

# The current distribution and putative spread of the channeled apple snail in California

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## RESEARCH NOTE

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A recent focus on globalization as the origin of a surge in invasive species translocations has been reported (Perrings et al. 2005; Meyerson and Mooney 2007; Hulme 2009). The general trend to the open transit of goods and services worldwide has caused some researchers to speculate or even predict that invasive species will become a greater problem in the future (Lodge et al. 2006; McNeely 2006; Sutherland et al. 2008). Unfortunately, invasive species have been considered the cause of or a contributing factor in the extinction of many species from several classes of wildlife (Clavero and Garcia-Berthou 2005). In particular, aquatic systems appear to be the most severely impacted ecosystems

(Moyle 1999), with nearly all freshwater catchments in North America containing at least one non-native species (Gido and Brown 1999). Nevertheless, Williamson (1996) suggested that non-native species invasions are a process that includes different stages, including transport, establishment, and spread. Occasionally this process is not successful but can unfortunately be repeated several or many times before establishment (Moyle 1999).

In California, numerous invasive species have been translocated to this novel environment with a great number becoming established (Ingram 1959; Grosholz and Ruiz 1995; Moyle 1999; Bolch et al. 2021). In the aquatic environment, Moyle (1999) reported at least 49 fish species that have become established with an additional 38 that failed. Numerous invertebrate species have also been introduced into California, with many more remaining undetected or unreported (Ingram 1959; Cohen et al. 1995; Grosholz and Ruiz 1995; Cohen and Carlton 1997).

In the late 1990s, the channeled (= golden) apple snail (*Pomacea canaliculata*, which has been reported as one of the most negatively impactful invasive species on earth (Lowe et al. 2000), was found in California (Cerutti 1998; Howells et al. 2006). Initially, these snails were thought to be introduced for the purpose of food for humans. Subsequent introductions or reintroductions, however, may have been generated from the aquatic pet trade (Cowie et al. 2017). The origin of this species is South America, specifically, Argentina, Bolivia, Paraguay, Uruguay, and Brazil (Rawlings et al. 2007), where it likely occupied similar habitats to those found in portions of the United States. This species is reported to be a voracious consumer of aquatic vegetation and is expected to compete for resources with native mollusks and other invertebrates (Naylor 1996; Wood et al. 2005). They are also believed to be a vector for the rat lungworm (*Angiostrongylus cantonensis*), which can cause significant illness in humans (Tseng et al. 2011; Lv et al. 2009). In California, if the species were to spread, it would be considered a threat to rice crops (Naylor 1996; Yeo 2004; Global Invasive Species Database 2021).

Herein, the current distribution and putative spread of *P. canaliculata* in California is reported. New locations where the species appears to have formed breeding populations are also reported.

We collected data from personal observations, previously reported/published works, museum collections, and confirmed community science reports. For community science reports, observations were verified if each report was supported by a photo that the authors could confirm, and/or included a site visit and subsequent search and confirmation of the species presence. We then categorized all sources of observations within decadal periods (i.e., 1990s, 2000s, 2010s, and 2020–2021). Changes were noted in the reported locations of observations or known occupied sites to determine if populations were increasing (geographically) and if new unassociated populations were becoming established. We mapped these data and compared them within decadal spans, when possible.

It was determined that *P. canaliculata* was first reported in California in 1997 from Miramar Lake in San Diego County (Cerutti 1998). In the same year, two other locations were also reported at Norton Simon Museum, Los Angeles County, and within drainage canals associated with the Salton Sea, in Riverside County (Howells et al. 2006). Howells et al. (2006) also noted a fourth site in Fremont, Alameda County that was subsequently reported as eradicated (**Fig. 1a and 1b**). A single additional site was reported between 2000 and 2010; *P. canaliculata* was found in a pond at the Los Coyotes Country Club, Orange County (USGS, unpublished data; **Fig. 1b**). In the 2010s, five additional counties in which this species was reported, as well as continued reports (population persistence) at the original sites (i.e., counties) in

which it was known (Los Angeles, Orange, Riverside, and San Diego Counties; [Fig. 1c.](#)) were recorded. In 2021, *P. canaliculata* was reported in three additional counties ([Fig. 1d](#) and [Fig. 2.](#)). As of summer 2021, all 10 counties with extant populations were made up of breeding populations (J. Alvarez, personal observation).



**Figure 1.** Progression of California counties with known occurrences of channel apple snail (*Pomacea canaliculata*). Red shading indicates positive sightings; orange triangle is approximate location.



**Figure 2.** Channeled apple snails (*Pomacea canaliculata*) discovered in a small community pond in Manteca, San Joaquin County, California, USA, in 2021. (Photo Credit: Mitch Alvarez)

Given that the original populations were observed in 1997, it appears that they have been self-sustaining for at least 24 years. Given the current geographic extent and disjunct nature of these populations reported herein, it appears that every occupied county has had a separate introduction event. It is noted that only two of the known populations appear to be hydrologically connected. The population at Big Break (Antioch, CA) and Dutch Slough (Bethel Island, CA) in Contra Costa County are hydrologically connected through the Sacramento-San Joaquin River Delta. Although the authors did not observe population connectivity between Big Break and Dutch Slough directly, there remains a high likelihood that this is a very large extended population that reaches more than 6 km. Two disjunct populations that occur in Oasis and Mecca, Riverside County, California are hydrologically connected via the Salton Sea. However, the Salton Sea is reported to have a salinity of at least 44 ppt (Schroeder et al. 2002), while Wada and Matsukura (2009) suggested that a salinity level of approximately 4 ppt may be lethal to a “majority” of individual snails. It is, therefore, concluded that the Salton Sea is likely a dispersal barrier for this species from one drainage canal or river to another.

Observations by the authors indicate that 32 of the 33 currently extant populations are allopatric, and are part of an iterative range expansion, which appears to indicate that all populations were introduced separately and over time. The current distribution also indicates an invasion pathway that is associated with numerous anthropogenic releases over a geographic area that includes more than half the length of California. This type of introduced species invasion follows that postulated by Williamson (1996) who suggested that successful invasion is a process that happens overtime (see also: Moyle 1999).

Yeo (2004) and the Global Invasive Species Database (2021) both suggested that this species may greatly impact rice production if the species were to be introduced into areas adjacent to productive fields. With a potentially large population of *P. canaliculata* established in the Sacramento-San Joaquin River Delta, which is hydrologically connected to agricultural areas supporting rice farming to the north, it is likely that future management of this invasive species would include limiting or avoiding further encroachment of northern dispersal into sensitive agricultural areas.

Based on observations by the authors, introductions into suitable habitat can occur anywhere that a golf ball-sized mollusk could be carried. Speculation has been abundant for cold temperatures as limiting

movement. Oya et al. (1987) and Mochida (1991), however reported that *P. canaliculata* could survive for up to 20 days at 0°C. This may be a limiting factor for this species in the Sierra Nevada Mountains but will not likely affect the spread of this snail in the northern Central Valley (i.e., Sacramento Valley) and lower elevations of the surrounding foothills. The current California climate, as well as potential future climate change may, in fact, facilitate occupation of millions of acres of California's lakes, creeks, natural wetlands, mitigation areas, agricultural ditches, sewage treatment ponds, and other sites where this species may impact native flora and fauna (Schoenherr 2007; Joshi et al. 2017).

is clearly increasing in its overall geographic spread, nearly entirely through anthropogenic translocation. We suggest that regulations be put in place to limit or curtail any possession, breeding, transportation, or release of this species into any water way in California. Without vigorous control of new populations, and control over dispersal of extant populations, *P. canaliculata* will undoubtedly become established in more areas of California, increasing the threat of eventually becoming established in sensitive agricultural areas.

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