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THE GOLDEN APPLE SNAIL *POMACEA CANALICULATA*: A REVIEW ON INVASION, DISPERSION AND CONTROL

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Abstract
The golden apple snail (GAS) *Pomacea canaliculata* is the dominant aquatic gastropod and a major rice pest in many Asian countries. We review GAS invasions and synthetic and natural products for its biological and chemical control in wetland agricultural systems.

Introduction
The freshwater golden apple snail (GAS), *Pomacea canaliculata* is endemic to South America (Fig 1). Golden apple snails were introduced several times in Asia (Hayes *et al.*, 2008) as a food source and for use in commercial aquaculture, but these intended uses were not commercially successful. Thus, unused specimens of *P.canaliculata* were discarded into and rapidly spread through aquatic habitats (Halwart, 1994) and their release led to them becoming a major pest in wetland agricultural systems, most particularly as a rice pest (Hickel *et al.*, 2012).

In SE Asia and elsewhere, chemical control of GAS using molluscicides has been favored due to the immediate results, but these chemicals are known to be detrimental to the environment and human health (Carlsson & Bronmark, 2006). Some farmers have attempted to remove or destroy the GAS egg masses (Fig 2) deposited on vegetation as an alternative to chemical control (Joshi, 2007), whereas in South America wooden perches have been used to attract snail kites *Rosthramus sociabilis* as effective predators of the snails. However, employment of plant-based molluscicides could be an effective organic alternative, as some plant products have been proven to be effective molluscicides in laboratory trials and can be cheaper and safer for the environment and human health than synthetic chemicals.

Apple snail distribution, invasion and damage
After its introduction, rapid dispersal of GAS occurred throughout East and Southeast Asia. Apart from becoming a major pest of rice, it induced a decrease in the numbers of native gastropods in the region (Karraker & Dudgeon, 2014) (Fig 3). The first introduction of *Pomacea canaliculata* into the USA occurred in 1989 in taro (*Colocasia esculenta*) fields on Hawaii, where it was reported from 139 sites on the island of Maui (Lach & Cowie, 1999). However, pomacean snails were first introduced in the USA during the 1950s *via* the aquarium trade with several different species becoming established in Florida, North Carolina, California, Texas, Georgia, and Arizona (Howells *et al.* 2006). Improved species taxonomy and identification has led to more accurate assessments of GAS and its distribution.

In its native range in southern Brazil, *P. canaliculata* has become a major pest for pre-germinated rice crops (Fig 4), together with other harmful species of gastropods, such as *Physella acuta, Physa marmorata, Biomphalaria tenagophila*, *Biomphalaria peregrine*. Wetland water, used for rice field irrigation allows these snails to invade during irrigation and heavy rainfall events, and feed on sprouting rice seed-

Figure 1. Golden Apple Snail (GAS). (Photo credits: Mr. Fabiano Carvalho de Brito, PUCRS, Brazil).

Figure 2. GAS Egg masses in Direct-Seeded Rice, Eldorado do Sul, Rio Grande do Sul, December 2015, Brazil. (Photo credits: Ms. Danielle Almeida, IRGA, Brazil).

lings resulting in extensive crop damage (Fig 4). There are no known registered products for direct control of snail rice pests in Brazil (Cowie, 2002).

In other Latin American countries, *P. canaliculata* has been a danger to rice crops since 2005 particularly the lowland regions of the Ecuadorian provinces of Guayas and Los Rios. Surveyed farmers noted that even with heavy use of the molluscicides, endosuflan and metaldehyde, snail rice crop damage remained high, especially during the rainy season. (Rodriguez *et al*., 2015). However, the predatory snail kite also increased, leading to an expansion of the snail kite's range which had been contracting since the 1970s (Horgan *et al*., 2014). Its spread into Mexico can be traced to the release of GAS into tributaries of the Colorado River by aquarists in the City of Yuma, Arizona, from which they dispersed downstream into Mexican portions of the Colorado River drainage system (Campos *et al*., 2013).

In Europe, snail damage has been reported in some Portuguese rice fields and in Spain, where rice is grown in the delta of the River Ebro, where it has been speculated that *P. canaliculata* or *P. lineata* might also be present (Lopez *et al*., 2010).

Since its release in Asia, the snail has fed on a wide range of aquatic plants of economic value, including young rice seedlings, taro, swamp cabbage, lotus, mat rush, Chinese mat grass, wild rice, Japanese parsley, water chestnuts, and azolla. But, by far, the greatest damage occurs in irrigated rice culture, which provides an ideal environment for GAS dispersal and growth. Thus, after its invasion and spread through direct release, animal trails or irrigation pipelines, GAS rapidly has become one of the most damaging rice pests in Asia (Naylor, 1996).

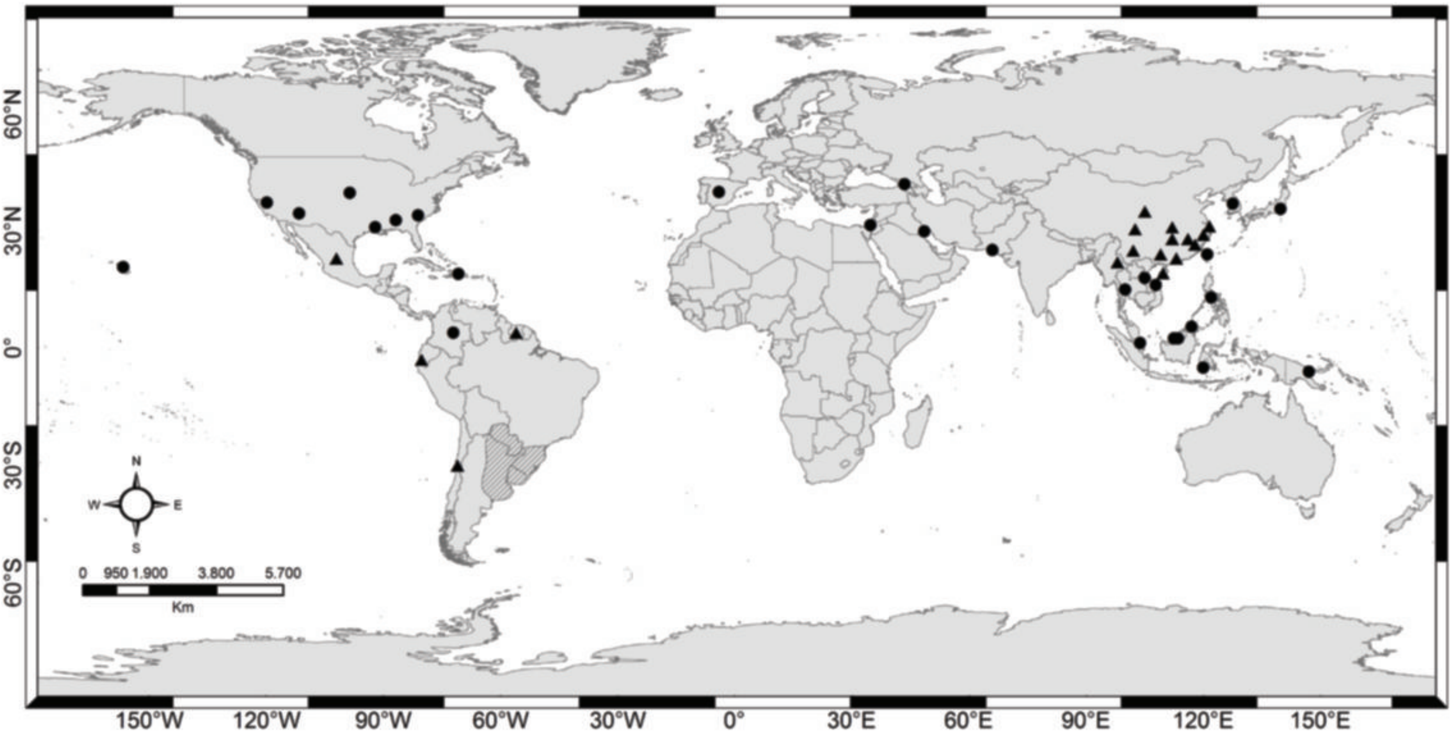

Fig. 3. GAS Global Distribution. (Photo credits: Mr. Fabiano Carvalho de Brito, PUCRS, Brazil).

Table 1. Global Distribution, Origin, Invasion Pathways, and Year reported of ***Pomacea*** spp.

Country Reported	Origin	Invasion Pathway	Year Reported	Reference
Alabama	Introduced	Aquarium trade	?	EPPO (2012)
Argentina	Native	?	?	Hayes et al. (2008)
Arizona	Introduced	Aquarium trade	2005	Howells et al. (2006)
Australia	Introduced	Intercepted	?	Plant and Health (2009)
California	Introduced	Aquarium trade	?	Howells et al. (2006)
Chile	Invasive	Dispersion?	Before 2008	Letelier & Soto-Acuna (2008)
China	Invasive	Food consumption	1981-1985	Halwart (1994)
Colombia	Introduced	?	?	Hayes et al. (2012)
Dominican Republic	Introduced	Clean fish production ponds	1990/1991	Hayes et al. (2012)
Ecuador	Invasive	?	2005	Felix (2011)
Fujian	Invasive	Food consumption	1985	Mochida (1991)
Georgia	Introduced	Aquarium trade	?	EPPO (2012)
Guangdong	Invasive	Food consumption	1988	Mochida (1991)
Guangxi	Invasive	Food consumption	?	Halwart (1994)
Hainan	Invasive	Food consumption	?	Lv et al. (2011)
Hawaii	Introduced	Aquarium trade	1989	Tran et al. (2008)
Hubei	Invasive	Food consumption	?	Lv et al. (2011)
Hunan	Invasive	Food consumption	?	Lv et al. (2011)
Indonesia	Introduced	Aquarium trade	1981-1984	Mochida (1991)
Iraq	Introduced	by ships?	2014	Khaled (2015)
Israel	Introduced	Aquarium trade	?	EPPO (2012)
Japan	Introduced	Food consumption	1981	Mochida (1991)
Jiangxi	Invasive	Food consumption	?	Lv et al. (2011)
Korea, Republic of	Introduced	Food consumption	1981-1986	Mochida (1991)
Laos PDR	Introduced	Food consumption	1991-1994	Douangboupha & Khamphoukeo (2006)
Louisiana	Introduced	Aquarium trade	?	EPPO (2012)
Malaysia	Introduced	Food consumption	1987	Yahaya et al. (2006)
Mexico	Invasive	?	2013	Campos et al. (2013)
Myanmar	Invasive	?	?	Hayes et al. (2008)
Pakistan	Introduced	Aquarium trade	2012	Baloch (2012)
Papua New Guinea	Introduced	?	1990-1993	Halwart & Bartley (2006)
Philippines	Introduced	Food consumption	1980-1982	Mochida (1991)
Sabah	Introduced	Food consumption	1992	Teo (2004)
Sarawak	Introduced	Food consumption	1987	Mochida (1991)
Shanghai	Invasive	Food consumption	?	Lv et al. (2011)
Sichuan	Invasive	Food consumption	?	Lv et al. (2011)
Singapore	Introduced	?	1993	Cowie (2002)
South Carolina	Introduced	Aquarium trade	?	EPPO (2012)
Spain	Introduced	?	2009	Anonymous (2011)
Suriname	Invasive	Aquarium trade	2006	Wiryareja & Tjoe-Awie (2006)
Taiwan	Introduced	Food consumption	1979-1981	Mochida (1991)
Thailand	Introduced	Food consumption	1982-1990	Mochida (1991)
Uruguay	Native	?	?	Hayes et al. (2008)
USA	Introduced	Aquarium trade	?	Howells et al. (2006)
Vietnam	Introduced	Food consumption	around 1988	Cuong (2006)
Yunnan	Invasive	Food consumption	?	Lv et al. (2011)
Zhejiang	Invasive	Food consumption	1985	Mochida (1991)

? -Information lacking.

Invasive aquatic invertebrates can have high negative environmental impacts, but their management is still less well developed than for other taxa such as mammals or birds. It is estimated that aquatic invertebrates account for approximately 24% of all environmental economic impacts (Pysek & Richardson, 2010). The degree of these impacts may increase as Ampullariid snail populations continue to expand further into currently uninfested countries. Hence, there is a need for management practices adapted to local conditions (Cowie, 2002).

It is estimated that damage caused by invasions of invasive species were costing the United States, United Kingdom, Australia, South Africa, India and Brazil more than $ 314 billion per year (Pimentel *et al.*, 2001). Quantifying the nega-

Fig. 4. GAS damage as cut leaves in Direct-Seeded Rice, Eldorado do Sul, Rio Grande do Sul, December 2015, Brazil. (Photo credits: Ms. Danielle Almeida, IRGA, Brazil).

tive impacts of these invasive species is difficult and complex as the knowledge required to assess the impacts of many taxa at regional scales is still scarce. Certainly, managing *P. canaliculata* damage has become very expensive. Published data on GAS damage appears to have been grossly underestimated. An estimated annual loss due to crop damage by non-indigenous species in Southeast Asian countries translates to about $33.5 billion of total damage including that to agriculture, the environment and public health. The total estimated damage caused by GAS in Southeast Asian countries is $1.47 billion annually. In Southeast Asian countries such as Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam, the estimates are probably conservative as they do not include damage to the environment or human health (Nghiem, 2013).

Golden apple snail biological control

The most effective method to control snails relates to crop establishment. For instance, transplanted 20-day-old seedlings are better able to withstand snail damage than 13-day-old transplanted seedlings or direct-seeded rice. Seedlings more than 30-days-old are more tolerant to snail damage than younger seedlings.

Over the past 15 years, a number of options for *P. canaliculata* biological control have emerged. The fire ant *Solenopsis geminata* consumed *P. canaliculata* eggs in Philippine field experiments in spite of the fact that the eggs are considered toxic to most animals (Dreon *et al*., 2014). Although another ant (*Pheidologeton* spp.) has also been reported to consume GAS eggs (Yusa, 2006), further studies are needed to confirm the impact of ants. The relative absence of natural predators has allowed the rapid establishment and growth of GAS populations soon after their introduction to an un-infested habitat.

Ducks have been extensively used to control *P. canaliculata* in both transplanted and direct-seeded rice culture, but with variable results, depending on the race of the ducks as well as the time of release. The effective number of ducks required is estimated to be around 5–10 ducks per hectare, with results being more favorable in transplanted rather than direct-seeded rice (Teo, 2001). While this strategy entails some cost, there is evidence that it has been effective in some Asian and southern Latin American countries (IRGA, 2010).

A number of different, fish will eat snails, including the African catfish (*Clarias gariepinus*) and common carp (*Cyprinus carpio*), but the latter was more adaptable to various different farming environments (Teo, 2006). Hence, the common carp is the recommended fish species of choice for controlling GAS in rice culture at a density of 10 fish/plot or 2041 fish/ha. Apart from being an alternative to using molluscicides, the deployment of carp can provide additional income for farmers. Halwart *et al*. (2014) studied the efficacy of fish predators for control of GAS in transplanted rice during dry and wet seasons. They showed that common carp were able to suppress snail populations by 58–87% compared to 48–87% by Nile tilapia (*Oreochromis niloticus*) both being greater than occurred in no-fish plots. However, neither fish species could completely prevent infestation by more mature snails with larger shell sizes.

The treatment of GAS eggs with the parasitic fungus *Paecilomyces lilacinus* led to 100% mortality of 1 day old juvenile snails, susceptible to the conidia and only 12% of eggs hatched in contrast to 100% in controls (Maketon *et al*., 2009). However, juvenile snails became increasingly less susceptible to the enzymatic activity of the fungus with increasing age and maturity, limiting its use as a biological control agent. In another laboratory study Salcedo (2013) evaluated the pathogenicity of the nematode *Heterorhabditis bacteriophora* and showed that the inoculation of up to 16,000 nematodes per snail leads to 100% snail mortality in 96 h.

Current biological control with fish seems to be the most promising option for sustainable GAS management. However, biocontrol must be complemented with other methods such as lowering water levels or draining the rice field. Draining will not kill GAS because they are able to survive long periods of desiccation. GAS move only in standing water and are immobile at depths less than half of their shell height, thus periodic draining of the fields to a depth of 1 cm is a very effective control practice because it prevents the specimens of *P. canaliculata* from moving and feeding (Wada, 2004). The field should be well levelled and maintained at saturation, minimizing the time it contains standing water. Farmers with their own pumps can manage water levels better than those served by large irrigation systems.

Chemical control

While plant components are natural and socially and environmentally acceptable, they are not necessarily non-toxic. Several plants have active ingredients that could be potential biodegradable molluscicides, including *saponins, flavonoids, steroids, tannins,* and other secondary metabolites (Valverde *et al*., 2010).

Huang *et al* (2003) exposed specimens of *P. canaliculata* to powder extracts of soap nut pericarp from *Sapindus mukorossi* (Sapindaceae) and attained LC_{50} values of 85, 22, and 17 ppm after treating for 24, 48, and 72h, respectively. Bioassay experiments with a new acetylated triterpene saponin, hederagenin, comparing it to niclosamide and metaldehyde revealed that all of the isolated saponins exhibited molluscicidal effects against *P. canaliculata*. Niclosamide (0.8 mgL^{-1}) exposure

Table 2. Effectiveness of the Biological (Botanicals and Natural Enemies) Control Agents against ***Pomacea*** spp.

Botanical Name	Active Compound/Substance	Effective Concentration	Reference
Sapindus mukorossi	Hederagenina (Saponin)	85 mg l-1 , 22 mg l-1 , and 17 mg l-1 in 24, 48, and 72h, respectively	Huang et al. (2003)
Artemisia douglasiana	Vulgarone B (Sesquiterpene)	50 mg l^{-1}	Joshi et al. (2005)
Chenopodium quinoa	Saponins from husk	33-54 mg l^{-1}	San Martin et al. (2008)
Azadirachta indica	Aqueous extracts from leaves	(LC 50) 142.75 mg l^{-1}	Venturini et al. (2008)
Chenopodium chinoa	Quinoa Saponins	9, 11 and 13 mg l^{-1} (ovicidal effects in 1-5 day old)	Joshi et al. (2008)
Oldenlandia affinis and *Viola odorata*	Cyclotides	150-300 μ/ml	Plan et al. (2008)
Chenopodium quinoa	Alkali modified Quinoa Saponins	30 mg l^{-1} in 36h	San Martin et al. (2009)
Nerium indicum	Cardiac Glycosides	(LC 50) 3.71mg l^{-1} in 96 h	Dai et al. (2011)
Azadiractha indica	Dried seed extracts	(LC 50) 500 mg l^{-1} in 96 h	Latip et al. (2013)
	Fresh seed extracts	(LC 50) 267.96 mg l^{-1} in 96 h	
Oryza sativa	Rice husk based on activated carbon	0.034 U/ml to disrupt the hatching process	Salleh et al. (2013)
Sapindus saponaria, Solanum mammosum and *Jatropha curcas*	Extracts containing alkaloids, phenols, tannins and saponins	(LC 50)17.8 mg l-1 and 24.04 mg l-1	Manzano et al. (2014)
Ilex paraguariensis St.-Hil	Extracts of unripe fruits	(LC 50) 26 mg l^{-1} in a 16 h	Brito (2015)
Natural Enemies	**Zoological Name**	**Stage of** *Pomacea* **spp. Consumed**	**Reference**
Ants	*Solenopsis geminata* *Pheidologeton* spp.	Predates on Egg masses	Yusa (2001)
Long-horned grasshoppers	*Conocephalus longipennis*	Predates on Egg masses	Joshi (2001)
	Conocephalus maculatus		Joshi (2001)
Ducks: Varieties: Mallard, William Siam, Taiwan, Peking, Cherry Valley, Muscovy and Khaki Campbell	–	Predates on Juveniles and Sub-adults	Teo (2001)
Study covered 46 species in 16 orders: Crayfishes, Dragonfly larvae, Diving beetles, freshwater fishes, Carp and turtles	*Macrobrachium formosense, Tribolodon hakonensis* and *Zacco temmincki*	Predates on Juveniles and Sub-adults	Yusa (2006; 2014)
Fish: Common carp	*Cyprinus carpio*	Predates on Juveniles and Sub-adults	Ichinose et al. (2002)
Fishes: Common carp and African catfish	*Cyprinus carpio* and *Clarias gariepinus*	Predates on Juveniles and Sub-adults	Teo (2006)
Fish: Pearl cichlid	*Geophagus brasiliensis*	Predates on Juveniles and Sub-adults	Silva & Figueiredo (2014)
Fishes: common and black carps	*Cyprinus carpio* and *Mylopharyngodon piceus*	Predates on Juveniles and Sub-adults	Qiu et al. (2014)
Fishes: Nile tilapia and Common carp	*Oreochromis niloticus* and *Cyprinus carpio*	Predates on Juveniles and Sub-adults	Halwart et al. (2014)
Fungi	*Paecilomyces lilacinus*	Parasitism by killed newly-hatched juvenile snails	Maketon et al. (2009)
Nematode	*Heterorhabditis bacteriophora*	Inoculations septicemia	Salcedo (2013)

yielded an 85% mortality rate while that of metaldehyde (20 ppm) was 40%. Likewise, the soap nut powder of pericarp extracts (4ppm) displayed 62% mortality to GAS in paddy fields (Huang *et al*., 2003). These results showed that both isolated saponins and crude soap nut extract express molluscicidal activity against *P. canaliculata*. However, at present, farmers appear to prefer the use of conventional pesticides as none of the botanical molluscicides identified has been produced commercially (Joshi, 2007).

Conclusion

The Invasive Species Compendium (CABI, 2014) contains extensive information on world-wide GAS invasions, establishment and damage. Extensive documented evidence suggests that its capacity for damage to invaded wetland agricultural systems should not be underestimated, as its range continues to expand with invasions throughout Asia (Joshi, 2007). The total cost of managing GAS amounts to more than $ 1200 million annually. This review of alternative methodologies to control damage by pest snails in wetland agriculture shows that the impact of various biological control systems examined in the laboratory need to be studied more fully under field conditions before they can be widely used to control GAS.

References

CABI, 2014. *Invasive Species Compendium*. Datasheets, maps, images, abstracts and full text on invasive species of the world. http://www.cabi.org/isc/datasheet/68490

Campos, E., Ruiz-Campos, G., Delgadillo, J., 2013. First record of the exotic apple snail *Pomacea canaliculata* (Gastropoda: Ampullariidae) in Mexico, with remarks on its spreading in the Lower Colorado River. *Revista Mexicana de Biodiversidad*. 84 (2), 671–675.

Carlsson, N.O.L., Bronmark, C., 2006. Size-dependent effects of an invasive herbivorous snail (*Pomacea canaliculata*) on macrophytes and periphyton in Asian wetlands. *Freshwater Biology.* 51, 695–704.

Cowie, R.H., 2002. Apple snails (Ampullariidae) as agricultural pests: their biology, impacts and management. In: Barker, G.M. (Ed.), *Molluscs as Crop Pests*. CABI. International, Wallingford, UK, pp. 145–189.

Dreon, M.S., Fernández, P.E, Gimeno, E.J., Heras, H. 2014. Insights into embryo defenses of the invasive apple snail *Pomacea canaliculata*: Egg mass ingestion affects rat intestine morphology and growth. *PLOS Neglected Tropical Diseases*. 8 (6), 1–10.

Halwart, M., 1994. The golden apple snail *Pomacea canaliculata* in Asian rice farming systems: present impact and future threat. *International Journal of Pest Management*. 40 (2), 199–206.

Halwart, M., Litsinger, J.A., Viray, M.C., Kaule, G., 2014. Efficacy of common carp and nile tilapia as biocontrol agents of the golden apple snail in the Philippines. *Philippine Journal of Science*. 143 (2), 25–136.

Hayes, K.A., Joshi, R.C., Thiengo, S.C., Cowie, R.H., 2008. Out of South America: Multiple origins of non-native apple snails in Asia. *Diversity and Distributions*. 14(4), 701–712.

Hickel, E.R., K.K. Scheuermann, D.S. Eberhardt. 2012. Manejo de caramujos em lavouras de arroz irrigado, em sistema de cultivo pré-germinado. *Agropecuária Catarinense*. 25 (1), 54–57.

Howells, R.G., Burlakova, L.E., Karatayev, A.Y., Marfurt. R.K., Burks, R.L., 2006. Native and introduced Ampullaridae in North America: History, status and ecology. In: Joshi, R.C., and Sebastian, L.S. (Eds.), *Global Advances in Ecology and Management of Golden Apple Snails*, Nueva Ecija: Philippine Rice Research Institute, pp. 73–112.

Horgan, F.G., Felix, M.I., Portalanza, D.E., Sanchez, L., Moya Rios, W.M., Farah, S.E., Wither, J.A., Andrade, C.I., Espin, E.B., 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.

Huang, H.C., Liao, S.C., Chang, F.R., Kuo, Y.H., Wu, Y.C., 2003. Molluscicide saponins from *Sapindus mukorossi*, inhibitory agents of golden apple snails, *Pomacea canaliculata*. *Journal of Agricultural and Food Chemistry.* 51, 4916–4919.

IRGA, 2010. Instituto Riograndense do Arroz: *Cresce o número de marrecos de Pequim na lavoura de arroz*. http://www.irga.rs.gov.br/conteudo/2560/cresce-o-numero-de-marrecos-de-pequim-na-lavoura-de-arroz-

Joshi, R.C., 2007. Problems with the management of the golden apple snail *Pomacea canaliculata*: an important exotic pest of rice in Asia. In: Vreysen, M.J.B., Robinson, A.S., Hendrichs, J., (Eds.), *Area-Wide Control of Insect Pests*, Springer Netherlands, p.257–264.

Karraker, N.E., Dudgeon D., 2014. Invasive apple snails (*Pomacea canaliculata*) are predators of amphibians in South China. *Biological Invasions*. 16, 1785–1789.

Lach, L., Cowie, R., 1999. The spread of the introduced freshwater apple snail *Pomacea canaliculata* (Lamarck) (Gastropoda: Ampullariidae) on O'ahu, *Hawai'i. Bishop Museum Occasional Papers.*, 58, 66–71.

Lopez, M.A., Altaba, C.R., Andree, K.B., Lopez, V., 2010. First invasion of the apple snail *Pomacea insularum* in Europe. Tentacle – The Newsletter of the IUCN/SSC Mollusk Specialist Group. 18, 26–28.

Maketon, M., Suttichart, K., Domhom, J., 2009. Effective control of invasive apple snail (*Pomacea canaliculata* Lamarck) using *Paecilomyces lilacinus* (Thom) Samson. *Malacologia*. 51(1), 181–190.

Naylor, R., 1996. Invasions in agriculture: Assessing the cost of the golden apple snail in Asia. *Ambio*. 25 (7), 443–448.

Nghiem, L.T.P., Soliman, T., Yeo, D.C.J., Tan, H.T.W., Evans, T.A., Mumford, J.D., 2013. Economic and environmental impacts of harmful non-indigenous species in Southeast Asia. *PLoS ONE* 8(8): e71255. doi:10.1371/journal.pone.0071255

Pimentel, D., McNair, S., Janecka, J., Wightman, J., Simmonds, C., O'Connell, E., Wong, L., Russel, J., Zern, T., Aquino, T., Tsomondo, T., 2001. Economic and environmental threats of alien plant, animal, and microbe invasions. *Agriculture, Ecosystems and Environment*. 84, 1–20.

Pysek, P., Richardson, D.M., 2010. Invasive species, environmental change and management, and health. *Annual Review of Environment and Resources*. 35, 25–55.

Rodriguez, M.C., Rodriguez, G.M.C., Burgos, J.A., Robles, L.,M. 2015. *Pomacea canaliculata* Plaga del Arroz en Ecuador. Universidad de las Fuerzas Armadas. Comission Editorial de la Universidad de las Fuerzas Armadas, ESPE.

Salcedo, G.A., 2013. Acción patogénica de *Heterorhabditis bacteriophora* (Poinar) sobre el caracol manzana (*Pomacea canaliculata* Lamarck), plaga de los cultivos de arroz (*Oriza sativa*) en la cuenca baja del río Daule, Guayas, Ecuador. *Avances en Investigación Agropecuaria*. 17(2), 53–56.

Teo, S.S., 2001. Evaluation of different duck varieties for the control of the golden apple snail (*Pomacea canaliculata*) in transplanted and direct seeded rice. *Crop Protection*. 20(7), 599–604.

Teo, S.S., 2006. Evaluation of different species of fish for biological control of golden apple snail *Pomacea canaliculata* (Lamarck) in rice. *Crop Protection*. 25, 1004–1012.

Valverde, A.L., Silva-Souza, N., Marques, A.M., Cantanhede, S.P., 2010. Atividade moluscicida de plantas: uma alternative profilática. *Brazilian Journal of Pharmacognosy.* 20(2), 282–288.

Wada, T., 2004. Strategies for controlling the apple snail *Pomacea canaliculata* (Lamarck) (Gastropoda: Ampullariidae) in Japanese direct-sown paddy fields. *Japan Agricultural Research Quarterly.* 38(2), 75–80.

Yusa, Y., 2006. Predators of the introduced apple snail, *Pomacea canaliculata* (Gastropoda: Ampullariidae): their effectiveness and utilization in biological control. In: Joshi, R.C., and Sebastian, L.S. (Eds.), *Global Advances In Ecology and Management of Golden Apple Snail*, Nueva Ecija: Philippine Rice Research Institute, pp.345–361.

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