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BRANCHINECTA HIBERNA, A NEW SPECIES OF FAIRY SHRIMP (CRUSTACEA: ANOSTRACA) FROM WESTERN NORTH AMERICA

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ABSTRACT.—*Branchinecta hiberna*, a new species of fairy shrimp, is described from temporary pools in the Great Basin region of south central Oregon, northeastern California, and adjacent Nevada. The new species shares several characters with *Branchinecta cornigera* Lynch, 1958: males bear a similar large patch of small spines on the basal segment of antenna 2, and females bear the similar robust antenna 2 with medial spur, brood pouch shape, and resting egg (cyst) morphology. The new species differs from *B. cornigera* in the shape of the distal segment of antenna 2 and the number and size of spines on the paired penis warts of males, and in the thoracic spine pattern and lack of dorsal cephalic projections in females. Observations on behavior and ecology of *B. hiberna* are discussed.

Key words: Branchinecta, new species, Branchinecta hiberna, Great Basin, fairy shrimp, Anostraca.

The following description presents a new species of *Branchinecta*. This is the 40th species described in this genus, which achieves its greatest diversity in the Americas. Most species occur in vernal pools and other seasonal wetlands in the western United States and in Argentina. One species is reported from the Antarctic (Jurasz et al. 1983), and 6 are reported from Eurasia (Belk and Brtek 1995). This new species is the 24th anostracan reported from California, the 8th from Oregon, and 6th from Nevada.

We each discovered this new species independently. Fugate reared specimens from soil samples collected from the Great Basin regions of Oregon, and Rogers collected live animals from the Great Basin regions of California, Oregon, and Nevada. Several biologists (Coopey 1946, Lynch 1972, C. Hunter personal communication) extensively sampled filled pools in this area, but none reported this species. Fugate sampled filled pools in the area during May 1993 and returned in October to collect soil samples. Rogers collected from filled pools in the area between the end of March and July 1987, 1989, 1990, and 1995 through 1999. Although numerous branchiopods were present April through June, the species described in this paper was not found until soil samples were hydrated in the laboratory or surveys were performed during the final winter months.

METHODS

Dry soil samples were collected in October 1993. Pieces of the top 2–5 cm of soil from the bottoms of dry pools were collected and stored in resealable plastic bags until samples were removed for hydration. Samples of approximately 75 mL dry soil were hydrated with deionized water in 10-L glass aquaria. The aquaria were placed in a 4°C walk-in cold room and aerated vigorously for 24 hours, stirred, and then gently aerated until the shrimp were fully grown. After 24–48 hours, incandescent lights were used to raise the temperature to 13–15°C. Hatching under these conditions normally occurred in 3–5 days. Shrimp were fed with baker's yeast dissolved in deionized water.

We collected live animals from pools in February and March 1998 in the Great Basin Desert regions of California, Oregon, and Nevada from pools that were thawed, partially covered with ice, or covered with a layer of ice or ice and snow. Collections were made with a dip net. Where animals were collected from clear water, we stalked each specimen individually due to the animal's strong avoidance of any disturbance in the water.

MATERIAL EXAMINED

USA. CALIFORNIA, *Lassen Co.*: Tire ruts on Smoke Creek Road, 14 mi E of Hwy 395, 1700

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m elev, 18 March 1999, 9 males, 11 females, D.C. Rogers. Volcanic mud-flow vernal pool, 18 mi E of Hwy 395, 1750 m elev, 18 March 1999, 59 males, 43 females, D.C. Rogers. *Modoc Co.*: Railroad bed pool, Clear Lake Reservoir Road, 100 m E of Hwy 139, 1800 m elev, 9 March 1998, 18 males, 14 females, D.C. Rogers. Railroad bed pool, Clear Lake Reservoir Road, 100 m E of Hwy 139, 17 March 1998, 78 males, 76 females, D.C. Rogers. Railroad bed pool, Clear Lake Reservoir Road, 100 m E of Hwy 139, 26 March 1998, 1 male, D.C. Rogers. Mud-flow temporary pool along Harvey Buttes Road, 3 mi W of Harvey Lake, 1800 m elev, 17 March 1998, 39 males, 56 females, D.C. Rogers. Volcanic mud-flow vernal pool, Harvey Buttes Road, 3 mi W of Harvey Lake, 1800 m elev, 3 mi west of Harvey Lake, 17 March 1998, 23 males, 34 females, D.C. Rogers. Volcanic mud-flow vernal pool, Harvey Buttes Road, 2 mi E of Harvey Lake, 1800 m elev, 17 March 1998, 13 males, 13 females, D.C. Rogers. Volcanic mud-flow vernal pool, Tucker Buttes Road, 3 mi E of Harvey Lake, 1800 m elev, 17 March 1998, 32 males, 31 females, D.C. Rogers. Volcanic mud-flow vernal pool, Tionesta Road, Perez, 0.25 mi W of Hwy 139, 1750 m elev, 17 March 1998, 12 males, 14 females, D.C. Rogers. Volcanic mud-flow vernal pool, 2.5 mi N of Big Sage Reservoir, 1750 m elev, 17 March 1998, 2 males, 3 females, D.C. Rogers. NEVADA, *Washoe Co.*: Vernal pool, SSR 8A (Hwy 299 in California), Surprise Valley, near the base of Fortynine Mountain, 1850 m elev, 17 March 1998, 3 males, 2 females, D.C. Rogers. OREGON, *Harney Co.*: Temporary pool 10 km S of Riley, Hwy 395, 43°27'54"N, 119°33'39"W, 16 April 1999, 1 male, R.E. Hill. Temporary pool 15.6 km S of Riley, Hwy 395, 16 April 1999, 1 male, R.E. Hill. Temporary pool 15.6 km S of Riley, Hwy 395, 16 April 1999, 3 males, 2 females, R.E. Hill. *Lake Co.*: Temporary pool (~0.2 ha) on the south side of Squaw Butte, bisected by OR 31, 2 km N of Carlon Rd (43°02'N, 120°47'W), soil samples collected October 1994, M. Fugate. Temporary pool (0.02 ha), 13 km W of US 395, 0.5 km N of XL Ranch Rd (42°47'N, 120°21'W), soil samples collected October 1994, M. Fugate. Large temporary pool (~0.2 ha), 5 km E of US 395, 0.2 km N of Hogback Rd (42°43'N, 120°03'W), soil samples collected October 1994, elev, 1300–1500 m, M. Fugate.

Branchinecta hiberna n. sp.

(Figs. 1–3)

TYPES.—Holotype, male, data: CALIFORNIA, *Modoc Co.*: Modoc Plateau, volcanic mud-flow temporary pool, 1530 m, 17 March 1998, D.C. Rogers, deposited: California Academy of Sciences, San Francisco, CAS type no. CASIZ 119132. Allotype, female: same data as holotype. Paratypes: same data as holotype, 10 females, 10 males, deposited: California Academy of Sciences, San Francisco, CASIZ 119133. Paratypes: same data as holotype, 2 females, 2 males, deposited: National Museum of Natural History, Washington, D.C., USNM 268594; 10 females, 10 males, deposited: DCR collection; 2 females, 3 males, deposited: collection of Denton Belk; 10 females, 12 males, deposited: collection of Richard Hill; 2 females, 2 males, deposited: Bohart Museum of Entomology, Davis, California.

TYPE LOCALITY.—The type locality is a volcanic mud-flow temporary pool (sensu Holland and Jain 1977) approximately 2 km north of Clear Lake Reservoir Road and 200 m east of Harvey Buttes Road, Modoc County, California. The area lies west of Clear Lake Reservoir, east of Hwy 139, and southeast of the community of Tule Lake. This pool is at an altitude of 1530 m on the Modoc Plateau. The pool, approximately 300 m² in size, generally inundates in November and dries in May. From the end of November through March the pool is frozen and under a few inches of snow. The pool has a grassy bottom with numerous volcanic rocks that project from the water. Surrounding uplands are dominated by *Artemisia* sp., annual grasses, and *Juniperus occidentalis* var. *occidentalis*.

ETYMOLOGY.—The species name is from the Latin word for winter, *hibernum*, and refers to the animal's late-winter activity period. Gender is masculine.

DIAGNOSIS.—*Male*: Basal segment of 2nd antenna with a ventrally directed medial bulge bearing small, scattered spines at distal end (Fig. 1A). Basal segment directed anteroventrally with distal half bent ventrally (Fig. 1B). Apophyses absent. Pulvilli ridgelike, lying at bases of 2nd antennae and directed medially. Distal 2nd antennal segment less than 1/3 length of basal segment. Distal segment flattened laterally, directed medially, with apex bent medially ~30° (Fig. 1D). Medial surface

of distal segment with patch of small spines. Anterior surface of base of distal 2nd antennal segment with patch of spines. Basal segments of 2nd antennae and labrum covered with fine spines. Genital segment with single ventrolateral conical protuberance on each side. Everted penes elongated, extending to the 3rd postgenital abdominal segment (Fig. 2A). Apices of everted penes bearing 2 dorsal wartlike mounds, each bearing 10–15 recurved spines about 1/3 as long as wartlike mound (Figs. 2B, C). Penes with a single medial basal spine

each. Endopodites ovate-triangular. Epipodite truncate (Fig. 2D).

Female: Distal 1/3 of basal segment of 2nd antenna bearing a stout, ventrally directed, medial spur. Thirty-three percent of females with an apical, anterolateral, hemispherical bulge covered in small spines on 2nd antenna (Fig. 1C). Distal end stout, medially curved, and apically acute. First antenna 60% length of 2nd antenna. Head without dorsal protuberances. Thorax with paired conical dorsolateral lobes on segments 3 and 5 or 6 through segments 10

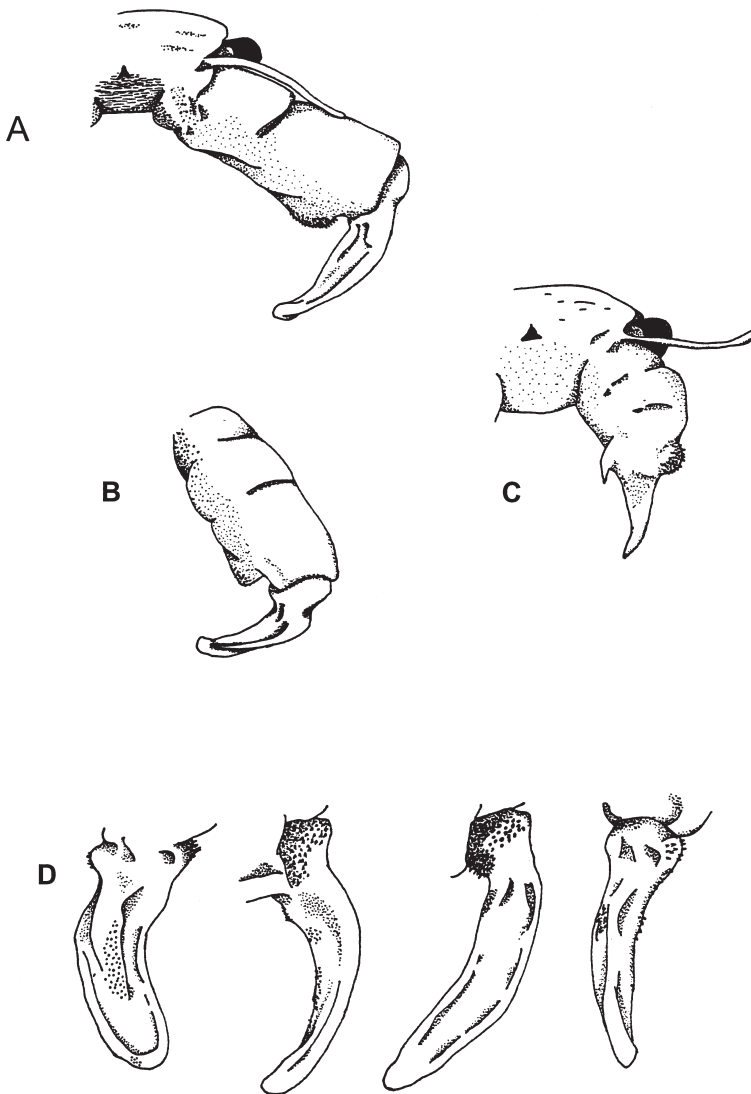


Fig. 1. *Branchinecta hiberna* n. sp. types: A, male, left side of head, anterior view; B, male, left 2nd antenna, anterolateral view; C, female, left side of head, anterior view; D, distal segment of left 2nd antenna of male, from left to right: medial view, anterior view, lateral view, posterior view.

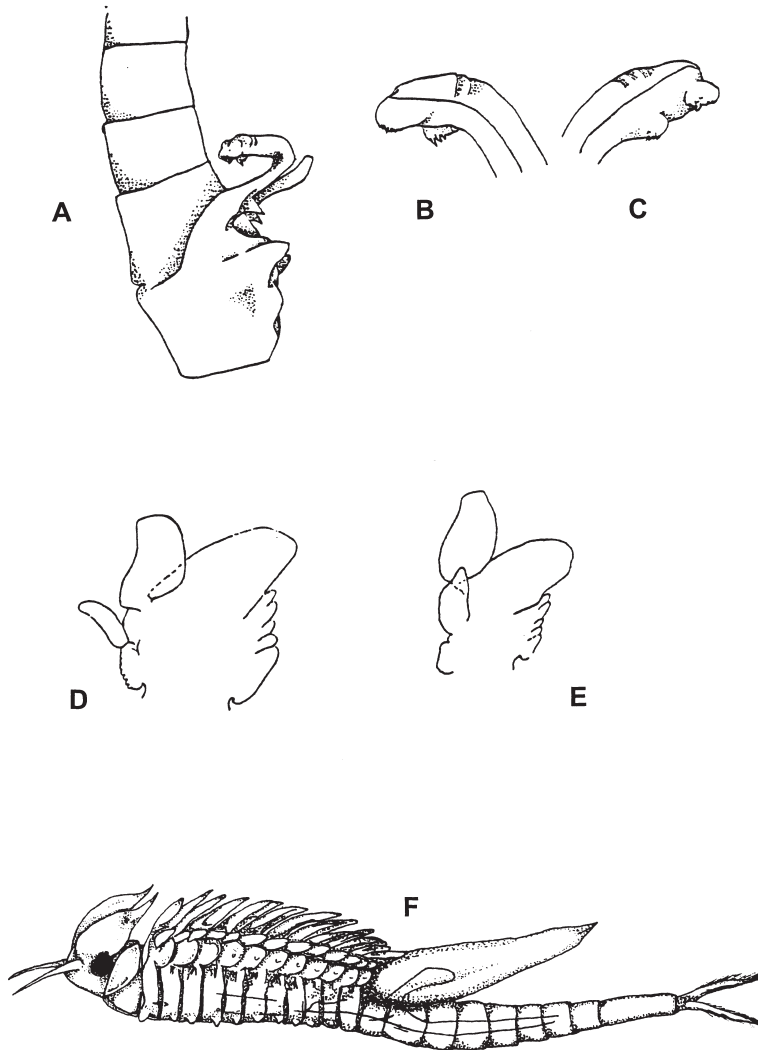


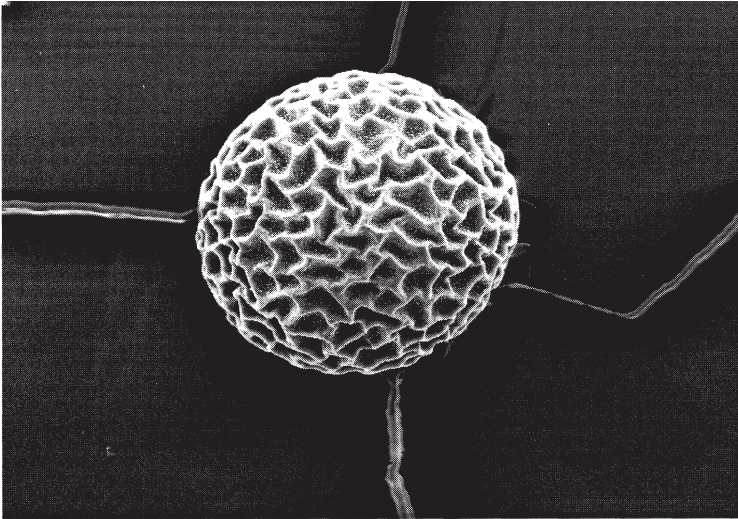
Fig. 2. *Branchinecta hiberna* n. sp.: A, male, penes everted; B, detail of apex of left pene, lateral view; C, detail of apex of left pene, medial view; D, endopodite of male of thoracic segment 5 (setae not shown); E, endopodite of female of thoracic segment 5 (setae not shown); F, allotype, lateral view.

or 11. Fourth thoracic segment bearing a single conical dorsolateral lobe on each side. Thorax bearing lateral hemispherical lobes on segments 3 through 9 or 11 (Fig. 2F). Ovisac fusiform, extending to postgenital abdominal segment 5 or 6. Endopodites ovate (Fig. 2E). Epipodite ovate. Seventeen percent of living females yellow-gold in color compared to typical off-white of other *Branchinecta* sp. and remaining 83%.

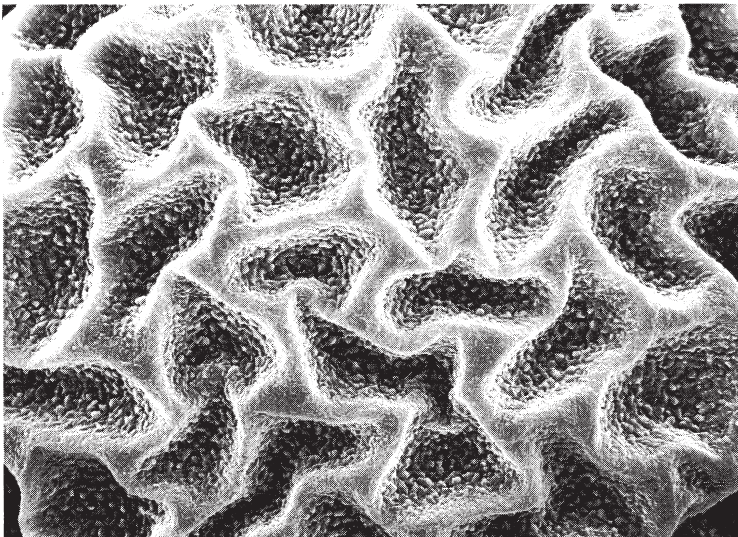
Resting egg: Desiccation-resistance cysts spherical, diameter approximately 250 μ m,

with angular, oval surface depressions, diameter 20 μ m, some depressions joined (Fig. 3).

COMPARISONS.—Male *Branchinecta hiberna* are separated from all other reported *Branchinecta* species by the presence of the ventrally directed medial bulge on the medial surface of the proximal segment of the 2nd antennae. Male *B. hiberna* most closely resemble *B. cornigera* Lynch, 1958; however, the distal segments of the 2nd antenna of *B. cornigera* males are nearly parallel sided and have acute apices. The everted penes of *B. hiberna* extend to the

**A**

Branchinecta hiberna n.sp.
Cyst from Squaw Butte,
Lake Co. OR.

**B**

Branchinecta hiberna n.sp.
Detail of Cyst

Fig. 3. *Branchinecta hiberna* n. sp.: A, cyst; cyst diameter = 250 μm ; Squaw Butte, Lake County, OR; B, detail of cyst surface; polygonal depressions average width = 20 μm .

3rd postgenital segment, whereas in *B. cornigera* the everted penes extend only to the 2nd postgenital segment. Similarly, the endopodites of *B. cornigera* are sickle shaped while those of *B. hiberna* are triangular. *Branchinecta hiberna* and *B. cornigera* share the large patch of small spines on the proximal segment of antenna 2, and the abbreviated length of the distal segment of antenna 2.

Branchinecta hiberna and *B. cornigera* females share the robust antenna 2 with medial spur, brood pouch shape, and bright coloration. Female *B. hiberna* are separated from *B. cornigera* Lynch, 1958 by the lack of transverse corneous projections at the sides of the head dorsal to the maxillary glands and by the arrangement of dorsolateral lobes. Female *B. cornigera* have dorsolateral lobes on segments

6 through 11. Female *B. hiberna* are separable from *B. pollicifera* Harding, 1940 by the lack of dorsomedial cleft thoracic projections. Female *B. hiberna* are separated from all other reported *Branchinecta* species by the presence of the subapical, medial spur on the basal segment of the 2nd antennae. Many (33%) *B. hiberna* females also bear an apical, anterolateral spinose bulge on the basal segment of 2nd antenna as does *B. cornigera*; however, this bulge is many times larger in *B. hiberna*. The resting cysts of both *B. cornigera* and *B. lynchi* have angular surface depressions but tend to be more circular than oval and have larger diameters (30–60 μm).

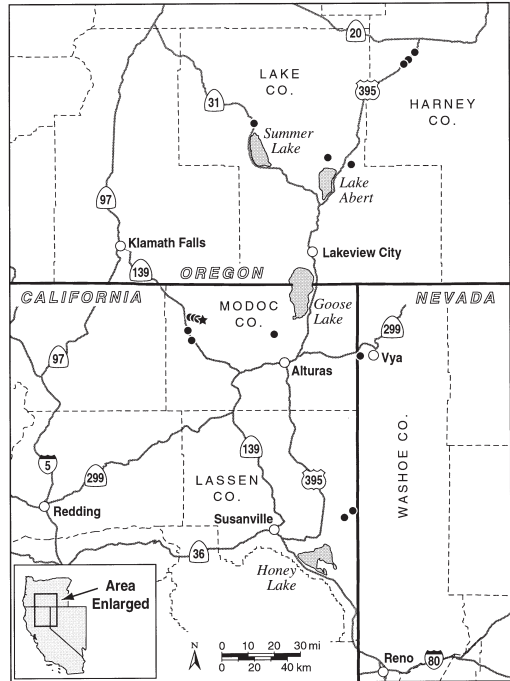
DISTRIBUTION AND HABITAT.—*Branchinecta hiberna* has been collected from south central Oregon, northeastern California, and adjacent Nevada (Fig. 4). Collection sites tend to be high-desert volcanic mud-flow vernal pools with clear or highly turbid water. *Branchinecta hiberna* was also collected from railroad bed toe-drains and roadside ditches, some as small as 0.15 m².

Populations were found throughout the Modoc Plateau from Lava Beds National Monument to Clear Lake Reservoir, and from the city of Tule Lake to the Skedaddle Mountains, north of Honey Lake in Lassen County, California. In some locations on the Modoc Plateau, *B. hiberna* was collected from pools covered with 0.5 to 2.5 cm of ice and 3.0 cm of snow. Pools ranged in size from 250 m² to 500 m².

Two of the Oregon populations are located north of Lake Abert within the boundaries of Pleistocene Lake Chewaucan, which dried approximately 10,000 years ago. Summer Lake and Lake Abert form the modern remains of the previously 1200-km² lake. A 3rd Oregon population was reared from soil collected below Squaw Butte, north of Summer Lake. All collection locations in Oregon are from Lake and Harney counties.

One population was found in Nevada on the south side of SSR 8A (Highway 299 in California) in Surprise Valley at the base of Forty-nine Mountain in Washoe County.

BEHAVIOR.—*Branchinecta hiberna* displayed a strong predator-avoidance response in the field. In pools with low turbidity and without ice, *B. hiberna* would quickly dart away from any disturbance in the water or at the surface. During the initial darting the animal would move as much as 1 m away and to the pool



● = *Branchinecta hiberna* n. sp. occurrence
★ = *Branchinecta hiberna* n. sp. type locality

Fig. 4. Distribution of *Branchinecta hiberna* n. sp. Star indicates type locality.

bottom. The animal would then swim quickly in a zig-zag pattern through the vegetation for another 0.5 m, always staying near the bottom. If there were no further disturbances, the animal would rise to mid-water and swim normally. In habitats that were covered with ice, the animals were slightly sluggish, yet still quickly swam from any disturbance.

DISCUSSION.—Hatching and rearing of branchiopod crustaceans from the dry soil of temporary pools often has been employed to reveal new species (e.g., Baird 1861, Brauer 1877, Sars 1896a, 1896b, 1898a, 1898b, Barnard 1928, Harding 1940). This technique is invaluable since pools are dry for most of the year and are often inaccessible when filled due to ice, mud, or snow. Barnard (1928) endorsed this technique: "This is an extremely valuable method of collecting, and no opportunity of collecting samples of mud should be neglected."

Branchinecta hiberna hatches sometime during the winter. In culture, hatching occurred soon after cysts were hydrated at 4°C, giving

no indication of a pre-hatching phase as Broch (1965) reported for *Eubranchipus bundyi* Forbes, 1876. *Branchinecta hiberna* appears to be univoltine but may have successive emergences in the event of subsequent thaws and refreezings. One frozen-over railroad toe-drain pool had no identifiable invertebrates on 28 February 1998. On 9 March 1998 the same location had, under ice and snow, numerous immature *B. hiberna* co-occurring with immature *Eubranchipus* and calanoid copepods. By 17 March 1998, *B. hiberna* females were actively shedding their cysts, while *Eubranchipus*, now identifiable as *E. serratus*, did not yet have cysts in their brood pouches, and many immature *B. dissimilis* were present, as were some aquatic insects, calanoid copepods, cladocera, and small *Lepidurus* sp. On 27 March 1998, *B. dissimilis* was present in large numbers, while only a single male *B. hiberna* and 8 male and female *E. serratus* were recovered after an hour of searching. On 10 April 1998 only *B. dissimilis* was present.

Shorebirds and ducks were observed in playas and sage flat wetlands near active *Branchinecta hiberna* populations and may be predatory on *B. hiberna*. However, no birds were observed on any wetlands as small as those from which *B. hiberna* was collected. Predaceous diving beetles (Dytiscidae), water scavenger beetles (Hydrophilidae), water crawling beetles (Haliplidae), and backswimmers (Notonectidae) were all present in *B. hiberna* habitat in low numbers when females were shedding their eggs and only appeared in larger numbers after *B. hiberna* had disappeared from the pools. *Branchinecta hiberna* was found co-occurring in pools with the fairy shrimps *Eubranchipus serratus* Forbes, 1876, *Branchinecta gigas* Lynch, 1937, and *Branchinecta dissimilis* Lynch, 1972; the tadpole shrimp *Lepidurus lemmoni* (Holmes), 1952 and *Lepidurus* sp.; and the clam shrimp *Lynceus brachyurus* Müller, 1776.

Branchinecta hiberna's short life cycle, strong disturbance-avoidance response, and activity period under ice may all serve as protection from predators and competitors, and may also explain why this species escaped detection for so long on the Modoc Plateau.

The presence of a medial spur on the 2nd antennae of *B. hiberna* and *B. cornigera* in North America and *B. pollicifera* in South

America suggests a relationship between these 3 species. Since *B. pollicifera* is quite morphologically distinct from other living *Branchinecta* (female with large, cleft thoracic processes, male with 2 basal spines on the penes versus 1, and an apophysis-like structure extending posteriomedially from the distal end of the basal segment of the 2nd antenna [Harding 1940]) and bears certain similarities to fossil *Branchinecta* (Belk and Schram in press), this 2nd antennal spur may be pleisiomorphic.

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