EPPO Datasheet: *Pomacea maculata*

Last updated: 2022-09-29

IDENTITY

Preferred name: *Pomacea maculata*
Authority: Perry
Taxonomic position: Animalia: Mollusca: Gastropoda: Architaenioglossa: Ampullariidae
Other scientific names: *Ampullaria gigas* Spix, *Ampullaria insularum* d'Orbigny, *Pomacea insularum* (d'Orbigny)
Common names: island apple snail
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EPPO Categorization: A2 list
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EU Categorization: Emergency measures
EPPO Code: POMAIN

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Notes on taxonomy and nomenclature

Pomacea maculata has been confused with other valid species of *Pomacea* (especially *Pomacea canaliculata*, another South American species that become a transcontinental invader), especially in invaded areas of South-East Asia but also in its native range. The list of synonyms for *P. maculata* was compiled by Cowie & Thiengo (2003), Cowie *et al.* (2017) and Hayes *et al.* (2012). The information about *P. maculata* is considerably less than for *P. canaliculata* but it is also possible that some of its impacts have been attributed to the latter species. The name *Pomacea insularum* was widely used for one of the South American apple snails that invaded South-East Asia and Southern North America but Hayes *et al.* (2012) synonymized *P. insularum* and *Pomacea gigas* with *P. maculata* and established it as a different species from *P. canaliculata*; they also provided a list of articles in which the two species have been confused or correctly identified. However, the taxonomic situation in South-East Asia and other invaded regions may be 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). Hybridization between *P. canaliculata* and *P. maculata* may be locally frequent in the native range (up to 30% of the snails analysed; Glasheen *et al.*, 2020) but may reach up to 53% in South-East Asia where pure *P. canaliculata* snails are common but pure *P. maculata* are extremely rare (Yang *et al*., 2020, 2022).

HOSTS

P. maculata and other *Pomacea* spp. are usually regarded as macrophytophagous, but they have no host plants in a strict sense (i.e. a plant to which some stage of the life cycle is closely linked). *P. maculata* uses aquatic macrophytes, mostly floating and submerged ones, primarily as food (Hayes *et al.*, 2015). It also uses emergent or riparian plants as a substrate for egg laying but they can also use any emergent substrate, either natural or artificial, as an oviposition site (Burks *et al*., 2010; Kyle *et al*., 2011).

The trophic ecology of *P. maculata* (often under the name *P. insularum*) has been studied almost entirely in the invaded range through palatability trials (no-choice feeding trials) (Burks *et al*., 2011; Burlakova *et al*., 2009; Baker *et al*., 2010; Low & Anderson, 2017; Morrison & Hay, 2011). The list of plants that can be attacked when no alternative food is provided is very long and includes species that would not normally be reached and consumed by the snails (e.g. riparian or terrestrial species). Generally, they do not eat emergent plants like cattails and reeds (Burlakova *et al*., 2009; Low & Anderson, 2017). Nevertheless, *P. maculata* has strong preferences for some aquatic plants over others, as shown by multi-species trials (Morrison & Hay, 2011). The high levels of damage to rice are probably more related to factors favouring high densities of *Pomacea* spp. in rice fields (shallow water, access to air, egg laying substrates, plant detritus, algae, biofilms, etc.) than to any preference or specificity of these apple snails for these crops.

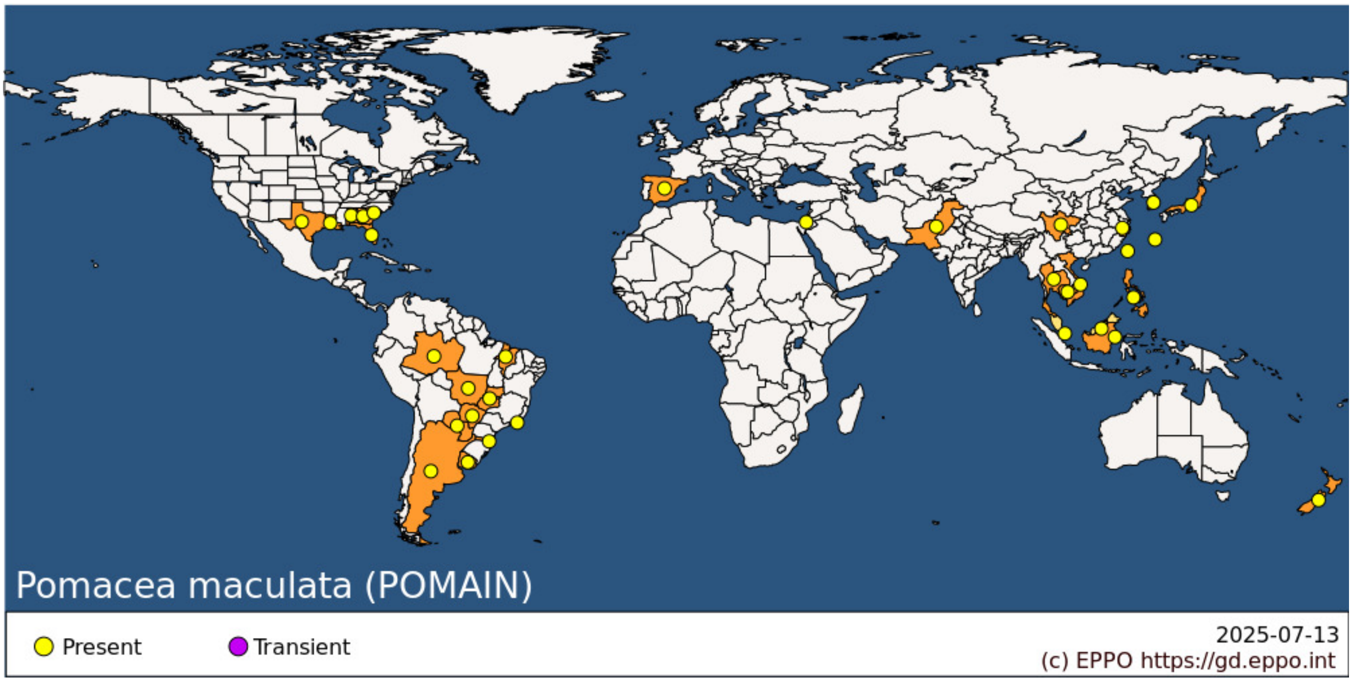
P. maculata has been reported to eat the following aquatic plants in no-choice trials (Bernatis, 2014; Burks *et al*., 2011; Burlakova *et al*., 2009; Baker *et al*., 2010; Low & Anderson, 2017; Morrison & Hay, 2011): *Alternanthera philoxeroides, Bacopa caroliniana, Ceratophyllum demersum, Chara* sp., *Colocasia esculenta, Hydrilla verticillata, Hymenocallis liriosme, Limnobium spongia, Myriophyllum spicatum, Najas guadalupensis, Nuphar advena, Nymphaea odorata, Panicum hemitomon, Panicum repens, Pontederia (Eichhornia) crassipes, Potamogeton illinoensis, Ruppia maritima, Sagittaria latifolia, Sagittaria lancifolia, Schoenoplectus californicus, Utricularia* sp ., *Vallisneria americana* and *Zizania aquatica.*

Host list: *Alternanthera philoxeroides*, *Bacopa caroliniana*, *Ceratophyllum demersum*, *Chara sp.*, *Colocasia esculenta*, *Hydrilla verticillata*, *Hymenocallis liriosme*, *Limnobium spongia*, *Myriophyllum spicatum*, *Najas guadalupensis*, *Nuphar advena*, *Nymphaea odorata*, *Oryza sativa*, *Panicum hemitomon*, *Panicum repens*, *Pontederia crassipes*, *Potamogeton illinoensis*, *Ruppia maritima*, *Sagittaria lancifolia*, *Sagittaria latifolia*, *Schoenoplectus californicus*, *Utricularia sp.*, *Vallisneria americana*, *Zizania aquatica*

GEOGRAPHICAL DISTRIBUTION

The native area of *P. maculata* comprises parts of Argentina, Uruguay, Paraguay and Brazil in South America, from the Paraná River to the Amazonas River Basin and probably also includes Bolivia, Peru and Ecuador (Hayes *et al*., 2012; Cowie *et al*., 2017). While *P. canaliculata* has expanded its distribution to contiguous and disjunct areas in Argentina and also to other South American countries in the last decades, *P. maculata* has been rarely found outside its historical distribution range (Seuffert & Martín, 2021).

P. maculata has been introduced to many countries in different continents, mainly as a potential aquaculture organism and also as an aquarium pet, although not to the same extent than *P. canaliculata*. The list of countries where *P. maculata* has been reported and the dates of introduction or first record was updated by Cowie *et al*. (2017): in South-Eastern Asia it was introduced to Thailand in 1990, to Cambodia before 1995, to China in 2006, to Japan, Malaysia, Singapore, Vietnam and South Korea in 2008 and to the Philippines in 2013. Genetic molecular analyses indicate that Argentinian and Brazilian populations were the source of South-East Asian populations (Yang *et al*. 2019, 2022). *P. maculata* has also been reported in other regions of Asia such as Israel (2008) and Pakistan (2009). In the USA it has been reported in several southeastern states since 1989 and for the first time in Europe in 2009, in the Ebro River Delta (Spain).



EPPO Region: Israel, Spain (mainland)
Asia: Cambodia, China (Sichuan, Zhejiang), Indonesia (Kalimantan), Israel, Japan (Honshu, Ryukyu Archipelago),

Korea, Republic of, Malaysia, Pakistan, Philippines, Singapore, Taiwan, Thailand, Vietnam
North America: United States of America (Alabama, Florida, Georgia, Louisiana, South Carolina, Texas)
South America: Argentina, Brazil (Amazonas, Goias, Maranhao, Mato Grosso, Mato Grosso do Sul, Rio de Janeiro, Santa Catarina), Paraguay, Uruguay
Oceania: New Zealand

BIOLOGY

Pomacea maculata is a very large freshwater snail that inhabits a great variety of habitats, such as shallow lakes, permanent and ephemeral ponds, rivers, streams, reservoirs, paddy fields, channels, etc. (Hayes *et al*., 2015; Burks *et al*., 2017). Density can be very different in each habitat type, for instance, less than 2 snails per square metre in permanent habitats compared to more than 132 snails per square metre in ephemeral ones (Burlakova *et al*., 2010). It can be found underwater on muddy sediment, bedrock or on aquatic plants, either submerged, floating or emergent. *P. maculata* has a dual respiratory system (a well-developed aquatic gill or ctenidium and an aerial lung), enabling it to perform aquatic and aerial respiration simultaneously and also allowing survival out of water and survival in water with no access to air (Mueck *et al*., 2019).

P. maculata is oviparous and dioecious and its reproductive habits are unusual among freshwater snails: females climb out of water onto emergent substrates to deposit bulky egg masses formed by hundreds to thousands of pink eggs with calcareous eggshells (Hayes *et al*., 2015; Burks *et al*., 2017). All other activities (crawling, feeding, respiration, copulation, etc.) are performed underwater. *P. maculata* egg masses are seldom attacked by predators, due to a complex suite of proteins with antidigestive, neurotoxic and antinutritive properties present in the perivitelline fluid that protects and nourishes the embryo inside the eggshell (Heras *et al*., 2017; Ip *et al*., 2019). Embryonic development takes place aerially inside the cleidoic egg and after 10 to 14 days the eggshell cracks and the hatchlings fall into the water. The embryos in the eggs can endure submersion but they need 6-9 days out of water to complete development (Burks *et al*., 2017). Submergence reduces hatching efficiency, but the effect diminishes with the age of the egg mass: less than 6 day-old egg masses may fail completely but the hatching efficiency varies between 38-87 % for 9 day-old egg masses. *P. maculata* hatchlings are quite tolerant to salinity and are able to survive in brackish water (salinities up to 8 psu) for two weeks (Underwood *et al*., 2019).

As is the case for most *Pomacea* spp. the life cycle of *P. maculata* is direct and simple: the hatchlings drop into the water and immediately crawl to reach the water surface and begin to breathe air and to eat; during the first days they consume the reserves of perivitelline fluid stored in their guts after which they can be considered as juveniles. Most life history traits of *P. maculata* and their plasticity are unknown, but Burks *et al.* (2017) compiled the available information. *P. maculata* attains sexual maturity and shows copulatory activity at a shell length of 30-33 mm, three to four months after hatching, and they probably live for one to three years, with a potential fecundity of 36 000 to 54 000 eggs per female. However, egg mass viability can be very low and even null.

Water temperature is of major importance in apple snail biology and ecology (Hayes *et al*., 2015). *P. maculata* feeds between 15 and 35°C and grows between 20 and 35°C but the highest rates are attained at 30°C (Gettys *et al*., 2008). After ten days at 15 °C, *P. maculata* remains active and showed no mortality but at 10 °C and 5 °C activity is reduced and mortality increases to 50 and 60 %; no snail survived after five days at 0 °C; nevertheless, *P. maculata* has established in locations where freezing temperatures occur in winter (Burks *et al.* 2017). Upper lethal limits are around 35-36.6 °C. *P. maculata* snails often live in ephemeral habitats and are able to aestivate during the dry season. Adults may survive for a year on moist sand if air relative humidity is higher than 80% but only for 22 weeks if the sand is dry and the relative humidity lower than 60 %. Even though adult *P. maculata* survive for three days at salinities of 10 psu, activity and feeding rates are almost null above 6 psu (McAskill & Douglass, 2017). They are able to crawl over dry land for three hours at a speed of 3 m per hour (Mueck *et al*., 2018), if water conditions are too stressful or if the waterbody dries up.

DETECTION AND IDENTIFICATION

Symptoms

The symptoms of *Pomacea* spp. 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 attacks of *P. maculata* are usually concentrated in floating or submersed leaves and stems of aquatic plants but they also feed on their roots, bulbs and rhizomes if they are accessible (Burks *et al.*, 2017; Bernatis, 2014). The attacked leaf blades show irregularly chewed margins, sometimes leaving only the main veins, but they could also appear as irregular holes. When feeding on emergent plants such as reeds the snails prefer new stems and shoots and do not attack older parts. Small floating plants such as duckweeds can be ingested in one bite by adult apple snails. *P. maculata* attacks the stems of *V. americana* just above the sediment and cuts-off the floating blades.

The consideration of *P. maculata* as a rice pest is due to its grazing on developing seedlings, especially when rice is directly seeded. Seedlings increase their resistance to apple snail grazing as they grow and apple snails increase their capacity to attack rice as they grow but 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 it can be avoided if soil is maintained saturated but with no free water above it. The big and pink egg masses on plants or other emergent substrates in rice fields or channels are an early warning of an increasing apple snail population. Round areas with no rice are a common symptom of apple snail infestation in rice fields, but they appear late, when population density or biomass are already high.

Morphology

Pomacea maculata is a very large apple snail, reaching up to 16.5 cm from the apex of the shell to the farthest point of the aperture (Cowie *et al.*, 2017; Hayes *et al.*, 2012). The shell is thick and usually smooth, globose, with a large ovoid aperture and a low spire; the suture is usually deeply channelled. The shell is yellowish brown, usually with several reddish to dark brown spiral bands of variable width, fine growth lines and thick arrest marks. The inner lip of the aperture of adult snails is usually pigmented (yellow to orange-red). The operculum is corneous, thick and inflexible, with concentric growth lines around an eccentric nucleus. Shell morphology, including shape, size, thickness and colouration, is frequently used for species identification but may be misleading since shells are similar in many *Pomacea* spp. and there is ample intraspecific variability in many of them.

The colour, shape and size of eggs, as well as the number of eggs per egg mass, although variable, are useful to distinguish *P. maculata* from *P. canaliculata* and other apple snails (Hayes *et al.*, 2012; Cowie *et al.*, 2017): *P. maculata* eggs are spherical, 1.94 mm in diameter and pink red to orange pink; the egg masses usually contain hundreds to thousands of loosely packed eggs (1500 on average and up to 4500). 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

The presence of *Pomacea maculata* in a waterbody can be determined by searching for adult snails, empty shells, shell remains and egg masses (Pierre *et al.*, 2017; Gutierre *et al*., 2019). In the field, *P. maculata* and congeners are most easily detected by the observation of their conspicuous aerial pink eggs-masses on emergent structures, allowing early detection 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.). Floating objects usually cannot be reached by egg-laying females, unless they are touching the bottom of the water body or other submerged objects. 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 more 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, leaving only a white mark with remains of eggshells or a few unhatched eggs. However, 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 of *P. maculata* and congeners can be detected by visual examination while wading or boating if water depth and turbidity are low but juveniles and hatchlings are not easy to spot. In turbid waters or among vegetation, adults can be detected underwater by touch. In shallow areas with vegetation apple snail density was monitored using 0.25 m^2 quadrats (Burlakova *et al.*, 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. Garden rakes passed through submerged vegetation, detritus and sediments can be used to detect hidden or inactive snails (Gooding *et al.*, 2018). Inspection of old strandlines could reveal the presence of empty shells and opercula, even if snails are inactive or buried at that time. Baited traps (e.g. grain and sugar placed in black plastic containers) can be used to attract apple snails and also as a control method (Burks *et al*., 2017).

Preliminary identification of *P. maculata* and other *Pomacea* spp. 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). However, anatomical examination of soft parts of live or well preserved adults by a trained malacologist is required for species confirmation (Hayes *et al*., 2012; Yang & Yu, 2019). Mitochondrial genetic markers (mostly COI) are usually used to discriminate *P. maculata* from *P. canaliculata* and to investigate the geographical origin of the apple snails (Cowie *et al.*, 2017; Yang *et al.*, 2019). The use of nuclear markers may also 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 maculata can disperse through a variety of natural mechanisms that allow displacement at different spatial scales (Smith, 2006; Gutierre *et al.*, 2019). Crawling and climbing are the only two modes of active apple snail movements, mostly within a waterbody or between contiguous ones. Apple snails can crawl several metres per day in streams and *P. maculata* is even able to crawl several metres over dry land (Mueck *et al.*, 2018). Climbing out of water to lay eggs or to avoid fouled water is a common way in which apple snails may leave a tank or channel and later drop outside and may reach a nearby waterbody or waterway.

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 but it can also take place attached to floating macrophyte mats (Gutierre *et al*., 2019). Snails may float or drift downstream with the current until they sink to the bottom or attach to the vegetation. Flooding facilitates the spread through these passive mechanisms. The capacity of *P. maculata* and other apple snails to endure desiccation and starvation and the aerial development of eggs increase the chances of anthropogenic transport, either incidental or intentional, and successful establishment (Smith, 2006; Burks *et al.*, 2017; Glasheen *et al.*, 2017). The capacity of fecundated *P. maculata* females to lay an egg mass with hundreds to thousands of eggs increases the chances of establishment.

Intentional transport of *P. maculata* and congeners has taken place through legal pathways and has even been supported by government agencies, but unregulated and illegal transport is common (Smith, 2006; Burks *et al*., 2017; Cowie *et al.*, 2017; Horgan, 2017, 2018). The aquarium pet trade and aquaculture projects are the main causes of intentional transport of *Pomacea* spp. across international borders and between continents. 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.

Incidental transport 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 of *Pomacea* spp. (Cowie *et al.*, 2017). Eggs masses of *P. maculata* deposited on boats can be transported during navigation (Gutierre *et al.*, 2019) 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.

PEST SIGNIFICANCE

Economic impact

The economic impacts of *Pomacea* spp. on agriculture are huge, especially in tropical countries where rice is one of the main crops, such as in South-East Asia. The economic impacts are the result of direct productivity losses due to the damage to crops plus the costs of control measures against the snail. Economic impacts of *P. maculata* alone has rarely been assessed but for the Ebro delta, where it is the only *Pomacea* species present, the costs of eradication and control have been estimated at 5.3 million EUR between 2010 and 2012 and 5 million EUR for the period 2014–2020 (Bertolero & Navarro, 2018). Costs associated with apple snail (*Pomacea* spp.) 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.*, 2006). A total annual cost between 806–2138 million USD was estimated for the rice sector of the Philippines, Vietnam and Thailand (Nghiem *et al.*, 2013). Economic estimates are not available yet for the multiple environmental impacts of apple snail invasions (Horgan *et al.*, 2014b; Carlsson, 2017; Martín *et al.*, 2019), for instance an increase in transmission of emerging human diseases and the loss or deterioration of ecosystem services (Lv *et al.*, 2011; Gilioli *et al.*, 2017a,b).

Control

Different control methods against *Pomacea* spp. have been proposed and applied mostly in aquatic crops but in the particular case of *P. maculata* several small scale eradication attempts were made in natural or man-managed wetlands (Burks *et al*., 2017). 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). In the case of *P. maculata* ecological impacts on natural wetlands and endangered species prompted many studies in southern areas of the USA (Burks *et al.*, 2017).

Cultural control methods aim to reduce damage to rice through a restriction of apple snail activities and of their 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. Manipulation of water levels may also be used to submerse egg masses or to leave hatchlings, juveniles and adults out of water, where there may die by desiccation or be attacked by predators (Burks *et al*., 2017). In the Ebro Delta winter flooding of rice fields was stopped to attempt to control *P. maculata* with no negative effects on the abundance of birds that use them to feed (Bernardo-Madrid *et al*., 2022); temporary flooding with marine water of rice fields and channels, especially the latter, have also been used in this irrigation system to control *P. maculata* (Gencat, 2018). 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 *Pomacea* spp. 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 and also in natural and artificial wetlands invaded by *P. maculata* (Burks *et al*., 2017). It can be very effective, inexpensive and environmentally friendly (Bernatis & Warren, 2014), especially in small and isolated wetlands. Spraying egg masses with different substances reduces or impedes egg development and hatching, if applied at the right moment (Wu *et al.*, 2005).

Handpicking of juvenile and adult apple 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. *Pomacea maculata* seem especially susceptible to baiting and trapping (Burks *et al*., 2017). 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, including application of copper sulphate, methaldehyde, niclosamide and diverse insecticides, are frequently used against apple snails because they are very effective although they are not specific and may harm other aquatic animals (Horgan, 2017; Burks *et al.,* 2017). Because of their lower side effects on other animals, new molluscicides based on plant extracts have been tried against *P. maculata* in the Ebro Delta (Castillo-Ruiz *et al*., 2018). Fertilizers commonly used in rice fields 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) and may also be predatory to *P. maculata* (Burks *et al.*, 2017). Farming ducks and fish in rice fields are effective ways of controlling apple snail populations. However, the adults of latter species may be invulnerable to many of these predators due to their big size, thick shell and hard operculum. On the contrary, the small size of *P. maculata* hatchlings renders them more susceptible than those of other *Pomacea* spp. to predation by crawfish (Dorn & Hafsadi, 2016) and freshwater prawns like *Macrobrachium rosenbergii*, whose biotechnologically developed all-male strains have been tried for inundative biocontrol of apple snails (Savaya-Alkalay *et al.*, 2018).

In order to control *P. canaliculata* in rice fields in Ecuador, farmers enhanced predation by highly specialized birds of prey (snail kites) (Horgan *et al.*, 2014a). Snail kites are also able to feed on *P. maculata* (Cattau *et al*., 2016), despite its much bigger size. Other wild native bird species, such as ibises, can also cause high levels of predation on *Pomacea* spp. (Bertolero & Navarro, 2018) 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. maculata* and *P. canaliculata* 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 European Union (EU), their introduction is prohibited and official inspections for the import and movement of aquatic plants within the EU have been set to prevent their introduction and spread (EFSA, 2020). 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 is the first measure to avoid the multiple negative impacts associated with the introduction of *P. maculata* and *P. canaliculata*, as once established their eradication is very difficult and costly, from both economic and environmental viewpoints (Burks *et al.*, 2017; Horgan, 2017, 2018). To prevent the entry and spread of *Pomacea* spp. their import and trade should be banned. Aestivating adult *Pomacea* spp. 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 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).

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