First record of *Lepidurus lemmoni* (Holmes 1894) (Crustacea: Notostraca) in California's Central Valley

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RESEARCH NOTE

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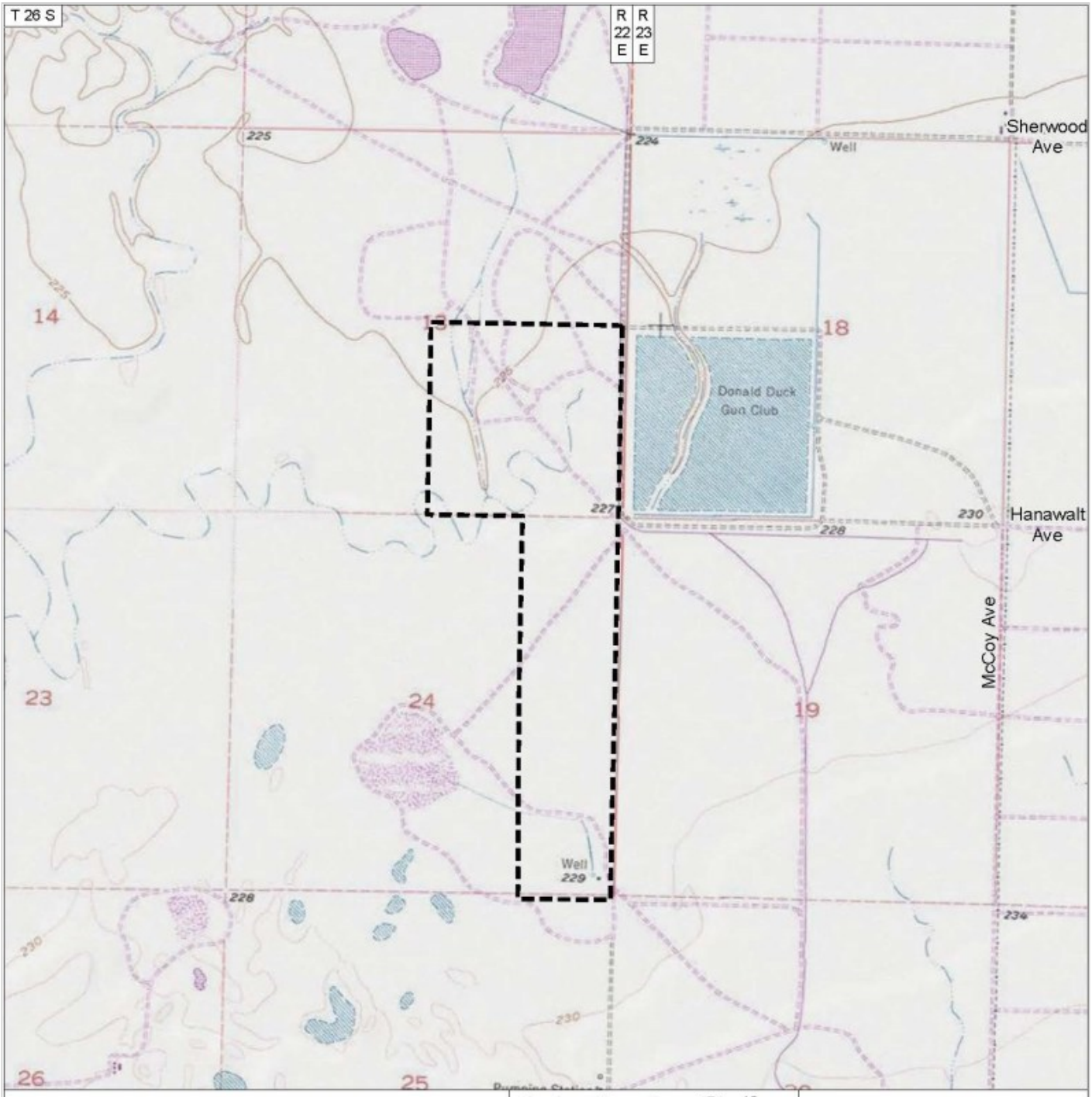
Tadpole shrimp (Order Notostraca) are an order of branchiopod crustaceans and one of the three large branchiopods (fairy shrimp, tadpole shrimp, and clam shrimp) (Brendonck et al. 2008). Two extant genera occur worldwide, *Triops* and *Lepidurus*. These animals occur in seasonally astatic aquatic habitats (Brendonck et al. 2022). Rogers (2001) and Helm and Noyes (2016) reported only one *Lepidurus* species from the California Great Central Valley, USA, the federally endangered vernal pool tadpole shrimp (*L. packardi* Simon, 1886), which occurs in vernal pool-type astatic wetlands. However, we observed *L. lemmoni* Holmes, 1894, in the southern portion of the Central Valley in 2019 in alkaline playa-type astatic wetlands. *Lepidurus lemmoni* has been referred to as the "alkali tadpole shrimp" (Helm 1998), "Lemmon's tadpole shrimp" (Helm and Noyes 2016), and "Lynch tadpole shrimp" (NatureServe 2024). We captured *L. lemmoni* from several playa-type pools while we conducted wet season surveys for

federally listed vernal pool crustaceans at Poso Plains Mitigation Site, owned and managed by Westervelt Ecological Services. The site covers nearly 130 ha east of Interstate 5 and north of State Highway 46, roughly 6 km south by southeast from the southeast corner of the Kern National Wildlife Refuge, Kern County, CA (**Fig. 1**). Specifically, the site occurs east of Corcoran Road, south of Sherwood Avenue Extension, and west of Gun Club Road (lat. 35.659° lon. -119.546° decimal degrees, World Geodetic System 1984). The site lies along the southern edge of the historic Tulare Lake shoreline, at elevations of 67.7-69.8 m above mean sea level (**Fig. 2**). The site occurs within the Garces Silt Loam soil mapping unit, which consists of saline alkali soils associated with the basin rim landform (Natural Resource Conservation Service 2024). We also observed *Lepidurus lemmoni* on the adjacent Semitropic Ecological Reserve, owned and managed by the California Department of Fish and Wildlife (CDFW), to the west of Poso Plains Mitigation Site (**Fig. 3**). We hypothesize that our new-found *L. lemmoni* occurrences represent a historical distribution of the species within the Central Valley that was previously undiscovered.



Study Area

Freeway (inset)

Highway (inset)

Water Body (inset)

Forest or Park (inset)

The Study Area is 321 acres. It is located in Kern County on the Lost Hills NE US Geological Survey (USGS) 7.5-minute topographical quadrangle map (USGS 1954 [revised 1977]); Sections 13 and 24, Township 26 South, Range 22 East, Mt. Diablo Base & Meridian.

Center coordinates (WGS 1984) are: 35.656535, -119.548263.

Regional Location

0 1,000 2,000 Feet

1 inch = 2,000 feet

Data Sources:
- Bing accessed Jan 2018
- ESRI US Topo Maps accessed Jan 2018

Figure 1. Topographic vicinity map of Poso Plains Mitigation Site, CA, USA.

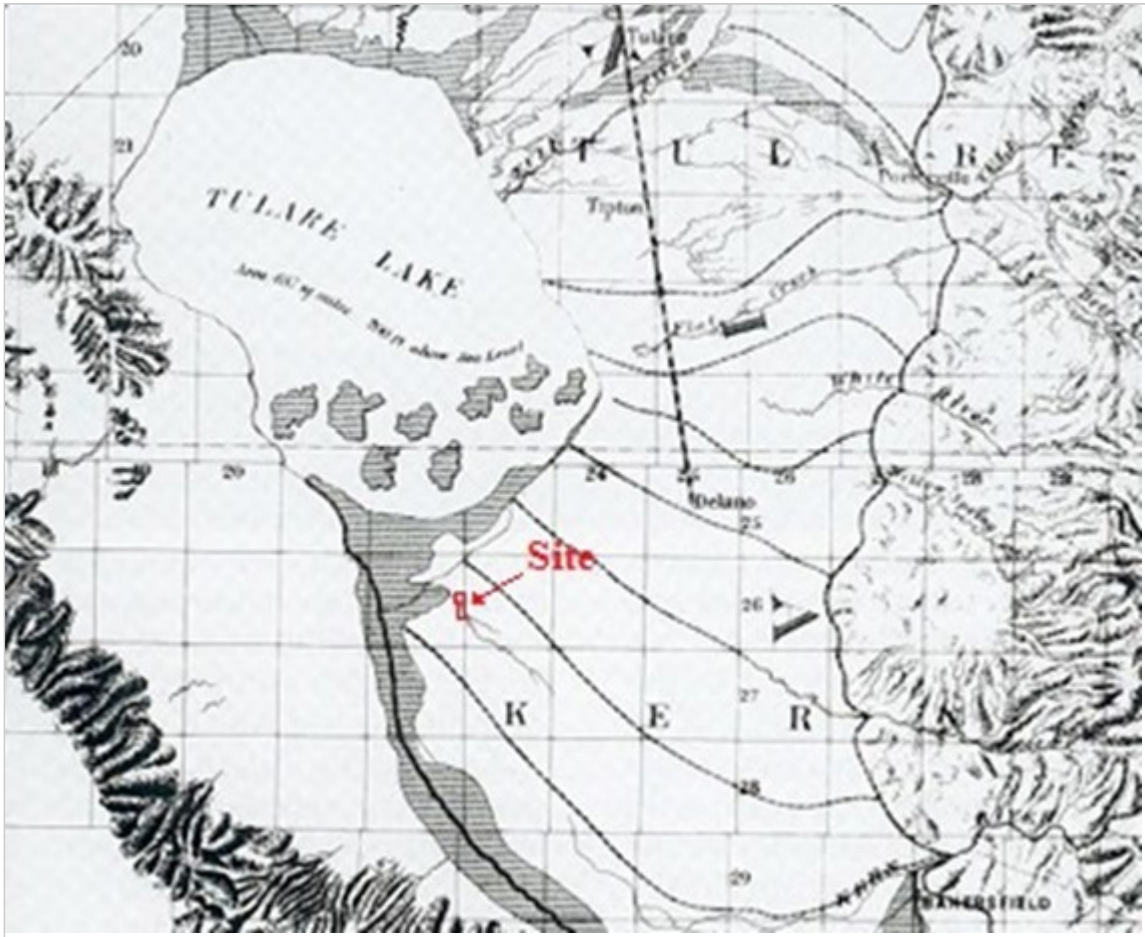
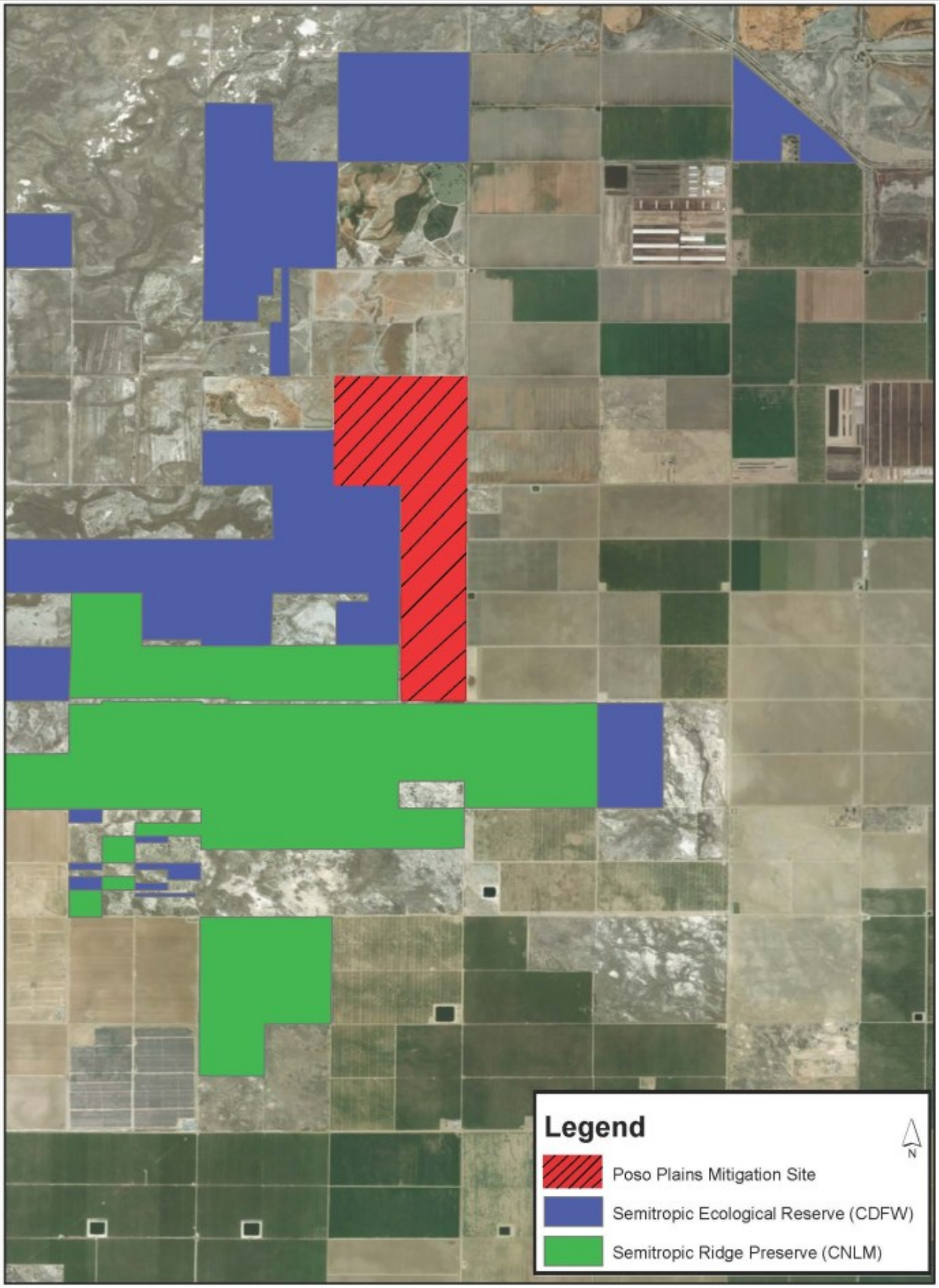


Figure 2. Poso Plains Mitigation Site (shown in red with hashes) relative to the Historic Tulare Lake (Mendell et al. 1874) in CA, USA.



CDFW = California Department of Fish and Wildlife

CNLM = Center for Natural Lands Management

Figure 3. Relative location of Poso Plains Mitigation Site (shown in red) to surrounding preserves in CA, USA.

We observed *L. lemmoni* on 26 March 2019 in three alkaline playa pools (Fig. 4). Co-occurring species included alkali fairy shrimp (*Branchinecta mackini* Dexter, 1956), versatile fairy shrimp (*B. lindahli* Packard, 1883), and tadpoles of the western spadefoot (*Spea hammondii* Baird, 1859). The *L. lemmoni* specimens were identified using Linder (1952), Pennak (1978), and Rogers (2001). For example, the nuchal organ arrangement was characteristic of *L. lemmoni* (Fig. 5), occurring behind a line drawn between the posterior apices of the eyes, unlike the nuchal organ of *L. packardi* which is intersected by such a drawn line (Rogers 2001). Additionally, the specimen was “shining yellow or grayish silver to light green,” which is characteristic (Rogers 2001).

Figure 4. Photographs of two pools from which new-found *Lepidurus lemmoni* was observed in the southern Central Valley, Tulare Basin (northwest Kern County, CA, USA).

Figure 5. Photographs of (left) new-found *Lepidurus lemmoni* specimen observed from the Tulare Basin portion of the Central Valley (northwest Kern County) and (right) *Lepidurus packardi* for comparison observed from Merced County, CA, USA. Note the difference between the nuchal organ arrangement shown by the red arrow.

Three *Lepidurus* species have been reported from California (Rogers 2001; Helm and Noyes 2016). Only *Lepidurus packardi* has previously been reported from the California Central Valley (Rogers 2001; Helm and Noyes 2016). *Lepidurus packardi* was listed as threatened in 1994 under the federal Endangered Species Act primarily due to destruction of its vernal pool habitats (Helm 1998), of which over 90% have been destroyed (Holland 2009; Witham 2021). *Lepidurus packardi* is reported from the Central Valley from Shasta County to Tulare/Kings County (Helm 1998; Rogers 2001; Helm and Noyes 2016). The southernmost occurrence of *L. packardi* is within alkaline pools at Cross Creek Preserve in northern Kings/Tulare County located ~80 km north of the newfound *L. lemmoni* occurrence.

Lepidurus lemmoni typically occurs in medium to large, hard, alkali desert playa-type astatic pools with pH values ranging from 8.2 to 11.3, although is occasionally observed in small turbid alkaline pools (Rogers 2001). The species is reported from Canada, Montana, Wyoming, Washington, Oregon, Nevada, California, Arizona, and Baja California Norte (Lynch 1966; Rogers 2001; Brostoff et al. 2010; Hossack et al. 2010; Rogers and Hill 2013). *Lepidurus lemmoni* is a common occurrence within California large alkali playas in the Great Basin (Lassen, Modoc, Siskiyou counties) and Mojave Desert (southeast Kern County and northern Los Angeles County). The species is not known from California's Central Valley (Rogers 2001; iNaturalist 2024).

Our new locality is ~162 km northwest of the nearest previously known record of the species located in the Mojave Desert west of Rogers Dry Lake (iNaturalist 2024) (**Fig. 6**). Given that large branchiopod eggs can survive ingestion by ducks and shorebirds (Rogers 2014), it is plausible that the Central Valley population was historically colonized via migrating waterfowl and other water birds. While great distance

and a major geographic barrier separates the two localities, their ecology and species assemblages are not dissimilar.

Figure 6. New locality of *Lepidurus lemmoni* at Poso Plains Mitigation Site (red pin) relative to the closest known locality near in Mojave Desert (blue pin) located ~162 km apart in CA, USA.

The climatic conditions of the new locality and nearest Mojave Desert locality are cold semi-arid/desert (BSk/BWk, Kottek et al. 2006; Germano et al. 2011) differing from the majority of the Central Valley, which is warm-summer Mediterranean (CSa, Kottek et al. 2006). The new locality and nearest Mojave Desert locality receive approximately 18 cm (7 in) of annual rainfall, lower than more northern portions of the Central Valley which receive between 33 cm (13 in) (Fresno) and 89 cm (35 in) (Redding) of annual rainfall (U.S. Climate Data 2024). Substrate pH in the Tulare Basin pools ranged from 9.23 to 10.52, which is within the range reported for this species (8.2 to 11.3) (Rogers 2001) and close to that of substrates near the nearest Mojave Desert locality (pH 9) (Brostoff et al. 2010). The Tulare Basin pools supporting *L. lemmoni* resemble Mojave Desert playa-type pools (large and flat-bottomed) (Germano et al. 2011). Tulare Basin playa-type pools and Mojave Desert playas share a similar hydrologic regime, in which they may remain dry for several years (Brostoff et al. 2010; authors, pers. obs.), unlike more northern Central Valley vernal pools which inundate more frequently.

The climate, hydrology, and soils result in similar vegetation types for both locations (Germano et al. 2011). The Tulare Basin playa-type pools are dominated by sparse salt-tolerant, aquatic plant species (<5% aerial cover) usually along their edges (**Fig. 4**). Typical plants include alkali barley (*Hordeum depressum*), alkali popcorn flower (*Plagiobothrys leptocladus*), alkali peppergrass (*Lepidium dictyotum*), alkali-weed (*Cressa truxillensis*), bush seepweed (*Suaeda nigra*), California alkali grass (*Pucchella simplex*), iodine bush (*Allenrolfea occidentalis*), saltbush species (*Atriplex* spp.), and saltgrass (*Distichlis spicata*). Similar taxa dominate Mojave Desert playa pools, which include the same species, with the addition of woody subshrubs – black greasewood (*Sarcobatus vermicularis*), Mojave red sage (*Neokochia californica*), and Boraxweed (*Nitrophila occidentalis*)(Brostoff et al. 2010; Germano et al. 2011).

The Tulare Basin and the Mojave Desert pools support similar assemblages of aquatic invertebrates, including alkali fairy shrimp and versatile fairy shrimp. *Lepidurus lemmoni* is known to prey upon fairy shrimp in Mojave Desert pools (Lynch 1966; Brostoff et al. 2010), and this is likely the case in Tulare Basin pools. Bothalkali fairy shrimp and versatile fairy shrimp are known to occur in alkali pools throughout the Mojave Desert, Great Basin, and the Central Valley (primarily the San Joaquin Valley and western side of the Sacramento Valley) (Eriksen and Belk 1999). However, Tulare Basin pools lacked other large branchiopods typical of Mojave Desert pools, including giant fairy shrimp (*Branchinecta gigas* Lynch, 1937), desert tadpole shrimp (*Triops* sp.), and clam shrimp (*Cyzicus* sp. and *Eocyzicus digueti* Richards, 1895).

The historical distribution of *L. lemmoni* in the Central Valley is difficult to ascertain because the majority of historical habitat has been destroyed and converted to agriculture (Preston 1981). Remnant alkali pools in the Tulare Basin are concentrated between 0 to 25 km south of the southern edge of the historic Tulare Lake (Mendell et al. 1874; Baker 1876), east of Interstate 5 and north of State Highway 46. These lands include federal and state preserves (e.g., U.S. Fish and Wildlife Service's Kern National Wildlife Refuge and CDFW's Semitropic Ecological Reserve), mitigation lands (Westervelt Ecological Service's Poso Plains, Alkali Flats, CD Hillman, and Antelope Plains Mitigation Sites and Center for Natural Lands Management's Semitropic Ridge Preserve), and private property (including several duck hunting clubs) (**Fig. 3**).

If *L. lemmoni* co-occurred in areas with other federally listed large branchiopods, it would have likely been detected in surveys for those species. *Lepidurus lemmoni* likely does not occur north of the Pixley National Wildlife Refuge, the southernmost extent of the federally threatened vernal pool fairy shrimp (*Branchinecta lynchi*; Eng et al. 1990), which occurs 32 km northeast of our new records. Areas between Poso Plains Mitigation Site and Pixley National Wildlife Refuge, such as CDFW's Allensworth Ecological Reserve, should conduct focused surveys for *L. lemmoni*.

The southernmost extent of *L. lemmoni* is even more difficult to speculate due to the minimal remaining suitable habitat and limited survey data. Private and public lands in this region, such as CDFW's Buttonwillow Ecological Reserve, Westervelt Ecological Services' proposed Buttonwillow Conservation Bank, and Jumper Conservation Bank Preserve, may require *L. lemmoni* focused surveys.

Alkali playa-type pool habitats in the Tulare Basin have had infrequent surveys due to the absence of federally-listed branchiopod species. Additionally, the Tulare Basin lacks consistent annual rainfall, and as such, the pools do not inundate each year to allow consistent surveys. Furthermore, when the saline/alkaline clay soils become wet (during the narrow survey window) it is very difficult to traverse.

Lastly, private landowners in this area are particularly resistant to biological surveys.

An alternative hypothesis is that this species occurrence represents a more recent natural or anthropogenic range expansion. The area in which this species was found has a rich history of waterfowl hunting and farming. Therefore, our new-found occurrence may be the result of a recent bird translocation. Similarly, *L. lemmoni* eggs could have been unintentionally imported from soil adhering to farming or hunting equipment (e.g., waders, decoys, blinds). Future surveys targeting *L. lemmoni* in the surrounding region may provide support for whether this is a recent or historical range expansion.

The order Notostraca is known to exhibit extreme morphological plasticity, so it is also possible that the newfound specimens are not *L. lemmoni*, but are new, cryptic species that diverged upon geographic isolation (King and Hanner 1998; Rogers 2001; Adamowicz and Purvis 2005; Brendonck et al. 2022). Exploration of this tertiary hypothesis would require additional morphological and genetic analysis.

The discovery of a new record (or possibly new or cryptic species) previously unreported from the Central Valley implies that Tulare Basin pools provide habitat for rare species at risk and should be protected (Preston 1981). Furthermore, alkali pools within this region should receive more intensive and widespread survey attention, especially for large branchiopods.

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Ethics Statement

This project was authorized by USFWS under permit number TE 795930.10.2.

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