Nursery levy at work: **Nursery Production Plant Health & Biosecurity Project**

Threat specific contingency plan for giant African Snail (GAS)

Queensland Department of Agriculture, Fisheries and Forestry

December 2015

Nursery & Garden Industry Australia

Queensland Government

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Acknowledgements

This document was written as part of the HIA funded project NY11001 Plant Health Biosecurity, Risk Management and Capacity Building for the Nursery Industry by Andrew Manners and John Duff. Thanks go to John Stanisic for providing photos of closely related snails and constructive comments that improved this document. Helpful comments were also received from John McDonald (NGIQ) and Christine Horlock (DAF).

1 Contents

2 Purpose and background of this contingency plan

The giant African snail (GAS), *Achatina fulica* Bowdich is probably the most economically damaging snail species in the world. This snail is not established in Australia (CABI, 2014; Stanisic & Potter, 1985) and would threaten agriculture, the environment and human health if it became established. This contingency plan has been compiled to provide a review of current knowledge, management options and recommended survey techniques for the giant African snail.

Continental USA has endured three incursions, in California post World War II and in Miami, Florida in 1966, both resulting in expensive eradication programs (USDA, 2002). The latest incursion is currently under eradication in Florida. GAS has been prevented from becoming established in the continental US, Australia and Fiji, largely through border quarantine measures and in rapid eradication once it has been detected (Colman, 1978; Ikin, 1983; Mead, 1979a).

Australia's only known breeding population of GAS occurred in Gordonvale, 19 km south of Cairns, Queensland. It was detected in April 1977 and eradication was declared three years later (Watson, 1985). Eradication of GAS can be achieved if detected in the early stages of establishment (Cowie & Robinson, 2004). Papua New Guinea (PNG) and Indonesia are the closest GAS infested countries. According to the quarantine services, in Australia the highest number of GAS interceptions originate from PNG. A more recent detection of a lone giant African snail was made on a property in the Currumbin Valley in 2004. A baiting program was established and extensive surveillance conducted in the surrounding area with no further detections. The latest intercept was of a lone GAS found creeping across a Brisbane container yard in March 2013.

3 Critical tasks

There are a number of areas which will require careful planning or implementation following the detection of GAS. These tasks include (but are not necessarily limited to):

1. Determine if GAS is notifiable as per the state/s legislation (e.g. at the time of writing, GAS was not a notifiable pest in SA and TAS).
2. Comprehensive lists of businesses that import and ship containers/cargo interstate, including production nurseries, across Australia do not exist. It will be important to compile a list of businesses relevant to the incursion. Also, contact the relevant state NGI organisations to assist in compiling production nursery businesses in the quarantine zone.
3. Negotiate with the local shire council to isolate a section of the shire rubbish tip or waste transfer station to accommodate disposal of refuse from infested areas.
4. Introduce quarantine procedures for pick-up, transport and delivery of refuse within the infested areas and the refuse tip.
5. If the infestation is considered to be reasonably extensive then an emergency use permit application should be submitted to the APVMA for the active ingredients methiocarb or carbaryl in liquid form to non-crop areas.

4 Australian nursery industry

The Australian nursery industry is a significant horticultural sector with a combined supply chain (production to retail/grower) valued at more than $6 billion dollars annually. The industry employs approximately 45,000 people spread over more than 20,000 small to medium sized businesses, including production nurseries and retail outlets. The industry is located predominantly along the Australian coastline, and in major inland regions servicing urban and production horticulture.

Nursery production adds significant value to Australia's primary industry's sector annually, contributing more than $2 billion to the national economy. Nursery production is a highly diverse industry, providing a critical service to the broader horticultural sector, valued at $14 billion within Australia (Table 1).

Table 1. Nursery production supply sectors within Australian horticulture

Production nursery	Horticultural market	Economic value
Container stock [1]	Ornamental/urban horticulture	$2.1 billion retail value
Foliage plants [1]	Interior-scapes	$89.7 million industry
Seedling stock [2]	Vegetable growers	$3.3 billion industry
Forestry stock [3]	Plantation timber	$1.7 billion industry
Fruit and nut tree stock [2]	Orchardists	$5.2 billion industry
Landscape stock [1]	Domestic & commercial projects	$2.25 billion industry
Plug and tube stock [4]	Cut flower	$319 million industry
Revegetation stock	Farmers, government, landcare groups	$110 million industry
Mine revegetation	Mine site rehabilitation	Value unknown

5 Eradication or containment decision matrix

The decision to eradicate should be based on the potential economic impact resulting from a GAS infestation, the cost of eradication and on technical feasibility. Eradication costs must factor in long term surveys to prove the success of the eradication program. A minimum number of years with no detections of GAS may be necessary to confirm that pest free status can be declared. The timeframe needs to be considered on a case by case basis, based both on the size of the infestion, the degree and distribution of the pest with the final decision determined by the National Management Group.

The decision matrix to aid in the decision between eradication and containment is shown in Fig. 1.

1 Data sourced from Market Monitor 2009
2 Data sourced from Horticultural Handbook 2004
3 Data sourced from ABARE 2005
4 Data sourced from industry

Fig. 1. Decision outline for the response to an exotic pest incursion and a summary of the basis on which each decision could be made.

Basis for technical feasibility: Early detection Confined space/restricted area of dispersal Known distribution of host plants Effective, reliable, quick detection method Support from industries, businesses and communities involved.
Basis for economic feasibility: Value of crop destroyed by uncontrolled pest is more than cost of controlling the pest Value of environmental amenity (native species lost) vs cost or loss of other amenity (loss of native insects due to spraying in native forests etc)
Basis for quarantine containment: Legislation to create a pest quarantine area (PQA) Resources to maintain the PQA, inspection points, staffing, detection equipment, diagnostics Support of industry and community to make the PQA work
Basis for destruction/control strategies required: How much destruction and or control measures are industry and individuals prepared to undertake? What level of destruction is technically feasible? Do the benefits of destruction outweigh the problems created?
What would containment or ongoing management look like? Is containment feasible? What would ongoing management really mean? Many similar features to eradication, but at less intense / restrictive levels.

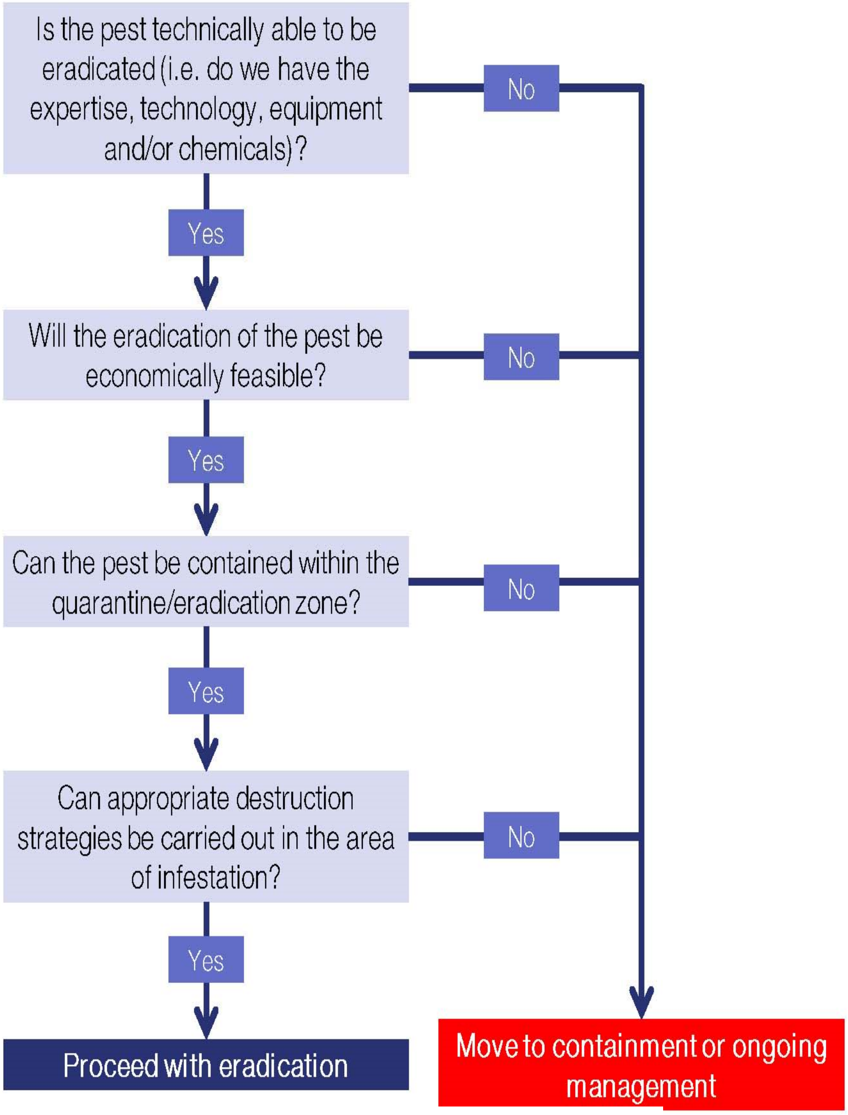

Table 2. Factors considered in determining whether eradication or alternative action will be taken for an EPP incident from PLANTPLAN (Plant Health Australia, 2014 Table 2).

a) the capability to accurately diagnose or identify the EPP.

b)	the effectiveness of recommended control technique options, which are likely to be the most cost-effective in eradicating the EPP.
c)	the ability to remove or destroy all EPPs present by the recommended control techniques.
d)	the ability to remove the EPP at a faster rate than it can propagate until proof of freedom can be achieved.
e)	the recommended control techniques are publicly acceptable (taking into consideration cultural and social values, humaneness, public health impacts, non-target impacts and environmental impacts)
f)	whether Emergency Containment measures have been put in place by the Lead Agency(s).
g)	whether there are controls methods, commonly employed for endemic pests and diseases, that may limit or prevent the establishment or impact of the EPP.
h)	any legislative impediments to undertaking an emergency response.
i)	the resources e.g. chemicals, personnel etc. required to undertake an emergency response are accessible or available.
j)	the ability to delimit the known area of infestation.
k)	the ability to identify the pathway for entry into, and trace the spread of the EPP within Australia.
l)	the ability to determine whether the likelihood of further introductions is sufficiently low.
m)	the dispersal ability of the EPP (that is, whether the EPP is capable of rapid spread over large distances).
n)	the capability to detect the EPP at very low densities for the purpose of declaring freedom, and that all sites affected by the EPP have or can be found.
o)	the ability to put in place surveillance activities to confirm Proof of Freedom for sites possibly infested by the EPP.
p)	whether community consultation activities have or will be undertaken.

Note: In the case of GAS, considerable information is already available from overseas eradication efforts for evaluating the prospects for eradication or containment.

6 Pest information/status

6.1 Pest details

Common names	Giant African snail, east African snail, giant east African snail, African land snail, east African Land snail, giant east African land snails.
Scientific name	*Lissachatina fulica (Bowdich)*
Synonyms	*Achatina fulica* Bowdich 1822 formerly Férussac 1821 The classification of this snail has recently changed from *Achatina* to *Lissachatina*. Consequently, most documents in the published literature and online use the old genus name.

6.2 Background

Lissachatina fulica (Bowdich), GAS, is a fast-growing polyphagous plant pest that has been introduced from its native range in east Africa to many parts of the world as a commercial food source (for humans, fish and livestock) and as a novelty pet. It easily becomes attached to any means of transport or machinery at any developmental stage, is able to go into a state of aestivation in cooler conditions and so is readily transportable over distances. Once escaped it has managed to establish itself and reproduce prodigiously in every tropical location. As a result, GAS has been classified as one of the world's top 100 invasive species by The World Conservation Union, IUCN (ISSG, 2003).

GAS is probably the most economically damaging snail species in the world and Australia is at highest risk of incursion. This snail is not established in Australia (CABI, 2014) and would threaten agriculture, the environment and human health if it became established. GAS can be differentiated from other Australian native snails due to its large size and relatively long, narrow, conical shell.

6.3 Description

In adults, the shell length is most commonly 5-10 cm, however can be up to 20 cm (Mead, 1961). When the head and foot are fully extended, the overall snail length is usually 8-15 cm but individuals up to 30 cm have been recorded (Watson, 1985). The colour of the shell is variable, but is commonly brown with pale cream streaks. Snails in different geographic regions can have darker or lighter colouration. Similarly, populations in different parts of the world tend to be larger or smaller, on average. This type of variability also extends to shell shape and is likely to be caused by environmental conditions and food availability. Like other molluscs, the soft body of the snail retracts entirely within the shell at will.

GAS is very distinctive compared to almost all snails found in Australia. Shells are axially banded (as opposed to most Australian snails with spiral banding), elongately ovate with a pointed spire (Fig. 2). The only snails in Australia that is grossly similar to GAS are *Pygmipanda* spp. (Fig. 3), which occur exclusively in temperate rainforests and subalpine areas south of Hastings River. However, these are much smaller and have thinner, narrower shells (Stanisic et al., 2010).

Fig. 2. Giant African snails are very large when mature (top left and right), but the eggs and newly hatched snails are still quite small (bottom left). The shells are variable is size and colour and are relatively conical in shape (bottom right). (bottom images by Pest and Disease Image Library, Bugwood.org).

Fig. 3. Snails that are superficially similar to GAS in Australia, *Pygmipanda automata* (left) and *Cornu aspersum* (right). Both photos by John Stanisic, Queensland Museum.

6.4 Life cycle

Sexual maturity is dependent on food supply, temperature, humidity and the availability of calcium for shell growth, but usually occurs from 5 to 9 months old (Watson, 1985). Eggs have a calcified shell and are laid in batches of 100-400 (Raut & Barker, 2002). They are spherical to oval in shape, approximately 5 mm in diameter and cream to yellow in colour (Mead, 1973). The number of eggs laid increases with age (Lambert, 1999). Generally, eggs are laid 8 to 20 days post-mating and at about monthly intervals (Lambert, 1999; Watson, 1985). Eggs take about 8 to 21 days to hatch depending upon temperature and humidity (CABI, 2014; Watson, 1985). GAS eggs are generally deposited in ‘nests’ excavated to 25 mm or so in decaying organic matter, but can occasionally be deposited in moist crevices among plant litter, stones and other debris on the ground (Raut & Barker, 2002). Newly hatched snails often remain underground for several days, consume their egg shell and sometimes the shells of unhatched eggs and organic matter.

Soil conditions including pH, calcium levels, other physical properties of the soil and organic matter can influence shell growth rate, size, weight, shape and colour of GAS individuals (Raut & Barker, 2002).

Mating occurs during most periods of the night and can continue for between 1.5 and 7.5 hours with an average time of 4.6 hours (Raut & Barker, 2002; Thangavelu & Singh, 1983; Tomiyama & Nakane, 1993), and after a single mating, the snail can produce a number of batches of eggs over a period of approximately 400 days (Capinera, 2014; MAF, 2002; Skelley et al., 2011; Venette & Larson, 2004).

GAS is nocturnal, searching for food at night and hiding in the soil and organic matter through the day. However, it can become active in the daytime when it is overcast and wet. Adult snails can crawl distances of up to 50 metres in a single night (Mead, 1973). GAS activity is independent of temperature and light conditions, but is regulated by humidity, only becoming active above 50% ambient relative humidity (Takeda & Ozaki, 1986). Raut and Barker (2002) suggest in many tropical areas, GAS activity is restricted to the monsoon season and the few months following. Foraging GAS spend on average 55.1% of their nightly activity crawling, 15.5% feeding and 29.4% resting; the distance travelled in a single night of activity may decrease as the season continues irrespective of the age structure of the population (Panja, 1995).

During unfavourable conditions, GAS burrows into the ground to shelter, seals the opening of its shell with a calcified membrane and aestivates. The snail has been known to aestivate between 10 months and several years until environmental conditions improve (Lambert, 1999; Venette & Larson, 2004). Adult snails aestivate basically anywhere that provides protection from light and desiccation (Raut & Barker, 2002). Newly hatched snails are much less robust and die from dessication within about 2 months under very dry conditions (Venette & Larson, 2004). The cue to aestivate appears to be low humidity, not temperature; aestivation can occur at 80-82% RH (Raut & Barker, 2002). Aestivation can occur singly or in aggregations and rainfall of 50mm or more can terminate aestivation at any time. GAS can also hibernate through very cold temperatures and low humidities, e.g. 5.5°C and 65% RH. In addition, larger individuals tend to hibernate before smaller individuals.

Optimal temperatures for GAS survival range between 22-32°C, but can survive as low as 6-7°C and as high as 45°C. Oviposition does not occur at temperatures below 15°C (Raut & Barker, 2002).

6.5 Dispersal

In snails, a ‘population explosion’ can occur soon after introduction, with densities as high as several hundred snails per square metre. These high densities often persist for several years. Without assisted spread, the infested area will expand by only a few hundred metres a year (Lambert, 1999). Juvenile snails tend to be the most active dispersers with some individuals moving 500m in six months while adults tend to have home ranges (Tomiyama & Nakane, 1993).

Spread of GAS outside of continental Africa is largely due to transport by man and is often deliberate (Bequaert, 1950). It is also suggested that with the advent of Achatinidae as a trade commodity on the world market, captive breeding programs in various parts of the world heightens the potential for further spread (Raut & Barker, 2002). GAS is traded for food, medicinal purposes and pets and snails deliberately introduced probably have a greater chance of survival as more than one individual is usually introduced and they generally receive active care to promote their growth and reproduction (Cowie & Robinson, 2004). Other major pathways for GAS introduction include transport on products, vehicles, containers, pallets and crating, flower pots and other earthenware, quarry products and ornamental rocks, machinery and heavy equipment (Robinson, 1999).

Introduction of a single mated snail is sufficient for the establishment of a colony (Raut & Barker, 2002). It is possible for GAS to travel as eggs, or perhaps small juveniles, which are less readily detected than adult snails (Cowie & Robinson, 2004).

As stated above, GAS is nocturnal, feeding at night and resting during the day. Some individuals return to the same resting site each night. Very young individuals tend to stay within the area in which they hatched for about 2 weeks and then begin to range further. Young snails are voracious feeders, consuming organic matter and preferred host plants. The larger the individual, the more likely they are to return to the same resting site. Small individuals, shell size 20-30 mm in length had only a 20% homing frequency observed, whereas 80% homing frequency of individuals shell size 70-80 mm in length (Raut & Barker, 2002). As a result, smaller individuals are more likely to move to new areas, but at a slower rate than larger individuals. Fewer large individuals will move to new areas, but will do so at greater speeds.

6.6 Host range

GAS has over 500 known host plants including many ornamentals, vegetables and leguminous cover crops, however it has a preference for brassicas, lettuce, potato, onion, sunflowers and eucalyptus (MAF, 2002). Breadfruit, cassava, peanut, and most varieties of beans, peas, cucumbers and melons may also be preferred hosts (Lambert, 1999; USDA, 2002). The bark of citrus, papaw, rubber and cocoa can also be consumed, particularly when snail populations are high (AQIS, 1997; Lambert, 1999). However, there is evidence that preference for food plants is highly influenced by plant species present in the particular area in question (Raut & Barker, 2002). Highest damage levels are likely to be observed when preferred host plant species predominate in the environment. Seedling plants are also preferred and most likely to be severely damaged.

GAS is a voracious herbivore, with individuals consuming around 10 per cent of their own weight daily (Schreurs, 1963). Depending upon the area of the any introduction, economic loss could be considerable if not eradicated.

6.7 Current geographic distribution

Originally from south of the Sahara in east Africa, GAS has a natural range from Natal and Mozambique in the south to Kenya and Italian Somaliland in the north (Raut & Barker, 2002). The snail is common throughout southeast Asia and the Pacific basin to 30° north and south of the Equator (Watson, 1985).

GAS owes most of its current wide distribution to human activity. It is now present everywhere in the Indo-Pacific except Banaba Island, Cook Islands, Lord Howe Island, Nauru, Niue, Norfolk Island, Pitcairn Island, Tokelau, Australia and New Zealand, and has been eradicated from Tuvalu (Cowie & Robinson, 2004). In 1989 it was recorded on both Martinique and Guadeloupe in the Caribbean (Schotman, 1989). It was introduced to South America (Brazil) in the late 1980s as a commercial species, is now present in 25 out of 26 Brazilian states and has been found to be spreading in other countries on the continent (Vogler et al., 2013). It is also likely to have become an established part of the snail fauna of West Africa following reports from Côte d'Ivoire, Togo and Nigeria, and a shell has been identified in Morocco (van Bruggen, 1987), the first discovery of this species from anywhere in the Palearctic (http://www.cabi.org/isc/datasheet/2640).

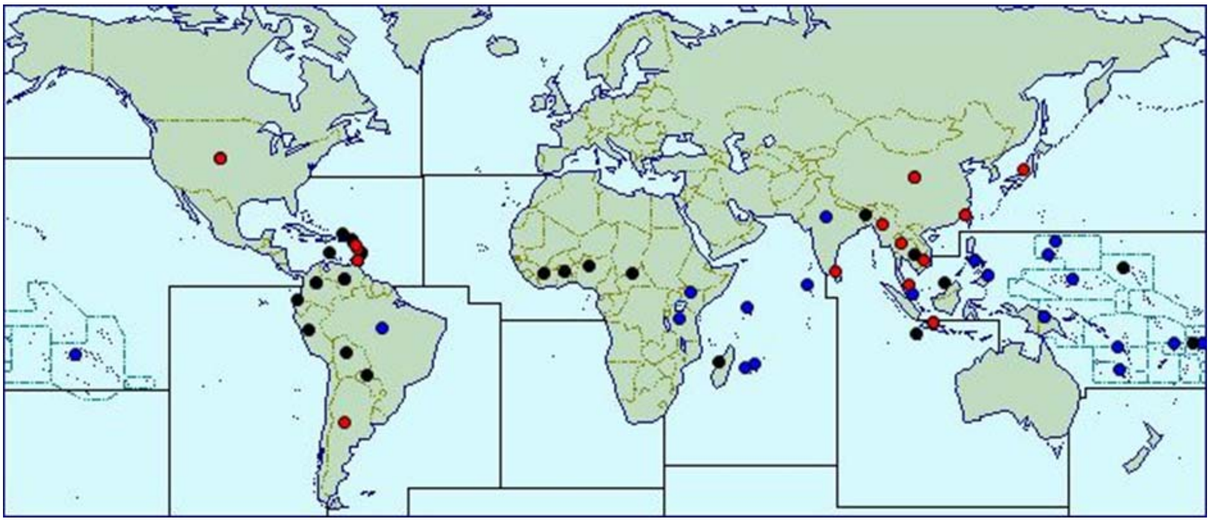

Fig. 3. Map of current distribution for GAS (up to February 2014).
(http://www.cabi.org/isc/datasheet/2640)

● = Present, no further details

● = Widespread;

● = Localised

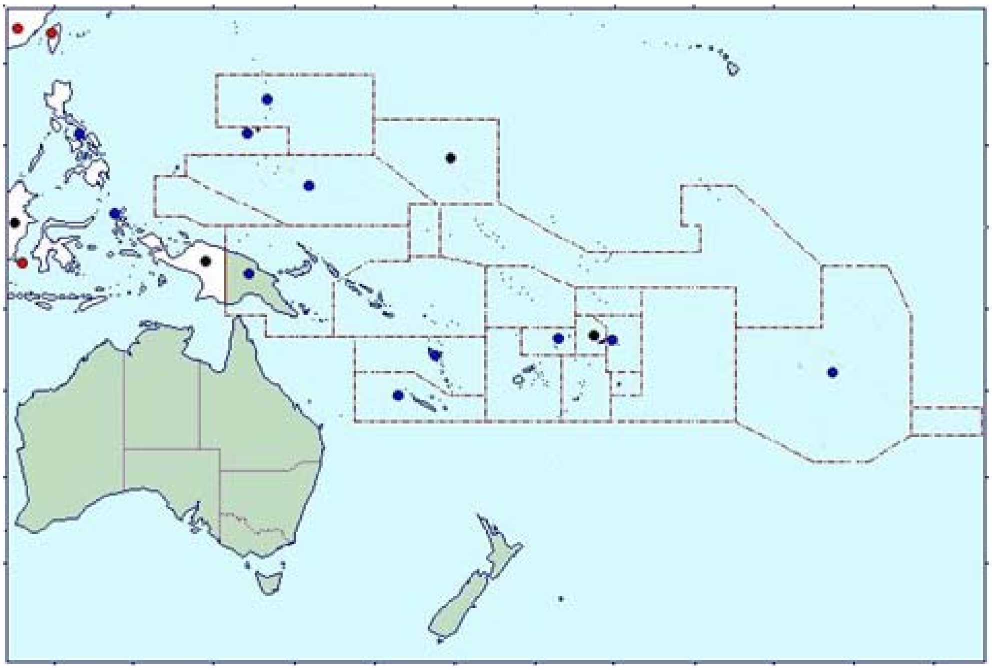

Fig. 4. Map of current distribution for Australia and pacific islands (up to February 2014).
(http://www.cabi.org/isc/datasheet/2640)

6.8 Potential distribution in Australia

The establishment potential of GAS in northern Australia is very high (Stanisic & Clark, 2002). Food crops and flower gardens provide ideal breeding grounds for GAS. The snails can also be found in nurseries, roadside weed growth, shrub thickets and forests (Lambert, 1999).

As stated above, GAS damage is greatest during the initial population explosion when they colonise an area. GAS attracts very little attention when introduced to a new area, because its prime food source appears to be decomposing vegetation, however it becomes omnivorous when its population increase in numbers (Watson, 1985).

Potential areas for survival and proliferation of GAS are northern Australia and coastal areas possibly as far south as 35° latitude (a little south of Wollongong, NSW and in line with Adelaide (SA) and Albany (WA), but where temperatures seldom fall below 1°C (Watson, 1985). It has also been suggested that GAS has the potential to occupy areas at 40° latitude (this is incorporates all of Australia except Tasmania), or the environmental equivalents at higher altitudes nearer the equator (Raut & Barker, 2002). Thus, in the event of a wide spread infestation, most Australians would be affected, either from nuisance value around homes, or by damage to horticultural and agricultural crops (Watson, 1985).

7 Symptoms

Juvenile GAS are saprophytic, feeding on decaying organisms and dead snails. Adults are phytophagous and attack a wide range of plants. The snail attains its principal requirements of calcium, necessary for shell growth, from decaying organic matter. In absence of decaying organic matter it eats growing plants (Kakoty & Das, 1987). In general, gastropods possess a distinct tooth-like organ called a radula, which is modified for scraping, grasping and chopping (Barth & Broshears, 1982). Salivary glands discharge mucus in the buccal cavity (a modified oral cavity), where inbound food is bound into a slimy string.

Damage to plants caused by GAS is caused by feeding. Feeding is by mechanical defoliation, rasping of stems, flowers or fruit and the exact symptoms may vary with plant species attacked (Raut & Barker, 2002). Standing plants can be crushed from the snail's weight and where mechanical harvesting of crops is practiced, problems arise with extracting the snails from harvested produce (Colman, 1978). GAS may also feed on the shells of dead snails, other aestivating snails and even their own shells, presumably to obtain calcium.

7.1 Economic loss

In tropical agriculture, the costs of GAS are threefold (Raut & Barker, 2002):

- Loss of agricultural productivity caused by herbivory on crop plants, shade plants or plants that enrich the soil. Damage can also occur through transmission of plant pathogens.
- Cost of labour and materials associated with managing GAS in crop situations.
- Restrictions on the type of crops that can be grown in infested areas that are resistant to GAS.

The damage caused by GAS varies between seasons, due to variation in plant composition and climatic favourability for gastropod activity (Raut & Barker, 2002). However, in irrigated agricultural areas where relatively constant moisture is maintained, seasonal variability and climatic favourability would be less of an issue.

Limited quantitative data is available on feeding preferences and impacts on plant communities. However, it is hypothesised that preference for a particular food plant at a particular locality depends on both the species present and the age of the plants belonging to the different species (Waterhouse & Norris, 1987). This is supported by observations that plant species consumed is inconsistent across the countries it has invaded and variability in preferred host plants listed in the literature. It also appears that most severe damage occurs when susceptible species are very abundant (Raut & Barker, 2002), however this can be modified by the age structure of the GAS population (Jaski, 1953).

Irrespective of the crop, the seedling or nursery stage is most preferred and most vulnerable, with damage being so severe in some areas that cultivation practices had to be changed substantially (Raut & Barker, 2002). In some countries, high density GAS infestations have made it uneconomical to grow vegetables or fruit crops (Chamberlin, 1952; Mead, 1961; Raut & Ghose, 1984).

GAS has been implicated in the transmission of *Phytophthora palmivora* in cocao, black pepper, betel pepper, coconut, papaw and vanilla, as well as *P. colocasiae* Racib in taro and *P. parasitica* Dastur in eggplant and tangerine (Mead, 1961; Mead, 1979b; Muniappan, 1983; Schotman, 1989; Turner, 1964; Turner, 1967). It seems possible that it may vector other soil borne pathogens as well.

Beyond economic loss associated with direct and indirect crop damage GAS can be a serious nuisance pest. For example, during the Miami, Florida incursion of 1969, annuals and vegetables could not be grown, shrubs were defoliated, lawn mowers were damaged by snails resting/aestivating in the soil under the grass, snails were crushed underfoot everywhere, floors of utility sheds were covered with excreta, house walls were covered with slime trails, air conditioners were stopped by snails resting inside them during daylight hours, and the odours of crushed and decaying snails permeated the air (Sturgeon, 1971).

7.1.1 Environmental costs

Costs of GAS to the natural environment include herbivory on native plant species. This could potentially alter species composition in certain areas if high infestations occur for long periods if seedlings are unable to reach maturity. It is likely that nutrient cycling during heavy GAS infestations would be altered and indigenous gastropod populations and other animals could be impacted. Indirect environmental costs associated with controlling an established GAS population includes non-target deaths associated with the control program.

7.1.2 Human health risks

GAS is attracted to animal faeces and decaying flesh. This can give rise to health problems as vectors for human diseases and parasites (Watson, 1985). While GAS can be eaten, it has been implicated in a range of serious health problems, including eosinophilic meningoencephalitis. In fact, this virus can be spread to humans and pets from skin contact with GAS.

7.1.3 Pathogen risk ratings and potential impacts

Stanisic and Clark (2002) estimate the risk of GAS entering Australia is very high. Between 1986 and 2002, the Australian Quarantine and Inspection Service (AQIS) intercepted GAS on 407 consignments in Australia, including 221 in Queensland. Interceptions are often on sea containers that have been stored outside wharf areas in infested countries. Papua New Guinea is the nearest known infested country and poses the highest threat for GAS introduction to Australia, with 196 interceptions, followed by Vanuatu with 28 interceptions. From 1974 to 1987, the US military have ranked GAS in the top twenty snails most commonly intercepted on retrograde military cargo or household effects, with the highest risk of interceptions originating from Hawaii, Republic of China and Hong Kong (AFPMB, 1993).

The nursery industry considers that the entry and establishment of GAS is high, with a medium-high spread potential and a high economic impact. Therefore the overall risk from GAS is considered to be high (Plant Health Australia Ltd, 2006).

7.2 Summary of surveillance following a detection

While GAS is a plant pest, it is not specific to any particular host plant and does not infect a host plant in such a way that plants must be destroyed. It can be considered an area pest, similar to that of red imported fire ants (*Solenopsis invicta*). The overall survey area will vary depending on the environmental conditions where the snail is detected. That is, the survey technique for a GAS infestation in dense natural vegetation would vary drastically compared to detection in residential areas or cropping systems. However, if GAS is detected the following generalised delimiting survey protocol is suggested based on its biology:

- Survey outwards from the detection site until all favourable sites within 500m of any detection have been investigated.
- Each property identified by trace forwards and trace backs from infested premises should be surveyed by searching all favourable sites within 100m of potentially exposed areas. For trace forwards and trace backs that involve very large properties, it will be important to identify areas that could have been exposed to GAS and then search within 100m of these areas.
- Follow up surveys on traced sites should be conducted at monthly intervals (allowing for detection of juvenile snails).

Depending on the exact area in which GAS has been detected, the private property of many residents and business owners may need to be searched. This can pose some challenges. Private property residents should be notified of a period of time that survey teams will be searching their property, including their backyards. They should be asked to contact the response team to make special arrangements if they wish to be present or have pets that could be either dangerous or escape during surveys. If no response is received it can then be assumed that entry is granted to the property. This correspondence should also inform them of the nature of the problem, include pictures of GAS, inform them that it is illegal to keep the animals as pets and that they have been known to spread human diseases including eosinophilic meningoencephalitis.

Sites that GAS are detected should be **monitored for three years** under good environmental conditions for GAS, longer under adverse environmental conditions. If no detections are made for three years after the last detection then there may be reason to believe that GAS has been eradicated. Obviously, this blanket statement may not apply to all situations and a great deal of information must be taken into account including the ease of detection in the environment, environmental conditions, the level of infestation and the age structure of individuals at the time the last detection was made. If only one individual is ever found it may be possible to consider GAS to be eradicated much more quickly than if many individuals are detected.

7.3 Surveys in production nurseries and nursery retail outlets

Production nurseries and nursery retail outlets are ideal environments for GAS. Such properties tend to have large numbers of young tender plants that are wet and have numerous places to hide between and within containers. They also represent a high risk of long distance human assisted dispersal of plants that are not easily traced once plants are sold to the public. Speak to managers of the nursery to determine if there is any unexplained removal of foliage anywhere in the nursery. Since GAS damage may resemble heavy infestations of some herbivorous insects (e.g. caterpillars), it is also recommended to ask if there has been herbivore damage observed recently (or over the period that is considered to be at risk). Surveillance at such businesses should include the following areas:

- Areas which have current or past suspect damage
- Among containers, particularly in shaded areas with overhead watering or areas in which the growing area is constantly or frequently wet
- Propagation areas
- Shaded, wet areas, where plants are on the ground.
- Areas with natural environments (which should be treated as natural habitats)

- Areas with ornamental and vegetable gardens, particularly amongst dense clumps of plants, e.g. long grass, shrubs, bananas, etc.
- On building walls, particularly when they are shaded and in humid environments
- Under buildings, amongst machinery, vehicles, trailers
- In and around dispatch areas
- On, around, in and under outdoor furniture, including pallets
- In and around refuse areas, compost heaps and throw-out areas

It should be noted that many production nurseries also have a family home present on the site. Such areas should also be searched as per 6.1.3.

7.4 Surveys in natural habitats

GAS flourishes at the edge of forests, modified forests and plantation habitats (Smith & Fowler, 2003). It is particularly well suited to tropical and subtropical moist broadleaf forests, tropical and subtropical dry broadleaf forests (Venette & Larson, 2004). Mature snails also have the ability to bury themselves in soil and remain inactive for up to 10 months (Raut & Barker, 2002). Therefore, surveillance in natural habitats may be difficult and must be completed consistently for long periods of time, particularly when conditions are dry. The following areas should be searched in natural habitats up to 500m from the detection area. GAS is more likely to be active approaching darkness therefore, if possible search at these times.

- On tree trunks, particularly when large populations are present or during wet/monsoonal seasons. Considerable distances can be travelled at such times.
- Under logs, stones and other objects, particularly if they are moderately large and in moist conditions.
- In holes and hollow logs
- On the ground or leaf litter (particularly in rainforests and humid, relatively dark environments).
- Within leaf litter, particularly in moist shaded areas, down to about 5-10cm.

Surveys in natural habitats are particularly suited to use of trained sniffer dog teams to more efficiently and effectively search areas at risk. Sniffer dog teams have been trained to find GAS in Florida, USA.

Accurate population estimates may assist in managing incursions in densely vegetated remote areas. In the event of an infestation of GAS in Queensland where the population has spread to densely vegetated areas, Craze and Mauremootoo (2002) outline a method of estimating GAS population size.

7.5 Surveys in urban and commercial areas

Surveys in urban and commercial areas will combine aspects of those from production nurseries and natural environments. All high risk areas (as described in 6.3 and 6.4) present at a site should be searched. As a matter of course, speak to people residing and working in these areas to ensure that no one has taken GAS individuals as pets.

7.6 Surveys in broadacre cropping environments

All areas with favourable sites within at risk sites, as explained in all points 6.2-6.4, should be searched thoroughly. In addition, the cropping area also needs to be searched. Areas with observable foliar herbivore damage should be searched more thoroughly. It is likely that the area under cropping will extend further than the area that requires search, as outlined in 6.1.

7.7 Trapping for GAS

Quarantine services (Department of Agriculture) have developed traps for GAS and other target snails in ports and high-risk areas of Australia that could be utilised for surveillance. This would be particularly helpful if the infestation is in a limited area. If the area to be surveyed is very large the frequency of trap placements (one trap every four to six metres) is not cost effective and reduces trapping viability. The exact protocol for this trapping is not known and is not considered to be cost effective compared to bait techniques.

7.8 Trace backs and trace forwards

Since GAS is an area pest and may not be associated with host plants, it is important account for movement of many goods and equipment to establish trace forwards and trace backs. Determine if the following equipment and materials have been moved on or off the detection area within an appropriate length of time.

- Plant and soil material
- Potted plants, including plants sold to and from production nurseries
- Garden trash
- Crates, containers or pallets
- Under vehicles (cars, trailers, tractors etc) and other machinery
- Timber and junk stacks
- Other items that have been in contact with the ground, particularly if they have been stored in dark, humid environments
- People having bought or sold GAS as pets
- Building contractors that have operated in the area within the last 3 years, perhaps less if appropriate evidence is available

The exact length of time within which trace forward and trace back sites should be compiled depends on current knowledge of the infestation. If only one snail has been detected in a container yard, for example, it may be sufficient to conduct extensive searches of the detection site (as per Section 6 above) and all sites that received goods from the detection site within about 2 weeks. Whereas detection of many snails over a number of acres would require trace backs and forwards be established from movements over at least 6 months. This will of course be modified by where they were detected, i.e. natural environment, commercial or urban area etc.

If the infestation is somewhat extensive, i.e. 100s of individuals, shells of captured snails should be distributed to state department and city council offices and other information centres in the area (e.g. shopping centres). This will encourage members of the public to report suspect GAS individuals.

7.9 Surveillance near the quarantine zone

Formal surveillance by biosecurity staff should be focused within the quarantine zone. However, it is advisable to survey very high risk areas near the quarantine zone. This ‘buffer zone’ area should be about 500m outside the quarantine zone. High risk sites that should be considered for surveillance will vary with the region. In residential and commercial areas, high risk sites would include businesses selling plants (e.g. production nurseries, retail nurseries, hardware stores, produce stores etc), timber yards, landscape suppliers, agricultural suppliers and hardware stores with equipment stored outside. Also included are properties with large junk heaps that have obviously been present for a long period of time as well as rubbish tips or waste transfer stations. In agricultural cropping or the natural environment that have few dwellings in the area, consider surveillance around houses, particularly where regular irrigation is applied to gardens. Areas near livestock water troughs and shelters should also be considered high risk in such areas. Ideally this surveillance should only be done once in summer and perhaps also completed in spring (once warmer temperatures and periods of higher ambient humidity occur).

Mail outs, signs, factsheets and other advertising material should be considered in areas near quarantine zones to encourage the public to be on the lookout and report suspicious snails.

7.10 Community involvement

The encouragement of community assisted surveillance for this pest is imperative and the following actions are recommended after detection of a GAS incursion:

- Produce leaflets describing the snail, its characteristics and requesting that biosecurity officers be notified of all possible sightings and distribute to householders within the vicinity of the infestation.
- Produce and distribute print media releases and conduct TV and radio interviews outlining GAS information, control information and incursion updates.
- Circulate regular campaign progress reports to householders within the infestation area and media.
- Produce and distribute posters and leaflets for display in state, federal and local government offices and schools in relevant areas (i.e. in the wider region that the detection has been made and potentially through the state and perhaps multiple states depending upon the exact region of the detection).
- Consult with local councils regarding quarantine areas, movement restrictions of high-risk materials and clean-ups.
- Contact landscape gardeners, production and retail nurseries, arborists, earth movers, construction and transport companies who work within the infested areas, outlining movement restrictions of risk material.

8 Quarantine and movement restrictions

Since August 2001, Cape York Peninsula from just north of Coen has been designated a quarantine area for a number of targeted plant pests, including GAS. If an infestation of GAS is detected in Cape York Peninsula within this quarantine zone then the necessary movement restrictions can be enforced immediately.

Any detection outside of the Cape York Peninsular quarantine zone should result in the implementation of a **quarantine of a 500m radius around all detection sites**. If further detections of GAS are made, the quarantine area should then be widened so all detection sites have a quarantine of 500m radius.

8.1 Movement restrictions in the quarantine area

GAS is an area pest and can be present on virtually any object, including potted plants, metals, wood rubbish and motor vehicles. As a result, it will be virtually impossible to limit movement of all material if the detection is within a residential and commercial area. Commercial producers of plants and other materials, however, are a higher risk as they can be transported interstate and should be regulated. The following movement restrictions are recommended in the event of an established GAS population in Australia:

- Initially, residents should NOT be encouraged to clean up their properties. This will allow the biosecurity personnel to conduct inspections of the area and prevent forced migration or accidental transport of the snails. When capture numbers of GAS are reduced greatly, household clean-ups should be encouraged, with requests to burn the refuse where it lay (if possible), as not to inadvertently transport GAS. As stated in section 7.4, this might be within a month or as long as three months after detection, perhaps longer if in a cooler region and environmental conditions are likely to have induced inactivity (refer to section 5.4)

- Residents should be encouraged to store vehicles away from long grass and bush land (idealy 50m), but it is acknowledged that this will not always be possible. This will limit accidental movement of snails on vehicles to areas outside the quarantine zone.
- Plants, soil, compost, garden trash, timber, equipment or junk that has been in contact with the ground within the quarantine area should be deemed infested and should not be moved without inspector's approval.
- Cease movement of all vehicles, equipment, planting and landscape materials from within infested areas to other places where the snail is deemed not to be present, keep in mind exceptions below.
- An area at the local council waste transfer station should be isolated and quarantined for regulated transport of household waste and garden material by the biosecurity personnel or delegated staff trained in quarantine matters. Such clean-up activity should be supervised by biosecurity and local council staff within particular regions of quarantine areas, perhaps doing separate sections at different times. The following guidelines are recommended.
    - If items to be disposed must leave the quarantine area then it must be completely covered with a tarp to stop any goods from coming loose and falling from the vehicle.
    - Vehicles leaving the waste transfer area should be inspected by biosecurity or trained council staff to ensure that GAS individuals are not left behind in the vehicle.
    - The area around the designated GAS waste area should be closely managed within a 100m radius. Ideally the area should be compacted dirt or rocks. If grasses are present they should be maintained at low heights, similar in height to that of residential lawns. Items that could be deemed a hiding place for GAS individuals should be removed, e.g. logs, bricks etc. (refer to section 6.2-6.5 for more details). Waste that is not from the quarantine area should also be kept clear of waste that is from the quarantine area.
    - Relevant waste should be burned. Waste that cannot be burned must be treated with an appropriate pesticide (preferably injected with a carbamate product under an emergency use permit) and inspected after an appropriate period of time prior to integration within the normal waste system (assuming no living snails were present).
    - The waste transfer area should be baited as per quarantine areas even if GAS are never detected at the site.
- If sniffer dogs have been trained to detect GAS they should be included in the clean-up exercises, particularly at the waste transfer station.
- Signage to indicate quarantine areas should be placed on relevant roads and pathways alerting people to the possibility of GAS being present. Ideally, one or more photos of GAS should be placed on the sign. The phone number to report suspicious snails should also be placed on the sign with a clear warning indicating that snails can spread human health diseases and that they should not be touched without rubber gloves.
- If possible, restrict movement into and within quarantine zones, particularly if the area is relatively remote and does not require regular public access. Consider if the following actions are feasible:
    - Fenced, barricaded or locked entry to quarantine areas.
    - Movement of equipment, machinery, plant material or growing media/soil by permit only.
    - All non-essential operations in the area or on the property should cease.
    - Where no dwellings are located within these areas, strong movement controls should be enforced.
- All machinery and equipment that has been housed overnight on quarantine properties should be thoroughly cleaned down with a high pressure cleaner prior to leaving the affected area. Machinery should be inspected for the presence of GAS. The clean down procedure should be carried out on a hard surface, preferably a designated wash-down area, to avoid mud being re-collected from the affected site onto the machine. When using high pressure water, care should be taken to contain all plant material and mud dislodged during the cleaning process

Materials should be allowed to be removed from quarantine areas if the following conditions are met:

1. Materials are inspected and shown to be free of GAS.
2. No GAS have been found within 50 metres of the entire production area within one month.
3. All goods that have been stored outside or in protected cropping or similar structures or that could easily be infested with GAS need to be easily accessible prior to release such that all pots, plants and manufactured goods could be inspected if directed by biosecurity staff. Such goods might include manufactured metals, landscaping materials, container plants, statues, outdoor furniture, rain water tanks, etc.)

8.2 Special arrangements to trade within the quarantine zone

Special arrangements may need to be made for production nurseries, retail nurseries, landscaping, hardware and other such businesses within the quarantine area to facilitate ongoing trade within the quarantine zone. Biosecurity agencies should work with each business to make a customised plan of action to facilitate continued trade that minimises the risk of transport of GAS. Such a plan should include regular site surveillance, crop monitoring and dispatch inspections plus management of adjacent grounds around production areas where stock is held such that protected habitats that GAS would use are minimised. Assuming that no detections of GAS are made within the production area where stock is grown (or held, in the case of landscape supplies etc) and a GAS management plan is in use, trade should be allowed to continue for businesses that have initial GAS detections on the property. Detection of GAS in the buffer zone or production area should be treated on a case by case basis considering the number of individuals detected, their size and exactly where they have been detected. Frequency of detection should also be taken into account.

In general, retail nurseries and greenlife markets are lower risk as they tend to sell plants locally. However, some retail nurseries and greenlife markets may ship longer distances. Production nurseries represent a higher risk as do manufacturers of goods held outside that may become infested with GAS, and ship their goods interstate. All relevant businesses within quarantine areas wishing to continue trading should have a customised GAS management plan with the following components. Relevant businesses include retail, greenlife markets, production nurseries and other businesses holding goods outside that could become infested with GAS. They are referred to below simply as businesses, except where specifically mentioned. Producing areas include all items that could be sold and moved off the business premises including, plants, soil, pots, timber and other items.

- Businesses should maintain a non-growing buffer area around producing areas. These buffer areas should be maintained with grasses, mowed to normal lawn height, gravel, concrete, road base or another surface agreed upon by the relevant biosecurity agency. This area should be baited as per section 9.3.
    - Buffer areas may include roads as these are very inhospitable areas for GAS. The buffer area will need to be customised for each business, particularly those that have producing areas very close to the border of their property.
    - Buffer areas may need to include buildings and sheds. Such areas should be treated individually and specify whether inspections occur inside the building or only externally, depending upon the ease of access by potential GAS individuals.
    - Where residential properties are within the buffer areas, mitigating strategies may need to be implemented. These may include strategies to make it difficult for snails to move under or through fences. Fences should be included in daily inspections by the property manager. Biosecurity inspectors may also be required to search adjacent properties on a regular basis.
    - While a buffer area ideally would be 30m, it is acknowledged that this will not always be possible due to legally defined property boundaries, etc. Be adaptable in mitigating risk based on the individual situation and available alternative measures.

- The non-growing/non-storage buffer areas should be inspected on a daily basis by a nursery/business staff member(s) trained to detect GAS. Results must be recorded daily and any detections reported to the biosecurity agency.
- The business should be inspected initially by biosecurity staff and high risk areas noted, e.g. areas with excessive water pooling, rubbish heaps etc. These areas should be managed to reduce the risk of attracting GAS, e.g. by increasing drainage, treating and removing the rubbish heap as per refuse in section 7.1.
- The growing or storage areas should be inspected for GAS by suitably trained nursery staff at least once per week (if no detections are made in buffer zones), carefully observing the presence of any snail present, particularly when plants are grown on ground level beds or materials are stored on the ground. Results should be recorded immediately after completing inspections.
- All snails detected in growing/storage areas and non-growing/storage areas should be collected. Collect snails while wearing suitable gloves and placed into sealable transparent bag (e.g. a ziplock bag). It is recommended that all snails collected at the end of the inspection period be photographed and emailed to biosecurity staff. Ensure that the bag has the business name and collection date on the bag in the photograph. Assuming that the number of snails is low it should be possible to spread them out within the bag so all are visible at once. Make sure the photograph is in focus. The bag of snails can be frozen for 48 hours before inclusion in normal waste. Bag snails from within the growing/storage area and in the non-growing/non-storage area separately.
- Individual businesses may have to comply with additional biosecurity parameters depending upon the exact scenario.
- Suspicious snails should be kept in the freezer and collected by biosecurity inspectors for identification.

8.3 Compensation

If trade of goods from a location is not possible, at no fault to business managers, and is not foreseeable for a long period of time, compensation should be considered for loss of trade in a similar way to the destruction of host plants when infected with an EPP under eradication. This might occur if there are large infestations of GAS in the immediate area and the risk of removing goods from the area is deemed to be too great.

9 Course of action

9.1 Summary of past eradications

In April 1977, a low level infestation of GAS was detected in Gordonvale, 19km south of Cairns in Queensland, Australia. The infestation was restricted to a suburban area covering 16 ha. (Watson, 1978). In 1981, the Queensland State Government declared GAS eradicated three years after the detection of the last snail (Ingram, 2001). Throughout the campaign over 400 snails ranging in size from 10 to 200 mm were poisoned and collected by the DPI, with hundreds of eggs and juveniles being eradicated by methyl bromide fumigation (Watson, 1978). A publicity campaign of information posters and a postal survey was launched to all households between Tully and Cape York. Of the 70 responses to the survey all proved to be local snail species (Ingram, 2001).

From 1969 to 1975, an eradication of GAS in Florida USA cost over US$1,000,000 and taking over seven years from initial introduction. Three GAS were smuggled into Miami in 1966 and were released into a backyard. After nine years, over 18,000 GAS were detected at five infestation sites, the furthest infestation being some 40 km from the introduction site. Eradication relied primarily on hand-picking, plus a granulated chemical bait (Simberloff, 1996) containing 3.25% metaldehyde and 5% calcium arsenate (Mead, 1979b).

In addition, GAS is currently under eradication in Florida. It was initially detected in 2011 in the Coral Gables area of Miami-Dade County, Florida. Latest media reports indicate that over $6 million have been spent on the eradication program and over 150,000 snails collected[5]. So far media report that the eradication program has stopped the spread of GAS from the infested area and has been highly successful.

An established GAS population in Queensland could be eradicated if detected early enough. The program outlined in this plan incorporates several methods including physical collection and destruction of snails, baiting with proprietary snail poison pellets and metaldehyde 'hard' baits. The options listed are an amalgam of successful eradication and control techniques used in Gordonvale by DPI as described by Watson (1978; 1985), Florida as described by USDA (2013) and in the Indo-Pacific islands as described by Lambert (1999).

9.2 Physical removal and disposal

Once detected, snails should not be handled without gloves; GAS can spread a serious virus (eosinophilic meningoencephalitis) to people from skin contact. Snails and eggs should be bagged and disposed of by freezing (48 hours) or immersion in alcohol or boiling water. Snails can also be incinerated in an appropriate oven. As an additional precaution hands should be washed in hot soapy water or rinsed in standard disinfectant after handling.

Hand collection and destruction of snails is the most common method of snail control, however is not very effective in rough terrain or dense vegetation. Regular collection of GAS from fields and gardens, particularly in rainy weather, should be carried out. Community cooperation by householders, schools or other groups can help to reduce snail numbers significantly, particularly in newly infested areas. Shire council refuge tips in the vicinity of the infested area should be included in the program. Place collected GAS directly into vials, jars or specimen bottles with 70% ethanol.

Snail specimens collected by members of the public should be placed into a sealed jar containing kerosene, mineral turpentine, diesel, methylated spirits, ethanol, boiling water, seawater or salt. Information such as where and when the snails were collected should be included using a permanent marker outside the jar; ensure the jar is complete dry before writing and that writing is clearly legible. The snails should not be kept alive and children should not be allowed to play with them. Any request for public collection should include strong health warnings.

9.3 Snail baits

In Florida, a number of snail baits are being used to kill GAS. These are summarised in Table 4. The combination of iron phosphate, boric acid and metaldehyde is probably the most effective baiting scheme (USDA, 2011; 2012; 2013). Metaldehyde is commercially available and registered in Australia for a number of purposes and at varying rates that would allow for application against GAS. Iron phosphate is commercially available for home and garden use, but suppliers listed as registrants do not have labels available. Boric acid is registered as a cockroach bait but the label is not available in Australia. The active ingredient iron-EDTA complex is readily available.

Table 4. Snail baits used in current eradication of GAS from Florida (USDA, 2011; 2012; 2013). All products observe a 3m buffer around aquatic areas.

Active	US product name	Rate	Use pattern

[5] http://www.npr.org/2014/11/20/364945713/floridas-hunt-for-giant-snails-leads-to-smelly-easter-eggs

ingredient			
Metaldehyde	Ortho Bug-Geta	About 0.5kg/400m^2	Broadcast-applied as a pellet to soil in lawns, near ornamental plants, and open areas where GAS occur.
Metaldehyde	Durham metaldehyde granules (7.5%)	About 0.5kg/230m^2	Broadcast-applied as a pellet to soil in lawns, near ornamental plants, and open areas where GAS occur.
Metaldehyde	Slug-Fest (25%)	About 2-4L/4000m^2	Spot applied as a liquid to areas under plants where high concentrations of GAS occur
Boric acid	NiBan (5% orthoboric acid)	About 1kg/50m^2 Applied every 4-6 weeks.	Broadcast-applied as a pellet to soil in lawns, near ornamental plants, and open areas where GAS occur.
Iron phosphate	Sluggo-AG (1% iron phosphate)	About 10-20kg/4000 m^2 applied every 2 weeks.	Broadcast-applied as a pellet to soil in lawns, near ornamental plants, and open areas where GAS occur.

Given that some of the above products are not readily available, metaldehyde is the first bait that should be used in the event of a detection. If the infested area is significant and eradication is deemed feasible then it is recommended to pursue availability of other baits that are registered, but may not be currently available. Alternatively, an emergency permit could be submitted for a commercially available product for use in a GAS response program. In addition, research should be conducted as to the efficacy of individual formulations that are available in Australia, similar to that completed in Florida (Smith et al., 2013). This should include choice and no-choice tests and will assist in optimising the bait program in the event that an extended eradication program is required.

Table 5. In Australia the following products are currently registered for all snails and could be legally used against GAS.

Active ingredient	Product names	%a.i.	formulation	Active ingredient proven against GAS
Iron Phosphate[1]	Slug and snail bait, Enviroguard Ferramol	2.8g/kg	Bait	Yes
Iron	Snail and slug killer	10g/kg	Bait	No
Iron-edta complex	Multiguard snail and slug killer, Eradicate	60g/kg	Bait	Yes
Metaldehyde	Numerous including: Snail and slug bait/pellets/buster, snail killer pellets, slugout, slimebuster, snail0dead bait	Ranging from 15g/kg to 50g/kg.	Pellet	Yes
Methiocarb	Baysol	20g/kg	Bait	Indirect indication that it may be effective[2] but no formal publication available to our knowledge

[1] Registration exists but may not be commercially available.
[2] www.fao.org

9.3.1 Snail bait technical guidelines

Given the risk associated with snail baits it is important to notify all residents, businesses and relevant managers that a treatment will occur prior to applying baits. Notification should be given that treatment will occur on the property within a certain window of time. People should be asked to contact the lead agency with concerns or questions and to make special arrangements in case pets need to be moved to a different property etc. This also eliminates the need to have direct contact with all residents, i.e. no response is considered as permission to treat the property. Notification that treatment has occurred should also be provided to each resident.

The exact method used may have to be modified depending upon the particular product. Bait should be applied as evenly as possible within 200m of where GAS has been detected. Clumps of pellets should be avoided to decrease the risk of poisoning. Small pellets are easier to distribute evenly in an area, but tend to disintegrate following rain and therefore must be reapplied frequently, i.e. every 2 weeks. Harder, larger baits are an option in high rainfall areas. It may be necessary to distribute these along fence lines, in gardens among clumps of plants and other areas that are not a nuisance to residents and decreases risk of poisoning (Watson, 1985).

If it is anticipated that the infestation is very large with many individuals present, i.e. 1000s of individuals, it is recommended to use more than one snail bait, each with active ingredients with different modes of action. This may be more effective in killing GAS and reduce the possibility of pesticide resistance. Consider baiting throughout the year when snails may be active. In north Queensland this will probably be all year round, but baiting may not be necessary in winter in southern areas of the Australia.

9.4 Chemical control

To our knowledge there are no pesticide products that have a general registration against snail pests in non-crop areas. There are registrations or minor use permits available for use in a variety of situations including the treatment of non-food producing plants for specific snail pests. These include the active ingredients methomyl, methiocarb and thiodicarb. Carbaryl is also considered an effective molluscicide but there are no current registrations against any snail in Australia. An application should be submitted to the APVMA for use when concentrated infestations of GAS are found in non-crop areas.

Areas that have a high numbers of GAS individuals should have a liquid application of a carbamate product on the surface and injected into the soil if possible, e.g. into compost heaps, thick layers of detritus, etc. Snail baits should also be spread in the area, as per section 8.3. All permit instructions should be followed and appropriate personal protective equipment must be worn.

9.5 Land management

Piles or stacks of bricks, pavers, wood and general ‘rubbish’ that can often accumulate on properties provide ideal places for GAS to hide. In the eradication in the late 1970s in North Queensland, residents were encouraged to clean up such piles after initial catches of GAS dropped considerably (which was about a month after initial detection) (Watson, 1985). A similar approach is recommended, particularly if local councils can be encouraged to take part and supervise in the clean-up. The exact timing of the clean-up will depend on where the snails were detected and the extent of the infestation. If the detection represents only a handful of snails, inspection of the sites may be possible by biosecurity staff without a clean-up per se. On the other hand, if 1000s of snails are involved then residents must be involved and provided clear guidelines on how to dispose of rubbish, perhaps in designated areas at particular waste disposal/transfer areas. Burning of appropriate garden rubbish should be encouraged within quarantine areas within current fire restrictions of the area. If this is not possible then it may be possible to treat rubbish with an appropriate pesticide (probably a carbamate under an emergency use permit) and then double bagged for transport to an appropriate waste facility managed for GAS as outlined in section 7.1. This might occur after 1-3 months after the initial detection depending upon the number of individuals detected in the area.

Large clumps of grass, bananas and other such plants also provide excellent hiding places for GAS. Residents should be encouraged to remove such sites and keep garden areas clean and tidy, reducing available hiding places for GAS after initial detection numbers have declined when individuals are active, i.e. during warm conditions. Do NOT encourage clean-up activities during periods when GAS are likely to be hiding in an inactive state as this could increase risk of inadvertent transport of individuals.

Refer to movement restriction for notes on how materials and rubbish might be moved out of quarantine areas for disposal in section 7.1.

9.6 Physical control

Physical control measures are effective in reducing snail populations where chemical control is too hazardous or expensive, or when GAS is aestivating and chemical control is not effective. Measures such as controlled burning, plowing, discing and culti-packing can be used.

Burning vegetation on which aestivating snails attach will reduce snail populations. Burning is most effective during the dry season and the majority of snails are aestivating on the vegetation above ground. The systematic use of commercial weed-burners is effective in reducing snail populations along fence rows and in areas where other measures may not be practical. In open fields, adjacent to outside storage and housing areas, plowing the soil twice a year has been found to reduce both *Theba sp.* and *Cochlicella sp.* populations, and should be effective for GAS. Cultivating the soil in late autumn destroys many of the immature and adult snails, as well as the eggs that have been deposited in the soil.

Discing and culti-packing is helpful in reducing land snail populations in areas where plowing may be not practical because of thin topsoil or where erosion may be a serious problem. The mechanical action of the disc and culti-packer will eliminate many adult snails, while stirring the soil will destroy many eggs. Good field sanitation and removal of mulches and other organic matter can reduce GAS breeding sites (Lambert, 1997). However, initially residents should be requested not to clear overgrown and neglected areas of their properties until a biosecurity inspection has been conducted.

Once inspections are complete, supervised clearing of rubbish and weeds from infested areas should be conducted to reduce breeding sites for the snails, collecting live snails detected as per section 10.4.1 of this plan.

Depending on where the incursion is, it is imperative to ensure that all seaports and airports, particularly where cargo and vehicles are stored, are kept free of the GAS. GAS rarely moves onto bare ground. Lambert (1999) suggests the following physical control method: a strip of bare earth (about 1.5 m wide) around cultivated areas; bands of sand spread around cultivated areas; and back-burns around crops (although not always appropriate) also destroying GAS adults and eggs. A combination of physical and chemical controls with regular snail collections would be more effective in controlling a GAS incursion than any one of these actions.

10 Technical debrief and analysis for stand down

Refer to PLANTPLAN (Plant Health Australia, 2014) for further details

The emergency response is considered to be ended when either:

Eradication has been deemed successful by the lead agency, with agreement by the Consultative Committee on Emergency Plant Pests and the Domestic Quarantine and Market Access Working Group.

Eradication has been deemed impractical and procedures for long-term management of GAS have been implemented.

A final report should be completed by the lead agency and the handling of the incident reviewed.

Eradication will be deemed impractical if, at any stage, the results of the delimiting surveys lead to a decision to move to containment/control.

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12 Appendices

12.1 Appendix 1: Agricultural crops subject to GAS feeding damage

List of known plant species that GAS may feed upon, (taken from Raut and Barker 2002)

Common name	**Species name**
African Locust bean	*Parkia filicoidea*
African oil palm	*Elaeis quineensis*
Air potato	*Dioscorea bulbifera*
Aloe	*Aloe indica*
Alsophila	*Alsophila sp.*
Amaranth	*Amaranthus* Linnaeus spp., including *A. blitum* Linnaeus, *A. tricolor* Linnaeus and *A. viridis* Linnaeus; *Comphrena globosa*
Apple	*Malus spp.*
Aztec marigold/Indian marigold	*Tagetes erecta* and *T patula*
Banana	*Musa* Linnaeus spp., particularly *M. acuminata* Colla and *M. paradisiaca* Linnaeus
Basella	*Basella alba* Linnaeus and *B. rubra*
Bauhinia	*Bauhinia acuminata*
Beans and peas	*Arachis hypogaea* Linnaeus; *Glycine max* (Linnaeus) Merill; *Lablab purpureus* (Linnaeus) Sweet; *Pisum* Linnaeus spp., particularly *P. sativum* Linnaeus; *Vigna radiata* (Linnaeus) Wilczek, *V. unguiculata* (Linnaeus) Walpers and *V. savi* ; *Phaseolus* sp.; *Cajanus cajan*
Betel	*Piper betel*
Bilimbi	*Averrhoa bilimbi* Linnaeus and *A. carambola* Linnaeus
Bird of Paradise	*Heliconia spp.*
Blue sage	*Eranthemum* spp.
Bluestem	*Andropogon* spp.
Boatlily	*Tradascantia spathacea*
Bouganvillea	*Bougainvillea spp.*

Breadfruits	*Artocaropus* Forster & Forster spp., including *A. altilis* (Parkinson) Fosberg and *A. heterophyllus* de Lamarck
Brinja;/aubergine	*Solanum melongena* Linnaeus
Brassica	*Brassica oleracea* Linnaeus cultivars; *Raphanus sativus* Linnaeus *B. campestris* var. *rapa; B. napus* var. *napus*
Buckhorn	*Opuntia spp.*
Bulrush	*Scripus ternatanus*
Butterfly pea	*Centrosema* sp.
Cacao (Sterculiaceae)	*Theobroma cacao* Linnaeus
Cactus	*Cereus* sp.
Calophyllum	*Calophyllum inophyllum*
Canna	*Canna* sp.
Carrot (Apiaceae)	*Daucus carota* Linnaeus
Cassava (Euphorbiaceae)	*Manihot esculenta* Crantz
Castor (Euphorbiaceae)	*Ricinus communis* Linnaeus
Cathedral bells	*Bryophyllum* [=*Kalanchoe*]
Chinese box	*Murray* asp.
Cherimoya	*Annona cheirimoya*
Chillies and peppers (Solanaceae)	*Capsicum* Linnaeus spp., particularly *C. annuum* Linnaeus and *C. baccatum* Linnaeus
Chrysanthemum	*Chrysanthemum coronarium var. coronarium*
Citrus (Rutaceae)	*Citrus* Linnaeus spp., particularly *C. sinensis* (Linnaeus) Osbeck and *C. reticulata* Blanco
Clitoria	*Clitoria ternatea*
Coffee (Rubiaceae)	*Coffea* Linnaeus spp., especially *C. arabica* Linnaeus and *C. canephora* Pierre ex Froehner
Coconut (Aracaceae)	*Cocos nucifera* Linnaeus
Corm (Araceae)	*Amorphophallus paeoniifolius* (Dennst.) Nicolson
Cosmos	*Cosmos* spp.
Cotton (Malvaceae)	*Gossypium* Linnaeus spp., especially *G. herbaceum* Linnaeus
Crinum	*Crinum* spp.
Crybaby tree	*Erythrina crista-galli*
Dahlia	*Dahlia* sp.
Devil's tree	*Alstonia scholaris*
Dixie rosemallow	*Hibiscus mutabilis*
Dracaena	*Dracaena sp.*
Drum stick (Morningaceae)	*Moringa oleifera* de Lamarck
Dumbcane	*Dieffenbachia sequine*
Elephant's ear	*Xanthosoma* sp.
Erythrina (Fabaceae)	*Erythrina* Linnaeus sp.
Eucalyptus (Myrtaceae)	*Eucaluptus* L'Héitier de Brutelle spp., especially *E. deglupta* Blume
False nettle	*Boehmeria sp.*
Figs (Moraceae)	*Ficus hispida* Linnaeus
Frangipani	*Plumeria acuminata*
Gardenia	*Gardenia angusta*
Ginger	*Zingiber sp.*
Goldenshower	*Cassia fistula*
Gourd/pumpkins/cucumber/melons (Cucurbitaceae)	*Citrullus lanatus* (Thunberg) Matsumura & Nakai; *Cucumis* Linnaeus spp., including *C. melo* Linnaeus and *C. sativus* Linnaeus; *Cucurbita* Linnaeus spp., including *C. maxima* Duchesne and *C. pepo* Linnaeus; *Edgaria darjellingensis* Clarke; *Lagenaria* Seringe spp., including *L. siceraria* (Molina) Standley; *Luffa* Miller spp., including *L. acutangula* (Linnaeus) Roxburgh and *L. aegyptiaca* Miller; *Momordica* Linnaeus spp., principally *M. cochinchinensis* (de Loureiro) Sperengel
Grape	*Vitis vinifera*

Hoary pea	*Tephrosia* sp.
Hyacinth bean	*Lablab purpureus*
Impatiens	*Impatiens balsamina*
Indian bark	*Cinnamonum tamala*
Indian mulberry	*Morinda citrifolia*
Indigo	*Indigofera* sp.
Jasmine	*Jasin samboc*
Jute (Tiliaceae)	*Corchorus capsularis* Linnaeus
Kalanchoe	*Kalanchoe pinnatum*
Kokko (Fabaceae)	*Albizzia* Durazzini spp., including *A. lebbeck* (Linnaeus) Bentham; *Falcataria moluccana* (Miquel) Barneby & Grimes
Kudzu	*Albizzia lebbeck*
Laceleaf	*Anthurium* spp.
Lady's finger	*Hibiscus esculentus*
Lagenaria	*Legenaria* sp.
Leadtree	*Leucaena* sp.
Lettuce (Asteraceae)	*Lactuca* Linnaeus spp., including *L. sativa* Linnaeus and *L. indica* Linnaeus
Light-blue snakeweed	*Stachytarpheta jamaicensis*
Lilly of the Incas	*Alstromeria* sp.
Mahogany (Meliaceae)	*Swietenia mahogoni* (Linnaeus) von Jacquin
Maiden grass	*Miscanthus condensatus*
Maize	*Zea mays*
Marshweed	*Lochnera rosea*
Madagascar periwinkle	*Lochnera rosea*
Mulberries (Moraceae)	*Broussonetia papyrifera* (Linnaeus) L'Héritier de Brutelle ex Ventenat; *Morus alba* Linnaeus
Naupaka	*Scaevola*
Night queen	*Cestrum nocturnum*
Nightshade	*Solanum* sp.
Nodeweed	*Synedrella nodiflora*
Okra (Malvaceae)	*Abelmoschus exulentus* (Linnaeus) Moench
Oleander	*Nerium indicum* and *N. oleander*
Onion/Chinese chive/Garlic (Liliaceae)	*Allium cepa* Linnaeus; *A. tuberosum* and *A. oleraceum*
Orchids	*Oncidium* sp.; *Phalaenopsis* spp.
Palm nuts (Arecaceae)	*Areca catechu* Linnaeus; *Elaeis quineensis* von Jacquin
Pancratium	*Pancratium* sp.
Papaya (Caricaceae)	*Carica papaya* Linnaeus
Passion-fruit (Passifloraceae)	*Passiflora* Linnaeus sp.
Patol	*Trichosanthes dioica*
Peacocksplume	*Falcataria moluccana*
Pepper	*Piper* sp.
Periwinkle	*Catharanthus roseus*
Peruvian groundcherry	*Physalis peruviana*
Pineapple	*Ananas comosus*
Pink wood sorel	*Oxalis corymbosa*
Pipturus	*Pipturus* sp.
Potato (Solanaceae)	*Solanum tuberosum* Linnaeus
Pothos	*Epipremnum pinnatum*
Purslane	*Portulaca grandiflora*
Quickstick	*Gliricidia sepium*
Rape-Jasmine	*Tabernaemontana divaricata*
Rattlesnakemaste	*Eryngium* sp.
Rice	*Oryza sativa*
Rose	*Rosa* spp.
Rubber (Euphorbiaceae)	*Hevea brasiliensis* (von Willdenow ex de Jussieu) Műller
Sadabahar	*Lachnera rosea*
Sage	*Salvia* sp.

Sanchezia	*Sanchezia nobilis vargeta*
Sanseviera	*Sansevieria trifasciata*
Scarlet pimpernel	*Anagallis arvensis*
Screw pine	*Pandanus tectorius*
Sensitive plant	*Mimosa* sp.
Sesame	*Sesamum indicum*
Shishu (Fabaceae)	*Dalbergia sissoo* Roxburgh ex de Candolle
Soursop (Annonaceae)	*Annona muricate* Linnaeus
Spinach (Chenopodiaceae)	*Spinacia oleracea* Linnaeus
Sunflower (Asteraceae)	*Helianthus annuus* Linnaeus
Sweet potato (Concolvulaceae)	*Ipomoea batatas* (Linnaeus) de Lamarck
Taro/coco yan (Araceae)	*Alocasia* (Schott O Don spp., including *A. macrorrhizos* (Linnaeus) Schott; *Colocasia esculenta* (Linnaeus) Schott; *Xanthosoma braziliense* (Desfontaines) Engler
Tea (Theaceae)	*Camellia sinensis* (Linnaeus) Kuntze
Teak (Verbenaceae)	*Tectona grandis* Linnaeus
Tobacco (Solanaceae)	*Nicotiana tabacum* Linnaeus
Tomato (Solanaceae)	*Lycopersicon esculentum* Miller
Vanilla (Orchidaceae)	*Vanilla* Miller sp.
Yam (Diascoreaceae)	*Dioscorea alata* Linnaeus

12.2 Appendix 2: Resources and facilities

Table 2 provides a list of diagnostic facilities for use in professional diagnosis and advisory services in the case of an incursion.

Table 2. Diagnostic service facilities in Australia capable of confirming the identity of *Achatina fulica* (giant African snail)

Name	Organisation	Phone number	Email
John Stanisic	Queensland Museum	07 3840 7555	john.stanisic@qm.qld.gov.au
Adnan Moussalli	Museum Victoria	03 8341 7642	amoussalli@museum.vic.gov.au
Frank Koehler	Australian Museum (Sydney)	02 9320 6382	frank.koehler@austmus.gov.au