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Invasions in Agriculture: Assessing the Cost of the Golden Apple Snail in Asia

The golden apple snail (*Pomacea canaliculata*) was introduced intentionally into Asia in 1980 with the expectation that it could be cultivated as a high-protein food source for local consumption and as an export commodity for high-income countries. It has since invaded Asian rice systems, where it is dispersed through extensive irrigation networks and feeds voraciously on young rice seedlings. This paper analyzes the economics of the golden apple snail invasion in Asia. The Philippines is used as a case study to quantify the direct, on-farm costs associated with yield loss, replanting, and snail control. The analysis shows that the cumulative (present-value) costs of the snail invasion to Philippine rice agriculture in 1990 were between USD 425 and USD 1200 mill., even without taking into account the nonmarket damages to human health and ecosystems. If this amount were invested in an effective quarantine and inspection program for nonindigenous species, similar exotic pest problems in agriculture could be avoided in the future.

"When contemplating the invasion of continents and islands and seas by plants and animals and their microscopic parasites, one's impression is of dislocation, unexpected consequences, an increase in the complexity of ecosystems already difficult enough to understand let alone control, *and the piling up of new human difficulties* (1) [emphasis added].

The deliberate movement of species between agricultural systems and regions has formed the basis of the world food economy as it now exists. The bread baskets of North America and Europe, as well as the Green Revolution agricultural systems of Asia, essentially originated from the introduction and cultivation of non-indigenous species (2). Indeed, the international transfer of crop seeds and modern agricultural technologies has been largely responsible for the near doubling of world grain production during the past 30 years. Yet the introduction and spread of weed seeds and crop diseases occasionally connected with these transfers have often posed serious threats to agricultural and natural ecosystems (3–5).

Intentional introductions of exotic species have also been used widely for biological control of pests in agriculture, with resulting successes and failures in terms of pest control and ecological balance (3, 6–9). In cases where biological agents have been successful at suppressing or eliminating pests, the benefits have been reflected in the mitigation of yield losses and the reduction in pesticide use. In other instances, however, exotic species introduced for pest control have invaded the agricultural systems they were intended to protect, with devastating consequences for crop yields, farm incomes, species richness, and ecological stability. Given the potential economic returns—but substantial risks—associated with the introduction of exotic species, it is clear that agricultural experts and policy-makers need to become more aware of both the process and implications of biological invasions, particularly in developing countries where resources in agriculture are relatively scarce.

This paper addresses the implications of biological invasions in agriculture by exploring the intentional, yet disastrous, introduction of the golden apple snail (*Pomacea canaliculata*) into East and Southeast Asian rice-growing regions (10). The case of the golden apple snail illustrates how a well-intended and seemingly harmless introduction can affect agricultural yields, farm income, human health, and natural ecosystems. It also demonstrates how complex even a well-managed agroecosystem can be, and how invasions are conditioned by economic as well as biological forces.

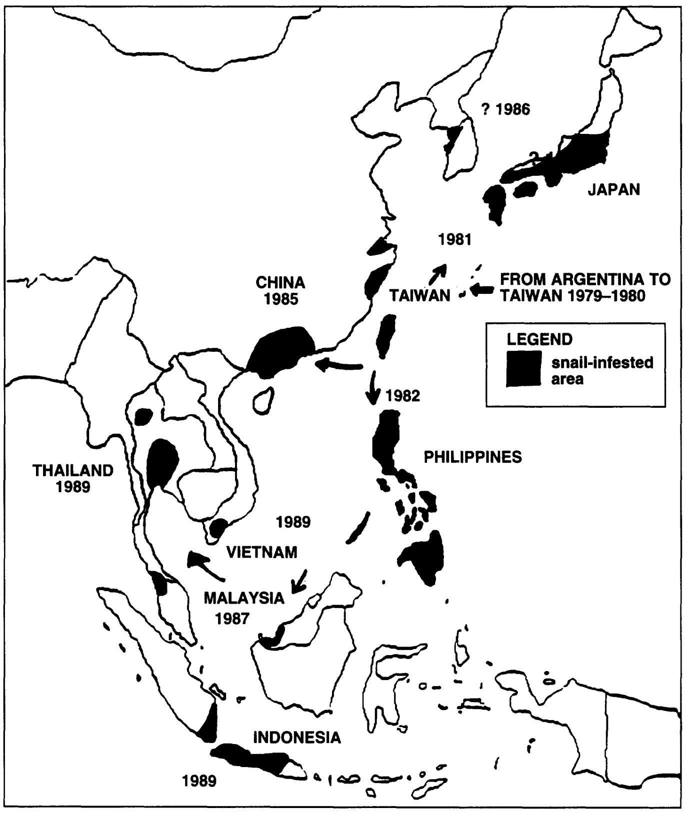

Figure 1. Distribution of the golden apple snail in Southeast Asia.

The stakes of avoiding exotic species invasions in Asian rice systems are high. Rice is the most important crop in Asian agriculture in terms of consumption, farm incomes, and employment. Substantial growth in irrigated rice yields will be required to meet demand in the next few decades, and this growth will have to occur at low costs so that rice remains affordable to poor consumers, who depend on rice as their primary staple. In recent years, however, yield growth in irrigated rice has plateaued, and farmers have come under increasing cost pressure as wage rates in most parts of Asia have risen (11, 12). Exotic species invasions that either damage yields significantly or impose high costs of control thus threaten food security and rural incomes—either at the local or regional level depending on the scale of the invasion. In the case of the golden apple snail, the invasion has now spread across many of the high-productivity, irrigated rice systems of Southeast and East Asia.

INTRODUCTION OF THE GOLDEN APPLE SNAIL INTO ASIA

The golden apple snail is indigenous to South America and was first introduced into Asia in 1979–1980 (13–19). It was introduced intentionally into the region with the expectation that it

Adult golden apple snails mating. Photo: R. Naylor.

Women in the Philippines picking the golden snail. Photo: R. Naylor.

could be cultivated as a high-protein food source for domestic consumption and as an export commodity for industrialized countries, where there has long been a cultivated taste for *escargot*. One of the most alluring features of the snail for entrepreneurs—and one of the most dreaded features for ecologists—is that it has a voracious appetite and breeds extremely rapidly. As a result, vast quantities of large snails (up to the size of an apple, and hence its name) can be produced for market within a relatively short time period, with low investment costs in terms of initial snail inputs. Potential financial returns to production are therefore substantial in the short run, provided that a viable market exists for the golden snail and that other inputs, particularly an abundance of soft, leafy vegetation and a constant freshwater supply, are available at relatively low prices. Because of its easy maintenance and fast breeding, the snail was referred to as "the golden miracle snail" at the time of its introduction (20).

The snail was identified first in Guadeloupe, but is thought to have originated from the swampy regions in the catchment of the Parana river in Paraguay (15, 21, 22). Populations of the golden snail have also been abundant in coastal rice-growing areas of Surinam, where they became a major pest when large-scale irrigated rice production began in the 1950s (17). Given the history of the golden apple snail as a major pest in irrigated rice in Surinam, it is surprising that it was intentionally introduced—even under controlled conditions—into Asian countries.

Initially, the golden apple snail was smuggled illegally into Taiwan (23). From Taiwan, it was brought into Japan by entrepreneurs in 1981, and was then introduced officially into the Philippines in 1982, where it was endorsed by the Department of Agriculture as a rural "livelihood" project (15, 24). Later in the 1980s, it was introduced into China, South Korea, Malaysia, Thailand, Indonesia, and Vietnam (14) (Fig. 1). Recent reports indicate that it was also introduced into Laos and Papua New Guinea in the early 1990s (22, 25).

In virtually all of these cases, the snail was introduced into cement tanks, managed ponds, and backyard soil pits. However, a combination of low market value and negligence—presumably correlated—soon resulted in the release and escape of the golden apple snail into irrigation ditches and public waterways throughout the regions in which they were introduced. It can only be surmized that entrepreneurs spreading the snail throughout Asia were myopic, deceptive, or simply ignorant of the market. A number of studies (13, 15, 16, 22-24) report that the market value for the snail dropped precipitously soon after its introduction, because industrialized countries maintained stringent health regulations that largely precluded its importation, and because Asian consumers did not like its taste. Despite its high protein content, even many low-income farmers in Asia have refused to eat the snail (26).

Evidence from Taiwan, Japan, and the Philippines shows that once the snails moved into irrigated systems, their infestation of rice paddies was rapid and widespread. In Taiwan, the occurrence of *Pomacea* snails was reported on 13 000 ha of rice fields in 1982 (2% of total rice area) and rose to 151 444 ha by 1986 (28% of total rice area) (13, 23). *Pomacea* snails were confirmed to have infested 34 of the 47 rice-growing districts in Japan by 1986 (14), and in the Philippines, the proportion of wet-rice area infested by the golden apple snail rose from less than 3% in 1982 to as much as 15% by 1991 (27). Within five years of its introduction to Vietnam, snail infestations were reported in every rice-growing province and in three-quarters of the country's rice-growing districts (pers. comm. Vo Mai, Vice Director, Department of Plant Protection, Ministry of Agriculture, Vietnam, 1995).

The relative abundance of golden apple snails in Asian agricultural systems has led to increasing reports of unintentional introductions in recent years (22, 24). In Malaysia, for example, imported water cabbage from Thailand has been found to be contaminated with young snails, which has caused the government to temporarily ban the import of vegetables from Thailand.

The golden apple snail now represents one of the most impor-

The golden apple snail (*Pomacea canaliculata*)-egg mass (larvae) in Asian rice. Photo: R. Naylor.

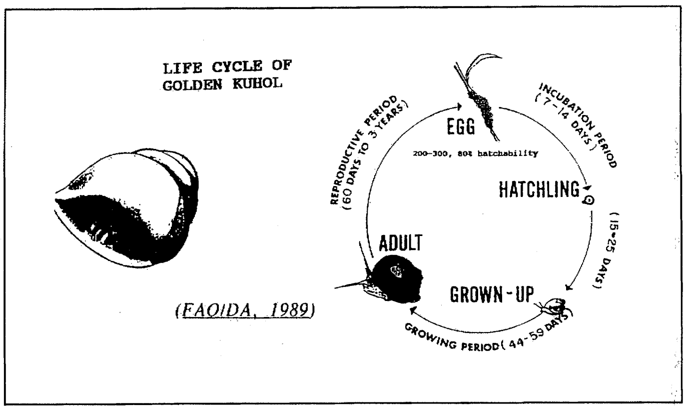

Figure 2. Life cycle of the Golden Kuhol.

tant non-seed-borne pests of rice in Asia from a quarantine perspective (13, 19). Since its release, the snail has fed on a wide range of aquatic plants of economic value to Asian farmers, including young rice seedlings, taro, swamp cabbage, lotus, mat rush, Chinese mat grass, wild rice, Japanese parsley, water chestnuts, and azolla (13, 14, 28). In addition, it has damaged maize (29) and citrus (30). By far the greatest damage has occurred in irrigated rice ecosystems, which provide an ideal environment for the dispersal and growth of the snail (13, 14).

RISK AND DAMAGE ASESSMENT

In hindsight, it seems evident that if the potential risks of snail infestation in irrigated rice had been weighed against the expected economic returns of snail cultivation, the golden apple snail would not have been introduced into Asia. Accurate marketing information about the snail was clearly absent, and the introductions apparently were made without any analysis of the ecological dynamics of the snail and its potential to invade flooded rice systems. A better understanding of the probability of invasion and possible extent of damage from the invasion surely would have signaled the need for strict quarantine restrictions throughout the region.

Probability of Invasion

A successful invasion by any exotic species depends on both the vulnerability of the ecosystem to invasions (invasability) and the characteristics of the invader as defined by its population dynamics and dispersal activity (1, 31). Like most invasions of exotic species, the golden apple snail invasion occurred in a human-altered and simplified ecosystem, with a lower number of species and predator-prey relationships than a natural, undisturbed ecosystem. Its main competitor, the native "kuhol" snail, is not closely related, and therefore the natural biological control agents for snails in this system have not been effective at controlling the exotic golden apple snail. The native regions of the golden snail in South America, characterized by coastal swamp areas, are remarkably similar to wet-rice ecosystems of Asia (17). The latter have thus provided a suitable environment for the golden apple snail's establishment.

Additional characteristics of successful invaders are that they often have high reproductive output, short juvenile periods, and high rates of dispersal. Figure 2 shows the life cycle of the snail. Sexual maturity is attained in 60 to 90 days after hatching, at which time the females begin laying eggs (32, 33). Females lay about 320 eggs in a bright pink egg mass on rice plants, the walls of irrigation canals, and fences at any given time. A female typically produces between 2400 and 8700 eggs per year, with hatchability of 7 to 90% depending on predator populations and human controls (13, 14, 34). Mating occurs at any time of the day among crowded plants and in all seasons of the year as long as there is a continuous supply of water (20). The golden apple snail reproduces about ten times faster than the native snail in Asian rice systems.

Successful invaders are dispersed rapidly by water, wind, or human activity, and tend to be resilient to changing climatic conditions. The golden snail is a freshwater snail, but it can also lead an amphibious life in the mud when the water recedes (14, 15, 20). The snail typically buries itself in moist mud and digs deeper into the ground as the dry season goes on. It can live dormant in the mud for six to eight months, then starts feeding again within minutes to hours once the soil is flooded. Given the monsoon patterns of Asia, the snail has a good chance of survival based on climatic conditions alone. It is most abundant in flood-prone areas and regions with poor water control, but it persistently reappears in high-productivity irrigated areas where dispersal through canals is high (18, 23, 27, 35).

The high correlation between characteristics of a successful invader based on ecological principles and characteristics of the golden apple snail in Asian rice systems indicate that the invasion of the snail could and should have been predicted. Indeed, the probability of invasion might have been estimated at well over 50% prior to the introduction. In hindsight, the probability of invasion was more in the order of 90%, given that virtually all reported introductions of the golden apple snail into rice ecosystems have resulted in invasions (17, 27).

Damage Assessment

The successful establishment and invasion of the golden apple snail in irrigated rice systems in many parts of Asia have led to significant economic damage. Farmers in the infested areas are faced with the options of paying additional costs to control the spread of snails, replanting damaged areas of paddy, or ignoring the problem all together at the risk of potentially large yield losses. Yield loss is a function of the density and average size of snails in the paddy, as well as the age of the crop. Experimental studies show that a density of 1 snail m^{-2} of paddy can reduce the crop stand by roughly 20%, whereas a density of 8 snails m^{-2} can reduce the stand by over 90% (16, 36). Experimental data also show that damage to rice in fields with large snails (over 5 cm.) is about three times greater than damage in fields with small snails (under 2 cm.).

Rice seedlings are most vulnerable to golden snails up to two weeks after they have been transplanted or up to 4 weeks after they have been direct (broadcast) seeded (17, 19, 20, 37, 38). Direct-seeded rice suffers significantly more damage than transplanted rice, because golden snails consume greater amounts of the younger, more succulent plants. Experimental data presented by Morallo-Rejesus et al. (18) show that snail damage in uncontrolled fields can be as high as 100% for rice seedlings in the germinating stage, as opposed to 20% on average in the transplanting stage. Where snail infestations are severe, replanting can cost twice as much or more per hectare than the initial savings earned by direct seeding as opposed to transplanting (26, 39). This point is of special significance because the newest rice varieties being developed for Asia are much more likely to be direct seeded rather than transplanted (40).

Market Costs

Unfortunately, there are few reliable data on the extent of infestation, crop damage, and yield loss in most rice-growing regions where the snail has been introduced. A wide range of field-survey data do exist, however, on the economic costs of the snail invasion in the Philippines (38, 41, 42). Based on reports cited throughout this paper, it appears that no country has suffered greater damage from the snail than the Philippines in terms of yield loss and costs of control. The Philippine experience thus serves as a good model for assessing the economic costs of the snail invasion. It also serves as a basis of comparison with other Asian countries to determine why the snail invasion is considered to be one of the leading pest problems in the Philippines, but a less serious economic problem—at least currently—in countries like Vietnam.

Damage to farmers' fields in the Philippines has been estimated at under 5% and up to 100% depending on the region and severity of infestation. Despite this large variation, the reported average losses generally have been high. The Rice IPM Network (41), for example, reported yield losses as high as 40% in infested fields of Luzon in 1990. In the Revilla et al. survey (38) in the province of Nueva Ecija in 1990–1991, almost one-half of the farmers interviewed reported more than 25% damage in their rice fields, and over 40% of the farmers reported more than a 25% yield reduction. Over 10% of these farmers claimed to have had no harvest at all.

Table 1 shows the total damage from snails to Philippine rice agriculture in 1990 based on the market costs of yield loss, replanting, and typical control measures. Assuming a snail density of 1 snail m^{-2} (43), the extreme loss in production (with no control or replanting) would be 270 000 tons (metric tons) of direct-seeded paddy, valued at almost USD 50 mill. in 1990. Actual production losses after replanting and control are estimated to be between 0.7–1.0% of total rough rice output (41). Such a loss amounts to 70 000–100 000 tons of paddy, valued at USD 12.5–17.8 mill. in 1990.

Table 1. Economic costs of golden apple snail damage in Philippine rice systems (USD mill. 1990).

Description of costs		Cost amount*
Yield loss with snail control and replanting	high	17.8
	low	12.5
Replanting costs with snail control	high	10.3
	low	2.8
Costs of control with molluscicides and handpicking	high	17.2
	low	12.5
Total cost of snails to farmers	high	45.3
	low	27.8
Yield loss with no snail control or replanting		48.0

*Assumptions for 1990 cost calculations:
Paddy production: 9.88 mill. ha. (44)
Rice area: 3.433 mill. ha. (44)
Yields (with snail) 2.9 ton ha^{-1} (without snail 3.0 ton ha^{-1}) (44)
Farm harvest paddy price (in pesos): 4720 ton^{-1} (59)
Agricultural wage: USD 2.15 day^{-1} (59)
Exchange rate: 24 pesos = 1 USD (45)
Infested rice area: 11–15% total rice area (27, 38, 41)
Replanting costs: 758 pesos ha^{-1} (low estimate), 2738 pesos ha^{-1} (high estimate), 2 crop yr^{-1} (26, 39)
Total molluscicide and insecticide use for snails: 40 000 L fentin acetate, 20 000 L fentin hydroxide, 110 000 L fentin chloride, 400 000 liter endosulfan (26, 39)
Pesticide prices: fentin acetate 700 pesos L^{-1}, fentin hydroxide 623 pesos L^{-1}, fentin chloride 525 pesos L^{-1}, endosulfan 223 pesos L^{-1} (26, 39)
Handpicking (when pesticides are used): 6–12 day ha^{-1} (2 crops) (26, 39).

Molluscicides and insecticides, as well as some labor for handpicking, have been used to control snail infestations in the Philippines (26, 27, 39). The cost of these controls in 1990 prices was roughly USD 12.5–USD 17.2 mill. In cases where the control was not completely effective, farmers either replanted or suffered a yield loss. Based on Warburton and Prabhu's 1990/91 farm survey estimates (26), replanting costs amounted to USD 32 ha^{-1} in well-controlled regions, and over USD 114 ha^{-1} in poorly controlled regions for a double crop year. Aggregate replanting costs thus ranged from USD 2.8–USD 10.3 mill.

Combined with the yield loss reported above, the total cost of golden apple snails in 1990 to Philippine farmers was between USD 28 and 45 mill. This amount is nontrivial for the Philippines; it is equivalent to 25–40% of the value of rice imports for the country in 1990 (44). Moreover, the losses are cumulative. Table 2 provides cost estimates on a present value basis, assuming discount rates of 5%, 10%, and 15% (45). The cumulative costs in 1990 prices range from USD 425 and USD 1200 mill., depending on the extent of damage and the discount rate. These costs are conservative, because the calculations assume that snail infestations are held at their 1990 level into the future.

Indirect and Nonmarket Effects

In addition to the direct costs of snail control, replanting, and yield loss that Asian rice farmers have and will incur as a result of the golden apple snail invasion, several indirect and nonmarket costs have arisen from both the methods of control and the invasion itself. For instance, the snail invasion may have implications for the health and functioning of surrounding natural ecosystems. In some nonarable areas of Japan, for instance, the snail feeds on decomposing organic matter and leafy vegetables, including wild rice (13, 20, 46). The likelihood of a significant invasion of the snail into natural areas has not been determined; however, it would most likely be confined to flood-prone or swampy areas and could conceivably eliminate some wild rice populations that could be critical sources of germplasm for rice agriculture in the future.

There are also some indirect threats to human health. The snail has been found to be an intermediate host of the lungworm, *Angiostrongylus cantonensis,* which is normally parasitic in rats, but which also causes the disease eosinophilic meningoencephalitis in humans (13, 19, 47, 48). Moreover, it acts as an intermediate host to various trematodes that can cause skin irritations (49).

One of the most widespread and immediate methods of control for the golden apple snail in the Philippines, Japan, and Taiwan has been the use of molluscicides, especially organotin compounds, and insecticides, such as endosulfan and niclosamide (13, 17, 20, 26, 28, 39, 50). These compounds have been shown to be extremely toxic to fish (51–53), and they present health risks to workers and plow animals in the field (54). Furthermore, they are toxic to many nontarget organisms, and thus alter predator-prey relationships of insects and other animals in the rice fields. In the Philippines, for example, the widespread use of endosulfan to control the golden snail has offset ongoing efforts to implement an integrated pest management strategy for insect control (39).

Botanical pesticides, which are biodegradable and therefore less likely than synthetic pesticides to leave harmful residues, are now being widely explored to control the golden apple snail (18, 55, 56). The most effective botanical pesticides that have been identified to date include: weed extracts, such as makania (*Makania cordata*) and garden spurge (*Euphorbia hirta*); leaves of trees and flowers, such as the starflower (*Calotropis gigantea*) and the makabuhai plant (*Tinospora rumphii*); and plant extracts from the Asian tubli tree *(Derris elliptica*). Although specific plant extracts with pesticidal properties have been identified, the active chemical substances in these extracts responsible for killing the golden apple snail have not yet been isolated (55). Furthermore, these chemicals are often not well targeted and do not necessarily have short half-lives.

ALTERNATIVES EXPLORED

Although molluscicides and insecticides are used widely in the Philippines, Japan, and Taiwan to control golden apple snail infestation, several other control measures are available to farmers. The most effective forms of population control for the snails are handpicking, pasturing ducks in the paddy, and careful water control that includes the occasional drainage of fields and maintenance of water levels below one centimeter (14, 27, 35, 41). Table 3 indicates the quantity of inputs and success rate for the various control techniques. Irrigation control is difficult to quantify, but the success rate for drainage can be 80% or more in the dry season. In the monsoon season, farmers only have limited control over water levels in their paddy fields.

The extent to which each of these alternative control measures are used in the Philippines and other Asian rice-growing countries depends on prices and institutions that govern labor costs, land holdings, duck markets, pesticide use, and irrigation systems. Comparative data from the Philippines and Vietnam shown in Table 4 provide some insight into the relative severity and costs of the snail problem in countries at different stages of development. In Vietnam, the low cost of labor makes handpicking and duck pasturing for snail control relatively attractive. Handpicking costs about USD 5 ha^{-1}, and duck pasturing costs just over USD 4.50 ha^{-1} (57). In comparison, handpicking costs roughly USD 10 ha^{-1}, and duck pasturing costs over USD 9 ha^{-1} in the Philippines. The use of molluscicides to control golden apple snails in the Philippines costs USD 7 ha^{-1} or more, with wide variation in costs depending on the chemical and rate of application (17, 26).

These numbers illustrate that current economic conditions allow for the maintenance of a quasi ecological equilibrium in Vietnam, in which human and duck populations are able to keep golden apple snail populations in check. Based on recent observations (by the author) in the Mekong Delta, it appears that most of the snail collectors are actually children, who are encouraged to pick golden apple snails as part of the government's eradication program. In one day, a child can pick up to 10 kg of snails and sell them as duck feed for about USD 0.50–0.60 (1995 prices). This provides children (and households) with additional income; however, the return is still well below the 1995 farm wages of USD 1 day^{-1} for women and USD 2 day^{-1} for men. The current equilibrium in snail populations is thus based in large part on the abundance of children and strong government controls that still exist in rural areas of Vietnam.

This type of equilibrium cannot easily be maintained in the Philippines, where the costs of labor and duck pasturing are significantly higher, and where a strong consumer market for ducks has not yet developed. Moreover, the golden apple snail was introduced much earlier into the Philippines, resulting in significantly larger populations than are observed currently in Vietnam. In ten years time, it is likely that the scope of the snail problem in Vietnam will rival the Philippine's present snail infestation, unless very effective control measures are pursued.

Table 2. Cumulative (present value) costs of the snail invasion in the Philippines (1990 prices, USD mill.)

	1980–1989[1]	1990[2]	1991 forward[3]	Total (present value) costs
5% discount rate				
high damage	243	45	893	1181
moderate damage	152	28	584	736
10% discount rate				
high damage	294	45	447	786
moderate damage	183	28	306	489
15% discount rate				
high damage	355	45	300	700
moderate damage	221	28	204	425

[1] Assumes linear growth in infested rice area and constant snail density of 1 snail m^{-2}.
[2] 1990 costs follow directly from Table 1.
[3] Assumes that real prices and the amount of yield loss, replanting, and control measures remains constant.

Table 3. Control techniques for the golden snails (2 snail m^{-2}, wet season).

Control Technique	Quantity	Success rate (%)[1]
Hand picking (hr ha^{-1})[2]	30–40	98
Pasturing ducks (no. ha^{-1})[3]	200	89
Associated labor (hr ha^{-1})[4]	32	
Molluscicides/Insecticides (kg ai ha^{-1})[5]	0.1–0.3[6]	90[7]
Associated labor (hr ha^{-1})	4	

[1] Defined by proportion of snails eliminated in a single season during the vulnerable period of plant growth.
[2] For reference see Hirai (16) and the Rice IPM Network (41).
[3] Ducks are pastured for two days, 8 hours per day immediately preceding transplanting (60).
[4] Assumes 1 duck herder for each 100 ducks.
[5] For reference see Warburton and Pradhu (26, 39) and Revilla et al. (38).
[6] Doses (kg ai ha^{-1}) vary by chemical: 0.1–0.2 for fentin chloride; 0.15–0.3 for fentin acetate and fentin hydroxide; and 0.2–0.3 for endosulfan. Standard deviations appear to be quite high.
[7] Success rate of 90% assumes low water level (less than 1 inch) and good water control. In deep water with flooding, the success rate is 0–20% (27, 61).

Table 4. Agricultural indicators related to snail control Philippines and Vietnam (1988–1991) (59).

Country	Median farm size, irrigated rice (ha)	Wage rate (USD day^{-1})	Farm paddy price (USD kg^{-1})	Wage rate/ paddy price (kg day^{-1})	Ducks per ha crop-land
Philippines	1.7–2.5	1.74	0.15	11.60	1.00
Vietnam	1.3	0.87	0.10	8.70	4.55

POLICY IMPLICATIONS

The extensive economic, ecological, and health ramifications of the golden snail invasion in Asia provide a perfect illustration of what Elton (1) meant by "the piling up of new human difficulties". This invasion is clearly a case of an introduction that should not—and perhaps would not—have occurred if closer policy attention had been directed toward the full set of risks associated with the introduction. It also raises the question of quarantine procedures, which are not very stringent in many industrialized countries, and noticeably absent in many developing countries where there is a lack of both training and regulations on species introductions (19).

Institutionalizing quarantine programs in developing countries that can effectively mitigate the introduction of exotic species is critical for two reasons: to reduce the scale of biodiversity loss and ecosystem damage globally; and to avoid large economic losses that poor countries and poor people can ill afford. Given that exotic species are most vulnerable at the early stage of establishment, investments in programs to avert introductions or to eliminate early establishments have a much higher return than investments in the control of a well-established pest. In the Philippines, for example, a loss as high as USD 45 mill. (Table 1) represents almost one-half the total amount that the U.S. Animal and Plant Health Inspection Service (APHIS) spent on agricultural quarantine and inspection in 1990 (58). This comparison is useful in showing that the resources spent by rice farmers on snail damage in the Philippines was equivalent to the amount that the government could have spent to implement a viable quarantine program for all agricultural introductions.

Instead, scarce resources were spent just on dealing with the golden snail invasion, and resources will continue to be spent on the snail problem for many years to come. There is an urgent need for more recent and precise data on the extent and full costs of the golden snail invasion in Asia. Better data are needed, in particular, to clarify the current and potential impact of the invasion on farm incomes and food security in the region. Improved data are also needed to help justify greater investments in quarantine programs throughout Asia and in research on biological controls for the snail. For given the complexity of rice agroecosystems and their importance in the Asian economy, preventing and controlling accidental, harmful, or potentially explosive invasions of species into Asian rice-growing areas should be given a much higher priority than it is being given today.

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