Invasive Apple Snails: Integrated Management in Lowland Ricefields of Cambodia and Probing their Utilization in Aquaculture

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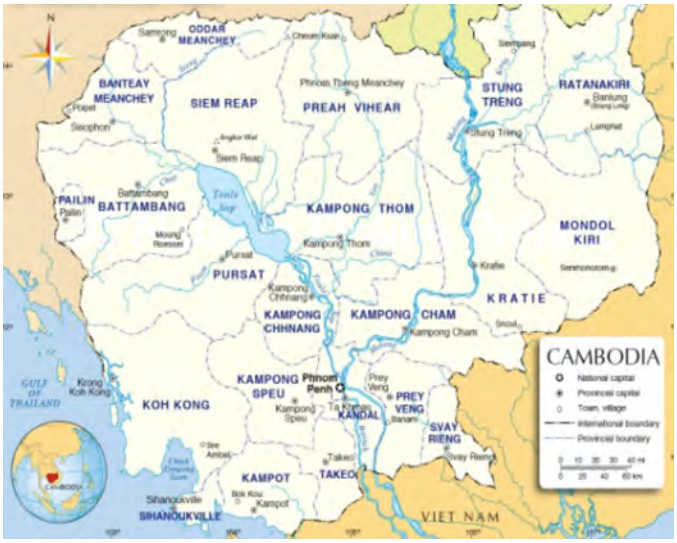
This article provides insights on the aquatic invasive apple snails of the genus *Pomacea* and rice cultivation in Cambodia. The first record or known date of introduction of this freshwater invasive snail is before 1995. It was deliberately introduced mainly as a food source for humans. Since then the snails quickly spread to many provinces, becoming a major pest of lowland rice fields and posing severe threat to natural wetland environments. To reduce damages to rice crops in Cambodia, researchers from the Cambodian Agricultural Research and Development Institute (formerly Cambodia-IRRI-Australia Project), conducted research to prevent further spread of the snails and developed integrated management options to reduce the misuse and abuse of pesticides meant to control the breeding of the snails. From the aquaculture point of view however, studies have been conducted on the possibility of utilizing the invasive apple snails as feed for various commodities being cultured.

Freshwater invasive apple snails (*Pomacea* spp.), commonly known to Cambodian farmers as "khyorng yuonto," belong to the family Ampullariidae. The apple snails were discovered by the Cambodia-IRRI-Australia Project (CIAP) in Svay Rieng in August 1995, through a farmer who purchased the snails from Phnom Penh and raised them in clay pots. CIAP and the Plant Protection and Phytosanitary Inspection Office of Cambodia searched the Phnom Penh area and found several places where people were breeding large numbers of the snails (CIAP 1995; Chanty 2002; Preap *et al*., 2006). In November 1995, it was found that farmers in Takeo Province were intentionally placing them in their rice fields to be raised as food, just as they would normally place the native snails. These farmers were not aware that the introduced snails would later become pests in rice fields.



Map of Cambodia showing the provinces where the invasive apple snails were bred by communities

Aside from those found in Phnom Penh, the snails were also raised in at least 10 provinces: Kampong Chhnang, Kampong Cham, Kampong Speu, Kandal, Prey Veng, Pursat, Siem Reap, Svay Rieng, Battambang, and Takeo (Anonymous 2005; Chanty 2002; Preap *et al*., 2006). The spread of *Pomacea* spp. (**Figure 1** and **Figure 2**) to rice fields in various provinces of Cambodia has also been enhanced in some other ways, for example, through the poorly developed Cambodian irrigation systems, and also through waterways from the rice fields along the Vietnamese border in the provinces of Svay Reing, Kandal, Takeo, and Kampot.

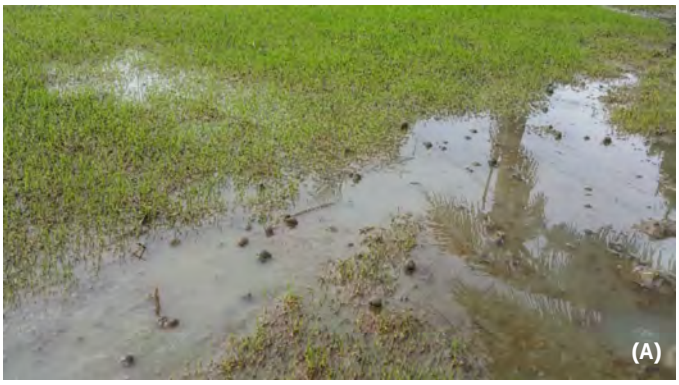


Figure 1. Invasive apple snails (*Pomacea* spp.) invading newly established direct-seeded rice **(A)** and transplanted rice **(B)**

(Photo Credits: Ravindra C Joshi)

The snails were deliberately introduced into Cambodia primarily as food for humans, because of their large size, capacity to grow rapidly and high reproductive potential, as well as its high protein contents (Cowie *et al*., 2017).

Species of *Pomacea* and Their Impacts

Many publications prior to 2012, failed to distinguish *Pomacea canaliculata* and *Pomacea maculata*, until the advent of molecular approaches (Hayes *et al*., 2008). For example, the *Pomacea* snails from Cambodia were mentioned as *P. canaliculata*, but are in fact *P. maculata* (Cowie, 2002). In Cambodia, there are two species of invasive apple snails:

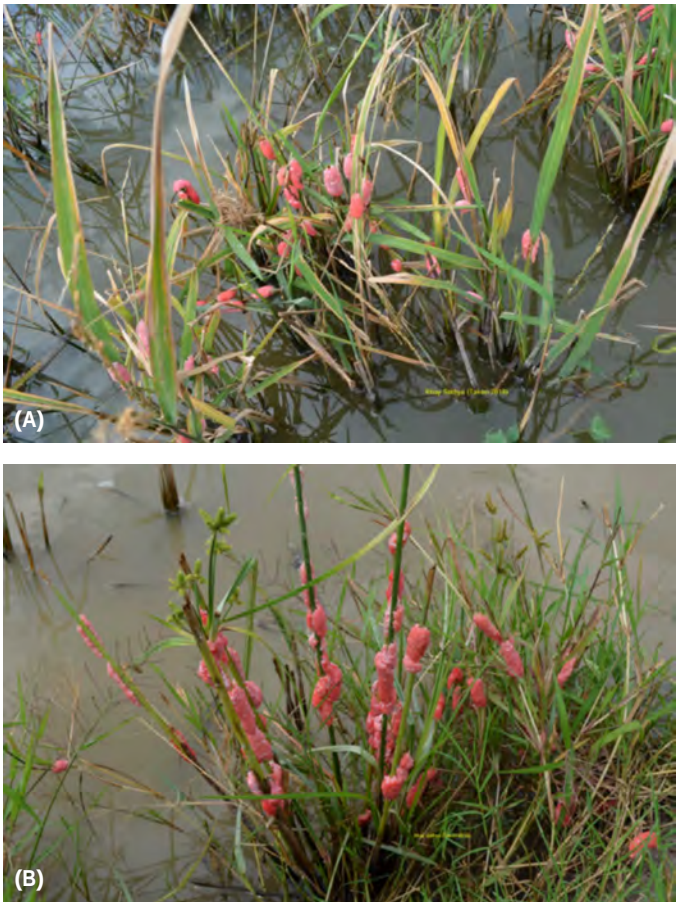


Figure 2. Invasive apple snails (*Pomacea* spp.) egg masses on rice **(A)** and in weeds along the rice field bunds **(B)**, Takeo Province, Cambodia

(Photo Credits: Khay Sathya)

P. canaliculata and *P. maculata* (Cowie 1995; Hayes *et al*., 2008), where *P. maculata* was originally referred to as *P. insularum*. *P. canaliculata* is listed among the world's 100 worst invasive alien species (GISD, 2018), largely because of the extensive damage that the snails could cause to both wetland rice and native ecosystems.

In addition, *Pomacea* species are also important transmitters of the rat lungworm parasite (*Angiostrongylus cantonensis*) that could cause major health consequences to humans when the snails are eaten raw. The name golden apple snails or GAS has been used widely in Asia for the introduced *Pomacea*, often without clarifying specifically which species, perhaps both was involved, or indeed simply assuming it to be *P. canaliculata* (Cowie *et al*., 2017). For clarity, this article avoids this ambiguous common name designation.

Rice Cultivation in Cambodia

In Cambodia, rice is cultivated twice a year both in wet (monsoon) and dry seasons, either by transplanting or direct-seeding. However, majority of farmers usually grow one crop of rice per year with a small portion of the farmers doing it twice a year. The total rice area accounted for about 3.21 million ha, with rice crop in the monsoon season accounting for about 77 % of the total country's paddy production. Majority of the farmers (more than 90 %) practiced direct-seeding method by manually broadcasting the rice seeds for almost in all rice growing seasons.

Nonetheless, with the climate change influencing precipitation, the country's rice planting calendar has shifted and has been adjusted. Now, the planting time for wet season rice starts from June to July (depending on the rain water), and harvesting is done from November to December (depending on the rice variety: early, medium or late maturity). For early maturing rice varieties, harvesting is made in October. In some places nearby water sources (*e.g.* lakes, rivers, reservoirs), farmers do recession rice (grow rice when water starts to decrease) in October. The national average rice yield is 3.29 tons/ha, with the total rice production of 10.52 million tons. Generally, the price of un-milled rice in the farm depends on the rice variety, moisture content, among others, and ranges from 700 to 1,300 Riel/kg (4,000 Riel=1U$D). At market places, the price of milled rice varies largely with the rice variety. Usually, rice harvest is bought by middlemen and milling companies.

Integrated Management of Invasive Apple Snails

Integrated management options against invasive apple snails were developed since it was first discovered in Cambodia, to address the misuse and abuse pesticides, aside from their impacts on farmers' health and the environment. As means of preventing the growth of snail population and eventual crop damage, some necessary culture techniques had been recommended for adoption in rice culture, as shown in the **Box**.

Box: Recommended techniques of rice culture to hamper the growth of snail population

- transplanting older seedlings as these are less preferred by snails for consumption
- adopting increased-seeding rate in direct-seeded rice fields as this compensates for the seedlings consumed by the snails
- installing screen traps on water inlets prevents snails from entering newly-established rice fields
- hand-picking of the snails in the morning and afternoon when they are active
- removing snails from rice paddies any time before final harrowing

The snails collected from rice fields could be used as feeds for ducks and livestock, and if completely cooked, could be eaten by humans. Moreover, direct control techniques are necessary when snail densities reach 2-3 snails/m^2, which could include: herding ducks through the rice fields immediately after harvest and 30 to 35 days after transplanting early maturing rice, or 40 to 50 days after transplanting late maturing rice; and placing bamboo stakes around the fields to provide places for snails to lay eggs and facilitate collection of eggs after which these should be destroyed (Jahn *et al*., 1997).

Table 1. Molluscicides active ingredients registered to be used in Cambodia

Active Ingredient (a.i.)	Dose (a.i. g/ha)	Country of Origin
Metaldehyde	240-360	Viet Nam, People's Republic of China
Niclosamide	175-210	Viet Nam, People's Republic of China
Saponin	750-1200	Viet Nam, People's Republic of China

Pesticides could also be used but properly and with extra care. In Cambodia, there are active ingredients allowed as molluscicides. These are: metaldehyde, niclosamide, and saponin, of which metaldehyde and niclosamide are synthetic molluscicides, while saponin is a plant-based molluscicide. These pesticides (**Table 1**) are imported from Viet Nam and the People's Republic of China.

The selected formulated products traded and approved for use in Cambodia are shown in **Table 2**. These products come either in small sachets or in 1 kg packaging. On an average, a rice farmer spends about US$ 16/ha (for one time application), and farmers usually apply twice per rice cropping season. The time of applying the molluscicides is either before crop establishment (direct-seeding or transplanting) or 1-2 weeks after crop establishment.

Presently most of the snail management techniques could not be easily adopted by farmers as these are labor-intensive (Cowie, 1995), not economical, not effective to reduce snail numbers at non-damaging levels, and not environment friendly (Joshi, 2007). Thus, new innovative approaches should be developed and promoted to manage the overpopulation of invasive snails, especially in direct-seeded rice fields.

Conclusion

Since these were first detected in 1995, the invasive apple snails have widely spread across the lowland rice areas in Cambodia, causing serious crop losses. In recent years, especially with increased flooding caused by climate change adversities, the snails have invaded new areas. With more farmers resorting to wet direct-seeding, more snail damages had been triggered resulting in increased usage of molluscicides. Aside from the direct rice damages and based on the aspects of snail bio-ecology, the negative impacts on non-target fauna and flora including human health and the environment are still unknown.

Nevertheless, some aquaculture research studies have shown that the invasive apple snails could be used as a cheap alternative to traditional processed feeds for various cultured commodities to lower production costs and increase income (Casal *et al*. 2017; Heuzé and Tran, 2017). In China, it is quite common for the crushed snails being used as protein supplement for rice-prawn farming (IIRR *et al*., 2001). Bombeo-Tuburan *et al*. (1995) established that the fatty acid profile of these introduced snails could provide the essential fatty acid required for the culture of black tiger shrimp (*Penaeus monodon*).

Based on the review of Castillo and Casal (2006), and Casal *et al*. (2017), invasive apple snails are utilized in small-scale aquaculture, where it was used as feed in the culture of the giant freshwater prawn (*Macrobrachium rosenbergii*) and the Japanese koi (*Cyprinus carpio*) in the Philippines. Also in the Mekong Delta of Viet Nam, some 20 to 25 tons of apple snails are collected annually and used as feed in giant freshwater prawn farming (Hasan and Halwart, 2009). The study of Jintasataporn *et al*. (2004) showed that in Thailand, apple snail meal could successfully replace 25 % of the fish meal for giant freshwater prawn culture in short period only, but not exceeding two-months. Moreover, *Pomacea canaliculata* meal had been a good source of protein for rabbitfish (*Siganus guttatus*) culture as established by Visca and Palla (2018).

The potentials for using of invasive apple snails as alternative feeds in aquaculture should therefore be explored through more intensive research, in order that the problem of snail infestation in rice fields could be reduced, and invasive apple snails would no longer be considered as pests but rather as an economic resource. It is in this regard that concerted efforts are necessary to develop ecologically sustainable snail management integrated approaches, through inter-country collaboration among the ASEAN Member States.

Table 2. Molluscicidal formulated products traded in Cambodia

Product Name	Company Name (Supplier)	Active Ingredient (a.i.)	Package Size (kg/g)	Price/Package
Molucide 6GB	Can Tho Pesticides Joint Stock Company, Viet Nam	metaldehyde 6 %W/W	1 kg	US$ 2.50
Toxbait 120AB	Anbio,Viet Nam	metaldehyde 120G/KG	1 kg	US$ 2.82
Nill 70WP	Sinamyang Company, Viet Nam	niclosamide 70 %WP	36 g	US$ 0.75
Snailicide 700WP	Nóng Phát, Viet Nam	niclosamide 700G/KG	36 g	US$ 0.70

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