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# Species occurrence and distribution of Trichoptera (caddisflies) in California

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## Abstract

A formal list of the caddisflies of California has not been published since 1956, at which time just over 170 species were included. Since then, the estimate of Trichoptera richness in the state has doubled. We used just under 7,000 digital records from online repositories and museum databases to compile a preliminary faunal list. To gain a broader view of the distribution of caddisflies in California, we augmented this dataset with almost 46,000 larval biomonitoring records for Trichoptera from the California Digital Exchange Network. We compared this digital species list derived from collection records to three existing literature resources: Donald Denning's original species list from 1956, a list by Donald Burdick in 2010, and the published records documented in the *Distributional Checklist of Nearctic Trichoptera* by Rasmussen & Morse in 2018. The California species richness for Trichoptera based on these resources is 333 species, with another 69 taxa occurring in collections that require expert review of the material before adding to these totals. Monitoring data, although extensive, did not contribute to the species list, but highlighted differences in collection location emphasis. Digital records can be powerful tools for compiling preliminary taxa and distribution lists, but oftentimes only partial verbatim label information (i.e. not containing full localities) limits further spatial analysis.

**Key words:** natural history collections, biomonitoring, faunistics, digital records

## Introduction

Faunal and floral lists have long been used by researchers, usually created at least in part by establishing a candidate pool of reported species in an area. Although comprehensive monographs of higher taxonomic groupings are useful across regions, regional faunal lists serve as a critical resource for applied studies such as biological monitoring. They are especially important when life history variation can occur among species in the same genus (Resh 1976), making identification at the species-level necessary in providing water quality tolerance information (Lenat & Resh 2001). Despite this critical use and applicability, formal updates to the lists may be infrequent because of the absence of local taxonomic specialists, funding availabilities, and research priorities.

In the case of California, updates to lists have been infrequent but do report a doubling of the initial species count over the past 60 years. The first attempts at a comprehensive treatment of Trichoptera at the state level in California was by Denning, who was employed in the agrochemical industry but trained as an entomologist, and who conducted Trichoptera studies in off-work hours (Resh 1989). Denning's work on Trichoptera appeared as a chapter in Usingers's *Aquatic Insects of California* (Usinger 1956). Denning included species-level keys for genera, species lists, and county-level distribution information. He included 171 species and predicted that several species from adjacent states might also be expected to occur in California.

A new list did not appear until over 50 years later, when Burdick, then retired from California State University at Fresno, reviewed specimens in the collections held by Denning while preparing them for

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deposition in the California Academy of Sciences (CAS). Burdick (2010) compiled a list of 403 taxa of Trichoptera, with most occurring in California. Burduck included material from Denning's publications and collections, and from his own material that he and others collected. He also assembled a website and provided a 510-page, digital, unpublished document that included some but quite minimal collection-record information for Trichoptera species occurring in California. Illustrations were made by Shannon Bickford. This online resource included undescribed species, as well as annotations regarding the status of the species in California; he also commented on taxonomic uncertainties, and in some cases proposed new synonymies (Ruiter & Harris 2016).

Others have assembled lists to summarize species richness and abundance in California, but none have been complete as Denning (1956) or Burdick (2010) at the species level for the entire state and for all habitat types. For example, Shepard (2006) made a list of 172 taxa available in a digital format on the Essig Museum of Entomology's website, but excluded some families such as Hydroptilidae that were not available because they were on loan to researchers. The Southern Association of Freshwater Invertebrate Taxonomists (SAFIT) published a list of Trichoptera taxa identifiable at the larval stage (Richards & Rogers 2011). Ball *et al.* (2013) reported 350 species of Trichoptera occurring in Mediterranean-climate areas of California but limited the count to lotic species and those with valid names, and did not examine material. Their count included additional records from the Global Biodiversity Information Facility (GBIF) and other museum collections. Although Ball *et al.* (2013) summarized the richness by family, they did not publish a list of species names they included in the count. Therefore, faunal lists for California Trichoptera still require additional compilation and investigation to consolidate efforts.

Digitally archived biomonitoring datasets hold potential value in identifying areas where larval caddisflies occur, but adults are underrepresented and perhaps undersampled. Biomonitoring primarily collect the aquatic, larval life-stage, which is present through a longer period of the year compared to the relatively short emergence period of adults. Because biomonitoring sites are sampled frequently and often over seasons and years, the likelihood of detecting the presence of Trichoptera genera is increased compared to adult collections from a single date. Moreover, studies often sample a more extensive area than those typically done for museum collections, and they include urban sites that have a wide variety of environmental conditions. Unfortunately, larvae are rarely identified to species level in biomonitoring studies, because larval-adult associations have not yet been made and keys do not exist below genus level for most groups. Efforts to compile these biomonitoring datasets into publicly accessible databases (e.g., the California Environmental Data Exchange Network, CEDEN, http://www.ceden.org/) increase the potential for biomonitoring studies to identify the spatial extent of Trichoptera habitats within California.

In this study, we compile a faunal list using existing lists of species reported to occur in California alongside digital records. We included records from digitally archived biomonitoring datasets, which primarily provide a source of generic-level larval records, to quantify the extent of sampling effort and abundance compared to records in natural history museum collections. We include past faunal lists and digital records to estimate Trichoptera species richness for California and provide annotations on the reliability of determinations. In this study, we present two lists: a primary list based on several lines of evidence of occurrence, and a secondary list of taxa that can serve as a baseline for continued work in California to confirm state records and distributions.

## Methods

### Record sources

We used digitally available records as the foundation for creating an exhaustive list of Trichoptera in California. We included records from natural history museum collections, personal records, and biomonitoring databases. We downloaded and imported museum records from the Global Biodiversity Information Facility (GBIF, https://www.gbif.org, accessed 1/11/2019). California Trichoptera records in GBIF included contributions from the Illinois Natural History Survey (INHS), the University of Alberta Sciences Museum (UASM), Monte L. Bean Life Science Museum (BYU), the Museum of Comparative Zoology (MCZ), the University of Kansas Biodiversity Institute & Natural History Museum (KU), the Field Museum of Natural History (FMNH), partial collections of the Essig Museum of Entomology (EMEC) at the

University of California, Berkeley, and the Stroud Water Resources Center. These records contain verbatim locality information and are partially georeferenced. EMEC records in GBIF are incomplete because databasing efforts there are ongoing and only about one half of the Trichoptera holdings have been databased. We augmented the EMEC GBIF records with the remainder of the EMEC holdings at the county level compiled by Marilyn Myers in 2000 (M. Myers, unpublished data). We also included records from the California Academy of Sciences (CAS) general collection, databased at the county level in the mid-1990s (N. Penny, personal communication). We also included the CAS digital database of Trichoptera type material but did not transcribe records detailed in Burdick (2010). We did not include records from the Natural History Museum of Los Angeles because digital records were not available online.

**Distribution of Trichoptera in California**

To compare distributions of museum-collected specimens with more recently collected material, we downloaded occurrence records from biological monitoring studies from CEDEN. CEDEN serves as a repository for data collected for water bodies in California and includes information on benthic organisms, habitat, water quality, and tissue analysis. Although a wide variety of habitats are sampled, data within CEDEN are biased toward lotic habitats and lentic species may be underrepresented. Most records are at the genus-level and voucher material is not available for verification. All records are georeferenced. We downloaded all records for Trichoptera from the years 1991-2009 (accessed 12/21/2014) and 2009-2018 (accessed 1/11/2019). We plotted CEDEN (through 2009) and georeferenced museum records (through 2014) to identify areas of collection overlaps.

**Species list for California**

To compile a species list of California Trichoptera, we created an exhaustive list that included names of taxa from the lists of Denning (1956), Burdick (2010), Rasmussen and Morse (2018), and the names assembled from digital collection records. The *Distributional Checklist of Nearctic Trichoptera* (Rasmussen & Morse 2018) provided additional records published in the taxonomic literature. We searched the publication for "CA". To include new species described within the past five years, we searched the Trichoptera World Checklist (TWC, Morse 2017, updated as of March 2017) for all species described in the United States but this same information was available in Rasmussen and Morse (2018).

We checked the entire list of names against the TWC and *Distributional Checklist of Nearctic Trichoptera* (August 2018 revision) to determine the valid name and note synonymies. Because spellings for names were sometimes inconsistent, we conducted most searches using partial names for species. In many cases, we only needed to update the species epithet based on these resources because the gender did not match that of the genus; in other cases, the species had been moved to a new or different genus. In rare cases, we could not find a satisfactory correction for a name, so those records are not included in our species estimates. We did not include any of the names for proposed new species designated by Denning or Burdick in Burdick (2010) if they were not formally described in the published literature.

To estimate species richness of Trichoptera in California, and to compare species lists over time with our digital records, we compiled a table of the validated and corrected lists of Denning (1956), Burdick (2010), Rasmussen and Morse (2018), and the digital collection records, organized by family and genus.

We include all species from all lists in two tables. For species with multiple records across these resources and records in Rasmussen & Morse (2018), we include them in Table 1. However, for species where occurrence in California remains in question, we instead include these species in Table 2 and include distribution information reported in Rasmussen and Morse (2018), the collection and county of the records, and any other notes such as those in Burdick (2010). For example, if we encountered a species with a collection record for Humboldt Co., which is in Northern California, and Rasmussen and Morse (2018) reported the species occurring in Oregon and Washington, the species appears in Table 2, and it may be present in California. However, if the species has an Eastern distribution and the only record occurred in Marin Co., its occurrence is doubtful, but it is still included in Table 2 because the specimen determination requires investigation. The species richness estimate is the total of Table 1 but may be higher based on investigations of specimens from Table 2. Synonyms are noted only if they occurred in a resource (e.g., Denning 1956).

**TABLE 1. Records for California Trichoptera.** Filled circles indicate the species was present in the resource. Filled circles with a number indicate that both the valid name and a synonym appeared in the resource. Empty circles with a number indicate the occurrence as one or more synonyms. The Total Species Richness includes all records for each resource. Resources include D 1956=Denning (1956), B 2010=Burdick (2010), R&M 2018=Rasmussen and Morse (2018) and CR=Collection Records. State abbreviations are standard. Other name is any other name (e.g., synonym) that occurred in a resource. Abbreviations: CAS=California Academy of Sciences, DB=Donald Burdick.

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other name in publication or resource |
|---|---|---|---|---|---|
| Apataniidae | | | | | |
| *Allomyia renoa* (Milne, 1935) | | ● | | ● | |
| *Apatania sorex* (Ross, 1941) | ● | ● | ● | ● | |
| *Pedomoecus sierra* Ross, 1947 | ● | ● | ● | ● | |
| Brachycentridae | | | | | |
| *Amiocentrus aspilus* (Ross, 1938) | ① | ● | ● | ❷ | [1]*Micrasema*, [2]*Oligoplectrum californicum* |
| *Brachycentrus americanus* (Banks, 1899) | ● | ● | ● | ● | |
| *Brachycentrus echo* (Ross, 1947) | ① | ● | ● | ● | [1]*Oligoplectrum* |
| *Micrasema bactro* Ross, 1938 | | ● | ● | ● | |
| *Micrasema diteris* Ross, 1947 | | ● | ● | ● | |
| *Micrasema onisca* Ross, 1947 | ● | ● | ● | ● | |
| Calamoceratidae | | | | | |
| *Heteroplectron californicum* McLachlan, 1871 | ● | ● | ● | ● | |
| Glossosomatidae | | | | | |
| *Agapetus arcita* Denning, 1951 | ● | ● | ● | ● | |
| *Agapetus celatus* McLachlan, 1871 | ● | ● | ● | ● | |
| *Agapetus joannia* Denning, 1965 | | ● | ● | ● | |
| *Agapetus malleatus* Banks, 1914 | ● | ● | ● | ● | |
| *Agapetus marlo* Milne, 1936 | ● | ● | ● | ● | |
| *Agapetus orosus* Denning, 1950 | ● | ● | ● | ● | |
| *Agapetus taho* Ross, 1947 | ● | ● | ● | ● | |
| *Anagapetus aisha* Denning, 1964 | | ● | ● | ● | |
| *Anagapetus bernea* Ross, 1947 | | ● | ● | ● | |
| *Anagapetus chandleri* Ross, 1951 | ● | ❶ | ● | ● | [1]*A. thirza* |
| *Glossosoma alascense* Banks, 1900 | | ● | ● | ● | |
| *Glossosoma bruna* Denning, 1954 | ● | ● | ● | ● | |
| *Glossosoma califica* Denning, 1948[A] | ● | ● | ● | ● | |
| *Glossosoma mereca* Denning, 1948 | ● | ● | ● | ● | |
| *Glossosoma oregonense* Ling, 1938 | ● | ● | ● | ● | |
| *Glossosoma penitum* Banks, 1914 | | ● | ● | ● | |
| *Glossosoma pternum* Ross, 1947[B] | ● | ● | ● | ● | |
| *Glossosoma sequoia* Denning, 1973 | | ● | ● | ● | |
| *Protoptila coloma* Ross, 1941 | ● | ● | ● | ● | |

[A] Ruiter *et al.* (2014): "initial genetic evidence has suggested that all three species [*G. pternum*, *G. californicum*, *G. wenatchee*] may all be the same"; Burdick (2010): "The differences are small and intermediates occur. It is likely these three species should be considered *G. pternum*."

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**TABLE 1.** (Continued)

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other name in publication or resource |
|---|---|---|---|---|---|
| Goeridae | | | | | |
| *Goera archaon* Ross, 1947 | | ● | ● | ● | |
| *Goeracea oregona* Denning, 1968 | | ● | ● | ● | |
| Helicopsychidae | | | | | |
| *Helicopsyche borealis* (Hagen, 1861) | ● | ● | ● | ❶ | [1]*H. californica* |
| *Helicopsyche mexicana* Banks, 1901 | | ● | ● | ● | |
| *Helicopsyche sinuata* Denning & Blickle, 1979 | | ● | ● | ● | |
| Hydropsychidae | | | | | |
| *Arctopsyche californica* Ling, 1938 | ● | ● | ● | ● | |
| *Arctopsyche grandis* (Banks, 1900) | ● | ❶ | ● | ● | [1]includes *A. inermis* |
| *Arctopsyche inermis* Banks, 1943 | ● | ❶ | ● | ● | [1]as *A. grandis* |
| *Cheumatopsyche arizonensis* (Ling, 1938) | | ● | ● | ● | |
| *Cheumatopsyche campyla* Ross, 1938 | ● | ● | ● | ● | |
| *Cheumatopsyche mickeli* Denning, 1942 | ● | ● | ● | ● | |
| *Cheumatopsyche mollala* Ross, 1941 | ● | ● | ● | ● | |
| *Diplectrona californica* Banks, 1914 | ● | ● | ● | ❶ | [1]*D. margarita* |
| *Homoplectra nigripennis* (Banks, 1911) | ● | ● | ● | ● | |
| *Homoplectra norada* Denning, 1975 | | ● | ● | ● | |
| *Homoplectra oaklandensis* (Ling, 1938) | ● | ● | ● | ● | |
| *Homoplectra shasta* Denning, 1949 | ● | ● | ● | ● | |
| *Homoplectra sierra* Ruiter, 2003 | | | ● | ● | |
| *Homoplectra spora* Denning, 1952 | ● | ● | ● | ● | |
| *Hydropsyche amblis* Ross, 1938 | | ● | ● | ❶ | [1]*Ceratopsyche* |
| *Hydropsyche californica* Banks, 1899 | ● | ● | ● | ● | |
| *Hydropsyche cockerelli* Banks, 1905 | ● | ● | ● | ❶ | [1]*Ceratopsyche* |
| *Hydropsyche cora* Denning, 1973 | | ● | ● | ❶ | [1]*Ceratopsyche* |
| *Hydropsyche intrica* Denning, 1965[B] | | ● | ● | ● | |
| *Hydropsyche occidentalis* Banks, 1900 | ● | ● | ● | ● | |
| *Hydropsyche oslari* Banks, 1905 | ● | ● | ● | ❶ | [1]*Ceratopsyche* |
| *Hydropsyche philo* Ross, 1941 | ● | ● | ● | ● | |
| *Parapsyche almota* Ross, 1938 | ● | ● | ● | ● | |
| *Parapsyche elsis* Milne, 1936 | ● | ● | ● | ❶ | [1]*Arctopsyche brevipennis* |
| *Parapsyche extensa* Denning, 1949 | ● | ● | ● | ● | |
| *Parapsyche spinata* Denning, 1949 | ● | ● | ● | ● | |
| *Parapsyche turbinata* Schmid, 1968 | | ● | ● | ● | |
| *Smicridea dispar* (Banks, 1905) | ① | ● | ● | ● | [1]*S. utico* |
| *Smicridea fasciatella* McLachlan, 1871 | | ● | ● | ● | |

[B] CAS (Mono Co.); DB "This may be the same as *H. cora* and *H. protis* or *H. tana*."

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**TABLE 1.** (Continued)

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other name in publication or resource |
|---|---|---|---|---|---|
| Hydroptilidae | | | | | |
| *Agraylea saltesea* Ross, 1938 | ● | ● | ● | ● | |
| *Hydroptila ajax* Ross, 1938 | | ● | ● | ● | |
| *Hydroptila arctia* Ross, 1938 | ① | ● | ● | ● | [1]*H. acoma* |
| *Hydroptila argosa* Ross, 1938 | ● | ● | ● | ● | |
| *Hydroptila hamata* Morton, 1905 | | ● | ● | ● | |
| *Hydroptila icona* Mosely, 1937 | | ● | ● | ● | |
| *Hydroptila rono* Ross, 1941 | ● | ● | ● | ● | |
| *Hydroptila xera* Ross, 1938 | ● | ● | ● | ● | |
| *Ithytrichia clavata* Morton, 1905 | | ● | ● | ● | |
| *Leucotrichia pictipes* (Banks, 1911) | ● | ● | ● | ● | |
| *Leucotrichia sarita* Ross, 1944 | | | ● | | |
| *Neotrichia halia* Denning, 1948 | | ● | ● | ● | |
| *Neotrichia kimi* Keth, 2015 | | | ● | | |
| *Neotrichia okopa* Ross, 1939 | | ● | ● | ● | |
| *Neotrichia pinnacles* Harris & Flint, 2016 | | | ● | | |
| *Nothotrichia shasta* Harris & Armitage, 1997 | | | ● | ● | |
| *Ochrotrichia alexanderi* Denning & Blickle, 1972 | | ● | ● | ● | |
| *Ochrotrichia alsea* Denning & Blickle, 1972 | | ● | ● | ● | |
| *Ochrotrichia arizonica* Denning & Blickle, 1972 | | ● | ● | ● | |
| *Ochrotrichia bickfordae* Ruiter, 2011 | | | ● | ● | |
| *Ochrotrichia bogani* Ruiter, 2011 | | | ● | ● | |
| *Ochrotrichia boydi* Ruiter & Harris, 2015 | | | ● | | |
| *Ochrotrichia buccata* Denning & Blickle, 1972 | | ● | ● | ● | |
| *Ochrotrichia burdicki* Denning, 1989 | | ● | ● | ● | |
| *Ochrotrichia confusa* (Morton, 1905) | | ● | ● | ● | |
| *Ochrotrichia footei* Keiper & Harris, 2002 | | | ● | | |
| *Ochrotrichia fossi* Ruiter & Harris, 2015 | | | ● | | |
| *Ochrotrichia hadria* Denning & Blickle, 1972 | | ● | ● | ● | |
| *Ochrotrichia honeyi* Blickle & Denning, 1977 | | ● | ● | ● | |
| *Ochrotrichia logana* (Ross, 1941) | | ● | ● | ● | |
| *Ochrotrichia lometa* (Ross, 1941) | ● | ● | ● | ● | |
| *Ochrotrichia lucia* Denning & Blickle, 1972 | | ● | ● | ● | |
| *Ochrotrichia malanae* Ruiter & Harris, 2015 | | | ● | | |
| *Ochrotrichia mono* (Ross, 1941) | ● | ● | ● | ● | |
| *Ochrotrichia myersae* Ruiter & Harris, 2015 | | | ● | | |
| *Ochrotrichia nacora* Denning & Blickle, 1972 | | ● | ● | ● | |
| *Ochrotrichia quadrispina* Denning & Blickle, 1972 | | ● | ● | ● | |
| *Ochrotrichia rothi* Denning & Blickle, 1972 | | ● | ● | ● | |
| *Ochrotrichia salaris* Blickle & Denning, 1977 | | ● | ● | ● | |
| *Ochrotrichia stylata* (Ross, 1938) | | ● | ● | ● | |

*...Continued on next page*

**TABLE 1.** (Continued)

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other name in publication or resource |
|---|---|---|---|---|---|
| *Ochrotrichia tenuata* Blickle & Denning, 1977 | | ● | ● | ● | |
| *Ochrotrichia trapoiza* Ross, 1947 | ● | ● | ● | ● | |
| *Ochrotrichia vertreesi* Denning & Blickle, 1972 | | ● | ● | ● | |
| *Oxyethira arizona* Ross, 1948 | | ● | ● | ● | |
| *Oxyethira dualis* Morton, 1905 | | ❶ | ● | ● | [1]*O. allosi* |
| *Oxyethira pallida* (Banks, 1904) | ● | ● | ● | ● | |
| *Palaeagapetus nearcticus* Banks, 1936 | ● | ● | ● | ● | |
| *Stactobiella delira* (Ross, 1938) | | ● | ● | ● | |
| Lepidostomatidae | | | | | |
| *Lepidostoma astanea* Denning, 1954 | ● | ● | ● | ● | |
| *Lepidostoma baxea* Denning, 1958 | | ● | ● | ● | |
| *Lepidostoma cantha* Ross, 1941 | ● | ● | ● | ● | |
| *Lepidostoma cascadense* (Milne, 1936) | ❶ | ● | ● | ● | [1]*L. mira* |
| *Lepidostoma castalianum* Weaver & Myers, 1998 | | | ● | | |
| *Lepidostoma cinereum* (Banks, 1899) | ① | ● | ● | ● | [1]*L. strophis* |
| *Lepidostoma ermanae* Weaver, 1988 | | ● | ● | ● | |
| *Lepidostoma errigena* Denning, 1954 | ● | ● | ● | ● | |
| *Lepidostoma jewetti* Ross, 1946 | ● | ● | ● | ● | |
| *Lepidostoma licola* Denning, 1975 | | ● | ● | ● | |
| *Lepidostoma lotor* Ross, 1946 | ● | ● | ● | ● | |
| *Lepidostoma ojanum* Weaver & Myers, 1998 | | | ● | ● | |
| *Lepidostoma pluviale* (Milne, 1936) | | ❶ | ● | ● | [1]*L. veleda* |
| *Lepidostoma podagrum* (McLachlan, 1871) | ● | ● | ● | ● | |
| *Lepidostoma rayneri* Ross, 1941 | ● | ● | ● | ❶ | [1]*L. crypta* |
| *Lepidostoma recina* Denning, 1954 | | ● | ● | ❶ | [1]*L. calensis* |
| *Lepidostoma roafi* (Milne, 1936) | ● | ● | ● | ● | |
| *Lepidostoma unicolor* (Banks, 1911) | ● | ● | ● | ● | |
| *Lepidostoma veroda* Ross, 1948 | | ● | ● | ● | |
| Leptoceridae | | | | | |
| *Ceraclea annulicornis* (Stephens, 1836) | ① | ● | ● | ● | [1]*Athripsodes* |
| *Ceraclea latahensis* (Smith, 1962) | | ● | ● | ● | |
| *Ceraclea maculata* (Banks, 1899) | | | ● | ● | |
| *Ceraclea tarsipunctata* (Vorhies, 1909) | ① | ● | ● | ❶ | [1]*Athripsodes* |
| *Mystacides alafimbriatus* Hill-Griffin, 1912 | ● | ● | ● | ❶ | [1]*Athripsodes* |
| *Mystacides sepulchralis* (Walker, 1852) | ● | ● | ● | ● | |
| *Nectopsyche dorsalis* (Banks, 1901) | | ● | ● | ● | |
| *Nectopsyche gracilis* (Banks, 1901) | | ● | ● | ● | |
| *Nectopsyche lahontanensis* Haddock, 1977 | | ● | ● | ● | |
| *Nectopsyche minuta* (Banks, 1900) | | ● | ● | ● | |
| *Oecetis disjuncta* (Banks, 1920) | ● | ● | ● | ● | |
| *Oecetis avara* (Banks, 1895) | | ● | ● | ● | |

*...Continued on next page*

**TABLE 1.** (Continued)

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other name in publication or resource |
|---|---|---|---|---|---|
| *Oecetis inconspicua* (Walker, 1852) | ● | ● | ● | ● | |
| *Oecetis ochracea* (Curtis, 1825) | ● | ● | ● | ● | |
| *Oecetis sordida* Blahnik & Holzenthal, 2014 | | | ● | | |
| *Triaenodes frontalis* Banks, 1907 | ● | ❶ | ● | ❶ | [1]*Ylodes* |
| *Triaenodes tardus* Milne, 1934 | | ● | ● | ● | |
| Limnephilidae | | | | | |
| *Allocosmoecus partitus* Banks, 1943 | | ● | ● | ● | |
| *Amphicosmoecus canax* (Ross, 1947) | | ● | ● | ● | |
| *Chyranda centralis* (Banks, 1900) | ● | ● | ● | ● | |
| *Clistoronia magnifica* (Banks, 1899) | | ● | ● | ● | |
| *Clostoeca disjuncta* (Banks, 1914) | ❶ | ❶ | ● | ● | [1]*C. sperryae* |
| *Cryptochia califca* Denning, 1968 | | ● | ● | ● | |
| *Cryptochia denningi* Wiggins, 1975 | | ● | ● | ● | |
| *Cryptochia excella* Denning, 1964 | | ● | ● | ● | |
| *Cryptochia shasta* Denning, 1975 | | ● | ● | ● | |
| *Desmona bethula* Denning, 1954 | ● | ● | ● | ● | |
| *Desmona denningi* Nimmo, 2012 | | | ● | | |
| *Dicosmoecus atripes* (Hagen, 1875) | ● | ● | ● | ● | |
| *Dicosmoecus gilvipes* (Hagen, 1875) | | ● | ● | ● | |
| *Dicosmoecus pallicornis* Banks, 1943 | | ● | ● | ● | |
| *Ecclisomyia bilera* Denning, 1951 | ● | ● | ● | ● | |
| *Ecclisomyia conspersa* Banks, 1907 | ● | ● | ● | ● | |
| *Ecclisomyia simulata* Banks, 1920 | ● | | ● | ● | |
| *Glyphopsyche irrorata* (Fabricius, 1781) | ● | ● | ● | ● | |
| *Hesperophylax alaskensis* (Banks, 1908) | | ● | ● | ● | |
| *Hesperophylax designatus* (Walker, 1852) | ① | ❷ | ● | ❶ | [1]*H. incisus*, [2]includes *H. magnus* |
| *Hesperophylax magnus* Banks, 1918 | ● | ❶ | ● | ● | [1]as *H. designata* |
| *Hesperophylax minutus* Ling, 1938 | | | ● | ● | |
| *Hesperophylax occidentalis* (Banks, 1908) | ● | ● | ● | ● | |
| *Homophylax insulas* Denning, 1964 | | ● | ● | ● | |
| *Homophylax nevadensis* Banks, 1903 | | ● | ● | ● | |
| *Homophylax rentzi* Denning, 1964 | | ● | ● | ● | |
| *Hydatophylax hesperus* (Banks, 1914) | ● | ● | ● | ❶ | [1]*Astenophylax needhami* |
| *Lenarchus gravidus* (Hagen, 1861) | ● | ● | ● | ● | |
| *Lenarchus rillus* (Milne, 1935) | ● | ● | ● | ● | |
| *Lenarchus vastus* (Hagen, 1861) | | ● | ● | ● | |
| *Limnephilus acnestus* Ross, 1938 | ● | ● | ● | ● | |
| *Limnephilus acula* Ross & Merkley, 1952 | | ● | ● | ● | |
| *Limnephilus alconura* Ross & Merkley, 1952 | | ● | ● | ● | |

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**TABLE 1.** (Continued)

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other name in publication or resource |
|---|---|---|---|---|---|
| *Limnephilus aretto* Ross, 1938 | ● | ● | ● | ❶ | [1]*Colpotalius tehamia* |
| *Limnephilus assimilis* (Banks, 1908) | ● | ● | ● | ● | |
| *Limnephilus atercus* Denning, 1965 | | ● | ● | ● | |
| *Limnephilus bucketti* Denning, 1965 | | ● | ● | ● | |
| *Limnephilus catula* Denning, 1965 | | ● | ● | ● | |
| *Limnephilus coloradensis* (Banks, 1899) | ● | ● | ● | ● | |
| *Limnephilus concolor* Banks, 1899 | ① | ❶ | ● | ❶ | [1]*L. lunonus* |
| *Limnephilus externus* Hagen, 1861 | ● | ● | ● | ● | |
| *Limnephilus frijole* Ross, 1944 | ● | ● | ● | ● | |
| *Limnephilus morrisoni* Banks, 1920 | ● | ● | ● | ● | |
| *Limnephilus nogus* Ross, 1944 | ● | ● | ● | ● | |
| *Limnephilus occidentalis* Banks, 1908 | ● | ● | ● | ● | |
| *Limnephilus peltus* Denning, 1962 | | ● | ● | ● | |
| *Limnephilus productus* Banks, 1914 | ● | ❶ | ● | ● | [1]*L. neoaculus* |
| *Limnephilus secludens* Banks, 1914 | ● | ● | ● | ● | |
| *Limnephilus sierrata* Denning, 1968 | | ● | ● | ● | |
| *Limnephilus spinatus* Banks, 1914 | ● | ● | ● | ● | |
| *Monophylax mono* (Denning, 1970) | | ① | ❶ | ① | [1]*Desmona* |
| *Onocosmoecus sequoiae* Wiggins & Richardson, 1986 | | ● | ● | ● | |
| *Onocosmoecus unicolor* (Banks, 1897) | ① | ● | ● | ● | [1]*Dicosmoecus* |
| *Philocasca rivularis* Wiggins, 1968 | | ● | ● | ● | |
| *Pseudostenophylax edwardsi* (Banks, 1920) | ① | ● | ● | ● | [1]*Drusinus* |
| *Psychoglypha alascensis* (Banks, 1900) | | ● | ● | ● | |
| *Psychoglypha avigo* (Ross, 1941) | ● | ● | ● | ● | |
| *Psychoglypha bella* (Banks, 1903) | ● | ● | ● | ● | |
| *Psychoglypha burdicki* Nimmo, 2012 | | | ● | | |
| *Psychoglypha denningi* Nimmo, 2012 | | | ● | | |
| *Psychoglypha klamathi* Denning, 1970 | | ● | ● | ● | |
| *Psychoglypha leechi* Denning, 1970 | | ● | ● | ● | |
| *Psychoglypha maderi* Nimmo, 2012 | | | ● | | |
| *Psychoglypha mazamae* Denning, 1970 | | ● | ● | ● | |
| *Psychoglypha mesalis* Nimmo, 2012 | | | ● | | |
| *Psychoglypha ormiae* (Ross, 1938) | ● | ● | ● | ● | |
| *Psychoglypha patricius* Nimmo, 2012 | | | ● | | |
| *Psychoglypha subborealis* (Banks, 1924) | | ● | ● | ● | |
| Odontoceridae | | | | | |
| *Marilia flexuosa* Ulmer, 1905 | ● | ● | ● | ● | |
| *Namamyia plutonis* Banks, 1905 | ● | ● | ● | ● | |
| *Nerophilus californicus* (Hagen, 1861) | ● | ● | ● | ❶ | [1]*Silo* |
| *Parthina linea* Denning, 1954 | ● | ● | ● | ● | |
| *Parthina vierra* Denning, 1973 | | ● | ● | ● | |

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**TABLE 1.** (Continued)

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other name in publication or resource |
|---|---|---|---|---|---|
| Philopotamidae | | | | | |
| *Chimarra angustipennis* Banks, 1903 | ① | ❶ | ● | ❶ | [1]*C. siva* |
| *Chimarra butleri* Denning, 1962 | | ● | ● | ● | |
| *Chimarra elia* Ross, 1944 | | ❶ | ● | ① | [1]*C. lara* |
| *Chimarra utahensis* Ross, 1938 | ● | ● | ● | ● | |
| *Dolophilodes aequalis* (Banks, 1924) | ● | ● | ● | ● | |
| *Dolophilodes andora* Denning, 1989 | | ● | ● | ● | |
| *Dolophilodes dorcus* (Ross, 1938) | ● | ● | ● | ● | |
| *Dolophilodes novusamericanus* (Ling, 1938) | ● | ● | ● | ❶ | [1]*Philopotamus* |
| *Dolophilodes pallidipes* Banks, 1936 | ● | ● | ● | ● | |
| *Sisko sisko* (Ross, 1949) | ① | ② | ● | ❶❷ | [1]*Wormaldia,* [2]*Dolophilodes* |
| *Wormaldia anilla* (Ross, 1941) | ● | ● | ● | ● | |
| *Wormaldia birneyi* Munoz-Quesada & Holzenthal, 2008 | | | ● | ● | |
| *Wormaldia gabriella* (Banks, 1930) | ● | ● | ● | ● | |
| *Wormaldia gesugta* Schmid, 1968 | | | ● | ● | |
| *Wormaldia hamata* Denning, 1951 | ● | ● | ● | ● | |
| *Wormaldia laona* Denning, 1989 | | ● | ● | ● | |
| *Wormaldia occidea* (Ross, 1938) | ❶ | ❶ | ● | ❶ | [1]*W. cruzensis* |
| *Wormaldia pachita* Denning, 1956 | ● | ● | ● | ● | |
| Phryganeidae | | | | | |
| *Agrypnia glacialis* Hagen, 1873 | ● | ❶ | ● | ● | [1]*A. dextra* |
| *Banksiola crotchi* Banks, 1944 | ● | ● | ● | ● | |
| *Phryganea cinerea* Walker, 1852 | | ● | ● | ● | |
| *Ptilostomis ocellifera* (Walker, 1852) | | | ● | | |
| *Yphria californica* (Banks, 1907) | ● | ● | ● | ● | |
| Polycentropodidae | | | | | |
| *Holocentropus flavus* Banks, 1908 | ① | ① | ● | ① | [1]*Polycentropus* |
| *Polycentropus halidus* Milne, 1936 | ● | ● | ● | ● | |
| *Polycentropus variegatus* Banks, 1900 | ● | ● | ● | ● | |
| Psychomyiidae | | | | | |
| *Psychomyia flavida* Hagen, 1861 | ● | ● | ● | ❶ | [1]*P. pulchella* |
| *Psychomyia lumina* (Ross, 1938) | | ● | ● | ● | |
| *Tinodes belisus* Denning, 1950 | ● | ● | ● | ● | |
| *Tinodes cascadius* Denning, 1956 | | ● | ● | ● | |
| *Tinodes consuetus* McLachlan, 1871 | ● | ● | ● | ● | |
| *Tinodes gabriella* Denning, 1973 | | ● | ● | ● | |
| *Tinodes parvulus* Denning, 1950 | ● | ● | ● | ● | |
| *Tinodes powelli* Denning, 1964 | | ● | ● | ● | |
| *Tinodes provo* Ross & Merkley, 1950 | ● | ● | ● | ● | |
| *Tinodes schusteri* Denning, 1983 | | ● | ● | ● | |

*...Continued on next page*

**TABLE 1.** (Continued)

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other name in publication or resource |
|---|---|---|---|---|---|
| *Tinodes sigodanus* Ross & Merkley, 1950 | ● | ● | ● | ● | |
| *Tinodes siskiyou* Denning, 1951 | | ● | ● | ● | |
| *Tinodes twilus* Denning, 1975 | | ● | ● | ● | |
| *Tinodes usillus* Denning, 1966 | | ● | ● | ● | |
| Rhyacophilidae | | | | | |
| *Himalopsyche phryganea* (Ross, 1941) | ① | ● | ● | ● | [1]*Rhyacophila* |
| *Rhyacophila amabilis* Denning, 1965 | | ● | ● | ● | |
| *Rhyacophila angelita* Banks, 1911 | ● | ● | ● | ● | |
| *Rhyacophila arcella* Denning, 1975 | | ● | ● | ● | |
| *Rhyacophila ardala* Denning, 1965 | | ● | ● | ● | |
| *Rhyacophila arnaudi* Denning, 1948 | | ● | ● | ● | |
| *Rhyacophila balosa* Denning, 1989 | | ● | ● | ● | |
| *Rhyacophila basalis* Banks, 1911 | ● | ● | ● | ● | |
| *Rhyacophila betteni* Ling, 1938 | ● | ● | ● | ● | |
| *Rhyacophila bifila* Banks, 1914 | ● | ● | ● | ● | |
| *Rhyacophila brunnea* Banks, 1911 | ① | ❶❷ | ● | ● | [1]includes *R. acropedes,* [2]includes *R. accuminata* |
| *Rhyacophila californica* Ling, 1938 | | ● | ● | ● | |
| *Rhyacophila cerita* Denning, 1971 | | ● | ● | ● | |
| *Rhyacophila chandleri* Denning, 1956 | ● | ● | ● | ● | |
| *Rhyacophila chordata* Denning, 1989 | | ● | ● | ● | |
| *Rhyacophila coloradensis* Banks, 1904 | | ● | ● | ● | |
| *Rhyacophila darbyi* Fields, 1981 | | ● | ● | ● | |
| *Rhyacophila ecosa* Ross, 1941 | ● | ● | ● | ● | |
| *Rhyacophila fenderi* Ross, 1948 | | ● | ● | ● | |
| *Rhyacophila grandis* Banks, 1911 | ● | ● | ● | ● | |
| *Rhyacophila harmstoni* Ross, 1944 | ● | ● | ● | ● | |
| *Rhyacophila hyalinata* Banks, 1905 | ① | ● | ● | ❶ | [1]*R. sonoma* |
| *Rhyacophila inculta* Ross & Spencer, 1952 | | ● | ● | ● | |
| *Rhyacophila insularis* Schmid, 1970 | | ● | ● | ● | |
| *Rhyacophila jenniferae* Peck, 1978 | | ● | ● | ● | |
| *Rhyacophila jewetti* Denning, 1954 | | ● | ● | ● | |
| *Rhyacophila karila* Denning, 1948 | ● | ● | ● | ● | |
| *Rhyacophila kernada* Ross, 1950 | ● | ❶ | ● | ● | [1]*R. reana* |
| *Rhyacophila leechi* Denning, 1975 | | ● | ● | ● | |
| *Rhyacophila lineata* Denning, 1956 | ● | ❶ | ● | ❶ | [1]*R. balosa* |
| *Rhyacophila lurella* Denning, 1975 | | ● | ● | ● | |
| *Rhyacophila mosana* Denning, 1965 | | ● | ● | ● | |
| *Rhyacophila narvae* Navas, 1926 | ① | ❶ | ● | ❶ | [1]*R. vepulsa* |
| *Rhyacophila neograndis* Denning, 1948 | ● | ● | ● | ● | |
| *Rhyacophila nevadensis* Banks, 1924 | ● | ● | ● | ● | |

*...Continued on next page*

**TABLE 1.** (Continued)

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other name in publication or resource |
|---|---|---|---|---|---|
| *Rhyacophila norcuta* Ross, 1938 | ● | ● | ● | ● | |
| *Rhyacophila oreta* Ross, 1941 | ● | ● | ● | ● | |
| *Rhyacophila pellisa* Ross, 1938 | ● | ● | ● | ● | |
| *Rhyacophila rayneri* Ross, 1951 | ● | ● | ● | ● | |
| *Rhyacophila reyesi* Denning, 1989 | | ● | ● | ● | |
| *Rhyacophila rotunda* Banks, 1924 | ● | ● | ● | ● | |
| *Rhyacophila sequoia* Denning, 1950 | ● | ● | ● | ● | |
| *Rhyacophila sierra* Denning, 1968 | | ● | ● | ● | |
| *Rhyacophila siskiyou* Denning, 1975 | | ● | ● | ● | |
| *Rhyacophila spinata* Denning, 1965 | | ● | ● | ● | |
| *Rhyacophila starki* Smith & Weaver, 1984 | | ● | ● | ● | |
| *Rhyacophila tamalpaisi* Denning, 1975 | | ● | ● | ● | |
| *Rhyacophila tehama* Denning, 1975 | | ● | ● | ● | |
| *Rhyacophila tucula* Ross, 1950 | | ● | ● | ● | |
| *Rhyacophila vaccua* Milne, 1936 | ● | ● | ● | ● | |
| *Rhyacophila vagrita* Milne, 1936 | | ● | ● | ● | |
| *Rhyacophila valuma* Milne, 1936 | ● | ● | ● | ● | |
| *Rhyacophila vao* Milne, 1936 | | ● | ● | ❶ | [1]*R. wallowa* |
| *Rhyacophila vedra* Milne, 1936 | ● | ● | ● | ● | |
| *Rhyacophila velora* Denning, 1954 | ● | ● | ● | ● | |
| *Rhyacophila verrula* Milne, 1936 | ● | ● | ● | ● | |
| *Rhyacophila vocala* Milne, 1936 | ● | ● | ● | ● | |
| *Rhyacophila vuzana* Milne, 1936 | | ● | ● | ● | |
| *Rhyacophila weitchpec* Lee & Ruiter, 2010 | | | ● | ● | |
| Sericostomatidae | | | | | |
| *Gumaga griseola* (McLachlan, 1871) | ① | ● | ● | ● | [1]*Sericostoma* |
| *Gumaga nigricula* (McLachlan, 1871) | | ● | ● | ● | |
| Thremmatidae | | | | | |
| *Neophylax occidentis* Banks, 1924 | ● | ● | ● | ● | |
| *Neophylax rickeri* Milne, 1935 | ● | ● | ● | ❶ | [1]*N. puchellus* |
| *Neophylax splendens* Denning, 1948 | | ● | ● | ● | |
| *Oligophlebodes sierra* Ross, 1944 | ● | ● | ● | ● | |
| Uenoidae | | | | | |
| *Farula geyseri* Denning, 1989 | | ● | ● | ● | |
| *Farula honeyi* Denning, 1973 | | ● | ● | ● | |
| *Farula moweri* Ruiter, 2003 | | | ● | ● | |
| *Farula petersoni* Denning, 1973 | | ❶ | ● | ❶ | [1]*F. wigginsi* |
| *Farula praelonga* Wiggins & Erman, 1987 | | ● | ● | ● | |
| *Neothremma alicia* Dodds & Hisaw, 1925 | | ● | ● | ● | |

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**TABLE 1.** (Continued)

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other name in publication or resource |
|---|---|---|---|---|---|
| *Neothremma genella* Denning, 1966 | | ● | ● | ● | |
| *Neothremma mucronata* Wiggins & Wisseman, 1992 | | ● | ● | | |
| *Neothremma siskiyou* Denning, 1975 | | ● | ● | ● | |
| **Total Richness by resource** | **165** | **305** | **333** | **316** | |

## Results

### Characteristics of records sources

We assembled almost 46,000 records from digital sources. Biomonitoring records contributed 41,894 of these records, only 3,976 of which were at the species level (65 species). Museums contributed 6,797 records (5,441 identified to the genus level and 4,163 of these records were further identified to the species level). ~2/3$^{rds}$ of the total museum records were contributed by the Essig Museum of Entomology (2,524) and the California Academy of Sciences (1,953). In contrast to biomonitoring records that were collected over the past ~27 years, museum-based records ranged in collection dates from 1895-2018. Many species were only represented by a few exemplars in museum records. Georeferenced museum collections had wider sampling coverage in high mountain and desert regions of the state than did biomonitoring records, which focused more on wadable streams and populated areas of the state (Figure 1).

The taxonomic resolution of biomonitoring records was overwhelmingly at the genus level and distribution of collection localities are biased toward wadable streams. However, they also included a higher number of sampling sites in urban and coastal areas of Southern California than do the museum records.

### Preliminary Faunal List

We estimate the current species richness of Trichoptera in California to be at a minimum 333 species based on the total records in Table 1, however the actual species richness is likely higher. Species of uncertain status potentially add to this total with 66 sourced from collection records, followed by 45 detailed in Burdick (2010). Denning (1956) and Rasmussen and Morse (2018) include 2 and 6 taxa, respectively. When including species where the status in California is in question, the estimate may be as high as 402, however many species on the list may be identification errors or represent new species.

At least 34 species have been synonymized and 14 new species have been described since 2010 (Table 1). Burdick (2010) included illustrations and notes for 36 new species that we do not included here because they were not formally described. Actually, none of these provisionally named new species have been formally described under the names proposed by Denning or Burdick; however, five have been described under different names (Ruiter 2011, Nimmo 2012, Ruiter & Harris 2016). Ruiter & Harris (2016) determined that 4 new species proposed by Denning and Burdick were not new species.

## Discussion

### California species richness

Our current estimate of species richness of Trichoptera in California is 333 species, compiled across all digital resources representing ~22% of the described Trichoptera from the continental United States and Canada (Rasmussen & Morse 2018). The adjacent states of Nevada-137 species (Ruiter *et al.* 2014), Oregon-280 (Anderson 1976), and Arizona-154 (Blinn & Ruiter 2005, Blinn & Ruiter 2006, Blinn & Ruiter 2009) show lower richness. The higher count in California is expected given the size of the state and the higher diversity

in habitat types. Compared to the other aquatic insect orders in California, Trichoptera had the highest reported species richness in lotic environments, followed by lotic Coleoptera (263) and Plecoptera (188) (Ball *et al.* 2013). Since Burdick's (2010) manuscript, at least 14 new species have been described that were illustrated as potential new species; clearly more new species remain undescribed (Burdick 2010, Givens 2014). New species described from California material are in Hydroptilidae (2 in *Ochrotrichia*, Ruiter 2011; 4 in *Ochrotrichia*, Ruiter & Harris 2015; 1 in *Neotrichia*, Keth *et al.* 2015; 1 in *Neotrichia*, Harris & Flint 2016) and Limnephilidae (5 in *Psychoglypha*, Nimmo 2012; 1 in *Desmona*, Nimmo 2012).

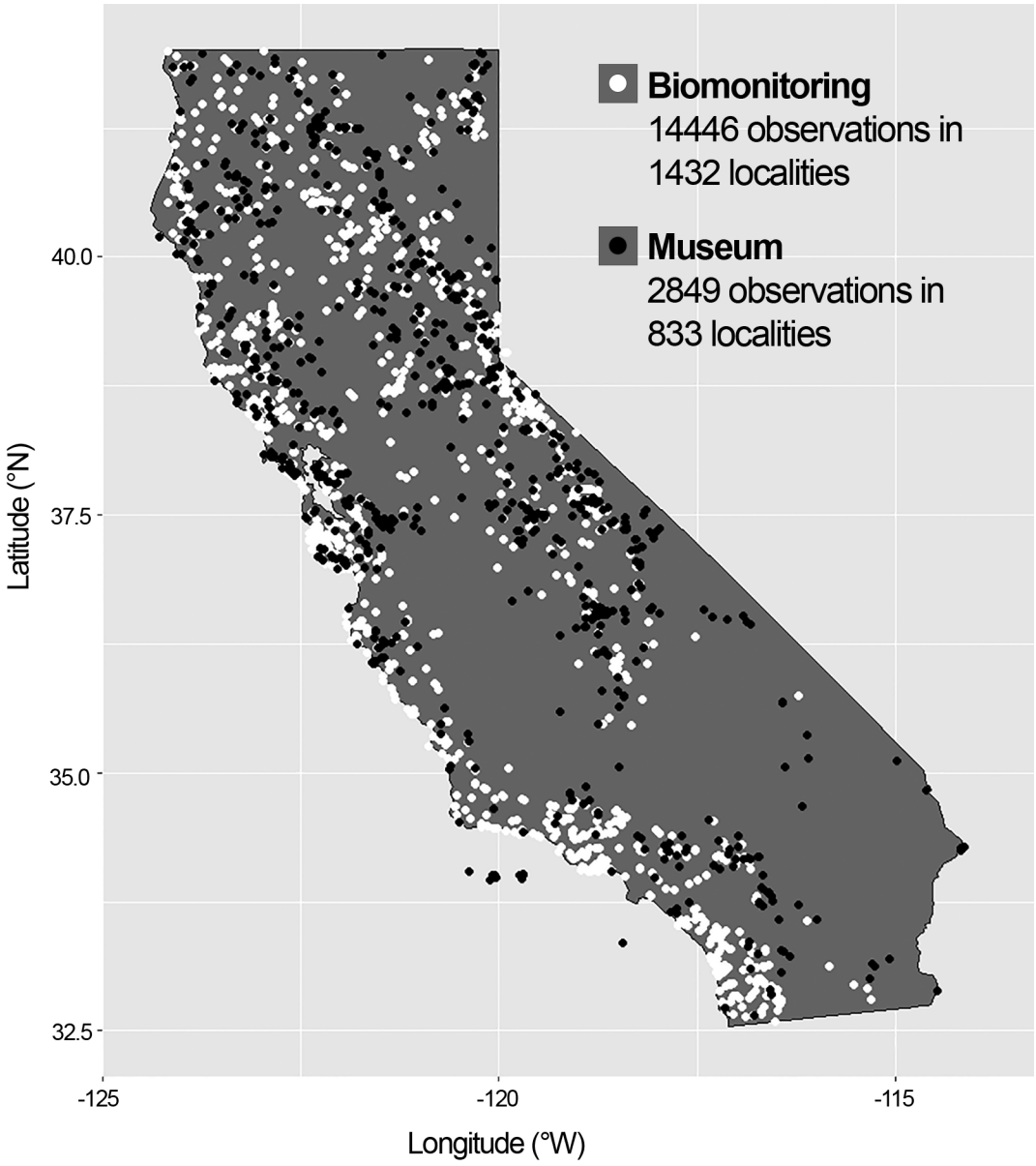


**FIGURE 1.** Distribution of sampled localities for biomonitoring and museum collections. The number of museum records plotted only includes georeferenced datapoints. Map includes only digital records databased through 2009 and 2014, for Biomonitoring and Museum resources, respectively.

Many of the species included in Table 2 are from collection material with determinations of identity only represented by one or two records for a species, some of these species occur in adjacent western states, and their occurrence in California is probable. Some records are clearly problematic because distribution ranges for these species are non-Western, yet material must be examined to make these determinations. Within this collection material, there are likely several exemplars that are misidentified (also noted by Burdick (2010)).

**TABLE 2. Species of uncertain status in California.** Filled circles indicate the species was present in the resource. Filled circles with a number indicate that both the valid name and a synonym appeared in the resource. Empty circles with a number indicate the occurrence as one or more synonyms. The Total Species Richness includes all records for each resource. Resources include D 1956=Denning (1956), B 2010=Burdick (2010), R&M 2018=Rasmussen and Morse (2018) and CR=Collection Records. Other name is any other name (e.g., synonym) that occurred in a resource. State abbreviations are standard. Abbreviations: CAS=California Academy of Sciences, EMEC=Essig Museum of Entomology, INHS=Illinois Natural History Collection, DD=Donald Denning, DB=Donald Burdick.

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other Name | State records, collection record & other notes |
|---|---|---|---|---|---|---|
| Apataniidae | | | | | | |
| *Allomyia cidoipes* (Schmid, 1968) | | ● | ● | ● | | BC, CA, OR, WA; CAS (Nevada Co.). |
| *Apatania chasica* (Denning, 1954) | | ● | | ● | | ID, MT, UT; CAS (Marin Co.); DB (Tuolumne Co.); DB "hold that Tuolomne Co. specimen *is A. sorex*" |
| *Moselyana comosa* Denning, 1949 | | ● | | ● | | OR, WA; CAS (Humboldt Co., larvae only) |
| Brachycentridae | | | | | | |
| *Brachycentrus occidentalis* Banks, 1911 | | ● | | ● | | Widespread, inc NV, OR, WA, UT & AZ; CAS (Fresno Co., Shasta Co., Siskiyou Co., Tulare Co.) |
| *Micrasema dimicki* (Milne, 1936) | | ● | | ● | | OR, WA; CAS (Marin Co.); DB (Humboldt Co., Marin Co., Shasta Co., Siskiyou Co.) |
| Glossosomatidae | | | | | | |
| *Anagapetus debilis* (Ross, 1938) | | | | ● | | AB, BC, CO, ID, MT, NV, OR, SD, UT, WA, WY; EMEC (Tulare Co.) |
| *Anagapetus hoodi* Ross, 1951 | | ● | | | | DB identified a species (Inyo Co.) as nr. *A. hoodi* or a new species |
| *Glossosoma excitum* Ross, 1938 | | ● | | ● | | BC, MT, OR, WA; EMEC (Shasta Co., Siskiyou Co., Trinity Co.) |
| *Glossosoma montanum* Ross, 1941 | | ● | | ● | | ID, MT, OR, UT, WA, WY; CAS (Contra Costa Co.); DB noted damaged specimen, likely a labeling error. |
| *Glossosoma schuhi* Ross, 1947 | | ● | | ● | | ID, NV, OR, UT; CAS (Lassen Co., Shasta Co.); EMEC (Siskiyou Co.); DB didn't have access to CAS material. |
| *Glossosoma traviatum* Banks, 1936 | | ● | | ● | | ID, MT, OR, UT, WA, WY; EMEC (Siskiyou Co.) |
| *Glossosoma verdonum* Ross, 1938 | | ● | ● | ● | | AB, AK, BC, CA, CO, ID, MT, NM, OR, UT, WA, WY, YT; CAS (No locality info); DB doubted the record. |
| *Glossosoma wenatchee* Ross & Spencer, 1952 | | ● | | ● | | BC, WA, OR, YT; EMEC (Nevada Co.); DB (Plumas Co.); Ruiter et al. (2014): "initial genetic evidence has suggested that all three species [*G. pternum*, *G. californicum*, *G. wenatchee*] may all be the same"; Burdick (2010): "The differences are small and intermediates occur. It is likely these three species should be considered *G. pternum*." |
| *Protoptila erotica* Ross, 1938 | | ● | | ● | | AZ, CO, IL, IN, MB, MI, MN, MT, NM, NV, QC, UT, WA, WI, WY; CAS (Lake Co., Siskiyou Co.); EMEC (Lake Co.); BD noted as nr. *P. erotica* or possibly new species. |
| Goeridae | | | | | | |
| *Goeracea genota* (Ross, 1941) | | ① | | ● | [1]*Goerita* | BC, ID, MT, OR, WA; CAS (Colusa Co.) |
| Hydropsychidae | | | | | | |
| *Cheumatopsyche analis* (Banks, 1903) | | | | ● | | Midwestern & Eastern distribution + WY; EMEC (No locality) |
| *Hydropsyche abella* Denning, 1952 | | ● | | ❶ | [1]*Ceratopsyche* | NV, OR, "probably a synonym [of *Hydropsyche amblis*], Flint pers comm [in Rasmussen and Morse (2018)]"; CAS (Fresno Co., Madera Co., Mono Co., Shasta Co., Placer Co., Shasta Co., Sierra Co., Tehama Co., Tulare Co., Tuoumne Co.) + DB (Nevada Co.); EMEC (El Dorado Co., Mono Co., Nevada Co., Siskiyou Co.); DB "*H. abella/H. amblis* appear to be the same species." |

*...Continued on next page*

**TABLE 2.** (Continued)

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other Name | State records, collection record & other notes |
|---|---|---|---|---|---|---|
| *Hydropsyche auricolor* Ulmer, 1905 | | | | ● | | AZ, NM, TX, Mx.; CAS (Sierra Co.) |
| *Hydropsyche protis* Ross, 1938 | | ● | | ❶ | [1]*Ceratopsyche* | AZ, NV, UT, WY; CAS (Fresno Co., Madera Co., Tulare Co.) + DB (Mariposa Co., Mendocino Co., San Benito Co.); DB "Same as *H. cora*". |
| *Hydropsyche tana* Ross, 1938 | | ● | ● | ❶ | [1]*Ceratopsyche* | BC, CA, ID, MT, NV, OR; DB no specimen. |
| Hydroptilidae | | | | | | |
| *Agraylea multipunctata* Curtis, 1834 | | ● | | ● | | Widespread (but not AZ, CA, NV); CAS (Lassen Co.) + DB (Trinity Co.); DB "in vials labeled as *A. multipunctata* or *A. saltesea*." |
| *Hydroptila angusta* Ross, 1938 | | | | ● | | Midwestern & Eastern distribution; CAS (Trinity Co.) + DB (Santa Barbara Co.) + DB "new species nr. H. angusta" |
| *Hydroptila consimilis* Morton, 1905 | | ● | | ● | | Midwestern & Eastern distribution + WY; CAS (Fresno Co., Humboldt Co., Kern Co., Madera Co., Marin Co., Nevada Co., San Diego Co., Tulare Co.) + DB (Mono Co., Santa Barbara Co.); INHS (Los Angeles Co., Santa Clara Co.) |
| *Hydroptila modica* Mosely, 1937 | | ● | | ● | | AZ, NM, OR, TX, WA, Mexico; CAS (Siskiyou Co., Trinity Co.); DB noted "same as *H. hamata*" (on *H. modica* illustration)' |
| *Hydroptila salmo* Ross, 1941 | | | | ● | | Midwestern & Eastern distribution + WY; CAS (Placer Co.) |
| *Ithytrichia mexicana* Harris & Contreras-Ramos, 1989 | | ● | | ● | | AZ, NM, NV, Mexico; CAS (Fresno Co., Mono Co.) + DB (Humboldt Co., Tulare Co.); DB "doubtful of the validity of this species" |
| *Ochrotrichia aldama* (Mosely, 1937) | | ● | | ● | | Not in North America; DB (Tulare Co.) |
| *Ochrotrichia phenosa* Ross, 1947 | | | ● | | | CA, OR; Bickle (1979) incorrect. Ross (1947) makes no mention of CA record, only OR holotype. |
| *Orthotrichia cristata* Morton, 1905 | | | | ● | | Widespread but not AZ, OR, NV, UT; CAS (Kern Co.) |
| *Oxyethira aculea* Ross, 1941 | | ● | | ● | | AL, AZ, NM, NV, OK, TX, Mexico; DB (Butte Co., Napa Co., Riverside Co.) |
| Lepidostomatidae | | | | | | |
| *Lepidostoma hoodi* Ross, 1948 | | ● | | ● | | BC, OR, WA; CAS (Humboldt Co.); DB noted this specimen was missing in CAS Denning collection. |
| *Lepidostoma ormeum* Ross, 1946 | | | | ● | | AZ, CO, NM, NV, UT, WY; CAS (Mono Co.) |
| Leptoceridae | | | | | | |
| *Ceraclea cancellata* (Betten, 1934) | | ● | | ● | | Midwestern & Eastern distribution; CAS (Modoc Co. & El Dorado Co.) |
| *Ceraclea transversa* (Hagen, 1861) | ① | ● | | ● | [1]*Athripsodes* | Midwestern & Eastern distribution + NV; CAS (Lake Co.) |
| *Nectopsyche exquisita* (Walker, 1852) | | | | ● | | Midwestern & Eastern distribution; CAS (No digital label information available) |
| Limnephilidae | | | | | | |
| *Asynarchus cinnamoneus* Schmid, 1950 | | ● | | ● | | AK, BC, OR; DB (Placer Co.) |
| *Ecclisomyia maculosa* Banks, 1907 | ● | ● | ● | ● | | Ruiter et al. (2014): "it is likely that most records for *Ecclisomyia maculosa* specimens west of the Rocky Mountains are *Ecclisomyia simulata*" |
| *Frenesia missa* (Milne, 1935) | | | | ● | | Midwestern & Eastern distribution; INHS (San Mateo Co.) |
| *Grammotaulius betteni* Hill-Griffin, 1912 | | | | ● | | BC, OR, WA, China; CAS (Alameda Co., San Diego Co., San Mateo Co.) |
| *Halesochila taylori* (Banks, 1904) | | ● | | ● | | AK, BC, ID, OR, WA; CAS (Siskiyou Co.); DB (larval material, Glenn Co.) |

...*Continued on next page*

**TABLE 2.** (Continued)

| Valid Name | D 1956 | B 2010 | R&M 2018 | CR | Other Name | State records, collection record & other notes |
|---|---|---|---|---|---|---|
| *Homophylax flavipennis* Banks, 1900 | | ● | | ● | | BC, CO, MT, UT, WY; CAS (El Dorado Co.) |
| *Lenarchus brevipennis* (Banks, 1899) | | ● | | ● | | AB, BC, CO, ID, MT, OR, UT, WA; CAS (Nevada Co.) |
| *Lenarchus rho* (Milne, 1935) | | ● | | ● | | BC, OR, WA; CAS (Del Norte Co., Humboldt Co., Trinity Co.); DB (Plumas Co.); EMEC (Humboldt Co.) |
| *Limnephilus alberta* Denning, 1958 | | | | ● | | BC, CO, MT, UT, WY; CAS (No digital label information available) |
| *Limnephilus castor* Ross & Merkley, 1952 | | | | ● | | CO, NM, NV, UT, WY; INHS (El Dorado Co.) |
| *Limnephilus diversus* (Banks, 1903) | | | | ● | | AZ, CO, ID, KS, NE, NM, UT, WY; INHS (Mono Co.) |
| *Limnephilus extractus* Walker, 1852 | | | | ● | | AB, BC, ID, MB, NH, NT, NY, ON, QC, SK, UT, YT; CAS (Plumas Co.) |
| *Limnephilus fagus* Ross, 1941 | | ● | | ● | | AK, BC, ID, MT, OR, WA, WY; CAS (Los Angeles Co.); DB noted that *L. fagus* was misidentified by DD, instead is *L. externus* |
| *Limnephilus flavastellus* Banks, 1918 | | | | ● | | AK, BC, OR, WA; EMEC (Marin Co.) |
| *Limnephilus moestus* Banks, 1908 | | | | ● | | Widespread inc. adjacent states except OR; EMEC (Glenn Co.); INHS (Mono Co.) |
| *Limnephilus sansoni* Banks, 1918 | | ● | | ● | | AK, BC, CO, MB, NT, WY, YT; CAS (Santa Barbara Co.); DB noted "Not likely to be correct." |
| *Limnephilus sitchensis* (Kolenati, 1859) | | ● | | ● | | AK, BC, ID, OR, WA, WY; CAS (Inyo Co. & DB noted as possible *L. spinatus*); DB notes Denning's determinations need to be checked; species not likely in California. |
| Philopotamidae | | | | | | |
| *Chimarra aterrima* Hagen, 1861 | | | | ● | | Midwestern & Eastern distribution; INHS (Fresno Co., possible georeferencing error, incomplete label information) |
| *Chimarra primula* Denning, 1950 | | | | ● | | AZ; CAS (Marin Co.) |
| *Dolophilodes columbia* Denning, 1989 | | | | ● | | WA; CAS ("California" but no other digital label information available) |
| Polycentropodidae | | | | | | |
| *Plectrocnemia remota* (Banks, 1911) | | | | ● | | Widespread, but no adjacent states; EMEC (Placer Co.) |
| *Polycentropus denningi* Smith, 1962 | | ● | | ● | | BC, ID, MT, OR, WA; DB (Siskiyou Co., Trinity Co.) |
| *Polycentropus gertschi* Denning, 1950 | | ● | | ● | | AZ, CO, TX; CAS (Riverside Co.) |
| Psychomyiidae | | | | | | |
| *Lype diversa* (Banks, 1914) | | | | ● | | Midwestern & Eastern distribution; CAS (No digital label information available) |
| Rhyacophilidae | | | | | | |
| *Rhyacophila alberta* Banks, 1918 | | ● | | ● | | AB, AK, BC, CO, ID, MT, NM, UT, WY, YT; DB (Listed localities under *R. tucula*); DB noted that *R. tucula* is a synonym of *R. alberta*, or all identified in California as *R. tuculae* are *R. albertae*. |
| *Rhyacophila chilsia* Denning, 1950 | | | | ● | | AB, AK, BC, OR, WA; UASM (Madera Co.) |
| *Rhyacophila colonus* Schmid, 1970 | | ● | | ● | | OR; DB (Trinity Co.) |
| *Rhyacophila malkini* Ross, 1947 | | ● | | ● | | BC, OR; DB (Marin Co., Shasta Co., Trinity Co.) |
| *Rhyacophila manistee* Ross, 1938 | | ● | | ● | | Eastern distribution; DB (Del Norte Co.) |
| *Rhyacophila perplana* Ross & Spencer, 1952 | | ● | | ● | | BC, OR, WA; DB (Marin Co.); DB noted opinion as a variant of *R. vazuna*) |
| *Rhyacophila rickeri* Ross, 1956 | | | | ● | | AB, AK, BC, WA; CAS (California) |
| *Rhyacophila tralala* Schmid, 1970 | | ● | | ● | | OR, WA; DB (Marin Co., Plumas Co.) |
| *Rhyacophila vaefes* Milne, 1936 | | ● | ● | | | BC, CA, OR, WA; DB notes that all *R. vaefes* in CA are *R. tucula* |
| *Rhyacophila viquaea* Milne, 1936 | | ● | | ● | | OR, WA; DB (Marin Co., Mendocino Co., Trinity Co.); INHS (Marin Co.) |
| **Total Richness by resource** | **2** | **45** | **6** | **66** | | |

Clearly voucher material must be reviewed by taxonomic experts, specimen label information must be updated, and digital lists must be actively maintained by collections managers. Because we focused on digital resources from GBIF and California natural history museums, this list does not include a full inventory from museums with substantial Trichoptera holdings, such as the National Museum of Natural History, the Royal Ontario Museum, the University of Minnesota Insect Collection, or the Canadian National Collection. A caveat about our lists should be noted. Although we annotated that some species records were unlikely based on distribution information, we did not examine the specimens that these records were based on and assumed that the records included in Rasmussen and Morse (2018) are reliable. However, many published records of Trichoptera in California are over 50 years old and may not represent the current concept of the species name. For example, Nimmo (2012), in many cases, described new species of *Psychoglypha*, yet material in some digital resources may not yet be updated with the current name to reflect the revised or modern species concept. Because we were not able to examine specimens, especially those detailed in Table 2, we caution that any new state records are provisional.

Taxonomic research on western Trichoptera emphasizes that much work is required to update and expand collections. Work by Ruiter *et al.* (2014), using morphological and genetic evidence, defined biogeographical boundaries and resurrected the species *Ecclisomyia simulata* as distributed west of the Rocky Mountains, making records of *Ecclisomyia maculosa* in California doubtful. Givens and Ruiter (2015) reinstated *Arctopsyche inermis* from Smith's (1968) synonomization with *Arctopsyche grandis* and identified morphological structures for separation. However, they did not examine any material from CAS or EMEC. Burdick (2010) noted several of Denning's proposed new species and identifications of specimens that are similar to described species. For *Glossosoma pternum*, *Glossosoma califica*, and *Glossosoma wenatchee*, he noted that "the differences are small and intermediates occur," and these similarities are supported by genetic evidence, although the species have yet to be formally synonymized (Ruiter *et al.* 2014). Consequently, this preliminary list is certainly an underestimate, based on the disparity between the locations of biomonitoring and of museum-based collection records. An important message from this study is that Trichoptera are clearly undersampled and much work remains on groups occurring in California.

*Limitations of current records sources*

The digitization of records of Trichoptera material still faces barriers related to the nature of working with specimens preserved in fluid material. For example, the CalBugs project (http://calbug.berkeley.edu) digitally images and databases collections of arthropods at multiple California natural history museums. When the CAS digitally cataloged their fluid material, they only recorded the species name and county because the task of recording full verbatim information was too time-intensive (N. Penny, personal communication). Although some museums barcode specimen vials with minimal disruption to the material (e.g., University of Minnesota Insect Collection), imaging of material requires specialist support, and training to manipulate the specimens without damaging them. In addition, each image from alcohol-filled vials requires more time to set up than pinned material because individuals must be removed from vials for imaging, and labels must be flattened. Improved methods for working with fluid materials (e.g., Mendez *et al.* 2018, DeWalt *et al.* 2018) will allow records to be more easily be used for research questions that require georeferenced coordinates.

Access to verbatim label-information forms the greatest barrier to generating preliminary species lists and to complete basic analysis of species-discovery trends over time. For example, the CAS Trichoptera type-specimen collection has 328 names and includes the original citation for the publication associated with the type, but no locality information. This list is kept separately from the general collection database and does not share any data fields with the exception of the species name. The names that appear in the type collection are not cataloged in the general collection.

The CAS general collection included county as a database field but did not include the year of collection. Without a date, we could not analyze museum collection activity over time, or date of species discovery. In addition, without full verbatim information, we could not georeference records. Only 56% of the museum-based records were georeferenced, limiting species-level spatial analysis.

*Resolution of names & digital taxonomic resources*

In generating this list, we worked with just under 7,000 records from museum-based collections and the task of checking for valid name status and synonymies was exceptionally laborious. For example, some species had multiple variants because of changes in the Latinized binomial gender and misspellings were common.

Although Rasmuseen and Morse (2018) is an extensive and exhaustive resource, names were checked by hand because automated scripts do not exist. There are digital tools (e.g., R packages) to bulk-check valid name status and identify synonyms for the Integrated Taxonomic Names System (ITIS, www.itis.gov) and GBIF. However we had to abandon their use, because they returned incorrect valid name status compared to the TWC and they did not work for variants on name spellings. ITIS has not been updated with data from the TWC since 2001 (J. Morse, personal communication) and GBIF also relies on this same list. Use of these digital resources for valid name status is strongly cautioned and we recommend only using the TWC or Rasmussen and Morse (2018) until these other resources are updated.

**Distribution and influence of biomonitoring records**

Caddisflies are distributed widely across California, but the source databases have different spatial strengths. In our study, biomonitoring records did not have a large influence on the total species richness for the state because they are generally reported at the genus level. However, the biomonitoring records from CEDEN increased the resolution of our mapped estimates of the overall distribution of caddisflies compared to museum localities, e.g. museum records were primarily only recorded at the county level and were not included as part of Figure 1. Because the duration of the adult flight period is often short, museum records are exceptionally sensitive to the collection happening at "the right place at the right time," and may only offer sparse estimates of distribution. Although museum records spanned a much longer collection history, the presence of species in these collections is clearly undersampled when compared to the collections included in CEDEN. CEDEN, by sampling within the larval life stage and often multiple times at a site, has a higher probability of encountering any taxon over time, yet identification resolution typically to the generic level limits its ability to contribute to species richness estimates.

In general, there is an unequal spatial distribution of sampling sites for museum and biomonitoring datasets. For example, in areas of southern California where there are extensive deserts and few roads, the area has not been well sampled with either approach. In contrast, museum collections tend to focus efforts in locations (e.g. Del Puerto Canyon for the University of California, Berkeley, and local sites near universities) and accessibility of sites, such as montane stream-road crossings. However, urban sampling locations are often not represented in museum collections. This pattern is not true of the biomonitoring sites because they center on capturing anthropogenic influences on water resources, which are more often in urban areas. The highest number of generic-level distribution records for Trichoptera in California result from the extensive state biomonitoring program that have sampled hundreds of locations throughout the state across a wide range of stream sizes and habitat types (e.g., Surface Water Ambient Monitoring Program, http://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/). However, they are focused heavily toward wadable stream habitats and often exclude lentic habitats.

As California experiences increasing pressures on its freshwater resources, intermittent and ephemeral steams are at risk from hydrological, physical, chemical, and biological alterations, threatening aquatic species (Chiu *et al.* 2017). Trichoptera such as those in the genera *Ochrotrichia* and *Sisko*, which inhabit intermittent streams, are increasingly threatened (Ruiter & Harris 2011). Many species included in this list of California Trichoptera are known from only one or two exemplars collected 50 years ago. Some species may be California endemics that are extremely constrained in their distribution and occur in only one watershed or spring. Other species may be more widespread, but vastly undercollected and consequently very little is known of their true distribution, habitats, and life-history characteristics.

**Conclusion**

This list of Trichoptera in California, like all faunal lists, is a work in progress and should be considered as list of potential species present in the state. The larval biomonitoring data included in this study highlight that many more localities have collection potential, yet additional collections of adults are critical to understanding the true distribution of species.

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