The current status of invasive apple snails, *Pomacea* spp, in Malaysia: a short review

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Abstract

Freshwater snails of the genus *Pomacea*, commonly known as apple snails, are native to South America, but have been introduced (intentionally and unintentionally) into many regions for various reasons. This invasive snail was unintentionally introduced into Malaysia as early as 1992. It is one of the most successful invaders of freshwaters and has a major impact on aquatic habitats, especially rice fields, where it destroys the growing stems of paddy, consequently causing massive economic losses. This invasive apple snail has spread and is widely distributed throughout Malaysian aquatic habitats including traditional and commercial rice fields, irrigation and drainage canals, rivers and tributaries, and wetlands, including those in Sabah and Sarawak, Borneo. Strategies have been devised and action undertaken by various government agricultural agencies, universities and research institutions to control and manage the infestations and invasions of apple snails in the rice fields. The impact of apple snail damage on rice fields in Malaysia has been extensively documented. However, more action should be taken to determine why invasive apple snails have become so successfully established, to be able to predict their future spread and impact.

Introduction

Experiences throughout the world have shown that a number of problems may arise following the introduction and invasion of a new species, such as disruption of the receiving environment, predation and interspecific competition, overcrowding and stunting, genetic degradation, introduction of parasites and diseases, and extinction of many native species including flora and fauna (Pallewatta *et al*, 2003; Simberloff *et al*, 2005; Joshi *et al*, 2017).

Spreading and dispersal of non-native species such as gastropods is one of the most important issues in natural resource management and conservation biology today. Invasive apple snails (*Pomacea* spp), native to South America, have been introduced intentionally and unintentionally in many regions for various reasons (Rejesus *et al*, 1990; Cowie, 2002; Joshi *et al*, 2017). This invasive apple snail was unintentionally introduced into Malaysia in 1992 (Arfan *et al*, 2014; Yahaya *et al*, 2017; Teo & Hamsein, 2017). Two species of apple snails, namely *Pomacea canaliculata* Lam. and *P. insularum* (D'Orbigny) have been identified (Cowie, 2002; Yahaya *et al*, 2006; Ng *et al*, 2017). However, Hayes *et al* (2008) state that *P. insularum* should be synonymised with *P. maculata* Perry. Thus, further detailed identification of *Pomacea* spp found in Malaysian waters using molecular techniques and anatomical examination should be conducted to differentiate between the species. Although *P. canaliculata* is more widely distributed in invaded areas than *P. maculata* (Hayes *et al*, 2008; Cowie *et al*, 2017), recent studies by Arfan *et al* (2014) found that *P. maculata* is also abundant and widespread in Peninsular Malaysia.

Ecology and distribution

Species of *Pomacea* have spread and are widely distributed throughout Malaysian aquatic habitats such as in traditional and commercial rice fields, irrigation and drainage canals, rivers and tributaries, wetlands, commercial and recreational ponds (Figure 1 A & B), including those in Sabah and Sarawak, Borneo (Figure 2) (Salleh *et al*, 2012; Arfan *et al*, 2016; Yahaya *et al*, 2017; Ng *et al*, 2017; Teo & Hamsein, 2017).

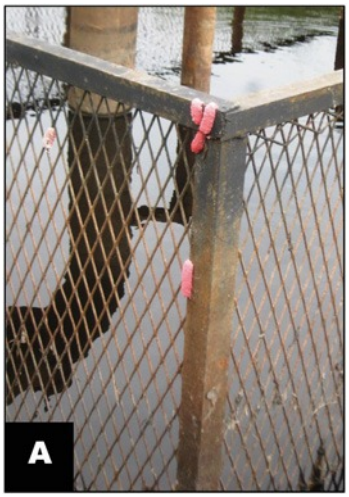

Figure 1. Invasive apple snail, *Pomacea* spp, egg masses (A), and missing rice plants in waterlogged areas (B), caused by their feeding, Sungai Besar, Selangor, Malaysia (Photos: Khairul Adha A Rahim)

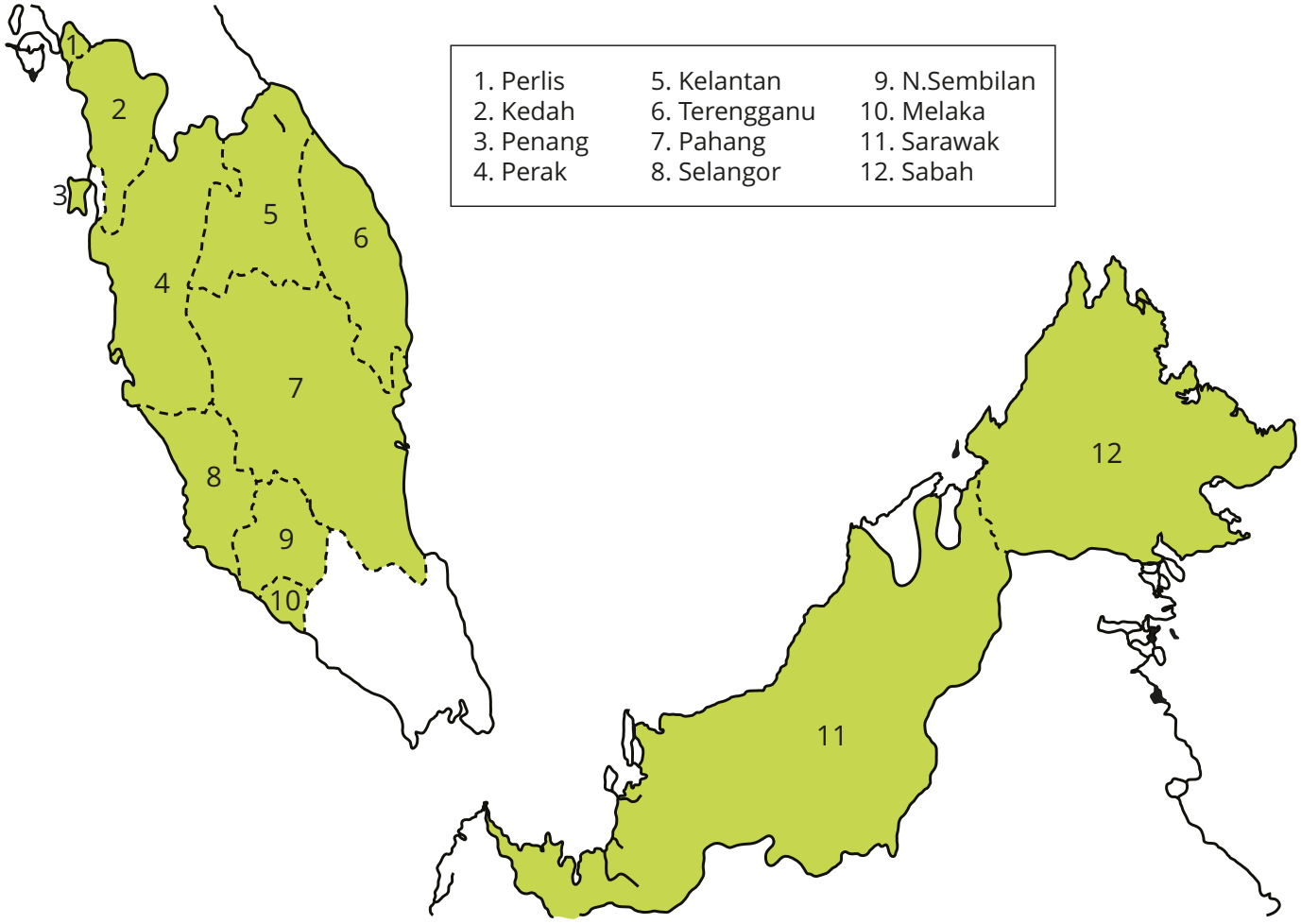

Figure 2. States with invasive apple snails, *Pomacea* spp, in Malaysia (Source: data from Yahaya *et al*, 2017; Teo & Hamsein, 2017; Arfan *et al*, 2016)

Invasions and pathways

Invasive apple snails are one of the main nuisance organisms that have destroyed the rice fields in Malaysia. Thus, the destruction they cause has received much attention from the Malaysian Government and concerned agencies (Salleh *et al*, 2012; Yahaya *et al*, 2017; Teo & Hamsein, 2017).

The major pathways of unintentional introductions of species of *Pomacea* include escape or accidental release from the aquarium industry into aquatic habitats, disposal of unwanted aquarium pets, food supplements for duck farming, transportation during inter-country trade, and natural disasters such as floods (Teo, 1999; Yahaya *et al*, 2006, 2017; Teo &

Hamsein, 2017). Furthermore, Yahaya *et al* (2017) found that these snails have also been transported from infested areas to new areas by farm machinery such as combine harvesters. A combine harvester that is not properly cleaned transports egg masses and mature apple snail shells that become attached to it. It is reported that these snails have invaded the commercial rice fields in Sungai Besar, Selangor via combine harvester from infested areas in Kedah (Azman bin Samsuri, commercial rice farmer, Sungai Besar rice bowl, personal communication, June 2017). According to Teo & Hamsein (2017), the intention of farmers to culture apple snails in their paddy field or backyard as a future food source also facilitated their spread into rice fields. This shows that humans are the main vector for the spread and translocation of non-native organisms such as apple snails in various habitats throughout Malaysia (Khairul Adha *et al*, 2013).

Impacts on socio-economy

According to Colautti *et al* (2006), invasion by invasive species can have adverse effects on economically important goods and services, and sometimes results in an 'invisible tax' on natural resources such as reduced yield. Yahaya *et al* (2017) state that *Pomacea* spp in Malaysia had invaded more than 20,000 hectares of rice fields by 2008. The invasive snails mostly fed on young rice seedlings resulting in complete loss of the rice crop (Teo, 2003). The total economic losses caused by them in 2010 were estimated as MYR 82 million (USD 28 million) (Yahaya *et al*, 2017). Therefore, understanding the magnitude of economic costs associated with non-indigenous nuisance species is important for environmental policy and management, and also for national economy development (Colautti *et al*, 2006).

Control and prevention

In Malaysia, the actions and strategies undertaken by various government agricultural agencies, universities and research institutions include mechanical, chemical and biological control, as well as public awareness campaigns among farmers. For instance, Teo (1999) used mechanical control by handpicking apple snails in infested areas. Manual handpicking is laborious and not very effective, particularly over large areas. However, the use of attractant baits and botanical traps can ease the difficulty of manual handpicking, not only as an important element in the integrated management of invasive apple snails, but also to avoid or minimise the excessive use of synthetic molluscicides (Teo, 1999, 2003; Joshi, 2007; Latip *et al*, 2017). Research conducted by Badrulhadza Amzah & Hafizi Yahaya (2014), and Syamsul *et al* (2016) has shown the effectiveness of botanical traps such as jackfruit skin, damaged pomelo, lettuce, papaya fruit and leaves, cassava leaves, tapioca, water melon and sweet potato in controlling apple snail populations. Syamsul *et al* (2016) concluded that jackfruit skin and damaged pomelo are the most attractive botanical traps.

Furthermore, several plant species with molluscicide properties – including wild sisal (*Furcraea selloa* K.Koch. var. *marginata* Trel.), yellow flamboyant [*Peltosporum pterocarpum* (de Candolle) K.Heyne], neem tree (*Azadirachta indica* A. Juss) and cassava leaves (*Manihot esculenta* Crantz) – were found very effective in combating apple snails. The recommended dosages of plant molluscicides are very high, however (tea seed cake at 51 kg/ha; wild sisal dry leaf powder at 45 kg/ha; and yellow flamboyant at 150 kg/ha), which makes their use prohibitively costly (Suryanto, 2000; Latip *et al*, 2013, 2017; Badrulhadza Amzah & Hafizi Yahaya, 2014).

Biological control such as duck and fish species (*eg* catfish and tilapia) have been used in the rice fields of Peninsular Malaysia, Sabah and Sarawak (Jambari & Suryanto, 1999; Teo, 2006; Khairul Adha, 2012; Teo & Hamsein, 2017). Generally, the methods and efforts have been successful in keeping apple snail populations below damaging levels, thus reducing crop losses.

Ecological and sustainable integrated management practices

The impact of *Pomacea* invasions in the rice fields of Malaysia has been extensively studied. However, the use of chemical and biological control to reduce and destroy their high populations should also be studied carefully. Some of the methods used are successful in controlling infestations. However, the application of these methods should be such that they do not have negative impacts on native fauna and flora, or on the environment in the affected area. Khairul Adha *et al* (2012) observed tilapia species used to control the apple snail populations that have destroyed rice fields in local communities. Although there are no detailed studies that evaluate the effectiveness of tilapia as biological control agents (Dennis *et al*, 2003), based on the local report, *Oreochromis* species were unsuitable. Fish introduced for biological control, such as common carp (*Cyprinus carpio* L.), have potentially destroyed the native aquatic vegetation by feeding on and uprooting plants (King & Hunt, 1967), thus decreasing the diversity and abundance of native invertebrates (Miller & Crowl, 2006; Roberts *et al*, 1995).

According to Yahaya *et al* (2017), although ducks are highly effective in controlling invasive apple snail populations in rice fields, they are potentially damaging to young rice seedlings and during the ripening stage.

In addition, using ducks to control invasive apple snails is only suitable if the paddy fields are near the local village and the farmer can readily visit the farm.

Although invasive apple snail in Malaysia only destroys the rice seedlings (Yahaya *et al*, 2006, 2017), their presence in local aquatic habitats may potentially threaten other aquatic plants and weeds. Arfan *et al* (2016) found high correlations of females and egg clusters of *P. maculata* on the aquatic ornamental plant, yellow burr-head (*Limnocharis flava* (L.) Buch.), which served as a source of food and as a substrate for oviposition. If environmental conditions are favourable, non-native species should exploit unoccupied environmental space and coexist with native species (Simberloff, 1981), which then results in an increase in total species richness (Gido & Brown, 1999). Thus, in order to clarify the significant effects of the invasive apple snails on aquatic environments, studies should be carried out on various aspects – such as feeding habits, habitat preferences, habitat-use overlap, and competition with native flora and fauna of the habitat surveyed.

The Department of Agriculture of Malaysia has discouraged farmers from using chemicals such as synthetic molluscicides to control apple snails because of their negative effects on human health, non-target organisms and the ecosystem. Furthermore, the abuse or misuse of chemicals probably has significant impact on native flora and fauna populations. Some chemicals, such as certain kinds of saponins, are toxic to most aquatic organisms such as fish and frogs (Minsalan & Chiu, 1986; Teo, 1999). For instance, the use of tea seed cake, derris root, and pesticides such as endrin (as Shell Endrex) and aldrin (as Shell Aldrex) to eradicate native fish ready for stocking with non-native fish in ex-mining lakes and ponds throughout Peninsular Malaysia in the late 1950s (Department of Fisheries, 1958), caused massive death of indigenous fish populations. Studies also need to be conducted to evaluate the effects of molluscicide applications used to control *Pomacea* spp on the native aquatic snails. Although there has been no record of poisoning caused by molluscicide use in Malaysia, the illegal application of molluscicides to control *Pomacea* spp, such as fentin acetate and the sodium salt of pentachlorophenol (NaPCP), can be a serious health hazard particularly to farmers (Yahaya *et al*, 2017). The active ingredients in all the synthetic molluscicides traded in Malaysia are niclosamide, niclosamide-olamine or metaldehyde; and they are sold in different formulations – wettable powder (WP), granule (GR), suspension concentrate (SC) or emulsifiable concentrate (EC) (Table 1).

Table 1. Synthetic molluscicides registered and sold in Malaysia

Active ingredient	Concentration (% w/w)	Trade name	Formulation
niclosamide-olamine	81.4	Bayluscide 70 WP	Wettable powder (WP)
niclosamide-olamine	83.1	Sipus	WP
niclosamide-olamine	59.4	Aquabosso 50	WP
niclosamide-olamine	83.1	Nikocide	WP
niclosamide-olamine	83.1	Agondan 83.1WP	WP
niclosamide	18.8	Mollus	Suspension concentrate (SC)
niclosamide	25.0	Kondor 25EC	Emulsifiable concentrate (EC)
niclosamide	25.0	Siputek 25 EC	EC
niclosamide	25.0	Kenlusid	EC
metaldehyde	5.0	Phoslin	Granule (GR)
metaldehyde	5.0	Hergetox	GR
metaldehyde	5.0	Mostox	GR
metaldehyde	5.0	Slugtox	GR
metaldehyde	5.0	Acmatox	GR
metaldehyde	5.0	Esaro	GR
metaldehyde	5.0	Racun Siput Berbutir	GR
metaldehyde	5.0	Ken-Siput	GR
metaldehyde	5.0	Sluggo M-5	GR

Active ingredient	Concentration (% w/w)	Trade name	Formulation
metaldehyde	5.0	Siputox	GR
metaldehyde	5.0	Metasan 5G	GR
metaldehyde	5.0	Meta 5G	GR
metaldehyde	36.5	Metasan 400	SC

Source: MOA (2014).

The occurrence of invasive apple snail populations may potentially have a direct effect on native apple snails [*Pila ampullacea* (L.)] and species of bivalve *Corbicula.* The invasion of *P. canaliculata* in rice fields was correlated with a decline in the number of native snails in Hong Kong (Kwong *et al*, 2009) and reduced native gastropods in other regions (Karraker & Dudgeon, 2014). The impacts of non-native species on native species, their distribution, their biotic characteristics and how exotic species become incorporated into local communities should be evaluated. Competition can occur between non-native apple snails and native snail species for food, habitat, mates or other essential resources when both share the same habitat.

Salleh *et al* (2012) concluded that most of the farmers in their study chose synthetic molluscicides due to their fast and effective results. However, their applications had negative effects on their health and on the ecosystem. Farmers have to be educated on chemicals' toxicity. The use of appropriate machinery with proper water management could help to control the snails.

Conclusion and recommendation

The Malaysian government and other relevant authorities have taken various actions to control the invasion of and destruction by invasive apple snails in rice fields. Managing the snails in local areas has been successful in reducing crop damage. However, this invasive apple snail has been found spreading continuously to various freshwater habitats and locations in Malaysia.

A main concern about the invasive apple snails' establishment is not only its potential to feed on young rice seedlings and reduce grain production, but also its displacement and destruction of other flora and fauna, such as native snail species, from their habitat; and its potential to thereby alter the habitat and facilitate invasions of additional non-native species.

Every effort should be taken to stop the further spread of invasive apple snail species from Malaysian water bodies. In fact, to protect native flora and fauna diversity, the management or authority should focus on *preventing their introduction*, because *eradication after establishment is usually not possible* (Lodge *et al*, 1998). More action should be taken to determine why invasive apple snails have become so successfully established and also to predict their future spread and impacts. Examining their distributions may contribute to understanding their invasiveness and help in designing eco-friendly integrated sustainable management approaches.

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