PROCEEDINGS OF THE BIOLOGICAL SOCIETY OF WASHINGTON
109(1):103–111. 1996

A new copepod species from California, U.S.A.: *Hesperodiaptomus californiensis* (Crustacea: Copepoda: Calanoida: Diaptomidae)

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Abstract.—*Hesperodiaptomus californiensis,* new species (Copepoda: Calanoida: Diaptomidae) was collected from vernal pools in Lassen County, northern California, U.S.A. It differs from its three most morphologically similar congeners, *Hesperodiaptomus schefferi, Hesperodiaptomus victoriaensis* and *Hesperodiaptomus kiseri* in having both leg 5 endopods of the male relatively long, the left lateral protrusion on the genital double somite of the female directed dorsally, and in other details. Co-occurring diaptomids were *Hesperodiaptomus novemdecimus* and *Leptodiaptomus tyrrelli.*

A new species of diaptomid copepod was collected in Lassen County, California, as part of a study of vernal pools (described by King et al. 1996). The new copepod occurred in three pools and at the time of collection was abundant in every pool.

Wilson (1959) listed 16 species of *Hesperodiaptomus* in North America; since then no new species has been recognized from this continent. However, the taxon *Hesperodiaptomus arcticus* (Marsh, 1920) s.l. may be composed of several cryptic species. Boileau & Hebert (1988) and Boileau (1991) found genetic differences between different North American populations of *H. arcticus,* which were accompanied by subtle morphological differences. On the other hand, Stepanova (in Borutskii et al. 1991) rejected efforts by Streletskaya (1983, 1986) to split Siberian *H. arcticus* into three taxa: *H. koolensis* Streletskaya, 1983, *H. judayi* Streletskaya, 1986 and *H. kurenkovi* Streletskaya, 1986, because of the supposedly minor degree of morphological differences.

Some other members of *Hesperodiaptomus* are so similar morphologically that the females cannot be reliably assigned to a particular species with present knowledge. These possible species complexes are *H. breweri* (Wilson, 1958a), *H. eiseni* (Lilljeborg in Guerne & Richard, 1889), and *H. arcticus*; as well as *H. kiseri* (Kincaid, 1953) and *H. victoriaensis* (Reed, 1958). The high degree of morphological similarity between *H. kiseri* and *H. victoriaensis* creates some difficulty in establishing the species from California as a new taxon, because it shares several characters with both these species.

Hesperodiaptomus species and other diaptomid copepods are characterized classically by the features of the fifth legs of the males and females, the right antennule of the male and setation of the left antennule of the male and both antennules of the female, and features of the somites, particularly the shape of the thoracic "wings" (expansions of the sixth thoracic somite). Pending eventual revision of the genus *Hesperodiaptomus* and the possible discovery of additional morphological and genetic characteristics, we describe the new species using these traditional discriminators.

The copepod specimens were originally fixed in buffered formalin and transferred to 70% ethanol for long term storage. Field sampling methods were described by King et al. (1996). Descriptions were made from whole specimens in glycerin and/or lactic acid; dissected specimens were mounted either in CMC-10 or in commercial polyvinyl lactophenol with a little Chlorazol Black E added. All measurements were made from specimens in glycerin. Specimens were deposited in the collections of the United States National Museum of Natural History, Smithsonian Institution (USNM) and the Natural History Museum of Los Angeles County, California (LACM).

Family Diaptomidae G. O. Sars
Genus *Hesperodiaptomus* Light, 1938
Hesperodiaptomus californiensis, new species
Figs. 1–3

Type material.—Holotype ♂, USNM 264057; allotype ♀, USNM 264058; paratypes: 3 ♂♂ 3 ♀♀, each dissected on slide in PVL or in CMC-10, and 464 ♂♂ ♀♀ + copepodids, USNM 264059; 463 ♂♂ ♀♀ + copepodids, LACM 95-50.1; all from California, Lassen County, pool #41, 40°37′N, 121°03′W, immediately adjacent to west side of Route 44, 1.4 km north of Bogart Safety Rest Area/Ranger Station, 2 m tow of wet meadow edge with plankton net, sample 215.

Additional, non-type material.—372 ♂♂ ♀♀ + copepodids, California, Lassen County, pool #42, 40°32′N, 121°0′W, 30 m west of Route 44, just south of railroad track crossing, 2 m tow of wet meadow lake edge with plankton net, sample 218, USNM 264060. 894 ♂♂ ♀♀, pool #42 bottom, sample 217, LACM 95-50.3. 41 ♂♂ ♀♀, pool #41, sample 214, USNM 264061. 400+ ♂♂ ♀♀, pool #42 surface, sample 216, LACM 95-50.4. 28 ♂♂ ♀♀, California, Lassen County, pool #43 (Long Lake), 40°31′N, 120°59′W, 100 m west of Route 44, about 0.36 km south of pool #41 (about 1.5 km south of intersection with Route A21), 2 m tow of wet meadow lake bottom with plankton net, sample 220, USNM 264062. 10 ♂♂ ♀♀, pool #43 (Long Lake), sample 219, LACM 95-50.2. All collected 23 April 1992 by J. L. King, D. Gluesenkamp and J. Tritt. Undissected specimens preserved in 70% ethanol.

Co-occurring species (determined by JWR).—Pool #41: *Hesperodiaptomus novemdecimus* (Wilson, 1953), *Leptodiaptomus tyrrelli* (Poppe, 1888), *Acanthocyclops carolinianus* (Yeatman, 1944), *Diacyclops crassicaudis* var. *brachycercus* (Kiefer, 1927), *Microcyclops rubellus* (Lilljeborg, 1901), *Bryocamptus washingtonensis* Wilson, 1958b; pool #42: *H. novemdecimus, L. tyrrelli, A. carolinianus, Acanthocyclops vernalis* (Fischer, 1853) s.l., *Diacyclops navus* (Herrick, 1882); pool #43 (Long Lake): *H. novemdecimus, L. tyrrelli, A. carolinianus, B. washingtonensis.*

Male.—Length (mm) of holotype 2.21; of ten paratypes, mean = 2.14, median = 2.18, range = 1.93–2.32. Pediger 5 (sixth thoracic somite) (Fig. 1a), lateral "wings" symmetrical, each with two sensilla. Urosome (Fig. 1a) symmetrical except urosomites 1 and 4 slightly produced laterally and posteriorly. Urosomites 2–4 and caudal rami with pore-canals, middle dorsal pore-canal of urosomite 4 displaced slightly to left of dorsal midline. Inner sides of caudal rami with long hairs, rest of ramal surfaces with short sparse hairs. Rostral points (Fig. 1b) short, acute.

Antennules (Fig. 1a, c, d) reaching middle of urosomite 2. Right antennule with two setae on segment 6; segment 8 with one seta and one spine; segment 10 with one seta and one stout spine reaching middle of segment 12; segment 11 with one seta and one stout spine, reaching distal end of segment 13; segment 13 with one stout spine reaching past middle of segment 14; segment 14 without spine; segment 15 with small acute process pointing distally; segment 16 with two setae. Segment 23 (Fig. 1d), process at distal end straight, reaching

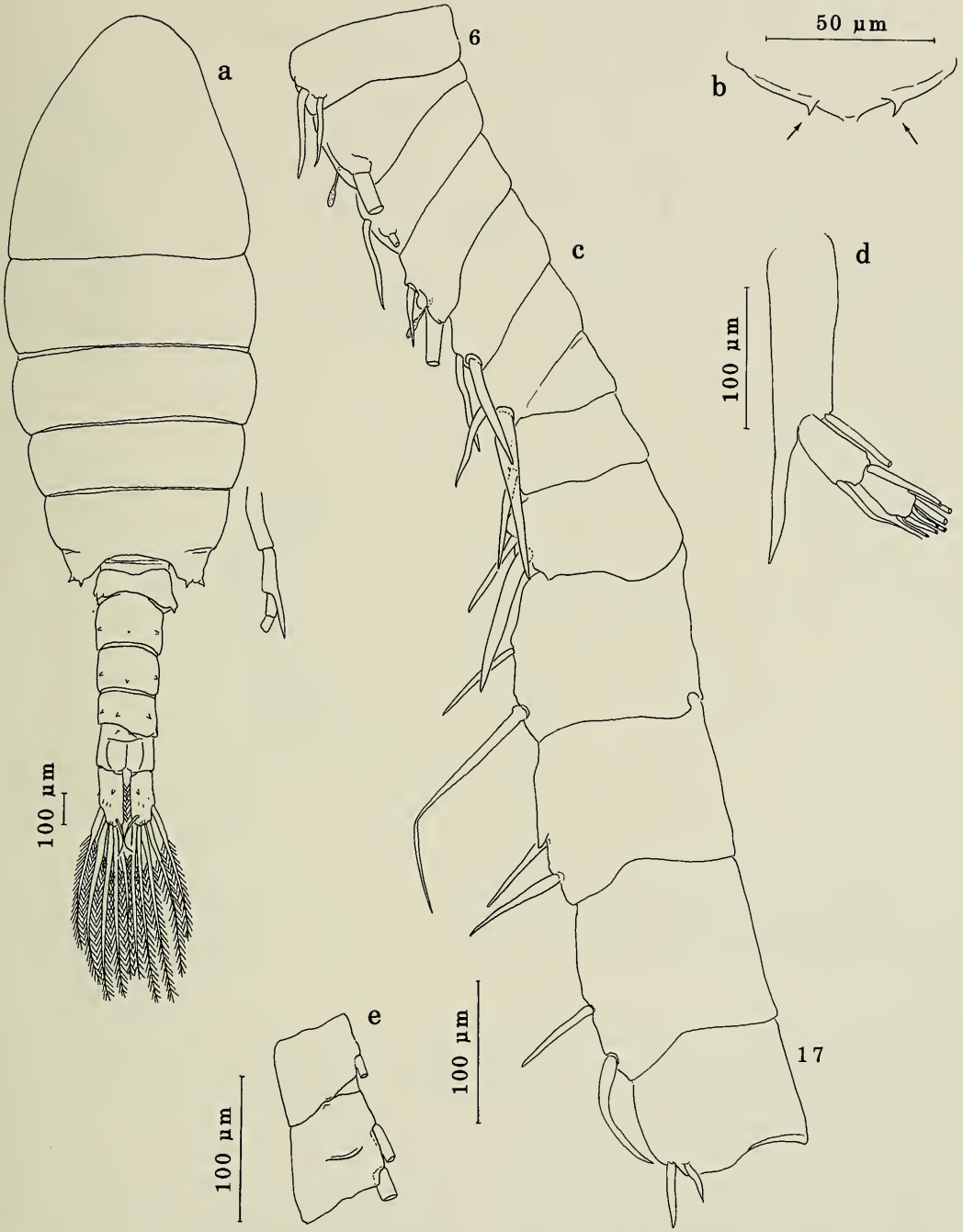

Fig. 1. *Hesperodiaptomus californiensis,* new species, male: a, Habitus, dorsal; b, Rostral points (indicated by arrows); c, Right antennule, segments 6–17; d, Right antennule, segments 23–25; e, Leg 2 endopod, segments 1 and 2, posterior.

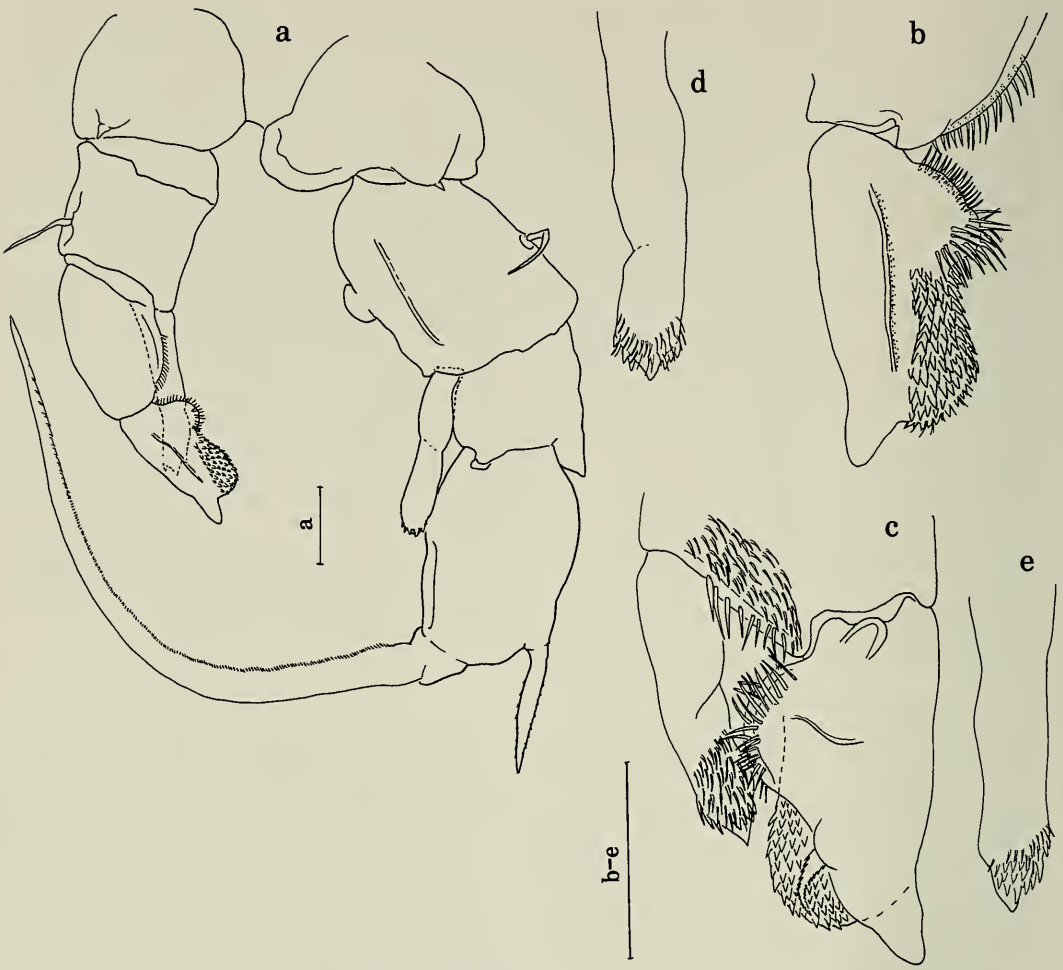

Fig. 2. *Hesperodiaptomus californiensis,* new species, male: a, Leg 5, posterior; b, Left leg 5 exopod, posterior; c, Left leg 5 exopod and endopod, anterior; d, Left leg 5 endopod, posterior; e, Right leg 5 endopod, anterior. Both scales = 50 μm.

end of last segment of antennule. Setation of left antennule as in female.

Leg 2 endopod segment 2 (Fig. 1e) without defined Schmeil's organ, but with small transverse ridge, more or less developed on different specimens.

Left leg 5 (Fig. 2a–d): Coxa, small process tipped with sensillum near outer posterodistal margin. Basis with lateral seta. Exopod segment 1 longer than segment 2, with haired pad on inner margin, hairs thick and as long as about half width of endopod. Exopod 2, tip forming stout, blunt, smooth lateral process; also with serrate digital process. Inner margin of exopod 2 with two pads, proximal pad haired, proximal hairs of this pad thinner and shorter than distal hairs; distal pad covered with rows of teeth and few tiny hairs near tip of exopod. Posterior surface of exopod 2 with longitudinal groove. Endopod reaching midlength of exopod 2, of one segment, narrowing at distal ⅓. Tip of endopod narrowing in acute process; also with five small subterminal spines and group of subterminal hairs.

Right leg (Fig. 2a, e): Coxa with small posterodistal process ending in sensillum. Basis with lateral seta, shallow longitudinal

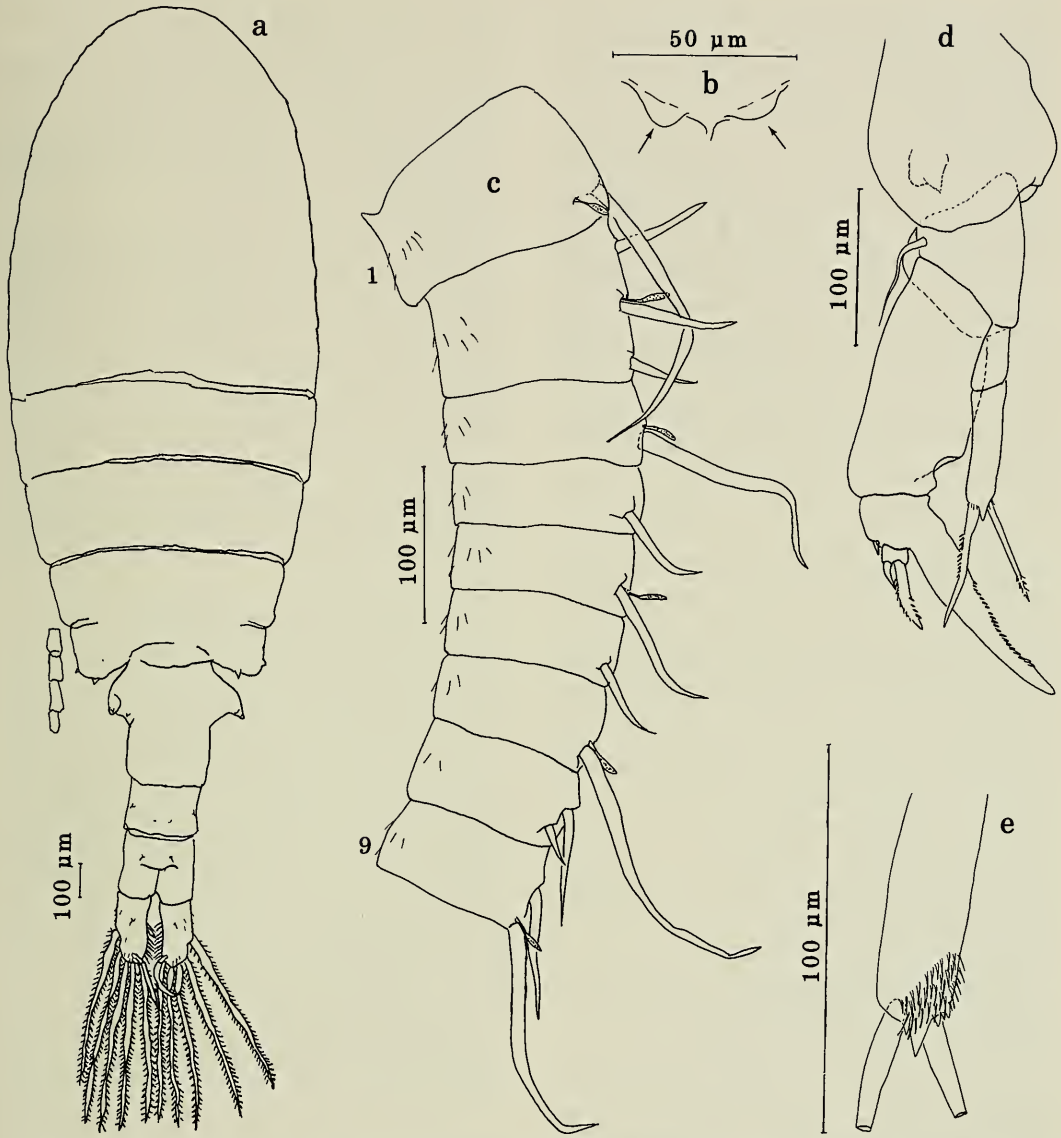

Fig. 3. *Hesperodiaptomus californiensis,* new species, female: a, Habitus, dorsal; b, Rostral points (indicated by arrows); c, Antennule, segments 1–9; d, Leg 5, anterior; e, Tip of leg 5 endopod, posterior.

groove on posterior surface, and rounded, unornamented protrusion on middle of inner margin; length of protrusion equal to width of endopod, its width equal to ½ width of endopod. Outer margin of exopod 1 with large, distally directed conical process on distolateral corner. Exopod 2 almost twice length of exopod 1, with shallow longitudinal groove along distal ½ of inner margin; lateral spine at distal ¾ of exopod 2, ½ thickness of endopod and ½ length of exopod 2, straight, finely denticulate. Terminal claw tapering gradually from enlarged base, twice length of exopods 1 and 2 combined, with row of teeth extending from tip of claw almost to base. Right endopod without suture on posterior surface, suture visible on anterior surface where en-

dopod narrows slightly at midlength; endopod tapering to blunt point; with 3–5 spines near outer distal margin, and subterminal group of small hairs.

Female.—Length (mm) of allotype 2.39; of ten paratypes, mean = 2.20, median = 2.22, range = 1.95–2.33. Prosome (Fig. 3a) symmetrical, thoracic wings symmetrical, each with two sensilla located on lateral and posterior margins. Genital double somite extended laterally in asymmetrical conical projections each tipped with sensillum, left projection directed dorsally, right projection laterally. Caudal rami haired in pattern similar to that of male. Rostral points (Fig. 3b) low, rounded.

Antennule (Fig. 3a, c) reaching midlength of genital double somite. Segments 1–8 or 9 each with few tiny hairs irregularly scattered on posterior surface. Seta on segment 1 long, reaching midlength of segment 4. Appendages per segment as follows (Roman numerals = segment, Arabic numerals = number of setae, a = aesthetasc, sp = spine): I(1+a), II(3+a), III(1+a), IV(1), V(1+a), VI(1), VII(1+a), VIII(1+sp), IX(2+a), X(1), XI(2), XII(1+sp+a), XIII(1), XIV(1+a), XV(1), XVI(1+a), XVII(1), XVIII(1), XIX(1+a), XX(1), XXI(1), XXII(2), XXIII(2), XXIV(5+a).

Leg 2 (not figured) of all females examined without trace of Schmeil's organ or transverse ridge on endopod 2.

Leg 5 (Fig. 3d, e): Coxa with posterior lateral protrusion ending in sensillum. Basis with lateral seta reaching ⅓ of length of exopod 1. Endopod two-segmented, distal segment twice length of proximal segment. Endopod 2 with two setae at tip, tip protruding in acute point between these setae, and 3–5 subterminal teeth surrounding tip of endopod. Exopod 2 a little longer than exopod 1, claw with inner margin toothed. Exopod 2 with small articulated spine lateral to outer margin of exopod 3, reaching from slightly beyond middle to end of exopod 3. Exopod 3 distinct from exopod 2. Inner spiniform seta of exopod 3 serrate on one or both margins, longer and stouter than outer, naked spiniform seta.

Type locality.—Pool #41, 40°37′N, 121°03′W, Lassen County, California.

Etymology.—The species name is given after the State of California, in which the type locality is located.

Habitat description.—The three pools (41, 42 and 43—Long Lake) are relatively large for vernal pools (400 × 400 m, 300 × 300 m and 800 × 200 m respectively at time of sampling), shallow (maximum depths 0.15–0.6 m), clear, and covered 70–90% with aquatic grasses. The electrical conductivity was low (30, 60 and 10 μMHO), water temperature 16, 16 and 23 C, pH 7.7, 7.7 and 8.2, alkalinity 20, 28 and 8 ppm, and total dissolved solids 10, 30 and 0 ppm respectively.

Discussion and comparisons.—*Hesperodiaptomus californiensis* differs from *H. schefferi* (Wilson, 1953) in the male leg 5: the conical process on the coxa of the right leg is larger; the inner protrusion on the basis of the right leg of *H. californiensis* is rounded, not quadrate as in *H. schefferi*; and the endopods of both left and right legs are longer in *H. californiensis.* In leg 5 of the female, *H. californiensis* has the endopod extended in a terminal point. The genital double somite in *H. schefferi* has very slight lateral projections.

Hesperodiaptomus victoriaensis is morphologically closest to *H. californiensis.* The male of *H. californiensis* differs from *H. victoriaensis* in having the right leg 5 with longer endopod, and in having the inner process on the basis larger and placed at about midlength rather than at the inner proximal corner. In the female of *H. victoriaensis,* the lateral projections of the genital double somite are slightly asymmetrical, the left projection being directed posterolaterally rather than dorsally.

Both *H. schefferi* and *H. victoriaensis* possess an acute process on the distal margin of segment 16 of the right antennule of the male. Such a process is lacking in *H. californiensis.*

The differences between *H. kiseri* and *H. californiensis* are primarily in leg 5 of the male: in *H. californiensis* there is no proximal protrusion on the inner margin of the right basis, and only one protrusion on the middle of the inner margin. There is no distally placed spiniform projection on the inner margin of the right exopod 1. The small protrusion on the posterior surface of the right exopod 2, present in *H. kiseri,* is lacking in *H. californiensis.* The claw is smoothly tapered in *H. californiensis,* without angles as in *H. kiseri.* The lateral projections of the genital double somite of the female are asymmetrical in *H. californiensis,* symmetrical in *H. kiseri.* The thoracic wings are not expanded laterally in *H. californiensis.*

In *H. californiensis,* the left lateral projection on the female double somite is dorsally directed. The second (middle) urosomite is relatively long. On leg 5 of the male, the endopodites are relatively longer than in other similar species.

In the most recent diagnosis of the genus *Hesperodiaptomus,* Borutskii et al. (1992) stated that the left antennule of the male is like that of the female. However, *H. hirsutus* (Wilson, 1953) always, and *H. schefferi* sometimes, display sexual dimorphism in setation on some segments (Wilson 1953). The observed setation pattern of *H. californiensis* was constant, similar in both sexes, and the most common pattern found in the genus (cf. Wilson 1953).

Species of the genus *Hesperodiaptomus* are supposed to lack Schmeil's organ (Wilson 1953). Schmeil's organ (Schmeil 1896) is a small protuberance of unknown function, which in diaptomids if present is located on the posterior surface of leg 2 endopod 2. If the small transverse ridge in this position which was noted in some of the males of *H. californiensis* examined, does correspond to Schmeil's organ, this is the first reported occurrence of this structure in the genus.

Most species of *Hesperodiaptomus* occur in northwestern North America. A few species are found in eastern Canada and the U.S.A., and the ranges of three species extend into Siberia (Borutskii et al. 1991). The species that are morphologically closest to *H. californiensis* occur well north of its range. *Hesperodiaptomus kiseri* is found in the State of Washington and in Saskatchewan (Wilson 1959). *Hesperodiaptomus schefferi* is found in the Pribilof Islands, Alaska, and the northern Rocky Mountain States (Wilson 1959). *Hesperodiaptomus victoriaensis* has been collected in the mountains of southwestern Alberta (Anderson 1967, 1971), near Churchill, Manitoba (Hebert 1985; Boileau & Hebert 1988), and on Victoria Island, N.W.T. (Reed 1958).

Two other species of diaptomids, *Leptodiaptomus tyrrelli* and *Hesperodiaptomus novemdecimus,* occurred in large numbers together with *H. californiensis* in all three pools sampled. Many instances of co-occurring diaptomid species have been reported and have been much discussed in the published literature, including reviews by Cole (1961) and Hutchinson (1967). Of 34 examples of co-occurrence listed by Cole (1961), 10 involved congeneric species. Hutchinson (1967) observed that co-occurring diaptomid species tend to be of different sizes and suggested that these size differences may indicate non-overlapping feeding niches, and that differences in feeding would likely be found to be related to structural differences.

Several co-occurrences of species of *Hesperodiaptomus* have been reported. Wilson (1953) reported *H. wardi* (Wilson, 1953) together with *H. novemdecimus.* Anderson (1971) collected *H. shoshone* (S. A. Forbes, 1893) with *H. arcticus,* and *H. shoshone* with *H. victoriaensis.* Hammer & Sawchyn (1968) found *H. arcticus* in the same pond as *H. kiseri,* although the incidences were separated by a five-day interval. These authors noted distinct size differences between the two species, but postulated mutual exclusion between them. An especially interesting example was given by Anderson (1967), who found *H. shoshone*

with *H. victoriaensis* and *L. tyrrelli* together in a pond in Alberta. There, *H. shoshone* individuals averaged 1.6 times longer than *H. victoriaensis* and preyed actively upon the much smaller *L. tyrrelli.* Anderson (1967) described the enlarged clawlike setae of the maxilliped of *H. shoshone,* which were apparently an adaptation for this predatory activity. The corresponding setae of *H. victoriaensis* were found to be unmodified, and this species apparently did not predate upon the smaller diaptomid. In the case of the Lassen County *Hesperodiaptomus* pair, the setae of the mouthparts and maxilliped of both species are unmodified. *Hesperodiaptomus novemdecimus* averaged larger than *H. californiensis* in all three ponds, and the two could be reliably sorted because of this size difference. In accordance with Hutchinson's (1967) hypothesis, we suggest that differences between these species in feeding niches are likely to exist, although we have made no direct observations.

Acknowledgments

This article was prepared during the senior author's participation in the Mentorship Program of the Thomas Jefferson High School for Science and Technology, Alexandria, Virginia. We thank the collector, Jamie L. King, University of California, Davis for providing habitat information and a draft of the article by King et al. Jamie King and two anonymous reviewers made valuable suggestions on an earlier draft.

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