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Heavy Predation on Freshwater Bryozoans by the Golden Apple Snail, *Pomacea canaliculata* Lamarck, 1822 (Ampullariidae)

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ABSTRACT.– Laboratory feeding observations confirm that the golden apple snail (*Pomacea canaliculata* Lamarck, 1822) is a voracious predator of phylactolaemate bryozoans. An invasive species in Southeast Asia since the early 1980s, the snail now occupies most freshwater ponds, lakes, and rivers throughout the region. Despite the absence of baseline data, it appears that the snail has had a profound effect on the freshwater bryozoan community, including both tubular and globular colonies. The common gymnolaemate, *Hislopia,* is less affected. From repeated feeding trials it appears that indigenous apple snails (*Pila* spp.) do not graze on bryozoans; nor does the large indigenous *Cipangopaludina chinensis*.

KEY WORDS: Bryozoa, Phylactolaemata, *Pomacea canaliculata,* predation

INTRODUCTION

In small lakes, ponds, and canals of Thailand, the presence of the golden apple snail (*Pomacea canaliculata* Lamark, 1822) almost always indicates the absence of freshwater bryozoans. This observation came to light during our survey of over 140 aquatic sites that began in 2002. Subsequent work has reinforced the possibility of massive and widespread disappearance of bryozoans due to heavy grazing by the invasive apple snail known primarily for its destructive herbivory. In this paper we document predation by these snails on bryozoans and discuss the impact on the bryozoan community.

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Golden apple snails (called cherry snails in Thailand) were deliberately introduced from Argentina to Taiwan in 1979-80 (Mochida, 1991). It was thought that a cottage industry of culturing the snails for human consumption would provide income for impoverished farmers. Within several years cherry snails had shown up in Japan, Philippines, mainland China, Korea, Malaysia, and Thailand. While local people found the snails unpalatable, the snails discovered conditions in tropical Asia that were close to ideal. According to Cowie (2002) adult females can lay their eggs at weekly intervals throughout the year, depositing them in pink masses above the water level. After hatching, the young reach sexual maturity within 2-3 months. With both gills and an air-breathing organ, the snails thrive even in water with low dissolved oxygen. During the dry season they burrow deeply into the mud of swamps and rice paddies and aestivate for several months (Mochida, 1991). Dispersing

with flowing water and even crawling overland, the cherry snail has spread rapidly and now occupies most of Southern Asia.

The agricultural impact of the snail has been thoroughly reviewed by Cowie (2002). Attention in Southeast Asia has focused mainly on the extensive damage to rice crops (Oya et al., 1986; Yamanaka et al., 1988; Basilio, 1991; Naylor, 1996). Lotus, water chestnut, taro (in Hawaii) and other economic plants also are affected. The application of chemical pesticides is costly and takes a heavy toll on nontarget species. The consequent chemical risk to human health is a serious concern, both for the farmer and for the consumer of potentially contaminated food. For poorer farmers there is a heavy labor cost to removing snails, destroying their egg clusters, and replanting damaged fields. Anecdotal evidence links the spread of the cherry snail (and use of molluscicides) to the near disappearance of local edible snails (*Pila* spp.) in many regions (Halwart, 1994).

Legitimate agricultural concerns have overshadowed the role of the cherry snail as a possible predator in the freshwater community. Our particular interest is in bryozoans, among the most common benthic suspension feeding animals in fresh waters. Bryozoans are coelomate invertebrates with a modular growth structure (Wood, 2001, 2004). Appearing as branching tubules or gelatinous mounds, they form colonies of identical zooids which grow on aquatic macrophytes as well as submerged wood, plastic, glass, and other firm substrata (Fig. 1). About 80 species are known worldwide, although until recently bryozoans have received little attention in Southeast Asia. Nearly all freshwater bryozoans are placed in the Class Phylactolaemata; a few genera, such as *Hislopia* and *Victorella*, belong to the Class Gymnolaemata which is otherwise mostly marine.

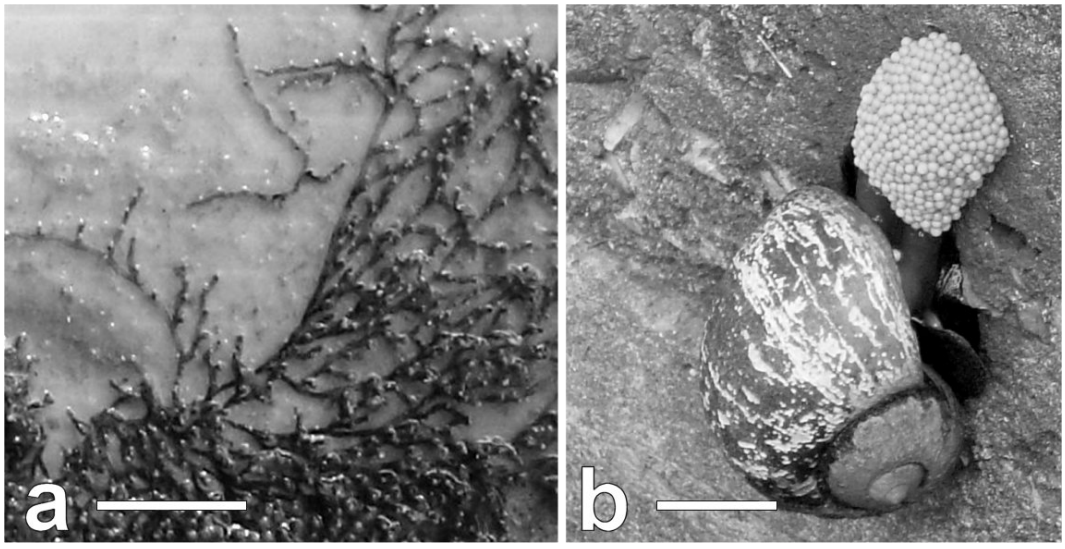

FIGURE 1. Prey and predator. **(a)** Bryozoan colony (*Plumatella bombayensis*) growing on a plastic panel; scale bar = 1 cm. **(b)** Female cherry snail (*Pomacea canaliculata*) laying a clutch of pink eggs above the water line; scale bar = 3 cm.

MATERIALS AND METHODS

To obtain bryozoans colonies, glass plates 19 cm square were suspended horizontally in a fish culture pond on the Bang Khen campus of Kasetsart University in Bangkok. Within four weeks the undersides of the plates were nearly covered with several bryozoans species. About 80% of the plate was occupied by *Plumatella bombayensis* Annandale, *Plumatella vorstmani* Toriumi and *Hislopia malayensis* Annandale; the remaining space was taken by *P. casmiana* Oka and an unnamed plumatellid species. In many places the plumatellid colonies had overgrown *Hislopia malayensis*. Small sponges also were present.

To observe snail feeding behavior we used an open polyethylene test chamber measuring 16 x 26 x 6 cm submerged in a pan of pond water with the glass plate of bryozoans placed across the top, bryozoan side down. The entire apparatus was placed under a dissection microscope so that the observer could focus directly on the bryozoans at magnification of 10-40x.

For comparative purposes, snails used in the study included *Pomacea canaliculata,* as well as indigenous Thai snails: *Pila pesmei* (Morelet, 1889), *Pila ampullaceal* (Linné, 1758), *Pila polita* (Deshayes, 1830), and *Cipangopaludina chinensis* (Reeve, 1863). The *Pila* species were identified according to the morphological criteria described by Keawjam (1986) and matched with reference specimens at Kasetsart University. *Cipangopaludina* and *Pomacea* were collected from ponds at Kasetsart University; the *Pila* species came from Bann Teoy, Wang Hin Subdistrict (Tambon), None-Thong District, Nakhon Ratchasima Province. All snails measured 3-4 cm in their largest diameter. Pairs of freshly collected snails were introduced to the chamber and allowed to roam freely. Observations were made continuously for about 30 minutes, then periodically over the next several hours. *Cipangopaludina chinensis* were left in the apparatus for eight hours. Digital video footage was taken of feeding behavior.

RESULTS

Pomacea canaliculata: After roaming the test chamber for several minutes, the snails mounted the underside of the glass plate and began feeding immediately on the bryozoans. They moved in the direction where bryozoan density was greatest, then returned to graze on the less heavily populated regions of the glass plate. After only one hour the phylactolaemate bryozoans were completely gone, but many of the *Hislopia* colonies remained alive and only slightly damaged. Figure 2 shows similar results using a petri plate rather than flat glass.

Cipangopaludina chinensis: After roaming the test chamber for several minutes, the snails mounted the underside of the glass plate and began feeding immediately, but not on bryozoans. Instead they scraped debris from the plate, working around the bryozoans, feeding immediately adjacent to the colonies and even in narrow crevices between lines of zooids. The snail radula made a flicking motion that scooped up only loose detritus. Some damage to young plumatellid colonies did occur, but after four hours the plate was polished clean and nearly all bryozoans remained intact and alive (Fig. 3).

Pila spp.: These snails roamed the test chamber for several hours, spending most of their time on or near the bottom. Sprints across the glass plate were brief and rapid. The snails glided over the bryozoan colonies but displayed no interest whatever. Thai residents familiar with *Pila* tell us that the snails normally live and feed in pond and wetland sediments. We could find no published information to support these reports.

Separate tests were run with cherry snails as small as 6 mm. Results of their predation were exactly the same as with large adults. We also confirmed cherry snail predation on *Lophopodella carteri*, a globular, gelatinous colony very different in structure from the branching tubular plumatellids. *Lophopodella carteri* (Hyatt, 1866) has been shown to be highly toxic to fish (Tenney & Wollcott, 1964), but it had no apparent effect on the snails.

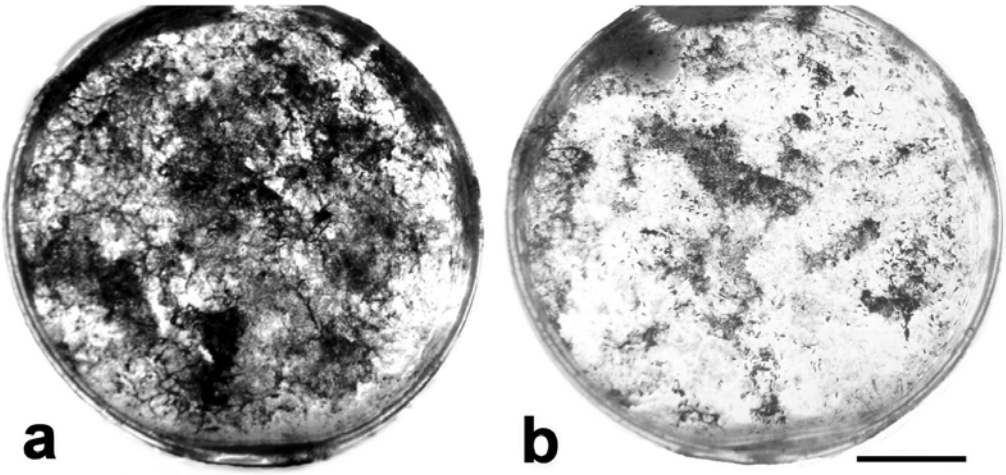

FIGURE 2. Effects of cherry snail predation; scale bar = 2 cm. **(a)** Petri dish with colony growths of *Plumatella bombayensis, Plumatella vorstmani,* and *Hislopia malayensis*. **(b)** Same dish after one hour of feeding by a single 4 cm diameter cherry snail. Most of the remaining material is living colonies of *Hislopia*.

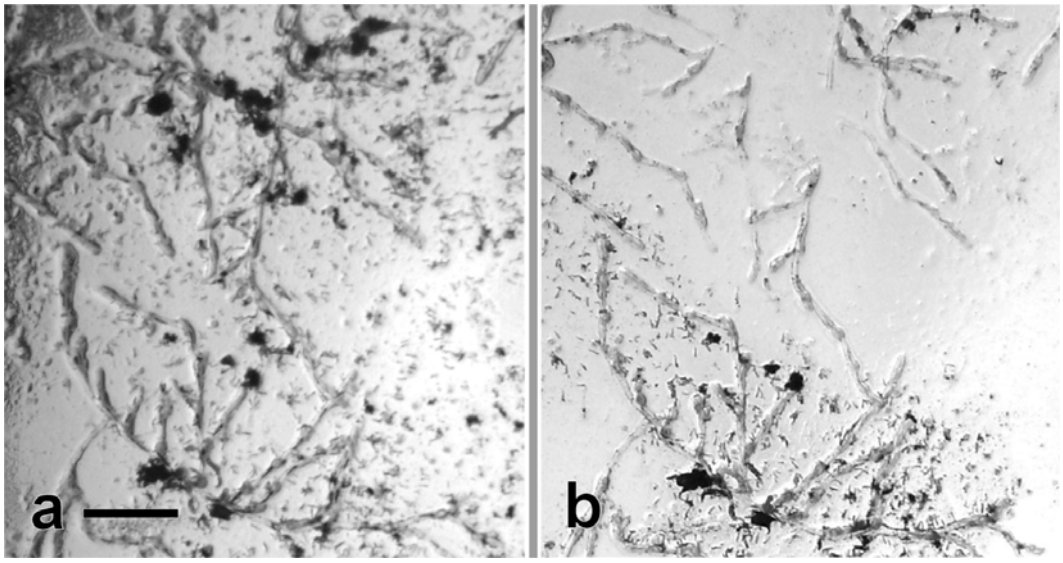

FIGURE 3. Effects of feeding by indigenous apple snail, *Pila pesmei* (Morlet, 1889); scale bar = 1 cm. **(a)** Glass plate with colonies of *Plumatella vorstmani* Toriumi **(b)** Same plate after 8 hour exposure to *Pila pesmei*, showing a much cleaner glass plate and relatively undamaged colonies.

DISCUSSION

Results confirmed our suspicion that cherry snails graze actively and selectively on freshwater bryozoans. Not merely accidental predators, the snails follow the path of colony branches, lingering over dense beds of zooids until they are completely consumed. This behavior of the invasive snail is in stark contrast to that of indigenous snails of the same large size, which do little damage to bryozoan colonies. Given the ubiquity of the cherry snail in Asia and the extensive freshwater habitat in which bryozoans are not present, we conclude that we are witnessing an unprecedented loss of bryozoans throughout the region. Moreover, this loss would be relatively recent, at least since the introduction of the cherry snail in the 1980s.

Missing, of course, is any reliable information about bryozoan populations in Thailand prior to the appearance of cherry snails. Previous reports or descriptions of new species from southern Asia include two from the Philippines (Kraepelin, 1886, 1906), two from Indonesia (Vorstman, 1928a, b), and eight from India (Rao, 1992; Wood & Wood, 2000). None of these includes notes on bryozoan ecology, abundance, or distribution. A pre-snail inventory from India includes six species that have not been reported since, nor have they been found in post-snail Thailand.

Thai bryozoans find apparent refuge from the cherry snail on floating structures that have little direct contact with the shore or bottom sediment, such as boats, buoys, and fish culture pens. In large lakes we find bryozoans growing on the undersides of leaves of the red water lily, (*Nymphaea lotus* Linné, 1753) which appears to be avoided by the cherry snail; but on the lotus (Nelumbo nucifera Gaertn., 1788) there are usually many cherry snails and very few bryozoan colonies. Finely divided substrata, such as exposed tree roots, frayed rope, and certain aquatic plants also appear to offer refuge to bryozoans, although they seem not to be ideal for vigorous colony growth.

Among bryozoan species in Thailand, the two most common are *Hislopia malayensis* and *Plumatella bombayensis*. Our results show that *Hislopia* is seldom damaged by cherry snail grazing, and so may actually benefit from reduced competition for space by other bryozoans. *Plumatella bombayensis* displays unusual speed in its growth and reproduction, and the zooids tend to be widely spaced. These features may offer some protection from cherry snail predation, at least in areas where the snail population is sparse.

Sponges often occur alongside bryozoans and would appear to be equally vulnerable to cherry snails. However, we have never observed snails grazing on sponges either in the lab or in the field. The dense meshwork of sharp spicules and the probable low nutritional value probably make sponges unpalatable to most grazers.

The long term impact of cherry snails on freshwater bryozoans in Southeast Asia is difficult to assess because the situation is unprecedented. The affected area is enormous, well exceeding 3 million km^2, not even including China where the extent of *Pomacea canaliculata* is yet unknown. In Europe and North America bryozoans survive predation by flatworms, various insect larvae, certain fish, crayfish, and snails (Wood & Okamura, 2005). However, the effects of these are generally localized and highly seasonal, while *Pomacea canaliculata* is ubiquitous and maintains an unremitting predation pressure. Moreover, populations of bryozoan predators in temperate regions seldom achieve the high densities or the mechanical feeding efficiencies comparable to cherry snails.

Another complicating factor in assessing long term impact is the lack of knowledge about freshwater bryozoans in Southeast Asia and in tropical habitats generally. Many species appear to thrive and reproduce both sexually and asexually throughout the year. Colony growth rates are often very high; dispersal with seasonal flood waters may be widespread and effective. All of these can be significant factors

in species survival against heavy predation, and yet no details are known.

For now our concern is with those bryozoan species already rare, many of which have yet to be described. Although the diversity of Thai species appears to be high, many species are known only from single, isolated populations. It is very possible that a number of phylactolaemate bryozoans will soon join legions of other species worldwide that have been lost through the innocent introduction of exotic predators.

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