



CAPNIA SHASTA, A NEW SPECIES IN THE CALIFORNICA GROUP FROM NORTHWESTERN CALIFORNIA (PLECOPTERA, CAPNIIDAE)

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ABSTRACT

The genus *Capnia* contains 56 species in North America and approximately 150 species worldwide. A past phylogenetic analysis of the Californica Group revealed two major subgroups. From that analysis and reviewing of pertinent specimens, the Californica Subgroup includes a new species that is herein described. *Capnia shasta* is unique in that it is the only member of the Californica Group in which males have tergal knobs only on segment 9 and has no distinctively divided process on the epiproct. Females are not reliably identified to species in the absence of males. We ran a branch and bound analysis using a corrected matrix based on the published analysis. Our analysis yielded six equally parsimonious trees. In all of these trees the topology conformed with the previously published tree, but with *Capnia shasta* joining the tree in a polytomy when a consensus tree was produced. *Capnia shasta* is currently known from a single locality on a single date from a small tributary of the Sacramento River. We suggest that further careful winter collections of many sites in the area are warranted. The limited distribution of *C. shasta* points to careful conservation of the tributaries of the Sacramento River.

Keywords: *Capnia*, Capniidae, Plecoptera, stonefly, new species, aquatic insect, systematics, morphology, biogeography, California

INTRODUCTION

The genus *Capnia* contains 56 species in North America (Stark et al. 2009) and approximately 150 species worldwide. Nelson & Baumann (1989) divided the Nearctic species into 10 species groups. Holarctic members of the genus, in general, are distinct from those of the Nearctic, with exceptions being a group of species near *C. nearctica* Banks, among others. The Californica Species Group, however, appears to be monophyletic (Nelson 2004) and limited in zoogeographic distribution to western North America. Nelson (2004) reviewed the Californica Group and his phylogenetic analysis

revealed two major clades, called here the Californica Subgroup and the Ventura Subgroup. This paper is concerned mainly with the somewhat basal members of the Californica Subgroup, including *C. umpqua* (Frison 1942) and a new species that is herein described.

While attempting to identify specimens of the group from southern California, Dr. Kenneth W. Stewart had difficulty placing it into one of the illustrated taxa. Using keys and illustrations in Nelson & Baumann's 1989 revision this specimen ran to the Californica group, and the epiproct looked superficially like *C. umpqua*, as illustrated. However,

the major abdominal tergal knobs were on tergum 8 not on tergum 9 as illustrated for *C. umpqua* in that revision (Nelson & Baumann 1989, Figs. 177-180). This problem was subsequently solved in a recent paper (Baumann & Stewart 2009). However, this left the species illustrated and keyed in Nelson & Baumann 1989 as *Capnia umpqua* undescribed. Thus, it became necessary to describe this new taxon. The description of this new species also presents the chance to give a comprehensive update to the phylogenetic relationships and zoogeography of members of the Californica Group given in Nelson (2004). The zoogeographic hypotheses for the group as previously presented (Nelson 2004) stands.

MATERIAL AND METHODS

We personally collected the specimens of this new species during one of our long trips that resulted in our revision (Nelson & Baumann 1989). In general, capniid specimens are most readily identified and manipulated for study if stored in 70% ethanol. We made identifications, scored morphological characters, and made some photographs using precision dissecting microscopes as well as a scanning electron microscope (SEM), Philips XL 30 ESEM FEG. They are presented as Figs. 1-8. When using the dissecting microscope we simply examined the specimens in the storage ethanol. Specimens used for SEM examination were prepared by dehydrating them in a series of increasingly concentrated solutions of ethanol. They were then dried in hexamethyldisilazane (HMDS) and sputter coated. We photographed the female of the new species with an Olympus DP70 digital camera attached to an Olympus MVX 10 light microscope connected to a personal computer running Microsuite V software (Fig. 9). Exact measurements presented in the description of the new species are based on the SEM male, not the holotype. Those of the female are from the allotype. We measured body length as distance from the anterior-most part of the head to the posterior-most part of the abdomen with the distal curl of the abdomen flattened. No compensation was made for telescoping abdominal segments. We measured interocular distance as the shortest distance between the eyes on the dorsum of the head. We measured wing length running from the basal attachment of the wing on the mesothorax to the

apex. All measurements were made with the Microsuite V software package.

Phylogenetic analysis followed the parsimony based algorithms in PAUP* version 4.0b10 for Macintosh™ (Swofford 2002) and the tree presented in Fig. 10 was produced using an exhaustive search of the 22 unordered characters given in Nelson (2004) modified slightly as noted in the caption of Table 1. *Capnia vernalis* and *C. nana* were defined as outgroups. All characters were of equal weight, and were added stepwise with the “furthest” option in force as well as accelerated transformation optimization. We coded all characters as binary. Character transformations were explored with MacClade© (Maddison & Maddison 2003, version 4.06) which was also used during tree drawing.

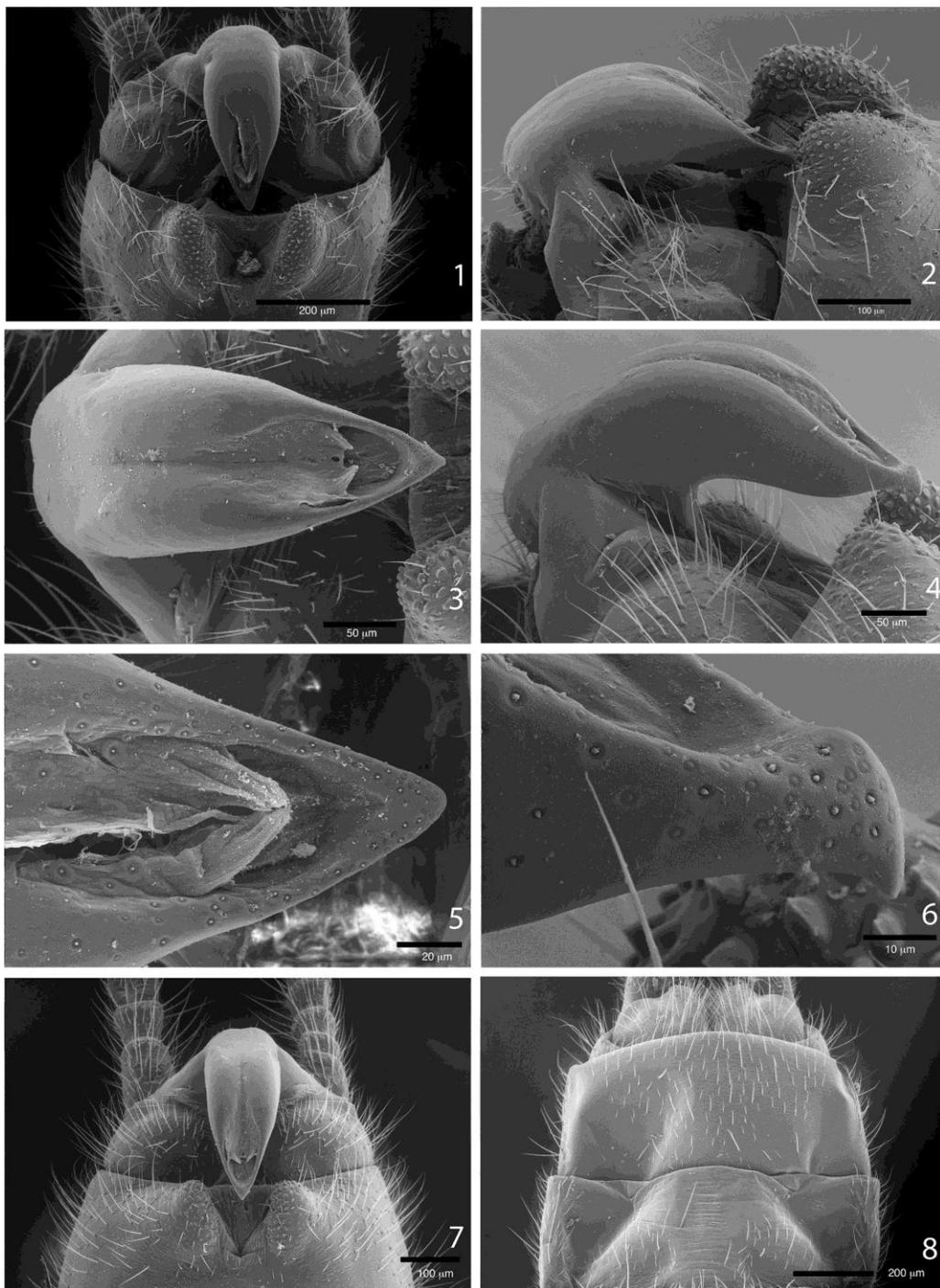
RESULTS

No additional characters for the Californica Group as a whole are added with this study. In brief, members of this group can be recognized by the male epiproct bearing an antepical membranous area along with having paired knobs on tergum 8, or 9, or both (except *C. jewetti* which has the knobs on terga 5 and 6). During the course of this study we found that true *C. umpqua* typically has large knobs on tergum 8 while the new species has them on tergum 9. Females have a sclerotized subgenital plate which is light in color on at least part of its expanse. Females are not easily or reliably identified to species in the absence of males.

Capnia shasta sp. n. (Figs. 1-9)

Capnia umpqua, Nelson & Baumann 1989:306, Figs. 177 – 180, 252, map Fig. 263 (Not *Capnia umpqua* Frison 1942)

Material examined. ♂ holotype, female allotype, and 2 male and 4 female paratypes, USA, California, Shasta Co., Sulphur Creek, Castle Crags State Park, 16 February 1985, R.W. Baumann & C.R. Nelson. The locality was checked with Google Earth internet software on 17 June 2009 and found the location just outside of the park at: N 41.15587° W 122.36285° elev. 708 m. Each primary type specimen has been placed in a separate vial, in 70% ethanol. One paratype male and the allotype female were the specimens



Figs. 1-8. *Capnia shasta*, scanning electron micrographs: 1. male terminalia, dorsal, anterior down, 152x, scale 200 μ m. 2. male terminalia, lateral, anterior to right, 249x, scale 100 μ m. 3. male epiproct, dorsal, anterior to right, 387x, scale 50 μ m. 4. male epiproct, lateral, anterior to right, 389x, scale 50 μ m. 5. details of male epiproct, dorsal, anterior to right, 868x, scale 20 μ m. 6. details of male epiproct, lateral, anterior to right, 1959x, scale 10 μ m. 7. male terminalia, dorsal, anterior down, 157x, scale 100 μ m. 8. female terminalia, ventral, anterior down, 108x, scale 200 μ m.

illustrated in Nelson & Baumann (1989) as *C. umpqua*. Of the paratypes, one male and three females are in 70% ethanol and the terminalia of 2 males and one female are dried and on SEM stubs, including the specimens used for Figs. 1-8 (the remainders of these specimens are in 70% ethanol vials). The holotype and allotype are deposited at the Smithsonian Institution, United States National Museum, Washington, D.C. (USNM). All paratypes are housed at the R.W. Baumann Aquatic Insect Collection, Monte L. Bean Life Science Museum, Brigham Young University, Provo, Utah (BYUC).

Male. Body length 5.10 mm; interocular distance 0.57 mm; wings macropterous, forewing length 5.9 mm; tergum 9 divided along one-half its length by medial membranous area, anterior margin heavily sclerotized. Well-developed tergal knobs present along inner margin of the divided tergum nine (Figs. 1-4), no tergal knobs on segment eight; epiproct broad, length 285 μ m, epiproct width 132 μ m, measured in dorsal view (Figs. 1, 3) with only a single process well-developed (Figs. 2, 4); apex of epiproct unforked (Figs. 1, 3, 5).



Fig. 9. Dissecting stereomicrograph of *Capnia shasta*, Allotype. Ventral view of female terminalia, posterior end up.

Female. Body length 6.48 mm; interocular distance 0.62 mm; wings macropterous, forewing length 6.80 mm; subgenital plate triangular with apex directed anteriorly (Figs. 8, 9); subgenital plate width 0.46 mm on hind margin; hind margin straight with margin thickened and not overlapping sternite 9; subgenital plate with paired lateral light thinnings of sclerotization near distal corners, immediately anterior to the hind margin, darker lines (probably internal) running much of the length of subgenital plate near medial line (Figs. 8-9).

Etymology. This species is named for prominent Mount Shasta of the Cascade Range in northern California as a noun, without gender, in apposition. It shares this name with a common, somewhat generic brand of soda water common in the western United States.

Diagnosis. *Capnia shasta* is unique in that it is the only member of the Californica Group with tergal knobs only on segment 9 and no distinctively divided process on the epiproct. It lacks the distinct upper process of the epiproct found in the Ventura Subgroup. It differs from the Californica Subgroup in lacking knobs on tergum 8. Phylogenetic relationships of *C. shasta* with all known members of the Californica Group are summarized in Fig. 10.

Discussion. Nelson & Baumann (1989) predicted that the area in California between Santa Barbara and Carmel would probably be a site for a new species or two yet to be discovered in the Californica Group. To this date, no one has reported any new records of *Capnia* species from this area but in this paper we describe *C. shasta*, from a more northerly thought-to-be-well-collected and central portion of the overall group range. The challenge remains to find coastal new members of the group in northern California.

Key to males. All males of the previously known species in the Californica Group except true *C. umpqua* can be identified using the key (p. 304) of Nelson & Baumann (1989). The following key is a modification of the 1989 key written to accommodate both true *C. umpqua* and *C. shasta*. Couplet numbering follows that key, with couplet 8 added and figures from various sources noted.

- 7(4) Terga 5 and 6 each bearing paired knobs (Figs. 69 and 70 of Nelson & Baumann 1989) *jewetti* Frison
- 7' Terga 8 or 9 bearing paired knobs (Figs. 1-4 and 7 in this publication and Figs. 177-178 of Nelson & Baumann 1989) 8
- 8(7) Terga 8 bearing paired knobs (Figs. 1-2 in Baumann & Stewart 2009) *umpqua* Frison
- 8' Terga 9 bearing paired knobs (Figs. 1-4 in this publication; Figs. 177-180 in Nelson & Baumann 1989; and Figs. 3-4 in Nelson 2004) *shasta*, new species

and a correction of species name for the Sulphur Creek, Castle Crags State Park specimens (*C. umpqua* of Nelson 2004) as *C. shasta*. We ran a branch and bound analysis using this corrected matrix (Table 1). This analysis yielded six equally parsimonious trees. In all of these trees, the topology conformed largely to that of the tree in Nelson (2004) except that now *C. nana* falls into a polytomy with *C. shasta* and the two subgroups (Fig. 10). Still *C. shasta* is basal to *C. jewetti*. In three of these trees *C. shasta* is immediately basal to *C. jewetti* and in the remaining three it is also basal to *C. regilla*. Thus in the consensus of the six trees it appears as a polytomy with the two major clades in the Californica Group (Fig. 10) and *C. nana*. The more important question then becomes, "Where does true *C. umpqua* fit on the tree?" In five of the six most parsimonious trees, *C. umpqua* fits in a pectinate fashion up the tree from *C. jewetti* and down from *C. ophiona*. In the sixth tree *C. umpqua* is still up tree from *C. jewetti* but in a polytomy with *C. ophiona* and (*C. californica* + *C. quadrituberosa*).

Phylogeny. A purported phylogeny for the entire Californica Group was produced in (Nelson 2004). In the 2004 paper, the species illustrated (and used for the phylogenetic analysis) as *C. umpqua* was the species we herein describe as *C. shasta*. Table 1 summarizes the morphological characters used in the 2004 paper with addition of character states observed from the holotype of *C. umpqua*, a minor reinterpretation of Character 14,

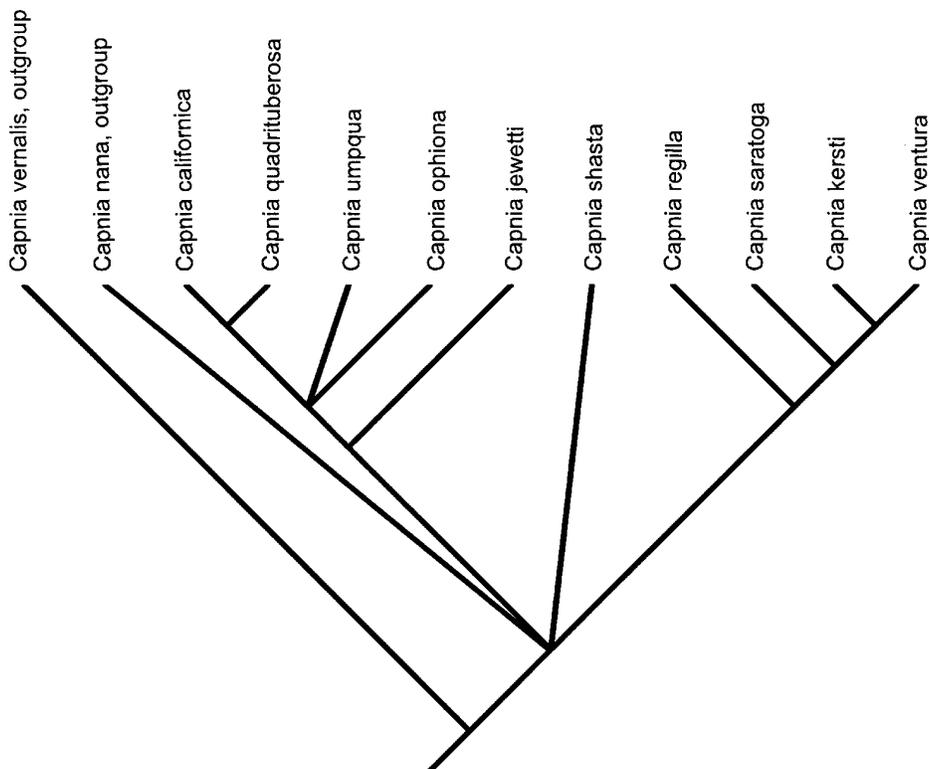


Fig. 10. Cladogram summarizing phylogenetic relationships among members of the Californica Group and two outgroups.

Table 1. Matrix of characters used in the parsimony analysis of the Californica Group, with *Capnia vernalis* and *C. nana* as outgroups. Character states updated from Nelson (2004), with the correction of data related to *C. umpqua* and addition of data for *C. shasta*. State of character 14 is corrected for *C. regilla* from 0 in Nelson (2004) to 1. All character state texts given are for the "1" state. Question marks (?) indicate missing data. Characters: 1. Knobs present on tergite 8; 2. Knobs present on tergite 9; 3. Lower process of epiproct forked. 4. Female subgenital plate overlapping posterior margin of sternum 8. 5. Upper process of epiproct absent (or very greatly reduced) apically. 6. Upper process of epiproct divided in lateral view. 7. Declivity between processes of epiproct vertical. 8. Lower process of epiproct longer than upper process. 9. Lower process of epiproct much longer than upper process. 10. Knobs present on tergites 5 and 6. 11. Both processes of epiproct of about the same length. 12. Lower process of epiproct widely forked in dorsal view. 13. Declivity between processes of epiproct medially carinate. 14. Declivity between upper and lower processes of epiproct with an extra medial process. 15. Knobs on tergite 8 angulate. 16. Notch between knobs of tergite 8 broad in dorsal view. 17. Notch between upper and lower processes deeply incised in lateral view. 18. Lower process of epiproct narrow in dorsal view. 19. Upper and lower processes of epiproct forming a 90 degree angle in lateral view. 20. Lower process of epiproct with lower surface bent at mid length in lateral view. 21. Lower process of epiproct constricted near apex in dorsal view. 22. Lower process of epiproct evenly tapered, not inflated at midlength in dorsal view.

Taxon	Characters																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
<i>Capnia vernalis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Capnia nana</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Capnia californica</i>	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
<i>Capnia quadrituberosa</i>	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Capnia ophiona</i>	1	1	1	?	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0
<i>Capnia jewetti</i>	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Capnia regilla</i>	0	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Capnia saratoga</i>	0	1	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	1	0
<i>Capnia kersti</i>	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0	1
<i>Capnia ventura</i>	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	1
<i>Capnia umpqua</i> , holotype	1	1	1	?	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Capnia shasta</i> , n. sp.	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Zoogeography. With the consensus cladogram of purported relationships (Fig. 10) and the overall distribution of the group's species in hand (Nelson 2004) one is tempted to hypothesize the origins, dispersal, and speciation sequence for members of the group. The zoogeography for the group as previously presented (Nelson 2004) stands. The Californica Group, taken as a whole (Nelson 2004, Fig. 3) divides into two sister taxa basally (Ventura Subgroup) and (Californica Subgroup + *C. umpqua* + *C. jewetti*). But our new species comes out in a polytomy with these two subgroups (and *C. nana*) and thus leads to no strong zoogeographic hypotheses.

Capnia shasta is currently known from a single locality on a single date. It is currently known only from far down the flanks of Mount Shasta in a small tributary of the Sacramento River at the northern head of California's Central Valley. We suggest that further careful winter collections of many sites in the area are warranted. We examined a range of specimens of *C. umpqua* from throughout its broad Oregon – southern California range. The shape of the epiproct in these specimens varied widely in relative width both within series from a single collection and across its range. Using this information we tentatively propose that *C. shasta*, *C. jewetti*, and *C. ophiona* arose as independent peripheral isolates from

the widespread *C. umpqua*-like ancestor. This speculative hypothesis could best be tested using fast evolving sequences of DNA. We have little hope that further morphological study of this question will resolve these polytomies, and hope that the sequences will.

Conclusions. This new, interesting species shows that small, relictual populations and species probably remain to be discovered in western North America. Careful, fine scale collecting of the numerous streams in northern California continues to yield new species. The limited distribution of *C. shasta* points to a need for careful conservation of the tributaries of the Sacramento River. The Californica Group remains an important and virtually untapped resource to learn more about the paleogeography of this part of western North America. The use of sequence data on a phylogeographic scale remains a next best step in sorting out the range relationships of these populations and species in understanding this perplexingly complex group of stoneflies.

ACKNOWLEDGEMENTS

We thank Kenneth Stewart and Eugene Drake for their collecting efforts that resulted in the discovery that *Capnia shasta* was a new species. In addition, we thank David Lauck for introducing us to the streams of northern California in 1985. It was on that trip we collected the type series of specimens for this species.

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Received 20 October 2009, Accepted 5 November 2009, Published 27 November 2009