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The potential ecological impact of the exotic snail *Pomacea canaliculata* on the Thai native snail *Pila scutata*

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ABSTRACT: The aims of this study were to compare food consumption, growth rates, time to reach food, and food preferences of the golden apple snail (*Pomacea canaliculata*) and the Thai native snail (*Pila scutata*). The eggs of the two species collected from natural habitats were hatched in the laboratory. Snails of one month were raised together and separately to determine growth rates and food consumption. It was found that the growth rate of *P. canaliculata* was significantly faster than that of *P. scutata* when both were raised together and when they were raised separately. Both snails grew better when raised separately. *P. canaliculata* consumed significantly more food than *P. scutata*. When raised separately, *P. canaliculata* crawled to food at a significantly faster rate than *P. scutata*. On average, *P. canaliculata* and *P. scutata* took 8.2 ± 3.2 and 15.1 ± 3.1 min, respectively, to reach the food offered. To test for food preferences, four local species of aquatic plants, namely *Hydrilla verticillata*, *Nymphaea lotus*, *Salvinia cucullata*, and *Alternanthera triandra* were provided to both snails. It was discovered that *P. canaliculata* consumed all the four different food species offered. In contrast, *P. scutata* tended to feed on *S. cucullata* rather than the other species. It is concluded that *P. canaliculata* was superior to *P. scutata* in terms of growth rates, food consumption, and was also non-selective for food and therefore there is no doubt that in a shared habitat, *P. canaliculata* will influence *P. scutata*.

KEYWORDS: invasive species, wetland, competition, food

INTRODUCTION

Among the 3500 non-native species introduced to Thailand, the golden apple snail (*Pomacea canaliculata*, Lamarck) appears to be one of the worst invasive species[1]. It was introduced almost 30 years ago as a dietary protein supplement and as a pet in the ornamental aquatic animal industry. The spread of *P. canaliculata* in Thailand as a result of intentional and accidental introduction has caused enormous economic and ecological impacts[2]. *P. canaliculata* has invaded wetlands and paddy fields and destroyed agricultural produce, especially rice[3] leading to economic losses and the use of chemical pesticides that also adversely alter aquatic ecosystems and impact human health[4–7]. It has been estimated that in Thailand alone, *P. canaliculata* has caused losses of at least 3000 million US dollars per year due to agricultural destruction[1].

The impacts of *P. canaliculata* on aquatic vegetation have been relatively well studied[6,8–11]. In contrast, there is still much to know on how invasion by *P. canaliculata* may also affect other local fauna species in the area. For instance, in Thailand, populations of *P. scutata*, locally known as apple snail and similar to *P. canaliculata* in terms of size and shape, have decreased to an alarming degree[12]. The population reduction of this snail may be linked to the invasion by *P. canaliculata* in a shared habitat[5]. *P. canaliculata* may displace local snail species competing for food and space[10]. A recent study showed that *P. canaliculata* introduced to the Everglades, USA appeared to consume and grow more than the native *P. paludosa* resulting in greater rates of expansion[11]. In addition, any reduction of the local snail species may result from predation by *P. canaliculata* since a study in southern China in 2009 indicated that *P. canaliculata* caused significant mortality of all the early stages of the local five snails[13]. *P. canaliculata* may also be more adaptive to invaded habitat than local species particularly with respect to feeding behaviour and food preferences. *P. canaliculata* may be non-selective for food[14] while local snail species may be food selective, thus lowering their chances to thrive in environments where food sources are limited.

Since there is still no scientific evidence documenting the reduction of Thai native species dwelling in areas invaded by the golden apple snail, this study aimed to investigate the potential impact of *P. canaliculata* on *P. scutata* with regard to food competition and growth rates. We also determined the time it took for snails to reach different food offered, together with their feeding behaviour and food preferences. The results reveal a competition for food between *P. canaliculata* and *P. scutata* and disclose that *P. scutata* is selective for their food source. An ecological understanding of non-indigenous and indigenous species will lead to proper management and conservation policies to protect local snail species, which otherwise may soon disappear from natural habitats.

MATERIAL AND METHODS

Sampling *P. canaliculata* and *P. scutata*

Eggs of *P. canaliculata* were collected from natural habitats at Kasetsart University, Bangkok (13° 50′ 52″ N 100° 34′ 15″ E) whereas eggs of *P. scutata* were obtained from canals in a palm oil plantation in Plaiwas subdistrict, Kanchanadit district, Surat Thani province, southern Thailand (9° 09′ 56″ N 99° 28′ 16″ E). The number of eggs per cluster of *P. canaliculata* ranged from 100–855, while the number of eggs per cluster of *P. scutata* was only 40–45. Eggs of *P. scutata* (0.5 cm in diameter) were bigger in size than those of *P. canaliculata* (0.2 cm). Eggs of *P. canaliculata* and *P. scutata* were different in colours, with those of *P. canaliculata* being pink whereas eggs of *P. scutata* were white. Eggs of both snails were incubated in separate containers at constant room temperature (approx. 30 °C) in a laboratory of the Department of Environmental Technology and Management, Faculty of Environment, Kasetsart University, Bangkok, Thailand. After hatching, water spinach (*Ipomoea aquatica*) was used to feed both species before the snails were used in the experiments.

To test for food competition and growth rates, *P. canaliculata* and *P. scutata* at shell width of 1.0 cm and weight of 0.5 g. (one month old) were raised in the laboratory under two sets of conditions in 2 l cylindrical containers (raised together at a 1:1 ratio of *P. canaliculata* and *P. scutata* and secondly raised separately with one snail in each container). All snails were fed with water spinach (*I. aquatica*) daily (24 h). The water spinach provided was weighed before and after feeding of each snail. Measurement of growth rates (weight, shell height, and width) and food consumption of each snail was conducted every week. The experiment was repeated five times and lasted for five months. We also recorded the time it took for *P. canaliculata* and *P. scutata* to crawl to the food that was offered.

Selective behaviour for food between *P. canaliculata* and *P. scutata* was studied in the laboratory. We hypothesized that *P. canaliculata* is non-selective for food in comparison with *P. scutata* that is a food-selective snail. Four types of plants were used in the study as food sources, namely submerged (*Hydrilla verticillata*), emergent (*Nymphaea lotus*), floating (*Salvinia cucullata*), and marginal (*Alternanthera triandra*). Approximately 2 g of each species was planted in containers (2 l cylindrical containers) with aeration to avoid anaerobic conditions developing. Afterwards, one *P. canaliculata* (0.5 cm, one month old) was released in a container. A *P. scutata* specimen of the same size was also released in a separate container with four species of aquatic plants inside. Five replicates were used for validity testing of data and the experiments were conducted for one month. The growth rates of both snails and the amount of plants consumed were measured daily (24 h) from the beginning of the experiment. Observations on feeding behaviour between the two species were carried out after each food presentation.

We used EXCEL 2010 and SPSS Statistics 17.0 packages for statistical analyses. An F-test was applied to determine differences in food consumption, growth rate and the time taken between the two snail species to reach food. Values presented throughout are given as mean $\pm$ standard deviation for the numbers of samples measured.

RESULTS

Comparisons of food consumption, growth rates, and time to reach food

The statistical analysis of food consumption and growth rates between *P. canaliculata* and *P. scutata* revealed that *P. canaliculata* consumed significantly more food and grew significantly better than *P. scutata* in conditions when both *P. canaliculata* and *P. scutata* were raised together and when they were raised separately (Table 1, Fig. 1, and Fig. 2). It was also found that the overall growth rates of *P. canaliculata* and *P. scutata* were better when they were raised separately compared with the growth rates when they were raised together.

When raised separately, *P. canaliculata* consumed three times as much food as *P. scutata*. It was also found that consumption of *P. canaliculata* and

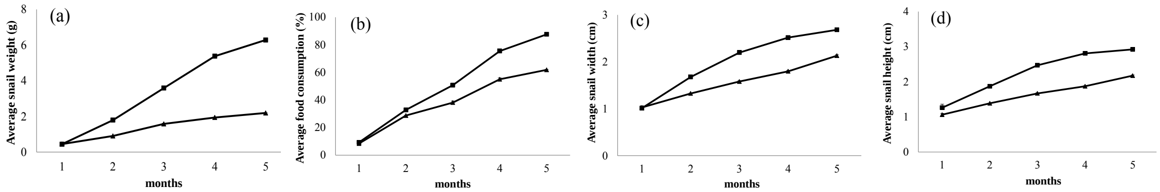

Fig. 1 Average food consumption and growth rates of *P. canaliculata* (black squares) and *P. scutata* (black triangles) when they were raised separately.

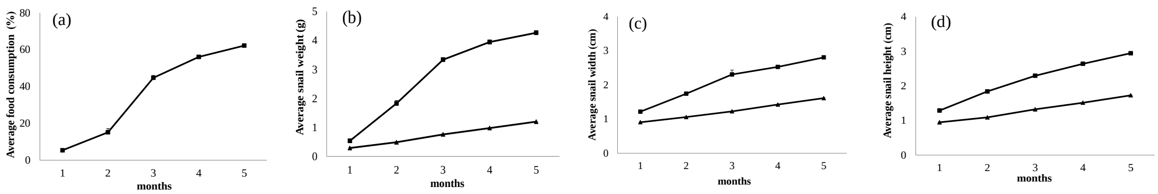

Fig. 2 Average food consumption and growth rates of *P. canaliculata* (black squares) and *P. scutata* (black triangles) when they were raised together.

Table 1 Growth rates of *P. canaliculata* and *P. scutata* when raised together and raised separately for two months ($n = 5$).

Measurement	*P. canaliculata*	*P. scutata*
Weight (g)		
Raised separately	3.2 ± 2.1	1.33 ± 0.65
Raised together	2.6 ± 1.4	0.69 ± 0.31
width (cm)		
Raised separately	1.94 ± 0.62	1.51 ± 0.37
Raised together	2.04 ± 0.66	1.21 ± 0.24
Height (cm)		
Raised separately	2.20 ± 0.68	1.57 ± 0.38
Raised together	2.12 ± 0.58	1.28 ± 0.27

Table 2 Food consumption (g) of *P. canaliculata* and *P. scutata* when raised together and raised separately for two months ($n = 5$).

	P. canaliculata	*P. scutata*	p value
Raised separately	1.80 ± 0.99	0.58 ± 0.49	< 0.05
Raised together	1.7 ± 1.1		

P. scutata together was lower than when raised separately (Table 2). In addition, when raised separately, *P. canaliculata* crawled to food at a significantly faster rate than *P. scutata*. In contrast, when raised together, the length of time to reach food for *P. canaliculata* and for *P. scutata* was not significantly different. However, the length of time taken to reach food by *P. scutata* was significantly different when raised separately and raised together but not for *P. canaliculata* (Table 3).

Table 3 Length of time (min) taken to reach food for *P. canaliculata* and *P. scutata* when raised together and raised separately for two months ($n = 5$).

	P. canaliculata	*P. scutata*	p value[b]
Raised separately	8.8 ± 3.6	19.8 ± 4.3	0.04
Raised together	8.2 ± 3.2	15.1 ± 3.1	0.67
p value[a]	0.23	< 0.05	

[a] Comparison within species.
[b] Comparison between species.

Table 4 Consumption (in g) by *P. canaliculata* and *P. scutata* feeding on *H. verticillata*, *N. lotus*, *S. cucullata* and *A. triandra* ($n = 3$).

Type of plant	*P. canaliculata*	*P. scutata*	p value
H. verticillata	0.47 ± 0.04	0.37 ± 0.04	0.97
S. cucullata	0.58 ± 0.03	0.51 ± 0.03	0.62
A. triandra	0.53 ± 0.03	0.35 ± 0.02	0.12
N. lotus	0.51 ± 0.04	0.39 ± 0.01	< 0.05

Rates of aquatic macrophyte consumption

Four types of aquatic macrophytes, namely *H. verticillata*, *N. lotus*, *S. cucullata* and *A. triandra* were offered to *P. canaliculata* and *P. scutata*. It was found that both snail species could consume all plants offered. In addition, the consumption rates by *P. canaliculata* and *P. scutata* when feeding on *H. verticillata*, *S. cucullata* and *A. triandra* were not significantly different. However, there was a significantly greater amount of *N. lotus* consumed by *P. canaliculata* than by *P. scutata* (Table 4).

Table 5 F-test for food preferences of *P. canaliculata* and *P. scutata*. Data in each row are p values ($n = 3$).

	H. verticillata	*S. cucullata*	*A. triandra*	*N. lotus*
P. canaliculata				
H. verticillata	1.00	0.29	0.31	0.74
S. cucullata	–	1.00	0.96	0.46
A. triandra	–	–	1.00	0.50
N. lotus	–	–	–	1.00
P. scutata				
H. verticillata	1.00	0.59	0.01*	0.00*
S. cucullata	–	1.00	0.05*	0.00*
A. triandra	–	–	1.00	0.03*
N. lotus	–	–	–	1.00

* Significant differences among data at $p < 0.05$.

P. canaliculata was non-selective for food, consuming similar levels of *H. verticillata*, *N. lotus*, *S. cucullata*, and *A. triandra* (Table 5). *P. scutata* however tended to consume preferentially *S. cucullata* rather than the other plant species offered.

DISCUSSION

According to our experiments, it could be stated that non-indigenous *P. canaliculata* is a successful invader as it consumed more food, grew better, reached food faster, and was non-selective for food in comparison to the native species, *P. scutata* (Fig. 1 and Fig. 2). The results clearly show that when raised separately, non-indigenous *P. canaliculata* consumed more (three times) and grew faster (twice) than *P. scutata*, compared to the Thai native snail that ate less and grew at a lower rate. Our study is in agreement with a study done in the USA showing that the non-native species *P. insularum* and *P. canaliculata* tend to eat more and grow faster than the native *P. paludosa*[11]. When raised together, the consumption and growth rates of both species were lower than when raised separately. The reduction in consumption and growth rates of both species when raised together could be linked to competition for food among species and perhaps linked to a space limitation when the two snails were raised in the same container. However, the food consumption and growth rates of *P. canaliculata* still tended to be higher and better than those of *P. scutata* when the two snails were raised together. Accordingly, in a shared habitat, it is likely that non-native *P. canaliculata* may displace the indigenous *P. scutata*. It is also interesting that the gap between growth rates (measured by weight) of the two snails was bigger when snails become larger. *P. canaliculata* may reach maturity faster than *P. scutata* and thus have a better chance to reproduce and expand its population.

The feeding patterns of *P. canaliculata* and *P. scutata* when offered food were different. *P. canaliculata* always moved quickly to the food regardless of whether the individual had been raised separately or raised together with the other species. This was indicated by the times taken to reach food by *P. canaliculata* which were not significantly different regardless of the rearing conditions. When *P. canaliculata* and *P. scutata* were raised separately, on average, *P. canaliculata* took about nine minutes to reach food offered, which was faster than for *P. scutata* as the latter species took much longer to reach food (20 min). A slower time to reach food for *P. scutata* when raised individually indicates that it does not have to compete for food with other snails. It is also interesting that when *P. canaliculata* and *P. scutata* were raised together, *P. scutata* took less time to reach food compared with the time for *P. scutata* raised separately. This may have been the result of competition for food experienced by the native species when living with non-indigenous species.

P. canaliculata and *P. scutata* appears to exhibit different food preferences. *P. canaliculata* did not show any preferences among the different food plants offered whereas *P. scutata* fed on preferred plants. *P. canaliculata* was non-selective for food since the amount of each plant species consumed was not different. *P. canaliculata* appears to feed indiscriminately regardless the plant species[14]. Other study also showed that when different food types were offered, *P. canaliculata* grazed heavily on both species of macrophytes provided[10]. A study conducted in Laos also supported this study that the absence of aquatic plants in wetlands may be linked to the presence of *P. canaliculata* as this species can eat almost any plant[15]. In contrast, *P. scutata* tended to be selective for food as it preferred *S. cucullata* over other species. Our study is in agreement with that of Carlsson[15] who reported that *P. canaliculata* had a strong negative effect on the growth and biomass of the preferred plants *S. cucullata* and *L. adscendens* that had been grazed down to very low levels. According to local residents, *S. cucullata* and *L. adscendens* have disappeared from the Vientiane wetlands since the snail was introduced in 1992[15]. Substantial grazing by *P. scutata* on *S. cucullata* may likely have been due to the softness of this plant species or perhaps it was easier to eat since it is a floating type of vegetation.

As they are non-selective eating snails, non-indigenous *P. canaliculata* may spread easily and survive better in natural habitats than other species such as the food-selective *P. scutata*. The food-selective behaviour of *P. scutata* was also confirmed in the study of Wood[16] who reported that *P. canaliculata* was not only a plant feeder but also had a profound effect on the freshwater bryozoan community through feeding, whereas the indigenous apple snail (*P. scutata*) does not graze on bryozoans. Our findings also reflect the fact that *P. canaliculata* is a non-food-selective snail that may cause a substantial impact on wetland vegetation that could result in a change from a plant-dominated state to a turbid phase dominated by phytoplankton[15].

Furthermore, it was obvious from direct observation that both *P. canaliculata* and *P. scutata* showed similar feeding behaviour as they first ate a floating plant, *S. cucullata* and then *A. triandra*, followed by *N. lotus*, and then by *H. verticillata* last as it is a submerged plant. This may have been due to easier accessibility to floating plants than submerged plants, thus resulting in lower consumption of *H. verticillata*.

In conclusion, the golden apple snail (*P. canaliculata*) was superior to the Thai native snail (*P. scutata*) in terms of food consumption, growth rate, time to reach food, and food preference. In a shared habitat, Thai native snails that eat less, move slowly to reach food, and are selective for food could be affected by golden apple snails, thus leading to a reduction in native snail populations. To conserve populations of *P. scutata*, the control of *P. canaliculata* in a shared habitat must be considered together with the promotion of pristine wetlands that consist of a great variety of aquatic macrophytes that can support the survival of local species like *P. scutata*.

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