U.S. Fish & Wildlife Service

Channeled Applesnail (*Pomacea canaliculata*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, March 2023
Revised, August 2023
Web Version, 7/25/2024

Organism Type: Mollusk
Overall Risk Assessment Category: High

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1 Native Range and Status in the United States

Native Range

From Hayes et al. (2012):

"The range of *P. canaliculata* is restricted to the Lower Paraná, Uruguay, and La Plata basins […] based on habitat similarity and watershed connections it is possible that it may also occur in the lower reaches of the Upper Paraná and parts of southern Brazil […]."

From Daniel (2023):

"**Native Range:** South America, central portion of the continent primarily Argentina (northern), Bolivia, Brazil, Paraguay, and Uruguay (Hayes et al. 2012)."

Status in the United States

According to Daniel (2023), nonindigenous occurrences of *Pomacea canaliculata* have been reported in the following U.S. States and territories, with range of observation years and watersheds (8-digit hydrologic unit) where reported given in parentheses.

- Arizona (2007-2020; Lower Colorado Lower Gila; Lower Salt)
- California (1997-2022 Middle Kern-Upper Tehachapi-Grapevine; Middle San Joaquin-Lower Chowchilla; Salton Sea; San Diego; San Gabriel; San Joaquin Delta; Santa Barbara Coastal; Santa Margarita)
- Florida (2005-2012; Lower St. Johns)
- Georgia (2005-2014; Lower Savannah; Satilla)
- Guam (2004-2004; Guam)
- Hawaii (1989-2019; Hawaii; Hawaii Region; Kauai; Lanai; Maui; Oahu)
- Idaho (1991-2016; Upper Snake-Rock)
- North Carolina (1992-1992; Upper Dan)

From Daniel (2023):

"**Status:** Established in California and Hawaii."

From Rawlings et al. (2007):

"Currently, the occurrence of *P. canaliculata* has been confirmed in California and Arizona in the continental U.S."

"The earliest report of an established population of *P. canaliculata* in California is 1997 in Lake Miramar, north of San Diego [Cerutti 1998]."

From Cowie (2013a):

"It was also recorded in Guam in 1989 (Smith, 1992) […] but whether it is established there is not known."

From Howells et al. (2006):

"Despite [State and Federal trade] restrictions, including potential legal fines and even imprisonment, some *P. canaliculata* complex species continue to appear in the aquarium trade in Texas and elsewhere. Trade in larger adults appears to have been reduced, but dealers often cannot or will not distinguish between the small juveniles of relatively harmless *P. bridgesii* and harmful *P. canaliculata* complex species, especially with gold and other domestic color morphs. Use of different common and scientific names has also undoubtedly contributed to identification problems in the pet trade."

From Cowie (2013a):

"It has also been seen in the domestic aquarium trade in Hawaii."

Regulations

From Rawlings et al. (2007):

"In response to [introductions of *Pomacea canaliculata*], the U.S. Department of Agriculture began requiring permits for importation or interstate movement of aquatic snails in 2006, specifically targeting apple snails with the hope of limiting their spread in the U.S."

From Cowie (2013a):

"In the United States its transport between states is restricted (Gaston, 2006), as is its transport between islands in the Hawaiian archipelago (Tamaru et al., 2006)."

The States of Arkansas (AGFC 2022) and California (CDFW 2021) regulate possession, transport, or sale of *P. canaliculata* at the individual species level.

The following U.S. States regulate possession, transport, or sale of all species in the genus *Pomacea*: Arizona (Arizona Game and Fish Commission 2022), Hawaii (HDOA 2019), Idaho (Idaho Department of Agriculture 2010), North Carolina (North Carolina DEQ 2022), and Texas (TPDW 2022; except *P. bridgesii*).

While effort was made to find all applicable regulations, this list may not be comprehensive.

Means of Introductions within the United States

From Cowie (2013a):

"In the Pacific, *P. canaliculata* was introduced to Hawaii by 1989, although there are unverified anecdotal accounts that it was present by 1983 or 1984 (Cowie, [1995]; Levin et al., 2006; Cowie et al., 2007). It was deliberately introduced as a food resource, almost certainly from the Philippines (Tran et al., 2008). It has also been seen in the domestic aquarium trade in Hawaii. It was also recorded in Guam in 1989 (Smith, 1992), purportedly accidentally introduced […]"

"*P. canaliculata* has also been introduced to North America. It was first recorded in California in 1997, possibly associated with the pet trade (Cerutti, 1998), but it may also have been introduced for human consumption, possibly from Hawaii or the Philippines […]"

Remarks

This ERSS was previously published in March 2018. Revisions were completed to incorporate new information and conform to updated standards.

From Rawlings et al. (2007):

"In the continental U.S., *P. canaliculata* is found only in Arizona and California, although we have not sampled the Alabama population of apple snails with channeled sutures. The East and West coast populations of apple snails with channeled sutures are therefore different species, and need to be treated as distinct management units. The match of haplotypes to Hawaiian samples suggests a possible pathway for its introduction to the western U.S., via the food trade."

"*Pomacea canaliculata* was reported in Florida and Texas in the late 1970s, probably based on misidentification of *P. haustrum* in Florida and *P. insularum* in Texas."

From Hayes et al. (2012):

"Two of the most pervasive and destructive invasive ampullariids are *Pomacea maculata* Perry, 1810 and *Pomacea canaliculata* (Lamarck, 1822), which, along with several other conchologically similar species [e.g. *Pomacea lineata* (Spix, 1827), *Pomacea figulina* (Spix, 1827), and *Pomacea dolioides* (Reeve, 1856)] are often lumped into what is termed the canaliculata group (Cazzaniga, 2002; Hayes et al., [2009]). Until recently, studies of these invasive snails and their impacts mistakenly referred both to a single widespread and highly variable species, *P. canaliculata*, which was considered one of the 100 worst invasive species in the world (Lowe et al., 2000). Molecular data confirmed that a second valid species could be recognized from within this assemblage, and this species has been referred to as *Pomacea insularum* (d'Orbigny, 1835) in most recent studies (Rawlings et al., 2007; Hayes et al., 2008, [2009] […]). Despite the recognition that two species could be differentiated, most recent studies fail to do so, and may even confuse other ampullariid species as representing members of this assemblage. Similarly, the results of previous studies are difficult to interpret as a consequence of this confusion (e.g. [Scott, 1958]; Andrews, 1964, 1965; Berthold, 1991; Thiengo, Borda & Araújo, 1993). Difficulty in accurately separating and identifying these species, and inconsistency in the names applied to them, has confounded efforts to evaluate the range of life-history variation and the biogeographic distribution of these species (Cazzaniga, 2002)."

"Molecular data confirm that *P. maculata* and *P. canaliculata* are two distinct species, each with an average of 2.71–2.81% sequence divergence at COI within populations, and as much as 4.80 and 6.87% sequence divergence between distantly separated populations of *P. maculata* and

P. canaliculata, respectively. Despite not being closely related within the genus, their shells are highly similar, their biogeographic distributions overlap, and both are frequently introduced pests. Until recently, representatives of both were typically referred to *P. canaliculata*, with published information sometimes ascribed to the incorrect species (e.g. data for *P. maculata* ascribed to *P. canaliculata*; [Scott, 1958]; Neck & Schultz, 1992; Carlsson & Lacoursière, 2005), or conflating the two (e.g. Naylor, 1996; Lowe et al., 2000; Cowie, 2002)."

"The large biogeographic distribution historically reported for *P. canaliculata* (e.g. Cazzaniga, 2002) is in part the result of confusion with *P. maculata*, but it also stems from misidentification of several other species within the genus (Hayes, 2009). Both species occur sympatrically in the Paraná and Uruguay river basins of Argentina and Uruguay, although *P. canaliculata* extends further south (Martín, Estebenet & Cazzaniga, 2001). *Pomacea maculata* has a much larger range, occurring throughout much of western Brazil, from the border of Paraguay in the south to the Amazon Basin in the north, and it is a significant component of the freshwater molluscan biodiversity of the Pantanal wetlands [south-central Brazil]."

From Cowie (2013a):

"Matsukura et al. (2013) reported genetic exchange and possible hybridization between *P. canaliculata* and *P. maculata*."

"International Common Names
English: apple snail; Argentinian apple snail; channeled apple snail; channeled applesnail; golden miracle snail; golden mystery snail; golden snail; jumbo snail; South American applesnail"

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2023):

Kingdom Animalia
  Subkingdom Bilateria
    Infrakingdom Protostomia
      Superphylum Lophozoa
        Phylum Mollusca
          Class Gastropoda
            Subclass Prosobranchia
              Order Architaenioglossa
                Family Ampullariidae
                  Genus *Pomacea*
                    Species *Pomacea canaliculata* Lamarck, 1822

According to MolluscaBase editors (2023), *Pomacea canaliculata* is the current accepted name of this species.

Size, Weight, and Age Range

From Hayes et al. (2012):

"[…] ~35 to > 165 mm in adult shell length […]"

From Holswade and Kondapalli (2013):

"The shell of this snail is globular, from 40-60 mm high and 45-75 mm wide, but can reach 150 mm in length. These numbers vary depending on environmental conditions; the shell grows mostly in the spring and summer but growth slows in the fall and winter."

From Pastorino and Darrigan (2012):

"In its native temperate range in South America, the species reaches maturity at 2 years and breeds for two annual breeding seasons with a life-span of about 4 years due to seasonality (temperatures fluctuating from 7°C-28°C). At a constant temperature of 25°C, the species has been reported to reach maturity after 7 months and complete one single breeding season of about 4 months, after which it died (Estebenet and Cazzaniga 1992)."

Environment

From Daniel (2023):

"*Pomacea canaliculata* optimal [sic] water temperatures for rearing is [sic] between 15-35 °C (Seuffert and Martín [2017])."

From Holswade and Kondapalli (2013):

"Temperature preferences for *P. canaliculata* range from 18 to 25 degrees C. Temperatures below 18 degrees or above 32 degrees C drastically increases the snail's mortality rate. (Cowie, 2005 […])"

From Pastorino and Darrigan (2012):

"Some ampullarids may be able to tolerate low levels of salinity, but do not generally live in brackish water habitats. Most are amphibious and inhabit slow-moving or stagnant water in lowland swamps, marshes, ditches, lakes and rivers (Cowie 2002). This species has been described as occurring in relatively still water in part of its native range in Argentina (Scott 1957). The species is also more resistant to lower temperatures than most other snails from the *Pomacea* genus (Cowie 2005)."

Climate

From Rawlings et al. (2007):

"The match of introduced haplotypes of *P. canaliculata* and *P. insularum* to native Argentinean samples from approximately 35°S suggests that the introduced populations of these species may be cold tolerant and capable of surviving occasional frosts. Moreover, *P. canaliculata* occurs as far as 38–39°S, and topography rather than climate may set the natural southern limit of this species [Martín et al. 2001, Martín et al. 2005]. The average minimum monthly temperature in Buenos Aires [Argentina] is 4–6 degrees Celsius (39–43 degrees Fahrenheit) from May to September, slightly lower than the average minimum winter monthly temperatures in Charleston, South Carolina."

From Cowie (2013a):

"*P. canaliculata* reaches its southernmost limit in the Southern Pampas of Argentina, part of its natural South American range, at 37 °S (Seuffert et al., 2010). Its northern limit, in its non-native range, is 36 °N, in Japan (Ito, 2002), around 31 °N in China (Lv et al., 2011) […]"

Distribution Outside the United States

Native

From Hayes et al. (2012):

"The range of *P. canaliculata* is restricted to the Lower Paraná, Uruguay, and La Plata basins […] although based on habitat similarity and watershed connections it is possible that it may also occur in the lower reaches of the Upper Paraná and parts of southern Brazil […]."

From Daniel (2023):

"**Native Range:** South America, central portion of the continent primarily Argentina (northern), Bolivia, Brazil, Paraguay, and Uruguay (Hayes et al. 2012)."

Introduced

From EPPO (2024):

"In the last decades, *P. canaliculata* has expanded to new contiguous and disjunct areas in Argentina (Seuffert & Martín, 2021) and has been introduced to other countries in South America, such as Chile (Letelier *et al.*, 2016), Ecuador (Horgan *et al.*, 2014) and Brazil (hybridizing with *P. maculata*; Glasheen *et al.*, 2020)."

"Cowie *et al.* (2017) updated the extensive list of countries where *P. canaliculata* has been reported together with the dates of introduction or first record. It established extensively in rice fields and other managed waterbodies and also in natural wetlands in South-Eastern Asia, where it was first introduced in Taiwan in 1979, and rapidly spread to the Philippines (1980), Japan, China, South Korea, Indonesia (1981), Thailand (1982), Malaysia (1987) and Vietnam (1988). In the 1990s it reached Laos, Papua-New Guinea, Singapore and since 2000 it has also reached Cambodia and Myanmar. Genetic molecular analyses indicate that Argentinian populations were the source of these South-East Asian populations in most cases but also that there have been multiple introductions in the same area (Yang *et al.* 2019, 2021). There are also reports of the pest in other regions of Asia, such as Israel (Roll *et al.*, 2009) and Siberia (Vinarski *et al.*, 2015). In North America and the Caribbean, it has been reported in the Dominican Republic (1991), […] Mexico (2009) and Trinidad (2014). […] In Europe one specimen of *P. canaliculata* has been reported in Spain together with *P. maculata* (Andree & López, 2013), but this isolated record remains unconfirmed. In Africa its presence has been confirmed only recently in rice fields from Kenya (Buddie *et al.*, 2021)."

From Letelier et al. (2016):

"In Chile, the species was first detected in 2008 in the outlet of Laguna Conchalí, Los Vilos, Northern Chile, based on morphological features of the shell, but this record required further confirmation. In the present study we examine biometry, reproductive traits, radula ultrastructure and molecular data to show that the snails found in Laguna Conchalí effectively correspond to *Pomacea canaliculata*."

"The high amount of egg clutches of *P. canaliculata* registered in Laguna Conchalí would point out that this exotic species is fully naturalized and adapted to this estuarine environment. The egg clutches were disseminated throughout the whole wetland during oviposition periods, indicating that this species is widely distributed in this aquatic ecosystem."

Roll et al. (2009) reports *P. canaliculata* from human-dominated habitats only in Israel, and not from natural habitats.

From Yanygina et al. (2010):

"The invasion of species unusual to the biocenoses of the southern part of West Siberia was caused by a constant long-term input of discharge water from the Belovskaya thermal power plant. […] mollusks (*Pomacea canaliculata* Lamarck) […] were found in the areas of the heated water discharge […] and their distribution was limited to the areas of maximal and moderate water heating."

From Buddie et al. (2021):

"Following reports of an invasive snail causing crop damage in the expansive Mwea irrigation scheme in Kenya, samples of snails and associated egg masses were collected and sent to CABI laboratories in the UK for molecular identification. DNA barcoding analyses using the cytochrome oxidase subunit I gene gave preliminary identification of the snails as *Pomacea canaliculata*, […] To the best of our knowledge, this is the first documented record of *P. canaliculata* in Kenya, and the first confirmed record of an established population in continental Africa."

From Yang et al. (2018):

"In Asia, *P. canaliculata* was introduced to Asia more than once from multiple locations in Argentina […]"

From NIES (2023):

"Range in Japan Central to western Japan including Ryukyu Islands [Okinawa Is.].

Origin Taiwan
Date 1981"

Means of Introduction Outside the United States

From Yang et al. (2018):

"It is recorded that apple snails were first introduced into Asia via Taiwan in 1979, and then introduced to other Asian countries, including Japan and the Philippines [Mochida 1991, Naylor 1996, Joshi and Sebastian 2006]. Subsequently, the prevalence of snails-farming and frequent agriculture contacts among our neighbor countries made a round introduction of apple snails and speed [sic] the wide spread of apple snails in Asia [Cowie 2002, Yusa et al. 2006]. Nevertheless the native origins of invasive apple snails were explicated, such complicated pattern in introduced ranges was probably result [sic] from extensive influence by human activities. Human factors were also the most likely driver for the fast spread of apple snails in China."

From Cowie (2013a):

"*P. canaliculata* may spread naturally predominantly by floating downstream, although crawling upstream is also possible, unless the flow rate is too great (Ranamukhaarachchi and Wikramasinghe, 2006). However, the rapid spread of *P. canaliculata* within Asia and Hawaii following introduction has been predominantly human mediated."

"The primary mode of spread of *P. canaliculata* has been deliberate introduction to new areas by people who see it as a potential source of food. Although usually confined initially to aquaculture facilities, the snails either escape or are deliberately released into agricultural or natural wetlands. This has happened despite knowledge of its serious pest status in areas already invaded. It has also been reported as having been introduced by the pet trade, although the main ampullariid in the pet trade is *P. diffusa* rather than *P. canaliculata*. Nonetheless it is known in the pet trade, and this has been thought of as the pathway of its introduction to Spain (Anonymous, 2011). Once introduced, it is further possible that it spreads naturally by floating downstream, to a limited extent by crawling upstream, during flooding, and even attached to birds (Levin et al., 2006). People also move it around accidentally; for instance, in Hawaii small juveniles have been inadvertently transported on taro parts used for propagation (Levin et al., 2006), and eggs can be transported on boats (Baker et al., 2012)."

"*P. canaliculata* spread rapidly through much of Southeast Asia following its initial introduction to Taiwan. It has now probably reached most areas in which it would be able to live within the region."

From Yanygina et al. (2010):

"Most likely, the mollusks were introduced into the Belovo cooling reservoir [Russia] from amateur aquariums."

From Buddie et al. (2021):

"Unconfirmed media reports in Kenya suggest that the snail was introduced to control weeds, but no permit to import the species has been issued by the Kenya Standing Technical Committee on Imports and Exports."

Short Description

From Hayes et al. (2012):

"*Shell:* Shell thin, smooth, ~35–60 mm in adult shell length […]; reddish to dark-brown spiral colour bands, variable in number and thickness, sometimes present; periostracum yellow–brown to greenish brown or dark chestnut; shoulder rounded; spire height generally low, with ratio of spire height to overall shell height ~0.07–0.16; aperture generally ovoid to kidney shaped; inside of pallial lip of shell unpigmented."

"*External anatomy:* Operculum moderately thick, flexible, thinning dorsally towards parietal edge."

Biology

From Hayes et al. (2012):

"*Eggs:* Number of eggs per clutch averaging less than 300, with as few as 12 to as many as ~1000 (Tamburi & Martín, 2011) […]"

From Cowie (2013a):

"*P. canaliculata* is dioecious (has separate sexes), internally fertilizing and oviparous. Females tend to be larger than males. Eggs are laid in clutches above water on the exposed parts of vegetation, rocks, etc., perhaps to avoid aquatic predators or in response to low oxygen tension in their often near-stagnant aquatic habitats. The eggs are enclosed in a calcium carbonate shell, which may or may not be used as a source of calcium for the developing embryo. Their bright pink colour serves as a warning to predators and the eggs as a result have very few predators (see also Dreon et al., 2010). These bright pink eggs are often the first visible signs of an infestation. Clutch size is very variable but averages about 260 eggs. Oviposition takes place predominantly at night, or in the early morning or evening, about a day after copulation. On each occasion a single clutch is laid. Copulation takes place about three times per week and occurs at any time of day or night, although there may be some diurnal rhythm, and it takes 10-18 hours. The interval between successive ovipositions has been reported to be from 5 to 14 days. Hatching generally takes place about 2 weeks after oviposition, but this period varies greatly and development is highly dependent on temperature (Koch et al., 2009). Newly hatched snails immediately fall or crawl into the water. The estimated average annual output of *P. canaliculata* is about 4400 eggs (Barnes et al., 2008)"

"All aspects of the life history are influenced by temperature ([Seuffert] et al., 2010, 2012). A laboratory study of *P. canaliculata* in its native Argentina (Estebenet and Cazzaniga, 1992) demonstrated the crucial role of temperature in growth and reproduction. At a constant 25°C, snails matured in 7 months and then bred continuously for a single 'season' of about 4 months, then died. In contrast, under seasonally fluctuating temperatures (7-28°C), the snails took 2 years to reach maturity; they then bred for two distinct annual breeding seasons, for a life-span of about 4 years. In the wild in Argentina, *P. canaliculata* breeds only during the summer (Hylton Scott, 1957), and the life-cycle under the fluctuating laboratory temperature regime may indeed reflect the life-cycle in the wild. Under semi-artificial conditions in Japan (an outdoor pond but with food provided), *P. canaliculata* grew to maturity in less than two months (Chang, 1985). In tropical regions of South-east Asia, release from the seasonality of its natural range may be at least one reason why *P. canaliculata* is so prolific; rapid growth and breeding, and hence rapid succession of generations, are permitted year round (Naylor, 1996), leading to rapid population expansion and high population densities."

"Males must attain a minimum age, regardless of size, for the onset of reproductive maturity, whereas females must reach a minimum size regardless of age (Estoy et al., 2002; Tamburi and Martín, 2009)."

"Most ampullariids, including *P. canaliculata*, are generalist herbivores. *P. canaliculata* grows rapidly when fed on numerous plant species (e.g. Lach et al., 2000; Qiu and Kwong, 2009; Wong et al., 2010)."

Human Uses

From Pastorino and Darrigan (2012):

"The species is used widely in the South East Asian part of its introduced range as a food item. It was introduced throughout its range here to be used for both local consumption and international export to the gourmet restaurant trade. Internationally, it is also widely used in the aquarium trade (Cowie 2002)."

From Cowie (2013a):

"*P. canaliculata* was initially introduced into Asia and Hawaii with a view to its development and sale to both local people as a food resource as well as to the gourmet restaurant trade locally and internationally. […] In the Philippines, small scale aquaculture of *P. canaliculata* provides fishmeal for fish, shrimp and prawn farming (Castillo and Casal, 2006)."

"In addition to its use as a food resource, *P. canaliculata* has also been used or recommended to a limited degree for biological control of weeds in rice paddies (Wada, 1997; Cazzaniga, 2006; Joshi et al., 2006). However, its use for this purpose is not widespread as it is a voracious feeder on rice shoots until they are a few weeks old, and as a result is a major pest of rice (Joshi and Sebastian, 2006)."

"In general, *P. canaliculata* was not well liked as a food in Asia and markets did not develop (e.g. Wada, 1997; Cheng and Kao, 2006; Preap [et al.], 2006; Wada, 2006; Yang et al., 2006; Yin et al., 2006), although in parts of southern China it became a popular delicacy, eaten raw (Cowie, 2013[b]; Yang et al., 2013)."

"[…] *P. canaliculata* is not the most common ampullariid in the trade (but see Baker et al., 2012). […] Internet or mail order trade of ampullariids occurs, but the relative contribution to this trade of *P. canaliculata* specifically has not been assessed."

"It has also been seen in the domestic aquarium trade in Hawaii."

From Howells et al. (2006):

"Despite [U.S. State and Federal trade] restrictions, including potential legal fines and even imprisonment, some *P. canaliculata* complex species continue to appear in the aquarium trade in Texas and elsewhere [in the United States]. Trade in larger adults appears to have been reduced, but dealers often cannot or will not distinguish between the small juveniles of relatively harmless *P. bridgesii* and harmful *P. canaliculata* complex species, especially with gold and other domestic color morphs. Use of different common and scientific names has also undoubtedly contributed to identification problems in the pet trade."

Diseases

No information was found associating *Pomacea canaliculata* with any diseases listed by the World Organisation for Animal Health (2023).

Poelen et al. (2014) lists *Echinostoma malayanum* and rat lungworm (*Angiostrongylus cantonensis*) as parasites of *Pomacea canaliculata*. Refer to the following section for more information on *Angiostrongylus cantonensis*.

Threat to Humans

From Rawlings et al. (2007):

"[…] introduction of all non-native ampullariids is a concern because of the suite of associated parasites and their potential effects on apple snail predators and humans. We know nothing at present about the parasites of introduced ampullariids in the continental U.S. Ampullariids, including *Pomacea canaliculata*, are intermediate hosts of important vertebrate parasites [Hollingsworth and Cowie 2006], most notably nematodes in the genus *Parastrongylus* (=*Angiostrongylus*). *Parastrongylus cantonensis* causes eosinophilic meningoencephalitis [Waugh et al. 2005], and *P. costaricensis* causes abdominal angiostrongyliasis in humans [Miller et al. 2006]. Transmission of *Parastrongylus* infections to mammalian hosts requires development to the L3 larval stage in an intermediate gastropod host. The spread of *Pomacea* species may therefore facilitate the spread of *Parastrongylus* species by completing the life cycle required to infect mammalian hosts. In Beijing, China, consumption of snails identified as *Pomacea canaliculata* resulted in 131 cases of human *Parastrongylus cantonensis* infection during a 4-month period [WorldWatch.org. 2006]."

From Cowie (2013a):

"The economic impacts of *P. canaliculata* have major impacts on the livelihoods of the individual farmers affected. *P. canaliculata* also has other important direct impacts on human wellbeing, notably its impact on human health."

"The empty shells of dead snails, perhaps following pesticide application, are a health hazard as they can cut the feet of people planting, harvesting or otherwise managing the crop (Cowie, 2002; Douangboupha and Khamphoukeo, 2006; Hendarsih-Suharto et al., 2006)."

"Poorly regulated application of dangerous pesticides can also cause human health problems (Cowie, 2002)."

3 Impacts of Introductions

From Rawlings et al. (2007):

"In Southeast Asia, *Pomacea canaliculata* and *Pomacea insularum* have become devastating agricultural pests, especially of rice [Cowie 2002, Lai et al. 2005, Joshi and Sebastian 2006] […]"

From Wang and Pei (2012):

"After 1 month of the rehabilitation process in the [half-open wetland (HOW)], we found that the golden apple snail had invaded the area and propagated quickly with densities of 10 snails/m^2, dominating the HOW. […] the golden apple snail reproduced significantly, and the mature snails massively fed on the [riparian wetland rehabilitation (RWR)] vegetation […]. Indeed, a large proportion of the plants were destroyed and decayed, including *P*[*otamogeton*] *crispus* and *H*[*ydrilla*] *verticillata* […]. According to our observations in the HOW and subsequent statistical analysis, of the mature golden apple snails, those that were 31-40 cm in length and 22.43-43.95 g in weight were the most harmful to the vegetation. During the river rehabilitation, golden apple snails destroyed 60% of the plants by cumulative consumption (according to the plant configuration numbers). They led to severe damage of transplanted vegetables […]"

From Cowie (2013a):

"**Impact on Habitats**
In Thailand, Carlsson et al. ([2004]) showed that *P. canaliculata* had a serious impact on aquatic vegetation, with high densities causing almost complete loss of plants as well as resulting in high nutrient concentrations and high phytoplankton biomass (caused by increased phosphorus levels in the water as a result of snail grazing on aquatic plants), and hence turbid water. In this way the snails caused a major change in ecosystem state and function. In other studies, in Laos, Carlsson and Lacoursière (2005) and Carlsson and Brönmark (2006) also showed that *P. canaliculata* at natural densities caused major loss of plant biomass, of both macrophytes and periphyton."

"**Impact on Biodiversity**
P. canaliculata has been suggested as the cause of the decline of native Asian species of freshwater snails, including native apple snails in the genus *Pila*, perhaps via competition [Halwart, 1994]. In the Phililppines, [sic] native *Pila* spp. are reported to have declined as a result of pesticide applications to control *P. canaliculata* (Anderson, 1993)."

"*P. canaliculata* will also prey on other species of aquatic snails (Cazzaniga, 1990; Kwong et al., 2009), although its potential population level impact is not known."

"In addition, *P. canaliculata* will prey on other organisms. For example, *P. canaliculata* feeds on bryozoans and was thought to be a significant factor in the absence of bryozoans from locations in which they would be expected to occur (Wood et al., 2005, 2006)."

"In Hawaii, there are cultural and lifestyle impacts. Taro is a culturally and spiritually important crop, especially for native Hawaiians, and farming taro is an important lifestyle. Taro is also important educationally, as students, teachers, and community groups use irrigated taro systems to explore topics in art, science, mathematics, health, capacity-building and Hawaiian culture. The introduction of *P. canaliculata* and the subsequent impacts on taro growing threaten all of these activities (Levin, 2006; Levin et al., 2006)."

"In Hawaii, following its introduction in 1989 or earlier, *P. canaliculata* spread widely during the 1990s (Lach and Cowie, 1999) and continued to spread subsequently (Cowie et al., 2007). In 2004, the farm value of taro was reported as US$2.7 million, but with 18-25% lost as a result of damage by *P. canaliculata* (Levin et al., 2006). It had dropped in 2005 to $2.2 million (Levin, 2006). Between 1989 and 2005, official agency (as opposed to individual farmer) costs of control projects in Hawaii were almost $400,000 (Levin, 2006)."

From Buddie et al. (2021):

"In Kenya farmers are already complaining about the damage caused to rice in Mwea, where over 70% of the country's rice is grown (Atera et al. 2018). In the initial area of infestation, farmers have reported up to 92% damage to newly transplanted rice seedlings."

The importation, possession, or trade of *Pomacea canaliculata* is regulated by the following U.S. States (see Section 1 for detailed information): Arkansas (AGFC 2022), Arizona (Arizona Game and Fish Commission 2022), California (CDFW 2021), Hawaii (HDOA 2019), North Carolina (North Carolina DEQ 2022), Idaho (Idaho Department of Agriculture 2010), and Texas (TPDW 2022). The species is also regulated at the U.S. Federal level by USDA-APHIS (2023).

4 History of Invasiveness

Pomacea canaliculata has a long history of introduction through aquaculture use and aquarium release. Peer-reviewed studies demonstrated that *P. canaliculata* can negatively impact macrophyte communities, influence water quality and turbidity through impacts on zooplankton and phytoplankton communities and cause substantial damage to economically and culturally valuable crops such as rice and taro. *P. canaliculata* is also a host for a parasite causing meningitis in humans. Because of the clear documentation of negative impacts of introduction from established populations of this species, the History of Invasiveness is classified as High.

5 Global Distribution

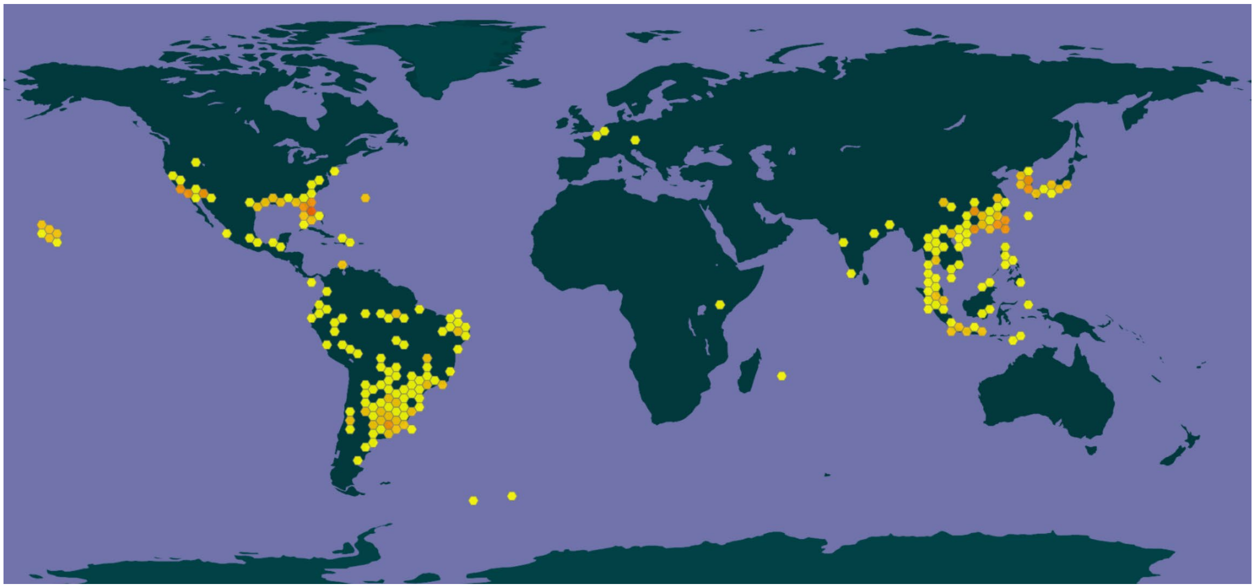

Figure 1. Reported global distribution of *Pomacea canaliculata*. Map from GBIF Secretariat (2022). Occurrences are reported from North America, South America, and Southeast Asia, primarily, with scattered occurrences in Europe, Africa, and other regions of Asia.

Point locations in Peru, northern and eastern Brazil, far western and southern Argentina, northern Paraguay, Colombia, and Bolivia were not used to select source points for the climate match because these are not in the native range described by Hayes et al. (2012) and are likely misidentifications of *P. maculata* or other congeneric species (see Remarks). Selected source locations in Chile and Ecuador were modified according to Letelier et al. (2016) and Horgan et al. (2014), respectively.

Point locations in Europe, the eastern and northern United States, Mexico, Guatemala, Panama, Cuba, the Dominican Republic, Bermuda, the southern Atlantic, Kazakhstan, Mauritius, India, Guam, and Timor-Leste were not used to select source points for the climate match because established populations of *P. canaliculata* could not be confirmed.

The established population in Russia was not included in selecting source points for the climate match because the population is restricted to thermally regulated waters and not subject to the full range of local climatic variation (Yanygina et al. 2010).

6 Distribution Within the United States

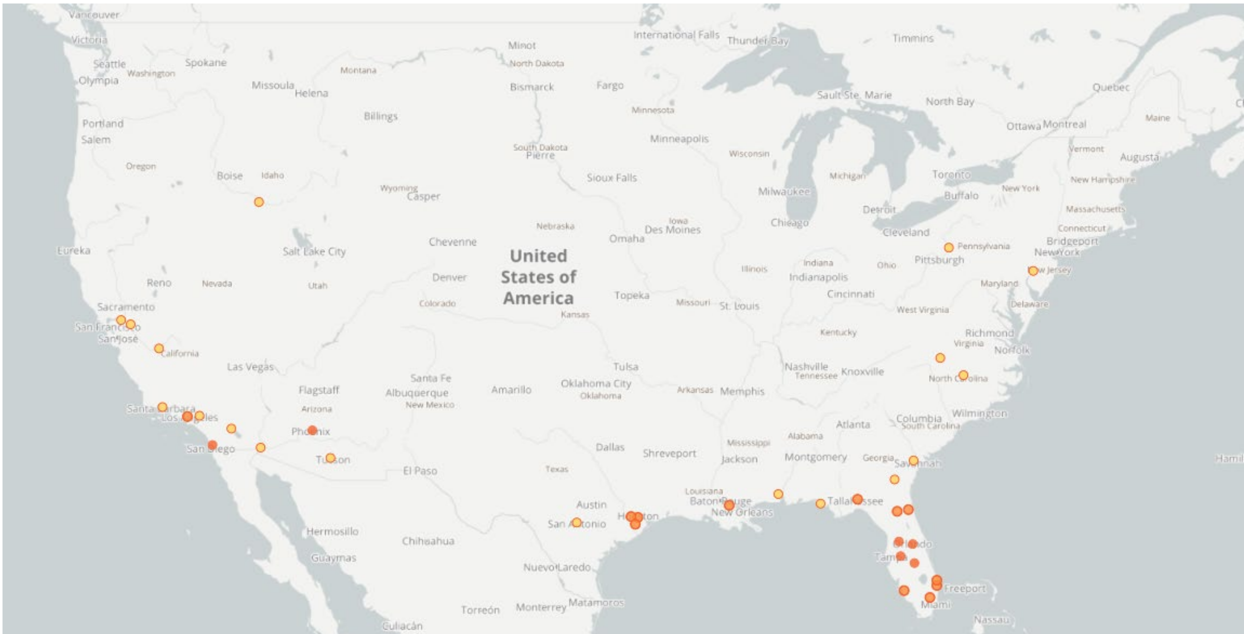

Figure 2. Reported distribution of *Pomacea canaliculata* in the United States. Map from GBIF-US (2023). According to Daniel (2023) and Rawlings et al. (2007), only populations in Arizona, California and Hawaii (shown in Figure. 3) are established. Locations in Idaho, Texas, Louisiana, Alabama, Florida, Georgia, North Carolina, and New Jersey were not used for climate matching analysis.

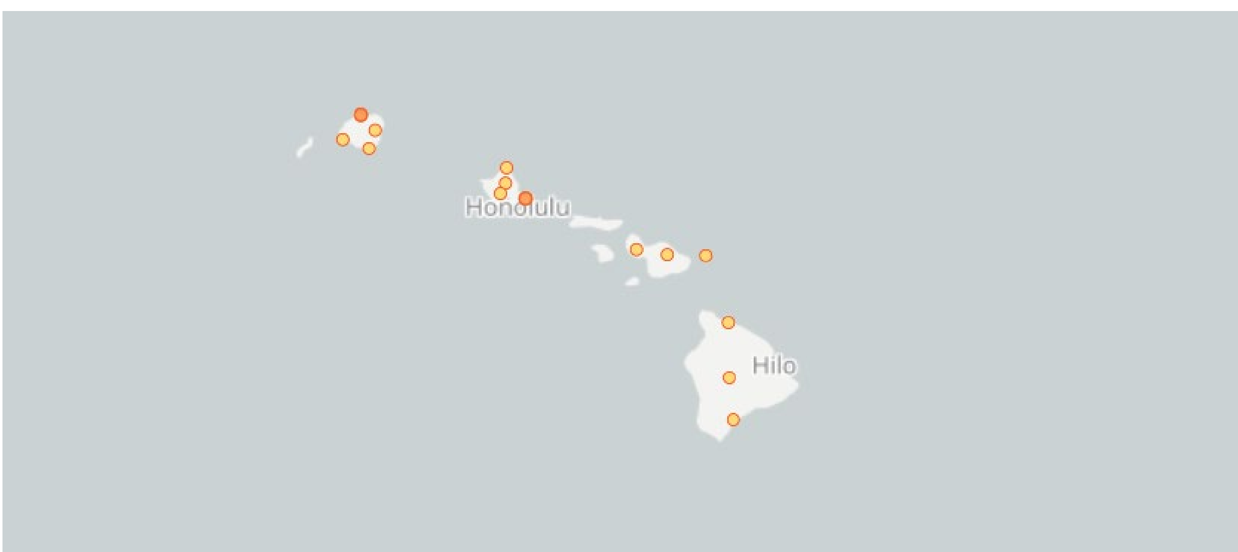

Figure 3. Reported distribution of *Pomacea canaliculata* in Hawaii. Map from GBIF-US (2023).

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Pomacea canaliculata* was generally medium to high across the contiguous United States with small areas of low climate match. The lowest match was found in the Pacific Northwest, but there were also areas of lower match in the Rocky Mountains, northern New England and in the Northern Plains region, along the border between Canada and the United States. The highest match was found in the Southwest, from southern California into eastern Arizona. Peninsular Florida, the Gulf Coast, and the southern Atlantic Coast also had a high climate match. Everywhere else had a medium to medium-high climate match. The overall Climate 6 score (Sanders et al. 2023; 16 climate variables; Euclidean distance) was 0.655, indicating that Yes, there is establishment concern for this species. The Climate 6 score is calculated as: (count of target points with scores ≥ 6)/(count of all target points). Establishment concern is warranted for Climate 6 scores greater than or equal to 0.002 based on an analysis of the establishment success of 356 nonnative aquatic species introduced to the United States (USFWS 2024).

Projected climate matches in the contiguous United States under future climate scenarios are available for *Pomacea canaliculata* (see Appendix). These projected climate matches are provided as additional context for the reader; future climate scenarios are not factored into the Overall Risk Assessment Category.

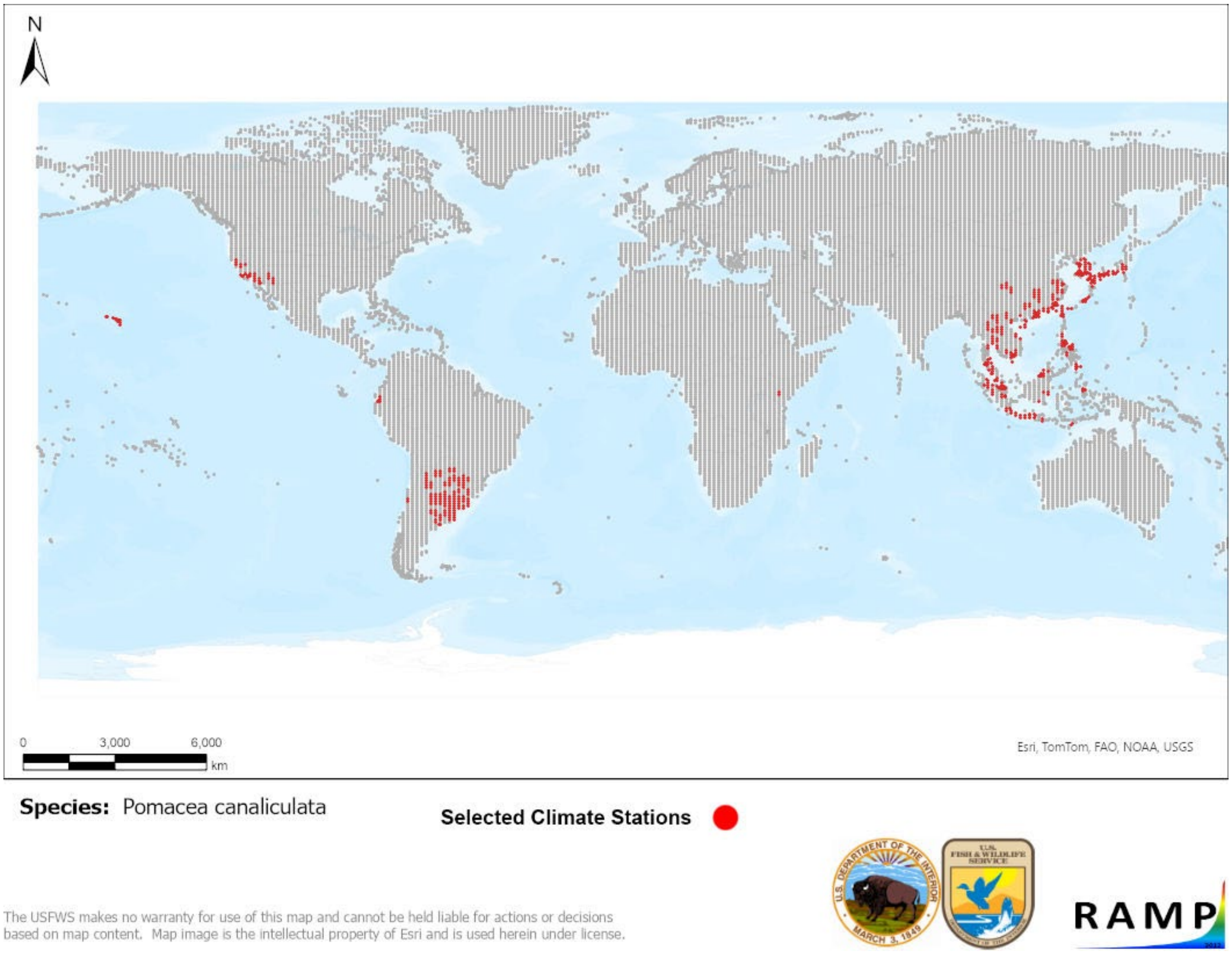

Figure 4. RAMP (Sanders et al. 2023) source map showing weather stations in North America, South America, Oceana, and Asia selected as source locations (red; United States, Brazil, Paraguay, Uruguay, Argentina, Chile, Ecuador, Kenya, Indonesia, Philippines, Malaysia, Singapore, Myanmar, Cambodia, Vietnam, Thailand, Laos, China, Taiwan, South Korea, and Japan) and non-source locations (gray) for *Pomacea canaliculata* climate matching. Source locations from GBIF Secretariat (2022). Additional source locations in Chile from Letelier et al. (2016). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

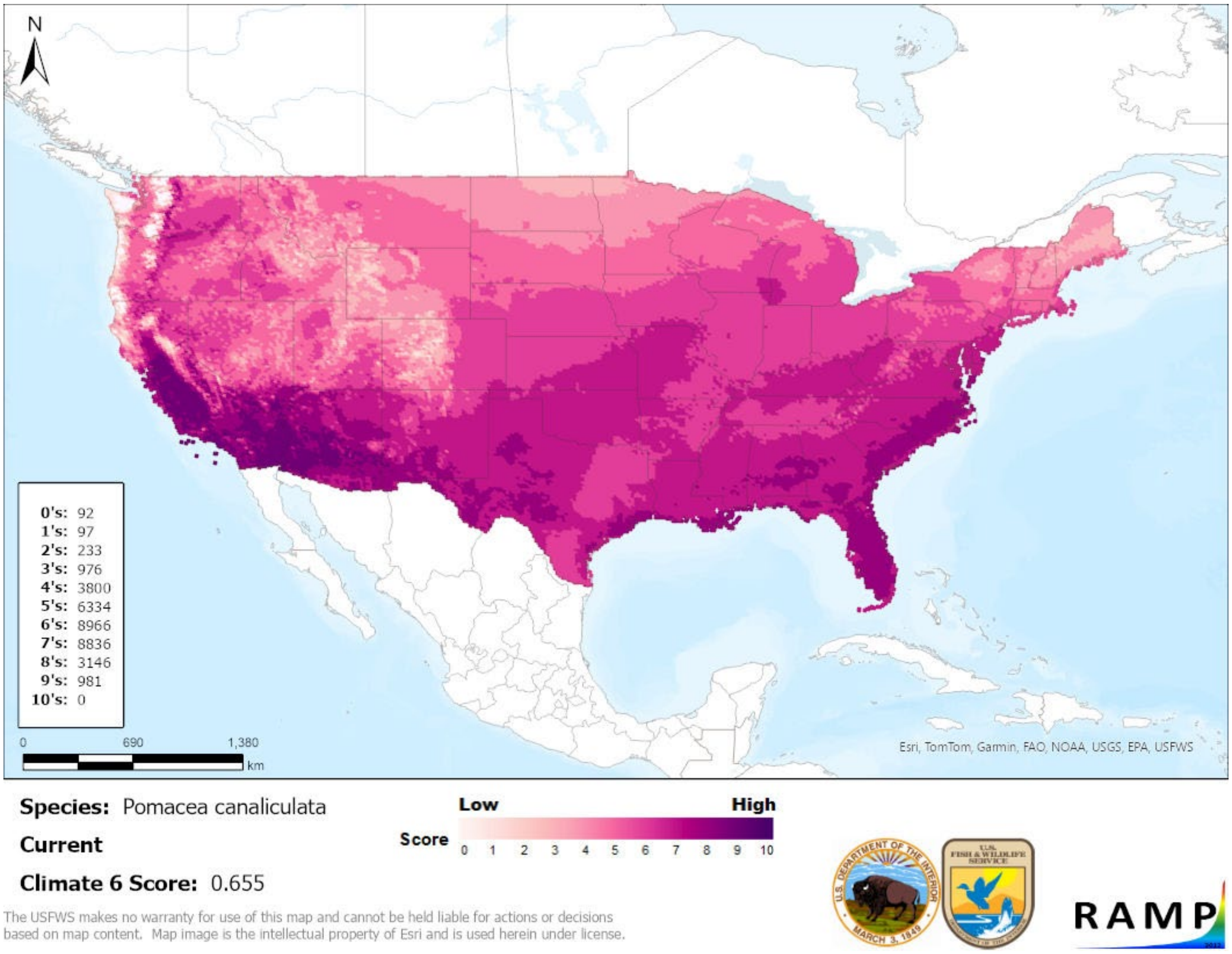

Figure 5. Map of RAMP (Sanders et al. 2023) climate matches for *Pomacea canaliculata* in the contiguous United States based on source locations reported by GBIF Secretariat (2022). Additional source locations in Chile from Letelier et al. (2016). Counts of climate match scores are tabulated on the left. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

8 Certainty of Assessment

The Certainty of Assessment is High. There is quality information available about the biology and ecology of *Pomacea canaliculata*. Records of introduction and establishment outside the native range were found. Information on impacts and history of invasiveness were from peer-reviewed sources. Although there have been misidentifications in gray literature and outdated peer-reviewed literature, genetic studies have clarified the true native and introduced range to the extent that Certainty of Assessment remains High.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Channeled Applesnail (*Pomacea canaliculata*) is a freshwater gastropod native to the Lower Paraná, Uruguay, and La Plata basins in Argentina, Paraguay, Uruguay and southern Brazil. It is sometimes used for aquaculture in Asia. It has been commonly confused with a congener, *Pomacea maculata*, that occurs in sympatry in the La Plata, but not the Amazon, basin, but recent molecular studies have determined that the two species are genetically distinct. *P. canaliculata* has been widely introduced and become established in eastern Asia, western North America, outside its native range in South America and, most recently, Africa. Reasons for introduction include aquaculture potential, aquarium dumping, and weed control in rice agriculture. However, *P. canaliculata* has been found to cause substantial damage to taro and rice crops themselves, as well as to negatively affect macrophyte communities in wetlands, alter zooplankton communities, and reduce water quality. For these reasons, the History of Invasiveness is High. The climate matching analysis for the contiguous United States indicates establishment concern for this species. The highest match was found in the Southwest, where *P. canaliculata* is already established, but high matches were also found in the Southeast. The Certainty of Assessment is High due to the abundance of information available on introductions and impacts. The Overall Risk Assessment Category is High.

Assessment Elements

- **History of Invasiveness (see section 4): High**
- **Establishment Concern (see section 7): Yes**
- **Certainty of Assessment (see section 8): High**
- **Remarks, Important additional information: Host of rat lungworm (*Angiostrongylus cantonensis*), which can cause eosinophilic meningoencephalitis in humans.**
- **Overall Risk Assessment Category: High**

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Appendix

Summary of Future Climate Matching Analysis

Future climate projections represent two Shared Socioeconomic Pathways (SSP) developed by the Intergovernmental Panel on Climate Change (IPCC 2021): SSP5, in which emissions triple by the end of the century; and SSP3, in which emissions double by the end of the century. Future climate matches were based on source locations reported by GBIF Secretariat (2022) and Letelier et al. (2016).

Under the future climate scenarios (figure A1), on average, high climate match for *Pomacea canaliculata* was projected to occur in California, Southern Atlantic Coast, Southern Florida, and Southwest regions of the contiguous United States. Most of the contiguous United States was projected to be a medium match under all future climate scenarios, except for the aforementioned high match regions and two notable areas of low match: the Northwest Pacific Coast and the Colorado Plateau. The Climate 6 scores for the individual future scenario models (figure A2) ranged from a low of 0.604 (model: MPI-ESM1-2-HR, SSP5, 2085) to a high of 0.795 (model: GFDL-ESM4, SSP5, 2085). All future scenario Climate 6 scores were above the Establishment Concern threshold, indicating that Yes, there is establishment concern for this species under future scenarios. The Climate 6 score for the current climate match (0.655, figure 5) falls within the range of scores for future projections. The time step and climate scenario with the most change relative to current conditions was SSP5, 2085, the most extreme climate change scenario. Under one or more time step and climate scenarios, areas within the Appalachian Range, Colorado Plateau, Great Basin, Great Lakes, Northeast, Northern Pacific Coast, Northern Plains, and Western Mountains (eastern side) saw a moderate increase in the climate match relative to current conditions. These changes were most pronounced at the 2085 time step. No large increases were observed regardless of time step and climate scenarios. Under one or more time step and climate scenarios, areas within the Western Mountains (western side) saw a large decrease in the climate match relative to current conditions. Additionally, areas within California, the Gulf Coast, Mid-Atlantic, Northern Pacific Coast, Southeast, Southern Plains, and Southwest saw a moderate decrease in the climate match relative to current conditions. California, the Western Mountains, and the Southeast were projected to have lower climate match under all future scenarios compared to current conditions, but other regions were not projected to have moderate to large decreases in climate match until the 2085 time step. Additional, very small areas of large or moderate change may be visible on the maps (figure A3).

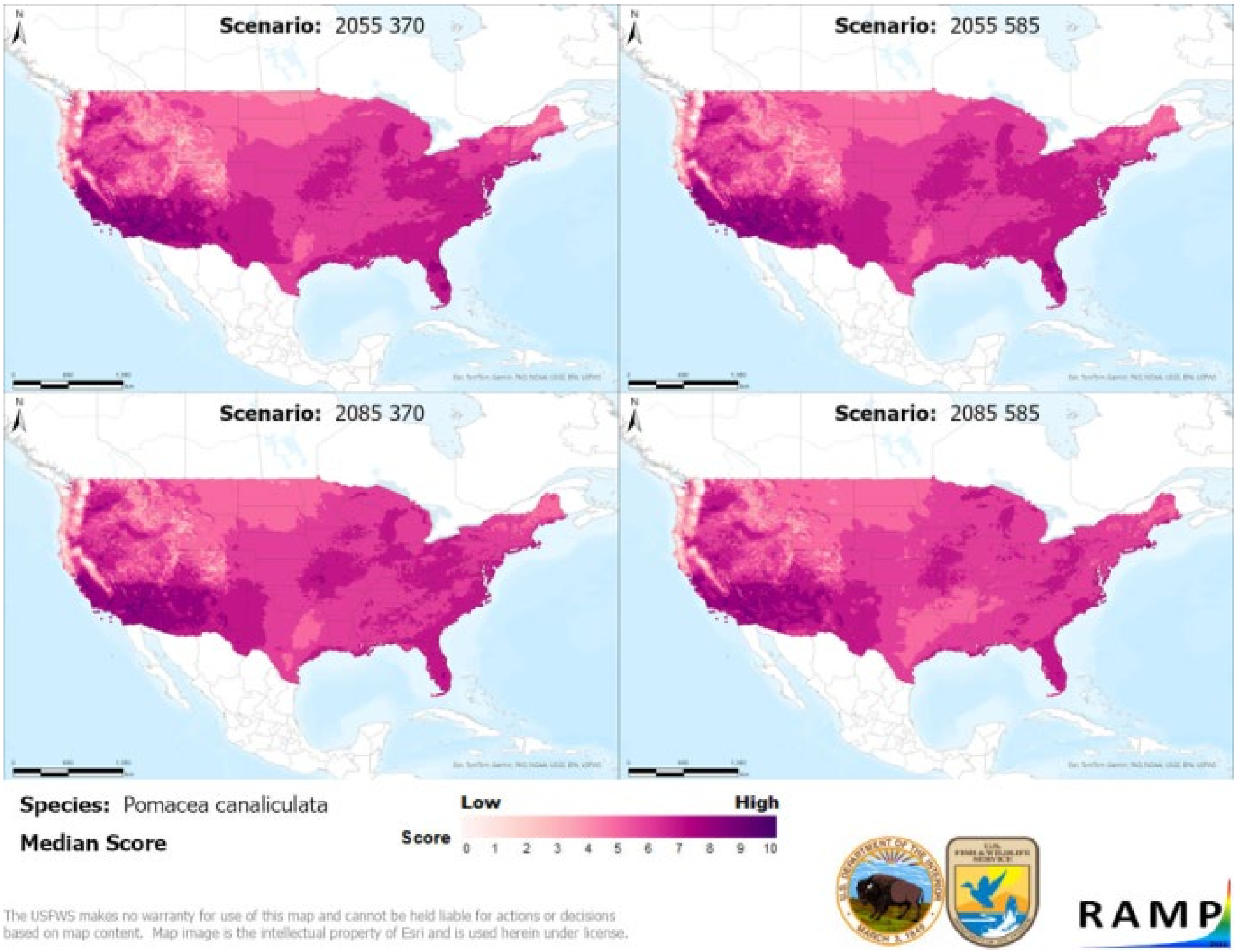

Figure A1. Maps of median RAMP (Sanders et al. 2023) climate matches projected under potential future climate conditions using five global climate models for *Pomacea canaliculata* in the contiguous United States. Climate matching is based on source locations reported by GBIF Secretariat (2022) and Letelier et al. (2016). Shared Socioeconomic Pathways (SSPs) used (from left to right): SSP3, SSP5 (IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global climate models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0. 0/Pale Pink = Lowest match, 10/Dark Purple = Highest match.

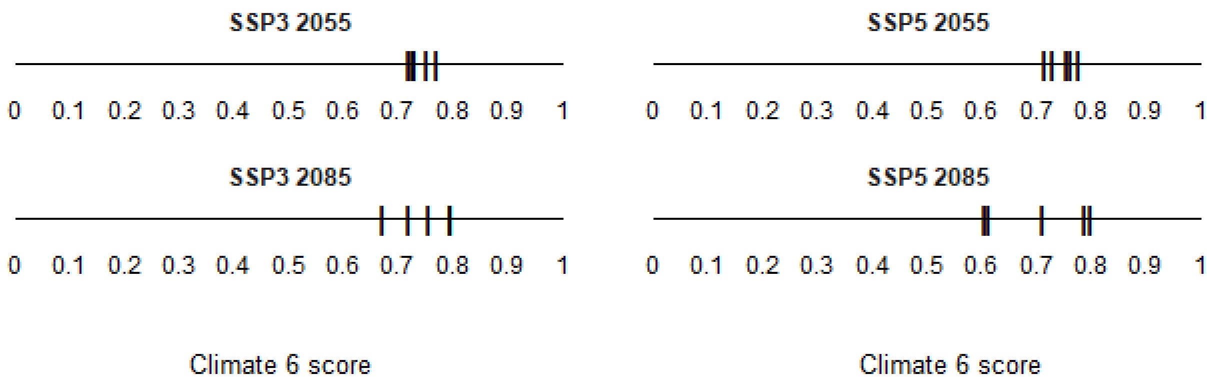

Figure A2. Comparison of projected future Climate 6 scores for *Pomacea canaliculata* in the contiguous United States for each of five global climate models under four combinations of Shared Socioeconomic Pathway (SSP) and time step. SSPs used (from left to right): SSP3, SSP5 (Karger et al. 2017, 2018; IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global climate models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0.

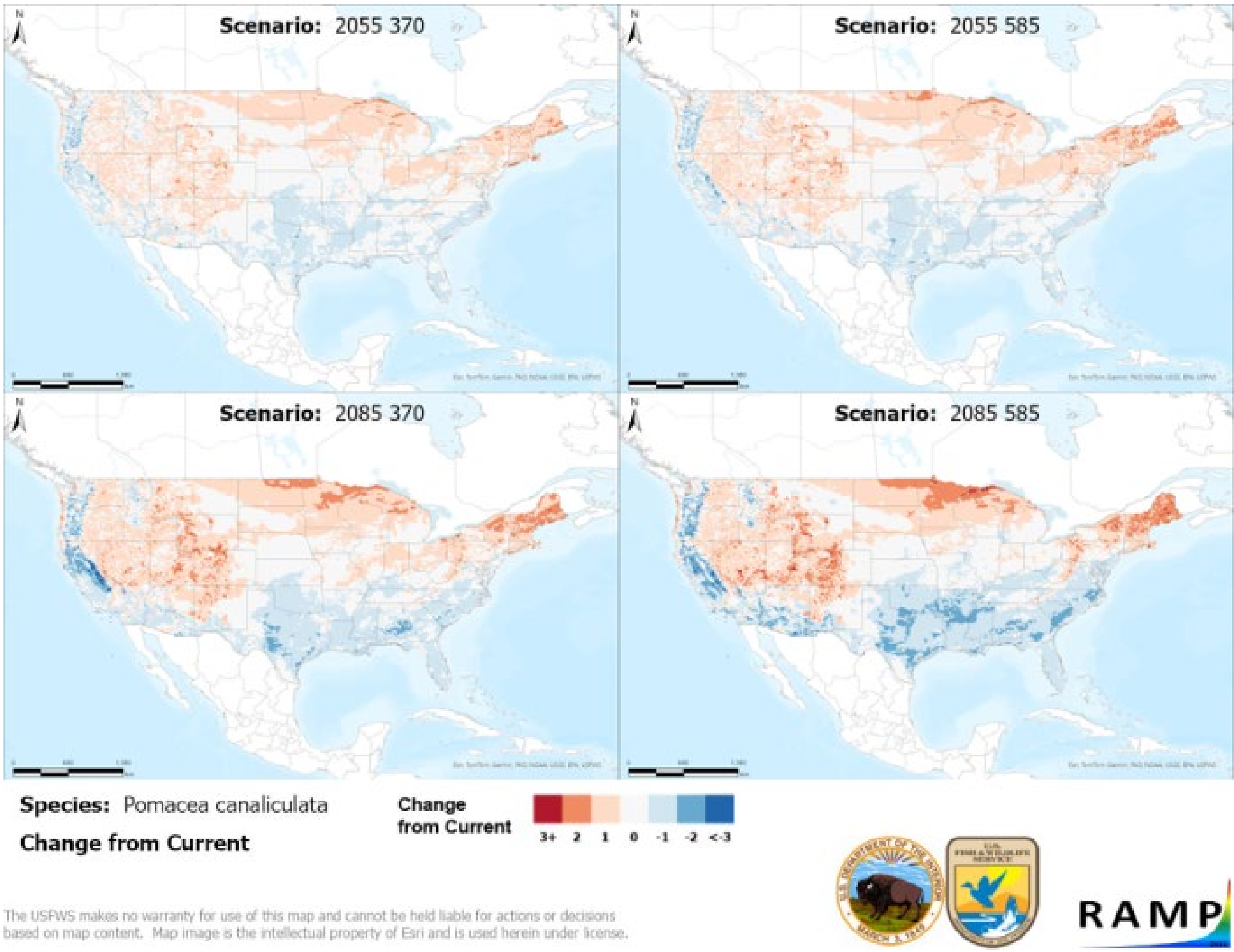

Figure A3. RAMP (Sanders et al. 2023) maps of the contiguous United States showing the difference between the current climate match target point score (figure 4) and the median target point score for future climate scenarios (figure A1) for *Pomacea canaliculata* based on source locations reported by GBIF Secretariat (2022) and Letelier et al. (2016). Shared Socioeconomic Pathways (SSPs) used (from left to right): SSP3, SSP5 (IPCC 2021). Time steps: 2055 (top row) and 2085 (bottom row). Climate source data from CHELSA (Karger et al. 2017, 2018); global models used: GFDL-ESM4, UKESM1-0-LL, MPI-ESM1-2-HR, IPSL-CM6A-LR, and MRI-ESM2-0. Shades of blue indicate a lower target point score under future scenarios than under current conditions. Shades of red indicate a higher target point score under future scenarios than under current conditions. Darker shades indicate greater change.

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