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

U.S. Fish & Wildlife Service, November 2016
Revised, December 2016
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1 Native Range and Status in the United States

Native Range

From Pastorino and Darrigan (2012):

"The species' native distribution is tropical and subtropical South America, including the Amazonas and the Plata basins; the southernmost record for the species is the Paso de las Piedras reservoir south of Buenos Aires province, and recently in Northern Patagonia: Balneario La Herradua, near the Limay River, province of Neuquén, Argentina (Darrigran et al. 2011)."

Status in the United States

From Pastorino and Darrigan (2012):

"Introduced: [. . .] United States (Alabama, Arizona, California, Florida, Georgia, Hawaiian Is., Ohio, Texas)"

Means of Introductions in the United States

From CABI (2016):

"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, but whether it is established there is not known."

"*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

From CABI (2016):

"**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 (2016):

"Kingdom Animalia
  Subkingdom Bilateria
    Infrakingdom Protostomia
      Superphylum Lophozoa
        Phylum Mollusca
          Class Gastropoda
            Subclass Prosobranchia
              Order Architaenioglossa
                Family Ampullariidae
                  Genus Pomacea
                    Species *Pomacea canaliculata* (Lamarck, 1828) – channeled applesnail"

“Taxonomic status: valid”

Size, Weight, and Age Range

From GISD (2016):

“Longevity is up to 4 years. Reproductive maturity is reached in 3 months to 2 years, depending on ambient temperature regime.”

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.”

Environment

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).”

Climate/Range

From CABI (2016):

“*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) and between 40 and 41 °N in Spain (Anonymous, 2011), assuming both *P. canaliculata* and *P. maculata* not just the latter are present in the Ebro Delta, Spain.”

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 […])”

Distribution Outside the United States

Native

From Pastorino and Darrigan (2012):

“Argentina; Bolivia, Plurinational States of; Brazil; Colombia; Ecuador; Paraguay; Peru; Uruguay; Venezuela, Bolivarian Republic of”

Introduced
From Pastorino and Darrigan (2012):

"Cambodia; China; Dominican Republic; Guam; Hong Kong; Indonesia (Jawa, Sumatera); Japan; Korea, Democratic People's Republic of; Korea, Republic of; Lao People's Democratic Republic; Malaysia (Peninsular Malaysia, Sarawak); Papua New Guinea; Philippines; Singapore; Sri Lanka; Taiwan, Province of China; Thailand; […] Viet Nam"

From CABI (2016):

"The first and so far only record in Europe is from the Ebro Delta in Spain, where it was first recorded in 2009. This record (López et al., 2010) is of *P. maculata*, but subsequent data suggest that both *P. maculata* and *P. canaliculata* may be present."

Means of Introduction Outside the United States
From CABI (2016):

"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. However, modelling its distribution in China under global warming scenarios indicates that it could spread north into areas that it has not yet invaded (Lv et al., 2011). Similar range expansions related to climate change could also occur elsewhere, for instance in Korea and Japan. It has not yet been reliably reported from India or Bangladesh, but based on climate matching these countries are susceptible, as are parts of Australia (Baker, 1998). Similarly, climate matching combined with two global warming scenarios identified areas in Europe that may be susceptible (Baker et al., 2012)."

"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; Yang et al., 2013). Deliberate introduction for food may therefore now be rare. Introduction by the aquarium trade (and via disposal of the contents of domestic aquaria) may also be rare, as *P. canaliculata* is not the most common ampullariid in the trade (but see Baker et al., 2012). Nonetheless, major new invasions may arise from the introduction of small propagules. Natural expansion of already introduced populations is probably important, and accidental introduction by people remains possible. Great caution is recommended when considering *P. canaliculata* as a biological control agent for aquatic weeds (Cazzaniga and Estebenet, 1985) and it is only appropriate in areas in which *P. canaliculata* is already established (Wada, 1997; Cazzaniga, 2006). Internet or mail order trade of ampullariids occurs, but the relative contribution to this trade of *P. canaliculata* specifically has not been assessed."

Short Description

From CABI (2016):

"The most thorough description available is by Hayes et al. (2012) [. . .] The adult shell is thin, smooth and ~35-60 mm in height. It coils dextrally – that is, when viewed with the apex uppermost the aperture is on the right side of the shell. Fully grown females are larger than males. The colour is yellow-brown to greenish-brown or dark chestnut, sometimes with dark brown spiral bands of variable number and thickness. The whorls are rounded and the suture between the whorls is deeply channelled. The shell spire is generally low. The aperture is generally ovoid to kidney-shaped, and the inside lip of the shell is unpigmented."

"The operculum (the trap-door like structure attached to the upper part of the animal's foot and used to close the shell aperture when the animal withdraws into the shell) is also brown; it is horny (corneous) in texture and flexible, and is uniformly concave in females, but concave at the centre and becoming convex toward the margins in males."

"The foot is oval with a squarish anterior edge. The tentacles are long and tapering, highly extensible and with large but short eye stalks at their outer bases. The snout is short, squarish and with lateral, anterior tips elaborated into long tapering labial palps. The neck is modified on the left into a long, extensible siphon. The mantle cavity is deep and broad, occupying a third to half of the body whorl. In males the penis sheath is visible just behind the mantle edge above the right tentacle. The lung occupies most of the left side of the mantle and the gill is situated in the mantle roof, anterior to the lung and just posterior to the base of the siphon."

Biology

From CABI (2016):

"**Reproductive Biology**
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. [. . .] 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)"

"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)."

"**Activity Patterns**
In the temperate regions where *P. canaliculata* is native, it only breeds during summer. Locally, variation in reproductive regime may be related to local climatic variation, especially availability of water. In their introduced humid tropical Southeast Asian range and the controlled environment of a rice paddy, *P. canaliculata* can grow and breed year round as long as sufficient water is present. In Hong Kong, it reaches full size in four to six months and reproduction occurs almost year round, although with some variation in snail biomass and density related to water temperature (Kwong et al., 2010). Under artificial conditions *P. canaliculata* can grow even faster. In cooler regions such as Japan, as paddies dry out and temperatures drop during winter, the snails bury into the mud and become dormant, awaiting warmer temperatures and reflooding of the paddies in spring. *P. canaliculata* is only reported to survive buried for up to three months (Schnorbach, 1995). Winter temperatures may limit the northern spread of *P. canaliculata* in Japan (Ito, 2002), although it can alter its behaviour and acclimate to these cooler temperatures to some degree, permitting over-wintering further north than would otherwise be possible (Wada and Matsukura 2007, Matsukura et al., 2009). Its southern limit in Argentina seems to be limited by temperature (Seuffert and Martín, 2009) and this may limit is spread to higher latitudes in its invaded range (Seuffert et al., 2010, 2012)."

"**Population Size and Density**
Densities of *P. canaliculata* in rice paddies in the Philippines generally are 1-5 m^{-2} but densities up to 150 m^{-2} have been reported (Halwart, [1994]; Schnorbach, 1995)."

"**Nutrition**
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). Growth rate generally correlates with feeding on the preferred plant(s). Some species will feed on other animals, including frogs, bryozoans and other smaller snails and their eggs, mostly but not always as carrion (e.g. Wood et al., 2005, 2006; Kwong et al., 2009; Wong et al., 2009; R.H. Cowie, personal observations). In Hong Kong, detritus was found more frequently than macrophytes in the stomachs of P. canaliculata; the snails also ate cyanobacteria, green algae and diatoms (Kwong et al., 2010). The predominant habit, however, is macrophytophagous, which from a pest standpoint is also the most significant. *P. canaliculata* (and *P. maculata*) seem particularly voracious and generalist compared to other *Pomacea* species (Morrison and Hay, 2011)."

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)."

Diseases

From CABI (2016):

"*P. canaliculata* is of serious human health concern in a number of regions as it acts as a vector for a number of parasites that cause human diseases, including schistosomes that cause dermatitis and a fluke that causes intestinal problems (Hollingsworth and Cowie, 2006). Most notably, however, it can act as a host of *Angiostrongylus cantonensis*, the rat lungworm, which can infect humans if ingested and cause potentially fatal eosinophilic meningitis. […] Although many species of gastropods can act as hosts of *A. cantonensis* (Wallace and Rosen, 1969; Kim et al., 2013; Thiengo et al., 2013), *P. canaliculata* is of particular significance in southern China, where it has become a delicacy when eaten raw, resulting in numerous cases of angiostrongyliasis (Lv et al., [2009], 2011; Cowie, 2013; Yang et al., 2013)."

From Keawjam et al. (1993):

"Golden apple snails, *Pomacea canaliculata*, were collected once a month during a year to search for their natural parasites. The collections were made at two localities having different ecological environments. Of 576 collected snails from a canal, 176 individuals (30.6%) were infected by three groups of metacercariae. These parasites were amphistome, distome and echinostome metacercariae, which had prevalences of 23.5, 19.5 and 0.5%, respectively. The incidence of infection was highest (68.4% in October) when the snail population was composed of the old, juvenile and young *Pomacea*. […]The snails from a pond, another locality, had a low proportion of infected individuals. Of 605 snails, only 24 individuals (4.0%) were infected, with the prevalence of amphistomes, distomes and echinostomes being 0.8, 1.8 and 2.1%, respectively. The incidence of infection for each month was zero or less than 10%, except in May when it was 30.2%."

No OIE-reportable diseases have been documented for this species.

Threat to Humans

From CABI (2016):

"*P. canaliculata* can infest paddy crops including rice (*Oryza sativa*), lotus (*Nelumbo nucifera*), taro (*Colocasia esculenta*), swamp cabbage (*Ipomoea aquatica*), mat rush (*Juncus decipiens*), watercress (*Rorippa* spp.), Japanese parsley (*Oenanthe stolonifera*), water chestnuts (*Trapa bicornis*), wild rice (*Zizania latifolia*), azolla (*Azolla* spp.), and water lilies (*Nymphaea* spp.) (Mochida, 1991; Chompoonut, 1998), as well as, no doubt, other less important crops."

"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)."

"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)."

See also: Diseases (above).

3 Impacts of Introductions

From CABI (2016):

"In the Philippines, farmers have considered *P. canaliculata* to be the most serious pest of rice (Halwart, [1994]). The infested area expanded rapidly from 300 ha in 1986 to 426,000 ha in 1988 and had reached more than 800,000 ha by 1995 (Cagauan et al., 1998; Cagauan and Joshi, 2003). In 1990, all 13 regions of the Philippines had infestations (Rice IPM Network, 1991). A 1999 survey by the Department of Agriculture-Philippine Rice Research Institute indicated that 35% of 71 provinces in various regions of the Philippines identified *P. canaliculata* as a pest in rice farms (Adalla and Magsino, 2006). Yield loss also increased from ca 2500 t in 1985 to 25,000 t in 1991 (Rice IPM Network, 1991). Pesticide expenditure for 1988 was estimated to be US$2.4 million (Halwart, [1994]). Yield loss of rice due to *P. canaliculata* in 1990 was estimated at 70,000 to 100,000 t, valued at US$12.5-17.8 million, with the total cost including yield loss, replanting cost and the cost of control (molluscicides and hand picking), estimated at US$28-45 million (Naylor, 1996). The cumulative costs after *P. canaliculata* invasion up to 1990 were estimated as between US$425-1,200 million (Naylor, 1996). Since then, there have been claims that *P. canaliculata* infestation has decreased due to the spread of integrated management approaches (Cagauan and Joshi, 2003). However, in 2003, of about 3 million ha of rice fields in the Philippines about 1.4 million ha were infested (Adalla and Magsino, 2006)."

"In Taiwan, 13,000 ha of rice fields were infested by *P. canaliculata* in 1983, increasing to 151,444 ha by 1986, and the area treated with molluscicides and the estimated loss in paddy fields increased from 46,000 ha and US$8.3 million to 90,000 ha and US$30.9 million (Mochida, 1991). Annual expenditure on molluscicides was US$1 million in 1982-1990 but in 2002-2003 had been reduced (for budgetary reasons and not because of the lack of need for control) to US$170,000-300,000 (Cheng and Kao, 2006). Annual figures of US$200 million and US$175.6 million have been given for costs of damage in the 'agricultural and ecological environment', by Cheng and Kao (2006) and Yang et al. (2006), respectively. In mainland China, *P. canaliculata* was first recorded in Guangdong province in 1981 and by 1988 the damaged area had grown to

130,000 ha in 37 counties in the province (Wu and Xie, 2006). It is now much more widespread in China (Lv et al., 2011). Damage to rice has gradually increased relative to the increasing levels of direct-seeded rice in South China. No economic costs are readily available."

"In Japan, the first record of rice damage caused by *P. canaliculata* was reported in 1984 (Yusa and Wada, 2002) and in the same year *P. canaliculata* was designated as a quarantine pest by the Japanese Government. Since then its distribution gradually expanded until by 1998 it occurred in 28 prefectures throughout south and central Japan (Wada, 2006). By 2004, it had infested 770,000 ha of rice fields, about 60% of this area being in Kyushu (Wada, 2006). The level of damage may have stopped increasing during the 1990s because of the application of various control methods. However, *P. canaliculata* is still a serious pest in areas of Kyushu where very young seedlings are transplanted and where it rains heavily during the transplanting season. In addition, the presence of the snail is a constraint in promoting direct seeding in Kyushu (Wada, 1997, 2006; Yusa and Wada, 1999). No economic costs are readily available."

"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)."

"**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. And in experiments in a pond in Hong Kong, similar result were found, although phosphorus content of the water was not heightened in the treatments with *P. canaliculata* (Fang et al., 2010)."

"**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, native *Pila* spp. are reported to have declined as a result of pesticide applications to control *Pomacea 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)."

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. crispus* and *H. 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 and posed an ecological risk to the local area."

"In the food consumption experiment, four small divisions were made in a barrel with a water height of 30 cm, and eight golden apple snails (of known weight) and vegetation were placed into the different divisions. After a period of time for breeding, we weighed the golden apple snails and vegetable matter (wet weight) […] The golden apple snails severely affected the growth of the submerged plants, *H. verticillata*, *P. crispus* and *C. demersum,* and the water quality worsened in these three barrels. The growth of *A. calamus, Z. caduuciflora,* and *C. palustris* was unaffected by the golden apple snails."

From Fang et al. (2010):

"We conducted mesocosm and laboratory experiments to examine the impact of the invasive apple snail *Pomacea canaliculata* on macrophytes, filamentous algae, nutrients and phytoplankton. […] In a freshwater pond, we confined 500 g of *Myriophyllum aquaticum* or *Eichhornia crassipes* with 0, 2, 4 or 8 apple snails in 1 m x 1 m x 1 m enclosures for approximately 1 month. Apple snails grazed heavily on both species of macrophytes, with higher overall weight losses at higher snail densities. The damage patterns differed between the two macrophytes. In *M. aquaticum*, both leaves and stems suffered from substantial herbivory, whereas in *E. crassipes*, only the roots suffered significant weight reduction. […] In addition to grazing on macrophytes, apple snails appeared to have controlled the growth of filamentous algae, as these did not develop in the snail treatments. The ability of *P. canaliculata* to control filamentous algae was supported by a laboratory experiment where the consumption was as high as 0.25 g g^{-1} snail DW d^{-1}. […] The treatment effects on chlorophyll a (Chl a) and phytoplankton composition varied in the two experiments. In the *M. aquaticum* experiment, with increasing snail density, Chl a increased, and the phytoplankton community became dominated by Cryptophyceae. In the *E. crassipes* experiment, Chl a level was independent of snail density, but with increasing snail density, the phytoplankton community became co-dominated by Cryptophyceae, Chlorophyceae and Bacillariophyceae."

4 Global Distribution

Figure 1. Known global distribution of *Pomacea canaliculata*. A point in Tanzania and a point in North Carolina were excluded from climate matching due to the record indicating they were preserved specimens. A point in Philadelphia was excluded from climate matching due to it being an aquarium specimen. Map from GBIF (2016).

5 Distribution Within the United States

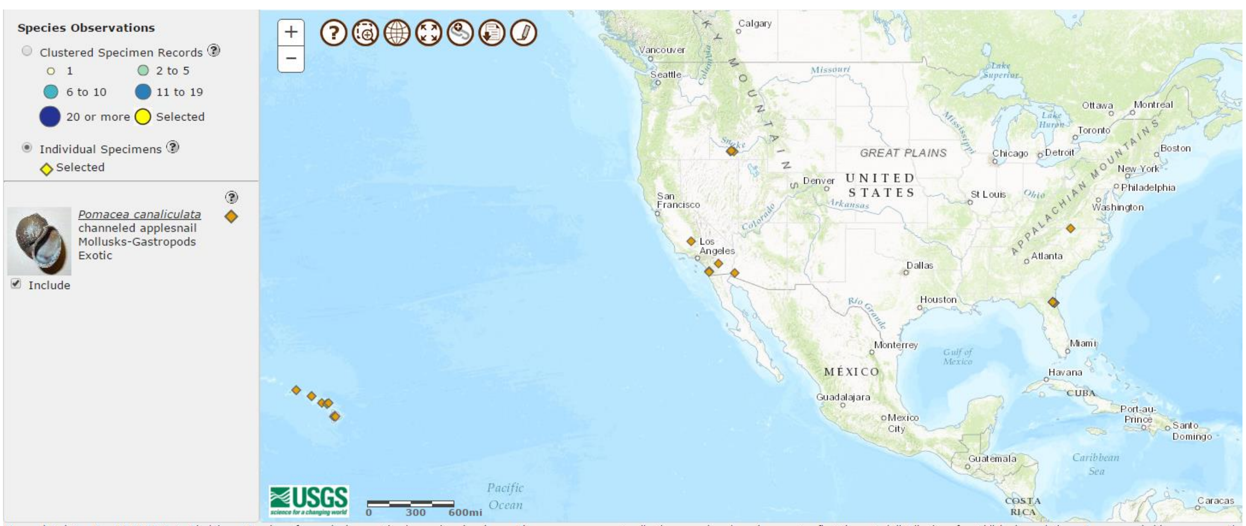

Figure 2. Known U.S. distribution of *Pomacea canaliculata*. Map from USGS (2016). Location in North Carolina was excluded from climate matching because it does not represent an established population.

6 Climate Matching

Summary of Climate Matching Analysis

The climate match (Sanders et al. 2014; 16 climate variables; Euclidean Distance) was medium to high throughout much of the United States, especially in coastal areas of the Southeast and parts of the West (states of California, Arizona, Nevada, Idaho, Oregon, and Washington). The climate match was low in the northeast, north-central, and eastern Rocky Mountain regions. Climate 6 proportion indicated that the contiguous U.S. has a high climate match. Proportions >0.103 represent a high climate match; the Climate 6 proportion of *Pomacea canaliculata* is 0.308.

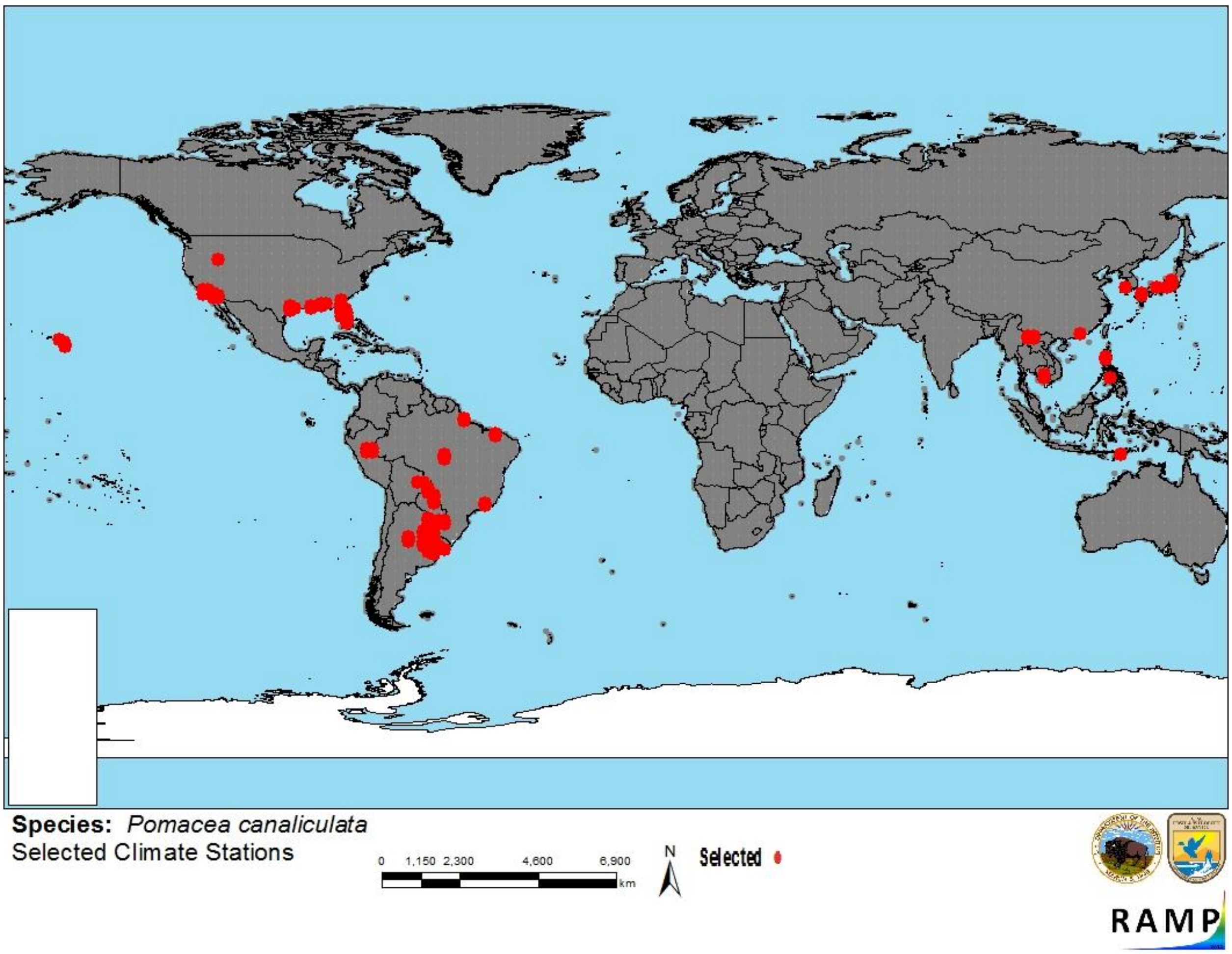

Figure 3. RAMP (Sanders et al. 2014) source map showing weather stations selected as source locations (red) and non-source locations (gray) for *Pomacea canaliculata* climate matching. Source locations from GBIF (2016) and USGS (2016). A point in Tanzania, a point in Pennsylvania, and points in North Carolina were excluded because the locations do not represent established populations.

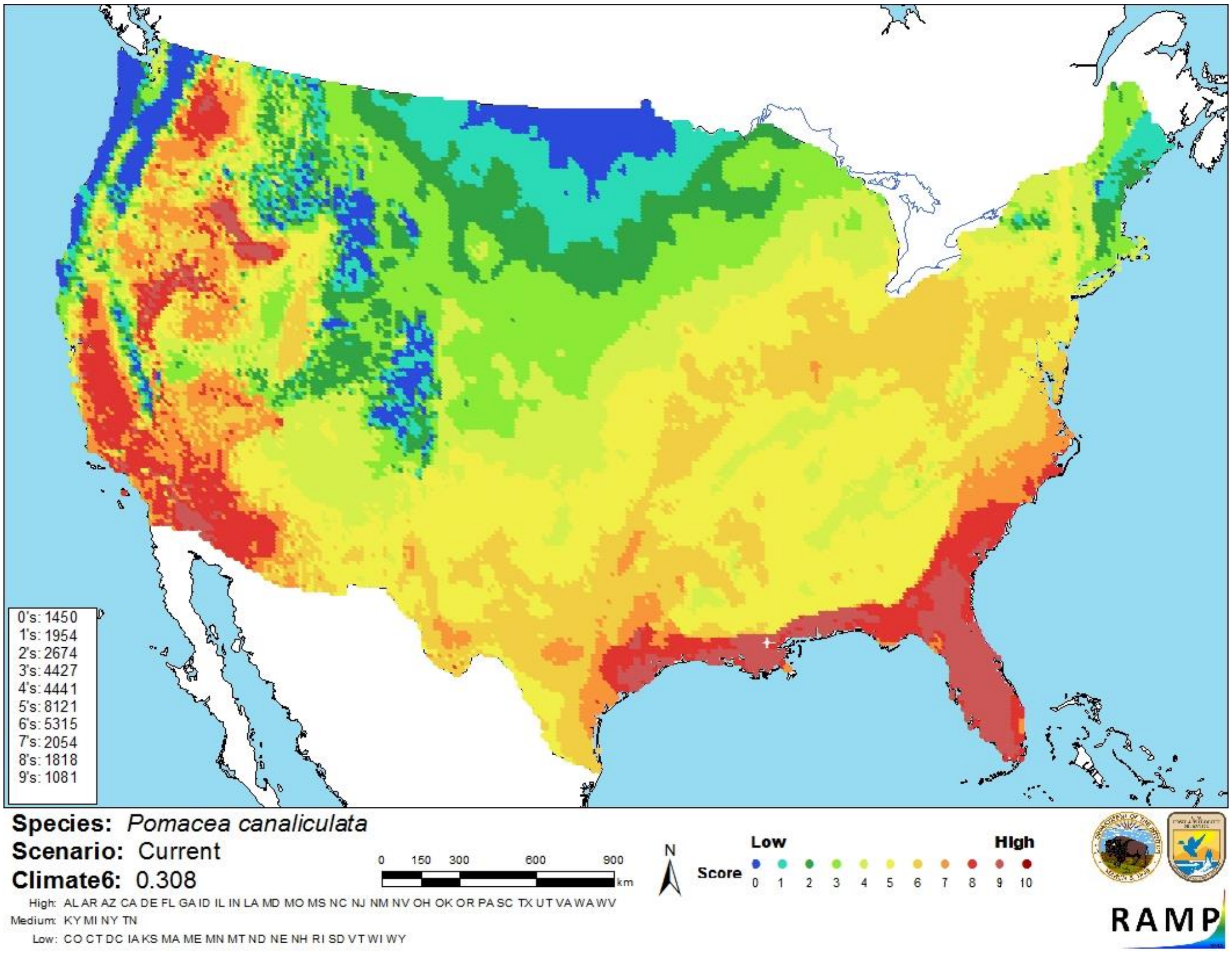

Figure 4. Map of RAMP (Sanders et al. 2014) climate matches for *Pomacea canaliculata* in the contiguous United States based on source locations reported by GBIF (2016) and USGS (2016). 0= Lowest match, 10=Highest match. Counts of climate match scores are tabulated on the left.

The “High”, “Medium”, and “Low” climate match categories are based on the following table:

Climate 6: Proportion of (Sum of Climate Scores 6-10) / (Sum of total Climate Scores)	Climate Match Category
0.000≤X≤0.005	Low
0.005<X<0.103	Medium
≥0.103	High

7 Certainty of Assessment

Information on the biology, distribution, and impacts of introduction of *P. canaliculata* is widely available. The negative impacts of this species where introduced have been adequately documented. No further information is needed to evaluate the negative impacts of this species. Certainty of this assessment is high.

8 Risk Assessment

Summary of Risk to the Contiguous United States

P. canaliculata is a freshwater snail that has been introduced in many countries, initially as a food source, but low demand and disposal of it allowed the snail to quickly spread into a variety of ecosystems. This species has a well-documented history of invasiveness and has caused crop damage resulting in considerable economic losses as well as macrophyte damage in native wetlands. It is implicated in the decline of native snail species in Asia due to competition. *P. canaliculata* has a high climate match with the contiguous United States, especially in the South and West. Overall risk posed by this species is high.

Assessment Elements

- **History of Invasiveness (Sec. 3): High**
- **Climate Match (Sec. 6): High**
- **Certainty of Assessment (Sec. 7): High**
- **Overall Risk Assessment Category: High**

9 References

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 10.

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