

# NPAG DATA: *POMACEA CANALICULATA* GOLDEN APPLE SNAIL

May 7, 1998

## TAXONOMY:

**Phylum:** Mollusca  
**Class:** Gastropoda  
**Subclass:** Prosobranchia  
**Order:** Mesogastropoda  
**Family:** Ampullariidae

This taxonomy follows Purchon (1977); the taxonomy of Taylor and Sohl (1962) is different.

**Full Name:** *Pomacea canaliculata* (Lamarck 1822)  
**Common Names:** Channeled apple snail (Neck & Schultz, 1992)  
Golden apple snail (Palis, Macatula, & Browning, 1997)  
Golden kuhol (Ponce de Leon & Carpo, 1994)

## US DETECTION DATA AND/OR DISTRIBUTION MAP:

### Initial Detection in Hawaii:

Location: ?, HI (Island of Lanai)  
Date: ?96 (probably earlier)  
Host: (?)  
Collector: ?R. Cowie, CA Department of Food and Agriculture  
Identifier: ?R. Cowie, Hawaii Biological Survey  
Bishop Museum, Honolulu, HI 96817-0916  
Iden. Date: ?1996 (date of article by Cowie)

### Initial Detection in Continental US:

Location: Palm Beach, FL (Palm Beach County; Haverhill Road)  
Date: 15Aug78  
Host: (No field notes available; lantana; drainage canal)  
Collector: John Spengler  
Identifier: Florida Museum of Natural History  
University of Florida, Gainesville, Fl 32611-7800  
Iden. Date: 1994 (date submitted to Florida Museum of Natural History)

### **Subsequent Detection(s) in Continental US:**

On its Internet site (<http://www.flmnh.edu/natsci/malacology/malacology.htm>), the Florida Museum of Natural History lists additional detections:

Palm Springs County, FL	Boynton Beach	1980
Collier County, FL	Along Tamiami Trail	1996
Hillsborough County, FL	Tampa, Interbay Peninsula	1996

Location: Houston, TX  
Date: 1989 (and 1990)  
Host: (?)  
Collector: (?Texas Parks and Wildlife Department, Austin, TX)  
Identifier: (?)  
Iden. Date: 1992 (date of article by Neck and Schultz; requested)

Location: Stoneville, NC (Rockingham County)  
Date: 22Oct92  
Host: (No field notes)  
Collector: Lloyd Garcia  
Identifier: Florida Museum of Natural History  
University of Florida, Gainesville, Fl 32611-7800  
Iden. Date: 1993 (3/4/93; date submitted to Florida Museum of Natural History)

Location: Lake Miramar, CA (San Diego County)  
Date: 1997 (late in the year)  
Host: (No host specified)  
Collector: CA Department of Fish and Game  
Identifier: Dr. Robert Cowie, Bishop Museum  
Honolulu, HI 96817  
Iden. Date: 1997 (CPPR, 1997)

### **QUARANTINES:**

Apparently, few, if any, quarantines initially existed because of the imagined value of the golden apple snail for snail farming and/or weed control.

When the golden apple snail started to cause serious damage in the Philippines, the Malaysian government immediately issued a quarantine act prohibiting the transport and culture of the snail (Halwart, 1994a).

No information on current quarantines was found; apparently few quarantines exist because of the rapid spread of the golden apple snail throughout Asia and North America.

Godan (1983; pg 282) does *not* include this species in a list of quarantine snails of special importance.

This species might have been considered as beneficial. Godan (1983) also states that *Pomacea* species which feed on eggs masses can contribute to population reductions for the freshwater snail, *Biomphalaria glabrata*. Cazzaniga and Estebenet (1985) state that *Pomacea canaliculata* has potential as a control agent of *Chara* and other aquatic weeds in drainage canals.

This snail does *not* appear in a 1960 listing of snails and slugs of quarantine significance to the United States (Agricultural Research Service, 1960).

Byas (1972) does *not* list this species; however, Byas lists three other species in the *Pomacea* and none are considered "injurious."

## **LIFE HISTORY:**

Lamarck first described this snail from Guadeloupe; however, there is reason to believe that the snails originated from the Paraguay (Parana) River. In Brazil, the golden apple snail is found in the wide floodplains of the Pantanal; in Bolivia, in swamps and hot springs. Provided with both gills and a lung-like breathing organ, *Pomacea* snails are well adapted to life in alternating wetland and dryland habitats such as seasonal swamps or rice fields (Halwart, 1994a).

**Egg Stage:** To lay eggs, adult females crawl out of the water in the early morning and evening and lay 25-500 eggs in bright pink batches on rice tillers, sedges, rice field dikes, or other firm substrata protruding from the water. Within one to two weeks after deposition, the eggs in the egg masses gradually lighten and hatching commences. Hatching time varies from 10 to 15 days in the Philippines to 3 weeks in Japan (Halwart, 1994a; Mochida, 1991). In Japan, hatchability was highly variable, ranging from 7% to 90% (Halwart, 1994a; Mochida, 1991).

**Pre-adult Stage:** The newly hatched neonate snails drop into the water and soon start moving about, feeding on algae and detrital aggregates. The abundance of juvenile snails is negatively correlated with the density of adult snails. When grown to a shell height of about 1.5 cm, juveniles start consuming plant material.

**Adult Stage:** The golden apple snail has separate sexes which can be morphologically distinguished by the curve of the operculum. In the Philippines, the sex ratio (m:f) of snails in rice fields was 1:2.1 (Halwart, 1994a).

Under favorable conditions, females reach maturity 60 to 85 days after hatching and may spawn at weekly intervals throughout the year (Halwart, 1994a).

**Ecology-Feeding:** Snails prefer soft plant tissue; therefore, transplanted rice is only vulnerable in the three weeks after transplanting. When attacking rice, golden apple snails appear to be more active during the night and at dawn (Halwart, 1994a).

**Ecology-Low Water and Drought:** Golden Apple snails follow receding water to low-lying areas and stop feeding and mating when the water drops below their shell height. They may even survive months of drought by digging deep into the mud and closing their operculum, surfacing again after renewed flooding (Halwart, 1994a).

**Ecology-Overwintering:** In Japan in north Kyushu, golden apple snails kept in storage incubators at 0°C, -3°C, and -6°C died within 25 days, 3 days, and 1 day, respectively. These results suggest that the survival of overwintering snails in the Temperate Zone is strongly affected by low temperatures below 0°C. Based on field investigations made in mid-April, the survival rate was about 20% in a non-irrigated paddy field but only 5% in a dry irrigation canal. Young snails with a shell height of 2-3 cm seemed to have a greater tolerance to low temperature than mature ones with a size larger than 3 cm (Oya et al., 1987).

**Ecology-Dispersal:** When snails escaped from snail farmers or were discarded, they rapidly spread through natural waterways and irrigation canals and eventually invaded rice fields (Halwart, 1994a). As moving bodies of water, both irrigation canals and rivers aid dispersal (Halwart, 1994a).

When snails were transferred (probably in 1981) from Taiwan to Nagasaki, Kyushu, and Wakayama (Japan), the snails rapidly dispersed northward. By 1986, the golden apple snail was in 34 out of 47 prefectures (Halwart, 1994a).

## **DISTRIBUTION:**

**South America:** Argentina (Buenos Aires; Corrientes; Entre Rios, San Juan; Santa Fe); Bolivia; Brazil (Minas Gerais); Paraguay (Boqueron); Surinam; Uruguay (Canelones)

**North America:** U. S. A. (Introduced into CA, FL, NC, TX)

**Europe:** (?)

**Africa:** (?; Egypt possibly)

**Asia:** China; Indonesia; Japan (Honshu; Kyushu); Korea; Laos; Malaysia; Papua New Guinea; Phillipines Islands; Taiwan; Thailand; Vietnam

The distribution in Asia comes from Halwart (1994a); in South America from the Florida Museum of Natural History, Ponce de Leon (1989), and Halwart (1994a). Halwart (1994a) mentions the introduction of golden apple snails into Asia from “Central America.”

## HOSTS:

<i>Azolla</i> spp.	Azolla	Halwart, 1994a; Mochida, 1991
<i>Chara</i> sp.	Chara	Cazzaniga & Estebenet, 1985
<i>Colocasia esculenta</i>	Taro	Halwart, 1994a
<i>Cyperus monophyllus</i>	Family Cyperaceae (Sedge)	Mochida, 1991
<i>Eichornia</i> sp.	Water hyacinth	Halwart, 1994a
<i>Ipomoea aquatica</i>	Swamp morning-glory	Mochida, 1991
<i>Juncus decipiens</i>	Family Juncaceae (Rush)	Mochida, 1991
<i>Lemna</i> sp.	Duckweed	Halwart, 1994a
<i>Nelumbo nucifera</i>	Lotus	Mochida, 1991
<i>Nelumbo</i> sp.	Lotus	Halwart, 1994a
<i>Oenanthe stolonifera</i>	Water dropwort	Mochida, 1991
<i>Oryza sativa</i>	Rice	Halwart, 1994a
<i>Pistia</i> sp.	Water lettuce	Purchon, 1977
<i>Scirpus californicus</i>	Southern bulrush	Cazzaniga & Estebenet, 1992
<i>Trapa bicornis</i>	Family Trapaceae	Mochida, 1991
<i>Vallisneria</i> sp.	Vallisneria	Purchon, 1977
<i>Zizania latifolia</i>	Manchurian wildrice	Mochida, 1991

In the Philippines, most lowland weeds, as well as rice, are accepted with young, succulent parts being preferred (Basilio & Litsinger, 1988; Halwart, 1994a).

## DAMAGE WHERE ESTABLISHED:

**Yield Loss:** The extent of snail damage in irrigated rice depends on the age of the crop, the snail density, and the age structure of the snail population. Young snails with a shell height of less than 1.5-1.6 cm are too small to feed on rice seedlings; adult snails larger than 5 cm can ingest 7 to 24 seedlings per day. The number of seedlings consumed correlates positively with shell height. Damage also increases with snail density; 0.5 snails per m<sup>2</sup> cause 6.5% of missing rice hills, 8.0 snails per m<sup>2</sup> cause 93% of missing rice hills. A rice hill is composed of four to six seedlings transplanted to one spot (Halwart, 1994a).

At 30 days after transplanting, medium-sized snails (2-3 cm shell height) at a density of 1 snail per m<sup>2</sup> reduced the number of tillers by 19%, 8 snails per m<sup>2</sup> reduced the number of tillers by 98% (Halwart, 1994a).

Under continuous flooding, snail damage to transplanted rice was severe: 52% of 16-day-old seedlings were consumed after 6 hours; 75% after 24 hours; and 100% after 4 days. In the other variants (ridge planting, ring canal, and draining for three weeks after transplanting), less than 8% of the seedlings were damaged seven days after transplanting. Snails did not normally feed on rice plants when there was no standing water at the base. Damage was limited to newly trans-

planted seedlings. Three weeks after transplanting, when plants had become established, snail damage was not important (Watanbe & Ventura, 1990).

The fast growth and reproduction of snails in irrigation systems and rice fields leads to population levels which can destroy entire crops. Interviews conducted in the major rice-growing area of the Philippines revealed that 75-100% of the rice farmers consider the golden apple snail to be their most serious pest problem.

**Cost of Chemicals:** The infested area has expanded rapidly and pesticide expenditures for 1988 are estimated at 2.4 million US\$ (Halwart, 1994a).

**Additional Costs:** Missing hills can be replanted, thus incurring “repair costs” (costs for additional seedlings and replanting time) which are difficult to quantify. Replanting may be necessary up to four times per crop, a practice not feasible in countries with high labor costs (Halwart, 1994a).

**Ecological Damage:** From an ecological point of view, the invasion of rice fields by golden apple snails has been a disaster. Pesticides applied for control, especially those not registered for use in an aquatic ecosystem, add further to the pesticide load in rice environments and have serious effects on non-target organisms (Halwart, 1994a).

**Medical Importance:** Apart from its damage to rice, the golden apple snail is also of medical importance as the intermediate host for *Angiostrongylus cantonensis* which causes eosinophilic meningoencephalitis in humans in Taiwan and China (Halwart, 1994a).

## **METHODS OF CONTROL:**

### **Control by Chemicals:**

The molluscicides niclosamide (Bayluscide), metaldehyde (Snailkil, Porsnail), cartap hydrochloride (Dimotin), and isazophos (Miral) have become available. Metaldehyde reduced snail damage significantly from 96% to 6% missing hills (Halwart, 1994a). Plants containing natural molluscicides are being screened (Halwart, 1994a; Morallo-Rejesus et al., 1990).

Snail populations usually recover quickly from pesticide applications. While some individuals may be found buried in the soil, other *Pomacea* snails avoid exposure by crawling out of treated water on clay clumps or emergent vegetation (Halwart, 1994a; Van Dinther, 1973). Egg batches laid above the water and snails carried by the irrigation water from neighboring fields are sources of constant re-infestation (Halwart, 1994a).

### **Control by Biological Organisms:**

In Asia, few natural enemies constrained the populations of the golden apple snail; the populations increased and the golden apple snail developed into a serious pest (Halwart, 1994a). To date, there is no known specific parasitoid or predator of *Pomacea* snails from South America that might be used for biological control in Asia (Halwart, 1994a).

Diseases caused by viruses, bacteria, and fungi are not likely to be important biological control measures (Godan, 1983).

Environmental factors affect attempts to use predators for the control of pest gastropods. Beetles are especially important as predators of mollusks. Gastropod predators are found in each of the vertebrate classes-fishes, amphibians, reptiles, birds, and mammals (Godan, 1983).

Birds, rats, lizards, frogs, toads, beetles, and ants are all natural enemies of *Pomacea* snails. However, they are either indifferent or detrimental to rice or the environment; therefore, they are not promoted as biocontrol agents. The predatory snail, *Marisa cornuarietis*, feeds on *Pomacea* snails but may also damage rice plants (Halwart, 1994a).

### **Control by Cultural Methods:**

Forced by increased yield losses, rice farmers in Asia started transplanting older seedlings because older seedling are less vulnerable (Halwart, 1994a).

### **PERTINENT POINTS/PREDICTED CONSEQUENCES:**

When private entrepreneurs introduced the golden apple snail from Florida and South America to Taiwan and the Phillipines, they sought to make large financial profits through snail farming. However, introductions were made without any analysis of ecological impacts. Even marketing information was apparently lacking as consumers did not like the taste of the snail, despite the mollusc being propagated as a delicacy (Halwart, 1994a). The golden apple snail may be deliberately introduced to serve as a either a food source or an income source.

A pet shop owner introduced the snail from Florida to the Philippines (Halwart, 1994a). The golden apple snail may be deliberately introduced as a species for aquariums.

Once introduced deliberately or by accident, the snail's reproductive and biological attributes favor rapid population growth and colonization of rice fields and other aquatic ecosystems (Halwart, 1994a).

**Ecological Factor: Climatic Conditions.** Using the Asian and South American maps of Walter and his coworkers (1975; 1977), the golden apple snail occurs in the following climatic zones:

Zone I	Equatorial Zone	Philippines Islands
Zone II	Tropical Zone	Taiwan
Zone II-V	A Transitional Zone	China
Zone II-VII	A Transitional Zone	Paraguay; Northeastern Argentina
Zone V	Warm Temperate Zone	Uruguay; Japan (Honshu; Kyushu)
Zone V-VII	A Transitional Zone	Uruguay
Zone III-VIIa	A Transitional Zone	Argentina (San Juan)
Zone V-VI	A Transitional Zone	Korea (Suweon)
Zone VII	Arid Temperate Zone	Argentina (Buenos Aires)

Using the maps of Heintzelman and Highsmith (1973), the humid subtropics are the transitional zones between the continually warm climates and the climates where winter cold becomes a definite characteristic (Fig. 11.1; The Humid Subtropics). The Humid Subtropics of South America center upon the middle and lower parts of the Parana Basin and the Rio de la Plata. The region contains most of the pampas of northeastern Argentina, all of Uruguay, most of the southern projection of Brazil, and the southern portion of Paraguay (Fig. 11.4. The Humid Subtropics of South America). The range of the golden apple snail includes the Humid Subtropics of South America.

According to Heintzelman and Highsmith (1973), the humid subtropics in North America generally coincides with the South (Fig. 11.3. The United States South). Using the maps of Heintzelman and Highsmith, the potential range of the golden apple snail in the eastern United States is likely to be in the United States South. (The next section discusses possible restriction to the warmer half because of freezing temperatures.)

**Ecological Factor: Freezing Temperatures.** Because of temperatures below 0°C (Oya et al., 1987), the golden apple snail may be limited in the eastern United States to the lower portion of the Warm Temperate Zone of Walter (the United States South of Heintzelman and Highsmith). (See maps from Visher, 1945; Figures 22, 25, and 26).

In Japan, the golden apple snail burrows into the mud and closes its operculum to hibernate (Halwart, 1994). This practice gives the golden apple snail some protection against freezing temperatures and may explain why the golden apple snail can survive the winters in Japan and Korea (and North Carolina). The existence of different ecotypes may explain differences in overwintering abilities.

**Economic Factor: Rice-growing Areas.** Significant rice production occurs in the States of Arkansas, California, Louisiana, Mississippi, Missouri, and Texas. See Table I-27 and Table I-28 from *Agricultural Statistics 1997*.

**Economic Factor: Medical Importance.** Apart from its damage to rice, the golden apple snail is also of medical importance as the intermediate host for *Angiostrongylus cantonensis*. In recent

years, *A. cantonensis* has caused eosinophilic meningoencephalitis in humans in Taiwan and China, in Southeast Asia, and in several Pacific islands (Halwart, 1994a).

During the last two centuries, the rat lungworm, *A. cantonensis*, seems to have spread from Madagascar eastward to vast areas of the tropical belt and up to Tahiti and Hawaii. One of the most important means of spread was the introduction to these areas of the giant African snail, *Achatina fulica*, an intermediate host of this parasite. The parasite migrates and undergoes development to the young adult stage in the central nervous systems of mammals. In the natural host, the parasite later travels to the pulmonary arteries and reaches sexual maturity. The adult female lays eggs which develop and hatch in the lungs, and the first-stage larvae eventually are eliminated in the feces. In unnatural hosts, such as cattle, pigs, rabbits, and man, the parasite develops in the brain, but usually does not travel to the lungs, and dies (Jindrak & Alicata, 1970).

## REFERENCES:

- Agricultural Research Service. 1960. *Some Snails and Slugs of Quarantine Significance to the United States*. ARS 82-1. Reproduced October 1, 1967 by the Naval Medical Field Research Laboratory, Camp Lejeune, North Carolina.
- Albrecht, E., Carreno, N., and Castro-Vasquez, A. 1996. A quantitative study of copulation and spawning in the South American apple-snail, *Pomacea canaliculata* (Prosobranchia: Ampullariidae). *Veliger* 39(2):142-147.
- Arthur, J., Taylor, E., and Bowen, I. Optimising the chemical control of the rice pest *Pomacea canaliculata* (Lamarck). *Slugs and Snail pests in Agriculture*. Proceedings of a symposium, University of Kent, Canterbury, UK. 24-26 September, 1996. Pages 389-396.
- Baldia, J. and Pantastico, J. 1989. Overview of golden snail research in the Philippines. Conference at Nueva Ecija, Philippines, 9-10 November, 1989. *ICLARM Conference Proceedings* 28:10.
- Basilio, R. and Litsinger, J. 1988. Host range and feeding preference of golden apple snail (Philippines). *International Rice Research Newsletter* 13(3):44-45.
- Byas, W. 1972. *Mollusks Intercepted by the Plant Quarantine Division*. Verified by Mr. W. J. Byas of the U. S. National Museum
- Cazzaniga, N. 1990a. Predation of *Pomacea canaliculata* (Ampullariidae) on adult *Biomphalaria peregrina* (Planorbidae). *Annals of Tropical Medicine and Parasitology* 84(1):97-100.
- Cazzaniga, N. 1990b. Sexual dimorphism in *Pomacea canaliculata* (Gastropoda: Amphullariidae). *Veliger* 33(4):384-388.
- Cazzaniga, N. 1987 (1988). *Pomacea canaliculata* (Gastropoda: Amphullariidae): New record in province of San Juan, Argentina. *Neotropica* 33(89):10.
- Cazzaniga, N. and Estebenet, A. 1992. Growth and demography of *Pomacea canaliculata* (Gastropoda: Amphullariidae) under laboratory conditions. *Malacological Review* 25:1-12. Contains detailed information on life cycle; egg masses collected in Buenos Aires Province.
- Cazzaniga, N. and Estebenet, A. 1990. A sinistral *Pomacea canaliculata* (Gastropoda: Amphullariidae). *Malacological Review* 23(1-2):99-102.
- Cazzaniga, N. and Estebenet, A. 1988. Effects of crowding on *Pomacea canaliculata* (Gastropoda: Amphullariidae). *Comparative Physiology and Ecology* 13(3):89-96.

- Cazzaniga, N. and Estebenet, A. 1985. A review of past work on the use of aquatic snails (Amphullariidae) in biological control programs. *Malezas* 13(1):23-39.
- Cowie, R. 1996. New records of introduced land and freshwater snails in the Hawaiian Islands. *Bishop Museum Occasional Papers* No. 46. Pages 25-27.
- CPPR. 1997. Golden apple snail - *Pomacea canaliculata*. *California Plant Protection ?D ?R* June-September, 1997. Pages 47-48.
- Estebenet, A. 1995. Food and feeding in *Pomacea canaliculata* (Gastropoda: Ampullariidae). *Veliger* 38(4):277-283.
- Estebenet, A. and Cazzaniga, N. 1993. Egg variability and the reproductive strategy of *Pomacea canaliculata* (Gastropoda: Ampullariidae). *Apex* 8(4):129-138.
- Estebenet, A. and Cazzaniga, N. 1992. Growth and demography of *Pomacea canaliculata* (Gastropoda: Ampullariidae). *Malacological Review* 25(1-2):1-12.
- Godan, D. 1983. *Pest Slugs and Snails: Biology and Control*. Springer-Verlang, New York City, NY.
- Guzman, E., Sana, E., and Enriquez, F. 1993. Non-chemical strategies for management of golden kuhol (*Pomacea* sp.) in lowland rice farms. *Philippines Journal of Crop Science* 18:39.
- Halwart, M. 1994a. The golden apple snail *Pomacea canaliculata* in Asian rice-farming systems: present impact and future threat. *International Journal of Pest Management* 40(2):199-206.
- Halwart, M. 1994b. Fish as biocontrol agents in rice: the potential of common carp *Cyprinus carpio* (L.) and Nile tilapia *Oreochromis niloticus* (L.). *Tropical Agroecology*. Published by Margraf Verlag, Weikersheim, Germany.
- Hamann, M. 1992. *Catadiscus pomacea* new species (Trematoda: Paramphistomatidae) from *Pomacea canaliculata* Lamarck 1801 (Prosobranchia: Ampullariidae). *Mem. Inst. Oswaldo Cruz Rio J.* 87(1):9-14.
- Hirai, Y. 1988. Apple snail in Japan: the present status and management. *Japan Agricultural Research Quarterly* 22(3):161-165.
- Heintzelman, O. and Highsmith, R. 1973. *World Regional Geography*. Prentice-Hall, Inc., Englewood Cliffs, NJ.
- Jindrak, K. and Alicata, J. 1970. Experimentally-induced *Angiostrongylus cantonensis* infection in dogs. *Amer. J. Vet. Res.* 31(3):449-456.

- Keawjam, R., Poonswad, P., Upatham, E., and Banpavichit, S. 1993. Natural parasitic infection of the golden apple snail, *Pomacea canaliculata*. *Southeast Asian Journal of Tropical Medicine and Public Health* 24(1):170-177.
- Litsinger, J. and Estano, D. 1993. Management of the golden apple snail, *Pomacea canaliculata* (Lamarck), in rice. *Crop Protection* 12(5):363-370.
- Lobo, P. and Llagas, F. 1991. Evaluation of starflower, *Calotropis gigantea*, against golden apple snail, *Pomacea canaliculata*, in lowland transplanted rice. *Philippines Journal of Crop Science* 16(3):103-107.
- Madeley, J. 1994. Beyond the pest killers... *New Scientist* 142:24-27.
- Malak, E. and Cheng, T. 1974. *Medical and Economic Malacology*. Academic Press, New York.
- Mochida, O. 1991. Spread of freshwater *Pomacea* snails (Mollusca: Pilidae) from Argentina to Asia. *Micronesia* 3 (Supplement):51-62.
- Nakhla, J. 1995. Studies on the seasonal abundance of land snails on date palm shoots in Sharkia Governorate (Egypt). *Egyptian Journal of Agricultural Research* 73(2):347-355.
- Naylor, R. 1996. Invasions in agriculture: Assessing the cost of the golden apple snail in Asia. *Ambio* 25(7):443-448.
- Neck, R. and Schultz, J. 1992. First record of living channeled applesnail, *Pomacea canaliculata* (Pilidae), from Texas. *Texas Journal of Science* 44(1):115-116.
- Okuma, M., Tanaka, K., and Sudo, S. 1994. Weed control method using apple snail, *Pomacea canaliculata*, in paddy fields. *Weed Research (Tokyo)* 39(2):114-119.
- Oya, S., Hirai, Y., and Miyahara, Y. 1987. Overwintering of the apple snail, *Pomacea canaliculata* Lamarck, in north Kyushu, Japan. *Japanese J. Applied Entomology and Zoology* 31(3):206-212.
- Ozawa, A., and Makino, Y. 1988. Overwintering of the apple snail, *Pomacea canaliculata* Lamarck, in Shizuoka Prefecture, Japan. *Bulletin of Shizuoka Agriculture Experiment Station* 33:65-77.
- Palis, F., Macatula, R., and Browning, L. 1997. Bayluscide 250 EC (niclosamide), an effective molluscicide for the golden apple snail, *Pomacea canaliculata* Lamarck, in the Philippines rice production system. *Philippines Journal of Crop Science* 22:41.
- Palis, F., Macatula, R., and Browning, L. 1997. Niclosamide, an effective molluscicide for the golden apple snail, *Pomacea canaliculata* Lamarck, control in the Philippines rice production

- systems. *Slugs and Snail pests in Agriculture*. Proceedings of a symposium, University of Kent, Canterbury, UK. 24-26 September, 1996. Pages 213-230.
- Parrella, M., Robb, K., and Morishita, P. 1985. Snails and slugs in ornamentals. *California Agriculture* January-February, 1985.
- Ponce de Leon, E. 1989. Description of *Tremnocephala haswelli*, new species Platyhelminthes, from mantle cavity of *Pomacea canaliculata*. *J. Parasitol.* 75(4):524-526.
- Ponce de Leon, E. and Carpo, M. 1994. Evaluation of pesticides against golden kuhol, *Pomacea canaliculata*. *Philippines Journal of Crop Science* 19:24.
- Purchon, R. 1977. *The Biology of the Mollusca*. Pergamon Press, New York.
- Rodriguez, C. and Lorenzana, O. 1989. Evaluation of molluscicides for the control of golden snail, *Pomacea canaliculata*. Conference at Nueva Ecija, Philippines, 9-10 November, 1989. *ICLARM Conference Proceedings* 28:15.
- Rondon, M., Baniqued, C., and Dela Cruz, M. 1992. Field evaluation of alternative pesticides against golden snail, *Pomacea canaliculata* Lamarck, in lowland rice. Report to Philippines Rice Research Institute, Los Banos, Laguna, Philippines.
- Sadoshima, T., Ushimaki, A., Ohara, K. and Ushio, S. 1993. Methyl bromide fumigation for quarantine control of the apple snail, *Pomacea canaliculata* Lamarck. *Research Bulletin of the Plant Protection Service, Japan* 29:77-79.
- Schnorbach, H. 1995. The golden apple snail, *Pomacea canaliculata* Lamarck, an increasingly important pest in rice, and methods of control with Bayluscid®. *Pflanzenschutz-Nachrichten Bayer* 48(2):313-346.
- Taylor, D. and Sohl, N. 1962. An outline of gastropod classification. *Malacologia* 1:7-32.
- Theingo, S., Borda, C., and Araujo, J. 1993. On *Pomacea canaliculata* Lamarck 1822, (Mollusca: Pilidae: Ampullariidae). *Mem. Inst. Oswaldo Cruz Rod de Janeiro* 88(1):67-71.
- Tzeng, D, Tzeng, H, Lee, M., and Yeh, YS. 1994. Sodium dodecyl sulfate as an alternate agent for the control of golden apple snail, *Pomacea canaliculata* Lamarck. *Proceedings of the National Science Council, Republic of China Part B: Life Sciences* 18(3):138-145.
- Van Dinther, J. 1973. Mollusks and their control. *World Crops* 25(6):282-286.
- Vega, R. et al. 1991. Agro-economic evaluation of non-chemical control method against golden kuhol, *Pomacea canaliculata*, in irrigated lowland rice. *Philippines Journal of Crop Science* 16:S9.

Visher, S. 1945. Climatic maps of geological interest. *Bulletin of the Geological Society of America* 56:713-736.

Walter, H. 1977. *Vegetation of the Earth in Relation to Climate and the Eco-Physiological Conditions*. Springer-Verlag, New York.

Watanabe, I. and Ventura, W. 1990. Management practices to control golden apple snail (*Pomacea* sp.) in lowland rice. *International Rice Research Newsletter* 15:33.