Plant Health AUSTRALIA

RICEGROWERS' ASSOCIATION OF AUSTRALIA INC

Contingency Plan

Golden apple snail

COMMON NAME:	Golden Apple Snail
SCIENTIFIC NAME:	*Pomacea canaliculata* (de Lamarck)
SYNONYMS:	Channeled Apple Snail (USA), Golden Kuhol (Philippines)

Background

The Golden Apple Snail (GAS) is regarded as one of the most serious threats to the Australian rice industry. GAS, which is native to South America, was introduced into Asia for aquaculture and the aquarium trade, escaped into the broader environment, and has now spread throughout eastern Asia. It is regarded as the single most serious invertebrate pest of rice in Asia. It is present in Indonesia and Papua New Guinea, and data provided by AQIS shows there were 64 interceptions of GAS entering Australia between September 1996 and June 2003. A CLIMEX prediction of the potential distribution of GAS in Australia is included in the Pest Risk Assessment for this pest.

Host range

Primary host range

Oryza sativa (rice), *Azolla*, *Colocasia esculenta* (taro).

The following wild hosts are known

Azolla pinnata (mosquito fern), *Cyperus* (flatsedge), *Cyperus difformis* (small-flowered nutsedge), *Echinochloa glabrescens*, *Fimbristylis littoralis* (lesser fimbristylis), *Ipomoea aquatica* (water spinach), *Juncus* (rushes), *Monochoria vaginalis* (pickerel weed), Nel*umbo nucifera* (sacred lotus), *Paspalum distichum* (couch paspalum), *Sphenoclea zeylanica* (gooseweed), *Trapa*, *Zizania*.

It is highly likely that the known host range of GAS will expand considerably as new geographic areas are invaded.

Part of plant/commodity affected

Rice stems and leaves.

Biology

Identification

Golden apple snails are large when mature (shell diameter 3 to 8 cm) with a distinct flat operculum carried on the back of the body behind the shell. The operculum is pulled inwards to seal the shell when the animal withdraws inside. Shell colour is extremely variable and not diagnostic. Separation of GAS from other large exotic operculate snails is difficult, and relies on examination of indentations between shell whorls. Within the rice producing areas of NSW, suspect GAS are relatively easy to differentiate from common native snails. Any operculate snail with a globose shell should be considered as a potential pest incursion and sent for expert identification.

GAS egg masses are pale to bright pink in colour and are generally laid on emergent vegetation. No snail species currently found in the rice production areas produces pink eggs masses.

A diagnostic standard for GAS is currently being prepared by Professor Robert Cowie of the University of Hawaii.

Symptoms

Snails under 1.5 cm in diameter do not attack rice plants, however larger snails can destroy 7 to 24 seedlings per day. Younger seedlings are more vulnerable. The snails typically sever the seedling just above ground level and consume the stem and leaves.

Life-history

Female snails emerge from the water and lay their egg masses on emergent vegetation or other structures. Egg masses turn a bright pink colour soon after they are laid, and typically contain 200 to 300 eggs. The eggs hatch after approximately 3 weeks and the young snails fall or crawl into the water. The young reach sexual maturity in 2 months. Individual snails can live for over 2 years, and females typically produce about 4,000 eggs during their lifetime. Golden apple snails can enter dormancy in the soil to survive dry periods between rice crops.

Dispersal

GAS is amphibious and can leave the water to lay its eggs. In high humidity situations the snail may remain out of water for some time. It has been reported that GAS can disperse ‘significant distances’ across land, however to what extent this may occur in temperate Australian rice producing areas remains unknown. Low humidity during the warmer months of the year is likely to severely restrict the period GAS can remain active on land. The related species, *P. lineata* (Spix) is capable of travelling several metres per hour (van Dinther, 1956), whilst *P. globosa* (Swainson) makes 'long excursions on land' for dispersal and egg production (Prashad, 1925). According to Cowie (2002), short term dispersal activity does not necessarily translate into long-term, long-distance dispersal, and there is little documentation of the spread of ampullariid snails from a focus of introduction. The exception to this general rule involves downstream dispersal in moving water, which can be quite rapid (1.5 km in 6-8 months for the ampullariid Marisa cornuarietis (Linnaeus) in Florida (Hunt, 1958)).

Other likely methods of dispersal are primarily anthropogenic, including deliberate movement of the snails by the aquarium industry, and the movement of viable egg masses attached to plant material caught up in agricultural machinery, such as tractors and harvesters.

Estimate of economic impact on production, allied industries and native ecosystems

Rice Production

Establishment of GAS in southern Australia would have a severe impact on rice production. Overseas data indicates that eight medium sized GAS per square metre can reduce tiller numbers by 98% 30 days after transplantation, with broadly corresponding reductions in grain yield. Damage in direct sown crops could be confidently expected to be greater than in transplanted crops. If not effectively controlled GAS would make rice production unviable in Australia, eliminating an industry estimated to be worth AUD 288 million per annum 'at the farm gate' and worth over AUD 0.5 billion p.a. when value adding is taken into account.

Pre-existing controls

There are no known sources of plant resistance to GAS, and no effective biological controls are known. In broad-acre Australian rice production, routine control of established GAS populations would rely largely on molluscicides, particularly niclosamide, copper sulfate, and possibly metaldehyde or chlorothalonil.

Niclosamide would be the mainstay of GAS control programs, both in any eradication attempt and in routine control operations if eradication failed. At present niclosamide is not registered for any crop use in Australia. Options for an emergency use permit are being discussed with the Australian Pesticides and Veterinary Medicines Authority, however developing niclosamide for an alternate use pattern (such as the control of native rice-feeding snails) would simplify this process and also ensure stocks of the material would be on hand to respond to any incursion.

Cost of routine control

Chemical control can reduce GAS populations to levels where they have minimal impact on rice crop yields. Estimating the cost of chemical control procedures is difficult, particularly because niclosamide, the most useful chemical against GAS, is not currently available in Australia. It could be expected, however, that the costs associated with routine GAS control could be in the vicinity of AUD 150 to 200 per hectare per season, which would have a profound effect on crop profitability.

Trade implications

Whilst the routine control of established GAS populations in Australia would have a severe effect on profitability, it would be unlikely to substantially affect trade. Whilst it is likely that snails and their egg masses would contaminate grain at harvest, neither the snails nor their eggs would survive in grain storage, and any grain contamination would be effectively removed during milling. Australia currently imports milled rice from countries where GAS is widespread.

Environmental impact

GAS has a wide host range, and it is highly likely that it will feed on a range of Australian aquatic and semi-aquatic plants. As a consequence, it is highly likely that GAS would colonise wetlands throughout eastern and northern Australia, where it could have a devastating effect on natural ecosystems.

Surveillance

General surveillance

The most realistic option for routine surveillance of rice growing areas in order to detect GAS infestations involves educating rice farmers and other industry professionals about the potential of GAS to damage their industry, the need for enhanced biosecurity measures, and techniques for identifying suspect snails that can then be sent for expert identification. Pictures and information on GAS have been distributed direct to rice producers (Stevens, 1997; Stevens et al., 2004), however this information has been within larger pest management publications, and preparation and distribution of a separate leaflet is justified to ensure the message reaches the target audience.

Figure 1. *Egg masses of Pomacea canaliculata*

Figure 2. *Pomacea canaliculata in Hawaii. Left – crawling in a taro patch. [Photo: K.A. Hayes and R.H. Cowie]. Right – in an aquarium.*

Increased awareness and surveillance outside the rice production area could be achieved through ensuring community groups and employees of agencies such as Catchment Management Authorities, National Parks Services, and water utility companies are made aware of the risk this snail poses to the environment, as well as to the rice industry.

Surveillance of northern Australia is an important component of preventing any establishment of GAS dispersing beyond the point where control is possible. Surveillance in these areas is managed by AQIS under the Northern Australia Quarantine Strategy (NAQS).

Targeted surveillance

Targeted surveillance is defined here as particular actions that should be undertaken to minimise risks of GAS entering and establishing within Australia.

The primary responsibility for preventing the entry of GAS into Australia resides with AQIS, who have intercepted GAS on several occasions. There have been at least two suspected GAS outbreaks in the last decade, one near Townsville and one in NW Western Australia. Both of these outbreaks were subsequently identified as the ‘mystery snail’ *Pomacea bridgesii* (Reeve), which is not known to be a crop pest. The available evidence indicates that AQIS inspection protocols are effective for excluding GAS from Australia, however vigilance must be maintained, particularly in regard to ‘hitchhiking’ snails on objects from high risk areas (e.g., shipping containers from Papua New Guinea).

The rapid dispersal of GAS throughout SE Asia has primarily been human-mediated (Cowie, 2002), and the deliberate introduction of GAS into Australia remains a strong possibility. Although GAS never achieved great popularity as a human food source, it is used as food in some areas, and the possibility exists that visitors may attempt to bring live material into Australia in passenger baggage. Passengers arriving through international airports need to be monitored accordingly.

In many instances, the spread of GAS has been facilitated by the aquarium trade. The ‘mystery snail’, *P.bridgesii* is popular in the aquarium trade in Australia, however it is difficult to separate from GAS and the possibility exists that GAS may be imported as misidentified *P.bridgesii*. Restrictions on the importation of both live snails and water plants (that may harbour snails) should be maintained, and where possible, strengthened.

Another possible mode of GAS entry into Australia involves the frequent illegal incursions of Indonesian fishing boats into Australian waters. These boats could be carrying live GAS, either as a human food source or as ‘hitchhikers’. It is imperative that intercepted vessels be inspected thoroughly before they are moored in or near Australian mainland ports.

The possession of live ampullariid snails, including GAS, is prohibited throughout the Rice Pest and Disease Exclusion Zone (Proclamation P174 under the Plant Diseases Act 1924 NSW Government Gazette No. 124 p8872-8873 20 October 2006). This proclamation needs continual enforcement to ensure that pet shops and aquarists do not maintain snails that could be either GAS or related species.

The value of this legislation, however, is limited by the small geographic area to which it applies. GAS can move significant distances downstream from infestations. Major centres (eg. Wagga Wagga, Albury) are upstream from the rice-producing areas and not covered by the legislation. Ideally the legislation should be extended to cover the entire irrigation catchment area for the NSW rice industry.

Exotic pest survey

Survey method

INTRODUCTION

Surveying for GAS using trapping methods is not a viable approach for determining presence or distribution in an outbreak scenario. There are no pheromone-based trapping systems available, however in Asian rice systems trapping techniques have been used to get snails to aggregate in small areas prior to manual removal. Nets filled with lettuce, cassava, sweet potato, taro, or papaya leaves can be placed in fields to attract the snails, however such an approach is likely to be limited as a survey technique by the limited mobility of snails within lentic environments. Whilst GAS is able to detect its foodplants from some distance using chemical cues in the water, baits have to be significantly more attractive to GAS than other nearby food sources, and providing additional food sources as baits may have the effect of enhancing pest numbers (Cowie, 2002). Surveillance targeted towards establishing the existence and extent of an outbreak must therefore rely largely on labour-intensive manual searching for snails and their eggs.

The following survey approach has been developed based on the scenario that GAS has been confirmed as present at a single location within a rice field or associated supply and drainage channels.

1. DEFINING THE OUTBREAK ZONE AND PREVENTING DOWNSTREAM MOVEMENT

An immediate first step, once GAS has been confirmed from a point location, is to stop all flowing water from leaving the area. Downstream movement of GAS in drainage water is the most likely way that a point infestation will expand to cover an area where eradication is no longer feasible. In a rice field, water inflow should be maintained, but only to the extent of maintaining water levels to compensate for evaporation. If located in a drainage channel, or in crops leading to a drainage channel, then that channel should be blocked 500 metres downstream and inflows into the channel should be minimised. It is important to maintain water in the fields/channel in order to keep GAS active and therefore susceptible to chemical control.

2. DISTRIBUTION SURVEY AND DEFINING BOUNDARIES OF THE AQUATIC ZONE

Once the drainage has been blocked, a further 500 m downstream from the blockage point should be surveyed for snails. Snails in the channel should be surveyed by walking upstream from end of the survey area (so as not to muddy the area being sampled), and collecting all visible snails (regardless of species or appearance), both by hand and, where necessary, by using a triangular framed sweep net drawn through the aquatic vegetation and top layer of sediment. Snails collected should be placed in jars of water, with a separate sample being isolated and labelled for each 50 metre stretch of channel. At the end of the survey the snails should be sorted by a diagnostician competent in separating GAS and other ampullariids from native gastropods. If suspect GAS are found in any part of the drainage channel the blockage needs to be re-established 500 m further downstream from the boundary of the infestation, and the survey repeated until a 500 m section is recognised as being clear of GAS. Tributaries entering the drainage system and their boundaries also need to be surveyed. Any tributary entering the drainage area and 500 m 'clear' zone needs to be surveyed for 400 metres upstream from its junction with the drainage channel, with the boundary being extended in response to any detection. The drain upstream from the rice field inflow and its tributaries needs to be surveyed in the same manner. It is important to retain surface water in the drains until chemical controls have been applied. A 400 metre zone is appropriate for these areas because upstream movement of GAS is much slower than downstream movement.

Within the rice fields themselves, all contiguous areas of rice (e.g., all bays within a block) will need to be treated in response to a positive identification of GAS within any part of the crop, since adult GAS can move through irrigation stops and readily cross the banks between adjacent rice bays. Whilst a systematic survey of all bays within an infested block may shed useful information on the age structure of populations, the level of human activity required for such a survey may facilitate the spread of the pest and delay control activities. Once GAS is confirmed within a rice block, the whole area should be chemically treated prior to extensive within-block surveys.

Supply channels feeding the infested area need to be surveyed upstream of the fields. An initial 400 metre area (and its banks) should be surveyed, with water levels being reduced to the minimum feasible for maintaining water levels in the receiving fields. Any detection of GAS will result in the survey area being extended 400 m further upstream from the detection point. **Note that if there is a supply junction within this 400 m area leading to downward flow (away from the infested area), then the downstream section needs to be treated in the same way as a drainage channel because of the risk of downstream movement of GAS with the water flow.** Any supply lines coming from the defined area of the supply channel (including pressurised pipes, drip systems etc) will need to be included in the infestation area and chemically treated. Areas receiving water from these systems, including dams and seepage areas, will also need to be surveyed using these protocols. Any standing water body (farm dams etc) within 1 km of the infestation area will require inspection for GAS.

3. EGG DISTRIBUTION SURVEY AND DEFINING BOUNDARIES OF ADJOINING TERRESTRIAL ZONES

GAS can emerge from the water to lay their eggs, and accordingly dryland areas adjacent to infested aquatic environments also need to be surveyed. The survey area should initially include a 30 m band on either side of the channel, which should be examined for pink snail egg masses. Egg masses are best searched for manually, with several people slowly walking line-abreast about 3 metres apart. If egg masses are located, the bankside survey area should be increased by another 30 metres from the point most distant from the channel where the eggs were found.

This initial survey will result in the area of infestation being defined, with the following boundaries:

- The infested block of contiguous rice bays, plus a dryland boundary area around the block equal to the most distant detection of GAS eggs from any aquatic area, **plus** a 30 metre 'clear' zone
- The drainage channel (including any recirculation storages) for at least 500 metres downstream of the block, or for the infested area of the drainage, **plus** a 500 metre 'clear'

zone, **plus** a dryland boundary area equal to the most distant detection of GAS eggs from any aquatic area **plus** a 30 metre 'clear' zone

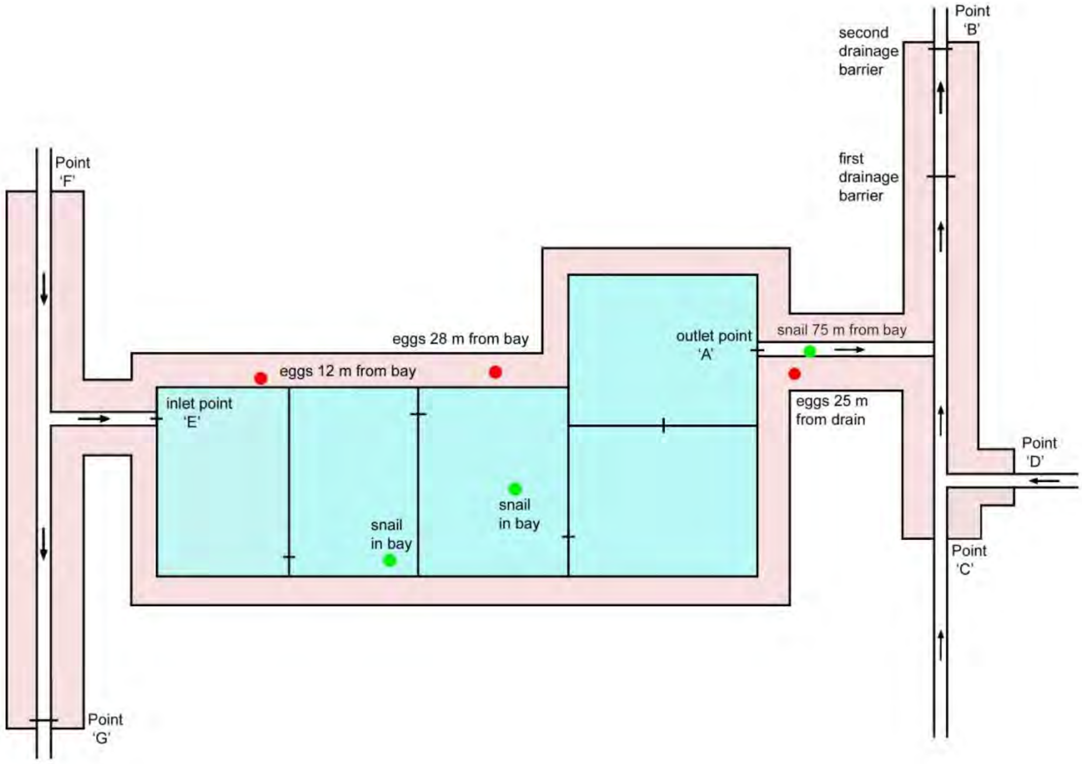
- Upstream and downstream tributaries to the drainage channel to a point 400 m from any GAS detection, **plus** a dryland boundary area equal to the most distant detection of GAS eggs from any aquatic area, **plus** a 30 metre 'clear' zone (this includes the drainage channel itself **upstream** from the point where flow from the infested area enters)
- The supply channel feeding the infested rice fields to a point 400 m upstream from any GAS detection, **plus** a dryland boundary area equal to the most distant detection of GAS eggs from any aquatic area, **plus** a 30 metre 'clear' zone. An example of the application of this protocol is shown in figure 2.

Diagnostics and laboratories

Preservation of samples being sent for specialist identification

Suspected GAS being sent for identification should be carefully cleaned of any mud or debris. Two treatment and preservation methods are outlined here; an 'optimal' (but relatively complex) method, and a simplified approach that can be applied without specialist materials, although the results are not as good.

Figure 3. *Application of the protocol for determining the extent of a GAS infestation in rice. Direction of normal water movement indicated by arrows. The pink zone (potential egg infestation zone) ends 58 metres from nearest standing water (most distant identified egg mass location (28 m from water) plus 30 m). Distance from outlet 'A' to first barrier 500 m; distance from outlet 'A' to second barrier (point 'B') 575 m (furthest identified downstream snail position plus 500 m); distance from drainage junction to points 'C' and 'D' 400 m. Distance from inlet point 'E' to point 'F' 400 m; distance from supply junction to point 'G' 500 m (since junction allowing downstream movement occurs within 400 m of point 'F').*



Optimal method:

1. Place the snails into clean water in a jar and add several crystals of menthol. Seal the jar and leave for 12 hours at room temperature. This will kill the snails and leave their bodies in a relaxed state.
2. Replace the water/menthol with 5% neutral formalin. This is prepared by adding 1 part concentrated formaldehyde solution to 8 parts of water and adding 5 g.L-1 of sodium bicarbonate. Seal the jar and ship to an approved diagnostician.

Simplified method:

1. Kill the snails by placing them in a plastic container (no water) in a domestic freezer for 24 hrs.
2. Transfer the snails to a glass jar containing a mixture of 70% methylated spirits and 30% water (by volume). Seal the jar and ship to an approved diagnostician.

Diagnostic laboratories

The following researchers should be consulted for diagnosis of suspected GAS:

IN AUSTRALIA

Dr Mark Stevens
NSW Department of Primary Industries
Yanco Agricultural Institute
Private Mail Bag
YANCO NSW 2703
Telephone: 02 6951 2611
Email: mark.stevens@dpi.nsw.gov.au

Dr Geoff Baker
CSIRO Division of Entomology
GPO Box 1700
CANBERRA ACT 2601
Telephone: 02 6246 4001
Email: Geoff.Baker@csiro.au

Dr Winston Ponder
Australian Museum
6 College Street
SYDNEY NSW 2010
Telephone: 02 9320 6000
Email: winstonp@austmus.gov.au

OVERSEAS:

The world authority of the taxonomy of GAS and related species is:

Professor Robert Cowie
Center for Conservation Research & Training
University of Hawaii - Manoa
3050 Maile Way
GILMORE 408 - HONOLULU, HI 96822
USA
Telephone: +1 808 956 4909
Email: cowie@hawii.edu

Management/control options

Quarantine and containment

Once the initial infestation area has been defined, it will be necessary to establish a quarantine zone around that area during the eradication phase of the operation. This quarantine area should extend for 500 metres around the infestation area, and all movements of people, vehicles and machinery need to be controlled until the eradication attempt has been declared successful.

Transport of GAS and their eggs on passenger vehicles is a distinct possibility, and vehicle tyres and undercarriages need to be disinfested prior to moving from the outbreak area into the quarantine zone, and also when leaving the quarantine zone. Ideally operational vehicles should stay in the quarantine zone until eradication has been confirmed.
Boots and waders worn by survey and control personnel similarly need to be disinfested, and if possible should not be moved out of the quarantine zone until eradication is confirmed.

Farm machinery that has been used in the outbreak area and quarantine zone during the preceding 6 months needs to be cleaned of any plant and soil debris then steam-cleaned and sprayed in situ. Similar cleaning protocols need to be followed when operational machinery is moved from the defined outbreak area into the quarantine zone, and again when leaving the quarantine zone.

Cleaning / disinfestation treatments for vehicles and machinery are discussed under 'Destruction / Eradication'.

Research and development

The available information on GAS is both extensive and fragmentary. Many researchers have worked on GAS, but their work has generally had a strong regional focus and coordinated international efforts have been rare. Whilst there is adequate data on the general biology of GAS, the data on chemical control, and particularly on the ovicidal activity of control compounds is not as strong as it should be. This reflects a focus on non-chemical control strategies in SE Asia, where the smaller scale of subsistence rice production allows manual collection and the use of ducks to be viable snail management options. In addition, the misuse of chemicals and their effects on human and environmental health in SE Asian rice production has led to chemical control being looked on unfavourably. In broadacre rice production, however, an eradication program will have to be based heavily on chemical control.

Niclosamide is probably the most useful chemical available for a GAS eradication attempt in Australia, however this compound has no registered crop uses in Australia, although it is registered for some veterinary uses. A major obstacle to implementing a contingency plan for GAS will be obtaining APVMA authorisation to use niclosamide. Accordingly, research should be conducted towards obtaining the OH&S and environmental residue data necessary to obtain an emergency use permit for Bayluscide® 250EC. In any GAS eradication attempt the affected crops would need to be destroyed, and the fact that they would not be harvested for food may make it easier to get approval for niclosamide use prior to crop destruction. The application of niclosamide for the control of GAS eggs also needs further research. Joshi et al. (2002) indicate that niclosamide does have ovicidal activity against GAS, however the level of activity they found was less than optimal for an eradication attempt.

Destruction/eradication

Destruction of a GAS infestation will rely heavily on both chemical control and modification of land use patterns for a two year period after chemical control.

Chemical control

The principal chemicals used effectively against GAS in the Philippines are metaldehyde, formulated as either bait pellets, wettable powders or flowable suspensions, and niclosamide, formulated as either an emulsifiable concentrate or wettable powder. The literature on the performance of these products if fragmentary, however evaluation of references included in the Scientific Information Database on Golden Apple Snail (Joshi et al., 2003) and at http://www.applesnail.net suggests that niclosamide formulated as a 250 $g.L^{-1}$ emulsifiable concentrate has the greatest potential for eliminating a golden apple snail infestation. It provides a high level of control when applied at 250 to

375 g active.ha^{-1} and also exhibits significant ovicidal activity. In an eradication program (as opposed to routine control of an established pest) higher application rates are justified, and an application rate of 500 g active.ha^{-1} would be desirable. An eradication program for golden apple snails in Australian rice fields and associated aquatic habitats would require the aquatic infestation zone to be treated with 3 applications of niclosamide each approximately 2 weeks apart. Aerial application of chemicals is preferred because it minimises the risk of snails becoming attached to machinery, however standing water in channels and bankside areas should be treated with backpack sprayers or direct dosing to achieve a niclosamide concentration in the water of at least 0.5 mg.L^{-1}. In crops with dense canopies, the second niclosamide treatment should be followed with aerially-applied metaldehyde bait pellets. The surrounding terrestrial zone should be treated with niclosamide at 250 g active.100 L^{-1} spray volume using fine spray nozzles. Two applications should be made 4 days apart.

Chemical disinfestation of machinery, vehicles, etc.

Disinfestation of machinery and vehicles can be achieved through chemical or heat treatment. High pressure steam cleaning is the optimum approach for machinery cleaning, and should be applied before any motor vehicle leaves the quarantine zone. Particular care should be taken to clean around the axles and wheel arches of passenger vehicles, and any other areas of the vehicle where vegetation contaminated by egg masses may have been caught. Any plant trash removed from vehicles should be either burned or buried within the quarantine zone. Rubber boots worn by operational staff should also be steam-cleaned externally before being removed from the site. Spraying machinery surfaces with niclosamide at a concentration of 1.5 – 2.5 g.L^{-1} offers an alternative disinfestation technique for situations where steam cleaning may not be appropriate, however steam cleaning should be considered the preferred option wherever possible.

Land use after chemical control

Five days after the last chemical application the infestation area should be resurveyed to determine if any live snails or viable eggs are present. If live GAS are found the chemical treatment phase may need to be repeated using higher application rates.

If no GAS or eggs are found, then all water flow into the infestation area should be stopped (inflows should only have been sufficient to maintain standing water up to this point). All low vegetation within the infestation area should be treated with glyphosate, allowed to die, and then cultivated into the soil. This includes the affected rice crop, surrounding paddock areas as defined previously, and bankside vegetation alongside supply and drainage channels. Banks of the infested rice fields need to be levelled to ensure they do not provide a refuge for dormant snails.

One of the main ways by which GAS could escape an eradication attempt is through the adult snails entering soil dormancy, either within the rice fields or within channels. The available data suggests that survival of dormant snails in rice fields should be limited, however to ensure eradication no irrigated crops should be grown in the infestation area for a minimum of 18 months (2 years for rice), and only then after intensive cultivation. The infestation area will need to regularly resprayed with glyphosate during this period to keep the soil as bare as possible. The use of impact soil compaction machines on the affected land prior to future rice production is strongly recommended.

Eradication of dormant snails from within channel banks represents a greater problem because these areas can develop standing water as a consequence of rainfall or seepage. Resolving this problem depends on the size of the drainage or supply channel involved. Small supply and drainage channels could be ripped, filled in, and alternative channels constructed on adjacent land before irrigation commences after the 18 month – 2 year quarantine period. Larger channels represent a greater problem, however the inner banks and floors of the channels could be disked to disrupt any dormant snails present in the sediment. Prior to use channels treated in this way should be blocked, flooded, and treated with niclosamide to achieve a minimum of 0.5 mg.L-1 twice during a 10 day period. They should then be inspected prior to the commencement of irrigation.

Documentation to establish area freedom

The biology of GAS is such that confirmation of eradication cannot be effectively made until aquatic habitats are re-established within the infestation zone. After the quarantine period has been observed, the supply and drainage channels should be filled and surveyed following the process used for defining the infestation area. Rice should then be grown over the area of the previously infested fields, with all drainage water entering a defined recirculation system, rather than being allowed to enter regional drainage systems. This will ensure that any surviving snails are contained.

The crop, supply, drainage channels, recirculation dam and associated channels need to be surveyed every 4 weeks during the rice season using the protocols for defining the infestation area. Survey of the crops themselves should be undertaken using 15 m diagonal transects and the collection protocol previously specified for use in drainage channels. No GAS recoveries by harvest indicates area freedom.

Stand down procedures

In addition to the preparation of an appropriate debriefing report in relation to operational issues, the following technical issues need to be evaluated in the event of an eradication attempt being unsuccessful.

1. Containment of an infestation. GAS disperses relatively slowly unless transported by humans, either deliberately or as a contaminant of machinery, etc. Even if an infestation cannot be eradicated, its spread to other areas could be slowed, or even prevented, through the implementation of appropriate movement controls. Options for containment should be thoroughly examined, taking into consideration the area of the infestation and the practicality of enforcing any State legislation enacted to facilitate containment.
2. Research on control options. Routine control of established GAS populations will rely heavily on agrochemicals, however crop rotations and physical control may also have a role within an integrated management plan. Much of the research conducted on chemical and cultural control of GAS has been fragmentary, whilst a large portion of the remainder has focussed on control options that are only viable in small-scale subsistence rice production. A systematic study on molluscicide efficacy under Australian conditions should be carried out, along with studies on GAS survival during dormancy. The Rural Industries Research and Development

Corporation should be approached to fund such research. The recent discovery of GAS in rice-producing areas of the southern USA may also provide opportunities for useful collaboration on the management of GAS in extensive rice production.

References

Cowie, R. H. 2002. *Apple snails (Ampullariidae) as agricultural pests: their biology, impacts and management.* pp. 145-192 in: Barker, G. M. (ed.), Molluscs as Crop Pests. CAB International, Wallingford, UK.

Dela Cruz, M. and Joshi, R.C. 2001. *Efficacy of commercial molluscicide formulations against the golden apple snail Pomacea canaliculata* (Lamarck) *The Philippine Agricultural Scientist* 84, 51-55.

Hunt, B. P. 1958. Introduction of *Marisa* into Florida. *The Nautilus* 72, 53-55.

Joshi, R.C., Dela Cruz, M.S. and Duca, A.V. 2002. Ovicidal effect of a molluscicide on golden apple snail in the Philippines. *International Rice Research Notes* 27, 26-28.

Joshi, R.C., Baucas, N.S., Joshi, E.E., and Verzola, E.A. 2003. *Scientific information database on golden apple snail* (Pomacea spp.) CD-ROM. Department of Agriculture – Cordillera Administrative Region / Cordillera Highland Agricultural Research Management Project / Philippine Rice Research Institute / Agricultural Librarians Association of the Philippines.

Palis, F.V., Macatula, R.F. and Browning, L. 1996. *Niclosamide, an effective molluscicide for the golden apple snail (Pomacea canaliculata Lamarck) control in Philippine rice production systems.* pp. 213-230 in: Slug & snail pests in Agriculture. Proceedings of a Symposium, University of Kent, UK, 24-26 September 1996.

Prashad, B. 1925. *Revision of the Indian Ampullariidae*. *Memoirs of the Indian Museum*. 8, 69-89.

Stevens, M. M. 1997. *Common invertebrates of New South Wales rice fields*. 55 pp., NSW Agriculture.

Stevens, M., Brickhill, J. and Brown, P. 2004. *Pest of rice crops – vertebrates and invertebrates.* 28 pp. (Ch. 10) in: Kealey, L. M.(ed.). Production of Quality Rice in South Eastern Australia. Rural Industries Research and Development Corporation, Canberra.

van Dinther, J. B. M. 1956. Control of *Pomacea* (*Ampullaria*) snails in rice fields. *Agricultural Experiment Station, Paramaribo, Surinam, Bulletin* 68, 1-20.