INTRODUCTION

The apple snail Pomacea canaliculata (Lamarck, 1819) is indigenous to South America. It was introduced as human food into Asia mainly in the 1980s, and became distributed in many countries in tropical, sub-tropical and temperate areas (Halwart, 1995), and its distribution is still expanding (Baker, 1998). *P. canaliculata* is a pest of rice in many Asian countries because it feeds voraciously on rice seedlings. Current methods to control *P. canaliculata* in paddy fields include draining or keeping water low while rice is young and susceptible to feeding, hand picking snails, and applying pesticides (Yusa & Wada, 1999). However, these methods are impossible or ineffective when fields are poorly-drained or flooded. Biological control may have potential not only in paddy fields (Halwart, 1995) but also in canals and ponds (Yusa & Wada, 1999). Ducks (Cagauan & Van Hove, 1998), carp or Nile tilapia (Halwart, 1995) have been released in paddy fields for snail control as well for as meat production. Biological control may have potential not only in paddy fields (Halwart, 1995) but also in canals and ponds (Yusa & Wada, 1999). Ducks (Cagauan & Van Hove, 1998), carp or Nile tilapia (Halwart, 1995) have been released in paddy fields for snail control as well for as meat production. They are often effective in reducing snail density, but require a special care. Predators such as leeches (Ozawa, Makino & Isigami, 1989), firefly larvae (Kondo & Tanaka, 1989) or dragonfly larvae (Suzuki, Miyamoto, Matsumura, Arimura & Tubiano, 1999) can eat the snail in laboratory conditions, but few animals have been observed to consume the snail in the field (Yusa, Sugiura & Ichinose, 2000).

The apple snail lays egg masses on stems of plants or walls above water, so the eggs face different predation pressures from young or adult snails. Irrespective of the conspicuous red color of the eggs, very few animals consume them, probably because they are unpalatable (Snyder & Snyder, 1971).

Predation on the eggs of *Pomacea canaliculata* by the fire ant Solenopsis geminata (Fabricius) (Hymenoptera: Formicidae) has been observed in the Philippines (Way, Islam, Heong & Joshi, 1998) and Thailand (Chanyapate, 1997). The ant is indigenous to the southern part of North America and Central America. It was unintentionally introduced into many tropical and sub-tropical areas. In this study, the extent of predation on the snail eggs by the ant was quantified in the Philippines.

MATERIALS AND METHODS

Observations were made at the International Rice Research Institute (IRRI), Los Baños, Central Luzon in the Philippines (14° 10’ N, 121° 12’ E). First, the first 50 egg masses of *P. canaliculata* found along levees of paddy fields were examined in the morning of 26 March 1998. More fire ants were observed near egg masses with higher degrees of damage. Secondly, when *Pomacea* egg masses found along levees of paddy fields were observed, more than half of them had some damage. More fire ants were observed near egg masses with higher degrees of damage. Secondly, when *Pomacea* egg masses were experimentally placed on levees, on average 50% of the eggs were lost (removed or damaged) within two days in March and 38% were lost within three days in August. Thirdly, egg masses were placed in cups with or without water on levees; no eggs were lost when ants were successfully excluded by water. The proportion of lost eggs was highly variable among egg masses, but there was no difference between day and night. Possible use of this ant as a biocontrol agent for the apple snail is considered.
an egg mass was estimated during a 20-second count. Fire ant behaviour was also observed.

Secondly, intact egg masses of the snail were placed on levees for two or three days and the extent of egg loss during these periods was estimated. Twenty-five and 39 egg masses were used in March and August 1998, respectively. Stems of rice or weeds with undamaged egg masses were cut, and a tip of each stem was put into a hole of a rubber plug placed on the levees 2 m apart from each other along a transect. The lowest part of each egg mass was set 3–5 cm above the ground. They were observed once or twice a day (5:00–7:00 and/or 17:00–19:00). In each observation, the maximum length of each egg mass, and its maximum width (diameter) perpendicular to it, were measured with calipers. The proportion of removed eggs (i.e., eggs carried away) between two consecutive observations was estimated from the change in the length and width, since the total number of eggs in an egg mass can be estimated from its maximum length and width (Tanaka, Watanabe, Higuchi, Miyamoto, Yusa, Kiyonaga, Kiyota, Suzuki & Wada, 1999). The proportion of damaged eggs (i.e., eggs broken in situ) was estimated by sight. The proportion of lost eggs was defined as proportion of removed eggs added to that of damaged eggs.

Thirdly, seven sites, 1–20 m apart, were randomly chosen along a transect on levees, to investigate the consequence of ant exclusion and the difference in ant predation rate between day and night. In each site one pair of plastic cups (ca. 7 cm diameter and 4 cm deep) with egg masses were placed 30 cm apart, for 4.5 days in March 1998. A rubber plug was placed at the center of each cup, and a plant stem with an intact egg mass of *P. canaliculata* was put in the hole of the rubber plug. Water (ca. 2 cm deep) was put in one cup of each pair to keep ants away from the eggs, and the other cup was kept without water. Egg masses were changed twice a day (5:00–7:00 and 17:00–19:00; thus 7 × 9 = 63 egg masses were used for each water condition), and the proportion of eggs lost (either removed or damaged) during 12 hours was estimated.

**RESULTS**

*Solenopsis geminata* were observed consuming eggs of 18% (9 / 50) of *Pomacea* egg masses found along levees. Most were minor workers, but there also were major workers. The ants usually tried to remove individual eggs from the egg mass with their mandibles, and when successful, they carried the eggs away, presumably to their nests. Ants consumed eggs at any developmental stage, from newly-laid eggs (distinguishable by their milky pink color) to those ready to hatch (grayish color, which reflects the pigments of snails inside the eggs).

Egg masses with damaged eggs were frequently found along the levees (Fig. 1), but ants appeared to damage eggs only when they failed to remove the eggs from the egg mass. Damaged eggs were found in 58% (29 / 50) of egg masses. More fire ants were found near egg masses with higher proportions of damaged eggs (Table 1; *H* = 19.4, *P* < 0.001, Kruskal-Wallis test).

Among egg masses experimentally placed on levees, both the number of masses with lost eggs (either removed or damaged) and the proportion of lost eggs per egg mass increased with time during the two- or three-day observation periods in March and August, respectively (Fig. 2). In March, at least some eggs in 92% (23 / 25) of egg masses were consumed in two days. In August, eggs in 59% (23 / 39) of egg masses were consumed in two days, and those in 67% (26 / 39) of egg masses in three days. Thus the number of egg masses with lost eggs were greater in March than in August within two days (*P* < 0.01; Fisher’s exact probability test). The average proportion of eggs lost per egg mass (including intact egg masses) was also greater in March than in August: 50 ± 38% (mean ± SD, *n* = 25) in March and 27 ± 35% in August in two days (*n* = 39; *U* = 302, *P* < 0.05; Mann-Whitney U-test), and 38 ± 42% in three days in August. The sizes of egg masses (expressed as maximum length × width in mm) were

![Figure 1. Egg mass of Pomacea canaliculata damaged by the fire ant Solenopsis geminata.](image)

Table 1. Relationship between proportion of damaged eggs in egg masses of *P. canaliculata* deposited along levees and number of fire ants within 20 cm of the plant with each mass

<table>
<thead>
<tr>
<th>Proportion of damaged eggs (%)</th>
<th>No. of egg masses observed</th>
<th>No. of ants (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21</td>
<td>0.67 ± 0.26</td>
</tr>
<tr>
<td>&lt; 25</td>
<td>20</td>
<td>8.70 ± 1.97</td>
</tr>
<tr>
<td>≥ 25</td>
<td>9</td>
<td>10.22 ± 2.75</td>
</tr>
</tbody>
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larger in March (mean ± SD = 304 ± 87) than in August (248 ± 56; U = 295, P < 0.01). In both months, the proportion of eggs lost in each egg mass varied greatly: some egg masses remained intact throughout the observation periods whereas others were completely lost (Fig. 2). Egg mass size had no significant correlation with the proportion of eggs lost at the end of the experiment both in March (τ = -0.13, P > 0.3; Kendall’s rank correlation test) and in August (τ = -0.12, P > 0.2).

When egg masses were placed in plastic cups without water, eggs in 34% (21 / 62) of egg masses were consumed within 12 hours (one egg mass was disturbed by accident and was excluded from the data). In contrast, only 2% (1 / 63) of egg masses were consumed when cups were filled with water. This was because the rice stem touched the edge of the cup and allowed ants to consume the eggs. Egg mass sizes were not significantly different between the two treatments (mean ± SD of the maximum length × width in mm = 305 ± 80, n = 62 for cups without water; 315 ± 74, n = 63 for cups with water; T_s = 835, P > 0.3; Wilcoxon’s signed-rank test for 62 pair observations).

Egg mass sizes were not significantly different between observations at day and at night of the same date (n_1 = n_2 = 7, T_s = 4.5, P > 0.8 for 27 March; n_1 = n_2 = 7, T_s = 0, P > 0.1 for 28 March; n_1 = n_2 = 7, T_s = 2, P > 0.5 for March 29; data for 30 March were impossible to test statistically due to small data size with different ranks; Wilcoxon’s signed-rank test). Egg mass sizes were not different between day- and night-observations (n_1 = n_2 = 7, T_s = 6–11, P > 0.1 for each of the above date).

**DISCUSSION**

Direct observations indicated that *S. geminata* consumed eggs of *P. canaliculata*. There was no loss of eggs in egg masses when ants were successfully excluded. An unidentified species of small brown ant was sometimes observed on or inside damaged eggs of *P. canaliculata*, but it was not observed consuming intact eggs. Ants of the genus *Pheidologeton* also consume eggs of *P. canaliculata* (Way, pers. comm.). *P. canaliculata* egg masses were frequently observed both at day and at night before, during and after the experiments, but no other animals were observed consuming snail eggs. Therefore most of the damage observed in this study was attributed to fire ant predation.

*Snyder & Snyder (1971)* reported that several animals, mainly fish and birds, eat eggs of the Florida apple snail *P. paludosa* Say in the laboratory. They also reported that a millipede and a frog infrequently ate eggs of *P. paludosa* in the field. In Brazil, Guimarães (1981) found that some aquatic birds consumed young and adult snails as well as egg masses of *P. haustrum* (Reeve), but the frequency of this predation was not recorded. Egg masses of *P. canaliculata* were examined by the present author in several places in southern Brazil and Argentina, but no predation was noticed. *S. geminata* is the only animal known to consume *Pomacea* eggs to any considerable extent in the field. In paddy fields without water, fire ants also attack young snails (Way et al., 1998; Yusa, pers. obs.). Recently, another fire ant, *S. invicta* Buren, was reported to attack adult apple snails, *P. paludosa* in a laboratory experiment (Stevens, Stevens, Darby & Percival, 1999).

Half of the eggs of *P. canaliculata* placed on the levees were lost within two days in March, and about

![Figure 2. Examples of change in the proportion of eggs of *P. canaliculata* lost over time in March (left) and in August (right). Each line indicates an egg mass. Thick line indicates the average.](image-url)
ACKNOWLEDGMENTS

I wish to thank Ms. Liberty Almazan and Mr. Nanding Elec for help, Drs. Kong Luen Heong, Yoshito Suzuki for discussion, Mr. Alberto Barrion and Dr. Tomonari Watanabe for information on Solenopsis, Drs. Takashi Wada, Katsuya Ichinose, Michael Way for critical reading of the manuscript. I am deeply indebted to Dr. Michael Way for his kind suggestion, discussion, and encouragement during this study. This study was supported by Japan-IRRI shuttle project on the ecology of Pomacea canaliculata.

REFERENCES


PREDATION ON *POMACEA* EGGS BY ANTS


