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## A NEW CAVERNICOLOUS *PAROBISIUM* CHAMBERLIN 1930 (PSEUDOSCORPIONES: NEOBISIIDAE) FROM YOSEMITE NATIONAL PARK, U.S.A.

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### ABSTRACT

A new species of troglobitic *Parobisium* pseudoscorpion is described from two caves developed in granite talus slopes in the Yosemite Valley, U.S.A. The 16 species of the genus are all from the northern hemisphere (western U.S.A., China, Japan, South Korea). A taxonomic key to the genus in the U.S.A. is provided. The new species has only an anterior pair of pale colored eyespots without tapetum and is blind. Extensive searching at other shallow nearby caves and on the surface has not revealed any other specimens of this species, although it is common within certain areas of the two known caves. This may be only the second troglobite described from granite talus caves in North America, and suggests the potential for fruitful exploration in regions not traditionally sampled for subterranean fauna.

Key words: cavernicolous, boulders, granitic cave, *Parobisium*, pseudoscorpions, talus, troglobite, Yosemite National Park

### INTRODUCTION

Yosemite Valley is glacially sculpted and bordered by iconic granite bedrock formations including Half Dome and El Capitan. According to Huber (1987), about a million years before present, a Sherwin-aged glacier excavated and shaped the valley. At least two later glaciations occurred (Tahoe and Tioga glaciations, which probably peaked about 130,000 and 15,000-20,000 years ago, respectively) but were of much lesser areal size and height (Huber 1987). Thus, the later events did little to further modify or smooth the walls of Yosemite Valley. Above the ice surfaces of those later glaciers, the valley walls had almost a million years to weather – joints widened, rock fractured and crumbled, with water flows and falls eroding back

into ravines and less durable rocks. The Merced River has further incised the one km deep valley, and along either side of the valley walls are talus piles ranging from smooth, gently sloping grades to steep boulder fields. Over 500 documented rock falls in historic times (Wieczorek and Snyder 2004) demonstrate the ongoing nature of the talus slope formation. Within these talus slopes are caves of varying sizes that simply consist of spaces within the jumble of boulders, with the largest boulders providing stable roofs for a few more extensive caves. The two caves of primary interest are likely only a few hundred years old. Talus caves are created, eroded, and then most likely the fauna moves into the more recent talus fall regions. Only the more

recent areas are accessible to humans, but countless voids large enough for invertebrates must exist in the old and buried rubble piles.

Krejca (2007) performed a biological inventory of two of the longer caves in Yosemite Valley, Spider Cave and Indian Cave, Mariposa County, California, in the summer of 2006. During that study four specimens

of a new species of pseudoscorpion were collected from Indian Cave for taxonomic identification. Two subsequent visits (3-4 March and 7-8 July 2009) were organized to collect additional material and attempt to determine if the species is actually cave-limited by sampling a variety of similar surface habitats. On these later trips a specimen also was obtained in Elf Village Cave, located less than 0.5 km from Indian Cave.

## MATERIALS AND METHODS

*Field observations.*—Surveyors used standard caving techniques and performed searches by crawling slowly along the entire zone in each cave, recording all fauna that occurred on each surface including the floor, ceiling, and walls. Search effort was measured in terms of surveyor-minute, and reflects the time it took to search the entire zone of the cave for pseudoscorpions. Temperature and relative humidity (RH) were measured using a fan-cooled wet and dry bulb psychrometer (Psychro-Dyne®, Industrial Instruments and Supplies). Atmospheric pressure was measured using a hand held Tech 0 digital barometer. Measurements were taken inside the caves at each zone where searches were performed. Relative humidity (RH) values were calculated from wet bulb, dry bulb, and barometric pressure measurements.

*Specimen repositories.*—All but one male and two female specimens are at the Museum of Texas Tech University (TTU-Z). Of the three other specimens, one male paratype (formerly TTU-Z 51564) and one female paratype (formerly TTU-Z 51536, Zara 3563) are deposited in the collection of the California Academy of Sciences (CAS), and one female paratype (formerly TTU-Z 51532) is deposited at the Florida State Collection of Arthropods (FSCA). All specimens are detailed under “type material and treatments.”

*Specimen preparation.*—The specimens were collected directly into 75% or 95% ethanol. The appendages from one side of the body of some of those in 95% ethanol were removed and placed in a -80°C freezer. The remainder was transferred to 75% ethanol. Most specimens were then transferred to lactophenol on a shallow depression slide and cleared. After study

with light microscopy, the specimens were returned to 75% ethanol. For SEM study the appendages were removed and dehydrated through a graded ethanol series, transferred to hexamethyldisilazane (HMDS) through an ethanol/HMDS series to pure HMDS, dried in a vent hood overnight at room temperature, and mounted on a stub without metal coating.

*Image and examination.*—Light microscopy (LM) included use of Nikon SL-3D and Leica MS5 microscopes with photo attachments and an 8 megapixel Nikon Coolpix 8700. Photoshop was used to enhance these and other photographs, some with the use of an i-pen Mouse (FingerSystem U.S.A. Inc.). Z-axis montages of LM images were created with Helicon Focus (Helicon Soft Ltd.). Scanning electron microscopy was achieved by the use of a Hitachi S-4300SE/N. Digital images presented herein as well as others to photographically document the specimens are retained in the Museum of Texas Tech University digital catalog under each specimen’s individual number (TTU-Z). Unless indicated otherwise, all illustrations are by the first author.

Measurements were made following the directions in Chamberlin (1931, p. 32-25), using an ocular micrometer with LM, or read directly off SEM scales. Trichobothria names follow those used by Chamberlin (1931). Harvey (1992) noted that the leg basifemur and telofemur were not both femoral segments, and are correctly termed the femur and patella. The cheliceral “flagellum” has been renamed the rallum (Judson 2007). The terminology for the female genitalia follows Judson (1993).

## TAXONOMY

Muchmore (1990) provided an annotated key to the various taxonomic levels down to and including genera of pseudoscorpions in the U.S.A., and this key is still useful, although slightly outdated. Harvey (1992) remains the modern standard for higher classification of pseudoscorpiones.

**Family Neobisiidae** Chamberlin 1930

*Diagnosis.*—Apex of palpal coxa (manducatory process) rounded and with three or more setae. Venom apparatus absent from moveable chelal finger (Harvey 1992).

**Subfamily Neobisiinae** Chamberlin 1930

*Diagnosis.*—Galea reduced to a sclerotic knob (Harvey 1992).

**Genus *Parobisium*** Chamberlin 1930

*Neobisium (Parobisium)* Chamberlin 1930:17; Beier 1932:84; Morikawa 1960:112-113; Hoff 1961:427.

*Parobisium* Chamberlin: Chamberlin and Malcolm 1960:112-113; Chamberlin 1962:123; Harvey 1991:394; Mahnert 2003:744-745.

*Diagnosis.*—Fixed chelal finger with a compact subterminal cluster of only three tactile setae (*et*, *it*, *est*) and a more diffuse subbasal to basal cluster of five tactile setae (*isb*, *ist*, *ib*, *esb*, *eb*); both clusters of setae number four (*et*, *est*, *it*, *ist/esb*, *eb*, *isb*, *ib*) in other genera, and seta *ist* is subterminal instead of subbasal in position (Chamberlin 1962).

*Subordinate taxa and distribution.*—*Parobisium* now consists of 16 described species and four additional subspecies (Harvey 2009): East Asia: China (three species), Japan (four species), South Korea (two species); North America: western U.S.A. (seven species).

North American (U.S.A.) taxa:

*Parobisium charlotteae* Chamberlin 1962. Type locality: Redmond Lava Cave, Deschutes County, Oregon.

*Parobisium hastatum* Schuster 1966. Type locality: 6 miles S El Dorado, El Dorado County, California. Other reported localities: Carson Ridge, Marin County; Bear Valley, Mariposa County; 10 miles S Monticello, Napa County; 4 miles W Newcastle, Placer County; Dutch Flat, Placer County; Placer Flat, Placer County; 7 miles NE Santa Rosa, Sonoma County; 6 miles N Rumsey, Yolo County, California.

*Parobisium hesperum* (Chamberlin 1930). Type locality: Cannon Beach, Clatsop County, Oregon. Other reported locality: Dunsuir, Shasta County, California.

*Parobisium hesternum* Schuster 1966. Type locality: Riverton, El Dorado County, California. Other reported localities: Bear Valley and Yosemite National Park, Mariposa County, California.

*Parobisium utahensis* Muchmore 1968. Type locality: Blacksmith Fork Canyon, Cache County, Utah.

*Parobisium vancleavei* (Hoff 1961). Type locality: Mesa Verde National Park, Montezuma County, Colorado.

*Parobisium yosemite* Cokendolpher and Krejca, n. sp. (this paper). Type locality: Indian Cave, Yosemite Valley, Yosemite National Park, Mariposa County, California. Also reported from: Elf Village Cave, Yosemite Valley.

KEY TO ADULTS OF THE GENUS *PAROBISIUM* OF NORTH AMERICA

1. Galea absent (Chamberlin 1962: Fig. 7H); large species, palpal femur and tibia each longer than 2.0 mm.....*Parobisium charlotteae* Chamberlin 1962 (troglophile, Deschutes County, Oregon)
  
- Galea present, small rounded sclerotic knob (Figs. 25-26, 28); small to medium sized species, palpal femur and tibia each 0.5-1.8 mm long.....2
  
2. Anterior eyes reduced in size or absent, posterior pair absent; palpal femur longer than 1.4 mm.....3
  
- Two pairs of eyes well developed; palpal femur shorter than 0.85 mm.....4
  
3. Epistomal process a small extension (Fig. 5), palp patella with bulge on mesal margin (Figs. 14-15), palpal hand elongated in dorsal and ventral view (Fig. 15).....*Parobisium yosemite* Cokendolpher and Krejca, n. sp. (troglobite, Mariposa County, California)
  
- Epistomal process absent, palpal patella smooth on mesal margin, palpal hand rounded in dorsal and ventral view (Schuster 1966: Fig. 12).....*Parobisium hesperum* (Chamberlin 1930) (humus, Clatsop County, Oregon; Shasta County, California)
  
4. Smaller robust species, palpal femur 0.57-0.64 mm long, California.....5
  
- Medium sized species, palpal femur 0.72-0.84 mm long, Utah, Colorado.....6
  
5. Galeal knob a long, low crest (Schuster 1966: Fig. 9); patella II with 11-12 setae; coxa IV with about 12 setae; anterior genital area (sternite II) of male with about 20 setae .....*Parobisium hastatum* Schuster 1966 (humus, El Dorado, Marin, Mariposa, Napa, Placer, Sonoma, Yolo counties, California)
  
- Galeal knob a short, rounded crest (Schuster 1966: Fig. 11); patella II with 18 setae; coxa IV with about 16 setae; anterior genital area (sternite II) of male with about 30 setae..... *Parobisium hesternum* Schuster 1966 (humus, El Dorado, Mariposa counties, California)
  
6. Posterior margin of carapace with 10-12 setae; palpal femur of male 3.9-4.1 times as long as broad, chela 3.3-3.4 times as long as broad; chelal fingers with 45-59 marginal teeth ..... *Parobisium vancleavei* (Hoff 1961) (beneath rocks in pinyon-juniper woodland, Montezuma County, Colorado)
  
- Posterior margin of carapace with 8-10 setae; palpal femur of male 4.2-4.4 times as long as broad; chela 3.7-3.8 times as long as broad; chelal fingers with 62-82 marginal macrodenticles .....*Parobisium utahensis* Muchmore 1968 (moss on rocks, Cache County, Utah)

*Parobisium yosemite* Cokendolpher and Krejca,  
new species

Figs. 1-29

*Type material and treatments* [75% ethanol→lactophenol→75% ethanol = 75elpe; 95% ethanol→lactophenol→75% ethanol = 95elpe].—U.S.A.: California: Mariposa County: Indian Cave (type locality): Holotype male, TTU-Z 51528 (Zara 3524), Journal Room, floor, 4 March 2009, leg. J. Krejca, K. McDermid, 95% ethanol, appendages -80°C, remainder 95elpe. Paratype male, TTU-Z 51540 (Zara-940), Journal Room, 15 August 2006, leg. J. Krejca, G. Stock, 75elpe. Paratype female, TTU-Z 51548 (Zara-915), Journal Room, 16 August 2006, leg. J. Krejca, G. Stock, elpe, appendages dried and mounted on SEM stub. Paratypes 2 females, TTU-Z 51584, 51588 (Zara 3532), Journal Room, 4 March 2009, leg. K. McDermid, J. Krejca, 95% ethanol, appendages -80°C, remainder room temperature. Not exposed to lactophenol. Paratypes 1 male, 1 female, CAS (formerly TTU-Z 51564 and 51536, Zara 3563), 1 female paratype, FSCA (formerly TTU-Z 51532), Journal Room 3 March 2009, leg. J. Krejca, K. McDermid, G. Stock, R. Sas, 95elpe. Male paratype, TTU-Z 51576, West Branch, 7 July 2009, leg. J. Krejca, poorly preserved - died in captivity, 75elpe. Male paratype, TTU-Z 51572, East Branch, 7 July 2009, leg. G. Stock, died in captivity - abdomen missing, poorly preserved, elpe. Female paratype, TTU-Z 51568, West Branch, 7 July 2009, leg. J. Krejca, died in captivity, 100% ethanol, -80°C, not exposed to lactophenol. Female paratype, TTU-Z 51556 (Zara 3549), East Branch, floor, 3 March 2009, leg. G. Stock, J. Krejca, K. McDermid, R. Sas, 95elpe. Tritonymph paratype, TTU-Z 51544 (Zara-920), Eastern Arm, 16 August 2006, leg. J. Krejca, G. Stock, elpe. Deutonymph paratype, TTU- 51552 (Zara 3549), East Branch, floor, 3 March 2009, leg. G. Stock, J. Krejca, K. McDermid, R. Sas, 95elpe. Deutonymph paratype, TTU-Z 51564 (Zara 3563), Journal Room, 3 March 2009, leg. J. Krejca, K. McDermid, G. Stock, R. Sas, 95elpe.

U.S.A.: California: Mariposa County: Elf Village Cave: Paratype female, TTU-Z 51580 (Zara 4175), 8 July 2009, leg. J. Krejca, left appendages in 100% ethanol, -80°C, body elpe.

*Etymology.*—The specific name Yosemite is used as a noun in apposition and is taken from the known localities which are in Yosemite (pronounced “yo-SEM-it-ee”) Valley in Yosemite National Park of the U.S.A. The area was apparently named after the Yosemite Indian peoples (<http://theautry.org/yosemite/> [accessed 1 Sept. 2010]).

*Vernacular name.*—Yosemite Cave Pseudoscorpion.

*Diagnosis.*—With the characters of the family, subfamily, and genus. Posterior eyes absent, anterior pair reduced to a small, irregular shaped eyespot without reflective tapetum (Fig. 5), epistomal process a small extension (Fig. 5), cheliceral galea a small rounded knob (Figs. 25-28), palpal patella with small bulge mesally (Figs. 14-15), chelal fingers with 68-95 teeth, carapace 0.98-1.31 mm long.

*Identification.*—The new species can be told apart from all described congeners from North America by the key provided above. *Parobisium hesternum* was recorded from the Yosemite National Park and Bear Valley by Schuster (1966), but no habitat data were associated with the collection. It is unknown if they were from the bottom of a valley or on top of the mountains. The new species and *Parobisium hesternum* differ primarily in the more elongated palp and loss of eyes in *P. yosemite*. The new species differs also by having a bulge on the mesal margin of the palpal patella (Figs. 14-15) and in setation: *P. yosemite* (followed by *P. hesternum* in brackets) patella II with 21-24 [18] setae; coxa IV with about 11-12 [16] setae; anterior genital area of sternite II of male with 58 [30] setae.

*Description.*—Coloration of abdomen and legs light tan to amber; prosoma, coxa and trochanter I-II, chelicerae, and palps reddish-brown (Figs. 1-4). Nymphs are similarly colored, but darkest areas are only light orange in color with lighter areas being cream to yellowish-amber.

Male (holotype): Body length 3.46 mm. Carapace a little longer than broad: widest in anterior fourth 0.99 mm; length 1.31 mm. Derm smooth; epistomal process small and rounded (Fig. 5). Posterior eyes absent, anterior pair reduced to a small, irregular shaped eyespot.

Chaetotaxy 4-5-3-4-2-6 (24); 2 pairs of small, medial lyrifissures at  $\frac{1}{4}$  and  $\frac{3}{4}$  carapace length (Fig. 5).

Abdomen elongated, 2.12 mm in length; widest in middle, 1.36 mm wide; width greater than width of carapace. Pleural membrane granulated (Fig. 9). Tergites and sternites entirely smooth (Figs. 9-10). Tergites wider than long. All tergites with setae in a single row: chaetotaxy 8:13:12:13:12:12:12:12:10:11:6 (121).

Male genital opening with 58 microsetae on sternite II. Sternite III with anteromedial cluster of 11 smaller setae near anterior margin, followed posteriorly by row of 4 setae, then row of 18 setae; total 34-35 setae on sternite III (Fig. 11). Internally, the ventral base of the genital operculum with 6 and 7 socketed spines bounded by larger triangular denticle on each side (Fig. 13).

Sternites V-VIII with 2 rows of setae, other sternites with single setal row posteriorly, plus anterior pair near midline, chaetotaxy IV-X: 27-0+13-2+15-2+15-2+13-12-10 (111). Anal plate with 2 anterior, 2 posterior setae.

Chelicera 1.05 mm long and 0.27 mm deep; moveable finger 0.52 mm long, with 9 macrodenticles, galea smooth, rounded, very short knob; with 2-4 pores (see Figs. 28-29); palm with 7 setae and one lyrifissure (Fig. 25: lf); fixed finger with 13 (9 larger) macrodenticles; rallum with two groups of blades: (1) with 5 setae (distal 2-3 with distal serrations) (Fig. 27, arrow on right), (2) three shorter hirsute filaments (Fig. 27, left arrow). Chaetotaxy of coxae: palp 6-6, legs 8-8:9-10:9-9:11-12. Posterior maxillary lyrifissure curved posteriorly at both ends (Figs. 7-8).

Palp long and slender, surface of each podomere with granules (Figs. 15, 18-24), except for hand smooth; granulations reduced or absent on dorsal side of patella and distal end of femur. Palpal trochanter 0.99 mm long, 0.33 mm deep; femur 1.82 mm long, 0.33 mm deep; patella 1.79 mm long, 0.42 mm deep; chela (tibia) 3.0 mm long, 0.64 mm deep, 0.68 mm tall; moveable finger (tarsus) 1.705 mm long. Apex of palpal coxa (manducatory process) curls around dorsally and extends anteriorly, rounded, with 4 (other type specimens with 4-6) setae on acute mesal edge. Venom duct only present in fixed palpal finger; short, not extending past  $\frac{1}{2}$  distance to *et* setae (Fig. 24). Palp

chela trichobothriotaxy: *st* close to *t*, *sb* closer to *st* than to *b*; on fixed finger *it*, *et*, and *est* near distal end, *ish*, *esb*, and *eb* at base (Fig. 24), and *ib* and *ist* on dorsum of hand (Fig. 18). Fixed chela finger with 91 teeth; moveable finger with 85 teeth.

Legs relatively long and thin. Patella II with 24 setae. Leg IV: (femur + patella) 1.13 mm long, 0.30 mm deep; tibia 1.07 mm long by 0.17 mm deep. Long tactile setae on tibia and both tarsi of leg IV. Claws long and smooth, flanked on each side with subterminal tarsal seta deeply bifurcate (bifurcation with a few further microtricia, Fig. 6), arolium less than half length of claws.

Female (Indian Cave TTU-Z 51548, followed by Elf Village Cave TTU-Z 51580 in parentheses or brackets). Features as in male, except in details listed below: Body length 4.17 (3.67) mm. Carapace a little longer than broad: widest in middle, 0.92 (1.02) mm; length 0.98 (1.22) mm. Chaetotaxy 4-5-4-1-6 (20) [4-4-2-2-4-5 (21)]; pairs of lyrifissures in median position at  $\frac{1}{4}$  and  $\frac{3}{4}$  distance of carapace.

Abdomen elongated 3.275 (2.65) mm in length; widest in middle, 1.24 (1.205) mm. Tergites all with setae in a single row: chaetotaxy 8-13-14-15-13-12-13-12-11-12-9 (132) [8:11:12:12:13:11:11:12:13:14:10 (127)].

Female genital opening with a pair of lyrifissures anteromedially (Fig. 12), 14 (7 right-7 left) [12 (4-8)] microsetae on sternite II and single row of 34 (37) setae (3-4 at each spiracle smaller than other setae) on sternite III (Figs. 9-10); tracheae visible (Fig. 9); details of internal genitalia as in Fig. 10.

Sternites VI (V in Elf Village Cave)-VIII with 2 rows of setae, others with single row posteriorly, anterior pair near midline or  $\frac{3}{4}$  line and of similar size and form to posterior setae: IV-X chaetotaxy: 29-0+15-2+17-2+14-2+15-12-12 (120), [22-2+13-2+14-2+15-2+12-14-13 (111)]. Anal plate with 2 (2) anterior, 2 (2) posterior setae. Genitalia with atrium between sternites II and III; small median genital sac (Fig. 10, arrow 5) covered with pores and extending posteriorly from the cribiform gonosacs. The cribiform plate holes are noticeably smaller in diameter than those ending as pores on the medium genital sac.

Chelicera 0.71 (0.745) mm long and 0.32 (0.27) mm deep; moveable finger 0.445 (0.46) mm long, with 7 (6) macrodenticles (and few microdenticles), galea a smooth short rounded knob; palm with 7 (7) setae; fixed finger with 14 (13) macrodenticles; rallum with 8 (7) setae, the first 2 (2) setae with short serrations (at or about width of setae), distal 3 (2) setae with long (1.5 width of setae) serrations; 3 (3) shorter hirsute filaments (Fig. 27). Chaetotaxy of coxae: palp 4-6 (4-5), legs 8-10-5-12-8-7-5-10 (65), [12-10-6-12-11-9-5-14 (79)].

Palp relatively long and slender when compared to other congeners, surface of each podomere with granules, except for most (basal and distal) of hand smooth (Figs. 23-24); granulations reduced or absent on dorsal side of patella and distal end of femur. Median maxillary lyrifissures of palpal coxae appearing elongate oval in Figs. 7-8, because of the angle of view, round in median view. Palpal trochanter 0.71 (0.825) mm long, 0.26 (0.29) mm deep; femur 1.44 (1.625) mm long, 0.265 (0.265) mm deep; patella 1.35 (1.56) mm long, 0.37 (0.39) mm deep; chela (tibia) 2.42 (2.75) mm long, 0.72 (0.63) mm tall; moveable finger (tarsus) 1.24 (1.415) mm long. Fixed chelal finger with 82 (74) teeth; moveable finger with 77 (68) teeth (Figs. 18, 20-23); teeth are more pointed anteriorly on fixed finger.

Legs relatively long and thin compared to other congeners. Leg IV: (femur + patella) 1.18 (1.05) mm long, femur 0.235 (0.18) mm deep, patella 0.18 (0.22) mm deep; tibia 1.05 (0.995) mm long by 0.15 (0.13) mm deep. Long tactile setae on tibia at  $\frac{1}{2}$  length and both tarsi of leg at  $\frac{1}{7}$  and  $\frac{1}{3}$ , respectively.

Nymphs: As in adults, leg claws long and smooth, flanked on each side with subterminal tarsal seta deeply bifurcate, arolium less than half length of claws in deutonymph and tritonymph. Eyespots not evident because cuticle is not darkly pigmented as in adults; no hint of a nerve fiber is evident.

*Distribution.*—This species has only been found in two granitic talus caves located less than 0.5 km apart, Indian Cave and Elf Village Cave in Yosemite Valley, Mariposa County, California (Fig. 30). These caves are located in a single expansive talus slope. Extensive hand searching and Berlese extraction of

leaf litter at the second most extensive known cave in the valley, Spider Cave (approximately 2 km to the west), yielded no pseudoscorpions, except for a nymph of *Apochthonius* sp. (Chthoniidae). Extensive hand searching and Berlese extraction at other unnamed minor talus caves and at nearby surface locations in the talus piles yielded other pseudoscorpions, but no specimens of *Parobisium* (Zara 2009).

*Habitat.*—Indian Cave and Elf Village Cave are granitic talus caves (Figs. 31-32). The initial structure of the talus caves was formed instantaneously as a result of a rock avalanche (Wieczorek et al. 1999), with subsequent weathering that may serve to make the habitat more cave-like (e.g., stable temperatures and humidities) as sediments and smaller rocks seal off alternate entrances and surface water runoff creates regular pathways for water flow. Indian Cave consists of a series of passages and small rooms surveyed to 64 m long with a total depth below the entrances of 14 m. The present cave probably formed relatively recently, perhaps only a few hundred years ago (Wieczorek et al. 1999); however earlier talus caves almost certainly existed in the area as a result of rock falls from the valley walls following retreat of the Last Glacial Maximum glacier approximately 15,000-20,000 years ago (Huber 1987). Even before the last glacial retreat, there were talus slopes uphill that were formed after the first glaciations about a million years earlier.

The entrance to Indian Cave (Fig. 31) consists of two discreet openings among boulders approximately 15 meters up a steep talus slope from a relatively flat terrace in the valley (Fig. 33). After a short climbdown from either opening is the first room of the cave, the Twilight Room, typified by low level sunlight, mossy walls, and a soil and leaf litter floor. After another short climbdown the passage splits, with the large obvious way being to the northeast, the Junction Room. This room marks the end of the light zone and a series of large steps downward and to the east in increasingly smaller passage leads to the East Branch of the cave. We found *Parobisium yosemite* in this branch. The substrate here consists of granite sand, rocks, leaf litter, and occasional rootlets with and without mold. From the Twilight Room climbdown to the southwest, a discreet smaller passage (West Branch, Fig. 35) winds under the entrance itself and continues as a crawlway

with a granite gravel and sediment floor, past some woody debris, over a perennial pool, past a couple narrow restrictions and down another climbdown into the terminal room of the cave, the Journal Room. We also found *Parobisium yosemite* in this branch. The Journal Room has a sediment floor with sparse woody debris and leaf litter, and scattered loose rocks (Fig. 34).

The entrance to Elf Village Cave (Fig. 32) is a small (0.5 m) opening at the base of a large (10 m+) boulder. Approximately 4 m of crawlway passage leads into a long and wide low room (over 10 m diameter, 1-2 m tall) that is situated at an approximately 30 degree slope. At the low end of that room is a moist area with a rock, gravel, and sand floor that is scattered with acorns and pine cones. This is the only part of the cave where we found *Parobisium yosemite*. Caves where the species were not found were shallower and shorter. These sites often had 15 m or less of traversable cave passage, had multiple entrances that may contribute to a lack of stable temperature and humidity, and most of the extent of these caves was in the twilight zone rather than having true darkness like Indian and Elf Village caves. Spider Cave was the exception, with a true dark zone and extensive passage. At present the species is limited to the rockslide that encompasses the two known localities, but it is possible that the species is less detectable at Spider Cave due to some other factor such as frequent human visitation or a natural environmental parameter.

*Microhabitat* (Figs. 34-35).—During visits in August 2006, March 2009, and July 2009 we recorded substrate and temperature data for 40 different *Parobisium yosemite* observations (not all specimens were collected). We found most individuals on the undersides of rocks (60%, or 24/40 observations), and some of those rocks were on woody debris, on sand, or on a gravel floor with rootlets and fungus. The next most common microhabitat was wood (33%, or 13/40 observations). Individuals were typically on the undersides of pieces of wood, and occasionally on the top of the wood. We found the remaining 7% (3/40 observations) of individuals on a granite and sand floor; one was under granitic rock on sand floor. Total available substrate type was not measured, however our qualitative assessment of available habitat indicates a preference for undersides of rocks and woody debris, considering

the majority of the floor area in the deep portions of the cave is breakdown, gravel, and granitic sand.

Temperatures ranged from 8.0-15.8°C with a mean of 10.5°C and standard deviation of 1.8°C. Relative humidity ranged from 73.2-100% with a mean of 92.7% and standard deviation of 7.3%. Sources of nutrients for this cave ecosystem include leaf litter and woody debris washed into the cave, rootlets penetrating into the cave, and possibly troglonexes including small mammals. We did not observe a large amount of small mammal scat, however in some places it seemed unlikely that acorns were washed in by rains, but more likely carried in by mammals. Some of the woody debris appears too large to have been carried in by animals, thus it is possible that it was captured during the rockslide event that formed the cave or carried into the cave by early explorers (Fig. 35).

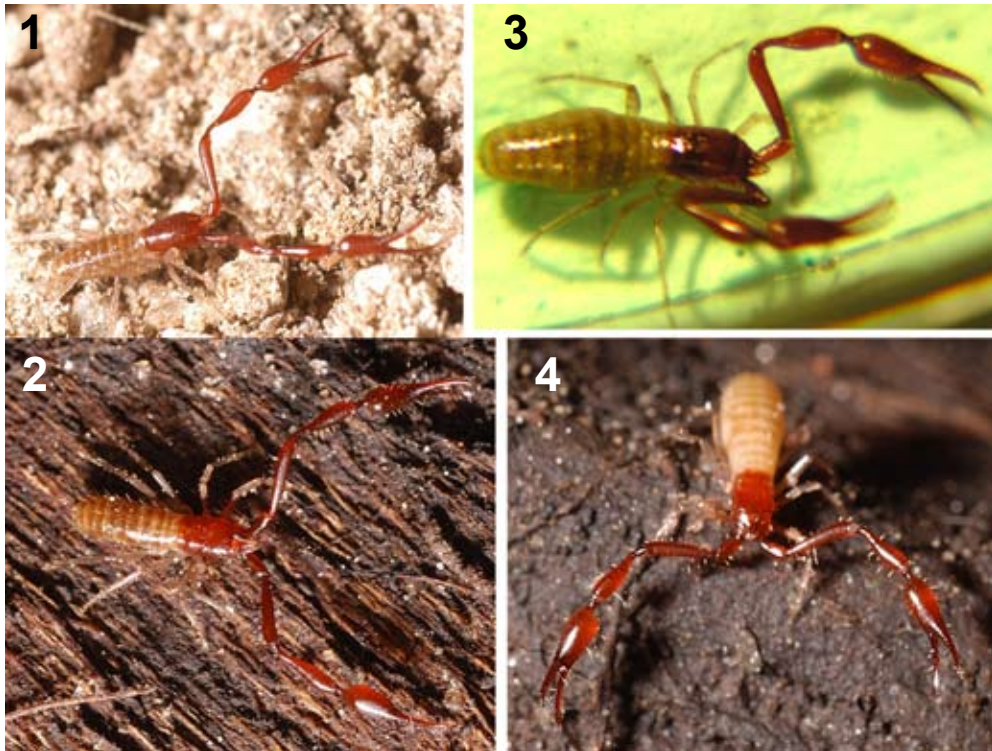
*Abundance*.—During visits in August 2006, March 2009, and July 2009 we recorded survey effort for 39 different *Parobisium yosemite* observations. At Indian Cave, in the zones where the species was found, one individual was found on average every 22 minutes (total seen = 36, total search effort = 784 person-minutes). At Elf Village Cave one individual was found on average every 11 minutes (total seen = 3, total search effort = 33 person-minutes).

*Prey*.—On 7 July 2009 in the Journal Room of Indian Cave we turned a rock over to find one *Parobisium yosemite* with a springtail in its chelicerae. The entomobryid, on field identification, appeared to be the fairly common small, white *Sinella* or *Pseudosinella* springtail. Other potential prey items we observed commonly included two species of free-living mites, flies, small spiders (nesticid and pimoid), beetles, ants, and millipedes. The larger silver *Tomocerus* springtails are more commonly seen near the cave entrance, not overlapping with the areas where *Parobisium yosemite* was seen.

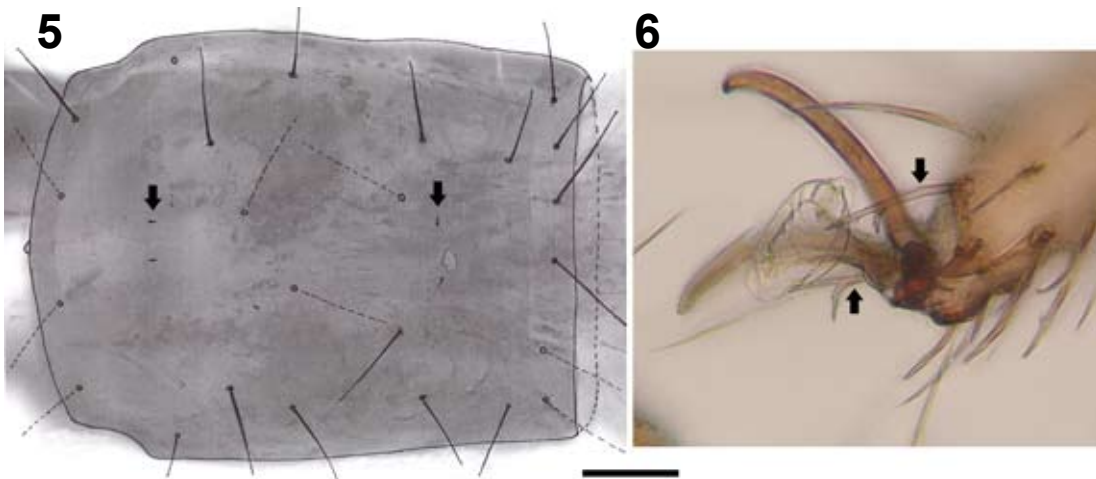
Three adult specimens we held in captivity in Petri dishes that were half-filled with Plaster of Paris and a small wax-lined hole for holding free water. A variety of small to tiny invertebrates were offered as food: snails, slugs, earthworms, nematodes, flies, ants, aphids, collembolla, moths, small crickets, and

(text continues on page 23)





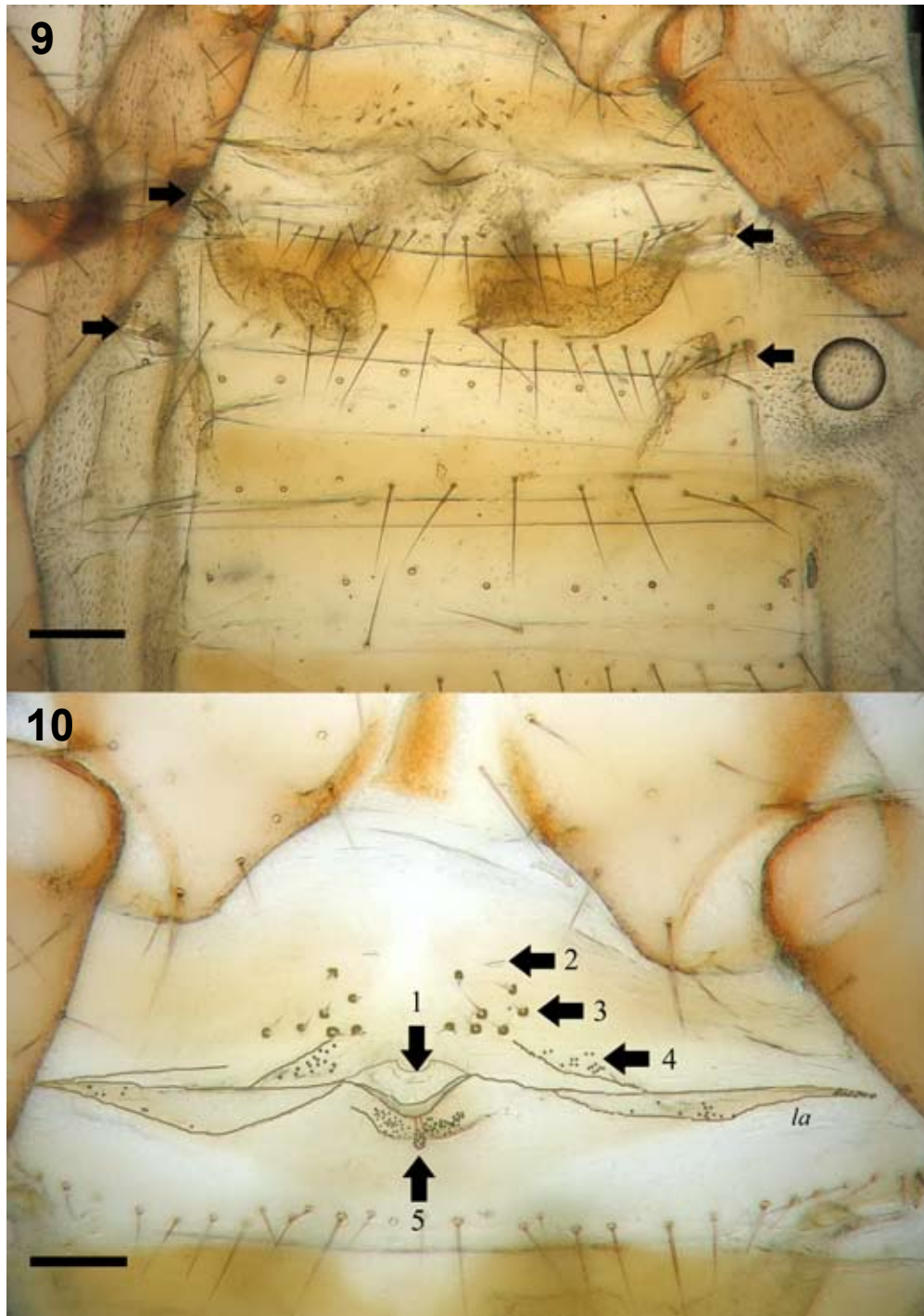
Figures 1-4. *Parobisium yosemite*, n. sp. from Indian Cave, Yosemite National Park. Males in cave: 1, dorsolateral aspect; 2, dorsal aspect. Females: 3, TTU-Z 51568 in laboratory, dorsal aspect; 4, in cave, anterodorsal aspect. Photographs not at same scales, but females are larger. The animals with outstretched palps and fingers open are actively moving through the environment. The female with palps pulled in closer to the body is in more of a resting position. An animal at full rest will have the palps closed and pulled in close to the body (JCC, pers. obs.). Photographs 1, 2, 4 by JKK, photograph 3 by JCC.



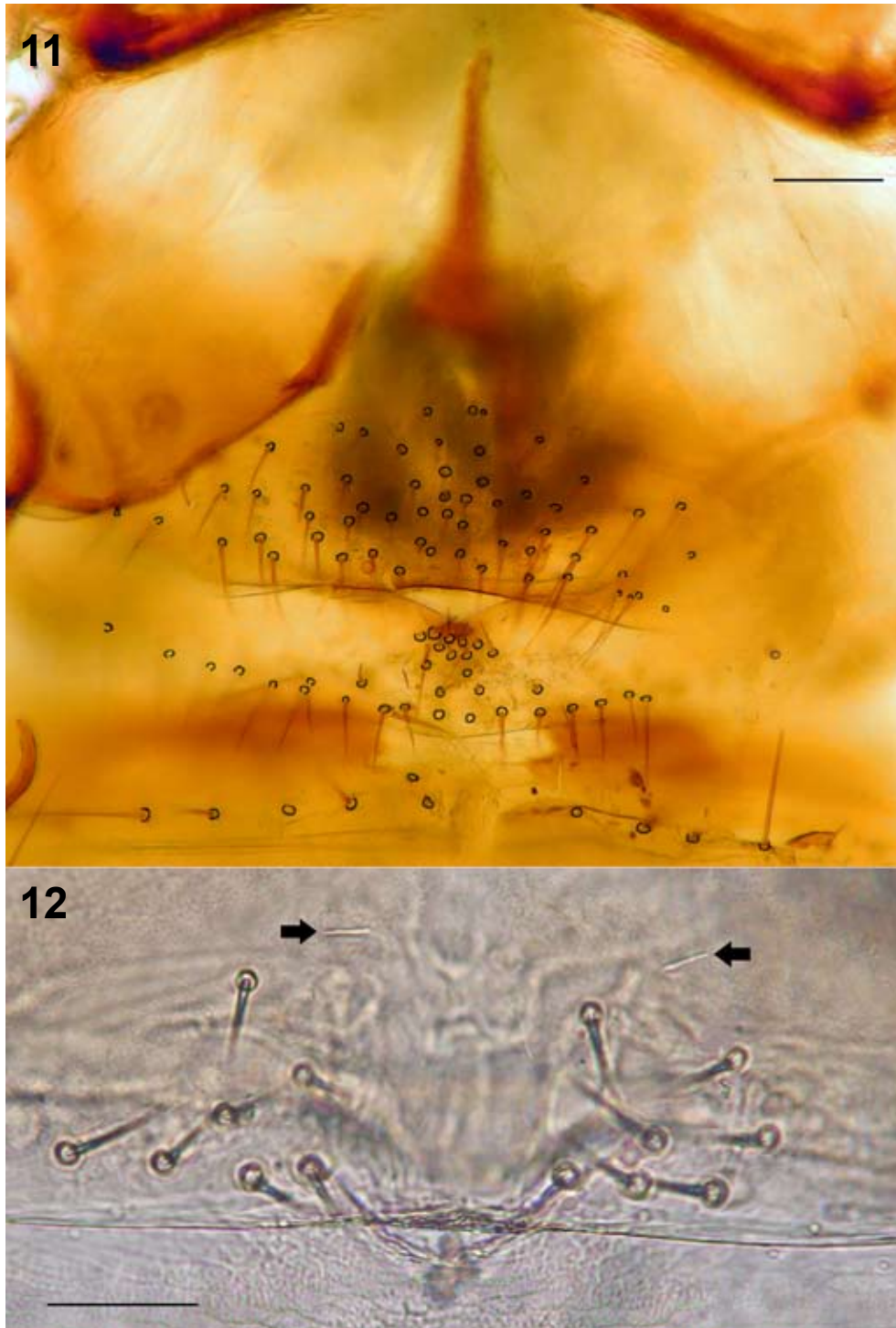
Figures 5-6. *Parobisium yosemite*, n. sp. from Indian Cave, Yosemite National Park. 5, holotype male (TTU-Z 51528) carapace, dorsal (anterior is to left; posterior pair of lyrifissures added and indicated by arrows - see text). 6, female (TTU-Z 51548) tarsus IV claw with bifurcate setae (indicated by arrows). Scale, 5 = 0.25 mm, 6 = 0.05 mm.



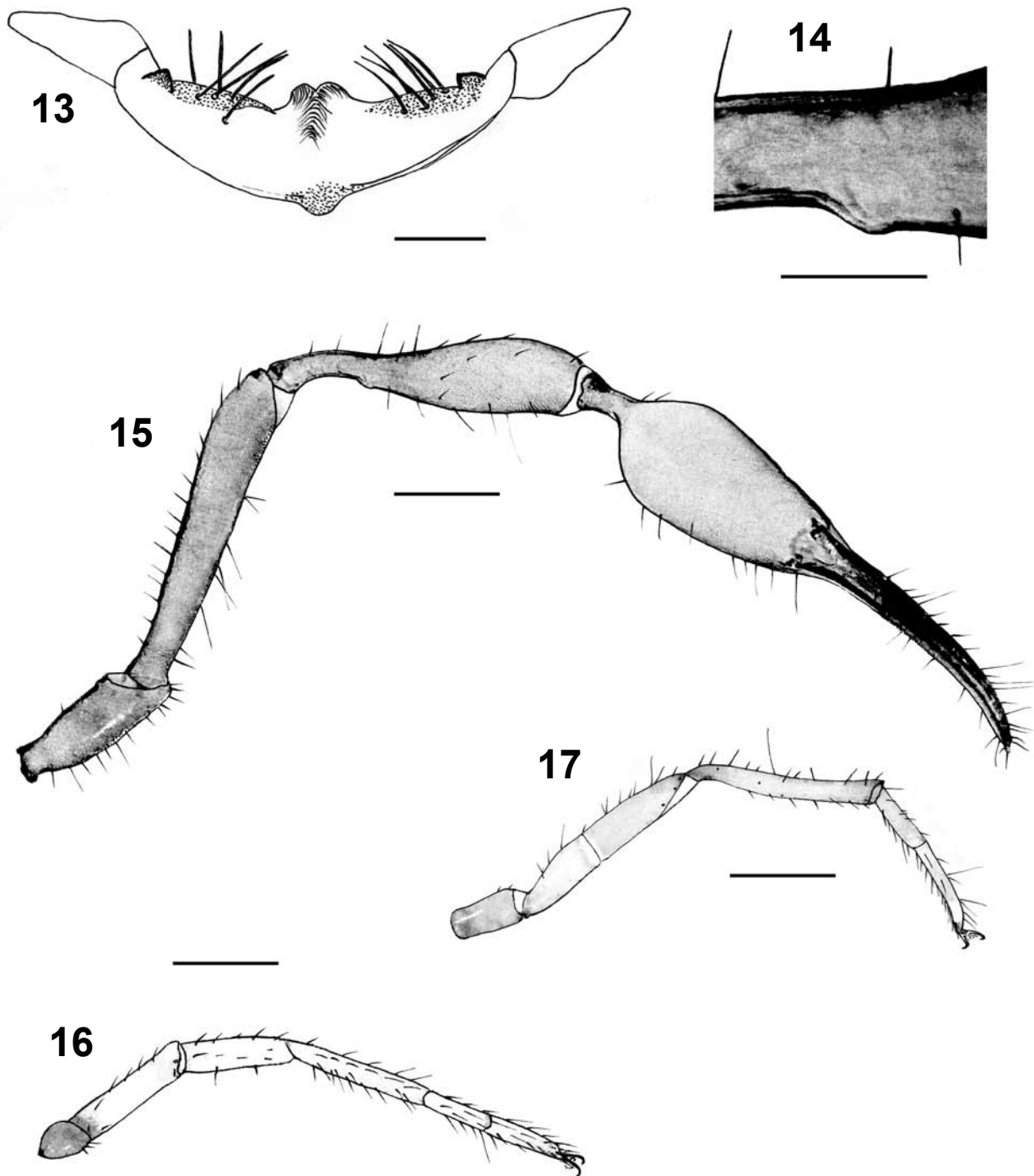
Figures 7-8. Paratype female (TTU-Z 51548) *Parobisium yosemite*, n. sp. from Indian Cave, Yosemite National Park. 7, palp and leg coxae. 8, left palp coxa. Rounded median maxillary lyrifissures (arrows pointing left - see text) and curved posterior maxillary lyrifissures (arrows pointing right). Scale = 0.15 mm.



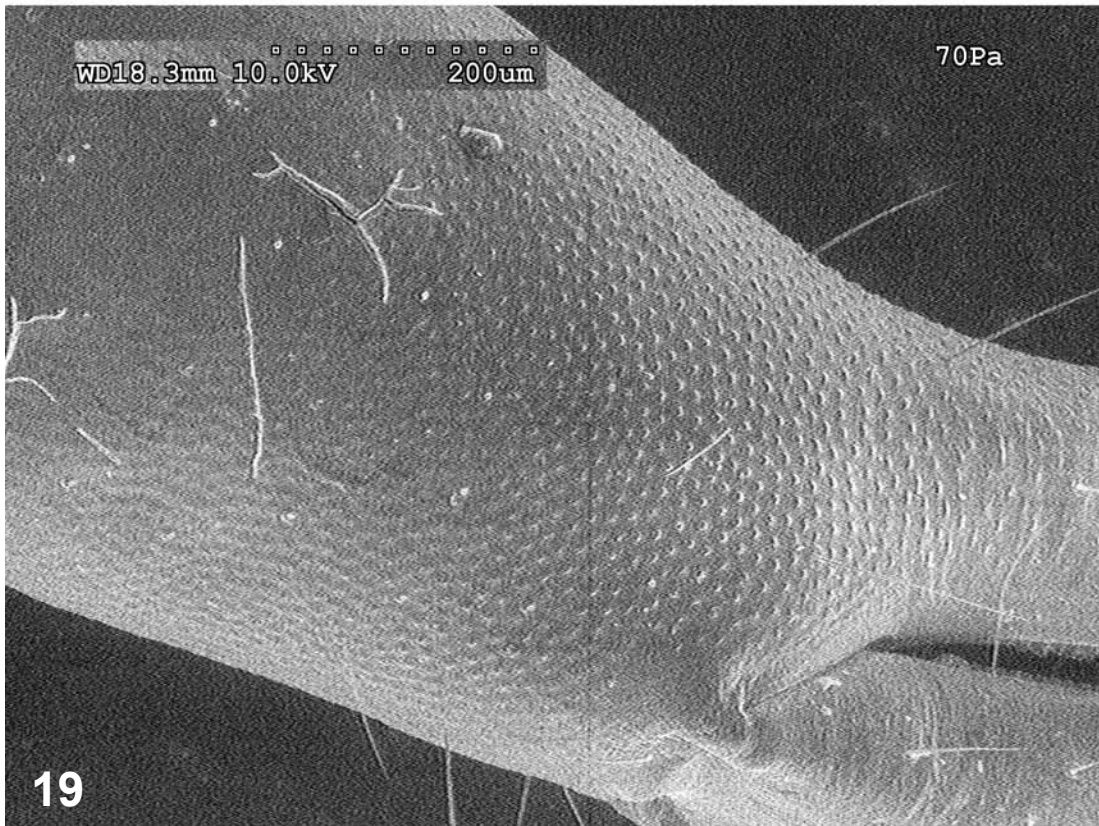
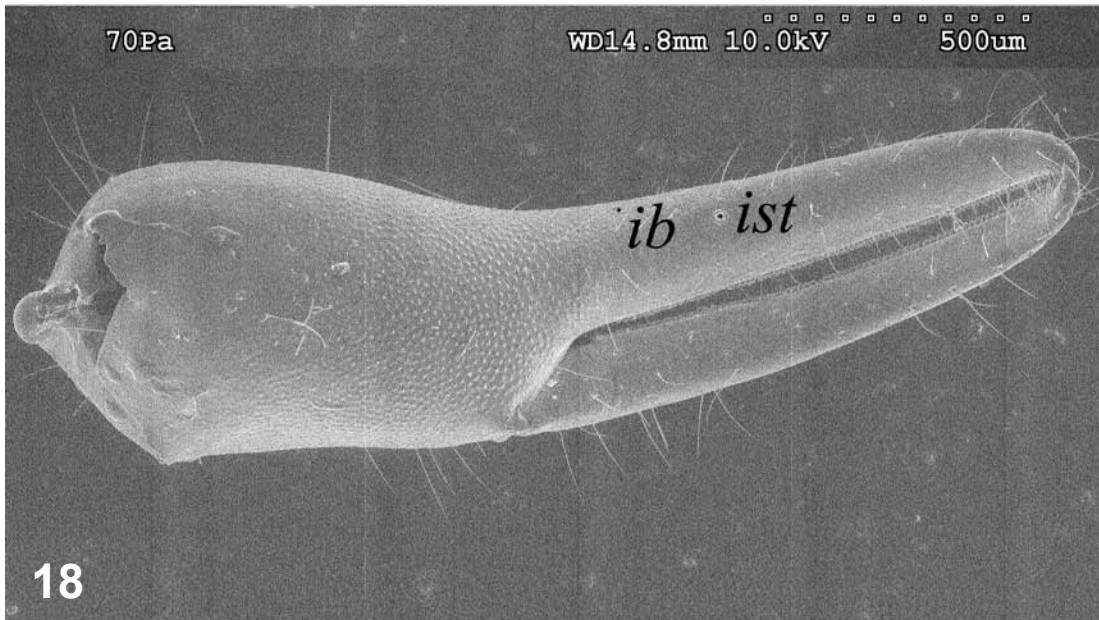
Figures 9-10. Paratype female (TTU-Z 51548) *Parobisium yosemite*, n. sp. from Indian Cave, Yosemite National Park. 9, sternites III and IV with spiracles positions noted with arrows; the trachea are easily visible, pleural membrane granulations indicated by circle. 10, enlarged view of genitalia: 1 = atrium, 2 = left lyrifissure, 3 = left group of seven setae on genital sternite, 4 = series of pores of lateral apodeme, 5 = medium genital sac below the pore covered gonosacs, *la* = part of cribriform plate of the lateral apodeme. Scales, 9 = 0.15 mm, 10 = 0.1 mm.



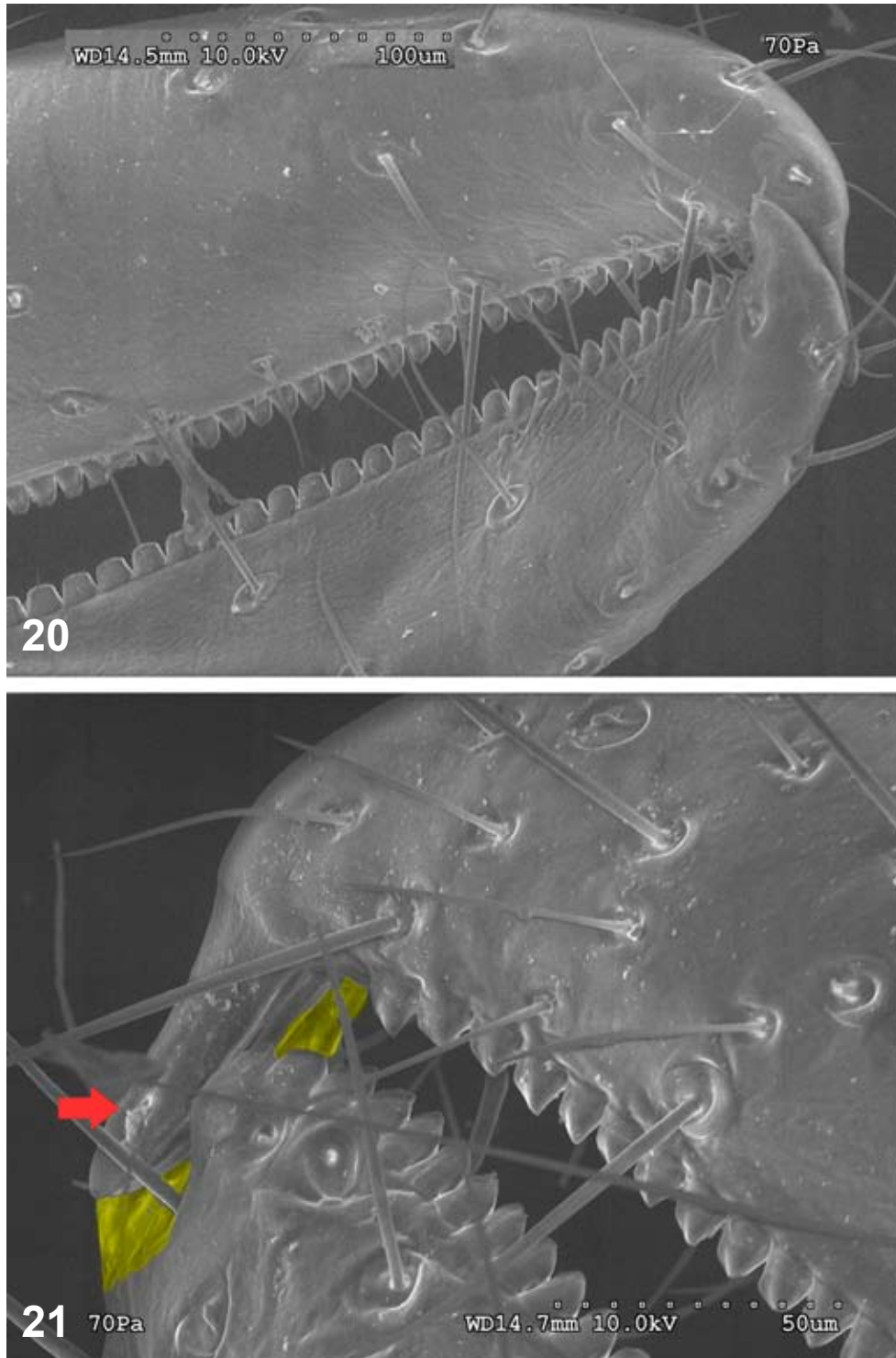
Figures 11-12. *Parobisium yosemite*, n. sp. from Indian Cave, Yosemite National Park (TTU-Z 51528). 11, male genital sternites. 12, paratype female (TTU-Z 51548) genital sternites with seven pairs of setae, arrows point to pair of lyrifissures. Scales, 11 = 0.1 mm, 12 = 0.05 mm.



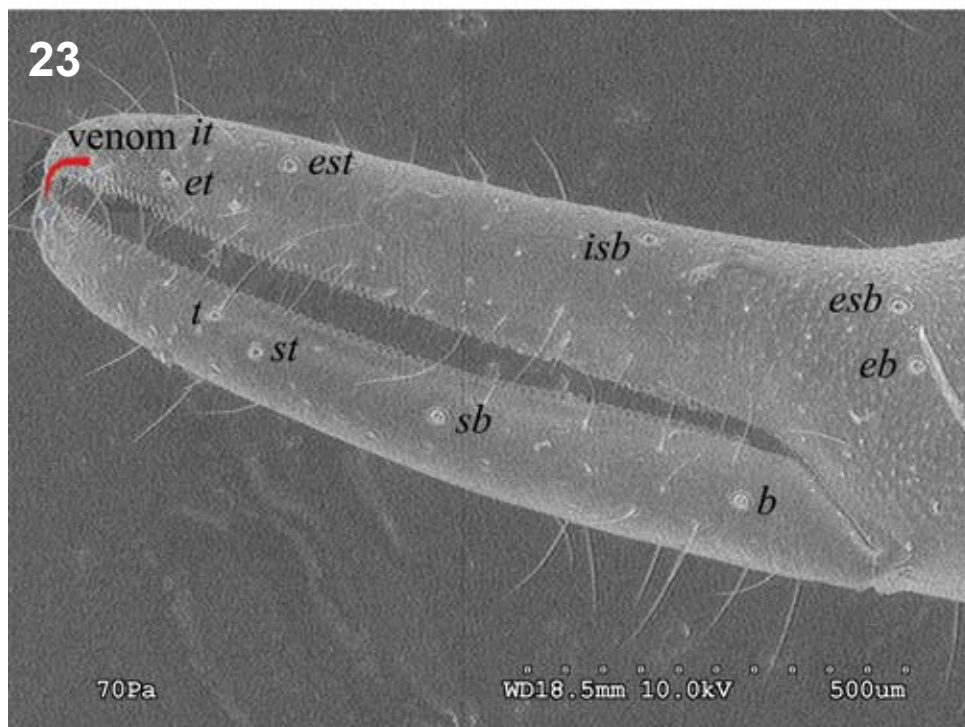
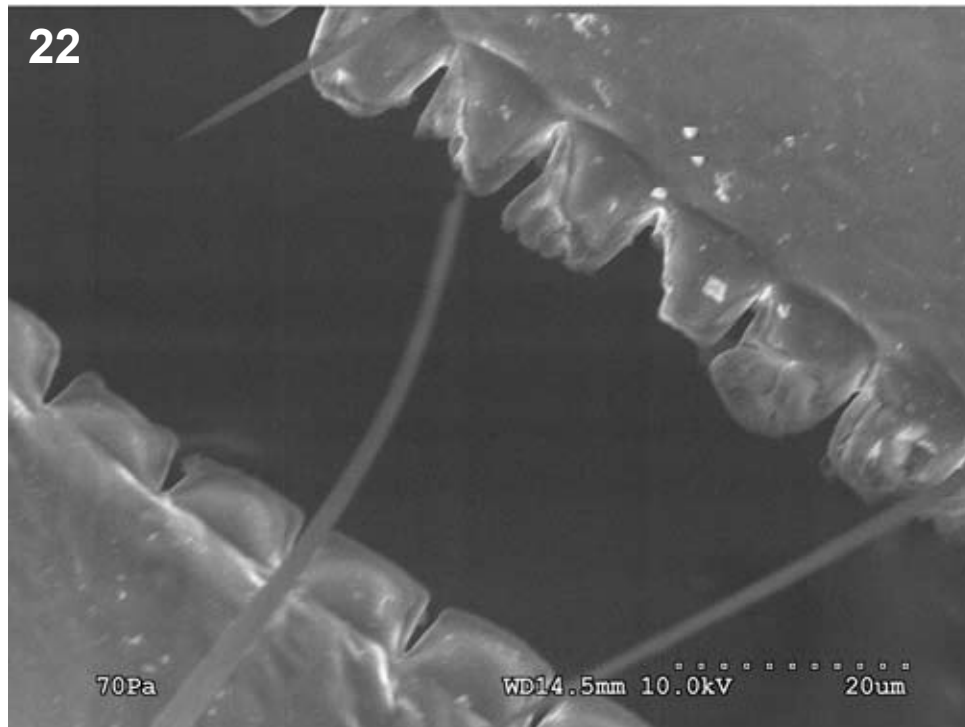
Figures 13-17. *Parobisium yosemite*, n. sp. from Indian Cave, Yosemite National Park. 13, holotype TTU-51528, internal male genitalia (internal piece of genital operculum) with six and seven socketed spines bounded by larger triangular denticles. 14-17 male paratype TTU-Z51576. 14, enlargement of palp patella base showing medial buldge, ventral aspect; 15, palp, ventral aspect; 16, leg I, posterior aspect; 17, leg IV, posterior aspect. Scales, 13 = 0.063 mm, 14 = 0.167 mm, 15-17 = 0.5 mm.



Figures 18-19. Paratype female (TTU-Z 51548) palp chela of *Parobisium yosemite*, n. sp. from Indian Cave, Yosemite National Park. Lateral aspect; 18, basal portion of hand broken off; 19, detail of hand showing granulation.

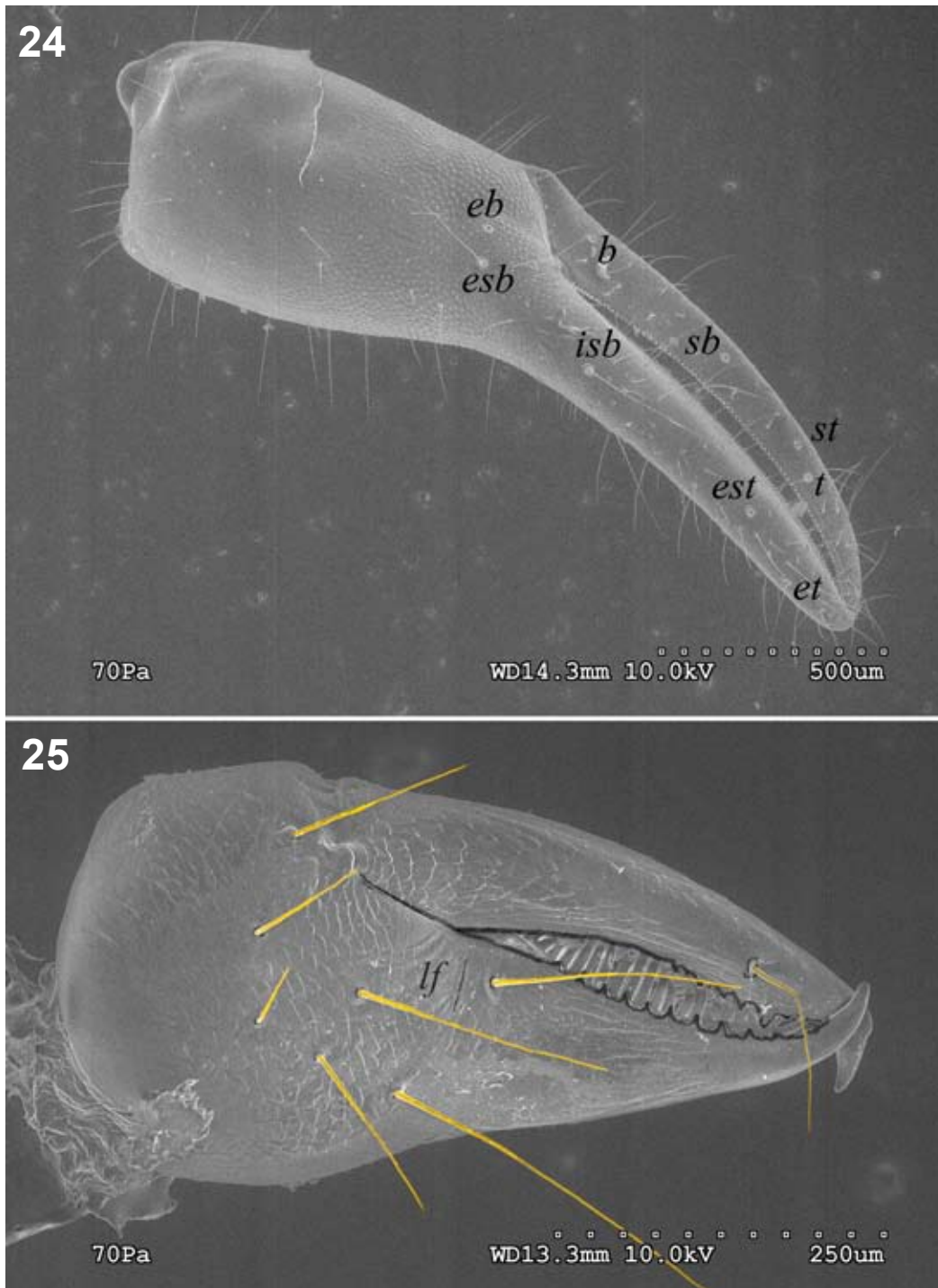


Figures 20-21. Paratype female (TTU-Z 51548) tips of chelal fingers of *Parobisium yosemite*, n. sp. from Indian Cave, Yosemite National Park. 20, lateral aspect; 21, mesal aspect showing longitudinally grooved distal tips (in yellow) and opening to the venom duct (red arrow). Teeth more flattened on moveable (ventral) finger of palp.

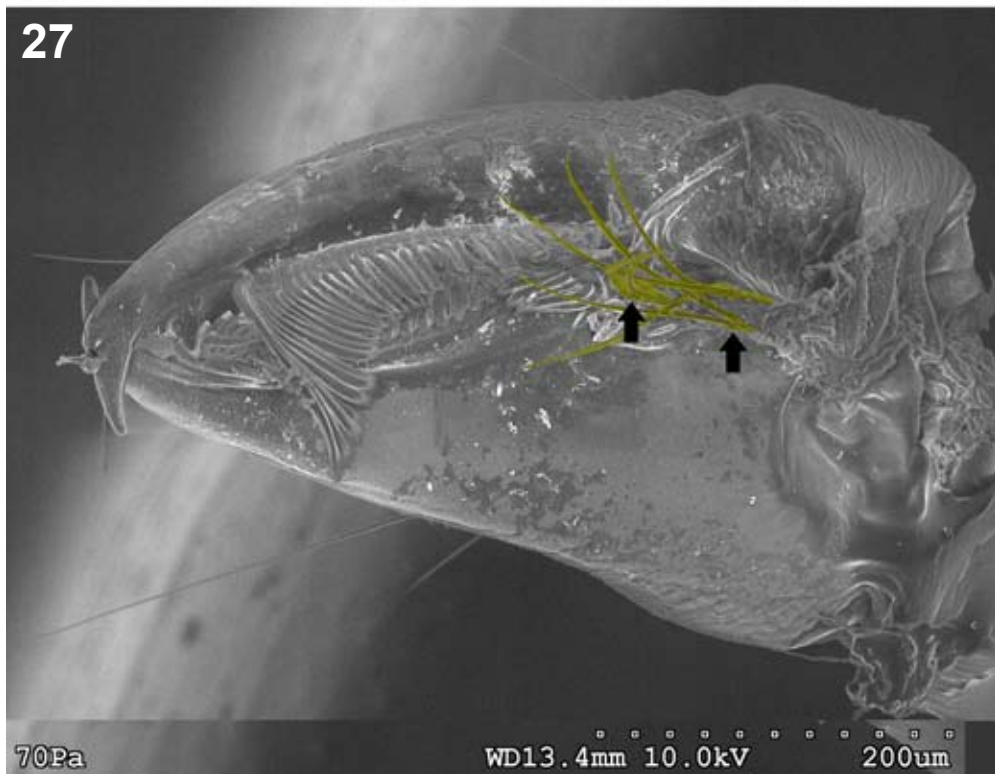
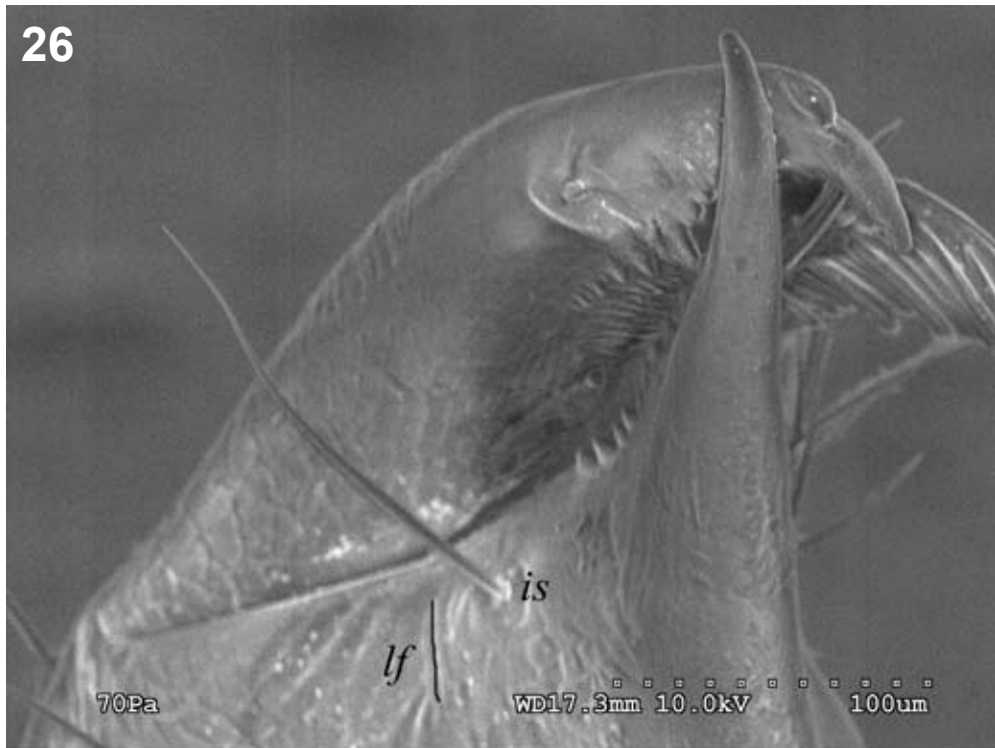


Figures 22-23. Paratype female (TTU-Z 51548) palp chelal of *Parobisium yosemite*, n. sp. from Indian Cave, Yosemite National Park. 22, basal group of macrodenticles of fingers; more flattened on moveable (ventral) finger of palp, upper denticles appear eroded with lateral rows of minute grooves; 23, trichobothria of lateral side; internal position of venom gland drawn in red; granulations of hand also visible.

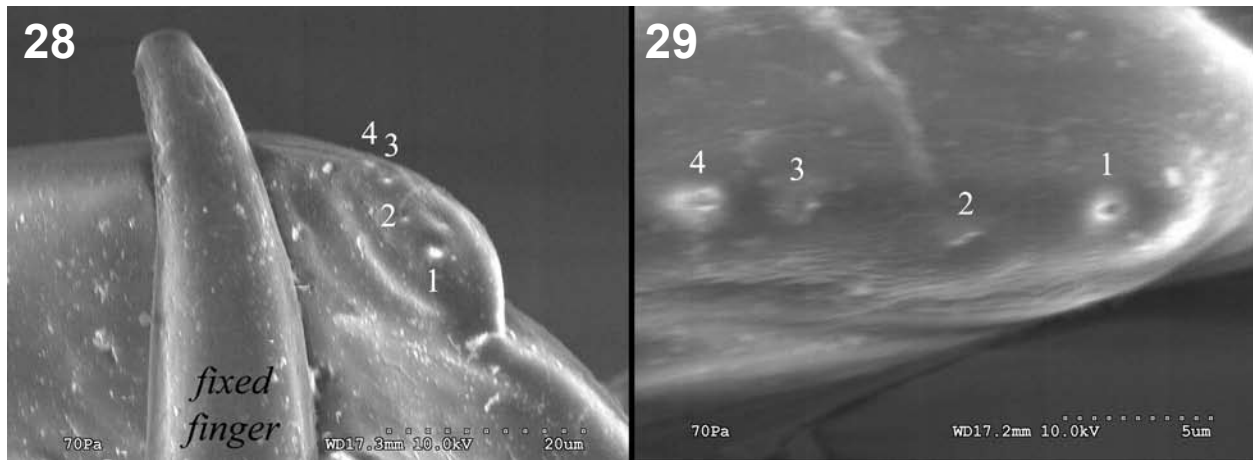




Figures 24-25. Paratype female (TTU-Z 51548) *Parobisium yosemite*, n. sp. from Indian Cave, Yosemite National Park. 24, upside-down view of palp hand (moveable finger should open ventrally), setal positions marked as well as in another view in Fig. 23 (damage to base of chela and basal portion of hand broken off); 25, lateral view of chelicera; seven setae on the hand and a setae on moveable finger are highlighted in yellow, macrodentacles of the fingers as well as the lyrifissure (= *lf*) are also marked.



Figures 26-27. Paratype female *Parobisium yosemite*, n. sp. (TTU-Z 51548) from Indian Cave, Yosemite National Park. 26, lateral view of chela tips; 27, mesal side of chela; five long hirsute filaments (arrow on right), plus three shorter hirsute filaments (arrow on left) in rallum.



Figures 28-29. Galea on moveable finger of chelicera of paratype female (TTU-Z 51548) *Parobisium yosemite*, n. sp. from Indian Cave, Yosemite National Park. 28, lateral aspect with 4 numbered pore positions; depression above 1 does not appear to be a pore; 29, anterior close-up of pores. Pores at 0.6  $\mu\text{m}$  diameter (measured at much higher resolution). Numbers 1, 4 are certainly pores, but the openings are less clear of the depressions at 2 and 3, but likely pores of the galea (spinneret).

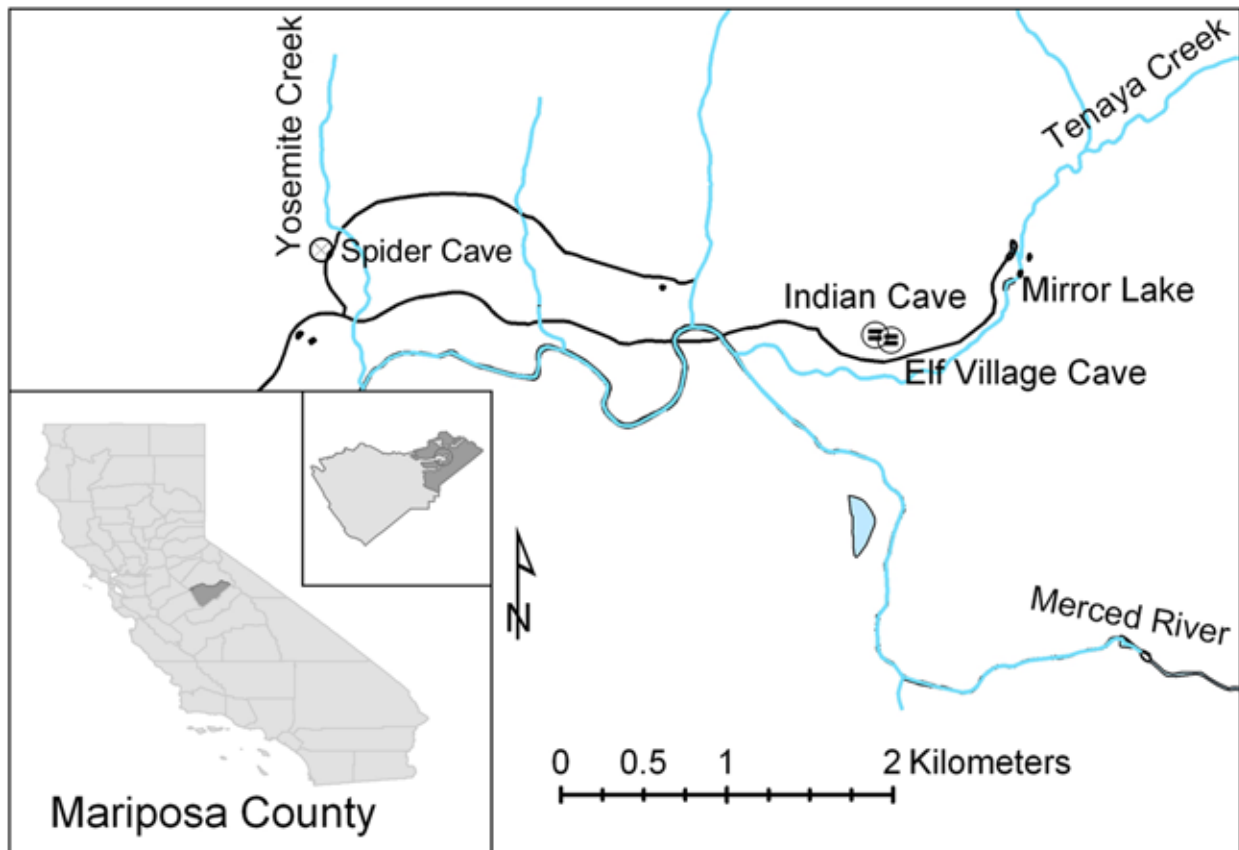
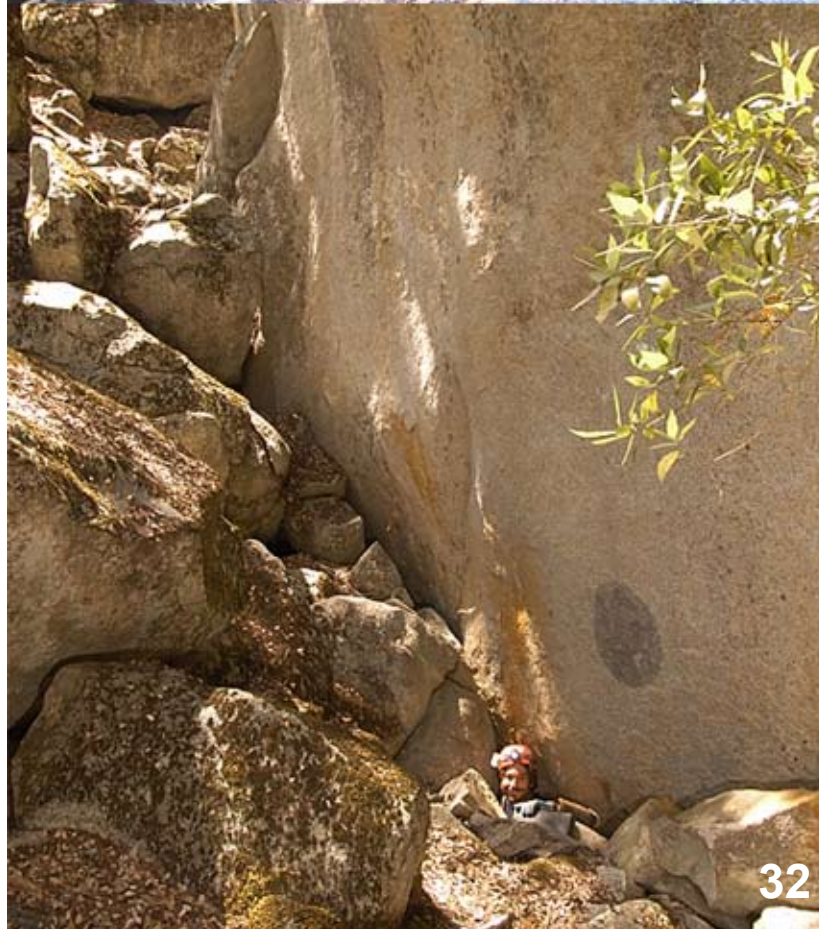
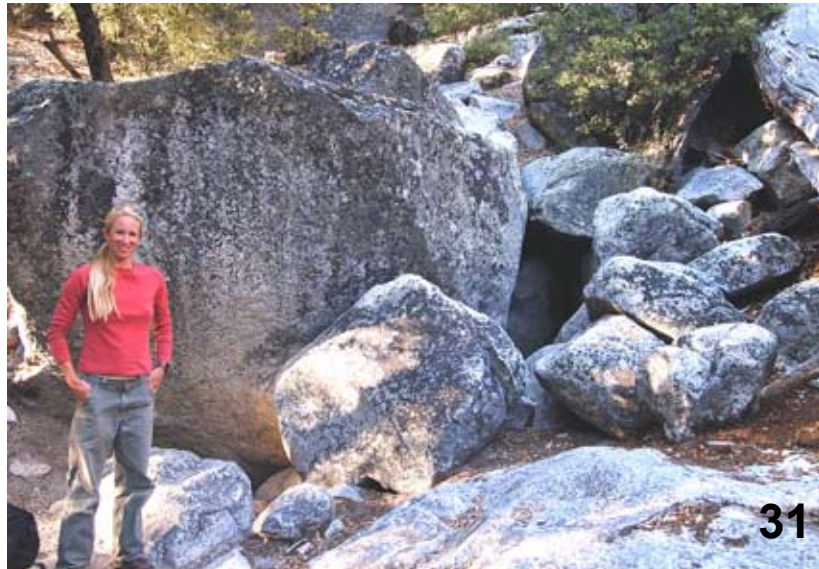


Figure 30. Map of Yosemite Valley and locations of caves in Yosemite National Park; insert is location within California. *Parobisium yosemite*, n. sp. is recorded from Indian Cave and Elf Village Cave. Map by K. McDermid.



Figures 31-32. Entrances to caves in Yosemite National Park which are known to have *Parobisium yosemite*, n. sp. 31, Sarah Stock in front of the double entrances to Indian Cave; 32, G. Robert Myers, III (see middle bottom of picture) in the entrance to Elf Village Cave. Photographs by JKK.

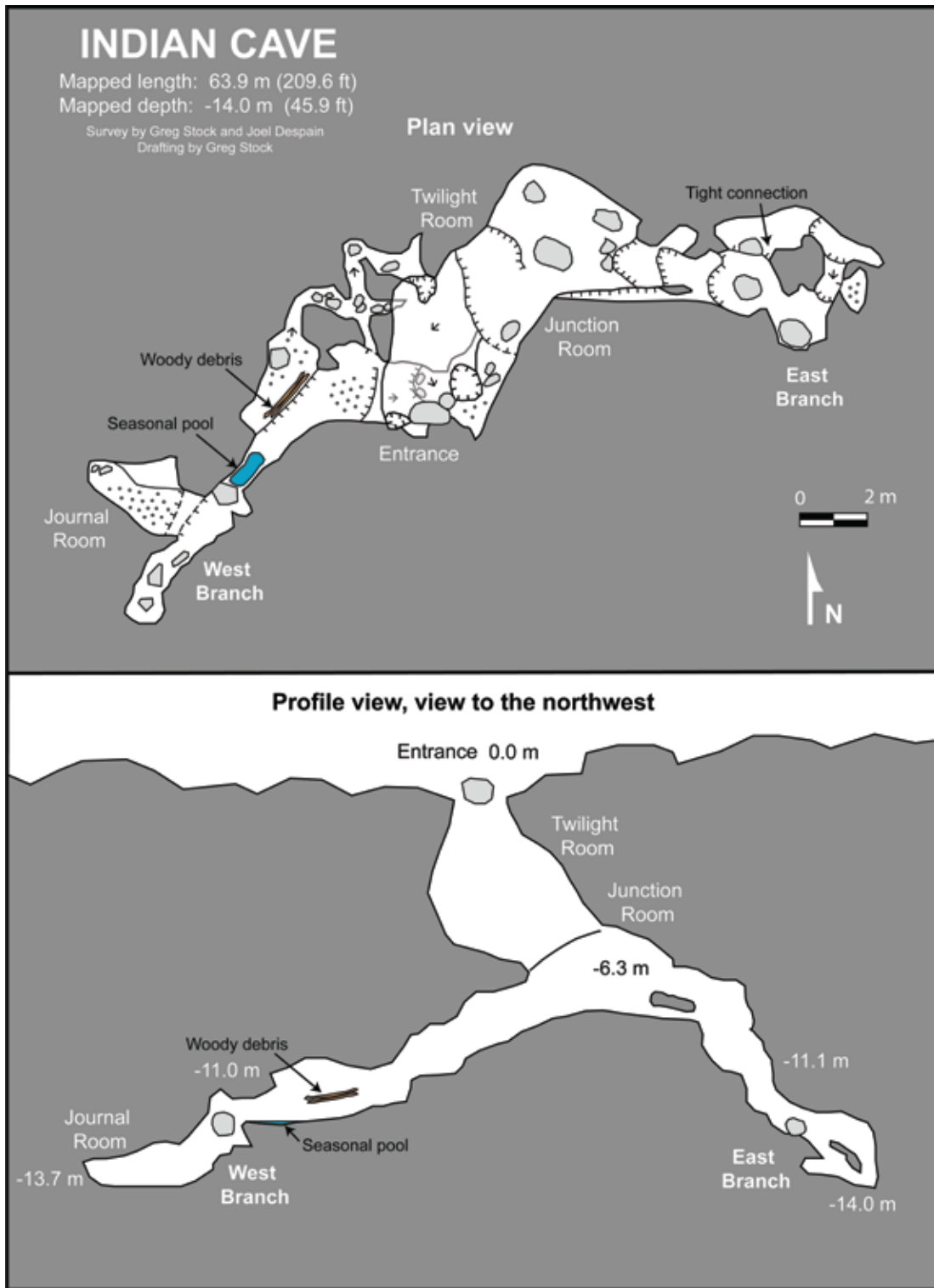


Figure 33. Map of Indian Cave, Yosemite National Park, showing locations mentioned in text. Map by G. Stock.



Figures 34-35. Habitat within Indian Cave, Yosemite National Park, which is the type locality for *Parobisium yosemite*, n. sp. 34, Krista McDermid in the Journal Room with granite boulder walls and ceiling, and smaller granitic rocks on sand and sediment floor with woody debris; 35, Greg Stock in the West Branch at the woody debris. Photographs by JKK and Steven Bumgardner, respectively.

(text continued from page 8)

linyphiid, uloborid, and theridiid spiders. The only item eaten was a small theridiid spider (probably *Theridion*). Pseudoscorpions held in captivity would slowly walk around the dish with palps extended and held open. Whenever they encountered a new potential prey in the container, they would tap the tips of the palps around the animal or appendage. As soon as the animal was touched the pseudoscorpion would retract the palps and change direction of movement. After this first encounter, the pseudoscorpion would not react upon touching the potential prey again and would often just walk over the potential prey. In one case an ant (*Solenopsis invicta*) reacted to the pseudoscorpion and bit and held onto a leg tarsus. The sting had been removed from the ant prior to introduction into the Petri dish.

The ant was dead, but still clinging to the leg when first observed, so it is not certain if the pseudoscorpion tried to eat the ant or visa-versa.

*Ecological Status.*—Extensive searching (>27 person-hours) of similar microhabitats nearby but outside of the granite talus caves where the species was found yielded other pseudoscorpion species but no examples of *Parobisium yosemite*. We searched under rocks, in packrat nests, under bark and in leaf litter using hand collections and Berlese funnel extractions (Zara 2009). While it is impossible to prove absence, this habitat association, combined with the eye loss and propensity for cave-adaptation of pseudoscorpions, lead us to believe this species is troglobitic.

## DISCUSSION

Troglobites are not well documented from talus caves, and this may be the first North American troglobite described from a talus cave, and possibly the first troglobite described from a granitic bedrock region in the world. Terrestrial troglobites are most commonly found in caves formed in calcareous bedrock or lava tubes, however in a few cases researchers described them from other dark, high humidity voids in the subsurface. Researchers found troglobitic fauna in Europe in thick layers of talus covering karstic bedrock, the presumed source of the subterranean fauna (Christian 1987). These voids are described as the “milieu souterrain superficiel” (MSS) (Juberthie et al. 1980), characterized by cracks and fissures in the surface of the bedrock and adjacent talus. The discovery of troglobites in this habitat has led to more extensive searching in the MSS in Europe, and even extended the range for some species beyond areas of calcareous bedrock and into regions of schists (Crouau-Roy 1989). However, there are also MSS species described from Europe from non-karstic MSS (e.g., *Traegaardhia distosolenidia* Zacharda [Zacharda et al. 2010]).

In Australia, troglobites are documented in atypical calcareous bedrock areas including pisolite, calcrete, and also in a (primarily volcanic) greenstone belt (Anonymous 2007, 2008; Barranco and Harvey 2008). In his summary of obligate cave-dwelling fauna of the U.S.A. and Canada, Peck (1998) noted that the

MSS and other similar aquatic habitats are not well explored in North America. In the U.S.A., Slay and Bitting (2007) found the same number of troglobites in mines dug into karstic bedrock as in natural caves, and there are many records of subterranean fauna from other types of voids in karstic rocks such as boreholes and wells.

To our knowledge there is only one other report of a troglobite from a granite talus cave in North America, the pseudoscorpion *Tyrannochthonius troglodytes* Muchmore from central Texas. Muchmore (1986) described this species as cave adapted, though the type locality is from the “twilight zone,” or near-entrance area of the cave with some light and temperature fluctuation, of a granite cave in Llano County, Texas. This granite area in central Texas, with several talus caves, is relatively small and surrounded on all sides by extensive limestone karst (Smith and Veni 1994). The granite area in Yosemite Valley, by contrast, is quite large, with only isolated calcareous bedrock (limestone and marble) being located farther, at least 15 km away. Consequently the likelihood is fairly high that *Parobisium yosemite* evolved in a granite talus setting, to which it is limited, whereas it is less certain that this is the case for *Tyrannochthonius troglodytes*.

It is interesting to consider the immigration and evolution of this troglobite given that these specific

caves were likely formed within the past 1,000 years (Wieczorek et al. 1999). Although it is possible that the species evolved in these most recent caves, more likely they evolved in caves that are now eroded away or buried, and immigrated to the caves that we can access nearer to the surface. In either scenario, the area was glaciated as recently as 15,000-20,000 ybp, indicating this is either a recently-evolved species or one that survived the lastest glaciation of the area, possibly taking refuge in talus slopes above or adjacent to the glaciers. The valley was formed over a million years ago by glacial activity, but none of the more recent glaciers have been as large and therefore talus forming slopes have been available as a habitat for the past million years. Another possibility is that the species invaded after glaciers retreated. Given that *Parobisium yosemite* occurs at two nearby caves in the same talus slope, it is likely that further collecting effort at other caves in this rockfall will yield new localities, and the rockfall area itself (approximately 1.5 km<sup>2</sup>) could be considered the total known range for the species. Even with this liberal definition, however,

its range is relatively small and conservation priority should be given to this species. In these very small passages, substrate compaction (Zara 2009) and small chemical spills (e.g., insect repellent, batteries) could play a large role in habitat.

Research priorities for this narrow endemic species include learning more about the talus cave ecosystem and the biology of the species. For example, what other species occur in the same environment? Are there species associations? Do the cave limited species rely primarily on organic debris carried into the cave via rains or does some other troglone species play a role? In the case of other cave systems, bats or cave crickets are important nutrient carriers, therefore the management of those species is critical for the cave ecosystem. The biology of *P. yosemite* is poorly known. General information on life history, including but not limited to seasonality, longevity, fecundity, population size, temperature and humidity tolerances, prey, and predators, is needed for management and understanding of this interesting species.

#### ACKNOWLEDGMENTS

The National Park Service provided funding for this project and the Yosemite Fund contributed funding to the field work that lead to the discovery of the species. Krista McDermid, George R. (Rob) Myers III, Robert Sas, Greg Stock, and Sarah Stock assisted with the field work. Greg Stock initiated and coordinated the various projects, performing a multitude of tasks ranging from applying for the initial funding to detailing field logistics – his vision about the potential value in these talus caves and motivation to sample them resulted in the discovery of the new pseudoscorpion.

We thank Krista McDermid and Greg Stock for the maps and Steven Bumgardner for help with a photograph. The collections were made under National Park Service permit #YOSE-2009-SCI-0121. We thank the Texas Tech University Imaging Center and Department of Biological Sciences for facilities and guidance to all things related to the Hitachi S-4300SE/N (grant # NSF MRI 04-511). Mark Judson and Steve Taylor are thanked for their helpful comments on a draft of the manuscript.

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