Contulma paluguillensis (Trichoptera:Anomalopsychidae), a new caddisfly from the high Andes of Ecuador, and its natural history

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Abstract. Adults and larvae of a new species of *Contulma* Flint (Trichoptera:Anomalopsychidae) are described from Ecuador. The new species is similar to *Contulma papallacta* Holzenthal and Flint, but differs in having shorter, less spatulate dorsolateral processes and shorter setose lateral processes of segment IX in the male genitalia. Monthly Hess, sticky trap, and emergence-trap collections indicated that the new species is uncommon, probably univoltine, but with continuous larval growth and extended adult emergence, and has algivorous larvae.

Key words: Andean high altitude streams, aquatic macroinvertebrates, autecology, species description, endemism, larvae, life history, morphology, Neotropics, taxonomy.

The Neotropical region harbors a rich diversity of caddisflies, 2nd only to the Oriental region in number of described species (Morse 2003). However, much of the Neotropics remains underexplored for caddisfly diversity, especially the central and northern Andes of Bolivia, Colombia, Ecuador, Perú, and Venezuela, which encompass one of the world's biodiversity "hotspots" (Myers et al. 2000).

Members of the caddisfly genus *Contulma* (Anomalopsychidae) are rarely collected. In fact, the 25 described species are known only from ~150 specimens. Furthermore, the species seem to display a high degree of local endemism (Holzenthal and Robertson 2006). Species are known from Costa Rica, the Andes from Colombia to Chile, and in the mountains of southeastern Brazil. These insects frequent small waterfalls, seeps, and small streams in lush forested mountainous areas as well as high elevation *páramo* streams above the tree line (Holzenthal and Flint 1995).

Eighteen species are known from the northern Andean countries (Ecuador, Colombia, Perú, and Bolivia), and all occur above 2000 m. Only 2 of these species are also found below this altitude (Holzenthal

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and Flint 1995, Holzenthal and Robertson 2006). Seven species occur in Ecuador (5 endemic and 2 present also in Colombia), and all of the Ecuadorian species occur in the highlands >2000 m.

The northern Andean highlands contain a number of unique, diverse, and understudied ecosystems (Sarmiento 1997). The region is one of the most active tectonic areas on the South American continent, if not the world, and has complex climatology and topography. These features have favored the formation of several vegetation types with high endemism (e.g., up to 60% of plant species are endemic; Myers et al. 2000, Hofstede et al. 2003). This endemism also is observed for other organisms in the region, including caddisflies, e.g., *Amphoropsyche* (Holzenthal 1985), *Atanatolica* (Holzenthal 1988), *Atopsyche* (Schmid 1989), and *Contulma*. In this region, each mountain habitat sampled has 1 or 2 endemic species (Holzenthal and Flint 1995). Thus, we expect that a large number of endemic species remain to be collected and described from Andean mountain environments.

In recent years, efforts to increase knowledge of the Andean aquatic biota and its ecology (e.g., www.ub.edu/riosandes) have provided new information on species and their distributions. Long-term sampling has provided important data on life histories of aquatic macroinvertebrate populations as advocated

by Resh and Rosenberg (2010) and others (Mendez and Resh 2007). As a part of these efforts to increase our basic understanding of Andean macroinvertebrates, the objectives of our paper are to describe life-history features and provide ecological information for a new species of *Contulma*, the first such information provided for any species in the genus.

Methods

Study site

Data reported in our study were collected as part of a larger research project (see Acknowledgements) to study the structure and function of Andean streams. The new species was collected from Quebrada Saltana (lat 0°19′1.80″S, long 78°13′8.8″W), a 1st-order pristine stream in the northeastern Andes of Ecuador and part of the headwaters of the Río Esmeraldas basin. The study reach (100 m) is 3848 m asl and is surrounded by mixed páramo vegetation (*Calamagrostis intermedia* tussock grass mixed with shrubs). Mean stream width was 95 cm (range 40–140 cm). Boulders, cobble, and gravel dominate the stream substrate. During the study period (April 2009–September 2010), stream flow fluctuated between 33.1 and 469.54 L/s, with an annual mean of 130 L/s. The highest discharges were found from June to August, whereas baseflow conditions were found from September to March. O_2 was close to saturation during the entire study period. Conductivity ranged from 63 to 70 μS/cm, pH ranged from 6.5 to 7.8, and water temperature ranged from 5.9 to 7.1°C (BRT, N. Prat [Universitat de Barcelona], A. C. Encalada [Universidad San Francisco de Quito], N. Bonada [Universitat de Barcelona], M. Rieradevall [Universitat de Barcelona], F. Gonzalez [Universidad San Francisco de Quito], unpublished data).

Sampling and data analysis

Benthos was sampled monthly from April 2009 to June 2010, and flying adults were sampled monthly from July 2009 to June 2010. Additional benthic and adult samples were collected in September 2010, April 2011, and October 2011. A Hess sampler (12 replicates, 0.02 m², 250-μm mesh) was used to collect larvae from the stream bottom, and a hand net was used to sample shoreline and aquatic vegetation (2 min in the reach each month). Velocity and substrate were recorded with each Hess sample. Velocity was measured using an FP101 Global Flow Probe (Global Water, Gold River, California). Benthic samples were fixed with 5% formalin and preserved in 90% ethanol.

Larval head width and body length of all specimens were recorded with the aid of an Olympus SZX16 stereomicroscope (Olympus America, Center Valley, Pennsylvania) calibrated for measuring with an ocular micrometer. Twenty random larvae were selected to determine dry mass and the relationship between body length and biomass. We made gut-content preparations by dissecting the digestive tracts of 10 mature larvae. We broke the digestive tracts open with forceps, placed all gut contents in glycerine on a glass microscope slide, and covered them with a coverslip. One slide was prepared for each individual, and 10 random visual fields/slide were analyzed at $100\times$ magnification on an Olympus BX41 compound microscope to classify the % occupancy of each food category: 1) coarse particulate organic matter (CPOM, ≥ 1 mm), 2) fine particulate organic matter (FPOM, <1 mm), 3) algae, or 4) arthropod exoskeleton. The data were expressed as % occupancy of each category of food per visual field.

We sampled adults with 3 amphibious emergence traps (model BD5740A; MegaView Science, Taiwan) ($1.1 \times 1.1 \times 1.1$ m) placed immediately above the stream and covering the entire stream width from one side to the other for 24 h/mo. We also placed 12 flight-intercept (vertical) and 8 platform (horizontal) sticky traps within the stream margins and sampled monthly for 24 h. We used Tree Tanglefoot sticky compound on the acetate sheets (210×297 mm) of the traps and citric-based solvent to remove the specimens from the traps (Encalada and Peckarsky 2007). After the new species was identified, ad hoc Malaise trap collections were made in April 2011 to obtain additional adult specimens, but without accompanying habitat data. All adult specimens collected were preserved in 96% ethanol. Low night temperatures (usually $<6°C$) in the area made light trapping unproductive. We used STATISTICA (version 8; StatSoft, Tulsa, Oklahoma) to construct the box-and-whisker plots of head-capsule widths by month for larvae of the new species.

Specimen preparation

We used the methods described by Blahnik and Holzenthal (2004) and Holzenthal and Andersen (2004) to prepare adult specimens for taxonomic study. Genitalia were cleared in 85% lactic acid heated to 125°C for 20 min (Blahnik et al. 2006). An Olympus BX41 compound microscope outfitted with a drawing tube was used to assist pencil drawings of genitalic structures. Final illustrations were rendered in Adobe Illustrator. Morphological terminology follows that of Holzenthal and Flint (1995). Each specimen or lot examined during the study was affixed with a barcode label (4-mil polyester, 8×14 mm, code

49) bearing a unique alphanumeric sequence beginning with the prefix UMSP. Specimen-level taxonomic and collection data are stored in Biota® (version 2.0; Sinauer Associates, Sunderland, Massachusetts; Colwell 2004).

Association of larvae and adults of the new species was by the metamorphotype method (Wiggins 1996). Types of the new species are deposited in the collections of the Museo Ecuatoriano de Ciencias Naturales, Quito, Ecuador (MECN), Museum of Zoology, Pontificia Universidad Católica del Ecuador, Quito, Ecuador (QCAZ), Museum of Zoology, Universidad Tecnológica Indoamérica, Quito (MZUTI), the University of Minnesota Insect Collection, St. Paul, Minnesota, USA (UMSP), and the National Museum of Natural History, Smithsonian Institution, Washington, DC, USA (NMNH).

Results

Contulma paluguillensis, new species, Holzenthal and Ríos-Touma Figs 1–3

Species description

The new species shares a genitalic morphology closest to that of *Contulma papallacta* Holzenthal and Flint, 1995 especially in the similarity in the 2 processes of segment IX and in the posteromesal projection of sternum IX. However, in *C. paluguillensis*, n. sp., the dorsolateral process of segment IX is much shorter and not spatulate as it is in *C. papallacta*, and the setose lateral process of segment IX is much shorter, not extending beyond the posterior margin of the segment (figs 78, 79 by Holzenthal and Flint 1995). The differences in the posteromesal projection of sternum IX of the 2 species lie in the somewhat more rounded and separated posterolateral lobes of the process in the new species when viewed ventrally (Fig. 1C) compared to *C. papallacta* (fig. 80 by Holzenthal and Flint 1995). The phallic apparatus of *C. paluguillensis* lacks the pair of apical tooth-like spines seen in *C. papallacta* (fig. 18 by Holzenthal and Flint 1995) and is very similar to the phallus of *Contulma nevada* (Holzenthal and Flint 1995). Finally, *C. paluguillensis* is substantially larger (6–6.5 mm forewing length) than *C. papallacta* (5.5 mm). The female and larva of *C. papallacta* are unknown, so no comparisons with the new species can be made. However, the larvae of the new species are very similar to those of *C. nevada* from west central Colombia described by Flint and Holzenthal (1995; figs 129–132), but differ in having a less distinct mound of scale-like setae on the frontoclypeus.

Male.—Forewing length 6–6.5 mm ($n = 6$). Color brown in alcohol. Genitalia: segment IX short dorsally; in lateral view, IX slightly extended anterolaterally; posteriorly with short flat dorsolateral process and very short, more lateral process bearing patch of long setae; posteroventral margins of IX forming large, blunt, very heavily setose lobes; sternum IX with elongate posteromesal, sclerotized projection, narrowest at midlength, its apex cleft mesally, apicolateral corners rounded, somewhat directed laterally. Segment X entirely membranous, but with lightly sclerotized band laterally; dorsally X trough-like. Inferior appendages short, curved, bearing 2 subapical setae and 2 peg-like setae on ventral edge (Fig. 1A [inset], E); fused basally and apparently fused to base of IX sternal projection, together forming complex structure as in Fig. 1A. Processes of subphallic membranes present, small, sclerotized, mound-like. Phallus complex; phallobase tubular, elongate, slender, heavily sclerotized; phallicata very lightly sclerotized; paired membranous lobe arising apicodorsally from phallobase and overlying dorsal part of phallicata; apical phallic membranes with light sclerotization dorsolaterally; without spines or other processes.

Female.—Forewing length 7–8 mm ($n = 10$). Color brown in alcohol. Genitalia: vaginal apparatus in ventral view with base elongate, parallel sided, narrowest medially; apex trident shaped, with paired sclerotized, slightly sinuate midlateral processes, their apices indistinct; single medial process elongate, narrow, sclerotized; medial membranes highly convoluted, with pair of indistinct, very lightly sclerotized structures laterally; apical membranes highly convoluted, slightly cleft medially, without sclerotized apical process (Fig. 2).

Egg mass.—Round, diameter ~0.7 mm ($n = 2$), orange–pink in color; internally filled with white matrix containing small (~0.01–0.15 mm), brown spheres (eggs). Two of 8 females had the egg mass attached to the body as described by Holzenthal and Flint (1995; fig. 10).

Larva.—Length 8.5 mm ($n = 2$ mature larvae). Structure typical for genus as described by Holzenthal and Flint (1995). Sclerites of head and pronotum dark brown, with paler muscle scars; meso- and metanota and legs paler. Labrum with dense brush of short setae on anterior half. Head with numerous long setae along anterior and anterolateral margins, with short scale-like setae along lateral margins and on frontoclypeus, basally frontoclypeus with dense patch of setae; head with strong carina around margin, interrupted by eye, continuing across anterior margin of frontoclypeus and posteriorly around vertex; ventrally head pale, lightly sclerotized. Pronotum
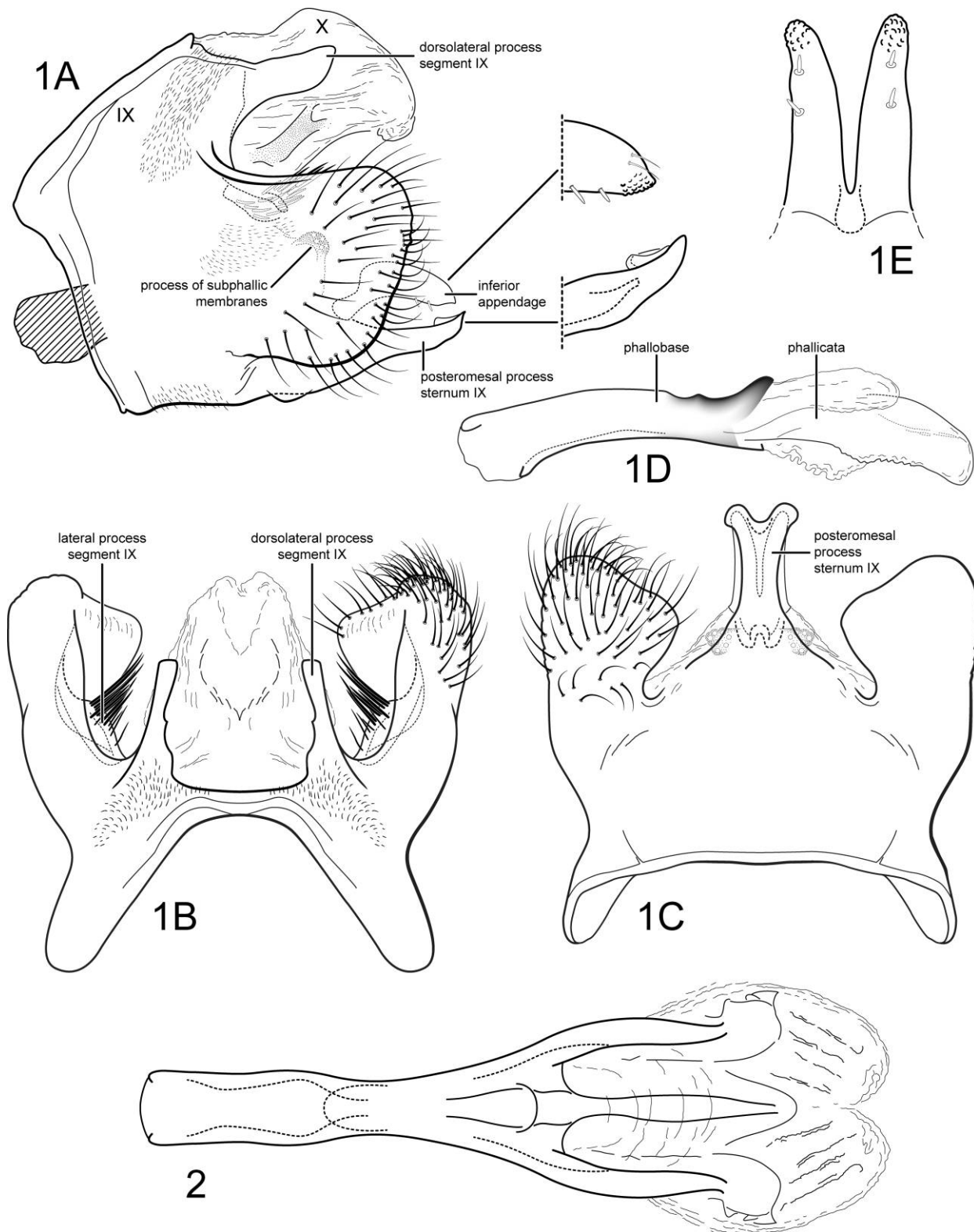
Figs 1, 2. *Contulma paluguillensis*, new species, male and female genitalia. Male genitalia: 1A.—Segments IX, X, lateral; insets: apices of inferior appendage, projection of sternum IX. 1B.—Segments IX, X, dorsal. 1C.—Segment IX, ventral. 1D.—Phallus, lateral. 1E.—Inferior appendages, ventral. Female genitalia: 2.—Vaginal apparatus, ventral (posterior apex to the right). IX, X = abdominal segments 9 and 10, respectively.
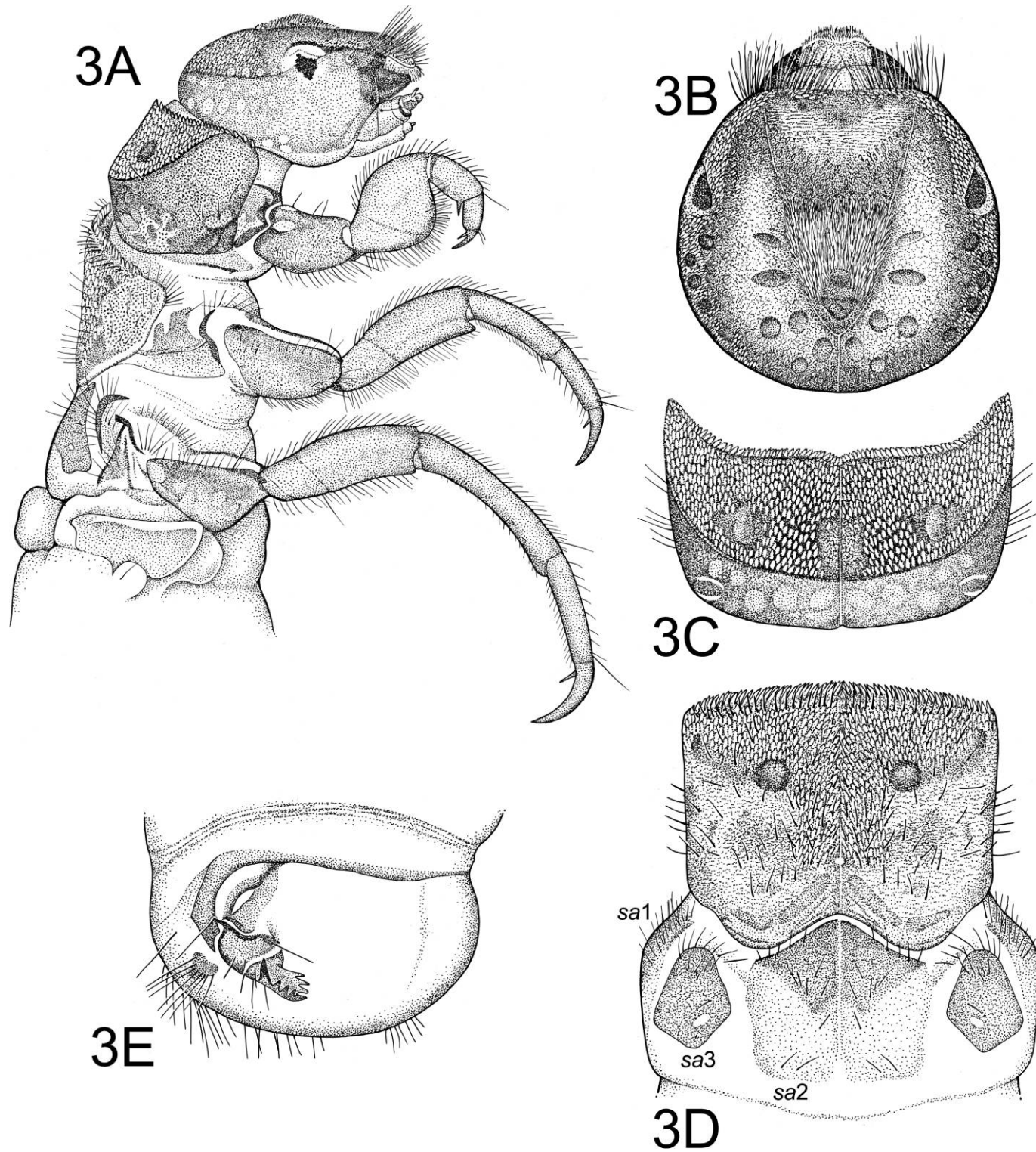
FIG. 3. *Contulma paluguillensis*, new species, larva. A.—Head, thorax, legs, and abdominal segment I, lateral. B.—Head, dorsal. C.—Pronotum, dorsal. D.—Meso- and metanota, dorsal. E.—Abdominal segment IX and anal proleg, oblique lateral. sa = setal area.

with strong carina near posterior margin produced anterolaterally as rounded, serrate lobe; surface rugose, densely covered with short, scale-like setae. Mesonotum with pair of dorsal plates bearing numerous short secondary setae as distributed in Fig. 3D, anterior half covered with short scale-like setae; with pair of rounded, bare areas medially. Metanotum with pair of distinct, darkly pigmented sclerites, with sa1 (sa = setal area) bearing numerous short setae; sa2 with pair of small setae, sa3 with small quadrate sclerite bearing 6–10 setae on anterior half and with unpigmented spot posteriorly. Legs bearing many setae along anterior and posterior edges of femora, tibiae, and tarsi; midleg without well developed ventral trochanteral brush. Dorsal hump of abdominal segment I difficult to discern, lateral hump sclerite elongate, anterior edge finely rugose. Abdomen without lateral line and gills; segment VIII bifid tubercles absent. Tergum IX without dorsal sclerite, but with dorsal setae; small setal bearing sclerite above anal proleg. Anal proleg short, associated lateral sclerite elongate, narrow; anal claw with ~7 accessory teeth, together forming cupped, cock's-comb-like structure.

Larval case.—8.4–9.6 mm (*n* = 2). Constructed of small sand grains finely attached with silk, with few strands of filamentous algae anteroventrally (cases collected in October 2011 had nodules of *Nostoc* along the dorsal surface); tapered and slightly curved posterad. Posterior opening almost closed by silken sheet, overhung by lip-like silken hood (as illustrated by figs 3, 155, 156 by Holzenthal and Flint 1995).

Pupa.—Identical to that illustrated and described for *C. adamsae* by Holzenthal and Flint (1995, figs 21–23).

Material examined

Holotype.—Male, **ECUADOR:** Pichincha, Reserva Paluguillo, Quebrada Saltana at 0°19′1.80″S, 78°13′8.8″W, 3848 m, 8.iv.2010, B. Ríos-Touma & F. González (UMSP) (UMSP000108109).

Paratypes.—Same data as holotype, 2 males, 7 females (UMSP, NMNH, MZUTI); same, except 10.ii.2010, 2 males, 3 females (MECN, UMSP); same, except 4.v.2010, 3 males, 1 female (UMSP); same except 22.vii.2009, 1 male (MZUTI); same, except 14–18.iv.2011, 3 females (UMSP); same, except 19–27.iv.2011, 3 females (QCAZ); same, except 15–16.x.2011, R. Holzenthal, B. Ríos-Touma, L. Pita, 1 female (UMSP); Napo, Reserva Ecológica Cayambe-Coca, Río Canoa, rd to Oyacachi, 00.28701°S, 78.11525°W, 3667 m, 16.x.2011, R. Holzenthal, B. Ríos-Touma, L. Pita, 2 males, 1 female (UMSP, MZUTI).

Additional material examined (UMSP).—Same data as holotype, 4 larvae; same, except 15.16.x.2011, R. Holzenthal, B. Ríos-Touma, L. Pita, 1 pharate male pupa, 15 larvae; same data as holotype, except 20.x.2009, 2 males, 1 female; same, except 18.xi.2009, 1 female; same, except 17.xii.2009, 2 males, 2 females; same, except 13.i.2010, 3 males, 2 females; same, except 10.iii.2010, 1 male, 1 female (these additional adult specimens were identifiable, but were badly damaged by sticky traps making them unsuitable to designate as paratypes).

Life-history features

Larvae.—Seventy-eight larvae were collected during the study period. Head widths of larvae ranged from 209 to 955 μm (Fig. 4), probably representing instars 2 to 5 with most individuals (66%) probably representing instars 4 and 5. Size distribution of instars was difficult to establish because of the low numbers of individuals collected, but seasonal distribution of head widths (Fig. 4) suggested continuous production with no temporal separation of larval instars, but with only 1 generation per year. The largest larvae were found in April, June, July, and September 2009, and again in April, June, and September 2010. Biomass (dry mass) of a subsample of 20 individuals ranged from 0.1–1 mg for larger larvae. No significant relationship was found between larval length and dry mass.

Larvae were collected in 13 of the 14 mo sampled. In most months, only 1 individual was collected, but higher densities were found in April, July, and September 2009, and again in April 2010. In general, *C. paluguillensis* was uncommon in the stream macroinvertebrate community.

Adults.—A total of 17 males and 21 females were collected on sticky or emergence traps during July and October to December 2009 and from January to May 2010. Six additional females were collected in a Malaise trap in April 2011. Adults were present during 9 mo of the year and were most abundant during January (*n* = 7; dry season) and April (*n* = 10; beginning of the wet season), but with only 1 individual collected during July and November 2009. We did not collect *Contulma paluguillensis* adults during August and September 2009 and June 2010. Three females carrying egg masses (see above) were collected in October 2009 (1 individual) and April 2010 (2 individuals).

Habitat and autecological information

In general, *C. paluguillensis* larvae were more abundant during months with higher flows. In fact,
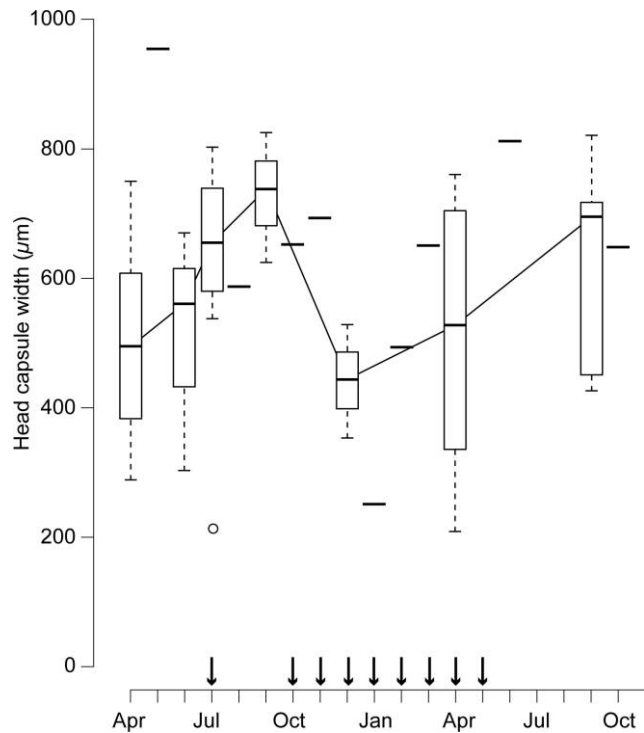
FIG. 4. Box-and-whisker plots for head-capsule widths by month for *Contulma paluguillensis*, new species, larvae in Quebrada Saltana, Ecuador. Lines in boxes show medians or single values, box ends show 50% quartiles, and whiskers show ranges, open circles show outliers. Black arrows indicate dates adults were collected.

larval densities had a strong direct correlation with flow (Spearman $\rho = 0.77$, $p < 0.05$; BRT, N. Prat, A. C. Encalada, N. Bonada, M. Rieradevall, F. Gonzalez, unpublished data). Larvae (up to 90%) were collected most commonly in cobbles and boulders and were rarely collected in pebbles and gravel (Fig. 5). A relationship between current velocity and larval density was not found. However, water velocities where larvae were collected ranged from 0.1 to 1.3 m/s, but most individuals (87%) were collected in areas with velocities <1 m/s.

Gut contents consisted of algae, mainly diatoms ($61.25 \pm 2.99\%$ [SE]), FPOM ($25.0 \pm 2.64\%$), and CPOM ($13.65 \pm 2.62\%$). No arthropod exoskeletons were found. Several species of diatoms (*Hannea arcus*, *Nitzchia linearis*, *Cocconeis placentula*, among others) were found in gut contents, results suggesting that *C. paluguillensis* is algivorous, at least in Quebrada Saltana.

Additional Trichoptera species collected at the study site included adults of *Anomalocosmoecus illiesi* (Marlier, 1963) and *Anomalocosmoecus*, new species (Limnephilidae), *Atopsyche*, new species, and *Cailloma lucidula* (Ulmer, 1909) (Hydrobiosidae), *Metrichia* sp. (Hydroptilidae), and *Nectopsyche* sp. (Leptoceridae).
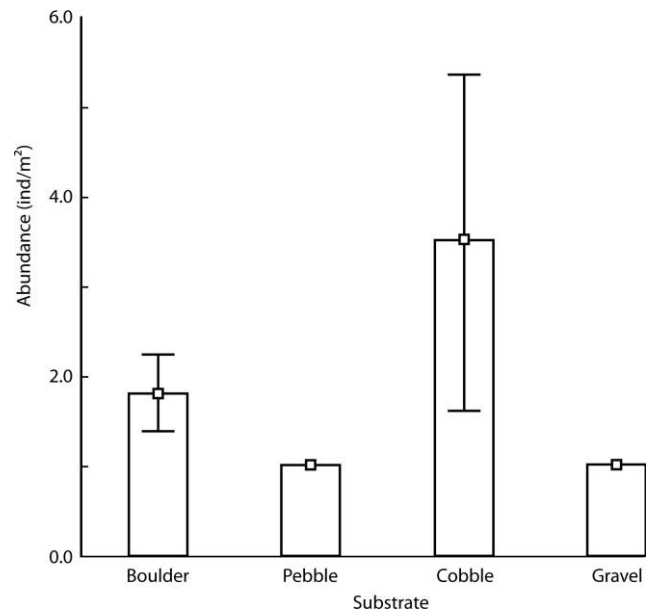

FIG. 5. Mean (± 1 SE) abundance of *Contulma paluguillensis*, new species, larvae on different substrates in Quebrada Saltana, Ecuador. Ind. = individuals.

In addition, larvae of *Mortoniella* (Glossosomatidae) were collected from the stream.

Discussion

Phylogenetic considerations

Contulma paluguillensis belongs to the *Cranifer* Group as defined by Holzenthal and Flint (1995) and is a member of the clade containing *C. papallacta*, *C. echinata*, and *C. nevada*. It shares with these species the elongate, apically cleft, posteromesal sclerotized projection of sternum IX (character 8, state 1 of Holzenthal and Flint 1995) and the mesolateral setose processes of segment IX (character 6, state 1 of Holzenthal and Flint 1995). However, *C. paluguillensis* lacks the phallic spines proposed as a synapomorphy for this clade by Holzenthal and Flint (1995; character 14). In addition, the shapes of the dorsolateral processes are much more similar among these 4 species than in other species in the *Cranifer* Group that also possess these processes (character 7, state 1 of Holzenthal and Flint 1995). Last, the larvae of *C. paluguillensis* and *C. nevada* are very similar and share the dense covering of scale-like setae on the head and thoracic sclerites, perhaps also supporting the close phylogenetic relationship among members of this clade. Scales also occur in *Contulma* sp. C from west central Colombia (fig. 162 by Holzenthal and Flint 1995) but are lacking in other known larvae in the genus.

Natural history

Contulma paluguillensis was uncommon in both the adult and larval stages throughout the study period and in all habitats sampled (116 individuals total). Conclusions about the phenology of the species are certainly biased by the small sample size. For example, more females were collected than males, but sex ratios can vary depending on the time during the day when adults are collected. In temperate regions, males of some species of caddisflies emerge before females, and sex ratios can be misinterpreted depending on the sampling time (Mendez and Resh 2008). Lack of discrete differentiation among larval head-capsule widths and little variation of seasonal water temperature suggest continuous larval growth (Fig. 4), but mature larvae and adults were collected for only part of the year. This pattern could be attributed to the low productivity and harsh conditions (low water temperatures, strong unpredictable seasonal winds) that affect larval development and adult emergence. In Mediterranean and northern regions in Europe, no pupal development occurred in other Trichoptera species when water temperature was <10°C, and longer developmental times were recorded at lower temperatures (Gíslason 1978, Prat 1981, Andersen and Klubnes 1983, Andersen and Tysse 1984, Gíslason and Sigfússon 1987). Stream temperature at the study site is <7°C, which could lead to slow, but continuous growth. However, we cannot ascertain the length of the life cycle of the species. Emergence could be related to small changes in temperature patterns, but our small sample size does not allow us to relate emergence to temperature or other environmental factors. Additional samples over more seasons are needed to better understand the emergence, life-cycle duration, voltinism, and sex ratios of this and other rare caddisfly species in the high Andes.

The species diversity of Trichoptera at the study site was low (8 species), but at least 3 species were new to science. If these species are endemic to the study site, as we predict, extrapolation to other, isolated mountaintops in the high Andes indicates that the number of undescribed species of caddisflies across the northern Andes could be very high. However, human activities, such as trout cultivation in the immediate vicinity of the type locality of *C. paluguillensis* (Vimos 2010) and global climate change, with its predicted negative affects on high altitude caddisfly populations (Brown et al. 2007), could threaten the existence of these species. Currently, we lack basic data on species taxonomy and distribution even to know which species may be or have already been affected or lost. We hope that studies contributing to knowledge of caddisflies and other aquatic groups continue in these poorly studied ecosystems.

Acknowledgements

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