 April 1984, R.L. Bottorff, 2 exuviae (RLBC). Same site, 12 May 1984, R.L. Bottorff, 1♀, 1 exuviae (RLBC). Same site, 6 May 1985, R.L. Bottorff, 1♂ (RLBC).

North Fork Cosumnes River, at Capps Crossing, 38.65056°, -120.40556°, 5 October 1995, CEDEN, 3 larvae.

North Fork Cosumnes River, 8 miles E Grizzly Flat, 38.644740°, -120.379374°, 15 July 1980, R.L. Bottorff, 3 larvae (RLBC).

North Fork Cosumnes River, Meiss Ranch, 10 miles E Grizzly Flat, 38.63579°, -120.33655°, 5 April to 31 May 1981 trap, R.L. Bottorff, 2 ♂, 1 larva, 2 exuviae (RLBC).

North Fork Cosumnes River, at Meiss Rd, 38.63611°, -120.32361°, 5 October 1995, CEDEN, 2 larvae.

North Fork Cosumnes River, upstream Meiss Ranch, 13 miles E Grizzly Flat, 38.638113°, -120.298392°, 26 May 1984, R.L. Bottorff, 1♀, 1 exuviae (RLBC).

North Fork Cosumnes River, Sciaroni Crossing, 2 miles N Grizzly Flat, 38.669092°, -120.533568°, 29 March to 19 April 1981 trap, R.L. Bottorff, 1♀ (RLBC). Same site, 4 April 1983, R.L. Bottorff, 1♀, 9 exuviae (RLBC). Same site, 21 April 1984, R.L. Bottorff, 1♀ (RLBC).

North Fork Cosumnes River, Sweeneys Crossing, 3 miles E Somerset, 38.65246°, -120.626°, 25 March 1984, R.L. Bottorff, 1♀, 6 exuviae (RLBC).

North Fork Cosumnes River, near Somerset, 4 September 1980, A.W. Knight, 2 larvae (BYU).

North Fork Cosumnes River, near confluence of Big Canyon Creek, 38.67°, -120.53278°, 17 October 1995, CEDEN, 1 larva.

Pilot Creek, Blodgett Forest, 6 October 1996, R. Leach, 1 larva (EMEC).

Pyramid Creek, 12 October 2012, I. Chan, 1 larva (JJLC).

Sayles Canyon Creek, 38.7907°, -120.104°, 24 July 2008, CEDEN, 1 larva.

South Fork American River, near Kyburz, 17 April 1998, R.L. Bottorff, 1♂, 1♀ (BPSC).

4 miles W Kyburz, 29 August 1953, J.M. Selander, R.B. Selander, 1 larva (BPSC).

South Fork American River, Riverton, Hwy 50, 14 May 1983, R.W. Baumann, R. Mower, 1♀ (BYU). Same site, 11 October 1971, W.C. Fields, 2 larvae (BYU).

South Fork American River, 2 miles above Riverton, 27 September 1986, D. McEwan, 2 larvae (CSUS).

South Fork American River, Strawberry, Hwy 50, 16 May 1998, C.R. Nelson, B. Stark, I. Sivec, R.L. Bottorff, S.W. Szczytko, 2 larvae (BYU).

South Fork American River, 0.5 miles SW of Strawberry, Hwy 50, 38.790972°, -120.151912°, 19 April 2012, R.L. Bottorff, 2 larvae (RLBC).

South Fork American River, Sayles Flat, 6415', Camp Sacramento, Hwy 50, 38.801853°, -120.119379°, 2 June 2017, R.L. Bottorff, 2♀ (RLBC). Same site, 5 June 2017, R.L. Bottorff, B. Stark, 3♀ (1♀ BPSC, 2♀ released). Same site, 7 June 2017, R.L. Bottorff, 4♀ (released).

South Fork American River, ~0.5 mi above Bryan Creek, 38.80829196°, -120.0937508°, 4 August 2016, CEDEN, 1 larva.

South Fork Silver Creek, upper reach above Ice House Reservoir, 38.82015°, -120.31364°, 8 September 2005, CEDEN, 1 larva. Same site, 7 September 2006, CEDEN, 2 larvae.

Strawberry Creek, 20 October 2011, I. Chan, 4 larvae (JJLC). Same site, 19 October 2012, I. Chan, 14 larvae (JJLC). Same site, 19 August 2016, I. Chan, 4 larvae (JJLC).

Strawberry Creek, ~3.5 mi above American River, 38.760828°, -120.1076994°, 17 August 2011, CEDEN, 9 larvae. Same site, 29 August 2011, CEDEN, 7 larvae.

Upper Truckee River, Hwy 50, Meyers, 2 October 1982, W.D. Shepard, 6 larvae (WDSC).

Upper Truckee River, ~1.6 mi above Upper Truckee Rd, 38.77875°, -120.02978°, 28 September 2011, CEDEN, 2 larvae.

Upper Truckee River, ~2.6 mi above South Upper Truckee Rd, 38.7648°, -120.0303°, 15 September 2016, CEDEN, 2 larvae.

Upper Truckee River, USGS stream gage, 5 mi SW Meyers, 38.796348°, -120.019243°, 19 April 2012, R.L. Bottorff, 4 larvae (RLBC).

Upper Truckee River, Lake Tahoe Basin, 38.77868°, -120.02816°, 9 October 2012, Lake Tahoe Regional Planning Agency, 1 larva (BYU). Same site, 2 September 2014, Lake Tahoe Regional Planning Agency, 2 larvae (BYU).

Upper Truckee River, Lake Tahoe Basin, 2101 m, 38.78536°, -120.02452°, 3 August 2015, Lake Tahoe Regional Planning Agency, 3 larvae (BYU).

Fresno Co.

Big Creek, 37°14'5.2"N, 119°9'38.5"W, 7024', 28 August 2005, L.E. Serpa, 1 larva (LESC).

Big Creek, ~1.9 mi above Hwy 168, 37.23381281°, -119.1358378°, 9 August 2010, CEDEN, 1 larva.

Dinkey Creek, 20 October 1962, A. Bertold, 1 larva (BYU).

Dinkey Creek, 37°4'2.1"N, 119°9'14.2"W, 5670', 7 September 2008, L.E. Serpa, 1 larva (LESC).

South Fork Kings River, 36.7893°, -118.551°, 14 July 2008, CEDEN, 1 larva.

Lassen Co.

Susan River, 10 miles W of Susanville, 19 August 1989, W.D. Shepard, 1 larva (CAS).

Susan River, 40°23'49.8"N, 120°46'20"W, 4608', 7 November 2004, L.E. Serpa, 2 larvae (LESC).

Madera Co.

Middle Fork San Joaquin River, 37.62111°, -119.07333°, 23 June 1994, CEDEN, 1 larva.

Mono Co.

West Fork Walker River, 10 miles S Walker, 10 August 1984, J. Beutler, 1 larva (CSUS).

West Walker River, Hwy 108, Leavitt Meadows Campground, 9 May 1986, R.W. Baumann, 2♂ (BYU).

West Walker River, 38°19'43.4"N, 119°33'4.9"W, 7129', 11 September 2004, L.E. Serpa, 3 larvae

(LESC).

West Walker River, below Leavitt Creek, 38.31982662°, -119.5494837°, 2 July 2014, CEDEN, 3 larvae.

Nevada Co.

Deer Creek, North and South Fork confluence, 39.29542°, -120.88678°, 12 June 2002, CEDEN, 1 larva.

Prosser Creek, ~1.2 mi below East/West Fork confluence, 39.38237595°, -120.2262394°, 9 August 2010, CEDEN, 1 larva.

Placer Co.

Bear Creek, Alpine Meadows, 9 December 1986, R.W. Baumann, C.R. Nelson, B.C. Kondratieff, S. Wells, 21 larvae (BYU).

Bear Creek, Alpine Meadows Rd, near Hwy 89, 9 December 1986, R.W. Baumann, C.R. Nelson, 18 larvae (BYU).

Bear Creek, below Alpine Meadows Ski Area, 21 April 1987, R.W. Baumann, C.R. Nelson, S. Wells, 4♂, 3♀, 5 larvae (BYU).

Bear Creek, above Truckee River, 39.19009°, -120.19875°, 26 July 2003, CEDEN, 2 larvae. Same site, 27 July 2004, CEDEN, 2 larvae. Same site, 27 July 2006, CEDEN, 1 larva.

Cold Creek, 39°18′55.7″N, 120°13′48.8″W, 4 February 2010, L.E. Serpa, 1 larva (LESC).

Duncan Creek, ~0.3 mi below Little Duncan Creek, 39.138794°, -120.4756184°, 22 July 2010, CEDEN, 3 larvae. Same site, 7 September 2010, CEDEN, 2 larvae. Same site, 12 October 2010, CEDEN, 1 larva.

South Fork Yuba River, Cisco Grove, 10 October 1982, T. Wragg, 1 larva (WDSC).

[South Fork Yuba River], Cisco Grove, off I-80, 29 January 1992, B.C. Kondratieff, 1 larva (CSUC).

[South Fork] Yuba River, 1 mile NE Nyack, 19 October 1987, W.D. Shepard, 1 larva (CAS).

South Fork Yuba River, 5 miles W Soda Springs, 11 September 1992, W.D. Shepard, 1 larva (WDSC).

Ward Creek, Lake Tahoe Basin, 9 February 2003, Lake Tahoe Regional Planning Agency, 10 larvae (BYU). Same site, 27 August 2003, Lake Tahoe Regional Planning Agency, 8 larvae (BYU).

Plumas Co.

Chambers Creek, Route 40A, tributary Feather River, 23 January 1955, S.W. Hitchcock, 1 larva (USNM).

Grizzly Creek, 3.8 mi E Bucks Lake, 39.88488°, -121.30286°, 5 October 2006, J.B. Sandberg, 1 larva (JBSC).

Grizzly Creek, 39°52′6.7″N, 121°22′24.7″W, 1640′, 1 December 2006, L.E. Serpa, 3 larvae (LESC).

Grizzly Creek, above Grizzly Forebay, 39.88909°, -121.27873°, 20 August 2008, CEDEN, 2 larvae.

Jamison Creek, 1.3 miles upstream from Middle Fork Feather River, 39.81211°, -120.6814°, 30 August 2000, CEDEN, 1 larva. Same site, 19 June 2013, CEDEN, 4 larvae.

Lights Creek, Moonlight Bridge, 40.1504°, -120.79448°, 25 July 2006, CEDEN, 1 larva.

Long Valley Creek, Hwy 70, Cromberg, 14 February 1985, R.W. Baumann, C.R. Nelson, 3 larvae (BYU).

North Fork Feather River, at Rock Creek, 19 October 1999, W.C. Fields, 1 larva (BYU).

Onion Valley Creek, 39.806186°, -121.042598464°. 17 August 2011, CEDEN, 1 larva.

Rice Creek, Feather River Meadows, Lassen National Forest, 30 May 1991, R.W. Baumann, B. Stark, 1♀ (BYU).

Rice Creek, North Arm, 40.4002°, -121.439°, 1 July 2015, CEDEN, 1 larva.

Sheepcamp Creek, 40°10′27.1″N, 121°2′32.3″W, 4213′, 25 November 2006, L.E. Serpa, 1 larva (LESC).

Sulphur Creek, 1 mile SE Clio, 9 December 1986, W.D. Shepard, 2 larvae (CAS).

Yellow Creek, ~0.4 mi above North Fork Feather River, 40.012071°, -121.2475051°. 17 August 2011, CEDEN, 1 larva.

Shasta Co.

Brandy Creek, above South Shore Drive, 40.61075°, -122.5768°, 5 June 2002, CEDEN, 1 larva.

Burney Creek, ~0.3 mi north of Green Burney Creek, 40.81571°, -121.72191°, 12 September 2001, CEDEN, 1 larva.

Cow Creek, South of Ponderosa Way, 40.60702°, -121.85347°, 2 October 2002, CEDEN, 2 larvae. Same site, 12 June 2003, CEDEN, 2 larvae.

Digger Creek, downstream Ponderosa Way, 40.436056°, -121.834607°, 25 October 2013, CEDEN, 1 larva.

Hatchet Creek, Hwy 299, 18 September 1974, D.R. Lauck, 1 larva (BYU). Same site, 13 October 1975, D.R. Lauck, 11 larvae (BYU). Same site, 1 November 1975, D.R. Lauck, 6 larvae (BYU). Same site, 15 October 1976, D.R. Lauck, 2 larvae (BYU).

Hatchet Creek, Moose Camp Rd, 40.86065°, -121.84702°, ~1150 m, 26 November 1983, D.R. Lauck, J. Lee, 2 larvae (JJLC). Same site, 6 July 1984, D.R. Lauck, J. Lee, 29 larvae (JJLC). Same site, 5 September 1984, D.R. Lauck, J. Lee, 1 larva (JJLC). Same site, 14 September 1984, D.R. Lauck, J. Lee, 2 larvae (JJLC). Same site, 11 January 1985, D.R. Lauck, J. Lee, 2 larvae (JJLC). Same site, 31 March 1985, D.R. Lauck, J. Lee, 1 larva (JJLC).

Roaring Creek, N Montgomery Creek, 2 November 1974, D.R. Lauck, 3 larvae (BYU). Same site, 20 March 1976, D.R. Lauck, 8 larvae (BYU).

Rock Creek, ~1.9 mi above Pit River, 41.02973681°, -121.7168642°, 3 August 2016, CEDEN, 2 larvae.

Tom Neal Creek, above Squaw Valley Creek, 41.096822105449°, -122.201183347085°, 16 September 2010, CEDEN, 1 larva.

Sierra Co.,

Haypress Creek, Sierra City, 20 August 1989, C.M. Murvosh, 1 larva (BYU).

Lacey Canyon Creek, confined section, 39.46409°, -120.42566°, 28 July 2015, CEDEN, 4 larvae.

Lavezzola Creek, 3.5 miles NE Downieville, 20 August 1989, W.D. Shepard, 2 larvae (CAS).

North Yuba River, Big Springs, 3600', 16 October 1966, A.L. Sheldon, 2 larvae (BYU).

North Fork Yuba River, 39°37'38.9"N, 120°34'20.9"W, 5566', 6 November 2004, L.E. Serpa, 1 larva (LESC).

Pass Creek, USFS, 39.50235°. -120.5271°, 16 July 2009, CEDEN, 1 larva. Same site, 27 July 2010, CEDEN, 1 larva. Same site, 9 August 2016, CEDEN, 4 larva.

Pauley Creek, ~2.6 mi above Downie River, 39.59001°, -120.80068°, 28 July 2013, CEDEN, 1 larva.

Pauley Creek, ~1.8 mi above Downie River, 39.5847°, -120.8103°, 10 June 2015, CEDEN, 11 larvae.

Sulphur Creek, ~0.7 mi above Sulphur Creek Loop, 39.68967°, -120.51204°, 18 June 2013, CEDEN, 9 larvae.

Tehama Co.

Big Chico Creek, Hwy 32 bridge, 40.06367°, -121.60387°, 24 September 2007, J.B. Sandberg, 1 larva (JBSC).

Big Chico Creek, 40°4'12.1"N, 121°36'2.2"W, 3510', 28 July 2005, L.E. Serpa, 1 larva (LESC).

Big Chico Creek, 40.07254°, -121.59867°, 8 October 1997, CEDEN, 1 larva. Same site, 13 August 2008, CEDEN, 1 larva.

Calf Creek, tributary to Deer Creek, 40.16818°, -121.56537°, 27 September 2016, CEDEN, 1 larva.

Cascade Creek, Scout Rd, 40.10772°, -121.56308°, 3 February 2007, J.B. Sandberg, A.B. Richards, 1 larva (JBSC).

Cub Creek, above Deer Creek, 40.202°, -121.509°, 24 August 2010, CEDEN, 1 larva.

Deer Creek, below Slate Creek confluence, 40.23455°, -121.45926°, 16 September 2016, CEDEN, 2 larvae.

Deer Creek, Potato Patch Campground, 6.5 mi NW Jonesville, 40.187778°, -121.531111°, 10 September 1998, J. May, 4 larvae (USGS NWQL).

Deer Creek, Potato Patch Campground, 40.17294°, -121.55389°, 2 October 1998, CEDEN, 4 larvae. Same site, 28 October 1999, CEDEN, 1 larva.

Middle Fork Antelope Creek, ~0.4 mi above Ponderosa Way, 40.26488048°, -121.7680965°, 26 July 2010, CEDEN, 1 larva.

Mill Creek, Hwy 36-89, tributary Sacramento River, 17 March 1972, R.A. Haick, 1 ♂ (USNM).

Mill Creek, below Big Bend, 40.25377314°, -121.560496°, 7 September 2011, CEDEN, 2 larvae.

North Fork Deer Creek, 12.2 miles NW Chester, Hwy 36/89, 8 September 2013, D.R. Givens, 1 larva (CSUC).

South Fork Antelope Creek, South Antelope Campground, 40.25306°, -121.759°, 9 October 2002, CEDEN, 1 larva.

South Fork Battle Creek, ~1.5 mi above Cold Creek, 40.35193°, -121.63451°, 31 October 2014, CEDEN, 2 larvae.

Trinity Co.

East Fork Coffee Creek, 1.3 mi above confluence, 41.13472°, -122.80333°, 28 August 2003, CEDEN, 2 larvae.

Rattlesnake Creek, ~0.4 mi above Flume Gulch Creek, 40.37818598°, -123.2988996°, 4 August 2011, CEDEN, 5 larvae.

Tulare Co.

Kaweah River, Ash Mountain, Kaweah Power Station, 10 March 1984, R.D. Haines, 1♀ (BYU). Same site, 17 March 1984, R.D. Haines, 1♀ (BYU).

Kaweah River, above Halstead Creek, 36.58194444°, -118.7825°, 7 July 2004, CEDEN, 2 larvae.

Marble Fork Kaweah River, below junction Silliman Creek, Sequoia National Park, 25 August 1942, J.W. Moffett, 2 larvae (INHS).

Marble Fork Kaweah River, below Bridge Campground, Sequoia National Park, 10 September 1942, J.W. Moffett, 1 larva (CNC).

Tuolumne Co.

Beaver Creek, 38°15′3.7″N, 120°15′31.4″W, 4398′, 24 September 2005, L.E. Serpa, 3 larvae (LESC).

Clark Fork Stanislaus River, 19 miles North Strawberry, 4 November 1983, M. Tapple, J. Shober, 2 larvae (CSUS). Same site, 6 November 1983, W.D. Shepard, 12 larvae (WDSC). Same site, 6 November 1983, W.D. Shepard, 9 larvae (CAS). Same site, 6 November 1983, W.D. Shepard, 4 larvae (BPSC). Same site, 6 November 1983, R. Titus, 5 larvae (BYU).

Clark Fork Stanislaus River, above Iceberg Meadow, 38.41626°, -119.74242°, 27 July 2009, CEDEN, 3 larvae.

Clavey River, 37.98209°, -120.0536°, 13 October 2005, CEDEN, 1 larva.

Clavey River, ~3 mi above Twomile Creek, 38.0457°, -120.0238°, 17 July 2012, CEDEN, 1 larva.

Deadman Creek tributary, 38°19′49.7″N, 119°39′20″W, 9206′, 11 September 2004, L.E. Serpa, 6 larvae (LESC).

Middle Fork Stanislaus River, 38°20′25.2″ N, 119°47′32.6″W, 6019′, 8 August 2007, L.E. Serpa, 2 larvae (LESC).

Middle Fork Stanislaus River, USFS, 38.32099°, -119.75207°, 5 September 2010, CEDEN, 2 larvae.

Middle Fork Tuolumne River, 108, 37.868693°, -119.90423152722°, 21 September 2011, CEDEN, 3 larvae.

North Crane Creek, above Tuolumne River, 37.80166667°, -119.8472222°, 17 August 2005, CEDEN, 1 larva.

North Fork Tuolumne River, ~3 mi below Pinecrest Lake Campground, 38.16542°, -120.03472°, 21 August 2001, CEDEN, 1 larva.

Upper Clark Fork Stanislaus River, ~0.6 mi above Fence Creek, 38.366°, -119.8692°, 29 August 2012, CEDEN, 1 larva.

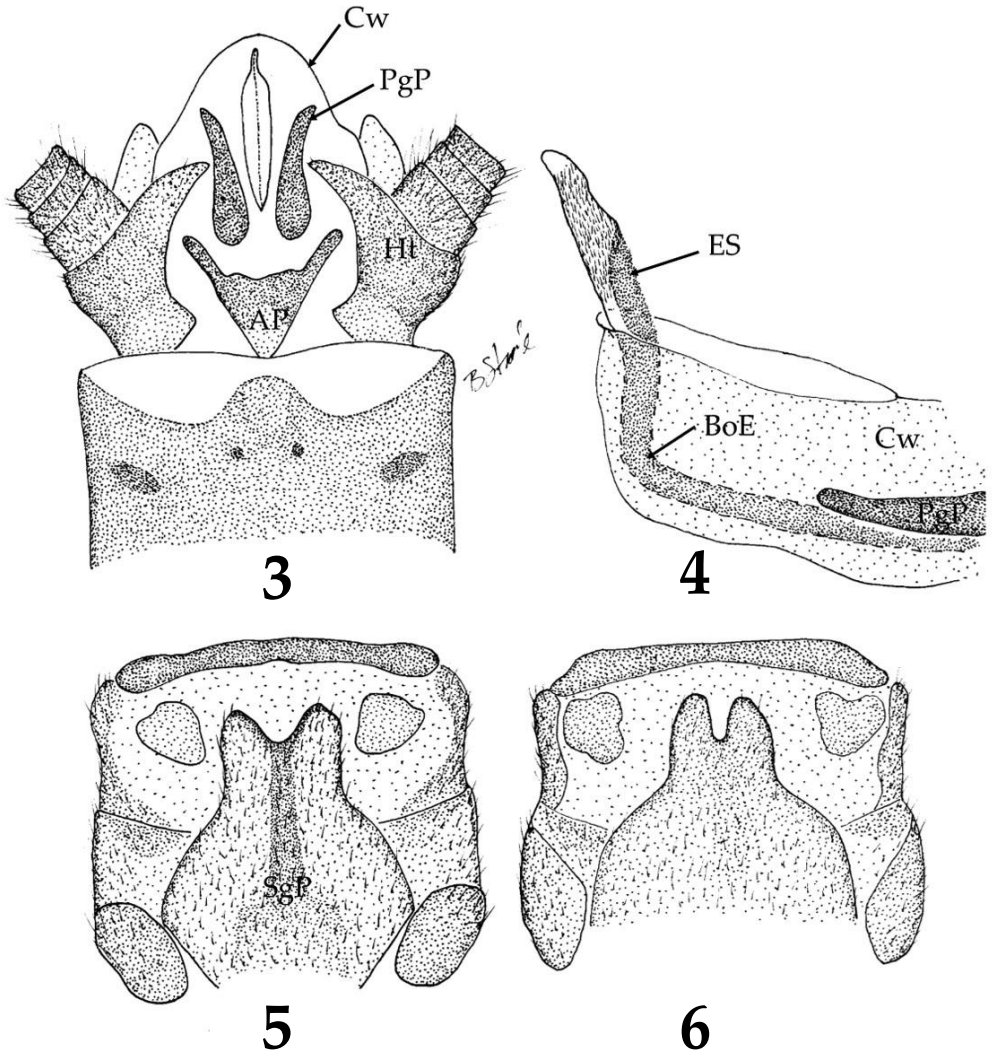
Yuba Co.

Deadwood Creek, tributary North Yuba River, Owl Gulch, 6 October 1999, W.C. Fields, 1 larva (BYU).

In addition to the above locations, David Herbst, Sierra Nevada Aquatic Research Laboratory, has found *O. barbara* larvae in the following eastern Sierra Nevada streams in **California: Alpine County** – Charity Valley Creek, East Fork Carson River (many sites), Forestdale Creek, Hot Springs Creek (above and below Grover Hot Springs), Indian Creek, Kinney Creek, Pleasant Valley Creek, Silver King Creek, West Fork Carson River (in Hope Valley and upstream); **El Dorado County** – Meeks Creek (upstream of Meeks Bay, Lake Tahoe), Upper Truckee River; **Placer County** – Cold Creek (Coldstream Valley near Donner Lake), Silverado Creek (tributary to Squaw Creek), Squaw Creek (Squaw Valley).

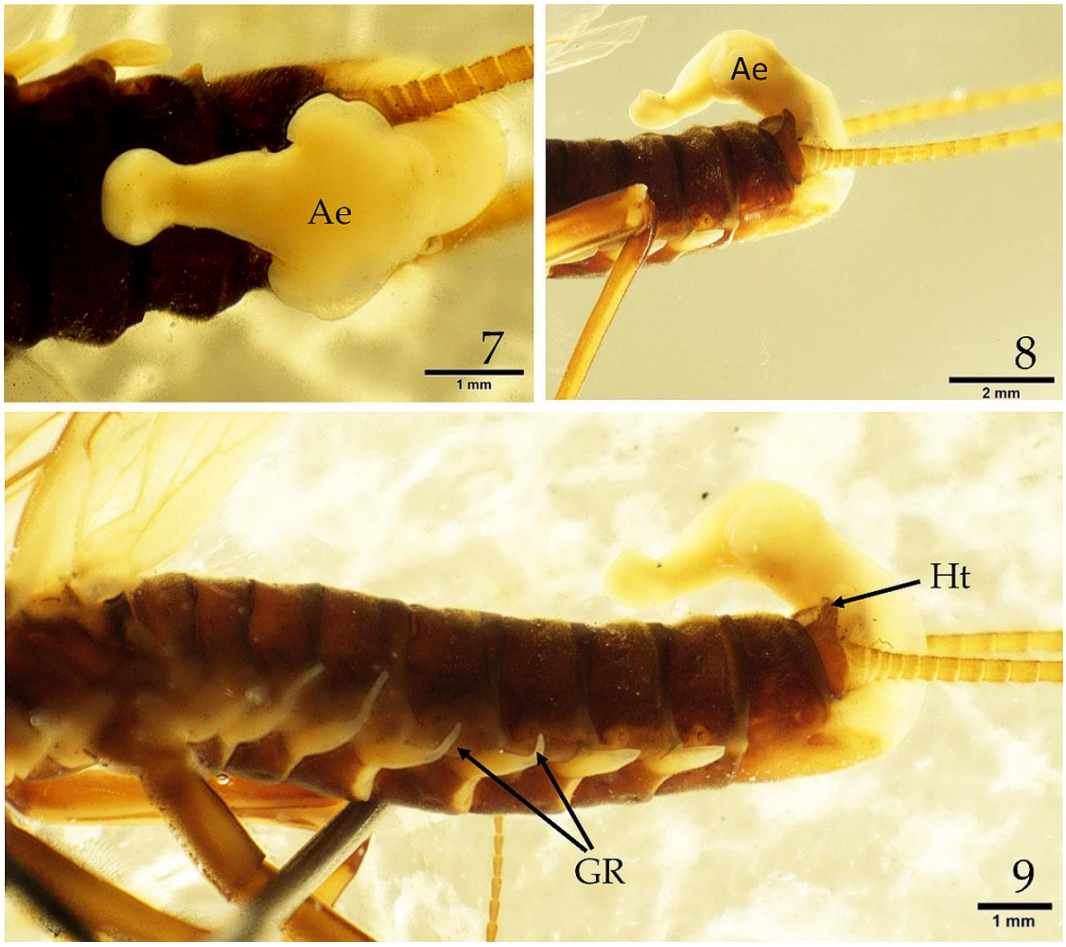
Adult habitus [Previously described by Jewett (1966)]. Male forewing length 15.0 mm (n = 1); female forewing length 19.0-20.5 mm (n = 3). Body dark brown, wings transparent with dark veins. Head dark brown with yellow markings; pronotum dark with a narrow, median yellow stripe. Antennae brown, cerci pale brown (Fig. 1). Abdominal gills present on ventrolateral corners of segments 1-7 (Fig. 9).

Male epiproct and 10th tergal complex [Previously described by Jewett (1966)]. Hemiterga of tergum 10 attenuated to form digit-like curved structures (Fig. 3). Black, Y-shaped, prominent epiproct



Figs. 3-6. *Oroperla barbara* external reproductive structures. Male: California, El Dorado Co., South Fork American River, Kyburz. Female: Same, except Sayles Flat, Camp Sacramento. 3. Male terga 9-10, dorsal aspect. 4. Male epiproct and surrounding cowl, lateral aspect. 5. Female subgenital plate and 9th abdominal sternum. 6. Variation in subgenital plate. (AP = anchor plate, BoE = bend in epiproct, Cw = epiproct cowl, ES = epiproct sclerite, Ht = hemitergum, PgP = paragenital plate, SgP = subgenital plate).

anchor located anteromedially between hemiterga, and a large membranous cowl extends posteriorly enclosing epiproct. Epiproct bent sharply at a near right angle at posteroventral region of cowl (Fig. 4); most of epiproct very darkly sclerotized within cowl, but a short apical section lacks strong sclerotization. Much of epiproct surface covered with fine, densely packed setae. Epiproct tip in lateral aspect slightly excavated and not quite as wide as the more basally located and heavily sclerotized section. In dorsal aspect, a pair of darkly sclerotized paragenital plates are imbedded in the membranous cowl. Lateral stylets not evident. Aedeagus glabrous and recurved over

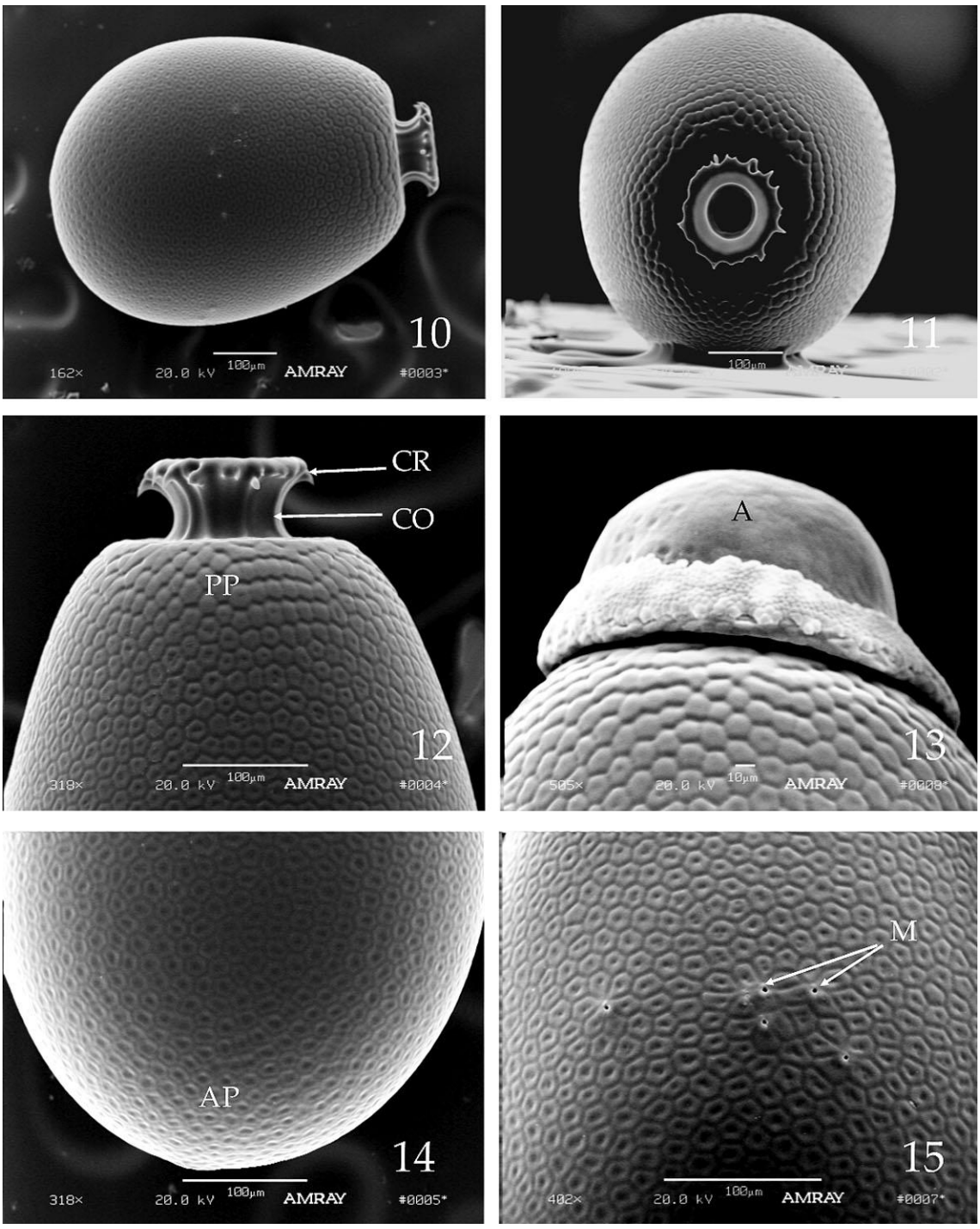


Figs. 7-9. *Oroperla barbara* adult male abdomen and genitalia. California, Alpine Co., West Fork Carson River, Hwy 89, Snowshoe Springs Campground. 7. Abdominal gills and everted aedeagus, dorsal aspect. 8. Abdominal gills and everted aedeagus, lateral aspect. 9. Complete abdomen, lateral aspect: gills, hemitergal lobe, aedeagus, and cerci. (Ae = aedeagus; GR = gill remnant; Ht = hemitergum).

terminal abdominal segments (Fig. 8). Dorsal aspect narrow, expanding into large, lateral lobes, narrowing abruptly with a rounded apex (Fig. 7). Lateral aspect with relatively constant width from base to anterior lobes, apex pointing downward and terminating in rounded tip (Figs. 8-9).

Female subgenital plate [Previously described by Siegfried et al. (1977)]. Subgenital plate broad basally, narrowed apically and bearing a variably shaped shallow median notch (Figs. 5-6). Most of sternum 9 membranous, but posterior margin bearing a slender, black, transverse sclerite. Midlateral membranous field of sternum 9 also bearing a pair of subtriangular sclerites.

Egg (n=8) [Previously described by Siegfried et al. (1977) and Stark & Szczytko (1984, 1988)]. Total length 623 µm, egg body length 561 µm, egg collar length 62 µm, egg diameter 419 µm, collar diameter 129 µm (Figs. 10-12). Chorionic surface covered throughout with hexagonal follicle cell impressions (FCI) (Figs. 10-15). Thick FCI walls surround a single, or a pair of pits (Fig. 15). FCI width near micropylar region 16-19 µm. Micropyles form irregular rows near midlength;



Figs. 10-15. *Oroperla barbara* egg structure. California, El Dorado Co., South Fork American River, Kyburz. 10. Entire egg, lateral. 11. Collar end, apical aspect. 12. Collar end, lateral aspect. 13. Collar end with anchor intact. 14. Anterior pole, lateral aspect. 15. Chorionic and micropylar detail (A = anchor, AP = anterior pole, CO = collar, CR = collar rim, M = micropyle, PP = posterior pole).

orifices small and often surrounded by rosettes composed of modified FCI's (Fig. 15). Anchor hat-shaped with turned up brim (Fig. 13).

Egg incubation and hatching. During our study of stoneflies of the Cosumnes River in west-central Sierra Nevada, one of us (RLB) found an adult female *O. barbara* with an extruded egg mass on 25 March 1984. The female produced additional eggs the next day in the laboratory (Hydrobiology Laboratory, University of California, Davis). All eggs were incubated in a cold water bath and regularly monitored for developmental status and hatching for the next seven months. The laboratory-built water bath had thermostat-controlled cooling units that regulated water temperature and timer-controlled lights. Water bath conditions, including water temperature and day length, were adjusted during the 7-month incubation to simulate natural seasonal variability of the river environment. For example, water temperature was gradually increased from 6.5°C (25 March) to 16.0°C (23 August), and then decreased to 12.5°C (23 October). Day length was gradually increased from 12 hours (25 March) to 15 hours (21 June) and then decreased to 11 hours (23 October). When placed in the water bath, the fusiform-shaped eggs measured 0.6 mm long and 0.5 mm wide. The posterior pole of each egg was capped with a distinct collar (Fig. 10-13) and a sticky, gelatinous anchor. Total egg length, including the collar and anchor was 0.75 mm.

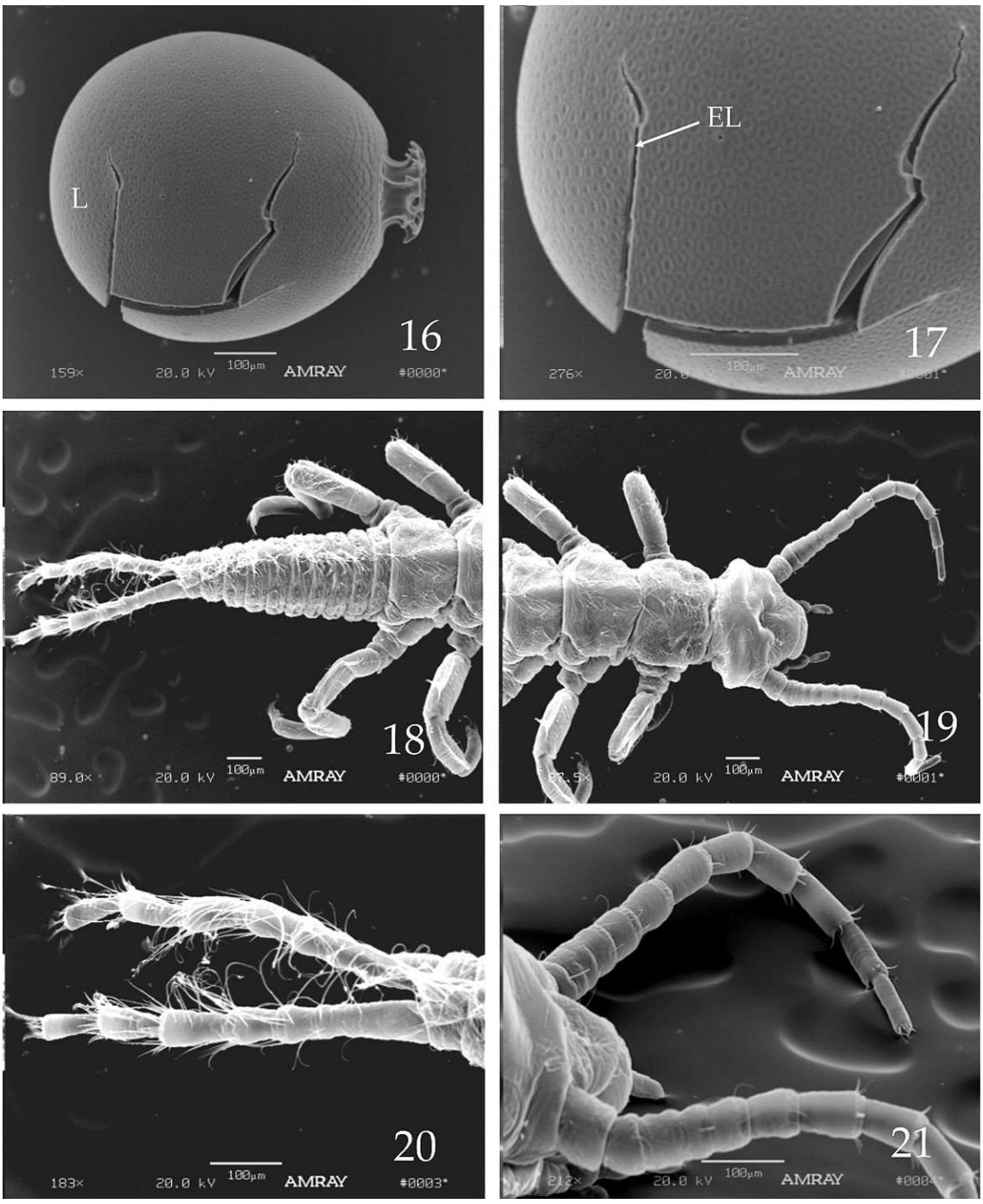
Eggs were routinely examined under a dissecting microscope. The initial uniform egg tissues aggregated into clumped cells within 20 days (mid-April) of being placed in the water bath. At 75 days (early-June), the development and aggregation of cells had advanced to where some embryos had distinct black eye spots and hatching appeared to be imminent. Eggs with eye spots were slightly larger than the initial eggs, now being 0.7 mm long without collar and anchor, and 0.6 mm wide. In addition, the initial fusiform egg had swollen somewhat closer to a spherical shape. At 83 days (mid-June), 1st instar larvae hatched from some eggs. Incubation continued for the next four months and some eggs appeared to develop and aggregate tissues into clumped cells, but no further hatching occurred. Incubation was discontinued after 212 days (late-October).

Growth Stage	Head Width mm	Body Length mm	Body Volume mm^3	Volume Increase from 1st Instar	Antennal Segments	Cercal Segments
1st Instar	0.4	1.7	0.2	1	11-12	6-7
Small	0.8	3.8	1.9	9	21	
Small	1.0	5.0	3.9	18	28-30	18-20
Medium	2.8	12.8	78.8	369	58	32
Mature	6.2	30.0	905.7	4240	68-80	35-38

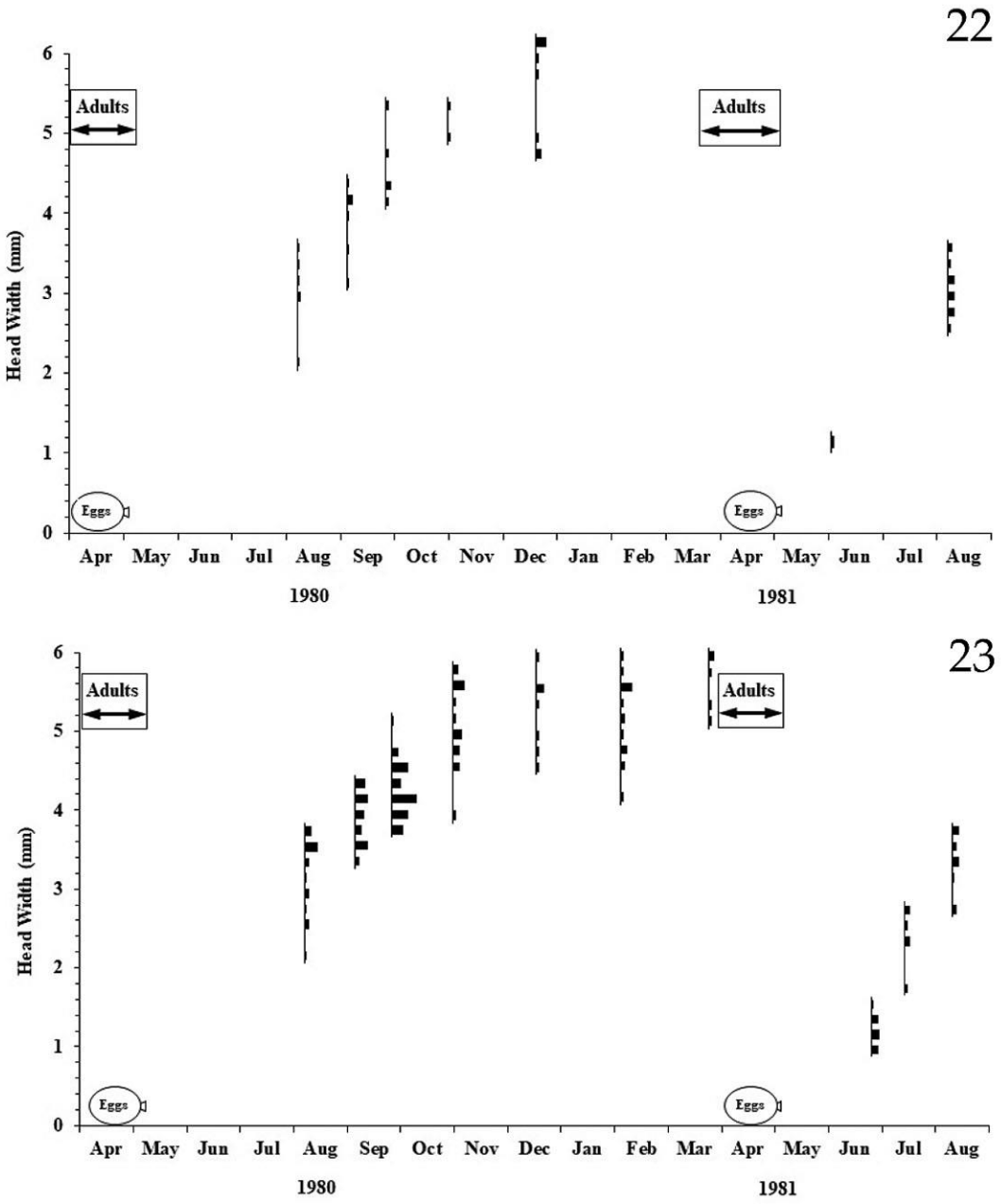
Table 1. Growth characteristics of *Oroperla barbara* larvae, Cosumnes River, west central Sierra Nevada, El Dorado County, California. Body volume was estimated using the equation for a cylinder (Volume $=\pi W^2L/4$; W = head width and L = body length).

Characteristics of small, medium, and large larvae

First instars (head width 0.4 mm). First instar larvae exited the egg through a transverse split of the shell about 2/3 of the distance from collar to anterior pole (Figs. 16-17). The split did not completely encircle the eggshell, but only opened



Figs. 16-21. *Oroperla barbara* egg shell and young hatchling. California, North Cosumnes River, Sweenys Crossing. 16. Eggshell with eclosion lines. 17. Eclosion line detail. 18. Young larva, posteroapical aspect. 19. Young larva, anteroapical aspect. 20. Young larval cerci. 21. Young larval antennae (EL = eclosion line, L = lid).



Figs. 22-23. *Oroperla barbara*, larval growth at two lower stations in the Cosumnes River, west central Sierra Nevada, El Dorado County, California. The graphs show when adults and eggs were present. Eggs are drawn to scale using vertical axis units. 22. Growth at 619 m elevation. 23. Growth at 978 m elevation.

enough for the anterior 1/3rd (lid) of the shell to hinge back for larval exit. Thus, empty eggs retained all their structures and showed the larval exit split, plus shorter longitudinal fissures. Empty eggs were 0.64 mm long (without collar and anchor) and 0.5 mm wide.

First instar larvae had a head width of 0.4 mm and a mean body length of 1.7 mm (n = 10). They had 11-12 antennal segments and 6-7 cercal segments (Table 1) (Figs. 18-19). Short setae

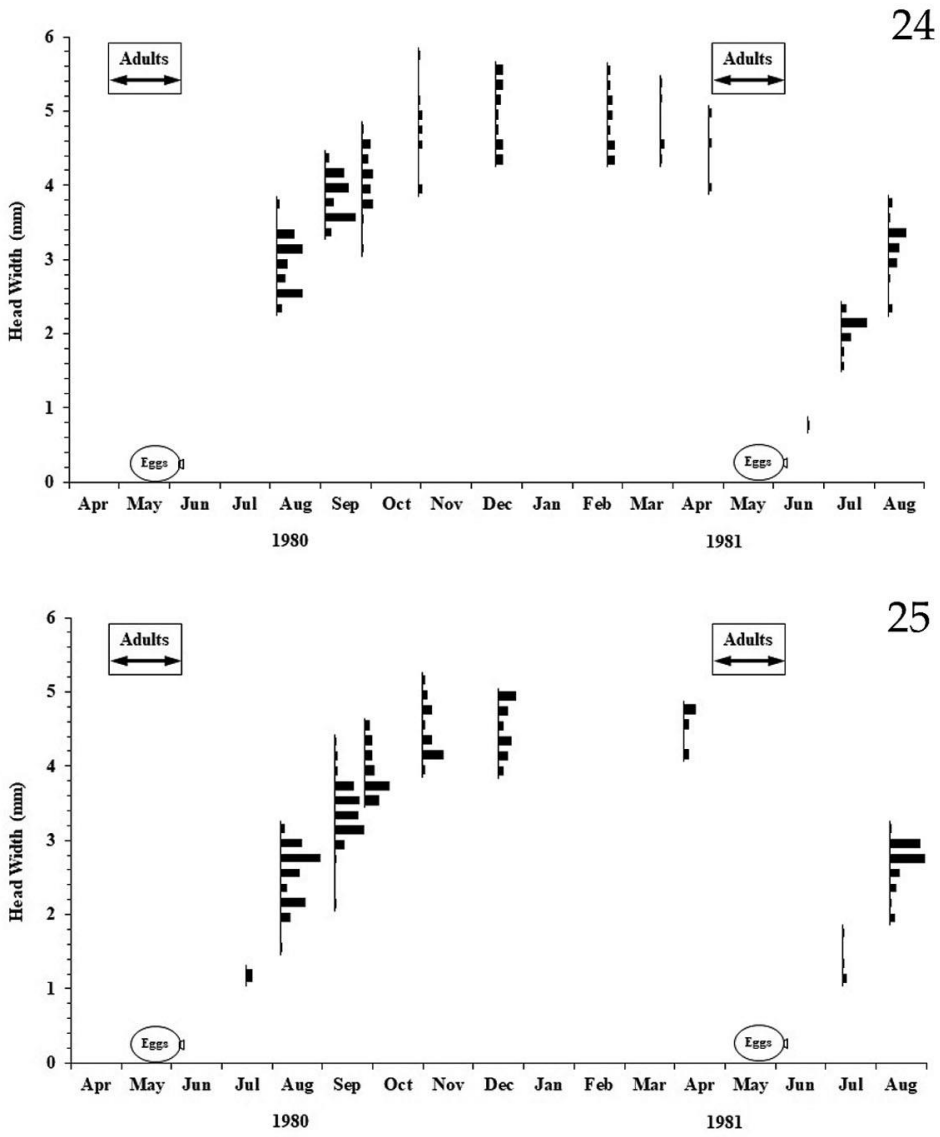
encircled the distal ends of antennal and cercal segments and a row of long silky setae occurred on the cerci (Figs. 20-21). Most antennal and cercal segments were distinctly separated from adjoining segments, but antennal segments 3-5 (counted from the base) were often difficult to distinguish. The dorsum of the thorax and abdomen was covered with setae. All legs had a row of long silky setae on the outer margin of femur and tibia, which also had a few scattered stout spine-like setae. Each leg was tipped with a pair of thin curved claws having a small basal tooth. Thoracic and abdominal gills were absent, however, the ventrolateral corners of abdominal segments 1-7 had small, bud-like swellings. First instar larvae had well-defined compound eyes (Fig. 19), rather than the simple ommatidia typical of first instar stoneflies (Harper 1979, Sephton & Hynes 1982). First instar body volume = 0.2 mm^3.

Small larva (head width 0.8 mm). One larva was found (24 June 1982) with a head width of 0.8 mm, body length of 3.8 mm, and 21 antennal segments (cercal segments were broken off). Basal antennal segments 3-4 were poorly defined and/or elongated. Long silky setae occurred on legs, cerci, thorax and abdomen. Short lateral double gills (length = width) occurred on the anterior meso- and metathorax, and single tapered gills occurred ventrolaterally on abdominal segments 1-7. These gills were thin extensions from broader basal swellings. Abdominal gill lengths on segments 2-4 equaled about 3 times width, while gill lengths on segments 1 and 5-7 were 1-2 times width. Gills were absent from the submentum and prothorax, however, slight swellings were present in the anterior median and supracoxal regions. A dark gut was visible within this larva, showing evidence of feeding. The lacinia had long, curved primary and secondary teeth, and a small spine at the anterior mesal corner. Small larvae body volume = 1.9 mm^3.

Small larvae (head width 1.0 mm). Few small larvae (n=3) were found (15 July 1980) by our field sampling methods, however, those with a head width of 1.0 mm had a body length of 5.0 mm, 28-30 antennal segments and 18-20 cercal segments. Basal segments of antennae and cerci were poorly defined. Body surfaces were covered with setae, including distinct rows of long silky setae on legs, cerci, thorax and abdomen. Well-developed lateral double gills occurred on the anterior meso- and metathorax, and single gills occurred ventrolaterally on abdominal segments 1-7. Submental gills appeared to be absent. Well-developed gills were absent on the prothorax, but pairs of bud-like swellings occurred in the anterior median and supracoxal regions (Shepard & Stewart 1983). Slender, curved, primary and secondary teeth, plus a small spine, were present on the lacinia. Small larvae body volume = 3.9 mm^3.

Medium larvae (head width 2.8 mm). Medium-sized larvae (n=6) had fully developed gills at six body locations (Shepard and Stewart 1983) – submental, anterior prothorax, supracoxal prothorax, anterior mesothorax, anterior metathorax, and abdominal segments 1-7. Gills were short for submentum (0.2 mm), anterior prothorax (0.4 mm), and supracoxal prothorax (0.2 mm), while they were elongated and tapered (0.7-1.0 mm) for anterior meso- and metathorax and abdominal segments 1-7. Larvae with a head width of 2.8 mm had a body length of 12.8 mm, 58 antennal segments, and 32 cercal segments. The rows of long silky setae on legs, cerci, thorax, and abdomen were denser on medium larvae than on younger larvae. Medium larvae body volume = 78.8 mm^3.

Mature larvae (head width 4.8-6.2 mm). Mature larvae had well-developed wing pads, a full set of submental, thoracic, and abdominal gills, and a complete clothing of setae on body and appendages (n=9). Mature female larvae could be distinguished from mature male larvae by a median projection on the posterior margin of abdominal sternum 8, a precursor of the subgenital plate. Larvae with a head width > 5.5 mm were typically females, whereas mature male larvae were smaller. Mature larvae had a head width of 4.8-6.2 mm, a body length of 25-30 mm (contracted specimens were as small as 20 mm), 68-80 antennal segments, and 35-38 cercal segments. Mature larvae body volume = 905.7 mm^3. The largest mature larvae increased their body volume (and



Figs. 24-25. *Oroperla barbara*, larval growth at two upper stations in the Cosumnes River, west central Sierra Nevada, El Dorado County, California. The graphs show when adults and eggs were present. Eggs are drawn to scale using vertical axis units. 24. Growth at 1536 m elevation. 25. Growth at 1658 m elevation.

body mass) more than 4000 times that of first instar larvae (Table 1).

Mature female larvae that were within a few weeks of emergence contained many well-formed eggs, but none had eyed embryos. For example, a female larva (head width, 4.8 mm) collected 19 April 2012 at 1719 m elevation in the South Fork American River contained a total of 316 eggs. About 80% of the eggs had brown sclerotized shells with a collar and gelatinous anchor, and were sized as described above. The remaining 20% were less well developed, being light tan or white. Eggs were carried inside this female larva in the pro-, meso-, and metathorax and abdomen.

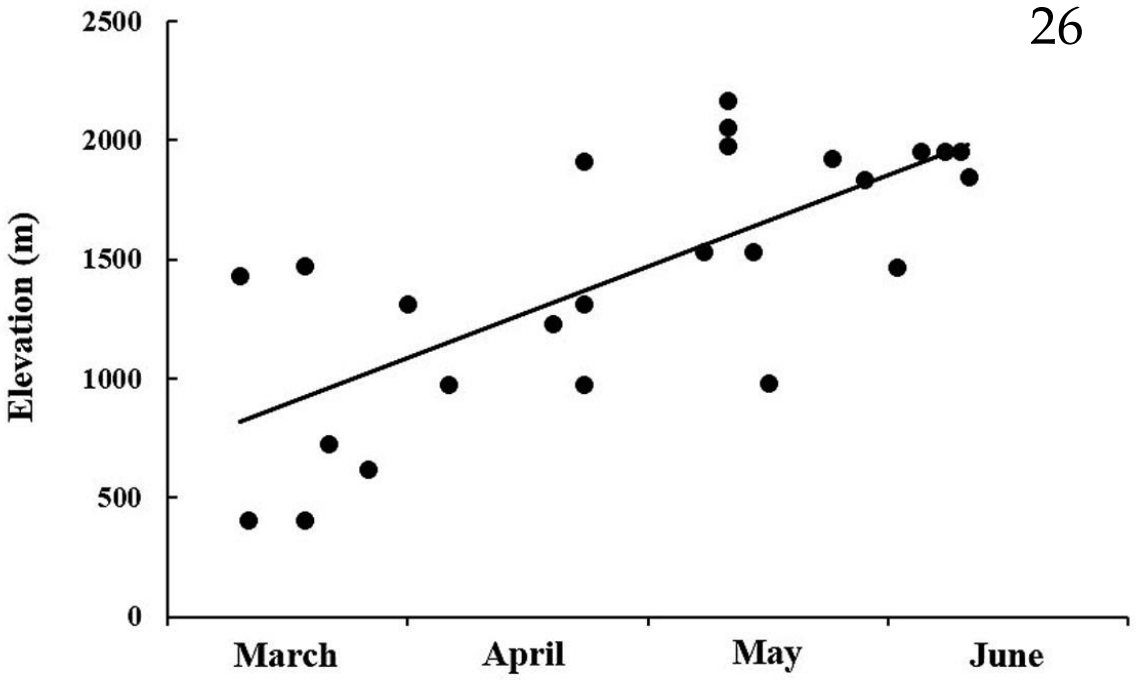


Fig. 26. Seasonal presence of *Oroperla barbara* adults by elevation for locations from throughout the species known distribution in California. The trend line has an R^2 value of 0.53.

Larval growth at different elevations

Growth of *O. barbara* was determined at four stations along the Cosumnes River continuum by regular sampling every 4-6 weeks by one of us (RLB) for more than a year. The four stations with *O. barbara* were located on the North Fork Cosumnes River, primarily within a mixed coniferous forest at the following elevations: 619 m (38.65246°, -120.626°), 978 m (38.669092°, -120.533568°), 1536 m (38.65045°, -120.40741°), and 1658 m (38.63579°, -120.33655°). Head capsule widths were measured for all larvae (n = 702) and plotted on charts to follow size changes between sampling dates (Figs. 22-25). Larvae varied in head width from 0.4 mm for first instars to as large as 6.2 mm for mature larvae. Maximum larval head widths varied inversely with elevation, reaching 6.2 mm at 619 m elevation, 6.0 mm at 978 m, 5.8 mm at 1536 m, and 5.2 mm at 1658 m.

Oroperla barbara larvae grew rapidly between July and October at all four stations, but then slowed or stopped during the winter months, this stasis continuing into spring when adults emerged (Figs. 22-25). Mature larvae became sparse or absent after late March-early May, the period when adults emerged and eggs began to incubate. Adults emerged between March and June, occurring earlier in the year at lower elevations (619-978 m) and later at higher elevations (1536-1658 m). A new cohort of smaller larvae became evident in the growth chart during June-July and reached head capsule widths > 2.0 mm by early August.

These growth patterns appear to document an annual life cycle for *O. barbara;* however, additional data on early-instar growth and egg incubation are needed to confirm this interpretation. For example,

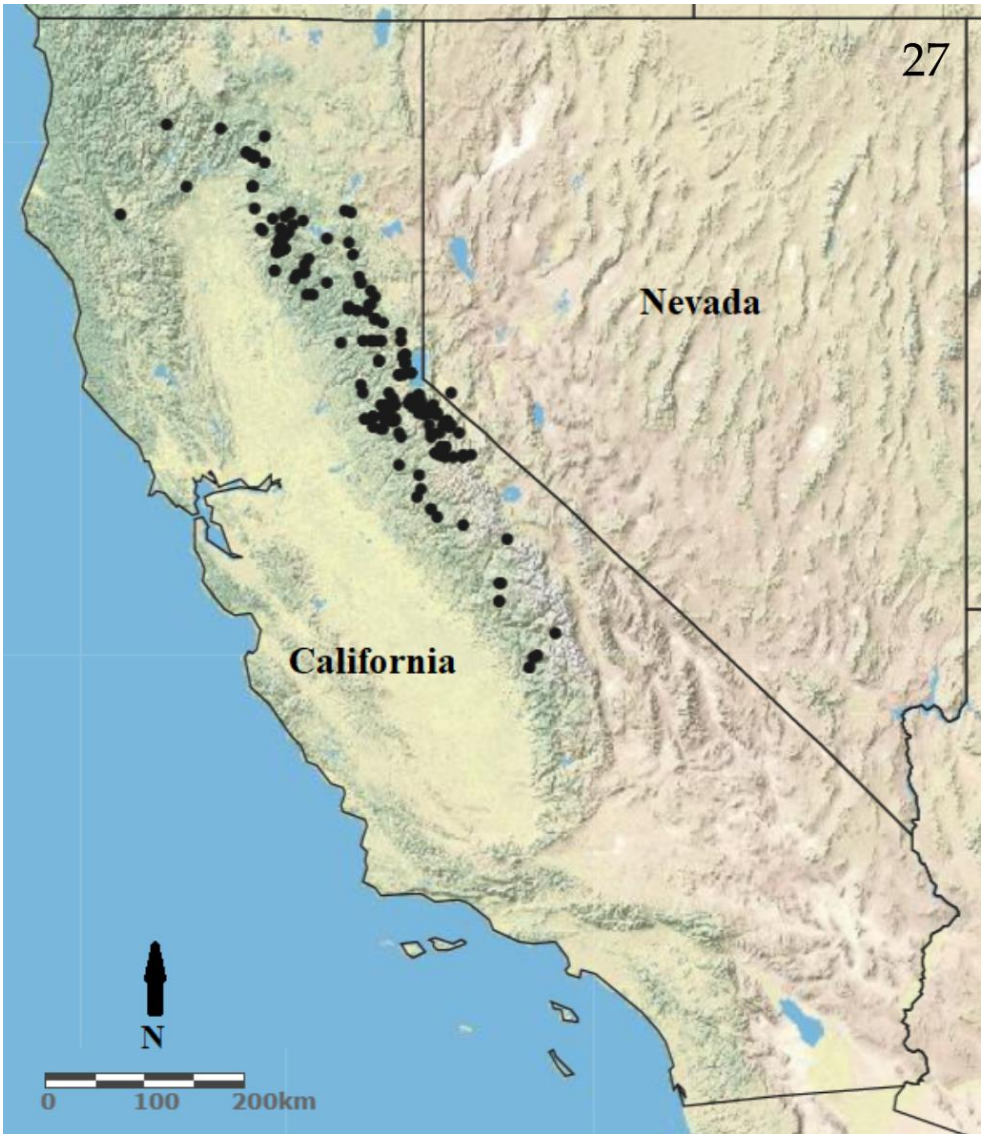


Fig. 27. *Oroperla barbara* distribution. Major Pacific river systems from north to south include the Trinity-Klamath, McCloud, Pit, Feather, Yuba, American, Cosumnes, Mokelumne, Stanislaus, Tuolumne, Merced, San Joaquin, Kings, and Kaweah. Major Great Basin river systems from north to south include the Susan, Truckee, Carson, and Walker. Map used with permission. Copyright © 2017 Esri, ArcGIS Online, and the GIS User Community. All rights reserved. Base map Copyright © 2013 National Geographic and i-cubed.

except for incubating one egg mass to obtain first instar larvae (head width of 0.4 mm), early life stages (head width < 1.5 mm) were not effectively sampled during this growth study. Therefore, the actual progression of growth between first instars and young larvae was unknown. Our laboratory egg incubation results showed that hatching occurred more than 70 days after oviposition, which occurred from late March to early June. At all stations except the lowest, this incubation delay pushed back the start of larval growth beyond June-July, when an earlier cohort (head width > 1.0-1.5 mm) already existed in the stream. For the upper three stations, an annual life cycle seems

possible only if egg incubation lasted for 30 days or less.

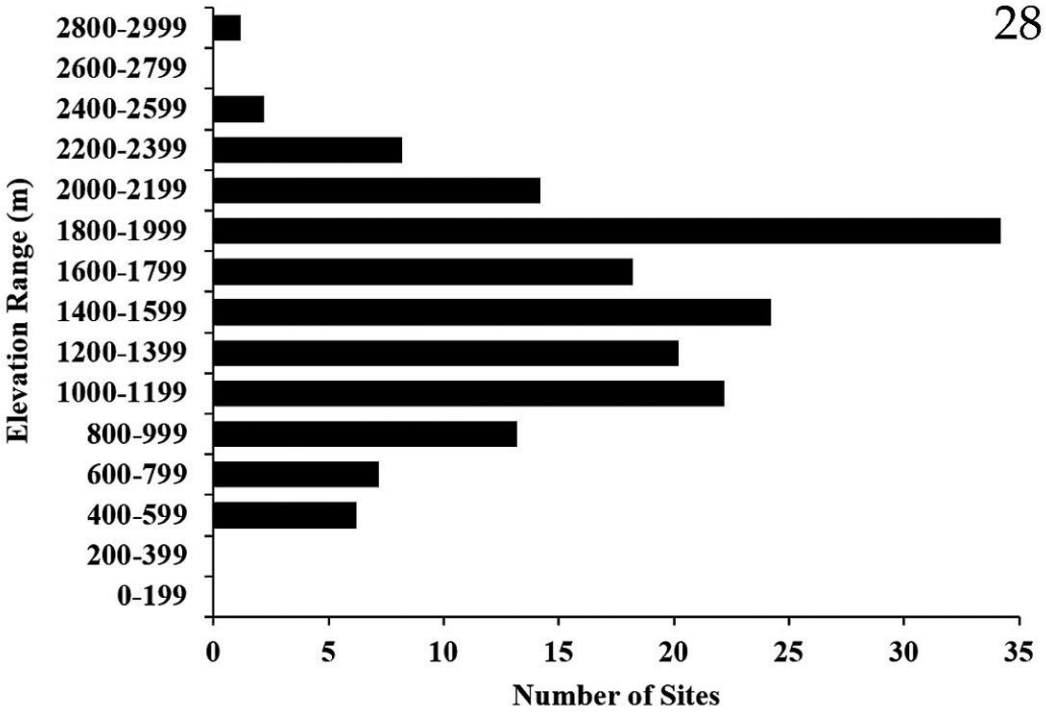
Thus, *O. barbara* may have a two-year life cycle in the upper Cosumnes River system, with the first year being used to incubate and hatch eggs, and grow larvae from those with head widths of 0.4 mm to those > 1.0-1.5 mm by the following July, when a distinct and rapidly growing cohort exists that can be tracked in subsequent months to eventual adult emergence during the following spring. Because *O. barbara* is a relatively large stonefly, a two-year life cycle seems to be needed to accumulate its large body mass, though the unique abdominal gills and increased respiratory potential of this species may accelerate growth beyond that found in other Perlodidae stoneflies. In this river system, three perlid stoneflies (*Calineuria californica* (Banks, 1905), *Doroneuria baumanni* Stark & Gaufin, 1974, and *Hesperoperla pacifica* (Banks, 1900)), all of similar size at maturity as *O. barbara,* are known to have 2- and 3-year life cycles (Bottorff 1990). Hitchcock (in Jewett 1966) found two distinct size classes of *O. barbara* during September in a high elevation stream (>1900 m) of the central Sierra Nevada, giving evidence of semi-voltinism.

Diet. The diet of *O. barbara* larvae was determined by examining the foregut contents of 20 specimens having a range of sizes (head capsule widths, 1.1-5.8 mm; body length 5.0-30.0 mm) and both sexes. These larvae were sampled from a range of elevations (619-1984 m) and dates (March, April, June, August, September, December) in the central Sierra Nevada. The foreguts of most larvae were packed with aquatic insect prey; four foreguts were empty, including two from newly molted individuals. Other classes of stream foods used by aquatic insects, such as filamentous algae, diatoms, and organic detritus, were absent in the *O. barbara* diet. Apparently, prey were engulfed whole since bodies were largely intact in the foregut, except for the loosening of sclerites by digestive action. The 16 larvae with food in their foreguts had consumed a total of 106 whole prey items. In particular, two prey types were important in the diet: (1) blackfly larvae (Simuliidae) were heavily consumed by larger larvae (head widths > 3 mm), and (2) baetid mayfly larvae (Baetidae) were eaten by smaller larvae (head widths < 2 mm). In addition, small numbers of midge larvae (Chironomidae), blackfly pupae (Simuliidae), mayfly larvae (Ephemerellidae, Heptageniidae), caddisfly larvae (Hydropsychidae, Philopotamidae), and stonefly larvae (Perlodidae) were found in foregut samples. The diet of larvae with head widths < 1.1 mm is unknown.

Adult Seasonal Presence. Of the more than 220 collections of *O. barbara* listed in this study, 31 records were of adults. Throughout its entire range, they were present for a 3-month period, from as early as 9 March to as late as 8 June. Much of this 3-month variation in adult seasonal presence was caused by differences in stream elevation, with early emergence at lower elevations and later emergence at higher elevations (Fig. 26). Of course other correlates of elevation, especially stream water temperature, are important factors that regulate larval growth, maturity, and emergence. At any single location, adults were present for about 4-6 weeks.

Distribution. At present, *O. barbara* is known from California and extreme western Nevada (Fig. 27). Its California distribution includes (1) most of the Sierra Nevada, (2) the southern Cascade Range, and (3) the Klamath Mountains, a total distance of 620 km spanning latitudes of 36.5° to 41.1° and longitudes of -118.6° to -123.3°.

Within the Sierra Nevada, it ranges at least 500 km through the northern, central and southern regions of these mountains. Most collections are from western-slope streams of the northern and central Sierras that flow to the Pacific Ocean via the Sacramento and San Joaquin rivers, but a few records exist as far south as Tulare County at latitude 36.5° N. Major western-slope Sierra rivers with known *O. barbara* records include, from north to south, the Feather, Yuba, American, Cosumnes, Mokelumne, Stanislaus, Tuolumne, Merced, San Joaquin, Kings, and Kaweah. It also occurs in smaller western-slope watersheds draining to the Sacramento River in Butte and Tehama counties, including, from north to south, Cow, Battle,



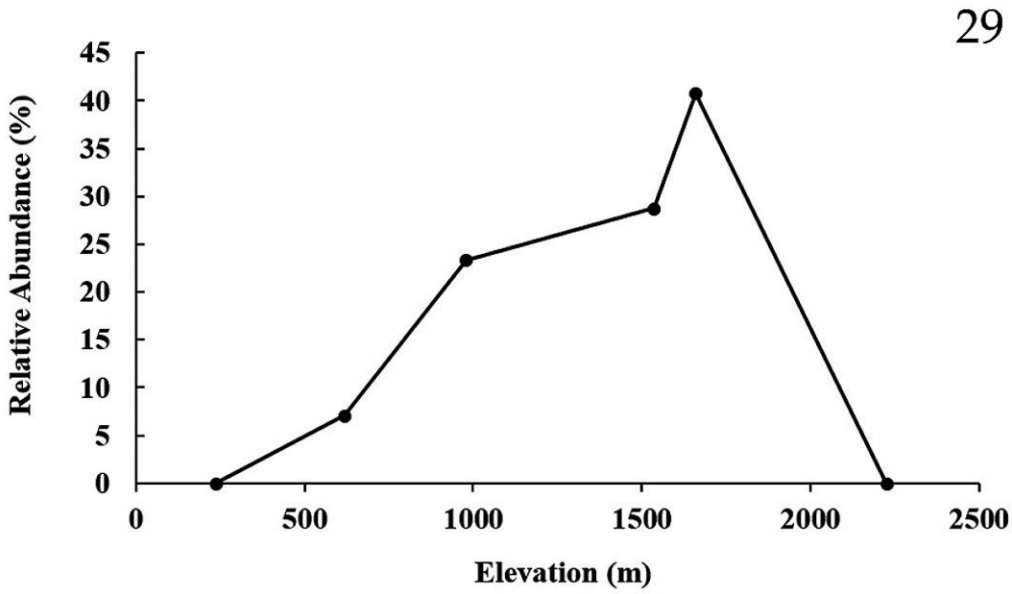


Fig. 28. Elevation range of *Oroperla barbara* based on 169 California stream sites known to have this species.

Fig. 29. Relative abundance of *Oroperla barbara* larvae at different elevations of the Cosumnes River, west central Sierra Nevada, El Dorado County, California. Relative abundance at any location is the percentage of larvae collected at that site in relation to the total number of larvae collected at all sites during the study (n=702).

Antelope, Mill, Deer, Big Chico, and Battle creeks. No collections are known from the Kern River or the Tehachapi Mountains at the southern end of California's Central Valley.

In the northern and central Sierra Nevada, *O. barbara* inhabits eastern-slope streams that flow into the Great Basin via the Susan, Truckee, Carson, and Walker rivers. It occurs near Lake Tahoe and south for at least 80 km, but is unknown from streams draining to Mono Lake and further south along the eastern Sierra Nevada (personal communication, David Herbst, Sierra Nevada Aquatic Research Laboratory, Mammoth Lakes, California). One collection is known from the East Fork Carson River in Nevada (Baumann et al. 2017).

Oroperla barbara is found in streams of the southern Cascade Range in Shasta County, including at least two major river systems, the McCloud and Pit, which flow southwest to the Sacramento River. Compared with the many *O. barbara* sites in the Sierra Nevada, the Cascade region has relatively few records, possibly reflecting less sampling effort.

Three records of *O. barbara* are known from the Klamath Mountains, which are part of the Pacific Coast Range of northwestern California. Two of these records are from creeks that drain to the Pacific Ocean via the Trinity and Klamath rivers, while the third flows to the upper Sacramento River near Redding. The Klamath River drainage spans the border of California and Oregon, and contains several endemic species of aquatic insects that have limited distributions in the Coast Range. For example, Jacobson and Courtney (2008) described a new species of net-winged midge (Diptera, Blephariceridae) from the Klamath Mountains, with paratypes from Klamath River tributaries in California and Oregon. Thus, *O. barbara* may occur in southern Oregon but further sampling is needed to validate this hypothesis.

Habitat, elevation, and abundance. *Oroperla barbara* inhabits medium to large streams at medium to upper elevations (Figs. 2, 28). In this study, it was found at elevations ranging from a minimum of 410 m (1345 feet) to a maximum of 2806 m (9206 feet). However, 86% of all records in this study came from elevations of 800-2200 m (2625-7218 feet). It is remarkable that this species can flourish along this substantial gradient in elevation, despite variations in water temperature and other environmental factors. Abdominal gills may facilitate its ability to survive wide environmental conditions. All streams where we found *O. barbara* were relatively pristine, typically in a forested watershed, and with clear water rapidly flowing over coarse, rocky substrates.

During a study of benthic macroinvertebrates along 123 km of a major Sierra Nevada river system, the Cosumnes River, between its headwater origins at 2249 m elevation and lower reaches at 27 m elevation, *O. barbara* occurred at four contiguous stations of nine sites studied (Bottorff 1990). In this watershed, larvae and adults were found at elevations between 619 m and 1860 m, though the actual range must have extended slightly higher and lower. Despite repeated sampling of the river during all seasons, it was not found at elevations at or below 238 m, or at or above 2225 m. *Oroperla barbara* inhabited 3rd to 5th order streams with stream widths of 3-11 m. At the four stations where this species occurred, sampling for more than a year typically found larvae during most months, but large larvae were uncommon or absent in April-June during, or immediately after, adult emergence. Larvae were most common in the river at elevations 1536-1658 m, slightly less common at 978 m, and uncommon at 619 m (Fig. 29).

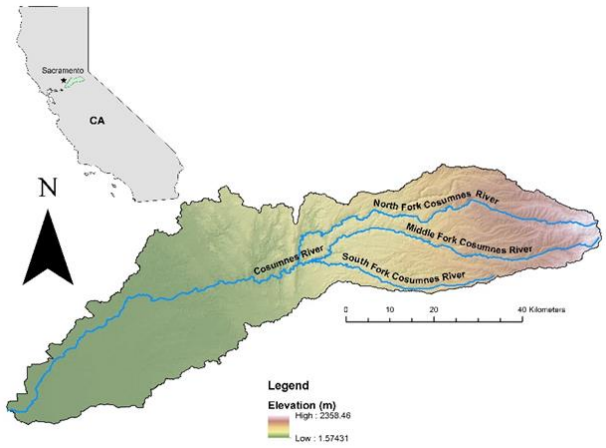


Fig. 30. Cosumnes River drainage basin, west-central Sierra Nevada, California.

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