EPPO Datasheet: *Pomacea canaliculata*

Last updated: 2022-04-27

IDENTITY

Preferred name: *Pomacea canaliculata*
Authority: (Lamarck)
Taxonomic position: Animalia: Mollusca: Gastropoda: Architaenioglossa: Ampullariidae
Common names: channeled apple snail, golden apple snail
view more common names online...
EPPO Categorization: A1 list
view more categorizations online...
EU Categorization: Emergency measures
EPPO Code: POMACA



more photos...

Notes on taxonomy and nomenclature

Pomacea canaliculata has been confused with many other valid species of *Pomacea* (especially *Pomacea maculata*, another South American species that become a transcontinental invader) and has also suffered from numerous misspellings and invalid nomenclatural changes, especially in invaded areas of South-East Asia but also in its native range. Cowie & Thiengo (2003), Cowie *et al.* (2017) and Hayes *et al.* (2012) analyzed in detail the extensive list of synonyms for *P. canaliculata*. Hayes *et al.* (2012) clarified the taxonomic status of *P. canaliculata* and *P. maculata*, describing their similarities and differences, and provided a list of articles in which they have been confused or correctly identified. Recent studies indicate that the taxonomic situation in South-East Asia is more complicated than previously thought since a new species (*Pomacea occulta*), not known in the native range of the genus, has been described in China (Yang & Yu, 2019). In addition, there is growing evidence of extensive hybridization (up to 53% of the snails analyzed) between *P. canaliculata* and *P. maculata* in South-East Asia and in the native range (Glasheen *et al.*, 2020; Yang *et al.* 2020, 2022).

HOSTS

Even if usually regarded as macrophytophagous, *P. canaliculata* has no host plants in a strict sense. It uses aquatic macrophytes as food and, in the case of emergent or riparian plants, as substrate for egg laying, but it can also eat plant detritus, biofilms, and animal material such as carrion, amphibian eggs and invertebrates. (Saveanu *et al.*, 2017; Hayes *et al.*, 2015; Carter *et al.*, 2018). It can also use any natural or artificial substrate as oviposition sites, as long as it is strong enough to support the weight of a mature female (Martín *et al.*, 2017). The trophic ecology of *P. canaliculata* has been extensively studied through palatability trials (no-choice feeding trials) with the result that it feeds on almost any organic material (Saveanu *et al.*, 2017; Wong *et al.*, 2010; Morrison & Hay, 2011; Manara *et al.*, 2019). Hence the list of plants that can be attacked is very long and may include species that have been covered by research studies, but which would not normally be consumed by the snails (e.g. riparian or terrestrial species). On the other hand, multi-offer feeding trials indicate that these snails have strong preferences for some aquatic plants over others (Morrison & Hay, 2011; Manara *et al.*, 2019). Nevertheless, once preferred plants are depleted by *P. canaliculata* grazing, these snails would turn to less preferred ones and can also reduce their biomass and coverage (Manara *et al.*, 2019).

The high levels of damage to some aquatic crops, especially rice, is probably more related to a suite of factors favouring high densities of *P. canaliculata* in the fields (shallow water, access to air, egg laying substrates, plant detritus, algae, biofilms, etc.) than to any preference or specificity of the snail for these crops.

In no-choice trials (Manara *et al*., 2019; Morrison & Hay, 2011; Wong *et al.*, 2010), the following potential aquatic plants could be eaten by *P. canaliculata*: *Ageratum conyzoides, Alternanthera philoxeroides, Amaranthus tricolor, Bacopa caroliniana, Bacopa monnieri, Chara contraria, Colocasia esculenta, Commelina diffusa, Egeria densa, Hydrocotyle sibthorpioides, Ipomoea aquatica, Lemna minor, Ludwigia adscendens, Ludwigia peploides, Myriophyllum aquaticum, Myriophyllum quitense, Nasturtium officinale, Nelumbo nucifera, Nymphaea alba, Nymphaea odorata, Persicaria barbata, Phragmites australis, Pistia stratiotes, Pontederia crassipes, Ranunculus*

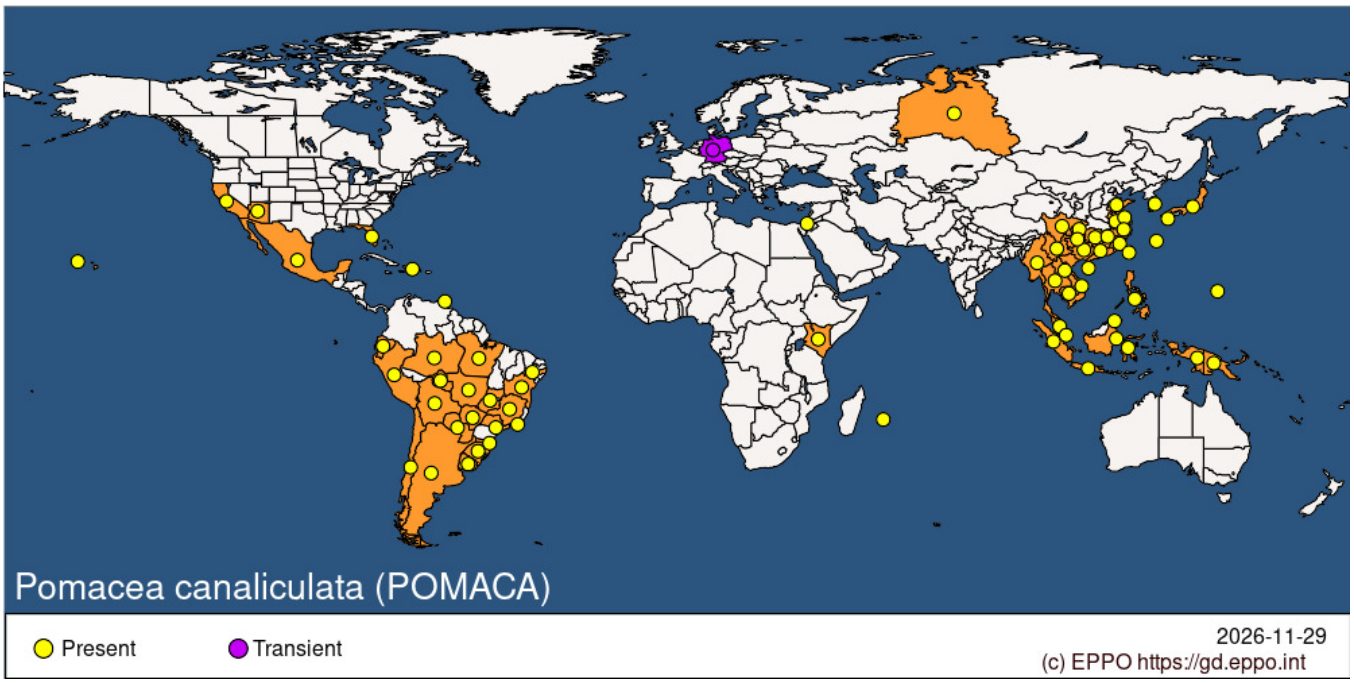
sceleratus, Sagittaria latifolia, Stuckenia striata, Utricularia sp., Vallisneria natans and *Zannichellia palustris.*

Host list: *Ageratum conyzoides, Alternanthera philoxeroides, Amaranthus tricolor, Bacopa caroliniana, Bacopa monnieri, Chara contraria, Colocasia esculenta, Commelina diffusa, Egeria densa, Hydrocotyle sibthorpioides, Ipomoea aquatica, Lemna minor, Ludwigia adscendens, Ludwigia peploides, Myriophyllum aquaticum, Myriophyllum quitense, Nasturtium officinale, Nelumbo nucifera, Nymphaea alba, Nymphaea odorata, Oryza sativa, Persicaria barbata, Phragmites australis, Pistia stratiotes, Pontederia crassipes, Ranunculus sceleratus, Sagittaria latifolia, Stuckenia striata, Utricularia sp., Vallisneria natans, Zannichellia palustris*

GEOGRAPHICAL DISTRIBUTION

The native area of *P. canaliculata* comprises most of Río de la Plata basin in Southern South America, including parts of Argentina, Brazil, Uruguay, Paraguay and probably also Bolivia (Hayes *et al.*, 2012; Cowie *et al.*, 2017). 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).

Pomacea canaliculata has also been introduced to many countries in different continents, mainly as potential aquaculture organism, and also as an aquarium pet. 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), the USA (1997), Mexico (2009) and Trinidad (2014). It has been reported in oceanic islands such as Guam and Hawaii (1989). 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).



EPPO Region: Germany, Israel, Russian Federation (Western Siberia)
Africa: Kenya, Reunion
Asia: Cambodia, China (Anhui, Chongqing, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Hunan, Jiangsu,

Jiangxi, Shandong, Sichuan, Yunnan, Zhejiang), Indonesia (Irian Jaya, Java, Kalimantan, Sulawesi, Sumatra), Israel, Japan (Honshu, Kyushu, Ryukyu Archipelago), Korea, Republic of, Lao People's Democratic Republic, Malaysia (Sabah, West), Myanmar, Philippines, Singapore, Taiwan, Thailand, Vietnam
North America: Mexico, United States of America (Arizona, California, Florida, Hawaii)
Central America and Caribbean: Dominican Republic, Trinidad and Tobago
South America: Argentina, Bolivia, Brazil (Amazonas, Bahia, Goias, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Para, Pernambuco, Rio de Janeiro, Rio Grande do Sul, Rondonia, Santa Catarina, Sao Paulo), Chile, Ecuador, Paraguay, Peru, Uruguay
Oceania: Guam, Papua New Guinea

BIOLOGY

Pomacea canaliculata is a large freshwater snail, which is oviparous and dioecious, and with females being usually larger than males. *P. canaliculata* inhabits a great variety of habitats (lakes, ponds, rivers, streams, reservoirs, paddy fields, channels, etc.; Seuffert & Martín, 2013, 2021; Kwong *et al.*, 2008). It is usually regarded as a lotic dweller but it can be very abundant in slow flowing streams (Martín *et al.*, 2017; Seuffert & Martín, 2012). It can be found underwater on muddy sediment, bedrock or on aquatic plants that are submerged, floating or emergent.

Pomacea canaliculata has a dual respiratory system composed of a well-developed aquatic gill or ctenidium and an aerial lung. It is able to perform aquatic and aerial respiration simultaneously and hence to dwell in hypoxic waters; aerial respiration is obligatory under most circumstances and the dependence on it increases with water temperature and snail size, being higher for females (Seuffert & Martín, 2010). The aerial lung is probably crucial for the notable capacity to survive out of water when the snails became stranded by water recession or self-bury during dry periods. Self-buried *P. canaliculata* survived up to 11 months and 29 months in dry and moist soil, respectively (Yusa *et al.*, 2006). The air in the lung increases the buoyancy of these snails and so their movements are greatly impeded when water depth is below their shell height.

The reproductive habits of *P. canaliculata* and congeners are quite unusual for a freshwater snail: although they perform all their activities underwater (crawling, feeding, respiration, copulation, etc.), egg laying occurs on emergent substrates onto which the female climbs and deposits a conspicuous pink egg mass formed by hundreds of eggs with a calcareous shell (Hayes *et al.*, 2015). All the embryonic development takes place aerially inside the cleidoic egg until the eggshell cracks (usually after two weeks at 25°C) and the hatchlings fall into the water. The egg masses can endure submersion at the expense of an extended development period and lower embryo viability, but they cannot develop successfully if permanently submersed (Pizani *et al.*, 2005). Due to their bright pink colour, size and location well above water level, the egg masses are conspicuous but seldom attacked by predators, probably due to the antidigestive, neurotoxic and antinutritive properties on the perivitelline fluid that surrounds the embryo inside the egg shell and serves as nutritional reserve and protective envelope (Heras *et al.*, 2017).

The life cycle of *P. canaliculata* is direct and quite simple but the life history traits are very plastic and in some cases sexually dimorphic (Estebenet & Martín, 2002; Hayes *et al.*, 2015; Martín *et al.*, 2017). Once the aerial eggs hatch, the hatchlings drop into the water and immediately try to reach the water surface and begin to breathe air and to eat; once they have consumed all the reserves of perivitelline fluid in their guts they can be considered as juveniles which develop quickly into males and females if food and temperature are adequate. At 25°C males mature at 15 weeks of age, irrespective of size and food availability, whereas females mature at sizes of ca. 32 mm, which are attained at 15 weeks of age when fed freely and at 50 weeks when food availability is reduced to 20 % of the amount consumed when fed freely. The age at which females lay their first egg mass is inversely related to water temperature and varies between 90 weeks at 20°C to 12.86 weeks at 30°C (Seuffert & Martín, 2017). The life cycle is annual and semelparous (one reproductive period) at a constant temperature of 25°C but a seasonal variation in temperature (9-32°C) induces an extended iteroparous life cycle with up to four reproductive seasons (Estebenet & Martín, 2002).

Temperature has an outstanding importance in the biology and ecology of *P. canaliculata* and is probably the main determinant of its distribution on a global scale (Gilioli *et al.*, 2017a; Hayes *et al.*, 2015). The snails are active above water temperatures of 15°C and up to 38-40°C (Seuffert *et al.*, 2010). Reproduction is possible between 20 and 30°C but sexual maturity is highly delayed in the lower limit and egg viability is reduced in the upper limit; survival and growth are good at 35°C but copulation is infrequent and females do not lay eggs (Seuffert & Martín, 2017). Degree days (DD) were estimated for egg development from 88.8 to 133.8 DD (Seuffert *et al.*, 2012) and at 1440 DD for the entire life cycle (Lv *et al.*, 2011), with threshold temperatures of 15.8-18.3°C and 11.7°C, respectively.

DETECTION AND IDENTIFICATION

Symptoms

The symptoms of *P. canaliculata* attacks on aquatic plants are quite unspecific and depend on the interaction of the feeding mechanism (combined action of the radula, a flexible ribbon with up to 35 seven-teeth rows, and a pair of stout jaws) with plant anatomy. The size structure of the apple snail population can also influence the effects on aquatic vegetation or aquatic crops, as small snails have less capacity to chew vegetal tissues but have a greater specific ingestion rate (Carlsson & Brönmark, 2006; Hayes *et al.*, 2015). The attacks of *P. canaliculata* are usually

concentrated in floating or submersed leaves and stems. The leaf blades show irregularly chewed margins, sometimes leaving only the main veins, but they could also appear as irregular holes; when the adaxial surface is too tough they gnaw the abaxial surface first and ingest the mesophyll, leaving clear translucent "windows" in the blade; this is common when the snails are small compared to the leaves. On the other hand, small snails can penetrate inside hollow but tough stems that adult snails cannot chew and eat them from inside (Carlsson & Brönmark, 2006). Small floating plants such as duckweeds can be ingested in one bite by an adult snail but large plants such as water hyacinth (*Pontederia crassipes*) are attacked from underwater, ingesting first the roots, then the lowest part of the spongy air-filled petioles and when, they fall to water, the leaf blades (Carlsson & Lacoursière, 2005).

The greatest agricultural concern raised by *P. canaliculata* grazing is for rice, especially when directly seeded, as apple snails of all sizes can eat the seedlings up to the three-leaf stage. Transplanted rice is far more resistant to apple snail grazing, especially by small individuals (Yahaya *et al.*, 2017; Horgan, 2017, 2018). Damage in rice fields also depends strongly on water depth in rice fields and damage, even to seedlings, can be avoided if soil is maintained saturated with water but with no free water above it. Even if apple snail infestation in rice fields is already high in terms of population density or biomass, symptoms appear late as round areas with no rice. Egg masses on plants or other emergent substrates in the fields or channels are an early warning of an increasing apple snail population.

Morphology

Pomacea canaliculata is a large snail, reaching up to 6 cm from the apex of the shell to the farthest point of the aperture (Estebenet *et al.*, 2006; Hayes *et al.*, 2012). The shell is thin and smooth, globose to subglobose, with an oval to kidney-shaped aperture and a low spire; the suture is usually deeply channeled. The shell is brown-green, showing up to 30 dark spiral bands of variable width and transverse growth lines. The operculum is corneous and flexible, with concentric growth lines around an eccentric nucleus, and tightly closes the shell aperture.

Shell morphology, including shape, size, thickness and colouration, is the most frequently used indicator for species identification but at the same time it is one of the less reliable since *Pomacea* spp. shells are similar and there is ample intraspecific variability in many of them. In particular, ontogenetic, sexual, genetic and ecophenotypic components of inter- and intrapopulation variation have been described in *P. canaliculata* (Estebenet *et al.*, 2006). Temperature, food availability and presence of predators can induce changes in shell morphology (Guo *et al.*, 2019).

The colour, shape and size of eggs, as well as the number of eggs per egg mass, although variable, are useful to distinguish *P. canaliculata* from *P. maculata* and other apple snails (Hayes *et al.*, 2012; Cowie *et al.*, 2017): *P. canaliculata* eggs are spherical, usually pink but sometimes with a reddish or orange taint, and around 3 mm in diameter; the egg masses usually contain hundreds of eggs (12-1000). A simple colorimetric test based on egg perivitellins has been developed to distinguish between *P. canaliculata* and *P. maculata* (Pasquevich & Heras, 2020). Hybridization between *P. canaliculata* and *P. maculata* results in homogenization in terms of size of eggs and egg masses (Yang *et al.*, 2020).

Detection and inspection methods

In the field, *Pomacea canaliculata* and congeners like *P. maculata* are most easily detected (e.g. allowing early detection) by the observation of their conspicuous aerial pink eggs-masses, even at low adult densities (EFSA, 2020). Egg masses can be found on almost any object emerging a few centimetres from the water surface (e.g. emergent plants, trees, poles, piers, rocks, boats, etc.), especially if they are touching the bottom of the water body or other submerged objects. However, floating objects usually cannot be reached by egg-laying females. Areas with still or slow flowing water are the sites most suited for inspection, which can be done by wading or boating personnel; inspection can be done also from the shore if emergent vegetation is sparse. Detection surveys of egg masses should take place at least once during the warm season in temperate climates or when water temperature exceeds 20°C in tropical ones. Surveys soon after sunrise are likely to find bright pink recently-laid egg masses, and also egg-laying females, as this behaviour is mostly nocturnal. The bright pink colour fades as egg development proceeds, becoming whitish and later brownish, when the embryo consumes the coloured perivitelline fluid and grows to occupy most of the eggshell. As eggs hatch, the egg mass losses its integrity and only a white mark with a few unhatched eggs remain. Unhatched egg masses or egg mass remains can last for a year or more if protected from rain and therefore, culverts, pipes and pillars under bridges are suitable places to search for them outside the reproductive season. Detection of egg masses could be aided by the use of binoculars and/or drones.

Adults and juveniles of *P. canaliculata* can be detected by visual examination while wading or boating if water depth and turbidity are low. In turbid waters or among vegetation, adults can be detected underwater by touch and net scoops through submerged vegetation or bottom surface can be used to detect juveniles (Seuffert & Martín, 2013). Under warm and hypoxic conditions, the need for ventilation of the aerial lung increases which increases the likelihood of seeing a snail taking air through their snorkel or siphon just below the water surface (Seuffert & Martín, 2010). Snail activity decreases as temperature decreases and they become inactive when water temperature drops below 15°C, when they may bury in the sediments or hide beneath rocks. Baited traps can be used to attract apple snails, but their effectiveness depends on the availability of other food sources and on habitat type. Inspection of old strandlines could reveal the presence of empty shells and opercula, even if snails are inactive or buried at that time.

Preliminary identification of *P. canaliculata* can be done on empty shells and egg masses and even high quality photographs can be used, especially to avoid misidentification with other genera of apple snails (*Pila, Lanistes, Asolene, Felipponea*, etc.) or other large freshwater snails (mostly Viviparidae). Anatomical examination of soft parts of live or preserved adults, preferably males larger than 25 mm, by a trained malacologist is required for species confirmation. Mitochondrial genetic markers (mostly COI) are usually used to further confirm identification of *P. canaliculata* and to investigate the geographical origin of the apple snails (Cowie *et al.*, 2017; Yang *et al.*, 2019). Furthermore, the use of nuclear markers may be necessary to disentangle the origin of the snails since there is evidence of hybridization both in the invaded and native range (Glasheen *et al.*, 2020; Yang *et al.*, 2019; 2022).

PATHWAYS FOR MOVEMENT

Pomacea canaliculata can disperse through a variety of natural mechanisms that allow displacement at different spatial scales (Smith, 2006; Seuffert & Martín, 2012). Crawling and climbing are the only two modes of active snail movements, mostly within a waterbody or between contiguous ones. Snails can crawl at speeds of up to 10 cm/minute and move up to 6 m upstream and 18 m downstream in one day (Seuffert & Martín, 2012). Climbing out of water to lay eggs or to avoid fouled water is a common way in which the snails may leave a tank or channel and later drop outside; they may be able to crawl outside water for a few metres and reach another mass of water or bury themselves in wet sediment. Floating and drifting are two ways in which apple snails can disperse passively within a water body or water course, probably at a scale from a few metres to hundreds of metres (if aided by wind or water currents). Floating is favoured by the air inside the lung which increases snail's buoyancy. Snails partially dried and well withdrawn inside the shell can also float for several hours until they rehydrate and sink. Snail dislodgement in flowing water occurs at relatively low velocities (Seuffert & Martín, 2012) and thereafter they drift downstream until the current is sufficiently slow so that they can adhere to the substrate with their foot. Flooding facilitates the spread of *P. canaliculata* (Ip & Qiu, 2017), probably through these passive mechanisms.

The success of anthropogenic transport, either incidental or intentional, is greatly enhanced by the capacity of *P. canaliculata* to endure desiccation and starvation (Smith, 2006; Yusa *et al.*, 2006; Tamburi & Martín, 2016) and by the aerial development of eggs. The female's capacity to store sperm and to lay thousands of viable eggs after a single copulation increases the chances of establishment of new populations.

Intentional transport of *P. canaliculata* has taken place through legal pathways and has even been supported by government agencies but unregulated and illegal transport is common (Smith, 2006; Carlsson, 2017; Cowie *et al.*, 2017; Horgan, 2017, 2018). The aquarium pet trade and aquaculture projects are the main causes of intentional transport of *P. canaliculata* across international borders and between continents. *P. canaliculata* is also transported as a biological control agent against weeds in rice fields. Juveniles and adults can be easily transported without water over several days and even weeks in luggage or cloths, which greatly facilitates smuggling. Recently laid egg masses can be transported in a match box, small flask or paper towel for up to two weeks until the eggs hatch and even after this the hatchlings would survive easily for another week without water. Apple snails are used as fishing bait as they can be easily captured and maintained for use in a fishing trip (Seuffert & Martín, 2021).

Incidental transport of *P. canaliculata* probably occurs most frequently through small hatchlings and remains of egg masses. The aquatic plants trade is a likely pathway for long distance movement of both life stages (Cowie *et al.*, 2017). Eggs masses deposited at night on the hull of boats located on or near the shore (Carlsson, 2017) can be transported during navigation or transported overland to a different waterbody until the eggs hatch. Egg masses and hatchlings can also be inadvertently transported with machinery used for agricultural activities or channel construction and maintenance. Hatchlings and small juveniles can be captured accidentally when netting for small

fish (e.g. to be used as live bait or for restocking) and later transported to a new waterbody (Seuffert & Martín, 2021).

PEST SIGNIFICANCE

Economic impact

The economic impact of *P. canaliculata* on agriculture, mainly rice, is twofold: direct productivity losses due to the damage to crops and the costs of control measures against the snail. The economic impacts of *P. canaliculata* on agriculture are huge, especially in tropical countries where rice is one of the main crops, such as in South-East Asia. Costs associated with apple snail damage in Malaysia were estimated at 28 million USD in 2010 (Yahaya *et al.* , 2017). In Taiwan annual economic losses were estimated as 3.89 million USD but the potential agricultural and ecological impacts could reach 176 million USD per year (Yang *et al.*, 2017). A total annual cost between 806–2138 million USD was estimated for the rice sector of Philippines, Vietnam and Thailand (Nghiem *et al.*, 2013). The total accumulated costs of *P. canaliculata* to Ecuador's rice sector in ten years (2005-2015) have been recently estimated at 155 million USD (Horgan *et al.*, 2021). After the recent discovery of *P. canaliculata* in Kenya, Djeddour *et al.* (2021) estimated projected annual losses in the rice sector of Kenya, Tanzania, Uganda, and Ethiopia reach between 67–116 million USD.

The environmental impacts of apple snail invasions, especially *P. canaliculata*, are multiple (Horgan *et al.*, 2014; Carlsson, 2017; Martín *et al.*, 2019) and involve emerging human diseases like eosinophilic meningoencephalitis (mostly due to an increased transmission of the rat lung-worm; Lv *et al.*, 2011) and the loss or deterioration of ecosystem services (Gilioli *et al*., 2017b), for which economic estimations are not available yet.

Control

Control methods against *P. canaliculata* have been proposed and applied in aquatic crops and only exceptionally in natural or man-managed wetlands (Martín *et al.*, 2019). Damage to rice is of outstanding importance and concerns several continents and thus, the control of *P. canaliculata* is one of the most studied aspects of this apple snail (Horgan, 2017; 2018).

Cultural control methods aim to reduce *P. canaliculata* damage to rice through a restriction of the snail activities and of the opportunities to encounter seedlings, the most vulnerable stage (Horgan, 2017). The manipulation of water depth, timing of inundation and drainage of rice, method of rice implantation (direct seeding or transplant) and crop density are the main variables that should be managed to reduce damage to rice. Local climate plays a crucial role as apple snails may hibernate if winters are cold enough or be active and reproduce throughout the year.

Control methods aimed directly to reduce *P. canaliculata* populations in rice crops include manual, mechanical, chemical and biological methods (Horgan, 2017). Control measures can be directed to the aerial (egg masses) or to the aquatic stages (hatchlings, juveniles and adults). Handpicking or crushing the aerial egg masses is often used as a control method in small farms; planting stakes that serve as egg laying substrates for *P. canaliculata* in rice fields facilitates this task. Spraying egg masses with different substances reduces or impedes egg development and hatching, if applied at the right moment (Wu *et al.*, 2005). Biological control with egg masses as targets has been investigated and only the fire ant *Solenopsis invicta* predates them, but it is also a rice pest (Yusa, 2001).

Handpicking of juvenile and adult snails is an effective but time-consuming control method that can be improved by using plant baits and digging furrows inside the fields where snails congregate. Mechanical methods include the intensification of customary cultural practices, such as tillage and puddling of rice fields, which can crush a high percentage of the snail population, especially hibernating ones. Chemical methods are frequently used because, although they are not specific, they are effective and include application of methaldehyde, niclosamide and diverse insecticides; baits with metaldehyde are also used. Plant extracts and plant based molluscicides are also gaining favour because of their lower side effects on other animals. Fertilizers commonly used in rice field (urea, calcium cyanamide and complete fertilizer) can also have a negative effect on apple snail populations, especially if used at high doses during low water periods.

Several species of fish, crustaceans and birds have been investigated or used as biological control agents against *P. canaliculata*

(Yusa, 2006). Farming ducks and fish in rice fields are effective ways of controlling snail populations. Populations of predatory prawns (*Macrobrachium rosenbergii*) developed biotechnologically to obtain only males have been tried for inundative biocontrol of apple snails with promising results (Savaya-Alkalay *et al.*, 2018). In Ecuador, which is in the native range of other *Pomacea* species, predation by the highly specialized snail kites (birds of prey) has been enhanced by farmers in order to control *P. canaliculata* (Horgan *et al.*, 2014). Other wild native bird species, such as storks, crows and ibises, can also cause high levels of predation on *P. canaliculata* and its congeners (Bertolero & Navarro, 2018; Uehara *et al.*, 2021; Sawangproh *et al.*, 2012) and some habitat amelioration measures to increase their use of rice fields may help to reduce snail numbers.

Phytosanitary risk

Pest Risks Analysis studies have concluded that *P. canaliculata* and other *Pomacea* species presented risks to plant health in the EPPO region (EFSA, 2012; EPPO, 2018). Due to difficulties in precise taxonomic determination and to uncertainty on the potential agricultural and environmental impacts of most species, apple snails from the whole genus *Pomacea* are considered quarantine pests in the EU, their introduction is prohibited and official inspections for the import and movement of aquatic plants within EU have been set to prevent their introduction and spread (EFSA, 2020).

Many countries such as Australia, China, Malaysia, Japan, USA and Vietnam also consider *P. canaliculata* as a quarantine pest. To avoid any further spread of apple snails, the implementation of quarantine measures is recommended for countries that are vulnerable to exotic apple snails, in particular for tropical countries (Horgan, 2017).

PHYTOSANITARY MEASURES

Prevention of introduction is the first measure to avoid the multiple negative impacts associated with *P. canaliculata,* as once established their eradication is very difficult and costly, from both economic and environmental viewpoints (Horgan, 2017, 2018). To prevent the entry and spread of *P. canaliculata* and other *Pomacea* spp. their import and trade should be banned. Aestivating adult *P. canaliculata* with their opercula tightly closed may be mistaken for empty shells and be easily smuggled, as well as egg masses hidden in paper towels or match boxes. To prevent or slow the spread of *P. canaliculata* from already infested places, boats and agricultural machinery should be thoroughly washed or inspected. It is recommended that plants for planting that can grow in water or soil that is permanently saturated with water should come from a pest-free area or a place of production which has been maintained free from the pest (EPPO, 2018).

REFERENCES

Andree KB & López MA (2013) Species identification from archived snail shells via genetic analysis: a method for DNA extraction from empty shells. *Molluscan Research* **33**(1), 1-5.

Bertolero A, Navarro J (2018) A native bird as a predator for the invasive apple snail, a novel rice field invader in Europe. *Aquatic Conservation: Marine and Freshwater Ecosystem* **28**(5), 1-6.

Carlsson NOH (2017) lnvasive apple snails are threatening natural ecosystems in Southeast Asia, Europe and North America. In *Biology and management of invasive apple snails* (eds. Joshi RC, Cowie RH & Sebastian LS), pp. 45-62. Philippine Rice Research Institute, Philippines.

Carlsson NO & Brönmark C (2006) Size?dependent effects of an invasive herbivorous snail (*Pomacea canaliculata*) on macrophytes and periphyton in Asian wetlands. *Freshwater Biology* **51**(4), 695-704.

Carlsson NO & Lacoursière JO (2005) Herbivory on aquatic vascular plants by the introduced golden apple snail (*Pomacea canaliculata*) in Lao PDR. *Biological invasions* **7**(2), 233-241.

Carter J, Johnson D & Merino S (2018) Exotic invasive *Pomacea maculata* (Giant Apple Snail) will depredate eggs of frog and toad species of the Southeastern US. *Southeastern Naturalist* **17**(3), 470-475.

Cowie RH, Hayes KA, Strong EE & Thiengo SC (2017) Non-native apple snails: systematics, distribution, invasion history and reasons for introduction. *Biology and management of invasive apple snails.* Philippine Rice Research Institute (PhilRice), Maligaya, Science City of Muñoz, Nueva Ecija, 3119, 3-32.

Cowie R & Thiengo S (2003) The apple snails of the Americas (Mollusca: Gastropoda: Ampullariidae: *Asolene, Felipponea, Marisa, Pomacea, Pomella*): a nomenclatural and type catalog. *Malacologia* **45**(1), 41–100.

Djeddour D, Pratt C, Makale F, Rwomushana I & Day R (2021) The apple snail, *Pomacea canaliculata*: an evidence note on invasiveness and potential economic impacts for East Africa. *CABI Working Paper* 21, 77 pp.

EFSA Panel on Plant Health (2012) Scientific Opinion on the evaluation of the pest risk analysis on *Pomacea insularum*, the island apple snail, prepared by the Spanish Ministry of Environment and Rural and Marine Affairs. *EFSA Journal* **10**(1), 2552, 57 pp. https://doi/org/10.2903/j.efsa.2012.2552 (last accessed 2022-02).

EFSA (European Food Safety Authority) Schrader G, Delbianco A & Vos S (2020) Pest survey card on *Pomacea* spp. *EFSA supporting publication* 2020: EN-1877. 37 pp.

EPPO (2018) Report of a Pest Risk Analysis for *Pomacea* species in the '*canaliculata* complex'.: https://pra.eppo.int/pra/cfba256e-2652-4c75-b4ff-53e7311c9e4d (last accessed 2022-02).

Estebenet AL, & Martín PR (2002) *Pomacea canaliculata* (Gastropoda: Ampullariidae): Life-history traits and their plasticity. *Biocell* **26**(1), 83-89.

Estebenet AL, Martín PR & Silvana B (2006) Conchological variation in *Pomacea canaliculata* and other South American Ampullariidae (Caenogastropoda, Architaenioglossa). *Biocell* **30**(2), 329-335.

Gilioli G, Pasquali S, Martín PR, Carlsson N & Mariani L (2017a) A temperature-dependent physiologically based model for the invasive apple snail *Pomacea canaliculata*. *International Journal of Biometeorology*, **61**(11), 1899-1911.

Gilioli G, Schrader G, Carlsson N, van Donk E, van Leeuwen CH, Martín PR & Vos S (2017b) Environmental risk assessment for invasive alien species: A case study of apple snails affecting ecosystem services in Europe. *Environmental Impact Assessment Review* **65**, 1-11.

Glasheen PM, Burks RL, Campos SR & Hayes KA (2020) First evidence of introgressive hybridization of apple snails (*Pomacea* spp.) in their native range. *Journal of Molluscan Studies* **86**(2), 96-103.

Guo J, Zhang C, Zhang J, & Zhao B (2019) Sex differences in the morphological defenses of an invasive snail: dimorphism and predator-induced plasticity. *Freshwater Science* **38**(3), 582-590.

Hayes KA, Burks RL, Castro-Vazquez A, Darby PC, Heras H, Martín PR & Cowie RH (2015) Insights from an integrated view of the biology of apple snails (Caenogastropoda: Ampullariidae). *Malacologia* **58**(1–2), 245-302.

Hayes KA, Cowie RH, Thiengo SC & Strong EE (2012) Comparing apples with apples: clarifying the identities of two highly invasive Neotropical Ampullariidae (Caenogastropoda). *Zoological Journal of the Linnean Society* **166** (4), 723-753.

Heras H, Dreon MS, Ituarte S, Pasquevich MY & Cadierno MP (2017) Apple snail perivitellins, multifunctional egg proteins. In *Biology and management of invasive apple snails* (eds. Joshi RC, Cowie RH & Sebastian LS), pp. 99-117. Philippine Rice Research Institute, Philippines.

Horgan FG (2017) Ecology and management of apple snails in rice. In: Chauhan BS, Jabran K, Mahajan G (eds.) *Rice production worldwide*. Springer, Switzerland, pp 393-418.

Horgan FG (2018) The ecophysiology of apple snails in rice: implications for crop management and policy. *Annals of Applied Biology* **172**(3), 245-267.

Horgan FG, Felix MI, Portalanza DE, Sánchez L, Rios WMM, Farah SE & Espin EB (2014) Responses by farmers to the apple snail invasion of Ecuador's rice fields and attitudes toward predatory snail kites. *Crop Protection* **62**, 135-143.

Horgan FG, Stuart AM & Kudavidanage EP (2014) Impact of invasive apple snails on the functioning and services of natural and managed wetlands. *Acta Oecologica* **54**, 90-100.

Horgan FG, Zhu Q, Portalanza DE & Felix MI (2021) Costs to Ecuador's rice sector during the first decade of an apple snail invasion and policy recommendations for regions at risk. *Crop Protection* **148**, 105746.

Ip KKL & Qiu J (2017) Invasive apple snails: ecology and management in Hong Kong. In *Biology and management of invasive apple snails* (eds. Joshi RC, Cowie RH & Sebastian LS), pp. 145-165. Philippine Rice Research Institute, Philippines.

Kwong KL, Wong PK, Lau SS & Qiu JW (2008) Determinants of the distribution of apple snails in Hong Kong two decades after their initial invasion. *Malacologia* **50**(1–2), 293–302.

Letelier S, Rebolledo A, Báez P, Fabres A, Soto-Acuña S & Jackson D (2016) The highly invasive freshwater apple snail *Pomacea canaliculata* (Gastropoda: Ampullariidae) in Northern Chile: morphological and molecular confirmation. *Journal of Zoological Studies* **3**, 119-128.

Lv S, Zhang YI, Steinmann P, Yang GJ, Yang KUN, Zhou XN & Utzinger J (2011) The emergence of angiostrongyliasis in the People's Republic of China: the interplay between invasive snails, climate change and transmission dynamics. *Freshwater Biology* **56**(4), 717-734.

Manara E, Maldonado MA & Martín PR (2019) The role of an invader in its native range: could differential grazing by apple snails structure the submersed macrophytes assemblages in Southern Pampas (Argentina)? *Hydrobiologia* **828**(1), 229-242.

Martín PR, Burela S, Seuffert ME, Tamburi NE & Saveanu L (2019) Invasive *Pomacea* snails: actual and potential environmental impacts and their underlying mechanisms. *CAB Reviews* **14**, 1-10.

Martín PR, Seuffert ME, Tamburi NE, Burela S & Saveanu L (2017) Behaviour and ecology of *Pomacea canaliculata* from Southern Pampas (Argentina). In *Biology and management of invasive apple snails* (eds. Joshi RC, Cowie RH & Sebastian LS), pp. 241-256. Philippine Rice Research Institute, Philippines.

Morrison WE & Hay ME (2011) Feeding and growth of native, invasive and non-invasive alien apple snails (Ampullariidae) in the United States: invasives eat more and grow more. *Biological Invasions* **13**(4), 945-955.

Nghiem LT, Soliman T, Yeo DC, Tan HT, Evans TA, Mumford JD & Carrasco LR (2013) Economic and environmental impacts of harmful non-indigenous species in Southeast Asia. *PLoS One* **8**(8), e71255.

Pasquevich MY & Heras H (2020) Apple snail egg perivitellin coloration, as a taxonomic character for invasive *Pomacea maculata* and *P. canaliculata*, determined by a simple method. *Biological Invasions* **22**(7), 2299-2307.

Pizani NV, Estebenet AL & Martín PR (2005) Effects of submersion and aerial exposure on clutches and hatchlings of *Pomacea canaliculata* (Gastropoda: Ampullariidae). *American Malacological Bulletin* **20**(1-2), 55-63.

Roll U, Dayan T, Simberloff D & Mienis HK (2009) Non-indigenous land and freshwater gastropods in Israel. *Biological Invasions* **11**(8), 1963-1972.

Savaya-Alkalay A, Ovadia O, Barki A, Sagi A (2018) Size-selective predation by all-male prawns: implications for sustainable biocontrol of snail invasions. *Biological Invasions* **20**(1), 137–49.

Saveanu L, Manara E & Martín PR (2017) Carrion consumption and its importance in a freshwater trophic generalist: the invasive apple snail *Pomacea canaliculata*. *Marine and Freshwater Research* **68**(4), 752-759.

Sawangproh W, Round PD, Poonswad P (2012) Asian openbill stork *Anastomus oscitans* as a predator of the invasive alien gastropod *Pomacea canaliculata* in Thailand. *Iberus* **30**(1), 111–117.

Seuffert ME & Martín PR (2010) Dependence on aerial respiration and its influence on microdistribution in the invasive freshwater snail *Pomacea canaliculata* (Caenogastropoda, Ampullariidae). *Biological Invasions* **12**(6), 1695-1708.

Seuffert ME, & Martín PR (2012) A lentic dweller in lotic habitats: the behavior of the invasive South American apple snail *Pomacea canaliculata* in flowing water. *Aquatic Ecology* **46**(1), 129-142.

Seuffert ME & Martín PR (2013) Distribution of the apple snail *Pomacea canaliculata* in Pampean streams (Argentina) at different spatial scales. *Limnologica* **43**(2), 91-99.

Seuffert ME & Martín PR (2017) Thermal limits for the establishment and growth of populations of the invasive apple snail *Pomacea canaliculata*. *Biological Invasions* **19**(4), 1169.

Seuffert ME & Martín PR (2021) Exceeding its own limits: range expansion in Argentina of the globally invasive apple snail *Pomacea canaliculata*. *Hydrobiologia* **848**(2), 385-401.

Seuffert ME, Burela S & Martín PR (2010) Influence of water temperature on the activity of the freshwater snail *Pomacea canaliculata* (Caenogastropoda: Ampullariidae) at its southernmost limit (Southern Pampas, Argentina). *Journal of Thermal Biology* **35**(2), 77-84.

Seuffert ME, Saveanu L & Martín PR (2012) Threshold temperatures and degree-day estimates for embryonic development of the invasive apple snail *Pomacea canaliculata* (Caenogastropoda: Ampullariidae). *Malacologia* **55** (2), 209-217.

Smith JW (2006) Ampullariidae pathways. In *Global advances in ecology and management of golden apple snails*, (eds. Joshi RC & Sebastian LS), pp. 113-120. Philippine Rice Research Institute, Philippines.

Tamburi NE & Martín PR (2016) Effects of absolute fasting on reproduction and survival of the invasive apple snail *Pomacea canaliculata* in its native range. *Current Zoology* **62**(4), 369-375.

Uehara H, Murakami H & Yusa Y (2021) Predation by the carrion crow *Corvus corone* (Passeriformes: Corvidae) on the apple snail *Pomacea canaliculata* (Architaenioglossa: Ampullariidae) in different locations in Japan. *Applied Entomology and Zoology*, 1-8.

Vinarski MV, Andreev NI, Andreeva SI, Kazantsev IE, Karimov AV & Lazutkina EA (2015) Alien mollusk species in the aquatic ecosystems of Western Siberia: a review. *Russian Journal of Biological Invasions* **6**(3), 137-147.

Wong PK, Liang YAN, Liu NY, & Qiu JW (2010) Palatability of macrophytes to the invasive freshwater snail *Pomacea canaliculata*: differential effects of multiple plant traits. *Freshwater Biology* **55**(10), 2023-2031.

Wu DC, Yu JZ, Chen BH, Lin CY & Ko WH (2005) Inhibition of egg hatching with apple wax solvent as a novel method for controlling golden apple snail (*Pomacea canaliculata*). *Crop Protection* **24**(5), 483-486.

Yahaya H, Nordin M, Hisham MNM, Sivapragasam A, Joshi RC, Cowie RH & Sebastian LS (2017) Invasive apple snails in Malaysia. In *Biology and management of invasive apple snails* (eds. Joshi RC, Cowie RH & Sebastian LS), pp. 169-195. Philippine Rice Research Institute, Philippines.

Yang P, Chen Y, Lee W & Chen Y (2006) Golden apple snail management and prevention in Taiwan. In *Global advances in ecology and management of golden apple snails*, (eds. Joshi RC & Sebastian LS), pp. 169-179. Philippine Rice Research Institute, Philippines.

Yang QQ & Yu XP (2019) A new species of apple snail in the genus *Pomacea* (Gastropoda: Caenogastropoda: Ampullariidae). *Zoological Studies* **58**, e13.

Yang QQ, He C, Liu GF, Yin CL, Xu YP, Liu SW. & Yu XP (2020) Introgressive hybridization between two non?native apple snails in China: widespread hybridization and homogenization in egg morphology. *Pest Management Science* **76**(12), 4231-4239.

Yang Q, Liu S, He C, Cowie RH, Yu X & Hayes KA (2019) Invisible apple snail invasions: importance of continued vigilance and rigorous taxonomic assessments. *Pest Management Science* **75**(5), 1277-1286.

Yusa Y (2001) Predation on eggs of the apple snail *Pomacea canaliculata* (Gastropoda: Ampullariidae) by the fire ant *Solenopsis geminata*. *Journal of Molluscan Studies* **67**(3), 275-279.

Yusa Y (2006) Predators of the introduced apple snail, *Pomacea canaliculata* (Gastropoda: Ampullariidae): their effectiveness and utilization in biological control. In *Global advances in ecology and management of golden apple snails*, (eds. Joshi RC & Sebastian LS), pp. 345-361. Philippine Rice Research Institute, Philippines.

Yusa Y, Wada T & Takahashi S (2006) Effects of dormant duration, body size, self-burial and water condition on the long-term survival of the apple snail, *Pomacea canaliculata* (Gastropoda: Ampullariidae). *Applied Entomology and Zoology* **41**(4), 627-632.

CABI and EFSA resources used when preparing this datasheet

CABI Invasive Species Compendium Datasheet on *Pomacea canaliculata.* https://www.cabi.org/isc/datasheet/68490#CDDB33ED-EC00-452E-A471-ACEFCE479041

EFSA Pest survey card on *Pomacea* spp. https://efsa.onlinelibrary.wiley.com/doi/abs/10.2903/sp.efsa.2020.EN-1877

ACKNOWLEDGEMENTS

This datasheet was prepared in 2022 by Dr Pablo R. Martín [Departamento de Biología, Bioquímica y Farmacia, Universidad Nacional del Sur and Instituto de Ciencias Biológicas y Biomédicas del Sur (UNS-CONICET), Argentina]. His valuable contribution is gratefully acknowledged.

How to cite this datasheet?

EPPO (2026) *Pomacea canaliculata*. EPPO datasheets on pests recommended for regulation. Available online. https://gd.eppo.int

Datasheet history

This datasheet was first published online in 2022. It is maintained in an electronic format in the EPPO Global Database. The sections on 'Identity', ‘Hosts’, and 'Geographical distribution' are automatically updated from the database. For other sections, the date of last revision is indicated on the right.

Co-funded by the European Union