Impact of the Introduction of Apple Snails and Their Control in Japan

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Abstract

The apple snail, *Pomacea canaliculata*[1], was imported into Japan and cultured extensively for food in the early 1980s. Not long after, escaped or discarded snails became feral and started feeding on rice seedlings and other aquatic plants. This was especially noted in Kyushu in southern Japan. Snails are still proliferating, but the area of damaged rice is not increasing as fast, mainly because of the success of snail control. Currently, the most effective methods of avoiding damage to rice are keeping water shallow, transplanting older seedlings and, in some cases, using molluscicides or repellents. However, these methods have almost no effect on damage by snail feeding when rice fields are flooded.

The apple snail is believed to be the most important obstacle to the spread of direct-sowing culture of rice in Kyushu. The Ministry of Agriculture, Forestry and Fisheries has launched a national project for the integrated management of the snail under direct-sowing rice culture. Some recent results from this project are briefly reviewed in this paper.

History of Introduction

The apple snail, *Pomacea canaliculata* (Fig. 1) is indigenous to tropical and temperate South America. It was imported into many Asian countries, including Taiwan, the Philippines, Vietnam and Thailand, mainly in the 1980s, as food for humans (Halwart 1994; Wada 1997a). It soon escaped into the wild and began to attack rice voraciously. It has now become one of the most destructive pests in rice cultivation in these countries. Other countries, such as Myanmar, Bangladesh and India, are threatened with invasion (Baker 1998).

In Japan, the first introduction of the apple snail can be traced back to 1964. A private company in Kumamoto prefecture, Kyushu, imported and cultured the 'albino' or 'golden' variety of the apple snail as an aquarium pet (Hamada and Matsumoto 1985). At that time the snails caused no apparent problems in the fields because they were cultured only for a few years in a cool mountainous area where escaped snails could not survive the winter.

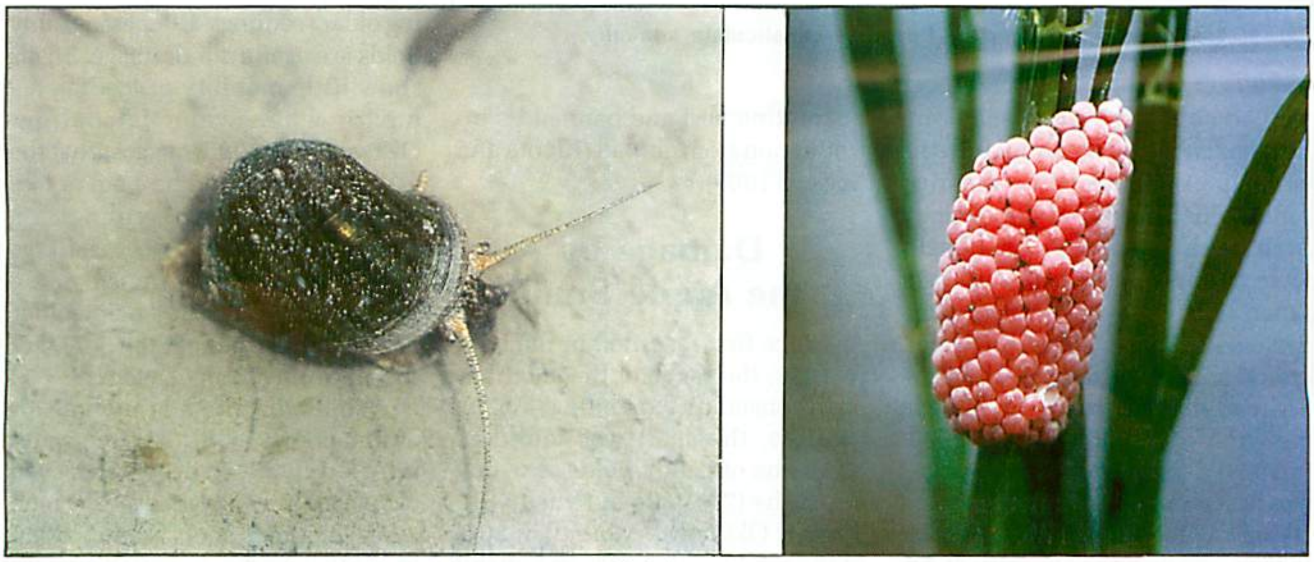

Fig. 1. **Pomacea canaliculata** *(left) and its egg mass (right).*

[1] Before Habe (1986), the apple snail was erroneously referred to as *Ampullarius insularus* D'Orbigny in Japanese literature.

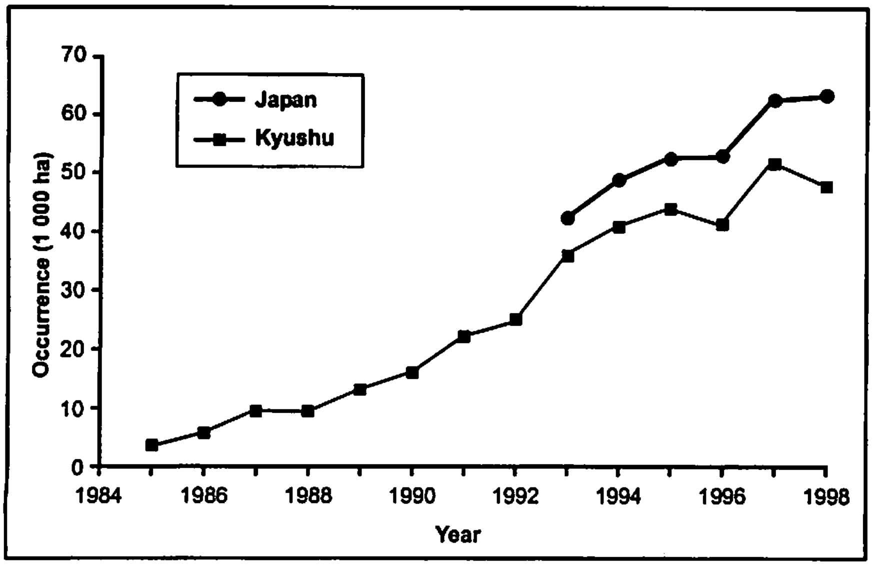

Fig. 2. Annual occurrences of Pomacea canaliculata *in paddy fields in Japan.*

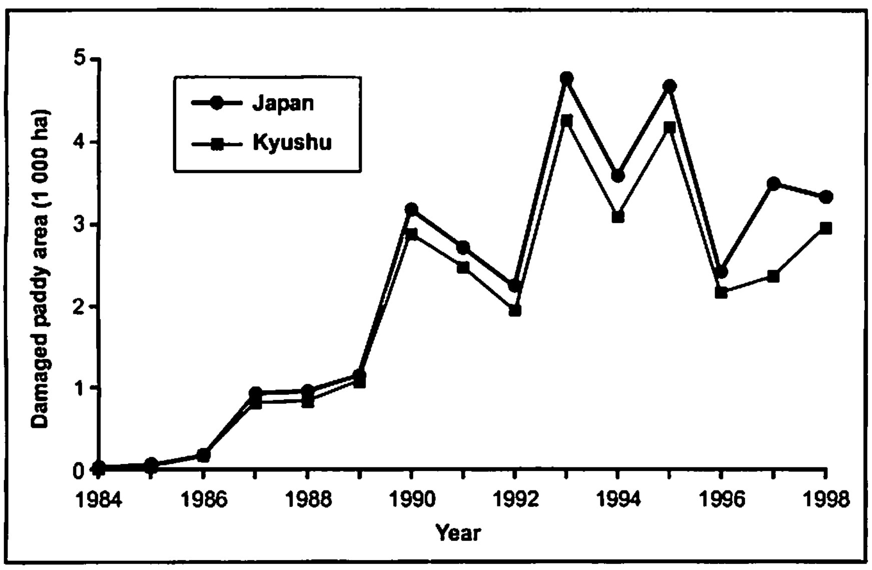

Fig. 3. Area of rice damaged by Pomacea canaliculata *annually.*

The culture of apple snails for human food became popular in the early 1980s. Snails were imported repeatedly from Taiwan or directly from South America. By 1983, snails were cultured in 495 sites all over Japan (Hirai 1989). Culture soon declined, however, because consumers did not like the taste of the snails. Escaped snails were found living in the wild for the first time in 1983. In 1984, damage to rice and rushes was first reported in Kumamoto and Okinawa prefectures (Wada 1997a). In the same year the Ministry of Agriculture, Forestry and Fisheries designated the apple snail as a quarantine pest and banned its introduction from abroad (Kiyota and Sogawa 1996).

Damage by the Apple Snail

Since first recorded in the wild in 1983, the range of the snail has been constantly expanding (Fig. 2). In 1998, the snail was found in 63 559 ha of paddy fields of which 48 162 ha (76%) are in Kyushu (including Okinawa). More than 20% of the total paddy fields in Kyushu were affected. Considering the difficulty of eradicating the snail or preventing it from spreading, it will probably continue to spread.

The area of cultivation infested by the apple snail has also been increasing since 1984 (Fig. 3). In 1998 the damaged area reached 3 273 ha, with 2 900 ha (89%) in Kyushu. The area varies considerably from year to year. The volume of rainfall during the rice transplanting season appears to be responsible for this variation. For instance, the damage was relatively small in 1996, when little rain fell during the rice transplanting season. The increase in the area of damage appears to have stopped in 1990. This is probably due to the success of snail control by farmers.

The apple snail also feeds on other paddy crops, including lotus, rush, taro, adlay millet (Job's tears) (Kiyota and Sogawa 1996; Wada 1997a). However, the damaged area of these crops is generally small, less than 30 ha all over Japan.

Current Methods of Snail Control

Table 1 lists methods currently used by Japanese farmers for controlling snails. Among these, the most effective and the most widely used are measures taken during the transplanting season, such as keeping the water level low or transplanting older seedlings. Ditches in paddy fields are useful for drainage. Snails show little mobility or feeding behavior when water is shallow. Ozawa et al. (1988) suggest that the water depth should be 4 cm or less to avoid damage to seedlings. As snails feed on young rice seedlings within 3 weeks after transplanting (Miyahara et al. 1986), using older rice seedlings reduces the period of susceptibility to snail attack.

When the field is uneven or drains poorly, control of the water level is difficult. In deep water, even older seedlings are attacked. In such cases, methods such as application of molluscicides or repellents are helpful. Among the chemicals currently registered in Japan, only calcium cyanamide (nitrolime) and IBP are molluscicides (Wada 1997a). All others are repellents. The application of calcium cyanamide is possible only before transplanting or after harvesting, as it is harmful to rice. Most farmers use one of these registered chemicals in cases where damage is likely. Some farmers use unregistered molluscicides, such as camellia seed cakes or metaldehyde. The former has a high toxicity for aquatic animals and should not be used. On the other hand, the latter is relatively safe and its registration as a molluscicide for this snail is now being pursued.

Another method for controlling snails during the rice transplanting season is early transplantation. Rice is usually transplanted in June in Kyushu, but earlier transplantation in cooler weather reduces snail feeding. However, this method is often not possible as many paddies in Kyushu have wheat as an off-season crop that is harvested in early June. The method is also unsuitable for subtropical areas.

All the above methods are useful in controlling snail infestation, but they have almost no effect when the fields are flooded. Most paddy fields with snail damage are in lowland areas in Nagasaki, Saga and Kagoshima prefectures, where the fields are sometimes flooded during the transplanting season.

Other methods aim mainly at reducing snail density and hence manifest infestation in both the current and the next season. Screens placed at water inlets and on high levees prevent snail intrusion. The effectiveness of screens differs among localities. When a screen was set at the water inlet in Shizuoka, Honshu, more than 4 000 snails were trapped during the rice season (Ozawa and Makino 1989).

Hand-picking of snails at transplanting may have the effect of reducing snail damage to rice. Removing 1 000 snails in a 10 ha paddy field takes only 1.5 hours and removing snails just once after puddling and once after transplanting successfully avoids damage (Hirai 1988). However, the effectiveness of removing snails or their egg masses in other seasons is often doubtful because there is a strong density compensation effect in this snail (Tanaka et al. submitted). Imperfect removal of snails or egg masses may have little effect on the snail density in the next generation.

The release of natural enemies is useful mainly for creeks rather than paddies, as chemical or physical control is difficult or impossible in creeks. Ducks (*Anas platyrhynchos*), turtles (*Amyda japonica*) and carp (*Cyprinus carpio*) have been released for snail control (Shobu 1996), but their effects are yet largely unknown. In one case, 20 ducks were released in a creek, but egg masses of snails did not decrease (Kondo and Tanaka 1991a). The effectiveness of several potential predators is now under examination.

Methods of snail control during the off-season include tillage, application of calcium cyanamide, removal of rice straw and drainage. Tillage reduces snail density by destroying snails, exposing them to cold air, or burying them deeply in the soil (Kiyota and Sogawa 1996). Application of calcium cyanamide after harvesting reduces snail density by directly killing snails, but it has little effect when the water temperature is below 15°C (Shobu

Table 1. Current methods for avoiding damage to rice.

Methods	Effects
Rice transplanting season	
Keeping water shallow or draining	Immobility of snails
Transplanting older seedlings	Less snail feeding
Molluscicides	Reduction of density
Repellents	Reduction of activity
Early transplanting	Low activity of snails
Rice growing season (including rice transplanting season)	
Setting screens at water inlets	Prevention of intrusion
Making high levees	Prevention of intrusion
Hand picking of snails	Reduction of density
Removal of egg masses	Reduction of recruitment
Release of natural enemies (especially in creeks)	Reduction of density
Off-season	
Tillage	Reduction of density
Calcium cyanamide	Reduction of density
Removing ice straw	Reduction of survival rate during winter
Draining (especially in creeks)	Reduction of survival rate during winter

Table 2. Topics under study in the National Research Project on the Integrated Management of* Pomacea canaliculata *in Rice Ecosystems.

Ecology of the snails and development of effective control methods in paddy fields
- Feeding and mating behavior
- Population dynamics in paddy fields
- Electrical control methods
- Cultural or chemical control methods under direct-sowing rice culture
- Mechanical control methods

Development of novel techniques for controlling apple snails in rice ecosystems
- Chemicals involved in feeding behavior
- Sex pheromones
- Hormones involved in reproduction
- Natural enemies in Japan
- Natural enemies in South America and tropical Asia

Integrated management of apple snails in rice ecosystems
- Integrated management

1996). Removal of rice straw and drainage reduces the wintering of snails in paddy fields and creeks, respectively.

The Apple Snail Project in Japan

The Ministry of Agriculture, Forestry and Fisheries in Japan is promoting direct-sowing of rice to reduce the cost of rice production. The apple snail is believed to be the most important obstacle to the spread of direct-sowing in Kyushu. Snail control is much more difficult under direct-sowing than under transplanting because small seedlings are more susceptible to snail attack. Novel techniques that keep snail density low ($\leq$0.5 snails per m^2; Kiyota and Sogawa 1996) or prevent snail feeding for a longer period are needed. The Ministry started a national project for the integrated management of the snails under direct-sowing culture in 1997. Its goal is to control snails with minimum reliance on pesticides and using novel techniques such as attractants, pheromones, or hormones that are in the process of being developed (Table 2).

Several significant results have been obtained through the project. For instance, draining just after sowing turns out to be highly effective at avoiding damage to rice by the snail. With the advent of effective herbicides, draining for a longer period is now possible. Paddy fields were drained for 3 weeks with no apparent damage to rice seedlings (Wada, submitted).

Forty-six species of freshwater animals in Japan were tested for their ability to feed on the apple snail. A wide variety of animals, including ducks, turtles, fishes, insects, crustaceans and leeches ate at least small snails (Yusa et al., unpubl.). Rats (*Rattus norvegicus*), ducks (*Anas platyrhynchos*), turtles (*Geoclemys reevesii*) and carp (*Cyprinus carpio*) turned out to be the most effective predators of adult snails. In the Philippines, a species of ant (*Solenopsis geminata*) was observed to feed voraciously on egg masses of the apple snail (Yusa, unpubl.; Way et al. 1998).

Conclusion and Future Directions

Drainage, transplanting of older seedlings and application of molluscicides or repellents are the most effective methods of snail control. Using these control methods can successfully avoid damage to rice in more than 90% of paddy fields affected by the apple snail. However, no effective methods have yet been devised for flooded fields. Moreover, methods applicable to direct-sowing rice culture or to creeks or other aquatic ecosystems are yet to be developed. Other problems include water pollution by molluscicides, a human health hazard due to the rat lungworm *Angiostrongylus cantonensis*, scenic fouling by the pinkish egg masses, and effects on the local ecosystems (Wada 1997a). On the other hand, the apple snail is a promising agent for paddy weeding (Okuma et al. 1994a, 1994b), probably the most effective among known biological agents. In fact, some farmers practicing organic rice culture already use this snail for weeding. The apple snail is also considered a good model for genetic studies (Fujio et al. 1991, 1997; Kobayashi and Fujio 1993) with its short life span, large body size, and ease of rearing. It has also been considered as a possible food source for space stations (Omori, pers. comm.). When the goal of controlling the snail is realized, it will be possible to make full use of them. The experience has indicated to us in Japan, the need for risk assessment before an exotic species is introduced.

Acknowledgments

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