



Article

urn:lsid:zoobank.org:pub:CDF4CD8E-93DD-48E2-BB5B-A17D067FCE47

Checklist of Inland Aquatic Amphipoda (Crustacea: Malacostraca) of California

G.O. GRAENING¹, D. CHRISTOPHER ROGERS², JOHN R. HOLSINGER³, CHERYL BARR⁴
& RICHARD BOTTORFF⁵

¹Department of Biological Sciences, California State University, Sacramento 9000 J Street, Sacramento, CA 95819

²Kansas Biological Survey, and Kansas Natural History Museum (Biodiversity Institute), University of Kansas Higuchi Hall, 2101 Constant Avenue, Lawrence, KS 66047

³Department of Biological Sciences, Old Dominion University 155 Hampton Boulevard, Norfolk, VA 23529

⁴Essig Museum of Entomology, University of California, Berkeley 1101 Valley Life Sciences Building #4780, Berkeley, CA 94720

⁵Department of Land, Air, and Water Resources, University of California, Davis One Shields Avenue, Davis, CA 95616

Abstract

We present the first comprehensive checklist of Amphipoda in Californian inland waters. Amphipod distribution records were based upon a thorough literature review and unpublished data of colleagues, as well as the collections of the authors. We report 62 species in 24 genera and 14 families, including 7 new taxa awaiting formal description. Sixteen species are exotic and at least 20 species are subterranean obligates. Endemicity is high: 40% of the native fauna are limited to a single locale, typically a spring or cave stream, and another 3 species are known from just 2 locales each. Conservation status rank revisions are offered in order to update the California Natural Diversity Database and IUCN Red List. Threats from invasive species are briefly discussed, as well as the use of amphipods as bioindicators.

Key words: Amphipoda, biodiversity, California, conservation, endemic, estuarine, invasive species, stygobiont

Introduction

Amphipods, commonly known as sideswimmers or scuds, are important components of freshwater biodiversity (Vainola *et al.* 2008). They function as vital links in aquatic foodwebs by processing detritus and serving as an important dietary component of fishes (Rogers *et al.* 2010). Recently, we found it necessary to summarize the known California inland aquatic fauna while attempting to distinguish some rare and novel amphipod taxa, and found no comprehensive checklist of Californian freshwater amphipods other than that of Rogers (2005), which is limited to genera. Although the marine fauna is not considered here, California hosts a diverse marine assemblage of at least 350 amphipod species (Chapman 2007). Estuarine habitats are complex and diverse ecotones, and euryhaline and eurokous taxa complicated the formulation of this checklist, which we attempted to limit to non-marine and inland niches. Furthermore, freshwater species may be washed into estuarine or marine habitats during stormflows, creating anomalous records, and during high flows, wedges of marine water will move upstream under the freshwater layer and temporarily introduce marine taxa (Bousfield 1973; Chapman 2007; Rogers *et al.* 2010). Terrestrial amphipods, such as the littoral beachhoppers (Orchestoidea), and exotic “lawn shrimp” (Talitridae) that have become established widely in California's temperate regions, are not considered here (Bousfield and Carlton 1967; Chapman 2007).

Methods

We conducted an exhaustive literature review, examined private collections and gray literature and occurrences reported from Californian freshwaters. The following data sources were consulted: California Academy of Sciences (CAS) Department of Invertebrate Zoology and Geology's Invertebrate Collection Catalog Database; California Department of Fish and Game's (CDFG) Natural Diversity Database (CDFG 2011); CDFG's Aquatic Bioassessment Laboratory (ABL) database, which includes data from the State Water Board's Surface Water Ambient Monitoring Program, US Environmental Protection Agency's Environmental Monitoring and Assessment Program, and regional agency and citizen monitoring programs; California Department of Water Resources' (CDWR) Bay Delta and Tributaries Project, Interagency Information Systems Services Office and Bay-Delta Monitoring and Analysis Section (CDWR 2010); Sierra Nevada Aquatic Research Laboratory (SNARL); the collections database of the National Museum of Natural History, Smithsonian Institution (NMNH); unpublished data of the Southwestern Association of Freshwater Invertebrate Taxonomists; and the United States Geologic Survey (USGS) Nonindigenous Aquatic Species Database (USGS 2010). All records not directly attributed to others are new records of the authors. Many of the specimens referenced in this checklist are, or will be, deposited in CAS or NMNH. Taxonomic keys consulted included: Bousfield 1958, 1973, 1975; Holsinger 1974; Conlan and Bousfield 1982; Bousfield and Morino 1992; Bousfield and Hoover 1997; Smith 2001; Zhang and Holsinger 2003; Rogers 2005; Tomikawa *et al.* 2006; Carlton 2007; and Rogers *et al.* 2010. Vernacular names are provided when known, and follow American Fisheries Society (2005).

Any aquatic species not found in strictly marine habitat was included in this checklist. Exotic and naturalized taxa are identified and ecological associations mentioned where known. Of special interest were the cold stenotherms that rely upon groundwater and display high specialization and narrow endemism (Figure 1)(Rogers *et al.* 2010). The term *stygobiont* was used for cavernicoles that are limited to, or adapted to, subterranean streams, while *phreatobiont* was applied to taxa occupying phreatic zones (or *nappe phréatique*), and are accessible only by sampling springs, seeps, wells, and bore holes, but not normally caves (Motas and Serban 1965; Holsinger 1967). Lotic interstitial habitats, or hyporheos, are typically separated from these subterranean (or hypogean) classifications because interaction with surface waters introduces nutrient pulses, predators, and temperature fluctuations not typically experienced in subterranean habitats.



FIGURE 1. This live *Stygobromus* displays the typical convergent evolutionary characters of a life in subterranean habitats (troglomorphy), including the loss of eyes and pigment, and appendage elongation (photo by Danté Fenolio).

Results

Family AMPELISCIDAE Costa, 1857

Ampelisca abdita Mills, 1964 (euryhaline, exotic)

Records: Reported from Bolinas Lagoon, Tomales Bay, San Francisco Bay, San Pablo Bay, Suisun Bay, Grizzly Bay, Honker Bay, Sherman Lake, Suisun Bay, Sacramento River (R.) (Chapman 1988; CDWR database).

Comments: Chapman (1988) predicted a wider Californian range after habitats are better inventoried; an estuarine species ranging naturally from Maine to Gulf of Mexico (Chapman 1988), *A. abdita* was probably associated with Atlantic oyster introductions.

AMPITHOIDAE Stebbing, 1888

Ampithoe lacertosa (Bate, 1858) (euryhaline)

Records & Comments: Found in algae and eelgrass, and in gravel and woody debris, in tidepools, wharf pilings and estuaries; distributed from Baja California to the Aleutian Islands, and Japan (Conlan and Bousfield, 1982; Chapman 2007). We know of no specific records for California.

Ampithoe valida Smith, 1873 (euryhaline, exotic)

Records: CDWR reported it from San Pablo Bay near Pinole Point and mouth of Petaluma R., and from the Sacramento R. above Point Sacramento. Conlan and Bousfield (1982) report it from Newport Bay (Orange Co.).

Comments: An estuarine species ranging on the Pacific from Newport Bay to British Columbia, and also Japan, but probably native to the North American Atlantic coast. This tube builder occurs mainly along sheltered coasts and estuaries, mainly in mesohaline to brackish waters, and is abundant in algae and fouling communities of pilings and mudflats (Conlan and Bousfield 1982; Barnard 1989; Chapman 2007).

ANISOGAMMARIDAE Bousfield, 1977

Anisogammarus pugettensis (Dana, 1853) (euryhaline)

Records: Humboldt Co. Fay Slough at Old Arcata Rd., 6 specimens, 12 Aug. 1993, D.C. Rogers.

Comments: Reported from low-salinity marshes and estuaries in California and farther north (Chapman 2007), and partially anoxic waters (Waldichuck and Bousfield 1962).

Eogammarus confervicolus (Stimpson, 1856) (euryhaline)

Records: Contra Costa, Sacramento, and Solano Co's. Suisun Bay, 2002, 1 specimen, and Sacramento R. above Point Sacramento, 2002 and 2004, 1 to 5 specimens, all from ponar dredge, CDWR; Pinole Cr. at Senior Center, 5 specimens (identified only to genus) 23 Apr 2003, S. Cressey. Humboldt Co. Eel R. at Rio Dell, 3 specimens, 12 Aug. 1993, D.C. Rogers. Los Angeles Co. Malibu Lagoon, Jan. and Feb. 1984, D. Galli (Tomikawa *et al.* 2006). Marin Co. Kay's Creek (Cr.) at Highway (Hwy) 1, 28 specimens, 16 July 2006, D.C. Rogers; Millerton Gulch at Hwy 1, 21 specimens, May 2004, D.C. Rogers. Mendocino Co. Navarro R. at Hwy 128, 6 specimens, 21 June 2001, D.C. Rogers; Ten Mile R. at Camp 2 Rd., 6 specimens, 14 June 1997, D.C. Rogers. Monterey Co. Elkhorn Slough (MacGinitie 1935); Salinas R. estuary (Smith 1953); Big Sur R. at Hwy 1, 11 specimens, 5 June 1997, D.C. Rogers. San Luis Obispo Co. Coon Cr., 17 specimens, 4 Apr. 2005, D.C. Rogers. Cuesta by the Sea, Sweet Springs, 9 specimens, 6 June 1997, D.C. Rogers; Pecho Cr., 1

specimen, 21 Mar. 2008, D.C. Rogers; and marsh near Guadalupe, 35 specimens (identified only to genus), 18 Sep. 1995, E. Bastin. **Solano Co.** Montezuma Sough near Montezuma, 4 specimens, 23 Aug. 1999, D.C. Rogers; Napa R. at Hwy 121, Napa, 13 specimens, 17 May 2004, D.C. Rogers. **Sonoma Co.** Petaluma R. at Petaluma, 2 specimens, 9 Sep. 1997, D.C. Rogers; Russian R. at Greenwood Park, 2 specimens, 21 Sep. 2008, D.C. Rogers.

Comments: This euryhaline species ranges from Los Angeles to Alaska (Carl 1937; Bousfield 1958; Rogers 2005; Tomikawa *et al.* 2006).

***Ramellogammarus californicus* Bousfield and Morino, 1992** (stenohaline?)

Records: Known only from the type locality in Humboldt Co., McKinleyville: “stream at Murray Rd. at McKinley Junction,” 1960, B. Neal (Bousfield and Morino 1992).

***Ramellogammarus columbianus* Bousfield and Morino, 1992** (hyporheic?)

Records: **Mendocino Co.** Ten Mile R. at Camp 2 Rd., 2 specimens, 14 June 1997, D.C. Rogers.

Comments: A freshwater species found in the benthos of rivers flowing into protected coastal bays from Oregon to Queen Charlotte Islands (Bousfield and Morino 1992; Chapman 2007).

***Ramellogammarus ramellus* (Weckel, 1907)** (stenohaline?)

Records: **Mendocino Co.** Point Arena (Weckel 1907); “stream mouth at [Albion] Biological Station, Mendocino, author coll., 1955” (Bousfield 1958); Irish Gulch Cr. below Hwy 1, 2004-2005, and 1.5 miles (mi.) upstream of ocean in seep, 2006 (Bottorff and Bottorff 2007). **Santa Clara Co.** San Francisquito Cr., 1 specimen, 29 Oct. 2010, G.O. Graening.

Comments: *R. ramellus* is reported only from California (Bousfield and Morino 1992; this study), but the *ramellus* species group, which consists of *R. ramellus*, *R. californicus*, *R. similimanus* (Bousfield 1961) and *R. campestris* Bousfield and Morino, 1992, ranges from northern California to northern Oregon.

Genus undet.

Records: The following records are from the ABL database and many have been tentatively assigned to *Ramellogammarus*, although records inland (outside of maritime climate) or those far south may either be another genus or represent an unconfirmed niche expansion of this taxon. **Alameda Co.** Alameda Cr. and Cesar Chavez Park, 2005. **Contra Costa Co.** Pinole Cr. **Del Norte Co.** Clarks Cr. above Hwy 199, 2004; Wilson Cr. 4.3 mi. above Pacific Ocean, 2010. **Humboldt Co.** Cooper Canyon Cr. above Myrtle Ave., 2006; Corner Cr. 2.5 mi. above Lawrence Cr., 2003; Fern Canyon Cr. 0.3 mi. above ocean bluffs, 2004; North Fork Mill Cr. 1.2 mi. above Central Ave., 2003. **Marin Co.** Millerton Gulch at Hwy 1, 2004. **Merced Co.** Merced R. at Snelling Rd., 2003. **Placer Co.** Antelope Cr. 0.6 mi. below Midas Ave., 2005; Clover Valley Cr. 2 mi. above Antelope Cr., 2005, Miners Ravine, 2005. **Sacramento Co.** Alder Cr. above Folsom Blvd.; 2004, Morrison Cr. at Beach Lake and at South Watt Ave., 2005. **San Joaquin Co.** Little John Cr. at Stanley Rd., 2004; Lone Tree Cr. at Lone Tree Rd., 2004. **San Luis Obispo Co.** Cayucos Cr. and San Simeon Cr., 2011. **San Mateo Co.** San Francisquito Cr., 2011. **Santa Barbara Co.** Santa Ynez R. downstream of Lake Cachuma at Hwy 154, 2007; Tecolote Cr. at Bacara Resort access road, 2003. **Santa Clara Co.** San Tomas Aquinas Cr. below Tasman Dr., 2008. **Santa Cruz Co.** Aptos Cr. at Spreckles Dr., 2003; San Lorenzo Estuary at Laurel Street, 2003 and 2007. **Stanislaus Co.** Lone Tree Cr. at Belota Rd., 2004; Orestimba Cr. above confluence of San Joaquin R. above Kilburn Rd., and near Crows Landing Rd. 2003-2004. **Ventura Co.** Lower Big Sycamore Canyon, 2007. **Yolo Co.** Union School Slough at Rd. 88, 2004. **Yuba Co.** Jack Slough at Loma Rica Rd., 2004.

Comments: Sytsma *et al.* (2004) reported *Ramellogammarus oregonensis* to range as far south as Eureka, California, but no specific collection sites or specimens are known; Bousfield and Morino (1992) report *R. oregonensis* to inhabit coastal streams and lakes of Oregon and Washington.

AORIDAE Walker, 1908

Grandidierella japonica Stephensen, 1938 (euryhaline, exotic)

Records: Tomales Bay, Drakes Estero, Bolinas Lagoon, and San Francisco Bay (Carlton 1979); Corte Madera (Chapman 1988); and Grizzly Bay, Honker Bay, San Pablo Bay, and Sacramento R. (CDWR database).

Comments: This Japanese amphipod was introduced to central California from oyster plantings and ballast water, and now occurs on the eastern Pacific from British Columbia to Baja California (Sytsma *et al.* 2004).

Microdeutopus gryllotalpa Costa, 1853 (euryhaline, exotic)

Records: Introduced from the Mediterranean and Atlantic into the Humboldt Bay estuary (Boyd *et al.* 2002).

COROPHIIDAE Leach, 1814

Americorophium salmonis (Stimpson, 1857) (euryhaline)

Records: **Humboldt Co.** Humboldt Bay (Chapman 2007). **Monterey Co.** Monterey Bay, Elkhorn Slough (MacGinitie 1935).

Comments: *A. salmonis* is an estuarine species in California, Oregon, Washington, British Columbia, and southern Alaska (Bottom and Jones 1990; Bousfield and Hoover 1997; Chapman 2007). It has been introduced into inland areas above tidal influence, including Putah Cr., California (Sytsma *et al.* 2004).

Americorophium spinicorne (Stimpson, 1857) (euryhaline)

Records: **Contra Costa Co.** Mallard Reservoir near Concord, 13 Feb. 1976, C. Johnson (CAS database); Brown's Island (Toft 2000); West Canal at Clifton Court Forebay intake, Pinole Point, Frank's Tract, and Big Break, lower Sacramento and San Joaquin R's (CDWR database); Walnut Cr. 0.7 mi. below Concord Ave., 2006 (ABL database). **Fresno Co.** San Joaquin R. at Firebaugh, 2011 (ABL database). **Marin Co.** Point Reyes (D. Fong, USNPS, unpub. data). **Mendocino Co.** Garcia R. at Hathaway Cr., 2009 (ABL database). **Merced Co.** Salt Slough above Wolfsen Rd., below Hereford Rd., downstream of Hwy 165, and at San Luis Nat. Wildlife Refuge near fishing access, 2003-2011; San Joaquin R. 2.2 mi. above Hwy 140, 2011 (ABL database). **Monterey Co.** Monterey Bay, Elkhorn Slough (MacGinitie 1935); Salinas R. estuary (Smith 1953); Carmel R. lagoon (Watson 2007). **Sacramento Co.** (and Contra Costa Co.): San Joaquin R. at Antioch and Bradford (Filice 1958; Aldrich 1961); Sherman Lake (CDWR database). **San Francisco Co.** Lake Merced (Shoemaker 1949; Miller 1958; Eriksen 1968). **San Joaquin Co.** Mandeville Tip and Mildred Island (Toft 2000); Old R. and South Mokelumne R. (CDWR database); Middle R. at Howard Rd., 2006, Port of Stockton, 2007 (ABL database). **San Luis Obispo Co.** Morro Bay, in *Salicornia* pans, and Chorro Cr., south of bridge (Barnard 1952); Oso Flaco Lake (Eriksen 1968). **Santa Clara Co.** Coyote Cr. at Tully Rd., 51 specimens, Aug. 1997, D.C. Rogers, and Coyote Cr. 0.5 mi. above Hwy 101, 2007, Los Gatos Cr. above East Hamilton Ave., 2010, San Tomas Aquinas Cr. below Tasman Dr., 2008 (ABL database). **Santa Cruz Co.** Waddell Cr. (Shoemaker 1949); Scott Cr. at Swanton Ranch and Soquel Cr. (SNARL database). **Solano Co.** Carquinez Strait, near the Benicia municipal pier, and Grizzly Island (Chapman 1988); Grizzly Bay and Honker Bay, lower Sacramento R. (CDWR database). **Sonoma Co.** Mouth of Petaluma R. (CDWR database). **Stanislaus Co.** Del Puerto Cr. below Elm Ave., 2008; Orestimba Cr. above Hwy 33, above

Morris Rd., and near Crows Landing Rd., 2004-2011 (ABL database). **Yolo Co.** Yolo Bypass, Tule Canal at Interstate Hwy 5, 29 specimens, Aug. 2009, D.C. Rogers; Sacramento Turning Basin (ABL database).

Comments: CDWR performed benthic sampling from 1975 to 2002, during which 156,000 specimens of *A. spinicorne* were collected in over 2,500 ponar dredge sampling events throughout the Sacramento River / San Joaquin River Delta (Delta) in the Sacramento R., Mokelumne R., Old R., Sherman Lake, Honker Bay, Frank's Tract, San Joaquin R., Suisun Bay, and Grizzly Bay. This euryhaline species inhabits coastal streams and brackish estuaries from central California to Alaska (Shoemaker 1949; Barnard 1952; Wones and Larson 1991; Chapman 2007), although there may be some question about the taxonomic status of the southern populations (Chapman 2007). Lester and Clark (2002) report it as established from barge ballast water in the freshwaters of the Snake R. as far upstream as the confluence with the Grande Ronde R. (Nez Perce Co., Idaho).

***Americorophium stimpsoni* (Shoemaker, 1941)** (euryhaline)

Records: **Marin Co.** Dillon Beach (Bousfield and Hoover 1997). **Mendocino Co.** Mendocino Bay (Bousfield and Hoover 1997). **Monterey Co.** Salinas R. estuary (Smith 1953). **San Francisco Co.** San Francisco Bay (Bousfield and Hoover 1997). **Santa Barbara Co.** Santa Cruz Island (Chapman 2007).

Comments: From 1975 to 2002, a CDWR sampling program collected 356,000 specimens of *A. stimpsoni* from over 2,500 ponar dredge samples from Contra Costa, Sacramento, San Joaquin, Solano, and Sonoma Co.'s. from San Pablo Bay, Suisun Bay, Grizzly Bay, Sacramento R., Sherman Lake, San Joaquin R., Mokelumne R., and Old R. This species is still common in estuaries of the San Francisco Bay and Delta, but it has not been found in recent decades in its larger historic range—tidally-influenced freshwaters from Santa Barbara Co. to southern Oregon (Bousfield and Hoover 1997; Chapman 2007). Kelley (1967) reported that *A. stimpsoni* and *A. spinicorne* were abundant in the Delta and were an important food source for bottom-feeding fish. Chapman (2007) considered *A. stimpsoni* to be a potentially threatened species.

***Americorophium* sp.**

Records: The following records are from the ABL database or this study.

Alameda Co. Alameda Cr. 2.8 mi. southeast of Dry Cr.; San Leandro Cr. **Contra Costa Co.** Alameda Cr., west Antioch Cr., Edwards Cr., Refugio Cr., San Pablo Cr., Wildcat Cr. **Los Angeles Co.** Ballona Cr. **Marin Co.** Novato Cr. above Redwood Blvd. **Monterey Co.** Salinas R., Carmel R. **Sacramento Co.** Lower American R. **San Diego Co.** Lower San Diego R., Santa Ysabel Cr. **San Luis Obispo Co.** Arroyo de la Cruz, Arroyo Grande, Chorro Cr., Pico Cr., Pismo Cr., San Luis Obispo R., San Simeon Cr., Santa Rosa Cr. **San Mateo Co.** San Francisquito Cr. 0.5 mi above Hwy 101; Gazos Cr. Lagoon at Hwy 1; San Gregorio USGS Gage. **Santa Clara Co.** Alviso Slough 0.5 mi below Hwy 237. **Santa Cruz Co.** Scott Cr. Lagoon at Hwy 1; Waddell Cr. and lagoon; Aptos Cr. at Spreckles Dr.; Pajaro R. **Solano Co.** Cordelia and Rockville. **Ventura Co.** Piru Cr., Calleguas Cr. **Yolo Co.** Sacramento R. at Sacramento State Park near Colusa.

***Apocorophium louisianum* Shoemaker, 1934** (euryhaline, exotic)

Records & Comments: This estuarine amphipod from the Gulf of Mexico was introduced to the Salton Sea (Riverside and Imperial Counties) probably when the Texas marine grass *Diplanthera* was intentionally introduced (Barnard and Gray 1968, 1969; Bousfield and Hoover, 1997; Simpson *et al.* 1998).

***Cheirimeidia macrocarpa* Bulycheva, 1952** (estuarine)

Records & Comments: Occurs in estuaries along California and Oregon coasts; possibly introduced (Myers and Lowry 2003; Chapman 2007).

***Monocorophium acherusicum* (Costa, 1857)** (euryhaline, exotic)

Records: Carlton (1979) summarized its occurrence in most bays and estuaries of California, including Humboldt Bay, Bodega Harbor, Tomales Bay, Morro Bay, Port Hueneme, all bays and harbors of Los Angeles and Orange Co's, San Diego Bay. CDWR reported it from San Pablo Bay, Grizzly Bay, Suisun Bay, Honker Bay, and the Sacramento R.

Comments: Native to the North Atlantic, but now cosmopolitan due to its ship fouling habit, this exotic species occurs in soft bottomed estuaries from Baja California to British Columbia (Bousfield and Hoover 1997; Chapman 2007).

***Monocorophium insidiosum* (Crawford, 1937)** (euryhaline, exotic)

Records: Carlton (1979) and Chapman (1988) summarized its sporadic occurrence in California, including Tomales Bay, Bolinas Lagoon, San Francisco Bay, Lake Merritt, Monterey Harbor, Elkhorn Slough, Santa Monica Bay, Long Beach Harbor, Alamitos Bay, and Newport Bay. CDWR reported it from San Pablo Bay, Grizzly Bay, Suisun Bay, and the Sacramento R.

Comments: Native to the North Atlantic, but now cosmopolitan due to ship fouling and oyster shipments, this species occurs in soft bottomed estuaries (Bousfield and Hoover 1997; Chapman 1988, 2007). Chapman (2007) suggests that *M. oaklandense* (Shoemaker, 1949) is a synonym.

***Monocorophium uenoi* (Stephensen, 1932)** (euryhaline, exotic)

Records: This species is reported from estuaries and harbors from central California to Baja California (Carlton 1979; Chapman 2007). Specific locales include Bodega Harbor, Tomales Bay, Bolinas Lagoon, San Pablo Bay, Sacramento R., Monterey Harbor, Elkhorn Slough, Morro Bay, Chorro Cr., Point Conception, Newport Bay (Barnard 1952; Carlton 1979; CDWR database).

Comments: Native to the Sea of Japan and the South China Sea, it was apparently introduced with imported Japanese oysters and other fisheries products (Chapman 1988; Bousfield and Hoover 1997).

***Paracorophium* sp.** (euryhaline, exotic)

Records: San Luis Obispo Co. Cuesta-by-the-Sea, Sweet Springs, 83 specimens, July 2009, D.C. Rogers and M. Hill.

Comments: This genus is endemic to the southern hemisphere (Barnard and Karaman 1991). However, an undetermined species has appeared in Humboldt Bay, Humboldt Co. (Chapman 2007) and another in Tomales Bay, Marin Co. (J. Chapman, pers. comm.).

***Sinocorophium alienense* (Chapman, 1988)** (euryhaline, exotic)

Records & Comments: CDWR reported that 37,000 specimens were collected via ponar dredge from 1985 to 2010 from San Pablo Bay, Grizzly Bay, Suisun Bay, Sherman Lake, and Sacramento R., in Solano, Sonoma, Contra Costa, and Sacramento Co's. Introduced to China and the USA during the Viet Nam War, *S. alienense* is reported from estuaries from Los Angeles Harbor, Tomales Bay, and from San Francisco Bay up through the Delta (Chapman 1988, 2007; Bousfield and Hoover 1997).

Sinocorophium heteroceratum (Yu, 1938) (euryhaline, exotic)

Records & Comments: CDWR reported that 15,000 specimens were collected via ponar dredge from 1987 to 2010 from San Pablo Bay near the mouth of the Petaluma R. and from near Pinole Point, Grizzly Bay, Suisun Bay, and the lower Sacramento R. in Sacramento, Solano, and Sonoma Co's. This invasive, exotic species is reported from Los Angeles Harbor and the San Francisco Bay and Delta regions (Chapman 2007).

CRANGONYCTIDAE Bousfield, 1973*Crangonyx floridanus* Bousfield, 1963; **Florida Amphipod** (stenohaline, exotic)

Records: Contra Costa, Sacramento, San Joaquin, and Solano Co's. In the Delta, including Brown's Island, Donlon Island, Lindsey Slough, Mandeville Island, Mildred R., Old R., Sand Mound Slough, Sherman Island, Sherman Lake, Venice Cut, and West Canal at Clifton Court Forebay intake (Toft 2000; Toft *et al.* 2002; CDWR database). **Contra Costa Co.** Simas Cr., Wildcat Cr. **El Dorado Co.** Hangtown Cr., 29 Oct. 2009. **Stanislaus Co.** Tuolumne R., 2002, N. Hume.

Comments: This invasive species is endemic to swamps, ponds, and caves in the southern and eastern USA, naturally ranging as far west as central Kansas (Zhang and Holsinger 2003). It has been introduced, possibly via aquarium and water garden plants or ship ballast, to California, Colorado, Oregon, Washington, and Japan (Zhang 1997; Toft *et al.* 2002; Zhang and Holsinger 2003; Sytsma *et al.* 2004).

Crangonyx pseudogracilis Bousfield, 1958; **Northern River Amphipod** (stenohaline, exotic)

Records: San Luis Obispo Co. Stenner Cr. and its tributary Brizzolara Cr., from several locations, in 2002-2003 (Bottorff *et al.* 2003).

Comments: Native to the central USA and southern Canada between the Great Plains and the Appalachian Mountains, *C. pseudogracilis* has been introduced to the United Kingdom, Ireland, and the Netherlands in Europe, probably via ballast water (Bousfield 1958; Zhang and Holsinger 2003). In North America, this species has been introduced to Arizona, California, Nevada, and the Columbia R. (Zhang 1997; Zhang and Holsinger 2003; Bottorff *et al.* 2003; Sytsma *et al.* 2004). Zhang (1997) reports specimens taken in 1955 from the Truckee R. (Washoe and Storey Co's, Nevada).

Crangonyx richmondensis Ellis, 1940; **Ellis' Bog Amphipod** (stenohaline)

Records: Sonoma Co. pond on Privot farm, 25 specimens, 1984, L. Eng, CA Dept. of Fish and Game (Zhang 1997; Zhang and Holsinger 2003).

Comments: *C. richmondensis sensu lato* is the most widely distributed of its congeners, found in many lentic and lotic habitats, and occasionally, in caves. It is distributed primarily in three regions—the Pacific Northwest (northern California to southern Alaska), the Great Lakes area (Minnesota to Newfoundland), and Atlantic Coastal Plain (Maine to Florida). Bousfield (1958) designated the subspecies *occidentalis*, *laurentianus*, and *richmondensis* for each of these regions, respectively, but Zhang and Holsinger (2003) report that intraspecific variation renders these subspecific designations invalid.

Crangonyx sp.

Records: The following records are tentative identifications from the ABL database or this study, and the generic distribution is mapped in Figure 2. **Alameda Co.** UC Berkeley, East Fork Redwood Cr. **Butte Co.** Mud Cr., Dry Cr., Feather R. **Calaveras Co.** Indian Cr., Stanislaus R. **Contra Costa Co.** Bear Cr. Rd., Franklin Cr., Grayson Cr.,

TERMS OF USE

**This pdf is provided by Magnolia Press for private/research use.
Commercial sale or deposition in a public library or website is prohibited.**

Las Trampas Cr., Murderers Cr., Pinole Cr., Possum Picnic Area, San Pablo Cr., Simas Cr., Wildcat Cr. **Del Norte Co.** Clarks Cr. **El Dorado Co.** Acorn Cr. in Skunk Canyon. **Glen Co.** Mud Cr., Little Butte Cr. **Humboldt Co.** North Fork Miller Cr., Salmon Cr., Sholes Cr. **Inyo Co.** Bishop Cr. **Madera Co.** Fresno R. **Marin Co.** “Keys at Irvin Road”, Big Carson Cr., Fairfax Cr., Green Gulch, Novato Cr. **Mendocino Co.** Outlet Cr., East Fork Russian R., Garcia R. **Merced Co.** Merced R., Salt Slough. **Mono Co.** Hot Cr. **Monterey Co.** Gabilan Cr. **Napa Co.** Napa R. **Nevada Co.** Deer Cr., Prosser Cr. **Placer Co.** Auburn Ravine, Boardman Canal, Clover Valley Cr., Dry Cr., Miners Ravine, Pleasant Grove Cr., Rubicon R., Secret Ravine, Truckee R. **Sacramento Co.** Alder Cr., American R., Arcade Cr., Dry Cr., Elder Cr., Laguna Cr., Linda Cr. **San Diego Co.** Escondido Cr., Rainbow Cr., San Luis Rey R. **San Joaquin Co.** Bear Cr., French Camp Slough, Little John Cr., Lone Tree Cr., Mokelumne R., Mosher Cr., Stanislaus R. **San Luis Obispo Co.** Arroyo De La Cruz, Garden Cr., Perfumo Cr., San Luis Obispo Cr., Stenner Cr. **Santa Barbara Co.** Santa Ynez R. **Santa Clara Co.** Chestnut Picnic Area, Saratoga. **Santa Cruz Co.** Aptos Cr., Scott Cr. **Siskiyou Co.** Yreka Cr. **Sonoma Co.** Matanzas Cr., Penngrove Park, Rainsville K.O.A. **Stanislaus Co.** Lone Tree Cr., Orestimba Cr., Stanislaus R., Tuolumne R. **Trinity Co.** Miner’s Cr. **Yuba Co.** Jack Slough.



FIGURE 2. Distribution of *Crangonyx* in California (with county boundaries in the background).

***Stygobromus cherylae* Wang and Holsinger, 2001; Cheryl's Amphipod** (phreatobiont)

Records: Known only from the type locality in Sonoma Co.: “unnamed spring box just east of Maacama Creek Bridge, beside highway 128, approximately 19.5 km east of Geyserville”, C. Barr (Wang and Holsinger 2001).

***Stygobromus cowani* Wang and Holsinger, 2001; Cowan's Amphipod** (phreatobiont)

Records: Known perhaps only from the type locality in Napa Co.: “roadside pipe from unnamed spring, Soda Canyon Road, approximately 6.4 km north of junction with Silverado Trail and about 6.4 km east of Yountville”, 23 Feb. 1991, C. Barr (Wang and Holsinger 2001).

Comments: *Stygobromus* nr. *cowani* was collected in Napa Co., Tucukey Cr., 29 Apr. 2000, by Friends of Napa Valley and Pacific Rivers Council (R. Wisseman, unpub. data), and also in Contra Costa Co., Wildcat Cr., 14 Apr. 2009, 6 specimens, by T. King.

***Stygobromus gallawayae* Wang and Holsinger, 2001; Gallaway's Amphipod** (phreatobiont)

Records: Known only from the type locality in Butte Co.: “unnamed spring on Rock Creek, about 20.8 km N of Chico”, 1996-1997, 11 specimens, J. Gallaway (Wang and Holsinger 2001).

***Stygobromus gradyi* Holsinger, 1974; Grady's Cave Amphipod** (stygobiont)

Records: **Amador Co.** Fern Frond Cave, 15 Apr. 1979, D.C. Rudolph, S. Winterath, E. van Ingen, and D. Cowan; Masonic Cave and Lulebell Cave, 17 Oct. 1987, F. Howarth; unnamed spring (Wang and Holsinger 2001). **Tuolumne Co.** Crystal Palace Cave, 15 Aug. 1968, M. Grady (Holsinger 1974), and confirmed present in 22 Oct. 2011, G.O. Graening and A. Aalbu; “small unnamed spring, ca. 14.8 km southeast of Angels Camp”, 19 Nov. 1978, D. Cowan (Wang and Holsinger 2001).

Comments: A stygobiont known only from springs and caves in the Mother Lode karst region, sometimes sympatrically with *S. grahami*.

***Stygobromus grahami* Holsinger, 1974; Graham's Cave Amphipod** (stygobiont)

Records: **Amador Co.** Fern Frond Cave, Masonic Cave (Wang and Holsinger 2001); Soldier Creek Cave (Holsinger 1974). **Calaveras Co.** Cave City Cave (= California Caverns), Cave of the Catacombs, Cave of the Quills, Shaws Cave, and Sink Cave (Holsinger 1974). **El Dorado Co.** Bacon Cr. Spring, springbox and outflow, Blodgett Forest Research Station, ca. 19 km east of Georgetown, 6 June 2004, C. Barr.

Comments: A stygobiont known only from springs and caves in the Mother Lode karst region.

***Stygobromus harai* Holsinger, 1974; Hara's Cave Amphipod** (stygobiont)

Records: A stygobiont known from only a few subterranean sites in Tuolumne Co.: Pinnacle Point Cave, and a mine tunnel near Pinnacle Point Cave, 27 Nov. 1974 (Holsinger 1974); Windeler Cave; and an “unnamed spring, 15 km southeast of Sonora” (Wang and Holsinger 2001).

***Stygobromus hyporheicus* Wang and Holsinger, 2001; Hyporheic Amphipod** (hyporheic)

Records: A phreatobiont known only from the type locality in Marin Co.: Golden Gate National Recreation Area,

“gravel-bed of intermittent stream, Cronan Creek”, at a depth of 40 cm, 1997, 5 specimens, R. Leach (Wang and Holsinger 2001).

Comments: No creek by that name is known, but there is a Cronin Gulch in this Recreation Area. Searches in 2010 and 2011 in the hyporheos of Cronin Gulch did not detect the species; the substrate of this stream is highly imbedded with silts and fines, and may no longer contain suitable habitat.

***Stygobromus imperialis* Wang and Holsinger, 2001; Empire Cave Amphipod** (stygobiont)

Records: A stygobiont known only from the type locality in Santa Cruz Co.: Empire Cave, 22 Apr. 1979, D. Rudolph, D. Cowan, and B. van Ingen; sympatric with *S. mackenziei* (Wang and Holsinger 2001).

Comments: *Stygobromus* nr. *imperialis* was collected in Monterey Co., Hastings Natural History Reservation east of Jamesburg, Arnold Spring (springbox), 14 Oct. 2003, C. Barr and W. Shepard.

***Stygobromus lacicolus* Holsinger, 1974** (nektobenthic?)

Records: Endemic to the benthos of Lake Tahoe; occurs sympatrically with *S. tahoensis* (Frantz and Cordone 1966; Holsinger 1974).

Comments: Caires *et al.* (2010) reported: “We found 3 specimens of *Stygobromus lacicolus*, 2 specimens that were smaller and were possibly *S. tahoensis*, and one specimen that was damaged and unidentified. All were collected between 67 and 107 m depth in McKinney Bay, near the west shore of Lake Tahoe. We only collected these 6 specimens, and from only one location in Lake Tahoe, out of about 400 samples in 2008-09, whereas stygobromids were extremely abundant (up to 3500 per square meter) from 200 to 350 meters at many different locations in ~400 samples collected in 1962-63.”

***Stygobromus mackenziei* Holsinger, 1974; McKenzie's Cave Amphipod** (stygobiont)

Records: Known only from the type locality in Santa Cruz Co.: Empire Cave, 6 specimens, 28 May 1967, D. McKenzie (Holsinger 1974); 5 specimens, 22 Apr. 1979, D.C. Rudolph, D. Cowan, and B. van Ingen, and 4 Dec. 1983, 2 specimens, T. Briggs (Wang and Holsinger 2001).

Stygobromus* sp. nov. cf. *mackenziei (hyporheic?)

Santa Clara Co. Creeks above Almaden Reservoir (probably washed out of sediments or in riffles), 19 May 1997, S. Fend; Saratoga Cr. at Tollgate Rd., May 1998 (probably washed out of sediments), S. Fend; Los Gatos Cr. below Lake Elsmán, probably washed out of sediments or seeps, 16 May 1997 S. Fend (unpub. data).

Stygobromus* sp. nov. aff. *mackenziei (hyporheic?)

Records: Stanislaus Co. Tuolumne R. at river miles (from confluence with San Joaquin R.) 25.4, 31.5, 38.1, 42.3, 43.2, 48.8, and 51.6, over 170 individuals collected in benthic samples by N. Hume *et al.* from 1996 to 2009 (Stillwater Sciences 2009).

***Stygobromus myersae* Wang and Holsinger, 2001; Myers' Amphipod** (phreatobiont)

Records: Inyo Co. “Black Canyon Spring, ca. 11 km E of Bishop”; “unnamed hillside spring, ca. 7 km S of Black Canyon Spring”; “unnamed hillside spring in Marble Canyon, ca. 7 km S of Black Canyon Spring” (Wang and Holsinger 2001).

Comments: Also known from Nevada, Esmeralda Co., at Log Spring (Wang and Holsinger 2001).

***Stygobromus mysticus* Holsinger, 1974; Secret Amphipod** (phreatobiont)

Records: Known only from a vague type locality in Siskiyou Co.: “*Subterranean habitat at Greenview*” in Klamath Mountains, 25 specimens, W. Barrett (Holsinger 1974).

Comments: We believe this locale is possibly a well; there is no other accession information (USNM # 142794 and -5).

***Stygobromus rudolphi* Wang and Holsinger, 2001; Rudolph’s Amphipod** (phreatobiont)

Records: Known only from the type locality in Santa Barbara Co.: Montgomery Spring, Los Padres National Forest, 8 specimens, 1974, D.C. Rudolph (Wang and Holsinger 2001).

***Stygobromus sheldoni* Holsinger, 1974; Sheldon’s Amphipod** (phreatobiont)

Records: Nevada Co. “*Bog spring tributary to Sagehen Creek*”, 2 other unnamed springs, and Station spring, Sagehen Field Research Station, June 1965, A. Sheldon (Holsinger 1974); Station spring, 2 specimens, 1999, C. Barr and W. Shepard (Wang and Holsinger 2001), and 25 June 2009, abundant in bryophytes in spring resurgence, C. Barr and G.O. Graening.

***Stygobromus sierrensis* Holsinger, 1974; Sierran Amphipod** (phreatobiont)

Records: Known only from a single site in Sierra Co.: “*Spring in Trosi canyon*”, 1,850 m elev., 10 May 1966, A. Sheldon (Holsinger 1974); we could not locate this site.

Comments: A. Sheldon (pers. com., 2009) stated that the elevation is incorrect, as the collection site was higher up the canyon; Sardine Spring is the likely locale. Three immature specimens, prob. *S. sierrensis*, were found in an unnamed spring 4 km southeast of Sardine Spring, Tahoe National Forest, 3 Oct. 2009, G.O. Graening and C. Akin.

Stygobromus* sp. nov., aff. *S. sierrensis (phreatobiont)

Records: Modoc Co. Modoc National Forest, Warner Mountains, Stough Reservoir Campground, unnamed spring with outflow pipe in tank above campground, elev. 1,900 m, 9 July 2007, C. Barr.

***Stygobromus tahoensis* Holsinger, 1974; Lake Tahoe Amphipod** (nektobenthic?)

Records: Endemic to the benthos of Lake Tahoe (Frantz and Cordone 1966; Holsinger 1974). **Comments:** Originally collected by Frantz and Cordone (1966) in dredge samples and erroneously reported as *S. hubbsi* Shoemaker, 1942, which does not occur in California (Holsinger 1974). Caires *et al.* (2010) performed similar dredge sampling and reported it to be extremely rare, and probably in decline.

***Stygobromus trinus* Wang and Holsinger, 2001; Trinity County Amphipod** (stygobiont)

Records: Known only from the type locality, Hall City Cave (Trinity Co.), from one collection event: 11 Apr. 1979, D. Rudolph, B. Martin, and S. Winterath (Wang and Holsinger 2001).

Comments: SCUBA divers did not detect any amphipods while mapping the submerged passages of Hall City Cave in 2012 (E. Jessup, California Academy of Sciences, pers. comm.).

Stygobromus wengerorum Holsinger, 1974; Wengers' Cave Amphipod (stygobiont)

Records: A stygobiont known only from 2 sites in Mariposa Co.: Bower Cave, May - June 1971, S. Shimek and B. Kruse (Holsinger 1974); and Centipede Cave, 30 July 1975, S. Shimek (Wang and Holsinger 2001).

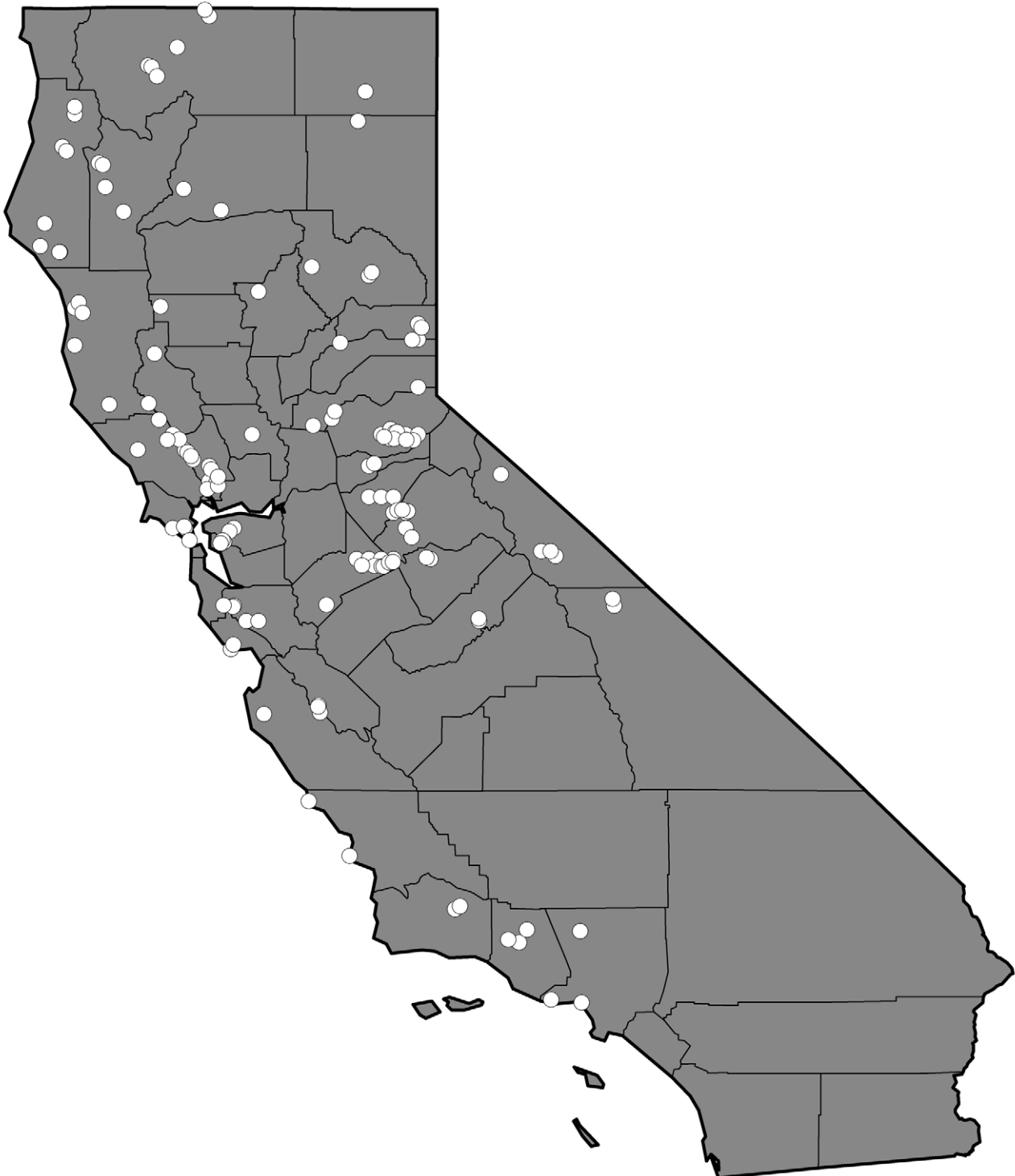


FIGURE 3. Distribution of *Stygobromus* in California (with county boundaries in the background).

Stygobromus sp. nov. (phreatobiont)

Records: A new taxon from Sonoma Co.: Hwy 128 at Maacama Bridge, 20 km east of Geyserville, at a springbox and hillside spring pipe feeding the spring box. In 2000, C. Barr and W. Shepard found it abundant and sympatric with a population of *S. cherylae*.

Stygobromus sp. nov. (phreatobiont)(Figure 3)

Records: At least one new taxon from San Benito Co.: Pinnacles National Monument, Oak Tree Spring, 24 Oct. 2010, 10 collected, 50 counted, G.O. Graening, T. Audisio, D. Chatterton, and D. Hunter, and Balconies Cave Spring, 1 specimen, 29 Oct. 2011, E. Kanawi, N. Macias, and G.O. Graening.

Stygobromus sp. nov. (hubbsi group) (hyporheic)

Records: A new phreatobiotic taxon from Los Angeles Co.: Malibu Cr., 1 female from benthic sampling, 19 Oct. 2000, M. Born.

Stygobromus sp.

Records: All of the following determinations are from the ABL database unless otherwise cited. The general distribution of *Stygobromus* is shown in Figure 4. **Alameda Co.** upper San Leandro Creek, M. Born, 2000-2001; Palo Seco, 2005. **Butte Co.** Sucker Run Cr. near Forbestown, 2003. **Contra Costa Co.** Reliez Cr. at 3400 Springhill Rd., possibly from spring discharge, 2003-2004 (Cressey and Sommers 2004); Chabot Regional Park, headwaters of San Leandro Cr., Site No. SLC-4 (Canyon School) and SLC-5 (Huckleberry Park), May 2000 (Breux *et al.* 2005); Marsh Cr., May 2011, and Wildcat Cr. at Big Springs, 2005-2006, A. Madrone and R. and L. Bottorff. **El Dorado Co.** Headwaters of North Cosumnes R., Singleton Springs, 20 Apr. 1982; North Cosumnes R. and tributary seeps at Sciaroni Crossing, 3 km north of Grizzly Flat, 1982 and 1986; 16 km east of Jenkinson Reservoir, Stump Spring, 24 Sep. 1982; North Cosumnes R., spring tributary upstream of Meiss, 18 km east of Grizzly Flat, 18 June 1986; Harrel Fire Tank spring, tributary to Long Canyon, 5 km northeast of Grizzly Flat, Sep. 1986; Big Canyon Cr., 5 km east of Grizzly Flat, 4 Apr. 1987; south bank of North Cosumnes R., about 3 km west of Capps Crossing, 22 Apr. 1987; Snow Cr., 13 km east of Jenkinson Reservoir, 27 Apr. 1987; Knickerbocker Cr. spring tributary, 1,600 m west of Hwy 49, 7 Feb. 1988; tributary to Knickerbocker Cr. near Cool, Mar. 2010 (all new county records of R. Bottorff). **Glenn Co.** Cold Cr. 1.3 mi. above confluence with Plasket Cr., 2003. **Humboldt Co.** Mason Gulch at Hwy 299 (upper Willow Cr.); Red Mountain Cr., Forest Service Rd. 10N12 (J. Lee, unpub. data); South Fork Eel R. above Briceland Bridge, 2004; Redwood Cr. 0.4 mi. above South Fork Eel R., 2004; Sholes Cr. 1.7 mi. above confluence with Mattole R., 2003; Squaw Cr. 0.3 mi. above Bull Cr., 2007. **Lake Co.** Rice Fork Cr. below Bear Cr. confluence, 2005, and Highland Cr., 2009. **Lassen Co.** Ash Cr., 2009. **Los Angeles Co.** Lower Santa Monica Canyon and Elizabeth Canyon, 2003. **Marin Co.** Bill Williams Cr., 5 km northwest of Corte Madera, Apr. 2000, R. Bottorff; Gerbode Valley, 2005. **Mendocino Co.** Angelo Coast Range Reserve headquarters, Sugar Cr. springbox and springhead drift, 2 fragments unidentifiable to species, C. Barr, 1 June 2003. Elder Cr., north of Branscomb, Nature Conservancy Reserve, 8 Oct. 1984, R. Bottorff, E. Connors, and A. Knight; Mud Cr. 1 mi. above South Fork Eel R., 2003, North Fork of South Fork Noyo R. 0.2 mi. above confluence, 2005, and Redwood Cr. above Mill Cr., 2009. **Modoc Co.** Canyon Cr. at Hwy 71, 2005. **Mono Co.** Swauger Cr.; upper Owens R. at Big Springs, Inaya, and EBASCO site (SNARL database). **Monterey Co.** San Clemente Cr. 1.3 mi. above Black Rock Cr., 2005. **Napa Co.** Napa R.: Browns Valley Cr., Carneros Cr., Kimball Cr., Kreuse Cr., Pickle Cr., Ritchie Cr., Sarco Cr., Sulphur Cr., and York Cr., over 100 individuals in benthic samples collected from 2003 to 2006, by Friends of Napa River and Institute for Conservation Advocacy, Research & Education (R. Wiseman, unpub. data). **Placer Co.** Miners Ravine, 2004. **Plumas Co.** Grizzly Cr., near Walker Mine, 19 km east of Quincy, 26 Sep. 1992, K. Maier; Chips Cr., 2009. **San Luis Obispo Co.** Arroyo de la Cruz at

TERMS OF USE

This pdf is provided by Magnolia Press for private/research use.
Commercial sale or deposition in a public library or website is prohibited.

Hwy 1, 2005, and Coon Cr. at Pecho Valley Rd., 2011. **Santa Clara Co.** Upper Stevens Cr., 2002, and Chestnut Picnic Area, 2002. **Shasta Co.** Bear Cr. Parkville Rd., 8.5 mi. south of Millville, 2003, and Brandy Cr. above South Shore Dr., 2005. **Sierra Co.** Yuba R. 0.9 mi. downstream of Indian Cr., 2001. **Siskiyou Co.** Fall Cr. (tributary to Klamath R.), 8 Oct. 2002, 2 specimens collected by CH2M Hill Inc. in benthic samples above and below PacifiCorp's bypass (R. Wisseman, unpub. data); Yreka Cr. above Interstate 5, 2007, and Scott R. above Etna Cr., 2006. **Sonoma Co.** Geyserville area, Blue Spring (CAS database); Big Sulphur Cr. 1.2 mi. above Geysers Canyon Cr., 2007, and Gilliam Cr., 2002. **Stanislaus Co.** Orestimba Cr. above Orestimba Rd., 2003. **Trinity Co.** unnamed, intermittent creek on Hwy 299, river mile mark 16.23 (J. Lee, unpub. data); Grassy Flat Cr. 0.2 mi. upstream of Hayfork Cr. **Ventura Co.** Lion Canyon, Tule Cr., and Piru Cr., 2003. **Yolo Co.** Cache Cr., 2009.



FIGURE 4. A new species of *Stygobromus* found in the springs and cisterns of Pinnacles National Monument, San Benito Co. (photo by David Hunter).

GAMMARIDAE Latreille, 1802***Gammarus daiberi* Bousfield, 1969** (euryhaline, exotic)

Records: Found in dredge samples collected in Contra Costa, Sacramento, San Joaquin, and Solano Counties at San Pablo Bay, Grizzly Bay, Suisun Bay, Sherman Lake, Frank's Tract, Sacramento R., Old R., Mandeville Tip, Brown's Island, and Mildred Island, San Joaquin R., and West Canal at Clifton Court Forebay intake (Toft 2000; CDWR database).

Comments: Introduced into the Delta probably from ballast water discharging (Cohen and Carlton 1998, Toft 2000, Toft *et al.* 2002, Chapman 2007).

***Gammarus lacustris sensu lato* Sars, 1864** (stenohaline)

Records: **Inyo Co.** "Lakes of Owens R. drainage basin (Mildred L., etc.), Bishop, N. Reimers coll., 1954" (Bousfield 1958); Owens R. at Hwy 136 (Usjak, in manuscript). **Kern Co.** Railroad Spring (Usjak, in manuscript). **Lassen Co.** Eagle Lake at Spaulding Rocks, 22 specimens, 22 May 1987, D.C. Rogers; Eagle Lake, trout stomach contents, taken off Gallatin Beach, 19 Aug. 1994, D.C. Rogers; Cleghorn Reservoir, 20 Aug. 1994, D.C. Rogers; Grasshopper Valley, unnamed spring at south end, 26 Apr. 1998, D.C. Rogers. **Mono Co.** Mono Lake in Dechambeau Cr. (Usjak, in manuscript). **Solano Co.** South of Suisun City, Hill Slough, in freshwater pools above *Salicornia* marsh, 2 Apr. 1994, D.C. Rogers.

Comments: *Gammarus lacustris* is reported from cold lakes, tundra ponds, sloughs, etc., of midwestern and western USA, Canada, Alaska, northwestern Europe, and Asia (Bousfield 1958, Holsinger 1972, Barnard and Barnard 1983, Hou *et al.* 2007). This holarctic taxon undoubtedly consists of several species (Barnard and Barnard 1983, Chapman 2007). *G. lacustris* was introduced to Lake Tahoe (Franz and Cordone 1966) and the Salton Sea (Barnard and Barnard 1983), but neither population established.

***Gammarus mucronatus* (Say, 1918)** (euryhaline, exotic)

Records & Comments: Native to North American Atlantic coastal waters, this species was introduced to the Salton Sea probably in 1957 when the marine grass *Diplanthera* from Texas was intentionally introduced (Barnard and Gray 1968). Simpson *et al.* (1998) reported that, "in the absence of fish *Gammarus mucronatus* dominated the benthos at the lower salinities.", but they also predicted that, "*Gammarus* will disappear from the Salton Sea as the salinity increases."

***Gammarus* sp.**

Records: The following are tentative gammarid identifications from the ABL database. **Alameda Co.** Codornices Cr. **Alpine Co.** Bagley Valley Cr. **Calaveras Co.** Deer Cr. **Contra Costa Co.** Pinole Cr., San Pablo Cr., Wildcat Cr. **Colusa Co.** Stone Corral Cr., Wilkens Slough. **El Dorado Co.** Deer Cr., Greenwood Cr., Taylor Cr. **Fresno Co.** San Joaquin R. **Glenn Co.** Baker Slough, Logan Cr. **Humboldt Co.** Fern Canyon Cr., Godwood Cr., Ryan Cr. **Inyo Co.** Bishop Cr. **Kern Co.** Eastside Lateral Canal. **Los Angeles Co.** Malibu lagoon, Bull Cr., Los Angeles R., San Gabriel R. **Madera Co.** San Joaquin R. **Marin Co.** San Antonio Rd. bridge, Fairfax Cr. **Mendocino Co.** Garcia R., East Fork Russian R. **Merced Co.** Ingalsbe Slough, Salt Slough, San Joaquin R., West San Juan Drain. **Mono Co.** Slinkard Cr., Kirman Cr., Little Walker Cr., Poore Cr., Hot Cr., Mammoth Cr., upper Owens R. **Monterey Co.** Carmel R., Salinas R. **Nevada Co.** Prosser Cr., Deer Cr. **Placer Co.** Antelope Cr., Auburn Ravine, Boardman Canal, Clover Valley Cr., Dry Cr., Pleasant Grove Cr., middle Truckee R. **Plumas Co.** Cow Cr., Grizzly Cr., Old House Cr., Snow Cr. **Sacramento Co.** Lower American R., Arcade Cr., Cosumnes R., Dry Cr. **San Benito Co.** Pajaro R. **San Diego Co.** Escondido Cr., San Luis Rey R., Santa Margarita R. **San Joaquin Co.** French Camp Slough, Little John Cr., Lone Trees Cr., Middle R., Port of Stockton, San Joaquin R. **San Luis Obispo Co.** Arroyo

De La Cruz, Chorro Cr., Las Tablas Cr., Los Osos Cr., Pico Cr., San Luis Obispo R., San Simeon Cr., Santa Rosa Cr., Stenner Cr. **Santa Barbara Co.** Atascadero Cr., Carpinteria Cr., Refugio Cr., Santa Ynez R. **Santa Clara Co.** Alamitos Cr., Coyote Cr., Lyndon Canyon, Llagas Cr., Uvas Cr., Pajaro R. **Santa Cruz Co.** Aptos Cr., Pajaro R., San Lorenzo R. and estuary, Scott Cr., Soquel Cr. lagoon, Waddell Cr. and lagoon, Zayante Cr. **Shasta Co.** Acid Canal. **Solano Co.** Alamo Cr., unnamed canals. **Sonoma Co.** Dutch Bill, Laguna de Santa Rosa, Maacama Cr., Mark West Cr., Matanzas Cr., Petaluma R. **Stanislaus Co.** Del Puerto Cr., Dry Cr., Modesto Main Canal, Orestimba Cr., San Joaquin R., Westley Wasteway. **Sutter Co.** Feather R., Pleasant Grove Cr. **Tulare Co.** Unnamed canal. **Ventura Co.** Arroyo Las Posas, Calleguas Cr., Conejo Cr., Piru Cr., Revolon Slough, Santa Clara R. estuary. **Yolo Co.** Sacramento Turning Basin. **Yuba Co.** Honcut Cr., Cordua Canal, Jack Slough, Yuba R. **Comments:** Ba *et al.* (2010) predicted that *Gammarus tigrinus* Sexton, 1939 will invade San Francisco Bay via ballast water discharge.

HAUSTORIIDAE Stebbing, 1906

Eohaustorius estuarius Bosworth, 1973 (estuarine)

Records: Occurs in sandy portions of estuaries along the central California coast (Chapman 2007).

HYALELLIDAE Bulycheva, 1957

Hyalella sp. Smith, 1874

Records: The following records are summarized from Bate 1862, Stebbing 1906, Weckel 1907, Smith 1953, Frantz and Cordone 1966, Eriksen 1968, McElray and Resh 1991, Toft 2000, Lee 2001, Bottorff *et al.* 2003, Cressey and Sommers 2004, Breaux *et al.* 2005, Lee and Coopridge 2005, Witt *et al.* 2006, Johnson 2008, CAS database, CDWR database, NMNH database, ABL database, and this study. **Alameda Co.** South Bay Aqueduct, Arroyo Las Positas, Berkeley Beach, Altamont Pass, Arroyo Mocho. **Alpine Co.** Bagley Valley Cr., Heenan Cr., Company Meadow, Poison Cr., Silver King Cr. **Amador Co.** Lower Cosumnes R.; Big Indian Cr. 4 mi. north of Plymouth. **Butte Co.** Cherokee Canal, Clear Cr., Gold Run Cr., Little Chico Cr. **Calaveras Co.** Coyote Cr. at Natural Bridges. **Contra Costa Co.** Alameda Cr., Alhambra Cr., west Antioch Cr., Botanic Garden, Clifton Court Forebay, Contra Costa Canal, Donnor Cr., Franklin Cr., Grayson Cr., Jewel Lake, Kirker Cr., Mallory Cr., Mitchell, Old R., Peacock in Irish Canyon, Periera Cr., Pinole Cr., Possum Picnic Area, Refugio Cr., Rodeo Cr., Sacramento R., San Joaquin R., San Pablo Cr., Simas Cr., Tice Cr., Walnut Cr., Wildcat Cr., unnamed cr. above Bear Creek Rd. **Del Norte Co.** Smith R. **El Dorado Co.** Lake Tahoe, Meeks Cr., Cosumnes R. (lower and middle reaches), Francis Lake near Loon Lake, Grass Lake, Acorn Cr. in Skunk Canyon. **Fresno Co.** Sycamore Cr. **Glenn Co.** Mud Cr., Stony Cr. **Humboldt Co.** Salmon Cr. **Imperial Co.** Holtville Drain. **Inyo Co.** Bishop Cr., Darwin Cr. **Kern Co.** Kern R., Stine Canal. **Lake Co.** Big Canyon Cr., Seigler Cr. **Lassen Co.** Ash Cr., Goodrich Cr., Willow Cr., Beaver Cr., Horse Cr., Parsnip Cr. **Los Angeles Co.** Ballona Cr., Big Tujunga Canyon, Castaic Cr., Cheeseboro Canyon, Corral Canyon Cr., Lachusa Cr., Las Virgenes Cr., Little Rock Cr., Los Angeles R., Malibu Cr., Medea Cr., Puerco Canyon Cr., Piru Cr., Rio Hondo, Rustic Canyon, Santa Monica canyon, Sweetwater Canyon Cr., Topanga Canyon Cr., Trancas Canyon Cr., Triunfo Canyon, Tuna Canyon Cr., Zuma Canyon. **Madera Co.** Fresno R., San Joaquin R. **Marin Co.** Chileno Valley, Gambonini Mine, Gerbode, Glenbrook Cr., Green Gulch, Home Ranch Cr., Keys Cr., Laguna Lake, Muddy Hollow Cr., Rolland Pond, Schooner Cr., Soulajule, Stemple Cr., Tennessee Valley, Verde Canyon, Walker Canyon, Walker Cr., spring on Old Springs Trail. **Mariposa Co.** Chowchilla R., Mariposa Cr. **Mendocino Co.** Navarro R., Outlet Cr., Tomki Cr. **Merced Co.** Colony Main Canal, Merced R., Salt Slough. **Modoc Co.** East Cr., Egg Lake Slough, Loma Alta Cr., Ash Cr., Fitzhugh Cr., Pit R., Turner Cr., Rattlesnake Cr., Willow Cr., Witcher Cr. **Mono Co.** A thermal spring near Bridgeport, East Walker R., Hot Cr., Kirman Cr., Little Walker R., Mammoth Cr., Owens R., Paramount Cr., Robinson Cr., Swauger Cr. **Monterey Co.** Alisal Cr., Arroyo Seco, Carmel R., Gabilan Cr., San Antonio Cr., San Jose Cr., Salinas R. estuary. **Napa Co.** Napa R. **Nevada Co.** Boca Spring, middle Truckee R., Paradise Lake, Prosser Cr. **Orange Co.** Arroyo Trabuco Cr., Brea Canyon,

Fullerton Cr., Laguna Canyon, San Gabriel R., San Juan Cr., Segunda Deshecha Canada, Tanner Cr., Telegraph Canyon. **Placer Co.** Auburn Ravine, Kaseberg Cr., Lake Tahoe, Linda Cr., Martis Cr., Miners Ravine Pleasant Grove Cr., salt springs in Lincoln, Secret Ravine, Truckee R.. **Plumas Co.** Corral Spring, Cow Cr., Desmona Cr., Fairy Spring, Freeman Cr., Grizzly Cr., Indian Cr., Jenkins Cr., Lake Davis, Last Chance Cr., Little Stony Cr., Moselia Spring, Old House Cr., Red Clover Cr., Spanish Cr. **Riverside Co.** Adobe Cr., Coachella Valley storm channel, Murrieta Cr., Salt Cr., Salton Sea Drain, Sandia Cr., Santa Ana R., Temecula Cr., Whitewater R.. **Sacramento Co.** Alder Cr., American R., Arcade Cr., lower Cosumnes R., Dry Cr., Elder Cr., Elk Grove Cr., Laguna Cr., Morrison Cr., Sacramento R.. **San Benito Co.** Chalone Cr., Sandy Cr. **San Bernardino Co.** Aliso Canyon Cr., Big Bear Lake, Mojave R., Water Canyon Cr. **San Diego Co.** Agua Hedionda Cr., Alvarado Cr., Black Mountain Cr., Boden Canyon Cr., Boulder Cr., Buena Vista Cr., Campo Cr., Carlsbad, Cedar Cr., Chicarita Cr., Chollas Cr., Conejos Cr., Cottonwood Cr., De Luz Cr., Devils Canyon Cr., Encinitas Cr., Escondido Cr., Forrester Cr., French Cr., Fry Cr., Gird Cr., Gopher Canyon, Green Valley Cr., Irons Springs, Jamul Cr., Keys Cr., Kit Carson Cr., La Posta Cr., Lawson Valley, Loma Alta Cr., Long Canyon Cr., Los Penasquitos Cr., Cottonwood Cr., Moosa Cr., Pauma Cr., Pine Cr., Rainbow Cr., Rattlesnake Cr., Rose Canyon Cr., San Diego R., San Luis Rey R., San Marcos Cr., San Mateo Cr., San Vicente Cr., Soledad Canyon Cr., Sweetwater R., Tecolote Cr., Troy Canyon Cr., Santa Ysabel Cr., Wilson Cr. **San Francisco Co.** Lake Merced, Lobos Cr. **San Joaquin Co.** Bear Cr., Calaveras R., Duck Cr., French Camp Slough, Little John Cr., Mormon Slough, Old R., Port of Stockton, San Joaquin R.. **San Luis Obispo Co.** San Luis Obispo, Arroyo Grande Cr., Brizzolara Cr., Camp Roberts, Cholame Cr., Chorro Cr., Chumash Cr., Coon Cr., Cuyama R., Dairy Cr., Garden Cr., Huasna R., Laguna Lake, Las Tablas Cr., Los Osos Cr., Nacimiento R., Orcutt Cr., Oso Flaco Lake, Pismo Cr., Salinas R., San Luis Obispo Cr., San Simeon Cr., Santa Rosa Cr., Stenner Cr., Toro Cr., Warden Cr. **San Mateo Co.** Above Mud Dam, Gazos Cr. Lagoon, Honsinger, Jones Gulch, San Francisquito Cr. **Santa Barbara Co.** Arroyo Burro, Atascadero Cr., Canada de la Gaviota, Jalama Cr., La Brea Cr., Santa Margarita R., Santa Maria R., Santa Ynez R., Shuman Cr., Sisquoc R., Zaca Cr., Zanja de Cota Cr. **Santa Clara Co.** Alamitos Cr., Alviso Slough, Arroyo Hondo, Guadalupe Cr., Lake Lagunita, Llagas Cr., Los Gatos Cr., Matadero Cr., Pacheco Cr., Pajaro R., Penitencia Cr., Saratoga, San Francisquito Cr. **Santa Cruz Co.** Baldwin Cr., Lombardi Cr., Sandy Flat Cr., Waddell Cr., Wilder Cr. **Shasta Co.** Acid Canal. **Sierra Co.** Cold Cr., unnamed spring in Sardine Valley. **Siskiyou Co.** Boles Cr., Butte Cr., Evans Ditch, Johns Meadow Cr., Klamath R., Oregon Slough, Shasta R., Yreka Cr. **Solano Co.** Alamo Cr., Chabot Lake, Putah South Canal, Sacramento R., Sweany Cr., Ulati Cr. **Sonoma Co.** Fairfield Osborn Preserve, Ellis, Lynch, Maacama Cr., Mark West Cr., Matanzas Cr., Russian R., Stemple Cr., Wallace Cr., Wine Cr. **Stanislaus Co.** Del Puerto Cr., Lateral Canal, Orestimba Cr., Stanislaus R., Tuolumne R.. **Sutter Co.** Feather R., Wadsworth Canal. **Tehama Co.** Antelope Cr., Big Dry Cr., Deer Cr., Duck Cr., Dye Cr., New Cr., Toomes Cr. **Trinity Co.** Hayfork Cr., Miner's Cr., Potato Cr. **Tulare Co.** Campbell-Moreland Ditch, Tule R., Yucca Cr. **Ventura Co.** Arroyo Conejo Cr., Arroyo Las Posas, Arroyo Simi, Beardsley Wash, Calleguas Cr., Conejo Cr., Las Virgenes Canyon, Lindero Canyon, Lockwood Cr., Mugu Drain, Padre Juan Canyon Cr., Piru Cr., Revolon Slough, Rincon Cr., Santa Clara R., Sespe Cr., Ventura R.. **Yolo Co.** Cache Cr., Sacramento Turning Basin, Willow Slough, Yolo Central Canal. **Yuba Co.** Cordua Canal, Honcut Cr., Jack Slough, Stahl Ditch.

Comments: The nomen *Hyaella azteca* (de Saussure 1858) has been broadly applied to members of the genus *Hyaella* for decades. However, Gonzales and Watling (2002a) demonstrated that *H. azteca* is probably limited to the region of Veracruz, México (the type locality). Various studies have demonstrated that the form typically referred to as *H. azteca* represents a polyphyletic complex that has been assigned unsystematically to populations throughout North and South America (Bousfield 1958; Gonzalez and Watling 2002a [and numerous studies cited within],b; Wellborn et al. 2005). This genus is nearly cosmopolitan in California, uncommon only in desert areas and above 600 m elevation (Figure 5). Chapman (2007) also reports that there are likely many introductions into novel estuarine habitats. Until the systematics and meristics are resolved, none of the California records are confidently assigned to any species.

***Hyaella muerta* Baldinger et al., 2000, Death Valley Amphipod (phreatobiont)**

Records & Comments: Known only from Inyo County, Death Valley National Park, in Texas Springs and Travertine Springs (Baldinger et al. 2000; Witt et al. 2006).

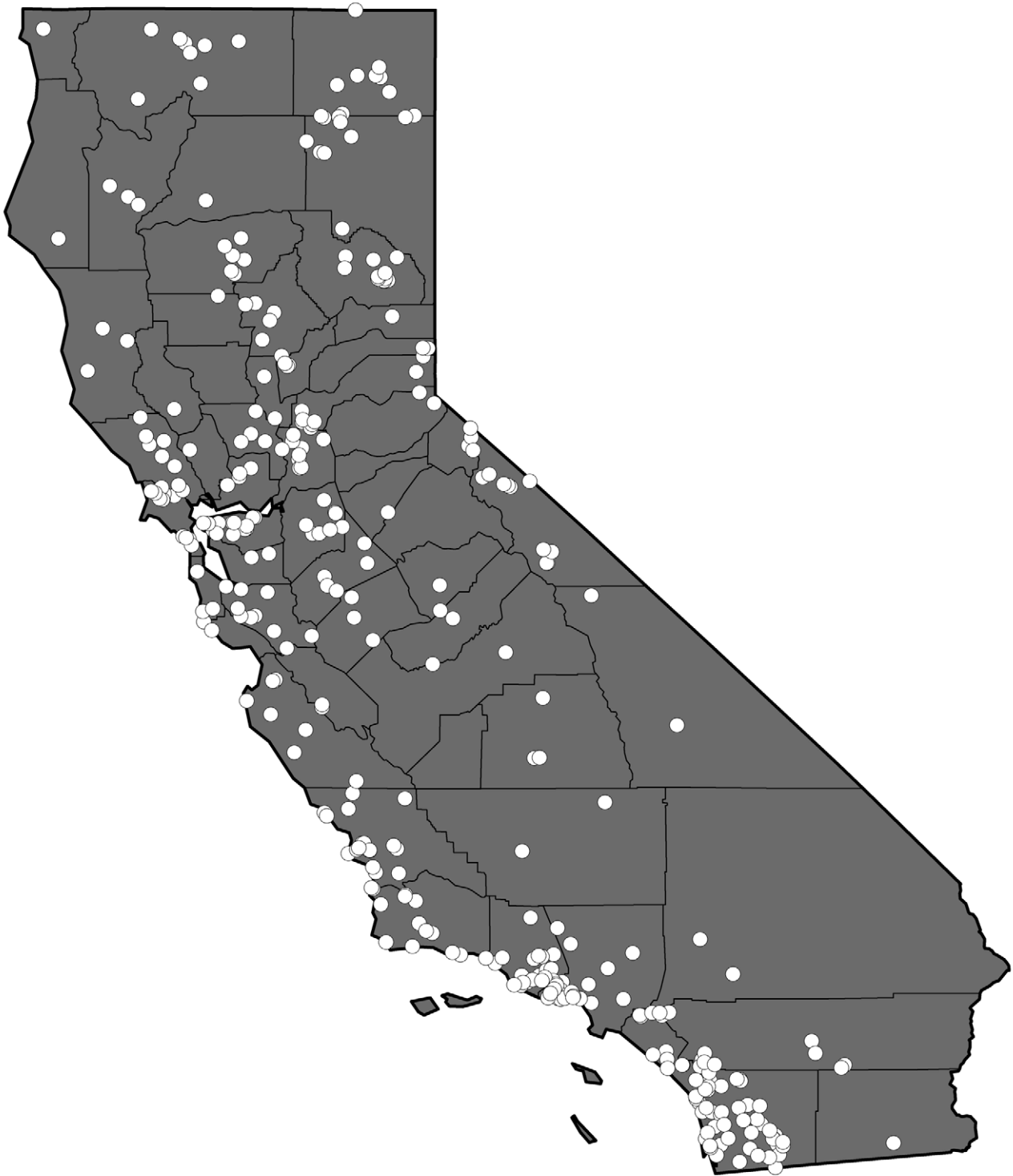


FIGURE 5. Distribution of *Hyaella* in California (with county boundaries in the background).

***Hyaella sandra sensu lato* Baldinger *et al.*, 2000** (phreatobiont)

Records & Comments: Known only from Inyo County, in Nevares Springs and Travertine Springs (Baldinger *et al.* 2000). Witt *et al.* (2006) concluded that the populations in these two springs are different species.

Hyaella sp. nov.

Records: **Inyo Co.** “HaPS9” in Warm Springs Canyon; “HaPS10” in Grapevine Spring; “HaPS13” in Saline Valley Marsh; “HaPS22” in Spring 94, Spring 97, Antelope Spring; “HaPS23” in Surprise Spring and Lower Vine Ranch Spring; “HaPS29” in Mule Spring; “HaPS30” in Warm Spring; “HaPS31” in Tuttle Cr., Owens R., and Lubkin Cr. **Mono Co.** “HaPS12” in BLM Spring; “HaPS24” in Fish Slough; “HaPS28” in Big Spring; “HaPS29” in Spring 103. **San Bernardino Co.** “HaPS13” in Cedar Springs, site on Mojave R., Big Morongo Spring, and Afton Canyon Spring.

Comments: At least 33 provisional species of *Hyaella* are present in the southern Great Basin ecoregion of California and Nevada; listed here are the haplotypes as distinguished by Witt *et al.* (2006). Witt *et al.* (2006) also reports a new species of *Hyaella* (“HaPS13”) on Catalina Island, Los Angeles Co.

HYALIDAE Bulycheva, 1957*Apothyale pugettensis* (Dana, 1853) (estuarine)

Records: **Humboldt Co.** South of Ferndale, Fleener Cr., above high tide mark in watercress above beach wrack, 21 June 1986, D.C. Rogers.

Comments: Occurs in brackish to freshwater at and above high tide marks, where streams reach the open coast in northern California (Chapman 2007).

MAERIDAE Krapp-Schickel, 2008*Elasmopus antennatus* (Stout, 1913) (euryhaline)

Records: **Contra Costa Co.** Old R. at Rancho Del Rio, 1983-1984, 1 to 5 specimens, CDWR. **Sacramento & Solano Co.’s.** Sacramento R. above Point Sacramento, 1983-1995, 1 to 8 specimens, from ponar dredge, CDWR.

Comments: This species is typically found in the intertidal zone from central California to Oregon.

Maera similis Stout, 1913 (estuarine)

Records & Comments: Reported from estuaries along the central California Coast (Chapman 2007).

MELITIDAE Bousfield, 1973*Melita nitida* Smith, 1873 or *setiflagella* Yamato, 1988 (estuarine, exotic)

Records: **Contra Costa Co.** Point Richmond and Lake Merritt (Carlton 1979); Suisun Bay and Grizzly Bay (CDWR database). **Los Angeles Co.** San Gabriel R. estuary (Cadien 2007); “*Malibu Creek, about 0.5 mile downstream of Century Reservoir*” (identified only to genus), and Cold Cr. (tributary to Malibu Cr.), 2002, M. Born and M. Abramson. **Monterey Co.** Elkhorn Slough (Carlton 1979; Sheridan 1979). **Sacramento Co.** Sacramento R. (CDWR database). **San Francisco Co.** San Francisco Harbor (Chapman 1988). **Solano Co.** Suisun Bay and Grizzly Bay (CDWR database).

Comments: *M. nitida* is an estuarine species that can tolerate very low salinities and is found in estuaries and freshwater seeps in its native range along the east coast of North America from the Gulf of Saint Lawrence to the Yucatan Peninsula (Bousfield 1973; Sheridan 1979; Chapman 1988). On the west coast, it has established from British Columbia to Long Beach Harbor, probably in association with Atlantic oyster shipments (Carlton 1979; Chapman 1988; Cadien 2007). However, the Asian *M. setiflagella* is apparently indistinguishable from the California populations (Jarrett and Bousfield 1996); therefore it may be that this species was introduced from Asia, rather than the Atlantic (Chapman 2007).

PHOXOCEPHALIDAE Sars, 1891*Grandifoxus grandis* (Stimpson, 1856) (euryhaline)

Records: CDWR reported *G. grandis* from San Pablo Bay near Pinole Point, Suisun Bay, and Sacramento R. below Rio Vista bridge.

Comments: This intertidal, burrowing amphipod tolerates low salinity and has been reported from Pacific Grove, California, to the Strait of Georgia, British Columbia (Barnard 1980; Carlton 2007).

PONTOGENEIIDAE Stebbing, 1906*Paramoera bousfieldi* Staude, 1995 (euryhaline)

Records: Humboldt Co. Trinidad, Mill Cr. at Pacific Ocean, 8 June 1986, D.C. Rogers.

Comments: Found in freshwater seeps and streams that join the sea (Chapman 2007).

Discussion

Amphipoda are found in every county and in every ecoregion in California, and range in population densities from rare individual sightings to numerical dominance in benthic macroinvertebrate communities. Forty-six native species and 16 exotic species are currently known from California's inland waters; an additional 12 taxa may be added if new hyalellids from the Great Basin ecoregion identified by Witt *et al.* (2006) are formally described. Thus, California contains about 16% of the known richness of North American freshwater amphipods: North America has approximately 236 taxa recognized from fresh or inland waters, as defined by Vainola *et al.* (2008), who only include estuarine taxa if there are "landlocked freshwater populations". Of these 46 native taxa, about 20 species are subterranean obligates (Figure 5), and almost exclusively stygobromids, which follows a broader pattern: more than half of all North American freshwater amphipod species occur exclusively in subterranean waters, with the family Crangonyctidae (and especially *Stygobromus*) dominating (Holsinger 1967). California's native amphipod fauna displays high endemism: 24 taxa are known only from California, and of these, 19 species are restricted to a single body of water (typically a spring or cave stream), and 3 additional species are known from only two locales. The undescribed hyalellids in California's portion of the Great Basin ecoregion are similarly restricted.

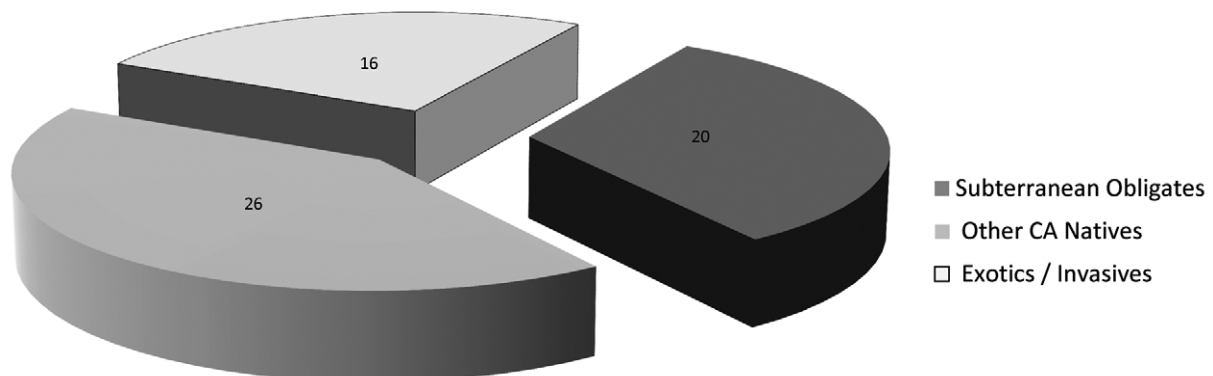


FIGURE 6. The majority of Californian freshwater amphipods are either stenohaline, cold stenotherms (and primarily, subterranean obligates) or invasive, euryhaline species.

The native freshwater amphipod fauna is still under-inventoried, especially in springs and other subterranean habitats. The shortage of taxonomists, a global crisis (Agnarsson and Kuntner 2007), hampers the identification of additional, novel Californian taxa as well as the enumeration of true alpha richness. Based upon our current understanding of the distribution of amphipods in California, and the conservation status assessment criteria established by the International Union for Conservation of Nature and Natural Resources (IUCN 2011) and

NatureServe (2011), new and revised conservation rankings are recommended (Table 1). Based upon these criteria, several taxa are globally rare and endangered.

TABLE 1. Current IUCN Red List and Natural Heritage Program conservation status ranks and suggested revisions for those taxa having sufficient data, and notes on endemism and population trends.

Taxon	Current Red List Rank	Suggested Red List Rank	Current Heritage Ranks	Suggested Heritage Ranks	Notes
<i>Americorophium spicorne</i>	---	DD	---, ---	S4	Known only from the Pacific Northwest
<i>Americorophium stimpsoni</i>	---	DD	---, ---	S3?	Potentially in decline (Chapman 2007), but additional bioinventory needed
<i>Crangonyx richmondensis</i>	---	LC	G5, ---	T1?	Very rare in California, but additional bioinventory needed
<i>Eogammarus confervicolus</i>	---	DD	---, ---	S2?	Known from about 20 sites in California; additional bioinventory needed
<i>Gammarus lacustris s. l.</i>	---	LC	---, ---	G5Q, S1	May be polyphyletic
<i>Hyalella muerta</i>	---	EN D2	G1, S1		Known globally from only 1 or 2 sites
<i>Hyalella sandra</i>	---	EN D2	G1, S1		Known globally from only 2 sites
<i>Ramellogammarus californicus</i>	---	CR D2	---, ---	G1, S1	Single-site endemic
<i>Ramello-gammarus columbianus</i>	---	DD	---, ---	S1?	Very rare in California; additional bioinventory needed
<i>Ramello-gammarus ramellus</i>	---	DD	---, ---	S2?	Rare in California; additional bioinventory needed
<i>Stygobromus cherylae</i>	---	CR D2	G1G2, ---	G1, S1	Single-site endemic
<i>Stygobromus cowani</i>	---	CR D2	G1G2, ---	G1, S1	Single-site endemic
<i>Stygobromus gallawayae</i>	---	CR D2	G1G2, ---	G1, S1	Single-site endemic
<i>Stygobromus gradyi</i>	VU D2	EN D2	G1, S1		Known from only 6 sites globally
<i>Stygobromus grahami</i>	---	VU D2	G2G3, ---	G2, S2	Known from only 9 sites globally
<i>Stygobromus harai</i>	VU D2	EN D2	G1G2, S1S2	G1, S1	Known from only 4 sites globally
<i>Stygobromus hyporheicus</i>	---	CR B1a-b; D2	G1G2, ---	GH, SH	Single-site endemic; may be extinct
<i>Stygobromus imperialis</i>	---	CR D2	G1G2, ---	G1, S1	Single-site endemic
<i>Stygobromus lacicolus</i>	---	CR B1a-b; D2	G2G3, ---	G1, S1	Single-site endemic; probably in decline (Caires <i>et al.</i> 2010)
<i>Stygobromus mackenziei</i>	VU D2	EN D2	G1G2, S1S2	G1, S1	Single-site endemic
<i>Stygobromus myersae</i>	---	EN D2	G1G3, ---	G1, S1	Known from less than 5 sites globally
<i>Stygobromus mysticus</i>	---	CR D2	G1G2, ---	G1, S1	Single-site endemic

..... continued on the next page

TABLE 1. (Continued)

Taxon	Current Red List Rank	Suggested Red List Rank	Current Heritage Ranks	Suggested Heritage Ranks	Notes
<i>Stygobromus rudolphi</i>	---	CR D2	G1G2, ---	G1, S1	Single-site endemic
<i>Stygobromus sheldoni</i>	---	CR D2	G1G2, ---	G1, S1	Single-site endemic
<i>Stygobromus sierrensis</i>	---	CR D2	G1G2, ---	G1, S1	Single-site endemic
<i>Stygobromus</i> sp. nov. (hubbsi group)	---	CR D2	---, ---	G1, S1	Single-site endemic
<i>Stygobromus</i> sp. nov. (Sonoma Co.)	---	CR D2	---, ---	G1, S1	Single-site endemic
<i>Stygobromus</i> sp. nov. aff. <i>imperialis</i>	---	CR D2	---, ---	G1, S1	Single-site endemic
<i>Stygobromus</i> sp. nov. aff. <i>mackenziei</i>	---	CR D2	---, ---	G1, S1	Single-site endemic
<i>Stygobromus</i> sp. nov. cf. <i>mackenziei</i>	---	EN D2	---, ---	G1, S1	Known from less than 5 sites globally
<i>Stygobromus</i> sp. nov. aff. <i>sierrensis</i>	---	CR D2	---, ---	G1, S1	Single-site endemic
<i>Stygobromus tahoensis</i>	---	CR B1a-b; D2	G2G3, ---	G1, S1	Single-site endemic; probably in decline (Caires <i>et al.</i> 2010)
<i>Stygobromus trinus</i>	---	CR D2	G1G2, ---	G1, S1	Single-site endemic
<i>Stygobromus wengerorum</i>	VU D2	EN D2	G1G2, S1S2	G1, S1	Known from only 2 sites globally

Notes: The full rationale and explanation for these conservation status ranking systems is detailed in IUCN (2011) for the Red List and in Master (1991) and NatureServe (2011) for the Natural Heritage Program, but briefly, for the Red List, LC = Least Concern, VU = vulnerable to extinction, EN = endangered, CR = critically endangered, and for the Heritage Program, G = global rank, S = subnational rank, and the numbers range from 1 = critically impaired to 5 = secure. Exotic species (not listed here) should be assigned the Red List category “LC” (i.e., of least conservation concern) and Natural Heritage rank “SNA” to indicate that they have no applicable conservation status in California. Native species not listed here, as well as those designated “DD”, are data deficient and thus cannot yet be fully ranked.

The ecological threat of exotic amphipods to freshwaters is severe. Certain euryhaline amphipod taxa are effective invaders and competitors, and benefit greatly from synanthropy and habitat disturbance—factors which characterize most Californian estuaries and harbors (Carlton 1979; Chapman 1988). Trans-oceanic shipping, and particularly the discharge of ballast water, is recognized as the most important factor in the dispersion of exotic aquatic species (Carlton 1985; Ba *et al.* 2010). San Francisco Bay, one of the world’s busiest shipping zones, has at least 10 invasive amphipod taxa (Ruiz *et al.* 2000; CDWR database; this study). Furthermore, extensive hydromodifications, such as the California Water Project, have interconnected previously isolated waters. For example, the CDWR documents at least 6 amphipoda at West Canal at the Clifton Court Forebay intake—*A. spinicorne*, *A. stimpsoni*, *C. alienense*, *C. floridanus*, *G. daiberi*, and *Hyaella*—most of which may be exotics originating downstream in the Delta. We tallied 18 exotic amphipod species in Californian inland waters, and the tally would be much larger with inclusion of marine environments. Many of these exotic taxa are specialized for life in subtidal mud and silt sediments. Such substrates are now common in the San Francisco Bay and Delta, which have experienced elevated sedimentation rates from historic hydraulic gold mining and intensive agricultural practices (Krone 1979; Chapman 1988). The impacts of these introductions includes the alteration of aquatic food webs and the transmission of parasites; invasive species are also implicated in the disappearance of native taxa, probably through competition, displacement, or direct predation (see review by Ba *et al.* 2010).

Amphipods and other malacostracans can serve as bioindicators of habitat quality and integrity, and should not be marginalized in bioassessment methodologies. Amphipod (and isopod) taxa display a varied response to environmental stressors, which allows their presence or absence to be used in habitat quality comparisons (Notenboom *et al.* 1994). Furthermore, differences in physiology and life history between epigeal and hypogean

taxa result in differing responses to acute and chronic pollutant exposure (Malard *et al.* 1996). Various metrics of abundance and richness have been employed in habitat bioassessments, especially the epigeal to hypogean fauna ratio and the amphipod to isopod ratio (Ronneberger 1975, Malard *et al.* 1994, 1996; Simon and Buikema 1997; Rogers *et al.* 2010).

Acknowledgments

We are indebted to the scientists who graciously shared their unpublished data or queried institutional databases, including the following: Rachel Barnett and Karen Gehrts (CDWR); Monique Born (Sustainable Land Stewardship Institute); Andrea Caires (U. of Nevada, Reno); Darren Fong (Golden Gate National Recreation Area); William Gerth (Oregon State U., Corvallis); Dave Herbst (SNARL); Noah Hume (Stillwater Sciences); Tom King (BioAssessment Services); Jon Lee (Jon Lee Consulting); Chris Malan (Institute for Conservation Advocacy, Research & Education); Darlene McGriff (CDFG); Peter Odie, Doug Post, and Dan Pickard (CDFG Aquatic Bioassessment Laboratory); Andy Sheldon (U. of Montana, Missoula); William Shepard (Essig Museum of Entomology); Robert Wisseman (Aquatic Biology Associates, Inc.); Jonathan Witt and Susan Usjak (U. of Waterloo). We also thank Jack Smith and Astra Gleason (CSUS Interlibrary Services Dept.) for literature acquisition, and the many land managers and landowners, for access to, and for protecting their aquatic resources. We would also like to acknowledge the fieldwork and literature review performed by CSUS students and graduates—Cheryl Akin, Tracy Audisio, Daniel Chatterton, Angela DePalma-Dow, Jeff Flores, Alex Keith, Rachel Gordon, Emerson Kanawi, Alex Mercado, Nick Macias, and Navneet Sharma—and other associates—Rolf Aalbu, Linda Babcock, Ron Davis, Guy Graening, David Hunter, and Paul Johnson.

Literature Cited

- Agnarsson, I. & Kuntner, M. (2007) Taxonomy in a changing world: seeking solutions for a science in crisis. *Systematic Biology*, 56, 531–539.
- Aldrich, F.A. (1961) Seasonal variations in the benthic invertebrate fauna of the San Joaquin River estuary of California, with emphasis on the amphipod *Corophium spinicorne* Stimpson. *Proceedings of the Academy of Natural Sciences of Philadelphia*, 113, 21–28.
- American Fisheries Society, Committee on Names of Aquatic Invertebrates (2005) *Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Crustaceans*, Special Publication 31. 545 pp.
- Ba, J., Hou, Z., Platvoet, D., Zhu, L. & Li, S. (2010) Is *Gammarus tigrinus* (Crustacea, Amphipoda) becoming cosmopolitan through shipping? Predicting its potential invasive range using ecological niche modeling. *Hydrobiologia*, 649, 183–194.
- Baldinger, A.J., Shepard, W.D. & Threlloff, D.L. (2000) Two new species of *Hyaella* (Crustacea: Amphipoda: Hyaellidae) from Death Valley National Park, California, U.S.A. *Proceedings of the Biological Society of Washington*, 113, 443–457.
- Barnard, J.L. (1952) Some amphipoda from central California. *Wasmann Journal of Biology*, 10, 9–36.
- Barnard, J. L. (1980) The genus *Grandifoxus* (Crustacea: Amphipoda: Phoxocephalidae) from the northeastern Pacific Ocean. *Proceedings of the Biological Society of Washington*, 93, 490–514.
- Barnard, J.L. (1989) Identification of gammaridean amphipods. In: Smith, R.I. & Carlton, J.T. (Eds) *Light's Manual: Intertidal Invertebrates of the Central California Coast, third edition*. University of California Press, Berkeley, California, pp. 314–366.
- Barnard, J.L. & Barnard, C.M. (1983) *Freshwater Amphipoda of the world, 1. Evolutionary patterns, and 2. Handbook and bibliography, XIX*. Hayfield Associates, Mt. Vernon, Virginia. 830 pp.
- Barnard, J.L. & Gray, W.S. (1968) Introduction of an amphipod crustacean into the Salton Sea, California. *Bulletin of the Southern California Academy of Sciences*, 67, 219–232.
- Barnard, J.L. & Gray, W.S. (1969) Biogeographic relationships of the Salton Sea amphipod, *Gammarus mucronatus* Say. *Bulletin of the Southern California Academy of Sciences*, 68, 1–9.
- Barnard, J.L. & Karaman G.S. (1991) The families and genera of marine gammaridean Amphipoda (except marine gammaroids) Part 1. *Records of the Australian Museum, Supplement 13 (Part 1)*.
- Bate, C.S. (1862) Catalogue of the specimens of amphipodous Crustacea in the collection of the British Museum.
- Bottom, D.L. & Jones, K.K. (1990) Species composition, distribution and invertebrate prey of fish assemblages in the Columbia River Estuary. *Progress in Oceanography*, 25, 243–270.
- Bottofff, R.L., Hamill, B.A. & Hamill, W.I. (2003) Records of the exotic freshwater amphipod *Crangonyx pseudogracilis*, in San Luis Obispo County, California. *California Fish and Game*, 89, 197–200.
- Bottofff, R.L. & Bottofff, L.D. (2007) Phenology and diversity of adult stoneflies (Plecoptera) of a small coastal stream,

- California. *Illiesia*, 3, 1–9.
- Bousfield, E.L. (1958) Fresh-water amphipod crustaceans of glaciated North America. *Canadian Field Naturalist*, 72, 55–113.
- Bousfield, E.L. (1973) *Shallow-water gammaridean amphipoda of New England*. Cornell University Press, Ithaca, New York, 312 pp.
- Bousfield, E.L. (1975) Morphological key to Talitridae. In: Smith, R.I. & Carlton J. (Eds), *Light's Manual: Intertidal Invertebrates of the Central California Coast, third edition*. University of California Press, Berkeley, California, pp. 352–355
- Bousfield, E.L. & Carlton, J.T. (1967) New records of Talitridae (Crustacea: Amphipoda) from the central California coast. *Bulletin of the Southern California Academy of Science*, 66, 277–84.
- Bousfield, E.L. & Morino, H. (1992) The amphipod genus *Ramellogammarus* in freshwaters of western North America: systematics and distributional ecology. *Royal British Columbia Museum Contributions to Natural Sciences*, 17, 1–22.
- Bousfield, E.L. & Hoover, P.M. (1997) The amphipod superfamily Corophioidea on the Pacific coast of North America. Part V. Family Corophiidae: Corophiinae, new subfamily. Systematics and distributional ecology. *Amphipacifica*, 2, 67–139.
- Boyd, M.J., Mulligan, T.J. & Shaughnessey, F.J. (2002) *Non-indigenous marine species of Humboldt Bay, California. Report to the Department of Fish and Game*. Humboldt State University, 118 pp.
- Breaux, A., Born, M., Suer, L., Cochran, S., & Looker, R. (2005) *Benthic macroinvertebrates as water quality indicators in highly urbanized streams in the San Francisco Bay Region, California, Final Report*. San Francisco Bay Regional Water Quality Control Board, Oakland, California, 69 pp.
- Cadien, D.B. (2007) *Hadzioidea of the NEP (Equator to Aleutians, intertidal to abyss): a review*. Southern California Association of Marine Intertidal Taxonomists, 26 pp.
- Caires, A., Chandra, S., Wittmann, M. & Schladow, G. (2010) *Long-term change in benthic invertebrate assemblages in Lake Tahoe, California/Nevada*. Great Lakes of the World International Symposium VI, Incline Village, Nevada.
- California Department of Fish and Game. (2011) *California Natural Diversity Database*. Rarefind 3.1.5 computer application, Biogeographic Data Branch, California Department of Fish and Game, Sacramento, California.
- California Department of Water Resources. (2010) *Environmental Monitoring Program*, Bay Delta Monitoring and Analysis Section. Available from: http://bdat.ca.gov/Php/Data_Retrieval/data_retrieval_by_category.php. (Accessed 2010).
- Carl, G.C. (1937) Flora and fauna of brackish water. *Ecology*, 18, 446–453.
- Carlton, J.T. (1979) *History, biogeography and ecology of the introduced marine and estuarine invertebrates of the Pacific coast of North America*. Doctoral dissertation, University of California, Davis, 904 pp.
- Carlton, J.T. (1985) Transoceanic and interoceanic dispersal of coastal marine organisms: the biology of ballast water. *Oceanography and Marine Biology Annual Review*, 23, 313–371.
- Carlton, J.T., editor. (2007) *The Light and Smith Manual: Intertidal Invertebrates from Central California to Oregon, fourth edition*. University of California Press, Berkeley, California.
- Chapman, J.W. (1988) Invasions of the Northeast Pacific by Asian and Atlantic gammaridean amphipod crustaceans, including a new species of *Corophium*. *Journal of Crustacean Biology*, 8(3), 364–382.
- Chapman, J.W. (2007) Gammaridea. In: Carlton, J.T. (Ed), *The Light and Smith Manual: Intertidal Invertebrates from Central California to Oregon, fourth edition*. University of California Press, Berkeley, California, 545–611 pp.
- Cohen, A.N. & Carlton, J.T. (1998) *Nonindigenous aquatic species in a United States estuary: a case study of the biological invasions of the San Francisco Bay and Delta*. A report for the United States Fish and Wildlife Service and the National Sea Grant College Program, Washington, D.C., USA.
- Conlan, K. & Bousfield, E.L. (1982) Studies on amphipod crustaceans of the Northeastern Pacific region. I. 2. Family Amphithoidae. *National Museums of Canada Publications in Biological Oceanography*, 10, 41–75.
- Cressey, S. & Sommers, C. (2004) *Contra Costa monitoring and assessment plan (CCMAP) 2004 Rapid Bioassessment Project Report, Contra Costa County, California. Submitted to Contra Costa Clean Water Program*. Published by Cressey & Associates, El Cerrito, California, and EOA Inc, Oakland, California, 66 pp.
- Eriksen, C.H. (1968) Aspects of the limno-ecology of *Corophium spinicorne* Stimpson (Amphipoda) and *Gnorimosphaeroma oregonensis* (Dana) (Isopoda). *Crustaceana*, 14, 1–12.
- Filice, F.P. (1958) Invertebrates from the estuarine portion of San Francisco Bay and some factors influencing their distribution. *Wasmann Journal of Biology*, 16, 159–211.
- Frantz, T.C. & Cordone, A.J. (1966) A preliminary checklist of invertebrates collected from Lake Tahoe, 1961–1964. *Occasional Papers of the Biological Society of Nevada*, No. 8, 12 pp.
- González, E.R. & Watling, L. (2002a) Redescription of *Hyaella azteca* from its type locality, Vera Cruz, Mexico (Amphipoda, Hyaellidae). *Journal of Crustacean Biology*, 22, 173–183.
- González, E.R. & Watling, L. (2002b) Redescription of the freshwater amphipod *Hyaella faxoni* from Costa Rica (Crustacea: Amphipoda: Hyaellidae). *Revista de Biología Tropical*, 50(2), 659–667.
- Holsinger, J.R. (1967) Systematics, speciation, and distribution of the subterranean amphipod genus *Stygonectes* (Gammaridae). *United States National Museum Bulletin*, 259, 1–176.
- Holsinger, J.R. (1972) *The freshwater amphipod crustaceans (Gammaridae) of North America. Biota of Freshwater Ecosystems, Identification Manual No. 5*. U. S. Environmental Protection Agency, Washington, D.C., 89 pp.
- Holsinger, J.R. (1974) Systematics of the subterranean amphipod genus *Stygobromus* (Gammaridae), Part I: Species of the western United States. *Smithsonian Contributions to Zoology*, 160, 1–63.

- Hou, Z., Fu, J. & Li, S. (2007) A molecular phylogeny of the genus *Gammarus* (Crustacea: Amphipoda) based on mitochondrial and nuclear gene sequences. *Molecular Phylogenetics and Evolution*, 45, 596–611.
- International Union for Conservation of Nature and Natural Resources (2011) *The IUCN Red List of Threatened Species (Internet database)*. IUCN Red List Unit, Cambridge, United Kingdom. Available from: <http://www.iucnredlist.org/>. (Accessed December 2011).
- Jarrett, N. E. & Bousfield, E.L. (1996) The amphipod superfamily Hadzioidea on the Pacific coast of North America: family Melitidae. Part I. The *Melita* Group: Systematics and distributional ecology. *Amphipacifica*, 2, 3–74.
- Johnson, P. (2008) *Riparian aquatic species inventory, Pinnacles National Monument 2001–2005, updated report*. Prepared for the San Francisco Bay Area Inventory and Monitoring Network, United States National Park Service, 31 pp.
- Kelley, D.W. (1967) Identification of *Corophium* from the Sacramento-San Joaquin Delta. *California Fish and Game*, 53, 295–296.
- Krone, R.B. (1979) Sedimentation in the San Francisco Bay system. In: Conomos, T.J. (Ed), *San Francisco Bay: the urbanized estuary*. California Academy of Sciences, San Francisco, California, pp. 85–96
- Lee, J. (2001) *Spring 2000 benthic macroinvertebrate analysis of twelve sites in Point Reyes National Seashore using the California Stream Bioassessment Procedure*. Prepared for National Park Service Point Reyes National Seashore Point Reyes Station, California, 22 pp.
- Lee, J. & Coopridge, M. (2005) *Spring 2004 benthic macroinvertebrate sample analysis of stream sites in San Francisco Bay Area National Park Service lands*. Prepared for Point Reyes National Seashore, Point Reyes Station, California, 42 pp.
- Lester, G.T. & Clark, W.H. (2002) Occurrence of *Corophium spinicorne* Stimpson, 1857 (Amphipoda: Corophiidae) in Idaho, USA. *Western North American Naturalist*, 62, 230–233.
- MacGinitie, G.E. (1935) Ecological aspects of a California marine estuary. *American Midland Naturalist*, 16, 629–765.
- Malard, F., Rey Grobelle, J., Mathieu, J., & La Font, M. (1994) The use of invertebrate communities to describe groundwater flow and contaminant transport in a fractured rock aquifer. *Archive fur Hydrobiologie*, 131(1), 93–110.
- Malard, F., Plenet, S. & Gibert, J. (1996) The use of invertebrates in groundwater monitoring: a rising research field. *Groundwater Monitoring and Remediation*, 16, 103–113.
- Master, L.L. (1991) Assessing threats and setting priorities for conservation. *Conservation Biology*, 5, 559–563.
- McElroy, E.P. & Resh, V.H. (1991) Distribution and seasonal occurrence of the hyporheic fauna in a northern California stream. *Hydrobiologia*, 220, 233–246.
- Miller, R.C. (1958) The relict fauna of Lake Merced, San Francisco. *Journal of Marine Research*, 17, 375–381.
- Motas, C. & Serban, E. (1965) Recherches phréatobiologiques II: La capture des *Niphargus* adultes par le procédé des sondages Karaman-Chappuis. Les crues et la biocénose de la nappe phréatique. *International Journal of Speleology*, 1, 321–332.
- Myers, A.A. & Lowry, J.K. (2003) A phylogeny and a new classification of the Corophiidea Leach, 1814 (Amphipoda). *Journal of Crustacean Biology*, 23, 443–485.
- NatureServe, Inc. (2011) *NatureServe Explorer: An online encyclopedia of life*, Version 7.1. NatureServe, Arlington, Virginia. Available from: <http://www.natureserve.org/explorer>. (Accessed 2010–2011).
- Notenboom, J., Plenet, S., & Turquin, J. (1994) Groundwater contamination and its impact on groundwater animals and ecosystems. In: Gibert, J., Danielopol, D. & Stanford, J. (Eds), *Groundwater Ecology*. Academic Press, San Diego, California, pp. 477–503
- Rogers, D.C. (2005) *Identification manual to the freshwater Crustacea of the western United States and adjacent areas encountered during bioassessment*. EcoAnalysts Technical Publication Series # 1, EcoAnalysts, Inc., Moscow, Idaho, 82 pp.
- Rogers, D.C., Covich, A.P. & Thorp J.H. (2010) Chapter 18—Introduction to the subphylum Crustacea. In: Thorp, J.H. & Covich, A.P. (Eds), *Ecology and classification of North American freshwater invertebrates, third edition*. Academic Press (Elsevier), San Diego, California, pp. 695–724.
- Ronneberger, D. (1975) Zur Kenntnis der Grundwasserfauna des Saale-Einzugsgebietes (Thüringen). *Limnologica*, 9, 323–319.
- Ruiz, G.M., Fofonoff, P.W., Carlton, J.T., Wonham, M.J. & Hines, A.H. (2000) Invasion of coastal marine communities in North America: Apparent patterns, processes, and biases. *Annual Review of Ecological Systematics*, 31, 481–531.
- Sheridan P.F. (1979) Three new special [sic] of *Melita* (Crustacea: Amphipoda), with notes on the amphipod fauna of the Apalachicola Estuary of northwest Florida. *Northeast Gulf Science*, 3, 60–73.
- Shoemaker, C.R. (1949) The amphipod genus *Corophium* on the west coast of America. *Journal of the Washington Academy of Science*, 39, 66–82.
- Simon, K. & Buikema Jr., A. (1997) Effects of organic pollution on an Appalachian cave: changes in macroinvertebrate populations and food supplies. *American Midland Naturalist*, 138, 387–401.
- Simpson, E.P., Gonzalez, M.R., Hart, C.M. & Hurlbert, S.H. (1998) Salinity and fish effects on Salton Sea microecosystems: benthos. *Hydrobiologia*, 381, 153–177.
- Smith, D.G. (2001) *Pennak's freshwater invertebrates of the United States: Porifera to Crustacea, 4th edition*. John Wiley and Sons, Inc., Hoboken, New Jersey, 638 pp.
- Smith, R.I. (1953) The distribution of the polychaete *Neanthes lighti* in the Salinas River Estuary, California, in relation to salinity, 1948–1952. *Woods Hole Marine Biological Laboratory Biological Bulletin*, 105, 335–347.
- Stebbing, T.R.R. (1906) Amphipod I. Gammaridea. *Das Tierreich* (Friedländer, Berlin), Volume 21. 806 pp.

- Stillwater Sciences. (2009) *Aquatic invertebrate monitoring reports and summary updates. Published in: Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299, report years 2003 to 2009*, Stillwater Ecosystem, Watershed and Riverine Sciences, Inc., Berkeley, California.
- Sytma, M.D., Cordell, J.R., Chapman, J.W. & Draheim, R.C. (2004) *Lower Columbia River aquatic nonindigenous species survey 2001–2004 Final Technical Report*. Center for Lakes and Reservoirs, Portland State University, Portland, Oregon. Prepared for the United States Coast Guard and the United States Fish and Wildlife Service.
- Toft, J.D. (2000) *Community effects of the non-indigenous aquatic plant water hyacinth (Eichhornia crassipes) in the Sacramento/San Joaquin Delta, California*. Master's thesis, University of Washington, Seattle, 86 pp.
- Toft, J.D., Cordell J.R. & Fields, W.C. (2002) New records of crustaceans (Amphipoda, Isopoda) in the Sacramento/San Joaquin Delta, California, and application of criteria for introduced species. *Journal of Crustacean Biology*, 22, 190–200.
- Tomikawa, K., Morino, H., Toft, J. & Mawatari, S. F. (2006) A revision of *Eogammarus* Birstein, 1933 (Crustacea, Amphipoda, Anisogammaridae), with a description of a new species. *Journal of Natural History*, 40, 1083–1148.
- United States Geological Survey. (2010) *USGS Nonindigenous Aquatic Species Database*, United States Geological Survey, Gainesville, Florida. Available from: <http://nas.er.usgs.gov/default.aspx>. (Accessed 2010).
- Usjak, S. In manuscript. *Comparative phylogeography of North American Diporeia hoyi and Gammarus lacustris (order: Amphipoda)*. Masters thesis, University of Waterloo, Ontario, Canada.
- Vainola, R., Witt, J.D.S., Grabowski, M., Bradbury, J.H., Jazdzewski, K. & Sket, B. (2008) Global diversity of amphipods (Amphipoda; Crustacea) in freshwater. *Hydrobiologia*, 595, 241–255.
- Waldichuck, M.E. & Bousfield, E.L. (1962) Amphipods in low-oxygen waters adjacent to a sulphite pulp mill. *Journal of Fisheries Research Board of Canada*, 19, 1163–1165.
- Wang, D. & Holsinger, J.R. (2001) Systematics of the subterranean amphipod genus *Stygobromus* (Crangonyctidae) in western North America, with emphasis on species of the *hubbsi* group. *Amphipacifica*, 3, 39–147.
- Watson, J. (2007) *The life history demographics of Corophium spinicorne in the Carmel River Lagoon*. Capstone Thesis Project, Division of Science and Environmental Policy, California State University, Monterey Bay, 49 pp.
- Weckel, A.L. (1907) The fresh-water Amphipoda of North America. *Proceedings of the United States National Museum*, 32, 25–58.
- Wellborn, G.A., Cothran, R. & Bartholf, S. (2005) Life history and allozyme diversification in regional ecomorphs of the *Hyalella azteca* (Crustacea: Amphipoda) species complex. *Biological Journal of the Linnean Society*, 84, 161–175.
- Witt, J.D.S., Threlloff, D.L. & Hebert, P.D.N. (2006) DNA barcoding reveals extraordinary cryptic diversity in an amphipod genus: implications for desert spring conservation. *Molecular Ecology*, 15, 3073–3082.
- Wones, A.G. & Larson, G.L. (1991) The benthic macroinvertebrate community in a coastal sand dune lake relative to habitat and changing lake levels. *Hydrobiologia*, 213, 167–181.
- Zhang, J. (1997) *Systematics of the freshwater amphipod genus Crangonyx (Crangonyctidae) in North America*. Doctoral dissertation, Old Dominion University, Norfolk, Virginia, 360 pp.
- Zhang, J. & Holsinger, J.R. (2003) Systematics of the freshwater amphipod genus *Crangonyx* (Crangonyctidae) in North America. *Virginia Museum of Natural History Memoir Number 6*, Martinsville, Virginia.