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LARVAE OF FIVE SPECIES OF THE WINTER STONEFLY GENUS *CAPNIA* (PLECOPTERA: CAPNIIDAE) FROM CALIFORNIA, U.S.A.

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ABSTRACT

Associated larvae of five *Capnia* species from California are comparatively described and illustrated for the first time. A provisional key is presented, based on differences in the measurements and shape of the 10th tergum of mature male larvae and the visible underlying, developing epiprocts of pharate individuals. Details of the structure of the left and right mandibles, and cercal setation, are further clarified with SEM, from the previous generic description based on a single species.

Keywords: Plecoptera, Capniidae, Larval descriptions, *Capnia,* California

INTRODUCTION

The generic level treatment of North American stonefly larvae by Stewart & Stark (2002) emphasized the importance and need to further increase taxonomic resolution to the species level. Stark & Lacey (2005) and Stewart (2009) reviewed the few such studies that have provided detailed species level larval descriptions and keys for individuals, regionally defined species, and generic groups. They further suggested that the need is no greater for any group than for the Capniidae, particularly speciose genera such as *Allocapnia* and *Capnia* whose larvae have few distinctive features and an absence of distinctive pigment patterns. Few of these larvae have been associated and described, except in regional studies of *Allocapnia* (Harper & Hynes 1971, Stark & Lacey 2005), therefore they have not been comparatively studied. Harper & Hynes (1971) referred to *Allocapnia* larvae from eastern Canada as disappointingly homogeneous with few distinctive features, yet with careful study, they were able to develop a key to the 15 regional species. Stark & Lacey (2005) associated and described the larvae of four common *Allocapnia* species in Mississippi: *Allocapnia aurora* Ricker (1952), *Allocapnia mystica* Frison (1929), *Allocapnia starki* Kondratieff & Kirchner (2000), and *Allocapnia virginiana* Frison (1942), and using characters for those of *Nemocapnia carolina* Banks (1938), *Allocapnia granulata* (Claassen 1924) and *Allocapnia rickeri* Frison (1929) from Stewart & Stark (2002) and Harper & Hynes (1971) found capniid larvae from eastern Canada to be "disappointingly homogenous" with "few distinctive features", yet with careful study they were able to develop a key to the 15 regional species.

The larval characters found useful in separating *Allocapnia* species in the aforementioned studies have been shape and setation of the galea, setal patterns of abdominal terga, and length and laterally observed shape of the developing male tergum 10. No similar

comparative descriptions have been previously reported for North American *Capnia* larvae, and only the larvae of *Capnia vernalis* (Newport 1851) of the currently recognized 56 continental species of this large and important genus have been described in detail by Stewart & Stark (2002). Partial descriptions, mostly side views with hairs in profile, and mouthparts, were presented for *Capnia coloradensis* Claassen (1937), *Capnia confusa* Claassen (1936), *Capnia gracilaria* Claassen (1924) and *Capnia vernalis*, variously by Claassen (1931), Ricker (1943), Harper & Hynes (1971) and Dosdall & Lehmkuhl (1979).

We began rearing and field associations to obtain larvae of five *Capnia* species from California in 2004: *Capnia coyote* Nelson & Baumann (1987), *Capnia inyo* Nelson & Baumann (1987), *Capnia teresa* Claassen (1924), *Capnia umpqua* Frison (1942), and *Capnia ventura* Nelson & Baumann (1987). Objectives were to: 1.) test the few generic characters proposed by Stewart & Stark (2002), based only on detailed study of *C. vernalis* and examination of four other field associated species, 2.) search for additional characters (with clues from the *Allocapnia* studies of Harper & Hynes 1971, and Stark & Lacey 2005) that might prove useful in future studies to better separate the difficult generic triad of *Capnia, Mesocapnia,* and *Utacapnia,* and that might separate these five species and be potentially useful for separating other *Capnia* species.

MATERIALS AND METHODS

Larvae were associated by one or more of the following methods: 1.) rearing in the laboratory, 2.) field collection of larvae, their exuviae, and adults where no congeners were known from repeated collections of the stream, and 3.) series containing pharate, pre-emergent males with diagnostic underlying genitalia along with late instar male and female larvae.

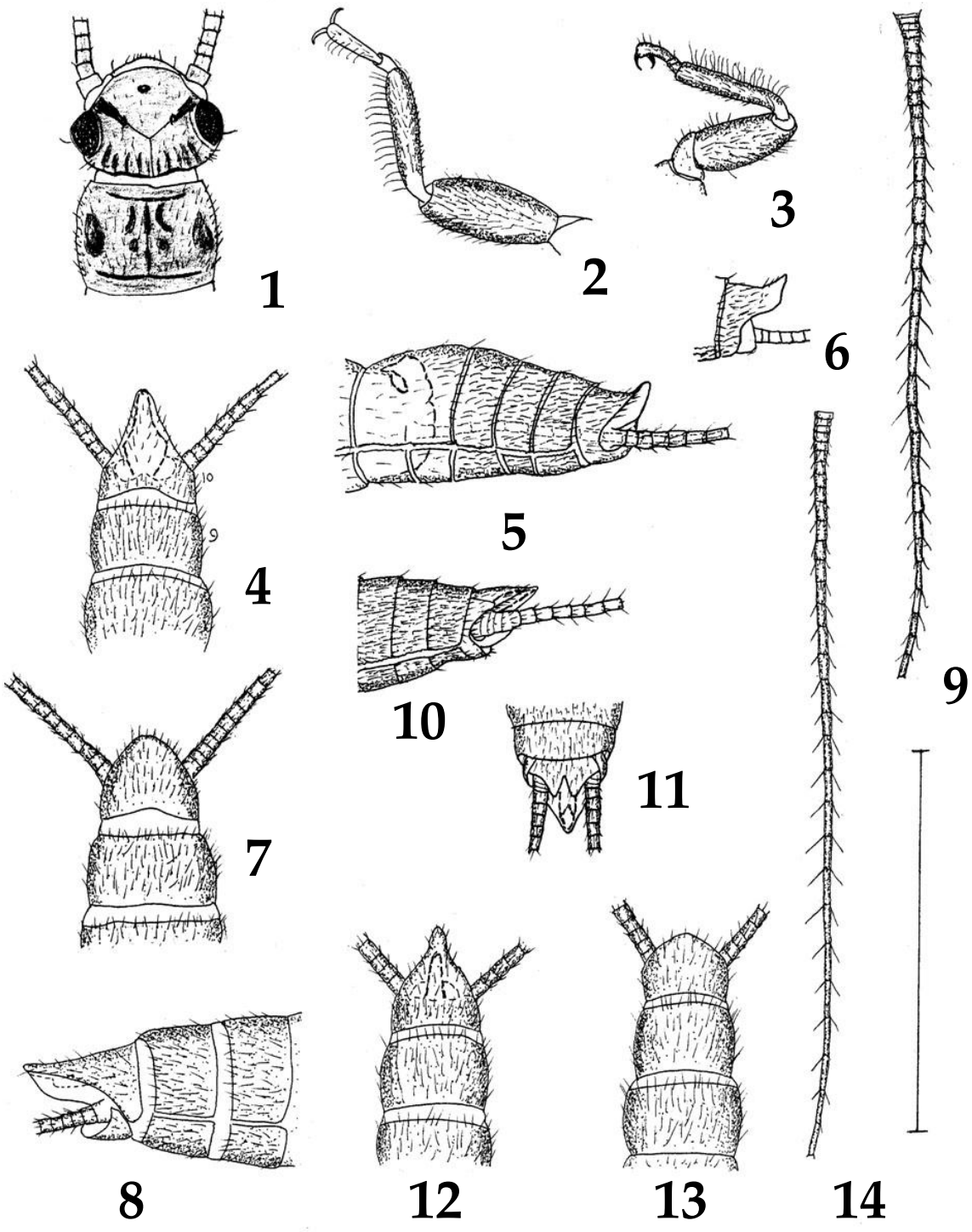
Adults, larvae and exuviae of the five species were collected from January to early March in 2004, 2007-2008, and 2010-2011. The 2009 season was lost due to extreme low water levels resulting from 3 years of drought in southern California. Adults were taken with a beating sheet or picked from streamside vegetation or leaf packs. Live mature larvae were collected with a kick net, or washed with a turkey baster from entrained leaves of alder, cottonwood or willow. Larvae were transported to the laboratory in 0.12 liter styrofoam cups placed into 6-pack or 12-pack drink coolers covered with snow or crushed ice in a larger container. Some larvae were killed in hot water; dark wingpad specimens were reared individually in styrofoam cups containing water and a single piece of leaf from the collection stream and kept in a refrigerator at 10^0C. Water and food were replaced about every 2 days, and any fecal material was removed. Successfully reared individuals were allowed to harden and become dark colored, then killed in warm ETOH and kept with the associated exuvium. Pharate individuals that died in rearing were preserved.

The variously associated specimens were preserved in 80% ETOH, and studied, measured and drawn with a Wild M-5 stereomicroscope with drawing attachment. Scanning electron micrographs of specific characters were taken using procedures outlined by Stark & Stewart (2005). The specimens studied are deposited in the K.W. Stewart Collection, University of North Texas, and the B.P. Stark Collection, Mississippi College.

RESULTS AND DISCUSSION

Generic Diagnosis of *Capnia* Larvae

The generic diagnosis of larval *Capnia* by Stewart & Stark (2002) was considered tentative, since so few larvae had been associated and were available at that time for study, and the same was true for larvae of *Mesocapnia* and *Utacapnia.* They stated that larvae of the Capniidae have remained the poorest known of all North American families, and that is still true. Larvae of the generic triad of *Capnia, Mesocapnia,* and *Utacapnia* are similar in general body conformation, lack of pigment pattern, hind wingpads notched on the inside margin, and long cerci with more than 20 segments having setation generally with no intercalary hairs and cercomeres terminating with a circlet of short hairs and one long dorsal and ventral hair. Separation of larvae of these three genera is still the most problematic in dealing with Plecoptera immatures. Whether the *Capnia* characters revealed in this study prove to be ultimately useful in separating larvae of these three genera will require further investigation of associated material of all three.



Figs. 1-14. *Capnia* larval characters. *C. coyote*: 1. Head, pronotum, dorsal. 2. Left front leg, dorsal. 4. Pharate male terminalia, dorsal. 7. Female terminalia, dorsal. 8. Male terminalia, lateral. *C. teresa*: 3. Right front leg, dorsal. 5. Partially emerged male in exuvium, lateral. 6. Male terminalia, lateral. 9. Cercus, lateral. *C. umpqua*: 10. Male terminalia, lateral. 11. Male terminalia, ventral. *C. ventura*: 12. Pharate male terminalia, dorsal. 13. Female terminalia, dorsal. 14. Cercus, lateral.

Species Accounts of Larvae

The following accounts include: 1.) known distribution, 2.) larval, exuvial and adult material examined and method of association, and 3.) description of characters that offer definitive or potential specific diagnosis. Particular attention was given to observed differences (or lack thereof) of pigment pattern, measurements of body length, head capsule width, and inside forewingpad length, counts of antennal and cercal segments, mouthparts, setal patterns, and shape of the male epiproct. The descriptions and referenced illustrations are based on typical individuals of the single or few populations that were successfully associated and studied; therefore, they do not address possible character variation.

Capnia coyote Nelson & Baumann 1987
(Figs. 1, 2, 4, 8, 26-31)

Distribution. California.

Material examined. California: San Bernadino Co., Lake Silverwood, Miller Campground, N 34° 16.241′ W 17° 17.490′, 7-III-2007, E.F. Drake, 4♂, 3♀, 1 reared ♂ with exuvium, 15♀ larvae, 1♂ exuvium, 1 confirmed ♀(by clearing pharate larva), 1 pharate ♀ larva; water temperatrure on collection date 11.11°C, air temperature 20°C, elevation 1109m, overstory of stream was Jeffrey Pine, Alder, Big Cone Spruce. Willows along stream had been cut for fire prevention. Same locality, 1-II-2011, E.F. Drake, 62♂, 31♀, 1 pair in-copulo.

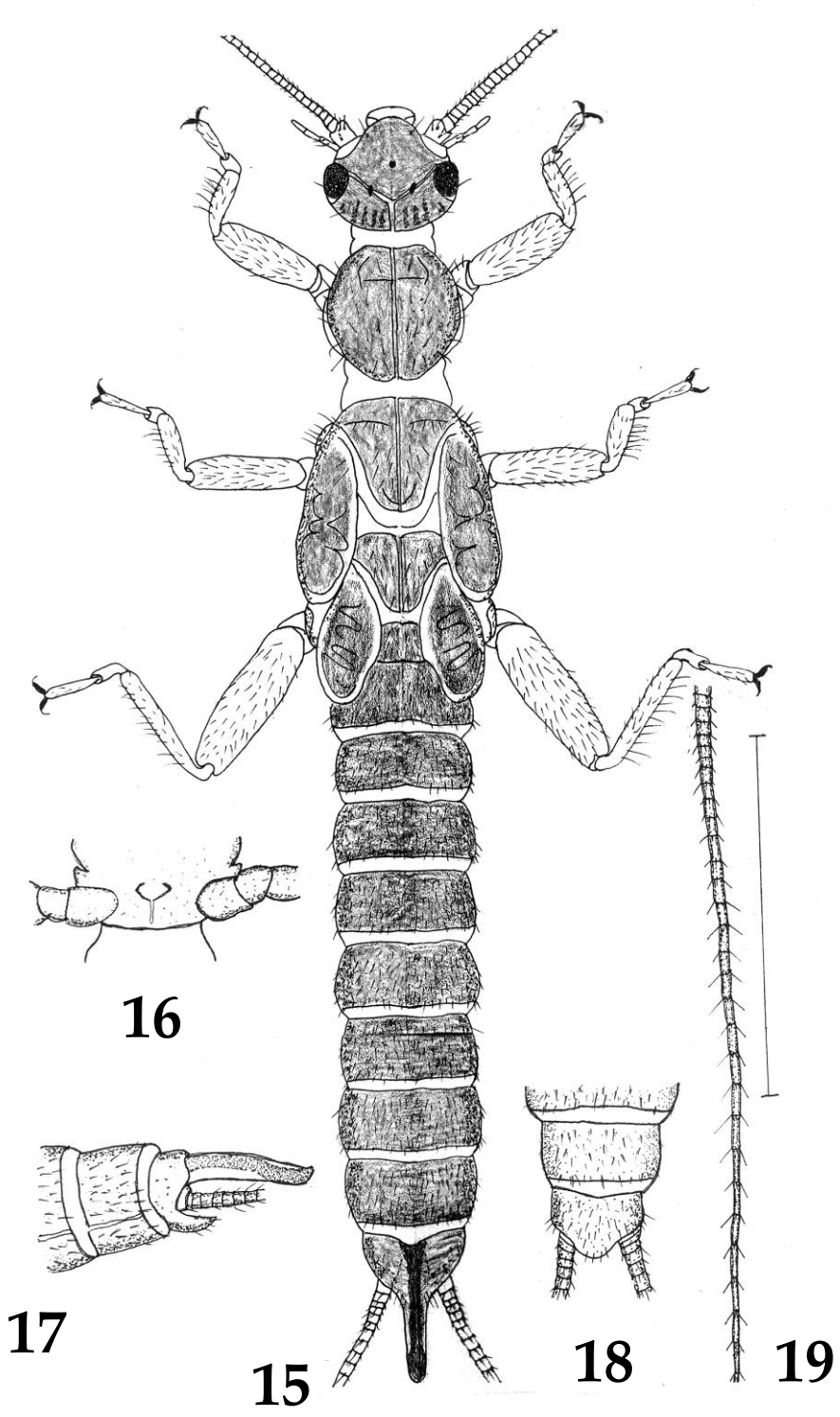
Characters. Body length ♂ 6.8-7.0mm, ♀ 7.5-9mm. Light to medium brown dorsally, ventrum lighter, little pattern except underlying muscles or developing adult pigment. Antennal segments 44-46, head capsule width ♂ 0.75-0.81mm, ♀ 0.90-1.02mm. Lacinia triangular, palmate, with longitudinally striate palm surface, broad apical teeth, ventral comb of 10-14 bristles and dorsal comb of 16-18 longer bristles (similar to *C. ventura*, Figs. 50, 51). Right mandible with apical teeth, molar pad of dense stiff bristles, and inner band of hairs from base of apical teeth to molar pad (similar to *C. umpqua*, Figs. 47, 48). Pronotum with scattered setae over surface, and as a marginal fringe (Fig. 1). Mesosternal Y-arms with enclosed subtriangular area about 0.3 times the intercostal width. Hind wingpads shallowly notched along inner margin (like *C. inyo* and *C. umpqua*, Figs. 15, 20); inside forewingpad length ♂ 0.96mm, ♀ 1.26mm. Femora with scattered surface bristles, and tibia with a silky outer fringe (Fig. 2). Abdominal segments with long surface hairs (Figs. 26-29). Sexual dimorphism evident. Male with posterior extension of 10th tergum, triangular in dorsal view with length 0.52-0.57mm; underlying developing wide-based epiproct visible in pharate individuals (Fig. 4); 10th tergum in lateral view subtriangular, nearly straight with slightly upturned tip dorsally (Fig. 8). Female without posterior extension of 10th tergum (Figs. 7, 28). Cercal segments 30-32; cercomeres with apical circlet of short and long bristles, longer dorsal and ventral bristle in lateral view, and occasional fine intercalary hair (Figs. 30-31), not usually visible under 50X light microscopy, and not present in any of the other 4 species studied.

Capnia inyo Nelson & Baumann 1987
(Figs. 15-19, 32-37)

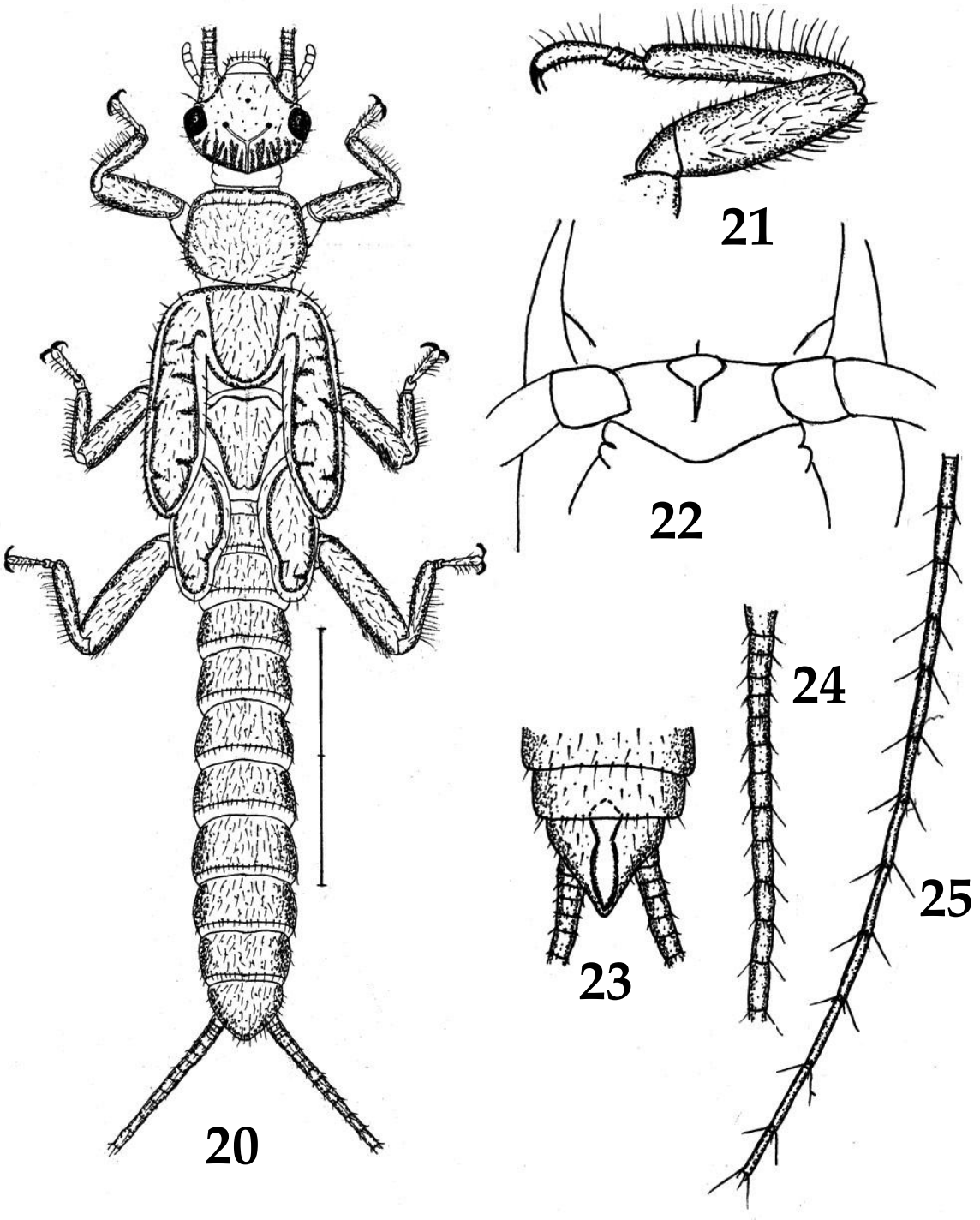
Distribution. California.

Material examined. California: Inyo Co., Lone Pine Creek, Lone Pine Campground, N 36° 35.860′ W 118° 11.203′, Elev. 1795m, 17-18-II-2010, E. F. Drake. 33♂, 14♀, 5 reared ♂ with exuviae, 3 reared ♀ with exuviae, 1 partially emerged ♂ in larval exuvium-aedeagus everted, 7♂ larvae, 22♀ larvae, 3♂ exuviae, 1♀ exuvium; water temperature on collection date 3.3°C, snow on ground.

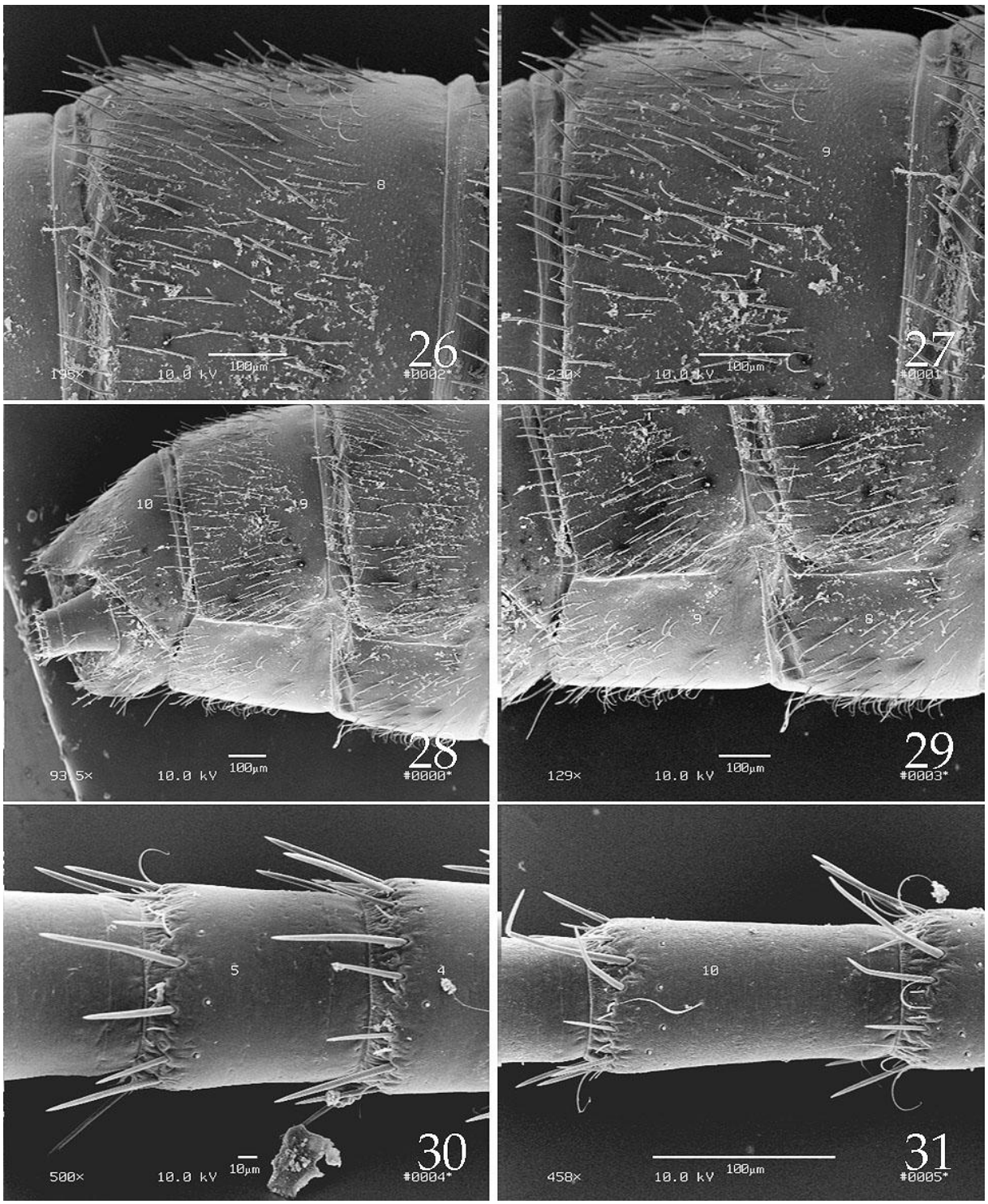
Characters. Body length ♂ 6.6-6.8mm, ♀ 6.9-7.2mm. Light to medium brown dorsally, ventrum lighter, little pattern except underlying muscles or developing adult pigment (Fig. 15). Antennal segments 42-44, head capsule width ♂ 0.72-0.75mm, ♀ 0.84-0.0.90mm. Lacinia and mandibles as described for *C. umpqua* and *C. ventura* (Figs. 44-48, 50-53). Pronotum with setae scattered over surface and as a sparse marginal fringe (Fig. 15). Mesosternal Y-arms enclose a subtriangular area about 0.3 times the intercostal width (Fig. 16). Hind wingpads shallowly notched along inner margins (Fig. 15); inside forewingpad length ♂ 0.96-0.99mm, ♀ 1.44-1.50mm. Femora bear scattered surface bristles, and tibia with a silky outer fringe (Fig. 15). Abdominal segments with long surface hairs (Figs. 32, 33). Sexual dimorphism evident. Male 10th tergum with 0.7-0.8mm long



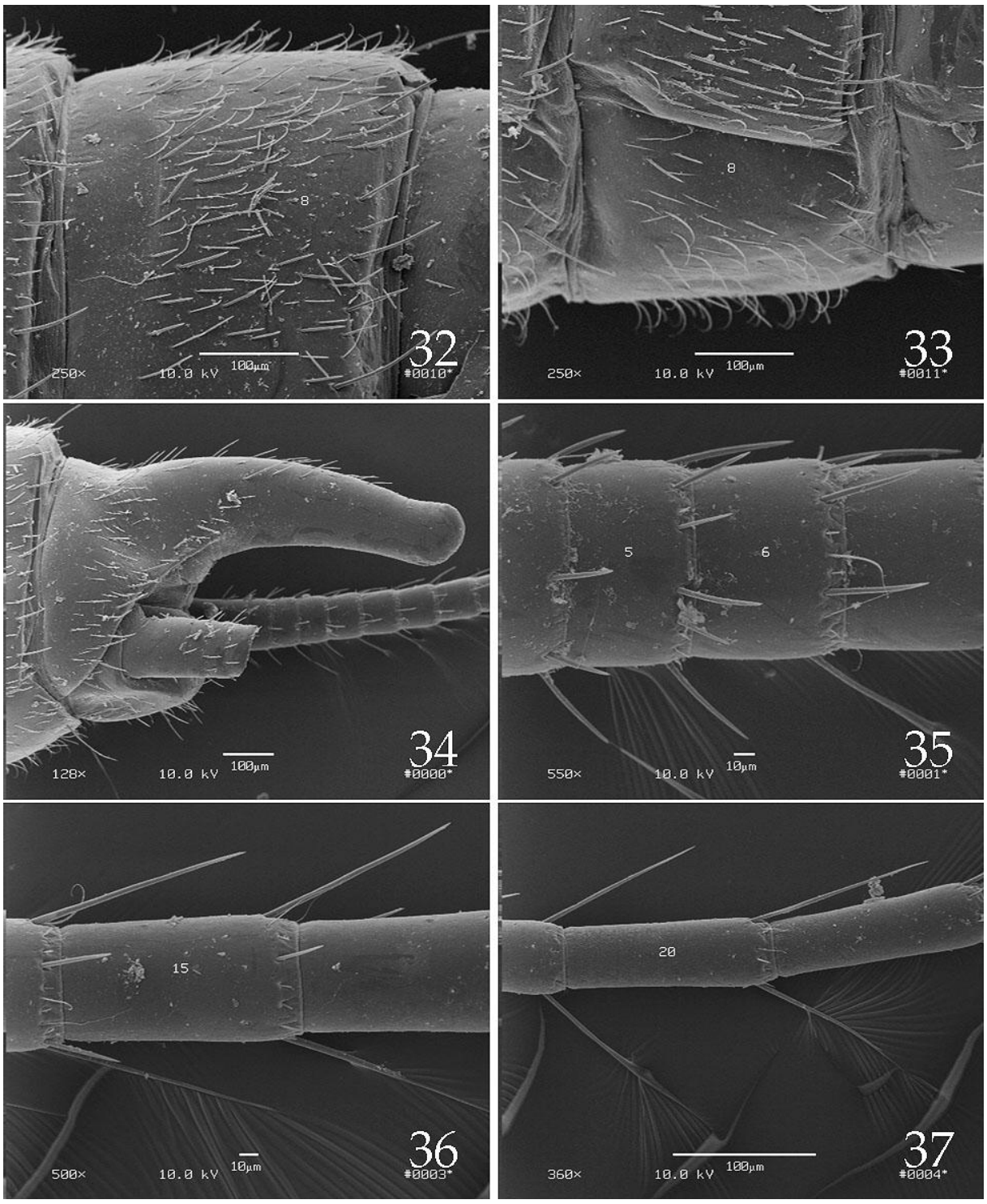
Figs. 15-19. *Capnia inyo* larval characters. 15. Male habitus. 16. Mesosternum. 17. Pharate male terminalia, lateral. 18. Female terminalia, dorsal. 19. Cercus, lateral. Scale line= 2mm.



Figs. 20-25. *Capnia umpqua* larval characters. 20.Female habitus. 21. Right front leg, dorsal. 22. Mesosternum. 23. Pharate male terminalia, dorsal. 24. Cercus, basal segments. 25. Cercus, apical segments. Scale line= 2mm.



Figs. 26-31. *Capnia coyote* larval characters. 26, 27. Abdominal segments 8, 9, lateral. 28. Female abdominal segments 9, 10, lateral. 29. Female abdominal segments 8, 9, lateral. 30. Cercomeres 4, 5, lateral. 31. Cercomeres 9, 10, lateral.



Figs. 32-37. *Capnia inyo* larval characters. 32. Abdominal tergum 8. 33. Abdominal sternum 8. 34. Male terminalia, lateral. 35-37. Cercomeres 5-6, 15, 20, lateral.

tubular posterior extension in dorsal view (Fig. 15); underlying tubular developing epiproct visible in pharate individuals (Fig. 15); 10th tergum in lateral view tubular and downcurved (Figs. 17, 34). Female without posterior extension of 10th tergum (Fig. 18). Cercal segments about 32; cercomeres with apical circlet of short and long bristles, longer dorsal and ventral bristle in lateral view, and no evident intercalary hairs (Fig. 35-37).

Capnia teresa Claassen 1924
(Figs. 3, 5, 6, 9, 38-43)

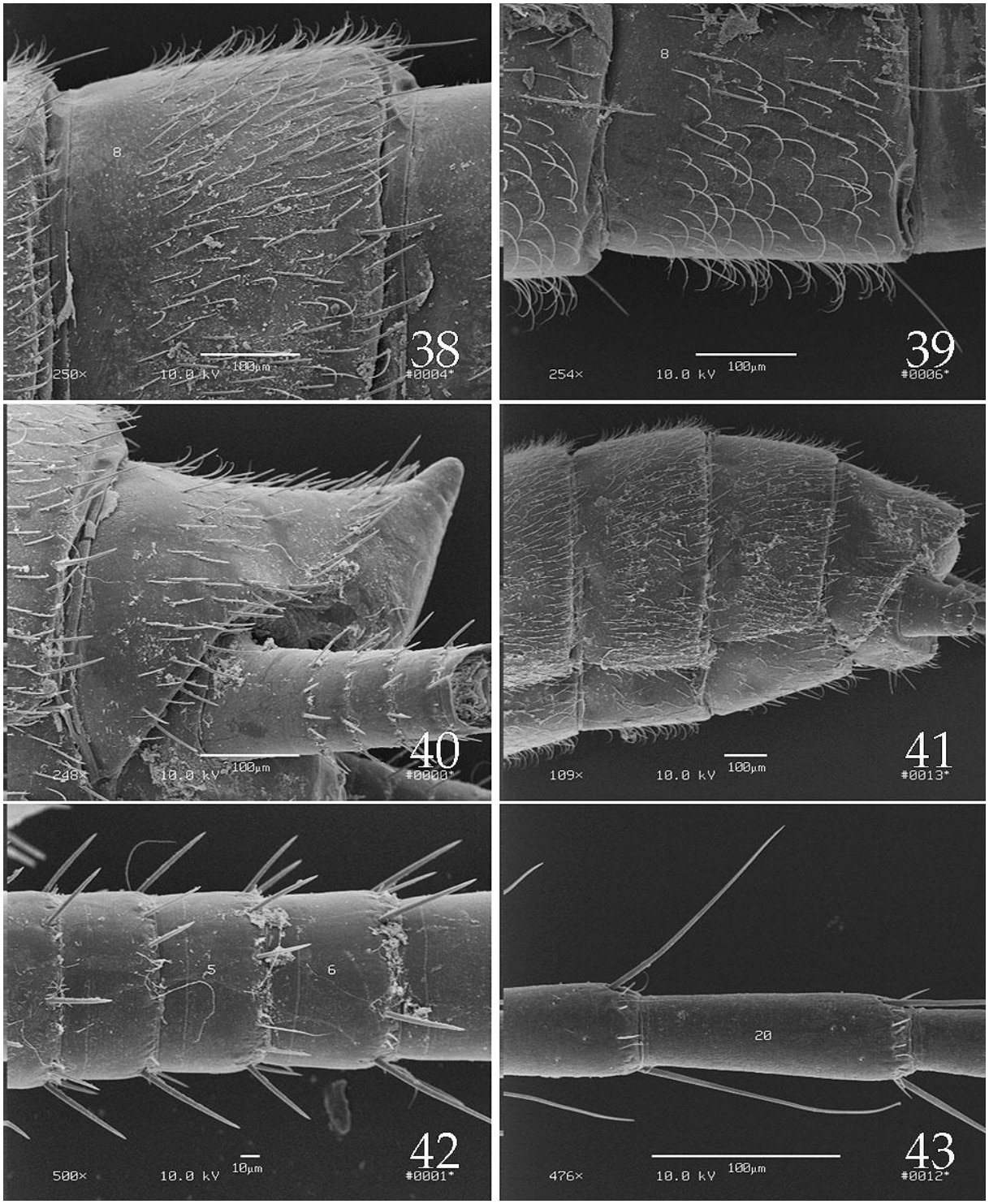
Distribution. California.
Material examined. California: San Bernadino Co. , Forsee Creek, N 30° 09.431′ W 116° 55.885′, Elev. 1812m, 27-II-2008, E F. Drake, 16♂, 17♀, 1 pharate ♂ in exuvium, 3 reared ♂ with exuviae, 5 reared ♀ with exuviae, 6 pharate ♀ in exuviae (1 partially emerged), 2♂ larvae, 10♀ larvae.
Characters. Body length ♂ 6.0-6.2mm,♀ 6.8-6.9mm. Light to medium brown dorsally, ventrum lighter, little pattern except underlying muscles or developing adult pigment. Antennal segments 44-50, head capsule width ♂ 0.75mm, ♀ 0.87mm. Lacinia and mandibles as described for *C. umpqua* and *C. ventura* (Figs. 44-48, 50-53). Pronotum with setae scattered over surface and as a sparse marginal fringe. Mesosternal Y-arms typical of genus. Hind wingpads shallowly notched along inner margins; inside forewingpad length ♂ 0.84mm, ♀ 1.02-1.08mm. Femora bear scattered surface bristles, and tibia with a silky outer fringe (Fig. 3). Abdominal segments with long surface hairs (Figs. 38-39). Sexual dimorphism evident. Male 10th tergum with short, upturned posterior extension (Figs. 5, 6, 40); underlying developing epiproct visible in pharate or partially emerged individuals (Fig. 5). Female without upturned extension of 10th tergum (Fig. 41). Cercal segments ♂ 30, ♀ 34; cercomeres with apical circlet of short and long bristles, longer dorsal and ventral bristle in lateral view, and no intercalary hairs (Figs. 9, 42, 43).

Capnia umpqua Frison 1942
(Figs. 10, 11, 20-25, 44-49, 56-59)

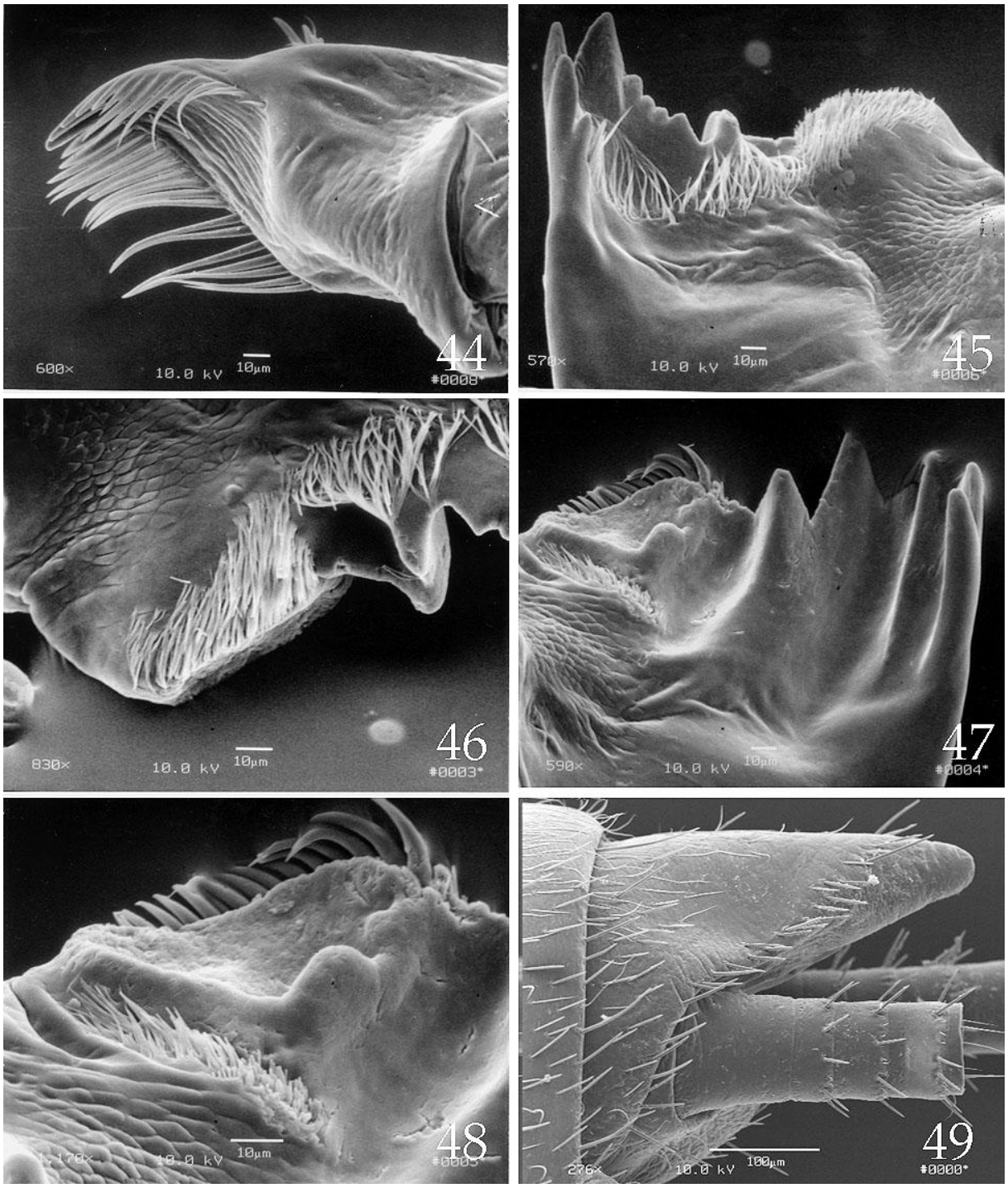
Distribution. California and Oregon.
Material examined. California: Orange Co., Trabuko Creek, Trabuko Canyon, 1st concrete low water crossing, N 33° 40.29′ W 117° 32.45′, 5-IV-2005, K.W. Stewart and E.F. Drake, 8♂, 58♀, 1♂ reared with exuvium, 2♂ larvae, 1♀ larva. Same locality, 25-IV-2005, E.F. Drake, 6♀. No other *Capnia* species collected at this locality.
Characters. Body length ♂ 5.0-6.0mm. Light to medium brown dorsally, ventrum lighter, little pattern except underlying muscles or developing adult pigment (Figs. 20, 23). Antennal segments 46-48, head capsule width ♂ 0.75mm, ♀ 0.96mm. Lacinia triangular, palmate with longitudinally striate palm surface, broad apical teeth, ventral comb of 10-14 bristles and dorsal comb of 16-18 longer bristles (Fig. 44). Right mandible with apical teeth, molar pad of dense, stiff bristles, and inner band of hairs from base of apical teeth to molar pad (Figs. 45, 46). Left mandible with molar cup bordered by outer (dorsal) comb of curved teeth (Figs. 47, 48). Pronotum with scattered setae over surface and as a marginal fringe (Fig. 20). Mesosternal Y-arms with enclosed subtriangular area about 0.3 times the intercostal width (Fig. 22). Hind wingpads shallowly notched along inner margin (Fig. 20); inside forewingpad length ♂ 0.96mm, ♀ 1.08mm. Femora with scattered surface bristles, and tibia with a silky outer fringe (Fig. 21). Abdominal segments with long surface hairs (Fig. 56). Sexual dimorphism evident. Males with short posterior extension of 10th tergum, triangular in dorsal and ventral views (Figs. 11, 23) with underlying developing narrow, tubular epiproct visible in pharate individuals (Figs. 11, 23); 10th tergum in lateral view subtriangular, nearly straight dorsally, with slightly downturned tip (Figs. 10, 49). Female without posterior extension of 10th tergum (Fig. 20). Cercal segments 28-30; cercomeres with apical circlet of short and long bristles, longer dorsal and ventral bristle in lateral view, and no intercalary hairs (Figs. 24, 25, 58, 59).

Capnia ventura Nelson & Baumann 1987
(Figs. 12-14, 50-55, 60, 61)

Distribution. California.
Material examined. California: Orange Co., Silverado Creek, Silverado Canyon, concrete low water crossing about 4.67km above Forest Service



Figs. 38-43. *Capnia teresa* larval characters. 38. Abdominal tergum 8. 39. Abdominal sternum 8. 40. Male terminalia, lateral. 41. Female terminalia, lateral. 42. Cercomeres 3-7, lateral. 43. Cercomeres 19, 20, lateral.



Figs. 44-49. *Capnia umpqua* larval characters. 44. Lacinia, ventral. 45. Right mandible. 46. Right mandible molar pad, detail. 47. Left mandible, ventral. 48. Left mandible molar cup, detail. 49. Male terminalia, lateral.

Fire Gate, N 33° 44.43′ W 117° 32.44′, 6-IV-2004, K.W. Stewart and E.F. Drake, 4♂, 7♀, 5♂ larval exuviae, 10♀ larval exuviae (adults and exuviae all together on a floating board), 11♀ larvae. Silverado Creek, 91.4m above Forest Service Fire Gate, 574.5m Elev., N 33° 44.55′ W 117° 34.56′, 9-II-2005, E.F. Drake, 2♂, 4♂ larvae, 23♀ larvae. Same locality, 10-III-2005, E.F. Drake, 1♂ larva, 9♀ larvae. Same locality, 25-III-2005, E.F. Drake, 1♂ larva, 6♀ larvae. Same locality, 18-II-2006, E.F. Drake, 3♂ reared with exuviae, 4♀ reared with exuviae. Same locality, 20-22-II-2006, 2♂, 3♀.

Characters. Body length ♂ 6.4-7.0mm, ♀ 7.2-7.3mm. Light to medium brown dorsally, ventrum lighter, little pattern except underlying muscles or adult pigment. Antennal segments ♂ 48-50, ♀ 48-52, head capsule width ♂ 0.75-0.81mm, ♀ 0.78-0.90mm. Lacinia triangular, palmate with longitudinally striate palm surface, broad apical teeth, ventral comb of about 10 bristles and dorsal comb of 16-18 longer bristles (Figs. 50, 51). Right mandible with apical teeth, molar pad of dense stiff bristles, and inner band of hairs from base of apical teeth to molar pad (Fig. 52). Left mandible with molar cup bordered by outer (dorsal) comb of curved teeth (Fig. 53). Pronotum with scattered setae over surface and as a marginal fringe (like Fig. 1). Mesosternal Y-arms and shallowly notched hind wingpads typical of genus; inside fore wingpad length ♂ 0.90-0.96mm, ♀ 1.02-1.08mm. Leg setation typical of genus (like Figs. 2, 3). Abdominal segments with long surface and posterior fringe hairs (Fig. 57). Sexual dimorphism evident. Male with posterior extension of 10th tergum nipple-shaped in dorsal view with underlying developing tubular epiproct visible in pharate individuals (Fig. 12); 10th tergum in lateral view with emarginated sides, cross-striated basal half, and narrowing apically (Figs. 54, 55). Female without posterior extension of 10th tergum (Fig. 13). Cercal segments ♂ 30-32, ♀ 32; cercomeres with apical circlet of short and long bristles, longer dorsal and ventral bristle in lateral view, and no intercalary hairs (Figs. 60, 61).

Provisional Key to Mature Male Larvae of Five California *Capnia* Species

1 Tergum 10 with 0.7-0.8 mm tubular posterior extension; developing tubular epiproct visible in pharate individuals (Figs. 15, 17, 34) ……*inyo*

1′ Tergum 10 shorter than 0.5 mm, its posterior extension variably shaped (Figs. 4, 5, 6, 8, 10, 11, 12, 40, 55) …….. 2

2 Posterior extension of 10th tergum subtriangular in dorsal view, with wide-based developing epiproct visible in pharate individuals (Fig. 4); dorsal margin nearly straight in lateral view, with slightly upturned tip (Fig. 8) …… *coyote*

2′ Posterior extension of 10th tergum with dorsal margin sharply upturned in lateral view (Figs. 5, 6, 40), or evenly downturned (Figs. 54-55), or nearly straight with slightly downturned tip (Fig. 10); developing epiproct in pharate individuals variously shaped (Figs. 5, 10, 12) …… 3

3 Base of tergum 10 extension with cross-striated surface, and in lateral view, with evenly downturned dorsal margin (Figs. 54-55) ... *ventura*

3′ Base of tergum 10 with smooth, unstriated surface …… 4

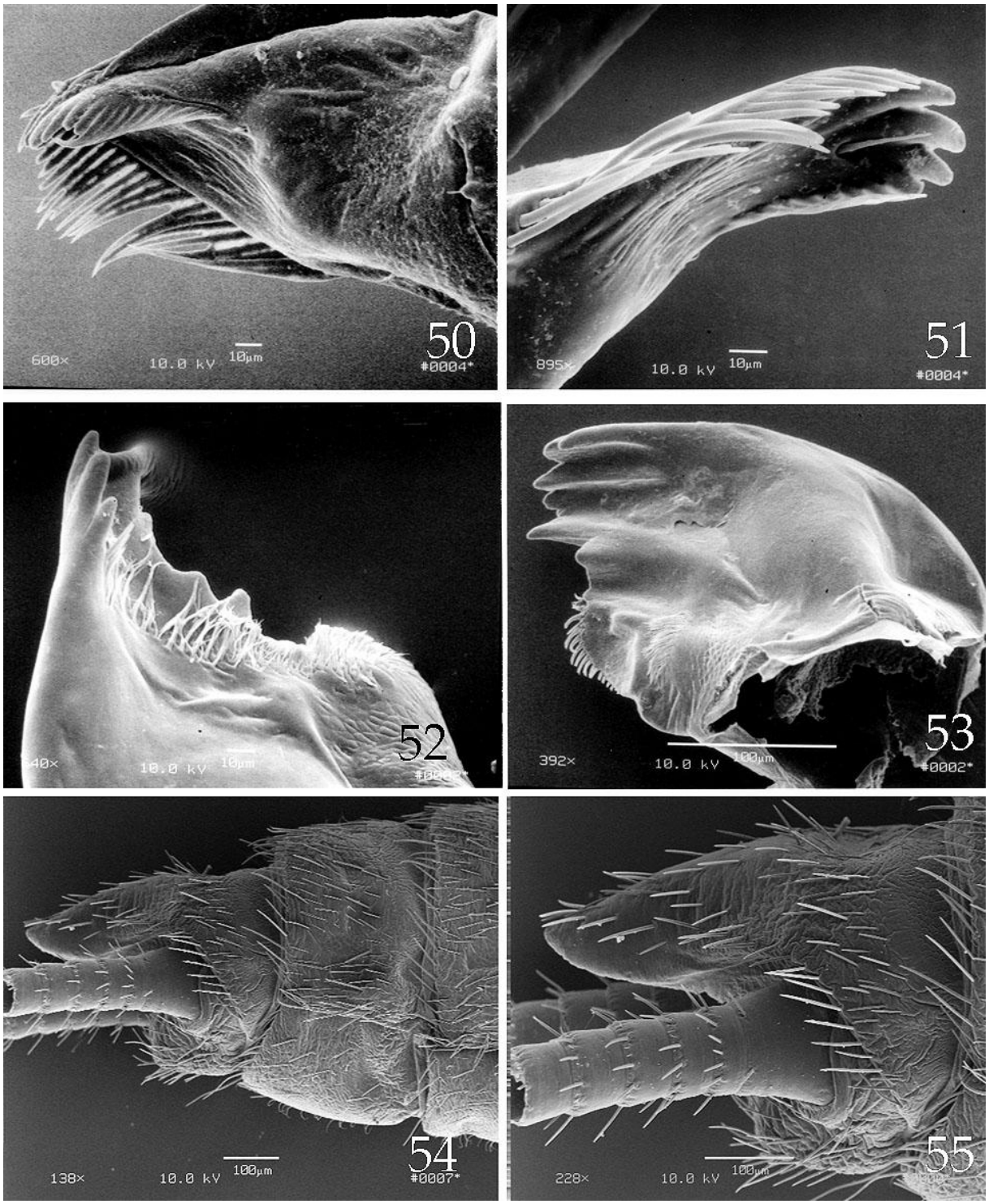
4 Tergum 10 extension sharply upturned in lateral view (Figs. 5, 6, 40) …….. *teresa*

4′ Tergum 10 extension with dorsal margin nearly straight, but with slightly downturned tip in lateral view …….. *umpqua*

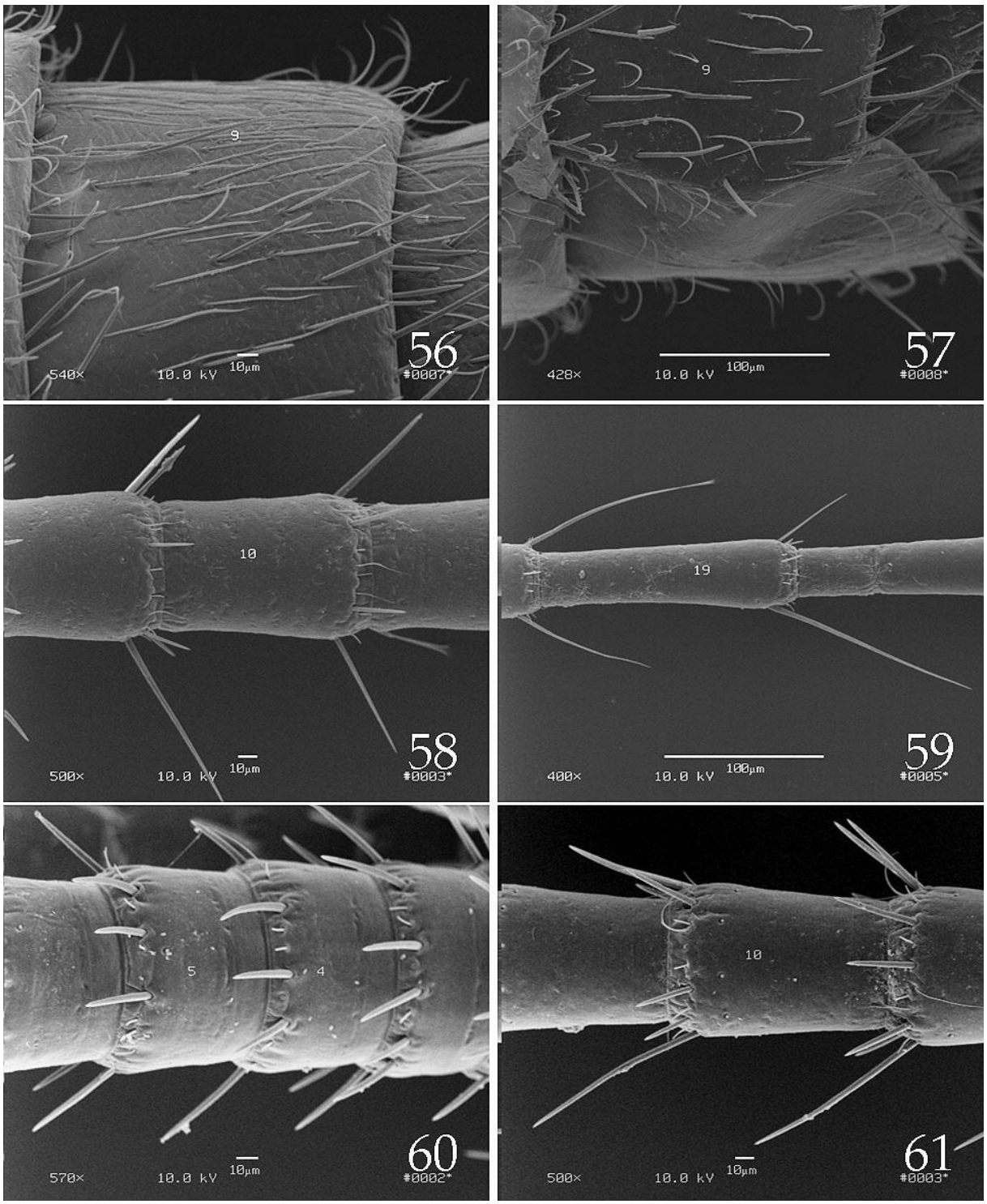
GENERAL DISCUSSION

Thirty five of the currently recognized 56 species of Nearctic *Capnia* occur in California, with 20 of them listed as endemic. The mature male larvae of these 5 species can be distinguished by the measurements and shape of their 10th tergum, and in the case of pharate individuals, by the visible, underlying, nearly-developed epiproct (see provisional key) that can be compared with that of adult males (Nelson & Baumann 1989). Whether this will hold true for larvae of all California species must await study of the other 30 species. We found no other characters to be diagnostic in the limited populations studied. The morphological homogeneity of *Capnia* larvae (Harper & Hynes 1971), particularly females and early and middle instars, may ultimately preclude practical separation of entire regional faunas with a dissecting microscope.

The mouthpart SEM's of *C. umpqua* and *C. ventura* larvae (Figs. 45-48, 52, 53) provide further clarification of left and right mandibular structure of *Capnia* larvae, from the generic description and illustration of Stewart & Stark (2002), that was



Figs. 50-55. *Capnia ventura* larval characters. 50. Lacinia, ventral. 51. Lacinial palm, detail. 52. Right mandible. 53. Left mandible. 54. Male terminalia, lateral. 55. Male terminalia, detail.



Figs. 56-61. *Capnia* larval characters. *C. umpqua*. 56. Abdominal tergum 9. 57. Abdominal sternum 9. 58. Cercomeres 9, 10. 59. Cercomere 19. *C. ventura*. 60. Cercomeres 3-6. 61. Cercomere 10.

based only on the one species, *C. vernalis*, that had been studied at that time. Their description of the molar area as a "smooth-crowned molar or scraping ridge" (their Fig. 7.6B) is now clarified in the right mandible as a raised molar pad having a surface of dense, short, stiff bristles (Figs. 45, 46, 52), and in the left mandible as a cup bordered by an outer comb of curved teeth (Figs. 47, 48, 53). These are presumed to function in grinding food particles in a "mortar-pestle-like" fashion, similar to the mandibles of *Podmosta* larvae recently described by Stewart & Stark (2011). The SEM's of *C. coyote* cerci (Figs. 30, 31) show an occasional fine intercalary hair of some segments, not evident in the other 4 species studied, nor in the generic description of *C. vernalis* by Stewart & Stark (2002).

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