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Department of Agriculture,
Fisheries and Forestry

Importation of live garden snails (*Cornu aspersum*) for heliciculture

Final Biosecurity Import Risk Review

Animal Biosecurity Branch | Biosecurity Animal Division

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Department of Agriculture, Fisheries and Forestry

GPO Box 858 Canberra ACT 2601

Telephone 1800 900 090

Web agriculture.gov.au

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Acknowledgement of Country

We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment and community. We pay our respects to the Traditional Custodians of the lands we live and work on, their culture, and their Elders past and present.

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1 Summary

The Department of Agriculture, Fisheries and Forestry (the department) has prepared this biosecurity import risk review to analyse the risks associated with the proposed importation into Australia of live snails of the terrestrial species, *Cornu aspersum*, as breed-stock to produce edible snails for human consumption. The review considered relevant scientific information, industry practices and operational practicalities. The review was also informed by peer-reviewed publications and a range of other available evidence, and used external specialist expertise and, as appropriate, drew on information provided by commercial parties.

The review encompassed the invasive potential of *C. aspersum*, as well as the diseases and pests considered relevant to the proposed importation of *C. aspersum*. Australia currently permits the importation of (killed) terrestrial snails for human consumption if they have been retorted in accordance with the import conditions (DAFF, 2024), including:

- The goods must have been hermetically sealed in a container before being heat treated to a minimum core temperature of 100°C, obtaining an F_0 value of at least 2.8.
- The final product must be imported in the hermetically sealed (airtight) container in which it was retorted.
- The goods must be retorted, commercially sterile and shelf stable.

There are also conditions for importation of freshwater snails for laboratory use.

This review focussed on live *C. aspersum*, with risk management measures proposed for the importation of both foundation adult breed-stock and hatchling snails. In accordance with the *Biosecurity Act 2015*, the measures for each will reduce biosecurity risk to a very low level, but not to zero. The measures will also seek to ensure that the correct species of snail is imported, thus mitigating any unassessed invasive potential.

The measures for the importation of either adult or hatchling *C. aspersum* include a prerequisite for the approval of both the exporting country, as a source for this commodity, and the individual snail farming establishments from which the adult or hatchling snails will be sourced. In particular, snail farms seeking to export *C. aspersum* to Australia must be commercial operations and government certified for basic quality standards for food safety and general hygienic operations. The current Quality Standard applicable to the commercial operation which is exporting *C. aspersum* to Australia must be linked to a specific import application and will be reviewed as part of the application assessment process. Some modification or amendment of this Quality Standard may be required.

There are **separate protocols for adult snails and for hatchling snails**, with each addressing both species verification and biosecurity.

Species verification and biosecurity measures for adult snails

- Adult snails exported to Australia must be certified by the exporter and exporting country as *C. aspersum* only. Certification of species may be based on morphological identification or on an approved molecular method. Approval will entail the development, validation and

standardisation of a molecular procedure that meets the department's requirements for sensitivity and specificity.

- Adult snails will be directed to an Approved Arrangement on arrival at the Australian border. This will be a biosecure facility and may be a government-supervised quarantine facility or may be a snail farming facility that is managed privately. The privately managed Approved Arrangement and site will include (*inter alia*) site design and security, as well as biosecurity protocols for site maintenance, people and the disposal of waste. The privately managed Approved Arrangement and site will also be subject to the department's requirements for audit and compliance.
- A subset of the snails within each imported consignment will be subject to species verification by morphological or molecular identification. Morphological Identification involves sacrifice of the selected snails as dissection is required. Dissection and identification must be undertaken by a suitably qualified inspector who has been approved by the department to undertake this task. Identification must be based on a diagnostic key that has been approved by the department for use in this context. Molecular identification will entail the development, validation and standardisation of a molecular procedure that meets the department's requirements for sensitivity and specificity. The identification procedure will be described in the Approved Arrangement and the protocol for its application will be based on the anticipated size of consignment.
- Imported adult snails will remain under the Approved Arrangement and within the biosecure facility where they will be bred to the next generation. Throughout this period, the imported snails will be isolated from Australian snails and from the definitive host of both *Angiostrongylus* spp. and *Crenosoma vulpis*. This will ensure that the following generation of *C. aspersum* will be free of *Angiostrongylus* spp. and *Crenosoma vulpis*. Isolation within the biosecure facility will also break the life cycle of vectored plant pathogens. Successive generation(s) of snails will then be eligible for release from the Approved Arrangement and site.

The imported adult snails will not be eligible for release from the Approved Arrangement site. They will either remain within the site for their natural life or will be euthanised. The remains of imported adult snails will be managed as biosecurity waste.

Species verification and biosecurity measures for hatchling snails

- Hatchling snails are snails less than 10 days old that have not been released from the hatching environment and have not been exposed to plant substrate.
- Hatchling snails must be sourced from establishments that employ either an internal or mixed (internal and external) farming system and must only have received commercially processed livestock feed.
- Hatchling snails must be certified by the exporter and exporting country as *C. aspersum* only. Certification of species may be based on morphological identification of breed stock or on an approved molecular method. Approval will entail the development, validation and standardisation of a molecular procedure that meets the department's requirements for sensitivity and specificity.

- Hatchling snails will be directed to an Approved Arrangement on arrival at the Australian border. This will be a government-supervised biosecure facility where the snails can be held while species is verified.
- A subset of the hatchling snails within each imported consignment will be subject to species verification by molecular identification. This will entail the development, validation and standardisation of a molecular procedure that meets the department's requirements for sensitivity and specificity. The protocol for the application of this procedure will be described in the Approved Arrangement and will be based on the anticipated size of a consignment.

Having verified the species of hatchling snails within a consignment (as above), the consignment may be released from biosecurity control. It will be a condition of the import permit that imported hatchling snails are for breeding purposes only and must not be used for human consumption.

2 Introduction

Australia's biosecurity policies aim to guard against the entry, establishment and spread of exotic diseases and pests which might otherwise threaten Australia's agricultural industries, natural environments, or people. Biosecurity import risk review enables the Department of Agriculture, Fisheries and Forestry (the department) to assess the level of biosecurity risk that may be associated with proposals to import goods into Australia. If the biosecurity risk exceeds Australia's appropriate level of protection (ALOP), risk management measures are proposed. If the biosecurity risk cannot be reduced to a very low level, but not to zero, as required under the Biosecurity Act and through means available to the department, the goods will not be imported into Australia.

Biosecurity import risk is assessed by the department using technical and scientific experts from relevant fields and involve consultation with stakeholders at various stages during the process. The assessment may take the form of a biosecurity import risk analysis (BIRA) or a non-regulated risk analysis (such as scientific review of existing policy and import conditions, or scientific advice). This biosecurity import risk review is a non-regulated analysis.

Further information about Australia's biosecurity framework is provided in the [Biosecurity import risk analysis guidelines 2016](#).

The department recognises that new scientific information and technologies, or other combinations of measures, may provide an equivalent level of biosecurity protection for the disease agents identified as requiring risk management. The department will consider technical submissions that objectively demonstrate suitable efficacy of alternative biosecurity measures.

2.1 Background

In response to members of the public (the applicants) with specific commercial interests in developing the Australian heliculture industry, the relevant departments of the Australian Government independently undertook analyses for the importation of live *C. aspersum*, as required under Australian law.

Two separate pieces of legislation underpin the required risk review for this import proposal.

The first evaluation (completed June 2020) was undertaken by the (then) Department of the Environment and Energy in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and was the project undertaken at the time of the first contact by the applicants. This evaluation recommended listing *C. aspersum* (Common Garden Snail) in Part 1 of the [List of Specimens taken to be Suitable for Live Import](#) (specimens that can be imported without a permit under the EPBC Act). Importation of *C. aspersum* would be subject to an importation approval under the Biosecurity Act.

The current biosecurity import risk review is being undertaken by the department with additional technical expertise provided by an external consultant, in accordance with the requirements of the Biosecurity Act.

Completion of both evaluations is a prerequisite to any live animal imports.

The applicants advised that there is significant interest in the restaurant industry in Australia, and internationally, in obtaining high quality *escargots* (edible snails) for human consumption. To service this need, they wished to develop Australian heliculture businesses by farming the common garden snail (*C. aspersum*). The snails bearing the desirable characteristics would be sourced from eligible overseas producers of edible snails.

The applicants have asserted that the *C. aspersum* currently available in Australia are smaller than the more commercially attractive snails available in Europe. Snails of less than 8 to 10 grams, and of small shell size, are reportedly unsuitable for sale. The applicants wish to use imported snails as a base to breed from, rather than 'spending years developing snails of a suitable size from domestic stock'.

At the beginning of the 20th century, two subspecies of this snail were defined based on shell characteristics: *Helix aspersa aspersa* (now classified as *Cornu aspersum aspersum*) and *Helix aspersa maxima* (now classified as *Cornu aspersum maximum*). These subspecies are currently recognised as genetically divergent, although there are differing views on whether they constitute separate subspecies (Guiller and Madec, 2010; Guiller *et al.*, 2001; Rygalo-Galewska *et al.*, 2022). *C. aspersum* is highly variable morphologically and several distinct morphotypes have also been described. Differences exist with respect to size, shape, thickness and colour of the shell. Some authors assert that the form *maximum* is a distinct subspecies *C. aspersa maximum* (Taylor, 1914), known in French as 'gros-gris', with *C. aspersum sensu stricto* known as the 'petit-gris'. The status of *C. aspersum maximum* as a valid subspecies is not consistently supported in the literature (Guiller *et al.*, 2001).

For the purpose of this biosecurity import risk review, the classification of separate subspecies has been accepted.

C. aspersum is farmed or collected in the wild in several countries for human consumption. Both subspecies are farmed. The subspecies *C. aspersum maximum* is larger and has a lifespan of more than 8 years, whereas the subspecies *C. aspersum aspersum* is smaller, more widely distributed and has a lifespan of 3 to 4 years (Russo and Madec, 2011). These subspecies also differ in their shell chemical composition (Ligaszewski, Surowka *et al.*, 2009) and metabolism (Czarnoleski, Labecka *et al.*, 2016) and potentially in other attributes yet to be defined. *Cornu aspersum maximum* does not occur in Australia.

According to the applicants, noting the information has not been verified by the department:

Heliculture farms in Europe have bred *C. aspersum* for eating for over 2000 years and have selectively bred snails for a consistent size and growth rate. Importing disease-free snails of the required age and size from a commercial snail farm would ensure that the breeding of snails for restaurants could commence quickly and safely. A single 60 kg shipment of adult snails (approximately 6,000 individuals) would be imported to begin breeding for future generations.

This biosecurity import risk review considers that certain controls over commercial establishments supplying *C. aspersum snails* to Australian importers (generally termed snail farms) must be in place to allow for effective biosecurity risk management. Standards governing the operation of such

establishments differ widely and, when present, tend to focus purely on food safety risks. In addition, snail farms often fatten large numbers of snails in an outside environment immediately before sale (Rygalo-Galewska *et al.*, 2022). This increases the likelihood that wild snails will enter the snail farm in the country of origin and be included in exported consignments.

Controls over commercial establishments is also considered in relationship to the likelihood that a biosecurity hazard can establish and spread within Australia. There is a significant likelihood that snails imported into Australia and released to commercial snail farms in Australia will enter the broader Australian environment, so hazards of concern must be effectively managed prior to that point.

2.2 Scope

This biosecurity import risk review focussed on the importation of live *C. aspersum* from any country to mainland Australia and Tasmania. The Australian External Territories are not considered. The intent is for imported snails to serve as breed-stock – that is, the imported snails will not be used for human consumption.

2.3 Next steps

This is the final report for the import risk review. The department will work with the applicants to establish the most practical approach to the implementation of the risk management measures.

3 Method

This biosecurity import risk review included three subsidiary assessments:

- Quarantine pest potential of *C. aspersum*
- Risk assessments for animal and human pathogens
- Risk assessment for *C. aspersum* as a vector for plant pathogens.

The (then) Department of the Environment and Energy undertook an evaluation of the invasive potential *C. aspersum*. This evaluation recommended listing *C. aspersum* (Common Garden Snail) in Part 1 of the **List of Specimens taken to be Suitable for Live Import** (specimens that can be imported without a permit under the EPBC Act). In the current biosecurity import risk review, a further evaluation was undertaken to determine whether *C. aspersum* fitted the International Plant Protection Convention's (IPPC) definition of a quarantine pest. Pest categorisation is documented in Section 4.

The biosecurity analyses for animal and human pathogens, documented in Section 5, followed the Department of Agriculture, Fisheries and Forestry's (the department's) Biosecurity Import Risk Analysis Guidelines (2016). Biosecurity risk is defined in the Biosecurity Act and refers to the likelihood of a pathogen entering, establishing or spreading in Australian territory, and the potential for the pathogen causing harm to human, animal or plant health, the environment, economic or community activities.

The analyses for animal and human pathogens commenced with a categorisation step that sought to filter a potentially large number of pathogens and focus on the assessment on those that are relevant to the commodity. This step is termed 'hazard identification' by the World Organisation for Animal Health (WOAH, previously the OIE), and is summarised in [Appendix A](#).

The evaluation for each pathogen of concern included assessment of the likelihood that the pathogen will enter Australia with the importation of live snails (*C. aspersum*) and that susceptible species within Australia will be exposed to the pathogen.

- Entry assessment describes the pathway for importation as it relates to the introduction of pathogens and estimates the likelihood of this complete pathway occurring. It considers: (a) biological factors; (b) country factors, such as the prevalence of the pathogen; and (c) commodity factors, such as the production system, the quantity to be imported, and any testing, treatment or processing that is part of baseline production.
- Exposure assessment describes the biological pathways necessary for exposure of susceptible animals, plants and the environment to the pathogen and estimates the likelihood of the exposure occurring. It again considers: (a) biological factors; (b) country factors, such as the presence of competent vectors, and relevant geographical and environmental characteristics; and (c) commodity factors, such as the quantity to be imported, its end use and disposal practices.

The likelihood that each pathogen will become established and spread within Australia was examined as part of the assessment of consequences, which focussed on impact at a national level.

The likelihood of entry and exposure, and the likely consequences, were then combined using the department's risk matrix (Table 3) to provide an estimate of unrestricted biosecurity risk.

An overview of this risk assessment process is given in Figure 1. All likelihoods were evaluated qualitatively, using the terms shown in Table 1. Likely consequences were also evaluated qualitatively, and the terms for this are given in Table 2.

The final part of the biosecurity analyses (Section 5.9) dealt with the potential for *C. aspersum* to vector key plant pathogens. This part of the review was necessarily less structured than other sections, as it considered a wide range of pathogens and included substantial uncertainty.

Figure 1 Components of the unrestricted risk estimate

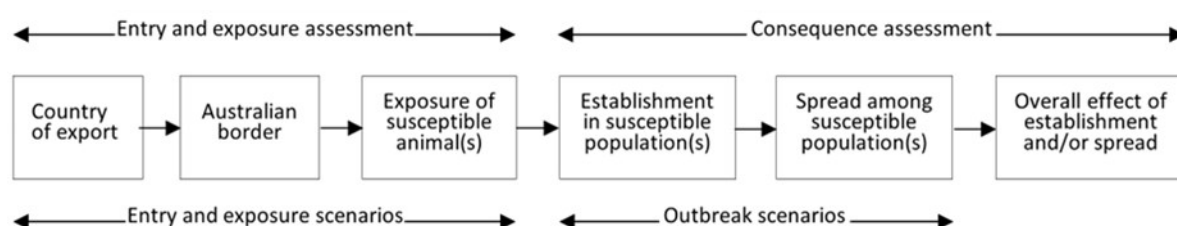


Table 1 Nomenclature for qualitative likelihoods

Likelihood	Descriptive definition
High	The event would be very likely to occur
Moderate	The event is equally likely to occur or not occur
Low	The event would be unlikely to occur
Very low	The event would be very unlikely to occur
Extremely low	The event would be extremely unlikely to occur
Negligible	The event would almost certainly not occur

Table 2 Rules for determining the likely consequences using effect categories

Overall effect	Description
Extreme	The effect is likely to be highly significant at the national level. Implies that economic stability, societal values or social well-being would be seriously affected.
High	The effect is likely to be significant at the national level and highly significant within affected zones. Implies that the effect would be of national concern. However, serious effects on economic stability, societal values or social well-being would be limited to a given zone.
Moderate	The effect is likely to be recognised on a national level and significant within affected zones. The effect is likely to be highly significant to directly affected parties.
Low	The effect is likely to be recognised within affected zones and significant to directly affected parties. It is not likely that the effect will be recognised at the national level.
Very low	The effect is likely to be minor to directly affected parties. The effect is unlikely to be recognised at any other level.
Negligible	The effect is unlikely to be recognised at any level within Australia.

Table 3 Risk estimation matrix – likelihood of entry and exposure and likely consequences

Likelihood of entry and exposure	<i>High</i>	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
	<i>Moderate</i>	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
	<i>Low</i>	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk	High risk
	<i>Very low</i>	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk
	<i>Extremely low</i>	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk
	<i>Negligible</i>	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk
		<i>Negligible</i>	<i>Very Low</i>	<i>Low</i>	<i>Moderate</i>	<i>High</i>	<i>Extreme</i>
Likely consequences							

4 *Cornu aspersum*: pest categorisation

4.1 Identification of species and subspecies

The species *C. aspersum*, previous name *Helix aspersa*, exhibits a wide variety of shell patterns and colouration (Chevallier 1977; Kougiagka *et al.*, 2022; Madec *et al.*, 1998). These morphological characteristics were the basis for the description of many forms, varieties and species of *Helix*, creating a complex and convoluted taxonomy history. The subspecies *C. aspersum maximum* (or *C. aspersum maxima*, as referenced elsewhere) (*Helix (Pomatia) aspersa* var. *maxima*) was initially described by Taylor (1883) based on specimens collected from Algeria. Chevallier (1977) describes a range of ‘morphs’ including *C. aspersum maximum* noting its large size, up to 45 mm, and distribution limited to the Mediterranean.

The native range of *C. aspersum maximum* is believed to be North Africa, although wild populations of the subspecies are unknown (Dupont-Nivet, Guiller and Bonnet 1997; Guiller *et al.*, 2001). The situation is further complicated by the selective breeding of *C. aspersum maximum* for commercial purposes.

Madec *et al.*, (1998) conducted studies to compare characteristics of *C. aspersum maximum* to previous studies on *C. aspersum aspersum*, reporting that differences observed between the species – larger clutch size and egg weight – were likely explained by size-effect since *C. aspersum maximum* are physically larger than *C. aspersum aspersum*. Similarly, Çelik *et al.*, (2018) demonstrated that physically larger *C. aspersum aspersum* laid larger eggs and subsequently produced larger juveniles.

Dupont-Nivet, Guiller and Bonnet (1997) suggested that the size of snails is a heritable trait based on breeding studies involving *C. aspersum aspersum* and *C. aspersum maximum*, and Freitas *et al.*, (2023) demonstrated heritability of weight in *C. aspersum maximum*.

However, environmental factors are known to impact the size and development rate of snails (Çelik *et al.*, 2019; Kougiagka *et al.*, 2022). For example, stocking density and temperature may affect the growth rate of *C. aspersum maximum* (Freitas *et al.*, 2023; Jess and Marks 1998). Inbreeding may also affect fitness and inherited traits in snails (Kougiagka *et al.*, 2022). Dupont-Nivet *et al.*, (2001) observed significant loss of genetic variability in a population of *C. aspersum* artificially selected for breeding.

Czarsoleski, Labecka and Kozłowski (2016) compared the size of *C. aspersum aspersum* and *C. aspersum maximum* grown at different temperatures; both subspecies produced larger individuals when grown at 20°C than 15°C. However, *C. aspersum aspersum* grown at 20°C, produced larger adults than *C. aspersum maximum* grown at 15°C.

Using partial sequences of the 16S gene, Guiller *et al.*, (2001) identified two haplotypes in *C. aspersum aspersum* designating them East and West based on geographic distribution in North Africa. Analysis of *C. aspersum maximum*, obtained from farmed snails in France, formed a separate third haplotype, which was more closely related to the East haplotype of *C. aspersum aspersum*. However, snails collected from Morocco exhibiting shell measurements consistent with *C. aspersum maximum*, did not align with the farmed French *C. aspersum maximum*, but were

related to the Western haplotype of *C. aspersum aspersum*. Guiller *et al.*, (2001) advised that their results of genetic analysis did not resolve the taxonomic relationships within the species.

Later phylogenetic studies seeking to resolve the evolutionary history of *C. aspersum aspersum* have used *C. aspersum maximum* as an outgroup (Guiller and Madec 2010; Guiller *et al.*, 2012; Sherpa *et al.*, 2018).

In investigating the closely related genus *Erctella*, Colomba *et al.*, (2015) suggest that *C. aspersum* may be a group of [cryptic] species, but specified further studies are necessary to confirm their hypothesis. It is noted that Colomba *et al.*, (2015) only included a small number of *C. aspersum* in their molecular analysis, and that all samples originated from Italy.

In 2022, Kougiagka *et al.*, (2022) compared morphological and genetic features of farmed *C. aspersum aspersum* and *C. aspersum maximum* in Greece. Both subspecies were divided into three haplotypes, with genetic variation observed within populations rather than between them.

Gomot-de Vaufléury and Borgo (2001) crossed the two subspecies, *C. aspersum aspersum* and *C. aspersum maximum*, achieving fertile offspring. The resulting hybrids had a high level of juvenile mortality and low fecundity, with poor fitness compared to the parents. The authors noted that although hybrids were obtained, the snails showed a tendency to reproductive isolation, both behavioural and anatomical, and support the validity of the two subspecies (Gomot-de Vaufléury and Borgo, 2001).

Finally, no differences in genitalia structure are recorded between the subspecies *C. aspersum aspersum* and *C. aspersum maximum*, although size differences within and between the subspecies are noted and discussed (Guiller and Madec, 2010; Madec, Bellido and Guiller, 2003; Sherpa *et al.*, 2018). Ziętek, Ziomek and Wilczyńska (2019) developed a dissection protocol appropriate for use on both subspecies.

In summary, the available genetic information is not sufficient to resolve the taxonomic status of the subspecies *C. aspersum maximum*. Based on morphological diagnosis and the other information presented here, the department supports *C. aspersum maximum* is a valid subspecies of *C. aspersum* and unlikely to be a cryptic species.

Given the absence of wild populations, it appears that the subspecies persists only due to commercial farming efforts in a number of countries. Evidence from published literature supports that *C. aspersum* adult size and weight are inherited; it is likely these traits are maintained in *C. aspersum maximum* through selective breeding and growth under optimal conditions.

4.2 Pest potential and status

IPPC ISPM 11 (Pest Risk Analysis for Quarantine Pests) states that the taxonomic level usually considered in a Pest Risk Analysis is 'species' – the use of 'subspecies' may be justified if there is scientific evidence demonstrating that differences in characteristics are stable and significantly affect phytosanitary status.

From a plant health perspective, the subspecies *C. aspersum maximum* does not meet the IPPC definition of a quarantine pest for Australia. The available evidence suggests that

C. aspersum maximum is very similar to *C. aspersum aspersum*, which is already present and widespread in Australia, and any impacts on plant health and the environment are likely to be commensurate with, or less than, those of *C. aspersum aspersum*.

The species *C. aspersum* was likely introduced to Australia shortly after European settlement and is present in all states and territories (Blacket *et al.*, 2016). The direct impact of *C. aspersum* on plant health in Australia is limited to agricultural and ornamental plants in human-disturbed environments.

Subspecies of *C. aspersum* are expected to have a similar biology and behaviours.

C. aspersum maximum is reported to be physically larger, show variation in some shell and have a longer lifespan (Russo and Madec, 2011) and lay more eggs than *C. aspersum aspersum* (Madec *et al.*, 1998; Rygała-Galewska, Zglińska and Niemiec, 2022). These traits are not necessarily indicators of increased potential for economic damage as they may be linked to trade-offs in fitness, such as the longer time taken to reach reproductive maturity (Février, Russo and Madec, 2009; Madec *et al.*, 1998; Russo and Madec, 2011).

Both *C. aspersum aspersum* and *C. aspersum maximum* are commercially farmed throughout Europe (Kougiagka *et al.*, 2022; Rygała-Galewska, Zglińska and Niemiec, 2022). There are reports of *C. aspersum maximum* being commercially farmed in France (Chevallier, 1980; Guiller and Madec, 2010), Greece (Kougiagka *et al.*, 2022), Italy (Zucaro *et al.*, 2016), Poland (Drozd *et al.*, 2017), Spain (Segade *et al.*, 2009) and Ukraine (Danilova, 2022), as well as Brazil (Soares, Hayashi and Cocito, 2002). Although both subspecies have been intentionally introduced to multiple countries for heliciculture, only *C. aspersum aspersum* has established outside its native range and become a pest.

There is a recent report of *C. aspersum* from the Lviv region of the Ukraine (Gural-Sverlova and Gural, 2021). Here the authors suggest one pathway of introduction into the environment is escape from snail farms, noting an illegal dumping event as well as an abandoned farm. Another potential introduction pathway discussed is infested imported plants. The authors comment that some of the snails recovered had a dark mantle, characteristic of the large form of *C. aspersum*, specifically *C. aspersum maximum*; no further taxonomic diagnosis is attempted. The authors specifically refer to these reports as 'colonies', highlighting that their findings indicate small, localised populations that have yet to establish.

The species *C. aspersum* is recognised as highly polyphagous, with a wide plant host range including but not limited to apple, apricot, citrus, peach, barley, oats, wheat, cabbage, carrot, cauliflower, celery, bean, beet, lettuce, onion, peas, tomato, as well as an array of ornamental plants (Dekle and Fasulo, 2021; Iglesias and Castillejo, 1999). Although *C. aspersum* is widely accepted as a serious pest of agricultural and ornamental plants, there is limited information on the direct impact on crop losses or yield (Sanchez, 2010), or the costs associated with management (Jiang *et al.*, 2022). Reports of crop damage found include losses in citrus fruits in California (Sakovich, 2002) and grapes in South Africa (Sanderson and Sirgel, 2002); in Australia, Sanderson and Sirgel (2002) highlight the issue of contamination with introduced snails *C. aspersum* and *Theba pisana*, in the dried fruit (sultana) industry, which was ultimately linked to changes in soil-management practices.

C. aspersum has not been found in native Australian bushland, despite being widespread in urban and agricultural settings (DAWE, 2020). Holland, McDonnell and Williams (2007) found small numbers of *C. aspersum* (reported as *Helix aspersa*) in remnant grasslands in Victoria, but excluded

these from their study of introduced molluscs in native grasslands, due to low numbers and the fact that this species was not found in the study traps. Daniell (1994) commented that the only invasive snails thought to have caused a significant impact on Australian native vegetation are ‘white snails’ of the Helicidae family, specifically *Theba pisana*.

There are no reports in the literature that the host range of the subspecies *C. aspersum maximum* differs from that of *C. aspersum aspersum*. Despite being recorded being farmed in several European countries, there are no reports any crop damage attributed to the subspecies *C. aspersum maximum*.

4.3 Similar farmed species

The most common species of snails farmed in Europe are: *C. aspersum aspersum* (peti gris), *C. aspersum maximum* (gros gris), *Helix lucorum* (Turkish snail), *H. pomatia* (Roman snail/ Burgundy snail) and *Eobania vermiculata* (chocolate banded snail) (Conte 2015; Rygała-Galewska, Zglińska and Niemiec 2022).

Of these farmed species, *Eobania vermiculata* and *Helix pomatia* morphologically resemble *C. aspersum*, especially at the juvenile stage, and are considered (under IPPC nomenclature) to be quarantine pests for Australia.

4.3.1 *Eobania vermiculata* (synonym *Massylaea vermiculata*)

Eobania vermiculata is native to the Mediterranean region (Schultes, 2014; Welter-Schultes, 2012). This species is reported from the European countries Albania, Bulgaria, Croatia, Cypress, France, Greece, Hungary, Italy, Macedonia, Malta, Montenegro, Spain and Ukraine (Bank and Neubert, 2017; Williams and Bunkley-Williams, 2023). *Eobania vermiculata* is also native to northern Africa occurring in Algeria, Lebanon, Libya, Morocco, the Republic of Türkiye and Tunisia (Bößneck, 2011; Dedov *et al.*, 2022; Schultes, 2014).

Eobania vermiculata is spreading globally and has been reported from Belgium (Ronsmans and Van den Neucker 2016), Bosnia and Herzegovina (Karaman 2006), Egypt (Desouky and Busais, 2012), Georgia (Mumladze and Paposhvili, 2016), Iraq (Bashê and Al-Qassab, 2024), Israel (Mienis, Rittner and Vaisman, 2016), Japan (Ueshima, Okamoto and Saito, 2004), Jordan (Amr, Baker and Katbeh-Bader, 2019), the Netherlands (Soes, 2014), Qatar (Al-Khayat, 2010), Romania (Grigore, 2021), the Russian Federation (Egorov, 2008), Saudi Arabia (Desouky and Busais, 2012; El-Wakil, Banaja and Amer, 2011), Slovakia (Páll-Gergely, Fehér and Čejka, 2020), South Africa (Herbert, 2010) and the United States (Puizina *et al.*, 2013). A specimen has been identified from the United Kingdom (Notton, 2006).

Massylaea spp. (which includes *E. vermiculata*) are listed as a National Priority Plant Pest for Australia. There are historic reports of isolated/local populations of *E. vermiculata* in NSW, SA and Tasmania, however these are considered now extinct (Blacket *et al.*, 2016; Smith, 1992). The Victorian and South Australian state governments are currently undertaking isolated, local eradication programs for *E. vermiculata*, following separate near border detections in 2017 and 2022 respectively.

Eobania vermiculata is intercepted by the department at the border on non-commodity goods (e.g. new and used vehicles, machinery and break-bulk cargo) and shipping containers. It is considered a hitchhiker pest due to its frequent association with non-plant pathways, and ability to survive the extended journey to Australia.

Internationally, between 1993–1998, *E. vermiculata* made up approximately 5% of gastropods intercepted by the United States Department of Agriculture (Robinson, 1999). Live *E. vermiculata* have been intercepted on commercial shipments by Israel (Mienis, Rittner and Vaisman, 2016), and on vehicles from Italy in China (GACC, 2019).

As a popular species for human consumption, *E. vermiculata* has been deliberately imported into several countries for production (Notton, 2006; Texas Invasive Species Institute, 2014). Now illegal in the United States, authorities have intercepted smuggled consignments of breeding stock (AJOT, 2017) as well as live snails (consignments up to 10 kg) found routinely in passenger baggage (Robinson, 1999).

Eobania vermiculata mainly inhabits coastal regions. Habitats include shrubland, wooded hinterland, fields, gardens, vineyards and agricultural crops. *Eobania vermiculata* has been observed sheltering in crevices in stone walls, behind shrubs and amongst low-growing vegetation (Herbert 2010; Puizina *et al.*, 2013), on stems of trees and shrubs, and under rubbish (e.g. cardboard and wood) (Mienis, Rittner and Vaisman 2016). Snails scale fences, trees, palms and bushes to escape heat (Mienis, Rittner and Vaisman, 2016; Yildirim, Kebapçı and Gümüş, 2004); juveniles are reported to hibernate under stones or leaves (Ronsmans and Van den Neucker, 2016).

Like many snails, *E. vermiculata* is polyphagous; hosts include fruit, vegetables and ornamental plants (Eshra, 2013; Mohammed, 2015). *Eobania vermiculata* has been a pest in Egypt since the mid-1960s (Abo Bakr, Eshra and Hussein, 2007), reported from a range of crops and ornamental plants (Abdel Kader *et al.*, 2016; Eshra 2013), including citrus (Hashem and El-Halawany, 1996). In the Republic of Türkiye, *E. vermiculata* is reported to cause damage to nectarines by gnawing fruits (Hazir and Ulusoy, 2012) and was recorded as a pest on avocado for the first time by Kahraman, Kirişik and Kahraman (2020).

Morphological similarities

Although adult *E. vermiculata* may have distinct shell patterning, variation within the species is widespread. For example, Welter-Schultes (2012) reports shell colour of *E. vermiculata* to be highly variable, from whitish to greenish yellow, often with colour bands or spots, and Desouky and Busais (2012) reported variation in morphological features between *E. vermiculata* populations from Egypt and Saudi Arabia.

The morphological identification of snail species that exhibit wide variation in shell complicates identification, especially in juvenile specimens (Blacket *et al.*, 2016). The geographic range of *C. aspersum* and *E. vermiculata* overlap. In addition, both species are commercially farmed in Europe.

In summary, *E. vermiculata* is a quarantine pest for Australia. It has the ability to establish and spread, demonstrated by its expansion to many countries outside its native range, with climates similar to areas of Australia. *Eobania vermiculata* has consequences for plant health, feeding on a range of crops, fruit and ornamental hosts that are present in Australia.

4.3.2 *Helix pomatia*

Helix pomatia is not present in Australia. Smith (1992) postulates that illegal breeding colonies may exist in southern Australia, however no further information is provided to support this claim. Blacket *et al.*, (2016) suggests that records of *H. pomatia* in Australia refer to intercepted specimens held in collections. No further records of *H. pomatia* in Australia were found.

Helix pomatia is native to Central and Western Europe (Egorov 2015; Welter-Schultes 2012). This species is reported to be present in Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Moldova, Montenegro, Netherlands, Norway, Poland, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine and the United Kingdom (England) (Bank and Neubert, 2017; Pollard, 1975).

Helix pomatia has been introduced to multiple European countries (Pollard 1975), as well as Brazil (Rumi, Sánchez and Ferrando, 2010), Canada (Forsyth and Kamstra, 2019), the Russian Federation (Egorov, 2015), and the United States (Dees, 1970; Imai and Hennessey, 1999). In Japan, one farm is commercially producing *H. pomatia* (Nippon News, 2016).

Helix pomatia has been detected at the border by the department, on non-commodity goods. However, numbers are significantly lower compared with other hitchhiking snail species. Due to its popularity as a gourmet food, *H. pomatia* is more likely to be imported illegally for commercial purposes (Twomey, 2017), as has been the case in other countries (Forsyth and Kamstra, 2019).

Helix pomatia inhabits mild coastal areas, as well as mountainous regions with continental climates (Błoszyk, Kacprowicz and Książkiewicz-Parulska, 2016; Forsyth and Kamstra 2019). Habitats include forest, shrublands, grasslands abutting woods, gardens and vineyards. *H. pomatia* is also common in gardens, parks, roadside verges/banks, and cemeteries, and is often found under debris; juveniles are reported to climb vegetation (Błoszyk, Kacprowicz and Książkiewicz-Parulska, 2016; Forsyth and Kamstra, 2019; Korábek, Juříčková and Petrusek, 2016; Pollard, 1975).

Helix pomatia has been referred to as a polyphagous generalist; information on specific hosts is limited. In England, *H. pomatia* was observed feeding on a range of plants with a preference for the knapweeds *Centaurea scabiosa* and *C. nigra* (Pollard, 1975). In Romania, *H. pomatia* has been observed to attack *Dahlia variabilis* (dahlia), *Lilium candidum* (lily), *Phaseolus vulgaris* (beans), *Lactuca sativa* (lettuce), and to a lesser extent *Phlox drummondii*, *Hosta plantaginea*, *Pisum sativum* (pea) (Călin *et al.*, 2014). Tluste and Birkhofer (2023) reported a preference for *Urtica dioica* (common nettle) in German populations of *H. pomatia*. The authors also identified that plant litter constituted a significant proportion of the snail's diet (Tluste and Birkhofer, 2023), in contrast to Pollard (1975) who stated that the bulk of *H. pomatia* diet consisted of fresh plants.

Helix pomatia is reported to be invasive in the United States (Purdue University, 2024), and Canada (Harrap, 2021) though there are no specific claims of damage to plants or crops found in the literature. Elmslie (2005) suggests that *H. pomatia* is less of an agricultural pest compared to *C. aspersum* due to smaller egg clutch size, also observing that there are no reports of rapid spread of *H. pomatia*.

Helix pomatia is claimed to be the most famous of the world's edible snails, thanks to its popularity in French cuisine (Elmslie, 2005). *H. pomatia* are more difficult to cultivate than *C. aspersum* and other edible snails. To meet the demand, many snails are collected from the wild (Rygało-Galewska, Zglińska and Niemiec, 2022). This has resulted in a decrease in populations in the native range, leading many European countries to regulate wild harvesting and/or protect the species (Łysak 1999; Pollard, 1975; Welch and Pollard, 1975).

Morphological similarities

Cornu aspersum can be distinguished from *H. pomatia* by the smaller shell, different pigmentation patterns and shell structure (Forsyth and Kamstra 2019). However, there is significant variation in shell patterns noted within populations of both species (Korábek, Juříčková and Petrusek, 2016; Kougiagka *et al.*, 2022; Madec, Bellido and Guiller, 2003; Neubert, 2014; Welter-Schultes, 2012); morphological identification alone may not be sufficient to determine identity.

The morphological identification of snail species that exhibit wide variation in shell complicates identification, especially in juvenile specimens (Blacket *et al.*, 2016). The geographic range of *C. aspersum* and *H. pomatia* overlap.

In summary, *H. pomatia* is a quarantine pest for Australia. It has the ability to establish and spread demonstrated by established populations in countries, both native and introduced, with climates similar to areas of Australia. *H. pomatia* has consequences for plant health, feeding on a range of ornamental and agricultural hosts that are present in Australia.

4.4 Conclusion

From a plant health perspective, the subspecies *C. aspersum maximum* does not meet the IPPC definition of a quarantine pest for Australia. The available evidence suggests that *C. aspersum maximum* is very similar to *C. aspersum aspersum*, which is already present and widespread in Australia, and any impacts on plant health and the environment are likely to be commensurate with, or less than, those of *C. aspersum aspersum*.

5 Biosecurity import risk assessment

5.1 *Angiostrongylus* spp.

5.1.1 Background

Angiostrongylus spp. are parasitic nematodes with an intermediate host (snails) and a definitive host (vertebrates). Some *Angiostrongylus* spp. use rodents as definitive hosts but most of these species display a high degree of host specificity (Anderson, 2000). Nematodes of this genus can cause potentially life-threatening diseases in several accidental host animal species, including humans (Colella *et al.*, 2016a). There are 4 species of *Angiostrongylus* (*A. vasorum*, *A. abstrusus*, *A. cantonensis*, *A. chabaudi*) known to use *C. aspersum* as an intermediate host. It is not yet known if *A. mackerrasae* can infect *C. aspersum*, but it is possible given its similarities to other *Angiostrongylus* species (Aghazadeh *et al.*, 2015a). *Angiostrongylus* spp. are common in wild snails (Anderson, 2000; Barcante *et al.*, 2003; Colella *et al.*, 2016b; Elsheikha *et al.*, 2018; Bowman *et al.*, 2002).

Angiostrongylus spp. infection is known as angiostrongylosis in vertebrate animals, including humans who consume raw snails. The disease primarily causes cardiopulmonary signs, but can also lead to eosinophilic meningitis, eosinophilic encephalitis and ocular angiostrongylosis (Wang *et al.*, 2012; Sawanyawisuth and Sawanyawisuth, 2008; Sawanyawisuth *et al.*, 2013). Clinical signs from *A. vasorum* can be highly variable with cardiopulmonary disorders (e.g. bronchopneumonia, cardiac dysfunction) being most common, followed by coagulopathies, then neurological presentations. Other non-specific signs have been reported such as ocular and gastrointestinal signs. Eosinophilic meningitis can also be associated with lifelong neurological impairments and well as loss of vision (da Silva and Morassutti, 2021). The variability in clinical presentations can make it challenging to differentiate from other canine diseases on initial presentation. There is a long prepatent period of 1 to 4 months (Di Cesare *et al.*, 2014). Cases with severe clinical signs, such as marked pulmonary hypertension, coagulopathies or neurological signs, are associated with a fatal outcome in up to 30% of cases. Conversely, in the absence of severe clinical signs 95% of cases have a positive outcome (Chapman *et al.*, 2004; Willesen *et al.*, 2007).

While disease is rare in Australia, eosinophilic meningitis caused by *A. cantonensis* has been found in a patient who ingested two garden slugs as part of a dare (Senanayake *et al.*, 2003). In parts of the world where disease is more common, occurrence is also attributed to direct ingestion of the intermediate host as part of the diet (Alicata and Brown, 1962) or from ingestion of products contaminated with infective larvae in secretions from infected intermediate hosts (Hughes and Biggs, 2002). In Taiwan cases of eosinophilic meningitis were attributed to contaminated raw vegetable juice (Tsai *et al.*, 2004). Cases of angiostrongylosis in humans have occurred with the accidental consumption of infected snails on produce (Yeung *et al.*, 2013).

Angiostrongylus cantonensis is present in Australia (Aghazadeh *et al.*, 2015a; Chan *et al.*, 2015; Prociw and Carlisle, 2001), as is *A. mackerrasae* (Bhaibulaya, 1968; Aghazadeh *et al.*, 2015b). *A. abstrusus* has been found in Australia (Anderson, 2000, Barrs *et al.*, 2008), though an extensive study of its range does not appear to have occurred. *A. vasorum* was only identified in Australia in a dog imported from the United Kingdom (Tebb *et al.*, 2007) and *A. chabaudi* has not been detected in Australia yet.

Little is known about *A. chabaudi*. Gherman *et al*, 2016 state it rarely infects felids. In contrast, Varcasia *et al*, 2014 citing Biocca (1957), stated wildcats may have high burdens of *A. chabaudi*. Whether wildcats (a different subspecies to the domestic cat) are a reservoir of infection for domestic cats in various parts of the world has not been clarified to date. Additional studies to determine its distribution and impact on the health of wild and domestic cats have been recommended (Varcasia *et al*, 2014).

5.1.2 Technical information

Agent properties

Angiostrongylus spp. are part of the phylum Nematoda, Class Chromadorea, Order Strongylida, family Angiostrongylidae (GBIF, 2022a). *A. vasorum*, *A. abstrusus*, *A. cantonensis*, and *A. chabaudi*, are known to infect *C. aspersum* as an intermediate host. *Helicarion* spp. appear to be the most important intermediate hosts of *A. mackerrasae*, at least in South-East Queensland and is theorised to be instrumental in the spread of the nematode south (Prociv *et al*, 2000)

All 5 *Angiostrongylus* spp. have similar lifecycles involving the cardiovascular system and/or lungs in the definitive host. The L1 larvae are shed by the definitive host and are either ingested by or penetrate the cuticle of the intermediate snail host (Anderson, 2000). The location of the larvae within the intermediate host varies depending on the species. *A. abstrusus* larvae are mostly found in the foot and viscera of the snail (Colella *et al*, 2015). *A. cantonensis* larvae are found in the foot, lung, muscle, liver and connective tissue of the snail (HeXiang *et al*, 2009; Modry *et al*, 2021). The period of larval development within mollusc species can vary depending on temperature and location (Alicata, 1965; Anderson, 2000; HeXiang *et al*, 2009). The larvae undergo 2 moults in the snail where they develop into an infective third stage (L3). The definitive (and accidental) hosts become infected when they directly ingest the infected snail (Cowie, 2013). They can also become indirectly infected through ingestion or contact with items contaminated by L3 containing secretions from the infected snail (Hughes and Biggs, 2002), noting L3 larvae persist in water and on moist soils (Alicata, 1965; Modry *et al*, 2021).

Epidemiology

Angiostrongylus spp. require intermediate and definite hosts to be present in the same environment in order to complete their lifecycle. Each *Angiostrongylus* species has different specific intermediate and definitive hosts (Table 4).

Table 4 *Angiostrongylus* species that use *C. aspersum* as a host, their intermediate and definitive hosts, their presence in Australia and in snail farms

Species	Intermediate host	Alternative intermediate host	Definitive host	Accidental or Paratenic host	Present in Australia	References
<i>Angiostrongylus vasorum</i>	Snail (range of terrestrial and aquatic) <i>C. aspersum</i> <i>Omalonyx matheroni</i> <i>Subulina octona</i> <i>Arionater</i> <i>A. rufus</i> <i>Biomphalaria glabrata</i> <i>Bradybaena similaris</i> <i>Deroceras leave</i> <i>Laevicaulus alte</i> <i>Prosoples javanicum</i>	Slug Frog <i>Rana temporaria</i> may also act as intermediate host	Canines <i>Canis lupus familiaris</i> <i>Cerdocyon thous</i> <i>Ducicyon azarae</i> <i>D. vetulus</i> <i>Fennecus zerda</i> <i>Vulpes vulpes</i>	Paratenic: lizards, mice, rats	No – only found in one imported dog	(Rosen <i>et al.</i> , 1970; Bolt <i>et al.</i> , 1993; Tebb <i>et al.</i> , 2007; Ferdushy and Hasan, 2010; Bessa <i>et al.</i> , 2000; Mozzer <i>et al.</i> , 2011; Di Cesare <i>et al.</i> , 2015) (Ferdushy <i>et al.</i> , 2009; Morgan <i>et al.</i> , 2005; Grewal <i>et al.</i> , 2003)
<i>Angiostrongylus abstrusus</i>	Snail <i>C. aspersum</i> <i>Agriolimax laevis</i> Snails of multiple genera	Slug	Felines <i>Felis catus</i> <i>Acinonyx jubatus</i> <i>Panthera onca</i> <i>Felis concolor</i> <i>Panthera leo</i> <i>Panthera tigris altaica</i>	-	Yes	(Hobmaier and Hobmaier, 1935; Mackerras, 1957; Anderson, 2000; Bjork <i>et al.</i> , 2000; Gonzalez <i>et al.</i> , 2007; Barrs <i>et al.</i> , 2008; Thiengo <i>et al.</i> , 2008; Moskvina, 2018; Di Cesare <i>et al.</i> , 2013)
<i>Angiostrongylus cantonensis</i> Different strains exist	Snail <i>C. aspersum</i> <i>Achatina fulica</i> <i>Bellamya ingallsiana</i> <i>Bradybaena similaris</i> <i>Cipangopaludina chinensis</i> <i>Deroceras leave</i> <i>Euglandina rosea</i>	Slugs <i>Girasia peguensis</i> <i>Microparmarion malayanurn</i> <i>Deroceras leave</i> <i>Vaginalus plebeius</i> <i>Veronicella alte</i> Frogs, experimentally	Rodents 24 rat species with <i>Rattus norvegicus</i> and <i>R. rattus</i> identified as responsible for greatest distribution	Low host specificity Accidental hosts: humans, Australian native fauna, domesticated and wild animals	Yes	(Alicata, 1965; Bhaibulaya, 1991; Anderson, 2000; Aghazadeh <i>et al.</i> , 2015a; Chan <i>et al.</i> , 2015; Stokes <i>et al.</i> , 2007; Kim <i>et al.</i> , 2014; Colella <i>et al.</i> , 2015)

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Species	Intermediate host	Alternative intermediate host	Definitive host	Accidental or Paratenic host	Present in Australia	References
	<i>Girasia peguensis</i> <i>Indoplanorbis exustus</i> <i>Laevicaulus alte</i> <i>Macrochlamys resplendens</i> <i>Microparmarion malayanus</i> <i>Opeas javanicum</i> <i>Pupina complanate</i> <i>Pila ampullaceal</i> <i>P. scutate</i> <i>Quantula striata</i> <i>Subulina octona</i> <i>Vaginalus plebeius</i> <i>Veronicella alte</i>	<i>Xenopus laevis</i> <i>Rana chensinensis</i>				
<i>Angiostrongylus mackerrasae</i>	Snail <i>Helicarion</i> spp.	Slugs	Rodents <i>Rattus fuscipes</i> <i>Melomys cervinipes</i> <i>R. leucopus</i>	Accidental host: <i>Pteropus alecto</i>	Yes, thought to be endemic to Australia	(Prociv <i>et al.</i> , 2000; Mackie <i>et al.</i> , 2013)
<i>Angiostrongylus chabaudi</i>	Snail <i>C. aspersum</i>	-	Felines	-	No	(Colella <i>et al.</i> , 2015; Colella <i>et al.</i> , 2017)

The main definitive hosts are rodents for *A. cantonensis* and *A. mackerrasae*, are felines for *A. abstrusus* and *A. chabaudi*, and canines for *A. vasorum*. A wide variety of species can act as paratenic hosts, which are optional hosts that have eaten infected snails. Paratenic hosts include terrestrial crabs, freshwater shrimp, frogs, fish and sea snakes. Their importance as a source of infection is not well understood (Prociv *et al.*, 2000).

The importation of infected snails such as *Achatina fulica* into areas previously considered infection-free is thought to have facilitated the spread of the parasite (particularly *A. cantonensis*) and thus plays an important role in the epidemiology of the disease (Colella *et al.*, 2015).

Achatina (Lissachatina) fulica was introduced in Brazil in the 1980s for commercial purposes (escargot farming) and is now widespread, and has become a pest of public health and veterinary importance (Thiengo *et al.*, 2008). *Pomacea canaliculata* was introduced into Taiwan from Argentina for use in commercial snail farms and ended up spreading throughout eastern Asia (Lv *et al.*, 2011). Two species, *Achatina fulica* and *P. canaliculata*, are thought to be closely associated with angiostrongylosis in China. These were first imported into mainland China in 1931 and 1981 respectively, and have rapidly extended their geographic ranges. They are now listed as invasive species in China (Lv *et al.*, 2009). The snail *P. canaliculata* was introduced into China in 1981 and has become the key intermediate host for *A. cantonensis* in China (Lv *et al.*, 2011).

Global warming, changes in phenology of mollusc intermediate hosts and movements of wild reservoirs have been implicated in spreading mollusc-borne parasites, including *A. vasorum* (Di Cesare *et al.*, 2015). *C. aspersum* is endemic in most regions of the world and is thought to be increasing the range of any parasites that it is harbouring (Di Cesare *et al.*, 2015).

Diagnosis

The diagnosis of *Angiostrongylus* spp. in a snail occurs post-mortem. The shell is removed, and body minced before being digested in a solution of hydrochloric acid and pepsin. This digestive fluid is then filtered and spun in a centrifuge. Larvae can be counted and examined for identifying characteristics under a light microscope (Di Cesare *et al.*, 2013; Cardillo *et al.*, 2018; Giannelli *et al.*, 2014). The larvae can also have their DNA sequenced using PCR to provide a definitive identification (Giannelli *et al.*, 2014; Colella *et al.*, 2017).

Treatment

No treatment options for snails were found. Various treatments are available for humans (Evans-Gilbert *et al.*, 2014; Senanayake *et al.*, 2003). Sporadic cases of *A. cantonensis* in Australia occur and medical treatment may not prevent morbidity or death.

Prevention in dogs and cats includes avoiding ingestion of infected intermediate hosts (e.g. snails, slugs, molluscs), and the use of routine prophylactic anthelmintics. The monthly use of spinosad/milbemycin oxime, imidacloprid 10%/moxidectin 2.5% has been shown to effectively eliminate larvae thereby preventing clinical angiostrongylosis.

In infected definitive felid hosts, several drugs are available to eliminate parasites. Fenbendazole (20–25 mg/kg, oral, once a day for 5 days, or 50 mg/kg, oral, once a day for 15 days), moxidectin (1 mg/kg, 1–3 applications topically in combination with imidacloprid), abamectin (0.3 mg/kg, subcutaneous, repeated in 2 weeks) and eprinomectin have all been identified as effective treatment of *A. abstrusus* in cats (Baydar and Kaya, 2021).

For *A. vasorum*, several drugs are available to eliminate worms in infected canid definitive hosts. Monitoring for anaphylaxis through treatment is advised (Elsheikha *et al.*, 2018). A range of anthelmintic protocols have been described for treatment: a spot-on formulation containing imidacloprid 10% and moxidectin 2.5% has an efficacy of 85.2 % after one single application; the use of 25 mg/kg fenbendazole orally once per day for 20 days has an efficacy of 91.3%; and the use of 0.5 mg/kg milbemycin oxime given orally once a week for 4 weeks has a 84.4% efficacy (Di Cesare and Traversa, 2014). In addition to anthelmintics, infected dogs may require supportive treatment according to the presenting clinical signs. This could include oxygen supplementation for respiratory compromise, transfusion of whole blood for coagulopathies, and ACE inhibitors and diuretics for cardiac dysfunction (Di Cesare and Traversa, 2014)

The sudden killing of these worms (as occurs with the use of levamisole at 7.5 mg/kg s/c q24 h for 2 days, then 10 mg/kg s/c q24 h for 2 days) can result in a severe allergic reaction, so concurrent treatment with corticosteroids to suppress potential anaphylaxis due to sudden release of worm antigens in those cases is recommended.

Occurrence

Angiostrongylus abstrusus and *A. cantonensis* are found globally, including cases within Australia (Barcante *et al.*, 2003; Colella *et al.*, 2016a; Elsheikha *et al.*, 2018).

While *A. abstrusus* has been recorded in Australia, an extensive study of its range does not appear to have occurred. It has the potential to be found throughout the country

Angiostrongylus cantonensis is endemic to temperate and tropical regions (York *et al.*, 2014; Anderson, 2000). Its current range includes Southeast Asia, Japan, the Pacific Islands, and Australia, as well as parts of Central and South America, the United States and the Caribbean (Wang *et al.*, 2008; Dard *et al.*, 2017; Qvarnstrom *et al.*, 2007; Lv *et al.*, 2011; Evans-Gilbert *et al.*, 2014; Stockdale Walden *et al.*, 2017). In Australia, *A. cantonensis* has been found in Sydney, Brisbane and in forests around Jervis Bay, NSW (Aghazadeh *et al.*, 2015a; Chan *et al.*, 2015; Stokes *et al.*, 2007). The full distribution of *A. cantonensis* within Australia is not known.

There is a patchy distribution of *A. vasorum* in many parts of the world, including tropical, sub-tropical and temperate regions (e.g. Europe, Africa, South America, Asia) (Colella *et al.*, 2016a; Elsheikha *et al.*, 2018). Clear evidence exists of both an increase in the number of cases within known endemic foci (e.g. Denmark, France, UK) and the appearance of new foci in several regions that were previously free of infection (Morgan and Wall, 2009; Morgan *et al.*, 2010; Lurati *et al.*, 2015). During the 1990s in the UK, *A. vasorum* was largely confined to dogs living in the south-east and south-west of England and south Wales. From 2008, the disease has become more common and has been identified as far north as Scotland (Elsheikha *et al.*, 2018). *A. vasorum* has also been found in *C. aspersum* in Scotland, indicating that this was not just a matter of movement of an infected definitive host (Helm *et al.*, 2015). *A. vasorum* is not present in Australia and has only been found in one imported dog (Tebb *et al.*, 2007)

Angiostrongylus chabaudi has so far only being identified in several European countries in wild and domestic cats (Colella *et al.*, 2017). It is known to be present in Italy and Greece (Morgan *et al.*, 2021). It has not yet been found in Australia.

5.1.3 Current biosecurity measures

For imported dogs and cats, the current generic biosecurity measures for internal parasites for Group 3 countries are that: a government approved veterinarian must treat the dog twice with an internal parasite treatment effective against internal parasites (nematodes and cestodes). The two treatments must be administered at least 14 days apart and within 45 days before export. The second treatment must be given within five (5) days before export.

There are no specific biosecurity measures in place for *Angiostrongylus* spp.

5.1.4 Risk assessment

Cornu aspersum is present in most regions of the world and is a vector of *Angiostrongylus* spp. and other parasites (Di Cesare *et al.*, 2013). Climate change is likely increasing the range of both intermediate and definitive hosts and may further increase expansion of the associated parasitic disease (Morgan and Wall, 2009). The presence of *A. cantonensis* in the Australian environment has been raised as a possible issue of concern for future reintroductions of native birds or mammals into areas known to have infected intermediate or definitive hosts. Fatal cases of infection have been reported in flying foxes (*Pteropus* spp.) and tawny frogmouths (*P. strigoides*) (Prociv and Carlisle, 2001; Barrett *et al.*, 2002; Monks *et al.*, 2005; Spratt, 2005; Ma *et al.*, 2013).

Entry and exposure assessment:

- *Angiostrongylus* spp. are parasitic nematodes that utilise an intermediate host (snails) and a definitive host (vertebrates).
- *Angiostrongylus* spp. have been detected in snails and produce sold for human consumption.
- There are 4 species of *Angiostrongylus* (*A. vasorum*, *A. abstrusus*, *A. cantonensis*, *A. chabaudi*) known to utilise *C. aspersum* as an intermediate host. *A. mackerrasae* may also infect *C. aspersum*.
- *A. vasorum*, *A. abstrusus*, *A. cantonensis* and *A. chabaudi* have similar lifecycles involving the cardiovascular system and/or lungs in the definitive host. The L1 larvae are shed by the definitive host and are either ingested by or penetrate the cuticle of the intermediate snail host.
- Most *Angiostrongylus* spp. display a high degree of host-specificity, except for *Angiostrongylus* species using rodents as definitive hosts. The definitive hosts for *A. vasorum* are canines and for *A. chabaudi* are felines.
- *Angiostrongylus cantonensis*, *A. abstrusus*, and *A. mackerrasae* have been found in Australia and therefore will not be considered further in this risk assessment.
- *Angiostrongylus vasorum* has a wide geographic distribution and is known to occur in dog populations in Africa, Europe, and North and South America.
- Prevalence estimates for *A. vasorum* in infected countries are not readily available, but are likely to vary considerably between regions and within a population based on exposure to infected intermediate or paratenic hosts.
- *Angiostrongylus vasorum* has spread across Europe since the 1990s and is now broadly endemic. It is likely that spread of the infected intermediate snail hosts have contributed (not simply

movement of definitive hosts). Affected countries includes countries proposed for sourcing of snails for breed stock in Australia.

- To determine if a snail is infected with any *Angiostrongylus* spp., the snail must first be euthanised. No treatment options for snails were found.
- A possible pathway for introduction of *A. vasorum* to Australia is via infected snails (as the intermediate host) if there is exposure to the L1 larvae shed by infected canids (as the definitive host). Entry of infected snails onto a snail farm may occur where the security of the farm is not sufficient to prevent entry and exit of snails from the external environment, or fattening or grow-out stages are situated outdoors. It is noted that many, if not all, commercial snail farms have external grow out stages.
- There is a long history of importation of dogs from countries where canine pulmonary angiostrongylosis due to infection with *A. vasorum*, is endemic. Available records indicate only one case of canine pulmonary angiostrongylus in Australia in 2007. The entry likelihood via a potentially infected definitive host is still considered to be very low (Department of Agriculture, 2013).
- The prevalence of *A. chabaudi* and where it occurs in the world is unclear. *A. chabaudi* has so far only being identified in wild and domestic cats in several European countries. It is known to be present in Italy and Greece. At least one paper has called for further research and greater awareness of this parasite.

Based on this information, the likelihood of entry of *A. vasorum* or *A. chabaudi* associated with the importation of infested farmed *C. aspersum* and exposure of potential hosts in Australia was estimated to be moderate.

This takes into account that no snail farm, even well established commercial facilities, could be considered 'closed' systems from the biosecurity perspective. *A. vasorum* appears to be endemic in a number of European countries and *A. chabaudi* has also been reported. A closed system does not allow for snail trade or the cryptic nature of snails which may enter and leave undetected within even very well-established facilities with certification of their premises and procedures.

Consequence assessment:

- *Angiostrongylus* spp. cause angiostrongylosis in vertebrate animals, including humans, in the form of respiratory and cardiac disease, as well as eosinophilic meningitis, eosinophilic encephalitis and ocular angiostrongylosis.
- The definitive (and accidental/paratenic) hosts become infected when they directly ingest the infected snail host. They can also become infected indirectly through ingestion or contact with items contaminated by L3 containing secretions shed from the infective intermediate host.
- In the UK in the 1990s, *A. vasorum* was largely confined to dogs living in the south-east and south-west of England and south Wales, but from 2008, the disease has become more common and has been identified as far north as Scotland. This was not likely to be just a matter of movement of an infected definitive host (dogs), as *A. vasorum* was also found in *C. aspersum* in Scotland. A similar scenario could unfold in Australia.

- Adverse health outcomes may occur for Australian dogs, with significant flow on impacts to their owners, if the intermediate host (snail) is imported in large volumes over time, spreads widely, and is carrying exotic *Angiostrongylus* spp.
- *A. chabaudi* has not been detected in Australia. There is general uncertainty about the prevalence and potential impacts on domestic cats. It can cause cardio-pulmonary disease in felids. Similarly to dogs, adverse health outcomes may eventuate in cats if the intermediate host (snail) is imported in large volumes over time and is carrying *A. chabaudi*.
- Treatment options for definitive hosts, and humans exist but are not always successful in preventing morbidity and mortality in the occasional cases of *angiostrongylus* reported in Australia due to endemic *Angiostrongylus* spp.

Based on this information, the likely consequences of establishment and/or spread of *Angiostrongylus* spp. associated with the importation of *C. aspersum* was estimated to be low.

Conclusions

Based on the preceding information, the likelihood of entry of *Angiostrongylus* spp. associated with imports of *C. aspersum* sourced from commercial, government certified snail farms is considered to be moderate the likely consequences of establishment and/or spread of *Angiostrongylus* spp. is considered low. Using Table 3, the likelihood of entry and exposure (moderate) was combined with the likely consequences of establishment and/or spread (low), which resulted in a risk estimation for *Angiostrongylus* spp. (*A. vasorum*, *A. chabaudi*) of low risk.

As the overall risk of *Angiostrongylus* spp. associated with the importation of *C. aspersum* from commercial government certified snail farms that produce snails for human consumption is low and therefore does not achieve Australia's ALOP with respect to animal biosecurity risks, additional biosecurity measures for *Angiostrongylus* spp. are required.

5.1.5 Risk management measures

Importation of adult snails: for the risk of *Angiostrongylus* spp. associated with the importation of live adult garden snails (*C. aspersum*), to achieve Australia's ALOP, the snails must be imported into an Approved Arrangement site, where they will be reared in isolation from other snails and the definitive host, thus breaking the lifecycle of the nematode. The next generation of *C. aspersum* would be free of *Angiostrongylus* spp. and would be eligible for release from the Approved Arrangement site.

Importation of hatchling snails: these are hatchlings less than 10 days old that have not been released from the hatching environment and have not been exposed to plant substrate. As these hatchling snails have also not been exposed to the definitive hosts for *Angiostrongylus* spp., the risk for hatchling snails will achieve Australia's ALOP.

5.2 *Brachylaima* spp.

5.2.1 Background

Brachylaima spp. are parasitic trematodes that have 2 intermediate hosts (snails) and a definitive host (vertebrate). There are four species of *Brachylaima* (*B. aspersae*, *B. cribbi*, *B. mascomai* and *B. llobregatensis*) that have been recorded using *C. aspersum* as an intermediate host.

Brachylaima spp. are common in field populations of *C. aspersum* (Gerard *et al.*, 2020; Kose *et al.*, 2015) and snail farms (Segade *et al.*, 2013; Segade *et al.*, 2011). *Brachylaima* spp. can cause brachylaimiasis in humans. The clinical signs of brachylaimiasis in humans include abdominal pain and recurrent diarrhoea and it has a mortality rate of 5–10% without treatment (Gracenea and Gallego, 2017; Butcher, 2016). Brachylaimiasis is rare but has been found in several patients in Australia through infection with *B. cribbi* (Butcher, 2016; Butcher *et al.*, 1996, Butcher *et al.*, 1998). The trematode would have been ingested with the snails (likely raw or undercooked) or from vegetables that had been in contact with snails (Butcher, 2016).

B. cribbi is present in Australia but the other *Brachylaima* spp. found in *C. aspersum* have not yet been recorded in Australia. (Gallego *et al.*, 2014).

5.2.2 Technical information

Agent properties

Brachylaima spp. are part of the phylum Platyhelminthes, class Trematoda, order Diplostomida and family Brachylaimidae (GBIF, 2022b). Four species are known to occur: *B. aspersae*, *B. cribbi*, *B. mascomai* and *B. llobregatensis* (Butcher and Grove, 2001; Gonzalez-Moreno and Gracenea, 2006; Segade *et al.*, 2011; Gracenea and Gonzalez-Moreno, 2002). Recent studies have shown that little is known about *Brachylaima* spp., with new species being discovered in France (Gerard *et al.*, 2020). Further snail research elsewhere may uncover more species.

Epidemiology

All four *Brachylaima* spp. have a similar lifecycle. *Brachylaima* eggs are ingested by the first snail host, in which cercariae will develop in sporocysts. When they reach maturity, the cercariae exit the host and crawl until they find a second host (another snail). Once inside the second host, they will form metacercariae usually located in the snail kidney. If the snail is ingested by a vertebrate (the definitive host), the trematode may become adults and colonise the intestine where they will mate. Eggs are excreted with the host faeces. If these eggs are ingested by a suitable first intermediate host, the lifecycle continues (Segade *et al.*, 2011; Butcher, 2016; Gracenea and Gonzalez-Moreno, 2002).

The intermediate and definitive hosts relevant to the lifecycle depend on the *Brachylaima* spp. (Table 5). The most thorough study on hosts was done in Australia with *B. cribbi*. In Australia, all snail species tested by Butcher and Grove (2005) were found to be second intermediate hosts of *B. cribbi*. The snail species tested included six introduced and two native species (Butcher and Grove, 2005b). This indicates that other snail species not yet tested could also be intermediate hosts. Mammals, birds and lizards were found to be definitive hosts but the authors suggest that more research is needed to fully ascertain host range (Butcher and Grove, 2005b). Birds likely spread the parasite broadly while mice and lizards contribute to local dispersion (Butcher and Grove, 2005b). There is

seasonal variation in *B. cribbi* infection in snails, with infection rates being higher in winter and spring, and lower in summer (Butcher and Grove, 2005a).

Table 5 *Brachylaima* species that use *C. aspersum* as a host, their intermediate and definitive hosts, their presence in Australia and in snail farms

Species	Intermediate host 1	Intermediate host 2	Definitive host	Present in Australia	Detected in snail farms	References
<i>Brachylaima aspersae</i>	Snail <i>C. aspersum</i>	Snail <i>C. aspersum</i>	Rodent mouse (<i>Mus musculus</i>)	No	Yes	(Segade <i>et al.</i> , 2013; Segade <i>et al.</i> , 2011)
<i>Brachylaima cribbi</i>	Snail <i>C. aspersum</i> <i>Theba pisana</i> <i>Cochlicella acuta</i> <i>Cochlicella barbara</i> <i>Microxeromagna armillata</i>	Snail Introduced: <i>C. aspersum</i> <i>Theba pisana</i> <i>Cochlicella acuta</i> <i>Cochlicella Barbara</i> <i>Cernuella virgata</i> <i>Microxeromagna armillata</i> Native: <i>Succinea australis</i> <i>Strangesta gawleri</i>	Bird: Emu (<i>Dromaius novaehollandiae</i>) Chickens (<i>Gallus gallus</i>) Pigeon (<i>Columba livia</i>) Little raven (<i>Corvus mellori</i>) Black bird (<i>Turdus merula</i>) Starling (<i>Sturnus vulgaris</i>) Mammal: Mouse (<i>Mus domesticus</i>) Sheep (<i>Ovis spp.</i>) Cat (<i>Felis catus</i>) Reptile: Shingleback lizards (<i>Tiliqua rugosa</i>)	Yes	Unknown	(Butcher <i>et al.</i> , 1996; Butcher and Grove, 2001; Butcher, 2016; Butcher and Grove, 2005b; Butcher and Grove, 2003)
<i>Brachylaima llobregatensis</i>	Snail <i>C. aspersum</i>	Snail <i>C. aspersum</i> <i>Theba pisana</i>	Rodent <i>Crocidura russula</i> <i>Mus spretus</i>	No	No	(Gonzalez-Moreno and Gracenea, 2006; Gallego <i>et al.</i> , 2014)

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Species	Intermediate host 1	Intermediate host 2	Definitive host	Present in Australia	Detected in snail farms	References
			<i>Mus musculus</i>			
<i>Brachylaima mascomai</i>	Snail	Snail	Rodent	No	No	(Gracenea and Gonzalez-Moreno, 2002; Gracenea and Gallego, 2017; Gallego <i>et al.</i> , 2014)
	<i>Pseudotachea splendida</i>	<i>C. aspersum</i>	<i>Rattus norvegicus</i>			
		<i>Theba pisana</i>	<i>Rattus rattus</i>			
		<i>Otala punctata</i>	<i>Mus musculus</i>			
		<i>Pseudotachea splendida</i>	<i>Crocidura russula</i>			
			<i>Meriones unguiculatus</i>			
			<i>Apodemus sylvaticus</i>			

The definitive host for *B. aspersae*, is the domestic mouse, *Mus musculus* (Segade *et al.*, 2011). All other *Brachylaima* spp. should be considered as non-specific as they have several definitive hosts, usually rodents (Table 5).

Gerard *et al.*, 2023 suggest that *C. aspersum* is capable of trapping cercariae (trematode larvae) in its shell, thus possibly reducing the intensity of infestation by these parasites.

Diagnosis

To determine if a snail is infected with *Brachylaima* spp., it needs to be dissected to look for the presence of sporocysts and metacercariae (Segade *et al.*, 2013; Segade *et al.*, 2011). In definitive hosts, dissections can also be used to look for the presence of adults in the gastrointestinal tract and eggs can be found in faeces (Butcher and Grove, 2005b; Butcher and Grove, 2001).

In humans, symptoms are linked to intestinal issues (abdominal pain, diarrhoea, weight loss) (Butcher, 2016). Symptoms can last from one month to one year. Diagnosis involves looking for eggs in faeces (Butcher, 2016; Butcher *et al.*, 1996).

Treatment

Snails can be treated with praziquantel by mixing it with food (Gallego and Gracenea, 2015).

In humans, brachylaimiasis was successfully treated with a daily dose of 20 mg/kg of praziquantel for three days. The treatment had no side effect (Butcher, 2016).

Occurrence

B. cribbi has been found in Australia (Victoria, South Australia and Western Australia). The origin of this parasite has not been confirmed. It is unclear whether *B. cribbi* is native or introduced (Butcher and Grove, 2003). *B. aspersae* is currently only found in Spain, while *B. ilobregatensis* is found in Spain and Algeria (Gonzalez-Moreno and Gracenea, 2006; Gallego *et al.*, 2014) and *B. mascomai* is found in Spain and South Africa (Gracenea and Gonzalez-Moreno, 2002). In the Republic of Türkiye, a *Brachylaima* species was detected in *C. aspersum* on pasture, with 2% of individuals infected. The *Brachylaima* were not identified at the species level (Kose *et al.*, 2015). Recently, Gerard *et al.*, (2020) identified a novel *Brachylaima* species on *C. aspersum* in France. This species has yet to be named. Prevalence in 2 wild populations was high with 10% and 73% of snails being infected (Gerard *et al.*, 2020).

Brachylaima spp. are commonly found in *C. aspersum* sold in markets (Gracenea and Gallego, 2017; Gallego *et al.*, 2014). In Spain, the overall percentage of snails infected in markets was over 40%, and closer to 60% in autumn (Gracenea and Gallego, 2017). Studies have shown that imported *C. aspersum* sold in markets in Spain were infected with different *Brachylaima* species (Gallego *et al.*, 2014). Imported snails could therefore contribute to the geographic spread of *Brachylaima* if they come in contact with local intermediate and definitive hosts (Gallego *et al.*, 2014).

B. aspersae is prevalent in snail farms and was found in every farm sampled in Spain (Segade *et al.*, 2011; Segade *et al.*, 2013), with metacercariae found in 10 to 97% of snails (Segade *et al.*, 2013). Infections were more common in *C. a. aspersum* than *C. aspersum maximum* (Segade *et al.*, 2013). Segade *et al.*, (2011) suggested that controlling mice, the definitive host of *B. aspersae*, would help reduce the infection rates of *C. aspersum* on farms (Segade *et al.*, 2013).

5.2.3 Current biosecurity measures

There are no specific biosecurity measures for *Brachylaima* spp. in Australia.

5.2.4 Risk assessment

Entry and exposure assessment:

- *Brachylaima* spp., including species not reported in Australia, may be common in snail farms overseas. *Brachylaima* spp. have been found in snails sold in markets and natural environments.
- *Brachylaima* spp. have been poorly studied; however, at least four species are known to use *C. aspersum* as a host (three of which have not been reported in Australia). More species are likely to be described in the future.
- *C. aspersum* is capable of trapping cercariae (trematode larvae) in its shell, thus possibly reducing the intensity of infestation by these parasites.
- *Brachylaima* sporocysts and metacercariae can only be detected by microscopic examination following dissection of the snails.
- Infested wild or field reared snails may introduce the infection to a snail farm. It is unknown whether testing is, or would be, regularly undertaken for this parasite on commercial premises.
- A probable pathway for the introduction of exotic *Brachylaima* spp. is via the importation of parasitised imported snails (infested intermediate host). These snails may then shed metacercaria that infect other intermediate hosts or that may be consumed by definitive vertebrate hosts. The possible impact on Australian wildlife is unknown.

Based on this information, the likelihood of entry of *Brachylaima* spp. associated with the importation of infested farmed *C. aspersum*, and exposure of potential hosts in Australia was estimated to be high.

Consequence assessment:

- Importation of *C. aspersum* for human consumption has been identified as a risk for the expansion of *Brachylaima* spp. distribution.
- Because detection requires dissection of the snail, an incursion of exotic *Brachylaima* spp. would likely remain undetected until a suitable survey was undertaken, or associated disease presented.
- Some species of *Brachylaima* can infect humans.
- There is potential for serious health impacts of *Brachylaima* infested *C. aspersum* on other definitive hosts (likely rodents). This has not yet been scientifically investigated.
- It is possible that the introduction, spread and establishment of exotic *Brachylaima* spp. could adversely impact native and introduced animals in Australia. There is little information in the available scientific literature to suggest consequences of animal biosecurity significance.

Based on this information, the likely consequences of establishment and/or spread of *Brachylaima* spp. associated with the importation of *C. aspersum* was estimated to be very low from an animal biosecurity perspective.

The consequence assessment rating should be reviewed by relevant experts within the Australian Government Department of Health and Aged Care as this agency has responsibility for estimating the level of adverse impacts on human health that might eventuate associated with importation of this parasite.

Conclusions

Based on the preceding information, the likelihood of entry of *Brachylaima* spp. associated with the importation of infested *C. aspersum* sourced from commercial, government certified snail farms is considered to be high and the likely consequences of establishment and/or spread of *Brachylaima* spp. are considered to be very low. Using Table 3, the likelihood of entry and exposure (high) was combined with the likely consequences of establishment and/or spread (very low), which resulted in a risk estimation for *Brachylaima* spp. of very low.

As the overall risk of *Brachylaima* spp. associated with the importation of *C. aspersum* is very low and therefore achieve Australia's ALOP with respect to animal biosecurity risks, additional biosecurity measures for *Brachylaima* spp. are not required.

5.3 *Crenosoma vulpis*

5.3.1 Background

Crenosoma vulpis identified by Dujardin (1845) is a lungworm nematode that causes chronic respiratory disease in domestic dogs in parts of Europe and in the north-eastern region of North America (Bihr and Conboy, 1999; Maksimov *et al.*, 2017; Fuehrer *et al.*, 2020; Elsheikha *et al.*, 2014). It is considered endemic in red fox populations across these regions. *C. vulpis* needs an intermediate host snail, including *C. aspersum*, and a vertebrate definitive host canid to complete its development (Colella *et al.*, 2016b; Fuehrer *et al.*, 2020). It is thought that *C. aspersum* plays an important role in infecting animals in the Mediterranean basin and in Austria (Colella *et al.*, 2016b). Other snail species, particularly the giant African snail *Achatina fulica*, have been identified as important intermediate hosts of canine lungworm species, including *C. vulpis* (Penagos-Tabares *et al.*, 2019).

C. vulpis has not been detected in Australia.

5.3.2 Technical information

Agent properties

C. vulpis is part of the phylum Nematoda, class Secernentea, order Strongylida, and family Crenosomatidae (Anderson, 2000). Four haplotypes of *C. vulpis* in wild and domestic carnivores were identified in Italy, with only one haplotype being infective to dogs and all four being infective to foxes (Latrofa *et al.*, 2015).

The lifecycle of *C. vulpis* starts in the definitive host, a canid. The first-stage larvae (L1) are coughed out of the lungs and swallowed, and then pass through with the faeces. Once in the environment the L1 infects the intermediate host, a snail, via the foot. It will then develop into the infective third-stage larvae (L3) within 17 days (Stockdale and Hulland, 1970). In infected snails, larvae are primarily located in the viscera (69%) and foot (31%) (Colella *et al.*, 2016b). L3 *C. vulpis* can also be shed by the snail host and may remain infective in the environment for up to 8 weeks (Robbins *et al.*, 2021).

The definitive host becomes infected after ingesting L3 larvae, either from environmental contamination or from ingesting an infected intermediate host (Stockdale and Hulland, 1970; Robbins *et al.*, 2021). Canids can be infected through eating or licking contaminated material or surfaces.

Once ingested, the L3 larva penetrates the definitive host's intestines and will reach its lungs within 20 hours using the hepatic portal system (Anderson, 2000; Elsheikha *et al.*, 2018). The larvae colonise the small bronchi and bronchioles of the lung. They moult twice before reaching adulthood (Nevarez *et al.*, 2005; Elsheikha *et al.*, 2018). Females are ovoviviparous and will start laying larvae 19 days post-infection. Adults are large, measuring 5 to 10 mm in length and can live up to nearly 10 months (Anderson, 2000).

The parasite causes microscopic lesions around the bronchi and bronchioles and to a lesser extent around the alveoli (Nevarez *et al.*, 2005). Crenosomosis is a frequent cause of chronic respiratory disease in domestic dogs (Elsheikha *et al.*, 2018), although it is rarely fatal (Maksimov *et al.*, 2017).

Epidemiology

Definitive hosts of *C. vulpis* are foxes (*Vulpes vulpes*), coyotes (*Canis latrans*), dogs (*Canis familiaris*) and badgers (*Meles meles*) (Bihr and Conboy, 1999; Barutzki and Schaper, 2009; Nelson *et al.*, 2007; Popiolek *et al.*, 2009).

A large range of terrestrial gastropods, including both snails and slugs can serve as the intermediate hosts for *C. vulpis* (Stockdale and Hulland, 1970; Anderson, 2000; Conboy *et al.*, 2017). *C. aspersum* is a suitable intermediate host (Colella *et al.*, 2016b).

There is seasonal variation in *C. vulpis* infection and distribution is thought to be influenced by precipitation and temperature (Tolnai *et al.*, 2015).

Diagnosis

The diagnosis in the intermediate host involves killing the snail and digesting it in a solution of hydrochloric acid and pepsin before being spun in a microcentrifuge (Colella *et al.*, 2016b). Any nematode larvae can be examined under a light microscope. It is also possible to identify *C. vulpis* larvae using a duplex RT-PCR (Lange *et al.*, 2018). However, availability and other details of this test are not clear.

In definitive hosts, diagnoses are made through detection of first-stage larvae in faeces or via transtracheal wash samples.

Treatment

There is no treatment for the immediate snail host.

In domestic dogs, treatment includes the administration of Febantel (14 mg/kg, oral, once a day for 7 days) and fenbendazole (25–50 mg/kg, oral, once a day for 3–14 days) or with oral milbemycin oxime (0.5 mg/kg) and moxidectin spot-on treatments with clinical cure reportedly occurring 7–10 days post-treatment with an efficacy of 98–99% (Conboy, 2004; Elsheikha *et al.*, 2018).

Occurrence

Crenosoma vulpis is endemic in red fox populations across Europe and north-east North America and the range of this nematode is thought to be expanding (Bihr and Conboy, 1999) (Maksimov *et al.*, 2017; Rinaldi *et al.*, 2007). In North America, occurrence primarily occurs in Canada's Atlantic provinces (New Brunswick, Newfoundland-Labrador, Nova Scotia, PEI), with some cases also reported in Ontario, Quebec, New York and Illinois (Nelson *et al.*, 2007; Maksimov *et al.*, 2017; Barutzki and Schaper, 2011; Conboy *et al.*, 2009).

The expansion of *C. vulpis* is a likely consequence of the red fox carrying the parasite across geographical boundaries and bringing the parasite into contact with domestic dogs and other susceptible wildlife (Latrofa *et al.*, 2015).

There is no record of *C. vulpis* in snail farms. However, absence of evidence does not infer evidence of absence. There may have been no incentive to specifically look for this parasite on snail farms to date. In the absence of targeted surveillance, the prevalence of this parasite is undefined.

5.3.3 Current biosecurity measures

For imported dogs and cats, the current generic biosecurity measures for internal parasites for Group 3 countries are that: a government approved veterinarian must treat the dog twice with an internal parasite treatment effective against internal parasites (nematodes and cestodes). The two treatments must be administered at least 14 days apart and within 45 days before export. The second treatment must be given within five (5) days before export.

There are no specific biosecurity measures for *C. vulpis* in Australia.

5.3.4 Risk assessment

Entry and exposure assessment:

- *C. vulpis* is endemic in red fox populations across Europe and north-east North America and the range of this nematode is thought to be expanding. Coyotes, dogs and badgers are other definitive hosts.
- *C. vulpis* can use *C. aspersum* as an intermediate host.
- The first-stage larvae (L1) are coughed out of the lungs of the canid definitive host, swallowed and are then passed in faeces. Once in the environment the L1 infects the intermediate host, a snail, via the foot. It will then develop into the infective third-stage larvae (L3) in the snail.
- There are no records of *C. vulpis* on snail farms to date. However, this information should receive appropriate weighting considering a general paucity of information and detailed scientific reports assessing the prevalence of pathogens and parasites in farmed snails that may represent a biosecurity (rather than food safety) risk.
- Diagnosis in the snail is a laboratory procedure. It involves killing and digesting the snail in a solution of hydrochloric acid and pepsin before being spun in a microcentrifuge. A species-specific PCR has also been used for diagnosis. However, test specific details are unclear.
- There is no treatment for the immediate snail host.

- A possible pathway for introduction of *C. vulpis* to Australia from farmed *C. aspersum* could be through importation of parasitised snails that have entered a snail farming unit (e.g. at the fattening stage outside) or been introduced into a facility (snail farm). In addition, if parasitised dogs or foxes are allowed access to the snail breeding facilities, and the snails are able to come into contact with the faeces of these canids, the lifecycle could be maintained within the facility. (Note: Depending on the mode of operation of the sourcing facility, this latter scenario with dogs accessing commercial government certified facilities may be more improbable than entry of parasitised snails).

It is also noted that there is a history of importation of dogs from countries where *C. vulpis* is endemic. No cases have been reported in Australian dogs. The risk management applied currently for internal parasites for imported dogs into Australia is considered appropriate, and infections in pet dogs in Australia would be highly likely to have been detected through veterinary investigation over the years.

Based on this information, the likelihood of entry of *C. vulpis* associated with the importation of infested farmed *C. aspersum*, and exposure of potential hosts in Australia was estimated to be moderate.

Consequence assessment:

- *C. vulpis* has not yet been detected in Australia.
- *C. vulpis* is a lungworm nematode that causes chronic respiratory disease in domestic dogs in parts of Europe and in the north-eastern region of North America. Crenosomosis is reported as a common cause of chronic respiratory disease in domestic dogs, although it is rarely fatal.
- Terrestrial gastropods, including both snails and slugs, serve as the intermediate hosts for *C. vulpis*. *C. aspersum* has been identified as a suitable intermediate host.
- Canids can be infected by eating intermediate hosts with L3 forms of this parasite. L3 *C. vulpis* can be shed by the gastropod intermediate host and remain infective in the environment for up to eight weeks. The canine hosts could become infected through eating or licking contaminated material or surfaces or eating parasitised snails.
- Since foxes and dogs are definitive hosts of this parasite, the presence of feral foxes and dogs in Australia could result in a rapid spread of this parasite (introduced by parasitised *C. aspersum* and potentially extending to *C. aspersum* populations already present in Australia) from agricultural to urban areas and natural areas. There is also a significant population of working and assistance dogs in rural and regional areas overlapping with populations of foxes and feral dogs. This parasite appears to prefer cold temperatures so this could limit its spread in parts of northern Australia.
- The introduction of this parasite into Australia would impact domestic dog and dingo populations resulting in chronic respiratory disease of a new origin. There is a large companion dog owning population in Australia, a number of whom could be impacted by introduction of a parasite that could cause significant disability in their animals as well as expense related to veterinary investigations and treatment. The impact on the working ability of working dogs on animal production could also be significant for primary producers.

Based on this information, the likely consequences of establishment and/or spread of *C. vulpis* associated with the importation of *C. aspersum* was estimated to be low-from an animal biosecurity perspective.

Conclusions

Based on the preceding information, the likelihood of entry of *C. vulpis* associated with imports of *C. aspersum* from commercial, government certified snail farms is considered to be moderate and the likely consequences of establishment and/or spread of *C. vulpis* is considered low. Using Table 3, the likelihood of entry and exposure moderate was combined with the likely consequences of establishment and/or spread (low), which resulted in a risk estimation for *C. vulpis* of low risk.

As the overall risk of *C. vulpis* associated with the importation of *C. aspersum* is low and therefore does not achieve Australia's ALOP with respect to animal biosecurity risks, specific biosecurity measures for *C. vulpis* are required.

5.3.5 Risk management measures

Importation of adult snails: for the risk of *C. vulpis* associated with the importation of live garden snails (*C. aspersum*), to achieve Australia's ALOP, the snails must be imported into an Approved Arrangement site, where they will be reared in isolation from other snails and the definitive host, thus breaking the lifecycle of the nematode. The next generation of *C. aspersum* would be free of *C. vulpis* and eligible for release from the Approved Arrangement site.

Importation of hatchling snails: these are hatchlings less than 10 days old that have not been released from the hatching environment and have not been exposed to plant substrate. As these hatchling snails have also not been exposed to the definitive hosts for *C. vulpis*, the risk for hatchling snails will achieve Australia's ALOP.

5.4 *Dicrocoelium dendriticum*

5.4.1 Background

Dicrocoelium dendriticum (Rudolphi, 1819), formerly known as *Distoma dendriticum*, is commonly known as the lancet liver fluke. It is a trematode that infests herbivorous and omnivorous mammals including humans. It requires two intermediate hosts, a snail and an ant (Ismail and Gurelli, 2018). The definitive hosts are often ruminants such as sheep and cattle, but can include rabbits, pigs and dogs (Kahl *et al.*, 2021). *D. dendriticum* infection is known as dicrocoeliasis and can infect many vertebrate species, including humans. Infection with *D. dendriticum* in humans has been associated with consuming raw liver of infected animals. However, infections are rare and often spurious (Schweiger, 2008). Most infections are subclinical and any clinical signs are typical of liver disease, as caused by other liver flukes (Jeandron *et al.*, 2011).

This parasite is reported as problematic in northern and southern Europe, northern Africa, western and eastern America and Asia (Arbabi *et al.*, 2021). It is unclear whether this parasite is in Australia. According to the online Global Biodiversity Information Facility database (GBIF), *D. dendriticum* is not present in Australia (GBIF, 2022c). The Atlas of Living Australia database only includes one species of *Dicrocoelium* (*D. antechini*) (Cribb, 1992). This parasite has been reported to infect people in the Republic of Türkiye, Iran, Canada and Kyrgyzstan (Jeandron *et al.*, 2011). Several references state that it is present in Australia, but the source of this information is unclear. For example, according to

Otranto and Traversa, 2003, it is found in some focal points in Australia, but no references are provided for this statement. Noting that cattle and sheep may show very large numbers of these parasites in the bile ducts it is probable that surveillance activities would have detected its presence if it were in Australia.

This group of trematodes usually have wide host range. *Dicrocoelium dendriticum* has only been recorded in one study on *C. aspersum* (Ismail and Gurelli, 2018).

5.4.2 Technical information

Agent properties

The genus *Dicrocoelium* (Rudolphi, 1819) is in the phylum Platyhelminthes, class Trematoda, order Plagiorchiida and in family Dicrocoeliidae.

The adults are semitransparent, 6–12 mm length and 1.5–2.5 mm width, with a small oral sucker and a larger ventral sucker. The eggs are dark brown, 35–45 µm in length and 22–30 µm wide (Kahl *et al.*, 2021)

Adults reside in the gall bladder and bile ducts of the definitive host. Embryonated eggs are shed via bile to the intestine and then are excreted in faeces into the environment. The first intermediate host, snails, feed on faeces consuming the eggs. The egg will hatch into a miracidium, then migrates through the intestinal wall into the hepatopancreas. The parasite remains inside the snail for 3 to 4 months while developing from miracidium to cercariae. The cercariae migrate to the respiratory tract and are expelled through the respiratory movements once coated in slime. The second intermediate host, an ant, will consume the ball of slime with the cercariae. Some of the cercariae will migrate into the suboesophageal ganglion causing a shift in ant behaviour where the ants cling to the vegetation. This increases the chance of being consumed by the definitive host. The remaining cercariae encyst in the abdomen of the ant. Once in the definitive host, the metacercariae excyst as juvenile fluke which follow the bile duct to the liver to mature into adult fluke thus completing the lifecycle (Kahl *et al.*, 2021).

Epidemiology

D. dendriticum requires two suitable intermediate hosts co-occurring in the environment to complete its lifecycle: a snail and an ant. Over 90 mollusc species, mostly from the Helicidae and Geomitridae families, can be intermediate hosts (Otranto and Traversa, 2003; Sanchez *et al.*, 2021). *Cernuella virgata* and *Cochlicella acuta* are commonly first intermediate hosts (Mitchell *et al.*, 2017; Fasanella *et al.*, 1995). These two introduced species are now widespread in Australia and are major pests of grain crops (Baker, 2008). *D. dendriticum* has been detected in *C. aspersum* in only one study to date. This study was conducted in Türkiye (Kose *et al.*, 2015).

D. dendriticum is less pathogenic than the liver fluke *Fasciola hepatica* (Cengiz *et al.*, 2010). It's pathology is often masked by the pathological effects of other parasitic infections of ruminants (Arbabi *et al.*, 2011). Unlike other flukes, *D. dendriticum* doesn't migrate within the host so doesn't cause tissue damage or bleeding. This helps explain the lack of clinical symptoms in infected animals (Kahl *et al.*, 2021). However, Arbabi *et al.* (2018) observed that infection can cause slow development and impaired fertility in animals, which can reduce product quality and rate of production. It could also increase costs of anthelmintic treatments and costs of stock replacement (Arbabi *et al.*, 2018).

In humans, *D. dendriticum* infection can cause abdominal pain, weight loss and chronic diarrhoea. Patients are often asymptomatic. Heavier infections can cause symptoms including anaemia, constipation, and eosinophilia (Cengiz *et al.*, 2010).

Egg excretion in sheep in the Mediterranean regions is seasonal, peaking during winter (Otranto and Traversa 2002). The eggs are very resistant, and they can survive for up to 20 months on pastures with the right conditions (dry and calcareous soils) (Otranto and Traversa, 2003).

Diagnosis

The diagnosis of *D. dendriticum* in humans is through the FLOTAC technique which identifies the presence of eggs in the stool.

It can be diagnosed in ruminants at slaughterhouses through the presence of worms in the bile duct and gall bladder, swollen livers, whitish spots and scarring on liver and cholangitis (Arbabi *et al.*, 2011).

Diagnosis in the intermediate hosts involves dissection followed by either microscopic morphological examination or molecular analysis using PCR. The PCR molecular analysis has a higher sensitivity (Mitchell *et al.*, 2017).

Transmission

Definitive hosts are infected through ingestion of the second intermediate host (the ant). The trematode inside the ant intermittently changes its behaviour so it clings to vegetation, increasing its chance of being eaten by the definitive host (Kahl *et al.*, 2021). The ant will attach to vegetation in cooler temperatures, but will detach if temperature exceeds 20°C. The ant then returns to normal worker activities but will reattach to the same place once the temperature cools down (Martin-Vega *et al.*, 2018).

Terrestrial snails enter hibernation during colder months. Transmission of *D. dendriticum* is higher in warmer months when snails are more active (Ismail and Gurelli, 2018).

Treatment

There is no treatment for intermediate hosts.

There are several treatments available for the definitive hosts. A field study showed that the use of praziquantel at 50 mg/kg in sheep was 95.9% effective against *D. dendriticum* (Akkaya, Deniz and Sezen 2006). Another study on merino sheep using 5% and 15% suspension of netobimin at a dose rate of 20 mg/kg showed good efficacy with 90.80% and 91.50% respectively (Senlik *et al.*, 2008). In another study, a double administration of micronized albendazole had higher efficacy than a single treatment against *D. dendriticum* (Bosco *et al.*, 2015). Khanjari *et al.*, (2010) recommends preventative measures through treating sheep with albendazole and triclabendazole before autumn (Khanjari *et al.*, 2010).

Occurrence

D. dendriticum occurs in northern and southern Europe, northern Africa, western and eastern America and Asia (Manga-Gonzalez, 2001). Distribution reporting may be confounded by linking to fasciolosis distribution.

Prevalence in livestock varies. Infection rates of cattle and sheep can reach 37.5% and 46% respectively in Northern France, or 80% overall in Poland (Tarry, 1969). Infection rates of up to 100% are reported in sheep located in the Mediterranean and Middle East (Jeandron *et al.*, 2011). In a more recent study, 21.1% (sheep) and 7.0% (goats) were infected with *D. dendriticum* in southern Germany (Alstedt *et al.*, 2022).

D. dendriticum was not observed in 4,680 sheep imported from Australia to Jordan (Maraqa *et al.*, 2005).

5.4.3 Current biosecurity measures

There are no specific biosecurity measures for *D. dendriticum* to manage risk of entry of this parasite into Australia.

5.4.4 Risk assessment

Entry and exposure assessment:

- *D. dendriticum* occurs in northern and southern Europe, northern Africa, western and eastern America and Asia. Its prevalence in livestock varies.
- *D. dendriticum* was detected in *C. aspersum* in one study overseas (I., 2015). *Cernuella virgata* and *Cochlicella acuta* are the common first intermediate hosts, and these species are now widespread in Australia.
- The status of *D. dendriticum* on snail farms is unknown.
- The life cycle requires two suitable intermediate hosts co-occurring in the environment: a snail and an ant, and definitive hosts which could be ruminants or humans.
- Diagnosis of infestation in the snail intermediate host requires dissection of the snail.
- A possible pathway for introduction of *D. dendriticum* to Australia from farmed *C. aspersum* could be through importation of parasitised snails that have entered a breeding and rearing facility (snail farm) undetected, or been deliberately introduced into an insecure breeding and rearing source facility; for example, from sourcing from other breeders or from a fattening stage in the external environment.

Based on this information, the likelihood of entry of *D. dendriticum* associated with the importation of infested farmed *C. aspersum*, and exposure of potential hosts in Australia was estimated to be low.

This takes into account that no snail farm, even well-established commercial facilities, could be considered 'closed' systems from a biosecurity perspective. A closed system does not allow for snail trade or the cryptic nature of snails which may enter and leave undetected within even well-established facilities that are regulated through certification of their premises and procedures.

Consequence assessment:

- It is unclear whether *D. dendriticum* is present in Australia. The available evidence suggests it is exotic as surveillance activities, including routine abattoir inspections, would likely detect it.

- The introduction of *D. dendriticum* to Australia could have adverse consequences for the agriculture industry. As seen in Iran, it is possible that infection could slow development, and impair fertility in livestock, which can reduce product quality and rate of production. It could also increase costs associated with anthelmintic treatments and costs of stock replacement. There is a lack of clinical symptoms in grazing animals.
- *D. dendriticum* can infect humans so may pose a public health risk.
- Two intermediate snail hosts are already widespread in Australia (*C. virgata* and *C. acuta*), therefore *D. dendriticum* already has some suitable intermediate hosts present. Australia has very diverse ants. Once introduced, it is likely *D. dendriticum* could spread geographically.
- The level of direct economic loss due to partial or total condemnation of livers infected with infected with *D. dendriticum* was found to be equivalent to the loss due to liver fluke (*Fasciola hepatica*) infection of sheep, goats and cattle in a 2018 Iranian study (Arabi *et al.*, 2018)

Based on this information, the likely consequences of establishment and/or spread of *D. dendriticum* associated with the importation of *C. aspersum* were estimated to be low from an animal biosecurity perspective. However, the consequence assessment rating should be reviewed by relevant experts within the Australian Government Department of Health and Aged Care for consideration of potential adverse impacts on human health that might eventuate associated with importation of this parasite.

Conclusions

Based on the preceding information, the likelihood of entry of *D. dendriticum* associated with imports of *C. aspersum* from commercial government certified snail farms is considered to be low, and the likely consequences of establishment and/or spread of *D. dendriticum* is considered low. Using Table 3, the likelihood of entry and exposure (low) was combined with the likely consequences of establishment and/or spread (low), which resulted in a risk estimation for *D. dendriticum* of very low risk.

As the overall risk of *D. dendriticum* associated with the importation of *C. aspersum* from commercial, government certified snail farms is very low and therefore achieves Australia's ALOP with respect to animal biosecurity risks, additional biosecurity measures for *D. dendriticum* are not required.

5.5 *Phasmarhabditis* spp.

5.5.1 Background

Phasmarhabditis hermaphrodita (synonym= *Pellioditis hermaphrodita* and *P. californica* are soil nematodes that are facultative parasites of gastropods. They are also able to live and reproduce in slug faeces and other organic material in the environment (Rae *et al.*, 2009).

Phasmarhabditis hermaphrodita has been well studied but comparatively little is known about *P. californica* (Mc Donnell *et al.*, 2020).

Several slug and snail species are susceptible to *P. hermaphrodita* and *P. californica*, including *C. aspersum* (Williams and Rae, 2015; Andrus *et al.*, 2020; Grannell *et al.*, 2021). *P. hermaphrodita* is

lethal to snails and slugs when associated with the bacterium *Moraxella osloensis* and is sold as a biocontrol agent across Europe as ‘Nemaslug’ (Holley, 2020).

There is no record of *Phasmarhabditis* spp. in Australia (Mc Donnell *et al.*, 2020).

5.5.2 Technical information

Agent properties

Phasmarhabditis spp. are in the Phylum Nematoda, class Chromadorea, order Rhabditida and family Rhabditidae. *Phasmarhabditis hermaphrodita* can parasitise several mollusc families including Limacidae, Agriolimacidae, Arionidae, Milacidae, Vaginulidae and Helicidae (Holley, 2020).

Phasmarhabditis hermaphrodita has a mutualistic relationship with bacteria carried in its intestines (Hapca *et al.*, 2007). The slug or snail becomes infected when encountering the infective juvenile stage (dauer larvae) in the environment. The nematode larvae enter the dorsal integumental pouch of the snail and then penetrate the shell cavity (Rae *et al.*, 2007). Once inside the shell cavity, the bacteria are released, producing an endotoxin (Grewal and Grewal, 2003). This leads to an accumulation of fluid, causing swelling in the shell cavity and death within 4–21 days after the initial infection (Rae *et al.*, 2007). After death of the host, the nematodes distribute themselves amongst the entirety of the corpse to feed on the decaying body (Rae *et al.*, 2007; Tan and Grewal, 2001a). They can also reproduce on slug faeces or other rich bacterial substrates (Rae *et al.*, 2007). New generations of dauer larvae will be produced and will migrate to the soil in search of their new host (Cutler and Rae, 2020). Dauer larvae are nonfeeding and rely on energy reserves until they infect a new host (Grewal and Grewal, 2003).

Epidemiology

Mortality of the host is caused by the bacteria, and not the nematode. Nematodes free from the bacteria were found to be non-pathogenic when injected directly into the host, while the bacteria killed the host without the nematode (Tan and Grewal, 2001b). Some snail species have developed resistance to *P. hermaphrodita* infection including *Cepaea nemoralis*, *Oxychilus helveticus*, *Disus rotundatus* and *Clausilia bidentata* (Williams and Rae, 2015). Resistance is also size and age dependent. Juvenile *C. aspersum* are susceptible but adults seem more resistant (Williams and Rae, 2015). The same resistance pattern was found with *P. californica* (Grannell *et al.*, 2021).

A single host carcass can support the production of thousands of nematodes. Fifty nematodes feeding on the carcass can result in the production of between 15,000–40,000 infectious dauer larvae (Morris *et al.*, 2018). These nematodes are also able to complete their life cycle in nonparasitic conditions, thus maximising their ability to survive in the environment (Tan and Grewal, 2001b).

Dauer larvae are sensitive to ultraviolet light, high temperatures and desiccation (El-Danasoury and Iglesias-Pineiro, 2017). However, they can survive relatively tough environmental conditions due to their thick cuticle and closed openings (Grewal and Grewal, 2003). The nematode is killed at temperatures over 35°C (Rae *et al.*, 2007). It is thought that the nematodes manipulate the spatial behaviour of the host to ensure the host dies in the soil, hence protecting against high temperature and escaping predation. The nematodes requires a few days to complete their life cycle inside the cadaver, where under normal circumstances the cadaver would be consumed by predators within a matter of hours (Pechova and Foltan, 2008).

Diagnosis

The diagnosis of *Phasmarhabditis* spp. is performed on dead snails, historically through dissection, which is time consuming (Wilson *et al.*, 2012). Wilson *et al* 2012 developed a new technique that was equally effective. This involved decapitating the host and incubating it for a week, allowing the development of the dauer larvae into adults.

Transmission

Transmission occurs in the soil when an infective larvae encounter a host. The larvae are attracted to mucus, faeces and volatile cues of snails and slugs (Andrus *et al.*, 2020). Optimum temperature for growth and transmission is 17°C, but transmission can occur at temperatures as low as 5°C (Rae *et al.*, 2007). Infection causes a great reduction in host movement and feeding, meaning environmental dispersal is minimal (Rae *et al.*, 2007).

Occurrence

P. hermaphrodita was first discovered in Germany and believed to be European in origin (Howe *et al.*, 2020). It is commercialised as Nemaslug and sold widely over Europe (14 countries) (MacMillan *et al.*, 2006). It has also been found in New Zealand, Chile, Iran, Egypt and the western United States. It is unknown whether these populations are naturally occurring or illegally introduced with the biological control agent, Nemaslug (Nemaslug is not available for sale in NZ or USA). *P. hermaphrodita*'s potential impacts on gastropods native to these areas is unknown (Howe *et al.*, 2020).

P. hermaphrodita has not been recorded in Australia. Australian average temperatures are higher than the optimum temperature of 15°C for transmission, and therefore it may not spread as much as in other countries (Charwat and Davies, 2001).

P. californica has been isolated from the U.K., U.S.A., New Zealand and Canada (Grannell *et al.*, 2021), but its native range remains unknown (Mc Donnell *et al.*, 2020).

5.5.3 Current biosecurity measures

There are no specific biosecurity measures for *Phasmarhabditis* spp. in Australia.

5.5.4 Risk assessment

Entry and exposure assessment:

- *Phasmarhabditis* spp. can infect *C. aspersum*.
- Infected gastropods can take up to three weeks to die from infection. It is possible that an infected snail would be moved while not showing symptoms. Adults seem more resistant and therefore they could carry the parasite without showing signs.
- The prevalence of *Phasmarhabditis* spp. in snail farms is unknown. It has been detected in various countries but its distribution is not well-described.
- Transmission occurs when infective larvae in the soil encounter a host (snail or slug).
- In a commercial government certified snail farm, it would be expected that loss of breeding stock (discovery of snail carcasses) would be investigated, the infection detected, and suitable action taken to protect stock.
- Only dead snails can be diagnosed with *Phasmarhabditis* spp.

Based on this information, the likelihood of entry of associated with the importation of infested farmed *C. aspersum*, and exposure of potential hosts in Australia was estimated to be very low.

Consequence assessment:

- There is no record of *Phasmarhabditis* spp. in Australia.
- *Phasmarhabditis* spp. can infect many slugs and snails.
- Environmental spread is limited due to decreased movement of the infected host. It is unlikely to move rapidly from any source of introduction.
- Average temperatures in Australia may be too high to support populations of this nematode in some areas, as optimum temperatures of infection are reported as being 15–17°C; however, transmission can occur at temperatures as low as 5°C.
- The introduction of this nematode to Australia could adversely impact native snails and slugs.

Based on this information, the likely consequences of establishment and/or spread of *Phasmarhabditis* spp. associated with the importation of *C. aspersum* was estimated to be negligible from an animal biosecurity perspective.

Conclusions

Based on the preceding information, the likelihood of entry of *Phasmarhabditis* spp. associated with imports of *C. aspersum* sourced from commercial, government certified snail farms is considered to be very low and the likely consequences of establishment and/or spread of *Phasmarhabditis* spp. is considered negligible. Using Table 3, the likelihood of entry and exposure (very low) was combined with the likely consequences of establishment and/or spread (negligible), which resulted in a risk estimation for *Phasmarhabditis* spp. of negligible.

As the overall risk of *Phasmarhabditis* spp. associated with the importation of *C. aspersum* is negligible and therefore achieves Australia's ALOP with respect to animal biosecurity risks, additional biosecurity measures for *Phasmarhabditis* spp. are not required.

The consequence assessment rating should be reviewed by relevant experts within the Australian Government Department of Climate Change, Energy the Environment and Water as this agency has responsibility for estimating the level of adverse impacts on native slugs and snails that might eventuate associated with import.

5.6 *Riccardoella limacum*

5.6.1 Background

Riccardoella limacum is a parasitic mite of snails. It is common on *C. aspersum* (Turk and Phillips, 1946) and can be found in snail farms (Segade *et al.*, 2013). It has not been recorded in Australia.

5.6.2 Technical information

Agent properties

Riccardoella limacum (Acari: Prostigmata: Ereyetidae) is a parasitic mite of snails. Little information exists on *Riccardoella* spp. in general as they are small, live inside hosts and are therefore inconspicuous. Two species have been confused in past studies. However, a study showed that one

species, *R. limacum* infects snails, while the other species *R. oudemans* infect slugs (Graham *et al.*, 1993). *R. limacum* can infect several snail species, with *C. aspersum* being one of the most common hosts (Turk and Phillips, 1946).

R. limacum is a hematophagous mite, feeding on its host blood while living in the mantle cavity. Eggs are laid in the host's lung cavity and hatch within eight to 12 days (Baker, 1970). There are three nymphal stages (Baker, 1970). Newly hatched nymphs have six legs and move fast allowing dispersal (Turk and Phillips, 1946). Adults are 0.4 mm long (Baker, 1970). Mating occurs inside the host and males are present for a short time only (Turk and Phillips, 1946). The total life cycle of *R. limacum* takes 19 to 23 days to complete at temperatures between 20.1–25.1°C (Baker, 1970). Therefore, several generations can occur in a year. There is a seasonal pattern in mite numbers, which peak during autumn (reviewed in Baur and Baur, 2005). Adult mites rarely survive winter in the host (Baker, 1970) and infections decrease over the host hibernating period (Haeussler *et al.*, 2012). Eggs appear to be the overwintering stage with nymphs hatching in spring (Baker, 1970; Haeussler *et al.*, 2012). The number of mites increases with host size with larger individuals having higher infestation load (Schupbach and Baur, 2010b).

Epidemiology

While *R. limacum* does not directly kill its hosts, several studies have found that infestation impact snail health. These impacts can be subtle. In a study where healthy *Arianta arbustorum* snails were infested with *R. limacum*, shell growth and reproduction (growth of albumen glands and reaching sexual maturity) were not affected by the mite, but they ingested less food (Wacker, 2008). In the same snail species, less eggs were produced when more mites were present in the host (Schupbach and Baur, 2008b). Several studies showed that snail mortality in infested individuals was higher in winter (Wacker, 2008; Schupbach and Baur, 2008b; Hausler *et al.*, 2012) and mortality increased with parasite load (Schupbach and Baur, 2010b).

Susceptibility to *R. limacum* is dependent on the snail family with some families being more resistant (Schupbach and Baur, 2010b). Intensity of infection was found to vary between field populations with some populations harbouring higher numbers of *R. limacum* per individual (Baur and Baur, 2005).

Diagnosis

The definitive diagnosis of *R. limacum* infestation is through dissection when the mite is found inside the host. While it is possible to observe mites in snails by looking through the respiratory pore, this is not a reliable technique and mite eggs cannot be detected (Baur and Baur, 2005). Dissection is therefore a necessary part of diagnosis. In a recent study on *Riccardoella tokyoensis*, it was shown that snails did not show any sign of inflammation after being artificially infected. (Waki *et al.*, 2021). It is impossible to assess infestation based on snail health only.

Transmission

Transmission occurs when snails come in contact with each other (Schupbach and Baur, 2010a) during courtship and mating, but they can also use mucus to infect new hosts (Schupbach and Baur, 2008a). Fresh mucus is most effective for transmission (Schupbach and Baur, 2008a). Transmission is influenced by the infested snail's parasite load. The heavier the infestation, the more transmission will occur (Schupbach and Baur, 2010a).

Occurrence

Parasitic *Riccardoella* spp. mites may be easily missed due to their small size and because they live within their hosts. Therefore, they could be more widely distributed than currently thought.

R. limacum is currently widespread in Europe. The greatest height it was found in Europe was at 1290 metres in Switzerland (Baur and Baur, 2005).

R. limacum is commonly found in snail farms. Segade *et al.*, (2013) found this mite species to be infecting predominantly *C. aspersum aspersum* (Segade *et al.*, 2013). In one of the farms sampled, close to 60% of individuals were infected by mites. Mites were less prevalent in *C. aspersum maximum* (Segade *et al.*, 2013).

R. oudemans is widespread in Australia however *R. limacum* has not been recorded in Australia to date (B. Halliday, personal communication).

5.6.3 Current biosecurity measures

There are no specific biosecurity measures for *R. limacum* in Australia.

5.6.4 Risk assessment

Entry and exposure assessment:

- *R. limacum* is widespread in Europe and it is commonly found in snail farms.
- The hosts for these parasites seem to be restricted to snails and slugs.
- As *R. limacum* is found within the mantle cavity of the snail, it is hard to detect, and dissection is necessary for diagnosis. Infested hosts may seem healthy based on visual inspection.
- Transmission occurs when snails come in contact with each other. The mites may also use snail mucus to infect new hosts. Any opportunity for entry of wild snails or field reared snails onto snail farms represents a potential entry point for this pathogen onto the farm.
- A probable pathway for the introduction of *R. limacum* is from infested imported snails transmitting *R. limacum* to local *C. aspersum* populations, which is one of the most common hosts. However, *R. limacum* can infest several snail species.

Based on this information, the likelihood of entry of *R. limacum* associated with the importation of infested farmed *C. aspersum*, and exposure of potential hosts in Australia was estimated to be high.

Consequence assessment:

- *R. limacum* has not been reported in Australia. A related species, *R. oudemans* is present and infests slugs.
- *R. limacum* has become widespread in Europe which suggests it is an efficient parasite in terms of ability to spread.
- Several studies have found that infestation with *R. limacum* impacts snail health, although such impacts may be subtle. Reported adverse effects for affected snails include lower food consumption, lower egg production, and increased mortality.
- Detrimental impacts on the existing population of *C. aspersum* might widely be viewed favourably by the Australian public, given its pest status. However, *R. limacum* may also infest

Australia's native snails, of which there are some 2,500 species (Stanisic *et al.*, 2022). This could result in potentially significant adverse outcomes for the ongoing viability of these species.

- Infestation of native snails (and possibly native slugs) could have wider implications for Australia's biodiversity and conservation efforts.

Based on this information, the likely consequences of establishment and/or spread of *R. limacum* associated with the importation of *C. aspersum* was estimated to be very low.

The consequence assessment rating should be reviewed by relevant experts within the Australian Government Department of Climate Change, Energy the Environment and Water as this agency has responsibility for estimating the level of adverse impacts to native fauna that might eventuate associated with importation of this parasite.

Conclusions

Based on the preceding information, the likelihood of entry of *R. limacum* associated with imports of *C. aspersum* sourced from commercial, government certified snail farms is considered to be high and the likely consequences of establishment and/or spread of *Riccardoella* spp. are considered to be very low. Using Table 3, the likelihood of entry and exposure (high) was combined with the likely consequences of establishment and/or spread (very low), which resulted in a risk estimation for *R. limacum* of very low.

As the overall risk of *R. limacum* associated with the importation of *C. aspersum* is very low and therefore achieve Australia's ALOP with respect to animal biosecurity risks, additional biosecurity measures for *R. limacum* are not required.

5.7 *Tetrahymena* spp.

5.7.1 Background

Tetrahymena rostrata and *Tetrahymena limacis* are free-living, ciliated protozoans that can also be facultative parasites of terrestrial snails and slugs (Haite *et al.*, 2021). Some studies suggest that the gastropod host is not harmed or injured when infected (Michelson, 1971), while others found that high parasitic loads in gastropods are often fatal once the ciliates enter internal organs, particularly the kidneys (Zhang and Vdacny, 2021).

T. rostrata is present in Australia and has been isolated from the egg of the grey field slug *Deroceras reticulatum* (Watt *et al.*, 2021).

T. rostrata is being considered for its potential as a biocontrol agent for *D. reticulatum* (Watt *et al.*, 2021).

5.7.2 Technical information

Agent properties

Tetrahymena spp. are part of the phylum Ciliophora, class: Oligohymenophorea, order Hymenostomatida and family Tetrahymenidae. These protozoans have four developmental stages: trophonts, tomons, tomites and theronts (Haite *et al.*, 2021).

The natural habitat for *T. rostrata* is diverse and can include soil, leaf litter and moss (Zhang and Vdacny, 2021). This species can survive harsh conditions and can persist in the environment for long

periods (Wilson *et al.*, 1998). As *T. rostrata* can go locally extinct due to the death of the host or exhaustion of its food source it must migrate frequently to find suitable environments to live (Kaczanowski *et al.*, 2016).

Infection of *T. rostrata* is largely concentrated in the nephridium or kidneys of the host (Segade *et al.*, 2009). Other areas of infection include the pulmonary chamber, muscle, albumen gland, hepatopancreas and gonads (Haitea *et al.*, 2021). Maximum densities in hosts can be very high. The maximum recorded by Segade *et al.* (2009) was 6300 ciliates for petit gris *C. a. aspersum* and 15,700 ciliates for *C. aspersum maximum* (Segade *et al.*, 2009).

T. limacis protozoans were also concentrated in the kidneys but in heavy infestations were also found in the body wall and mantle shield. In heavy infections the ciliates can also replace the normal tissue structure (Michelson, 1971).

Epidemiology

Tetrahymena spp. have several host species. *Tetrahymena limacis* can use hosts from the Arionidae, Milacidae and Limacidae slug families and from the Bradybaenidae, Daudebardidae, Helicidae (which includes *C. aspersum*), Hygromiidae, Succineidae, Vitrinidae and Zonitidae snail families. *Tetrahymena rostrata* is known to infect species such as *C. aspersum*, *Chochilcopa lubrica*, and more commonly, *Deroceras reticulatum* (Kaczanowski *et al.*, 2016). It has been found in seven slug species in Agriolimacidae and Arionidae families and seven snail species in the Oleacinidae and Zonitidae families (Van As and Basson, 2004).

In *C. aspersum*, high *T. rostrata* density causes mantle swelling and severe renal pathology (Segade *et al.*, 2009). It is reported that snails infected with *T. rostrata* have slower growth rates, lower feeding rates and decreased fecundity. Heavily parasitised *C. aspersum* suffer significant damage to the renal epithelium alongside deleterious effects such as the inability to retract their body back into their shell and mantle collar swelling (Zhang and Vdacny, 2021). Infected slugs will also have reduced tentacle mobility (Haitea *et al.*, 2021).

Prevalence of *Tetrahymena* spp. is significantly reduced after hibernation (Segade *et al.*, 2013).

Diagnosis

T. rostrata is identifiable in the kidneys of infected snails such as *C. aspersum*. Diagnosis therefore requires dissection of the snail (Haitea *et al.*, 2021). It is assumed this also applies to *T. limacis*.

Transmission

The host becomes infected by trophonts. It is likely that snails or slugs are also infected by the free-swimming, excysted cells (theronts) that penetrate the host's urethras and renal organs, as mucus of snails enhances *T. rostrata* excystment (Kaczanowski *et al.*, 2016). Snails can also undergo secondary self-infections by excysted cells which outcompete the remaining older cells (Kaczanowski *et al.*, 2016).

Transmission of *T. limacis* is faecal-oral, with host becoming infected when ingesting *T. limacis*. Direct infection into the respiratory chamber also seems possible in *D. reticulatum* (Michelson, 1971).

Occurrence

The first discovery of *T. rostrata* occurred in New Zealand and today it can be found in the USA, North America, Europe and Australia (Kaczanowski *et al.*, 2016). The distribution in Australia has not been defined.

T. rostrata is common in snail farms (Segade *et al.*, 2009; Segade *et al.*, 2013). A study into parasite prevalence in mixed system-based heliciculture farms in North-West Spain found *T. rostrata* in approximately 3% of *C. aspersum* populations involved in the study. However, infection rate can be higher with 12.6% of juveniles being infected (Segade *et al.*, 2013).

A Spanish study found that *T. limacis* had an overall prevalence of 0.5% in heliciculture systems., with higher prevalence in juveniles with 29.4% of individuals infected (Segade *et al.*, 2013).

5.7.3 Current biosecurity measures

There are no specific biosecurity measures for this species in Australia.

5.7.4 Risk assessment

Entry and exposure assessment:

- *T. rostrata* is known to be present in Australia; however, available information for *T. rostrata* is likely to be largely applicable to the related species, *T. limacis*.
- *T. limacis* are free-living, ciliated protozoans that are also facultative parasites of terrestrial snails and slugs.
- *T. limacis* has an overall prevalence of 0.5% in heliciculture systems., with a higher prevalence in juveniles with 29.4% of individuals infected.
- Transmission of *T. limacis* is faecal-oral, with the host becoming infected when ingesting *T. limacis*.
- Diagnosis requires dissection of the snail.

There is a paucity of relevant scientific information on *T. limacis*; however, based on this information, the likelihood of entry of associated with the importation of infested farmed *C. aspersum*, and exposure of potential hosts in Australia was estimated to be very low.

Consequence assessment:

- The status in Australia of *T. limacis* is unknown. The related species, *T. rostrata* is here.
- The impact of *Tetrahymena* spp. on their mollusc hosts is unknown; but there is a possibility that in heavy infections the ciliates could replace the normal tissue structure in parts of the snail or slug.
- The fact that *T. rostrata* is being considered for its potential as a biocontrol agent for *D. reticulatum* would suggest significant harm to the host; in this case the grey field slug.
- The full host range is unknown.
- *Tetrahymena* spp. could also have an impact on snail farms if initial stock is infected.

- The introduction of new species of these protozoans to Australia could adversely impact native slugs and snails.

Based on this information, the likely consequences of establishment and/or spread of *T. limacis* associated with the importation of *C. aspersum* was estimated to be negligible from an animal biosecurity perspective.

Conclusions

Based on the preceding information, the likelihood of entry of *T. limacis* associated with imports of *C. aspersum* sourced from commercial, government certified snail farms is considered to be very low and the likely consequences of establishment and/or spread of *T. limacis* is considered negligible. Using Table 3, the likelihood of entry and exposure (very low) was combined with the likely consequences of establishment and/or spread (negligible), which resulted in a risk estimation for *T. limacis* of negligible.

As the overall risk of *T. limacis* associated with the importation of *C. aspersum* is negligible and therefore achieves Australia's ALOP with respect to animal biosecurity risks, additional biosecurity measures for *T. limacis* are not required.

The consequence assessment rating should be reviewed by relevant experts within the Australian Government Department of Climate Change, Energy the Environment and Water as this agency has responsibility for estimating the level of adverse impacts on native slugs and snails that might occur.

5.8 *Troglostrongylus brevior*

5.8.1 Background

Troglostrongylus brevior (Gerichter, 1948) is a nematode lungworm that uses gastropods as intermediate hosts and cats as definitive hosts. It can cause serious broncho-pulmonary disease in cats which are the definitive hosts and is often fatal in kittens (Traversa *et al.*, 2014). It was initially considered as a parasite of wild cats, but its prevalence in domestic cats appears to be increasing. This is difficult to be certain of as it is believed that *T. brevior* infection has frequently been historically misidentified as *A. abstrusus* (Traversa *et al.*, 2014). Several gastropods serve as intermediate hosts including *C. aspersum* (Brianti *et al.*, 2013). *T. brevior* has not been detected in Australia.

5.8.2 Technical information

Agent properties

T. brevior is a nematode in the class Chromadorea, order Strongylida and family Crenosomatidae (GBIF, 2022). First stage larvae (L1) are released into the environment through faeces of the definitive host, cats. The larvae penetrate the integument of molluscs, the intermediate hosts. Inside the snail they develop until they become infective L3 larvae. The definitive host will become infected by eating the intermediate host or indirectly by eating a paratenic host that has ingested an infected snail (rodents, birds, reptiles, and amphibians) (Traversa *et al.*, 2014). Kittens may also acquire infection through vertical transmission and ingestion of L3 stage larvae in their mother's milk (Brianti *et al.*, 2013).

Once inside the digestive system of the definitive host, the L3 larvae penetrate the intestinal tract and enter the blood stream or lymphatic system to eventually reach the lungs where they will mature

to adults (Brianti *et al.*, 2013). Adults live in the bronchi and bronchioles where they will reproduce (Traversa *et al.*, 2014). Females release eggs in the lungs. These will hatch into L1 larvae, exit the respiratory system to be swallowed back by the host and travel down the digestive system until they are released in the environment through faeces for the lifecycle to recommence (Traversa *et al.*, 2014). The lifecycle takes approximately 28 days to complete.

Epidemiology

Several gastropods serve as intermediate hosts of *T. brevior* including *Agriolimax* spp., *Helicella* spp., *Helix* spp., *Monacha* spp. and *Theba* spp. (Brianti *et al.*, 2013). These authors also note *C. aspersum* as an intermediate host.

Feline symptoms can range from subclinical to life threatening and include dyspnoea, mucoid-purulent nasal discharge, sneezing, depression, anorexia (Giannelli *et al.*, 2014), as well as irreversible pulmonary hypertension and death (Morelli *et al.*, 2020). Severity of infection is a result of the large body size of the nematodes and their location in the trachea, bronchi, and bronchioles (Brianti *et al.*, 2013). Prevalence is higher in kittens (85.7%) than in adults (64.3%) (Falsone *et al.*, 2014). There is limited data on prevalence and potential for co-infections of cat metastrongylid species in Europe.

Seasonal patterns of transmission in southern Europe have been observed. A decrease in temperature favours the development of *T. brevior* in the snail, therefore infection rates in snails are highest in autumn and winter. The highest infection rates in cats are seen in spring when gastropods exit hibernation (Morelli *et al.*, 2020).

Diagnosis

The diagnosis of *T. brevior* infection in the intermediate gastropod host involves dissection as for other lungworms.

Diagnosis in the definitive host require microscopic analysis of faecal samples following the ZnSO₄ flotation and Baermann method. Diagnosis can be complicated by the non-specific nature of the clinical signs and an absence of clinical signs in some infected animals (Jefferies *et al* 2010 citing Travers and Guglielmini 2008).

Transmission

T. brevior infects the snail host as L1 larvae when they come in contact in the environment with faeces carrying an egg burden from an infected feline. Transmission between snails is also possible with L3 larvae being shed in the snail mucus (Brianti *et al.*, 2021). Cats can acquire the infection directly through ingestion of infected intermediate hosts or indirectly through ingestion of paratenic hosts (birds, amphibians, reptiles or rodents), which have ingested the infected snails (Morelli *et al.*, 2020). Research has also shown kittens can acquire infection through lactation (Brianti *et al.*, 2013).

Treatment

In a pilot study, *T. brevior* infection was successfully treated in cats with Advocate® spot-on solution for cats (Bayer Animal Health GmbH) which contains 1% w/v moxidectin and 10% w/v imidacloprid (Diakou *et al.*, 2019).

There are no known treatments for *T. brevior* in intermediate hosts.

Occurrence

Troglostrongylus brevior has been reported in the Mediterranean Basin, Eastern Europe and South America (Morelli *et al.*, 2020). In Europe it has been recorded in Spain, Italy, Greece, Bulgaria, Romania and Cyprus (Deak *et al.*, 2017). All of Mediterranean Europe provides suitable conditions for this parasite (Diakou *et al.*, 2015). Infection rates can be very high in wild felids. In Italy, 71.4% of wildcats were shown to be infected (Falsone *et al.*, 2014).

5.8.3 Current biosecurity measures

For imported dogs and cats, the current generic biosecurity measures for internal parasites for Group 3 countries are that: a government approved veterinarian must treat the dog twice with an internal parasite treatment effective against internal parasites (nematodes and cestodes). The two treatments must be administered at least 14 days apart and within 45 days before export. The second treatment must be given within five (5) days before export.

There are no specific biosecurity measures for *T. brevior* in Australia.

5.8.4 Risk assessment

Entry and exposure assessment:

- *T. brevior* may use *C. aspersum* as an intermediate host and infections may be increasing in domestic cats in Europe based on detection of a number of cases in domestic cats over the last decade. However, there is little information available for clear statements about prevalence.
- Domestic cats are known to eat snails but it can be assumed this is not their preferred diet. Therefore, detection of cases may argue for an increasing prevalence in the snail host and/or infested potential paratenic hosts. It may also reflect increased research effort.
- *T. brevior* has not been reported on snail farms. As with *C. vulpis*, this information should receive appropriate weighting considering a general paucity of information and detailed scientific reports assessing the prevalence of pathogens and parasites in farmed snails that may represent a biosecurity (rather than food safety) risk.
- Diagnosis in the snail is a laboratory procedure and requires dissection.
- There is no treatment available for snails.

Based on this information, the likelihood of entry of *T. brevior* associated with the importation of infested farmed *C. aspersum*, and exposure of potential hosts in Australia was estimated to be low.

Consequence assessment:

- *T. brevior* has not been detected in Australia in intermediate hosts or definitive hosts.
- Several gastropods serve as intermediate hosts of *T. brevior*, including *C. aspersum*. *T. brevior* would likely have ample intermediate, paratenic and definitive hosts (domestic and feral cats) in Australia if it were introduced. Once introduced, there is potential for this parasite to establish and spread.
- *T. brevior* can infect domestic cats and may be fatal in kittens.
- Feline symptoms can range from subclinical to life threatening and include dyspnoea, mucoid-purulent nasal discharge, sneezing, depression and anorexia, as well as irreversible pulmonary

hypertension and death. Severity of infection is variable and some infected animals may show no clinical signs.

- Cats can be diagnosed through clinical signs and a faecal examination. Diagnosis can be complicated by the non-specific nature of the clinical signs in affected animals as well as the possibility of a complete absence of clinical signs in infected animals.
- Cats can be successfully treated based on limited studies.
- Impact on the domestic (companion) cat population in Australia, if *T. brevior* was introduced in the snail, is anticipated to be minimal. There is potential for kittens to succumb and incur treatment costs.

Based on this information, the likely consequences of establishment and/or spread of *T. brevior* associated with the importation of *C. aspersum* was estimated to be low.

Conclusions

Based on the preceding information, the likelihood of entry of *T. brevior* associated with imports of *C. aspersum* sourced from commercial, government certified snail farms is considered to be low and the likely consequences of establishment and/or spread of *T. brevior* is considered low. Using Table 3, the likelihood of entry and exposure (low) was combined with the likely consequences of establishment and/or spread low), which resulted in a risk estimation for *T. brevior* of very low.

As the overall risk of *T. brevior* associated with the importation of *C. aspersum* is very low and therefore achieves Australia's ALOP with respect to animal biosecurity risks, additional biosecurity measures for *T. brevior* are not required.

5.9 *Cornu aspersum* as a vector for plant pathogens

This section examines the potential for garden snails, including *C. aspersum*, to vector microorganisms that are not pathogenic to snails but may have an impact on plant life and health.

5.9.1 Relevant vectored plant pathogens

The potential transmission of plant disease agents by snails, including *C. aspersum*, has received little attention. A number of plant pathogenic organisms have been recovered from snails; however, there is no evidence that snails play a key role in the dispersal of these disease agents or are the primary vectors of these organisms:

- El-Hamalawi and Menge (1996) demonstrated the transmission of *Phytophthora citricola* by *C. aspersum* (syn. *Helix aspersa*) to *Persea americana* (avocado) plants and *P. indica* stem cuttings.
- Alvarez et al. (2009) demonstrated *C. aspersum* (syn. *H. aspersa*) successfully transmitted *Phytophthora citrophthora* (*Phytophthora* branch canker of citrus) to three varieties of citrus plants.
- Hyder, Coffey and Stanghellini (2009) demonstrated successful transmission of the plant pathogen *Phytophthora ramorum* by *C. aspersum* (syn. *H. aspersa*) to *Rhododendron* leaves.

The transmission of *Phytophthora* by snails has not been directly observed in the field, and transmission studies are often conducted under controlled conditions. *Phytophthora* are spread naturally via soil, rain splash, water, wind and water and by humans moving infected plant material, soil and equipment (DAWR, 2015; Ristaino and Gumpertz, 2000). These modes of transmission are highly effective in spreading the disease to new hosts.

In contrast to microbial disease, snails are well documented vectoring and transmitting a range of nematodes, and similar organisms, associated with animal and human diseases – similarly, plant related nematodes have also been found inhabiting *C. aspersum*.

- Sanchez (2010) recovered an extensive range of nematodes and bacteria from *C. aspersum* (as *H. aspersa*) collected in California, USA. Nematodes were recovered from 92% of snails, including plant pathogenic species *Aphelenchoides fragariae*, *Heterodera schachtii* and *Xiphinema index*. Thirty-one bacterial species were isolated from snail organ tissues and mucus slime; of these, only one was phytopathogenic – *Xanthomonas campestris* pv. *campestris*. Many of the bacterial species recovered are frequently found in or on plants, soil and water. Some bacteria isolated during the study have been reported to be entomopathogenic such as *Pseudomonas entomophila*, *Serratia marcescens* and *S. proteamaculans*, and several are associated with infections in humans.
- Sanchez (2015) further investigated the role of *C. aspersum* (as *H. aspersa*) in transmitting plant pathogens. Additional plant pathogenic nematodes *Ditylenchus dipsaci*, *Mesocriconema discus* and *Pratylenchus vulnus*, as well as fungi *Fusarium solani*, *F. oxysporum* f. sp. *callistephi*, *F. oxysporum* f. sp. *chrysanthemi*, *Mucor hiemalis* and *Rhizoctonia solani*, were recovered from snails collected in California, USA.
- In controlled studies, Sanchez (2015) demonstrated that plant parasitic nematodes survived digestion by *C. aspersum*, and were passed in decreasing numbers in snail faeces for up to eight days (minimal nematodes were recovered after 9 days). Likewise, viable fungi were also recovered from snail faecal pellets.
- Sanchez (2015) went on to demonstrate that root knot nematodes consumed by *C. aspersa*, successfully infected tomato plants, when collected faecal pellets were placed on the base of seedlings and incubated for two months.
- Similarly, Michaud (2019) also demonstrated the consumption, and passing of viable plant nematodes *Meloidogyne javanica* and *Heterodera schachtii* by *C. aspersum*. Egg masses and cysts consumed by the snails, survived digestion and were viable after excretion. The hatched nematodes were infective, causing galls on tomato plants.

Each of these authors point to the potential role that *C. aspersum* may play in distributing plant pathogens within crops/hosts. Thus far, all studies have been conducted under controlled conditions. There are no publications that identify plant pathogenic nematodes being transmitted by snails in either agricultural or environmental settings, and no known plant pathogenic nematodes that rely on snails as the sole method of dispersal, or in contrast to animal pathogenic nematodes, rely on snails as an obligate intermediate host.

5.9.2 Risk assessment and management for vectored plant pathogens

There is substantial uncertainty in respect of both: (a) the likelihood that imported *C. aspersum* will vector an individual pathogen; and (b) the likely consequences of introduction within Australia in respect of the impact of each of these pests and diseases may have on plant life and health. In view of this uncertainty, and the potential for significant impact, the biosecurity risk attached to each vectored pest or disease was conservatively estimated as low and, thus requiring risk management if the importation of *C. aspersum* is to achieve Australia's ALOP.

Importation of adult snails: the management measure that has been specified for *Angiostrongylus* spp. and for *Crenosoma vulpis* (Sections 5.1 and 5.3, respectively) is to require that adult snails are imported into an Approved Arrangement site, where they can be reared in isolation from other snails and any other host species. This measure can be extended to manage vectored diseases and pests. Isolation would break the life cycle of plant pathogens. The next generation of *C. aspersum* would then be considered free of any key vectored diseases and pests and will be eligible for release from the Approved Arrangement site.

Importation of hatchling snails: these are hatchlings less than 10 days old that have not been released from the hatching environment and have not been exposed to plant substrate. As these hatchling snails have not been exposed to plant substrate, the likelihood that they will vector plant pathogens will be sufficiently low as to achieve Australia's ALOP.

6 Species verification and biosecurity

In this biosecurity import risk review, risk management describes the process of implementing measures to address the underlying requirement for species verification, as well as the biosecurity risks identified in the review as exceeding Australia's ALOP. In establishing these measures, the negative effects on trade have been minimised.

Before issuing an import permit for this commodity, the department will consider (*inter alia*) certain criteria, including:

- The animal health status of the country
- The effectiveness of the country's animal and plant health authorities
- Legislative controls over animal and plant health, including biosecurity policies and practices
- The standard of reporting to WOA and IPPC, of significant disease and pest outbreaks
- The effectiveness of official laboratory services, including compliance with relevant international standards
- The effectiveness of systems for the certification and documentation of products intended for export to Australia.

6.1 Measures for species verification and biosecurity

Biosecurity measures will be required for the importation of live *C. aspersum* for heliculture within Australia, noting that the scope of this review was extended from *adult C. aspersum* for heliculture to include the option for the importation of hatchling snails.

Exporting country: *C. aspersum* breed-stock must only be sourced from approved countries. Approval will depend on the department undertaking a Competent Authority assessment for this commodity.

Snail farming establishments: snail farms seeking to export *C. aspersum* to Australia must be commercial operations and government certified for basic quality standards for food safety, and general hygienic operations. Government certification for relevant biosecurity controls will also be required at the time of export. The current Quality Standard applicable to the commercial operation which is exporting *C. aspersum* to Australia must be linked to a specific import application and will be reviewed as part of the application assessment process. Some modification or amendment of this Quality Standard may be required.

Species verification and biosecurity measures for adult snails

- Adult snails exported to Australia must be certified by the exporter and exporting country as *C. aspersum* only. Certification of species may be based on morphological identification or on an approved molecular method. Approval will entail the development, validation and standardisation of a molecular procedure that meets the department's requirements for sensitivity and specificity.
- Adult snails will be directed to an Approved Arrangement on arrival at the Australian border. This will be a biosecure facility and may be a government-supervised quarantine facility or may be a snail farming facility that is managed privately. The privately managed Approved Arrangement and site will include (*inter alia*) site design and security, as well as biosecurity protocols for site maintenance, people and the disposal of waste. The privately managed Approved Arrangement and site will also be subject to the department's requirements for audit and compliance.
- A subset of the snails within each imported consignment will be subject to species verification by morphological or molecular identification. Morphological Identification involves sacrifice of the selected snails as dissection is required. Dissection and identification must be undertaken by a suitably qualified inspector who has been approved by the department to undertake this task. Identification must be based on a diagnostic key that has been approved by the department for use in this context. Molecular identification will entail the development, validation and standardisation of a molecular procedure that meets the department's requirements for sensitivity and specificity. The identification procedure will be described in the Approved Arrangement and the protocol for its application will be based on the anticipated size of consignment.
- Imported adult snails will remain under the Approved Arrangement and within the biosecure facility where they will be bred to the next generation. Throughout this period, the imported snails will be isolated from Australian snails and from the definitive host of both *Angiostrongylus spp.* and *Crenosoma vulpis*. This will ensure that the following generation of *C. aspersum* will be free of *Angiostrongylus spp.* and *Crenosoma vulpis*. Isolation within the biosecure facility will also break the life cycle of vectored plant pathogens. Successive generation(s) of snails will then be eligible for release from the Approved Arrangement and site.
- The imported adult snails will not be eligible for release from the Approved Arrangement site. They will either remain within the site for their natural life or will be euthanised. The remains of imported adult snails will be managed as biosecurity waste.

Species verification and biosecurity measures for hatchling snails

- Hatchling snails are hatchlings less than 10 days old that have not been released from the hatching environment and have not been exposed to plant substrate.
- Hatchling snails must be sourced from establishments that employ either an internal or mixed (internal and external) farming system and must only have received commercially processed livestock feed.
- Hatchling snails must be certified by the exporter and exporting country as *C. aspersum* only. Certification of species may be based on morphological identification of breed stock or on an

approved molecular method. Approval will entail the development, validation and standardisation of a molecular procedure that meets the department's requirements for sensitivity and specificity.

- Hatchling snails will be directed to an Approved Arrangement on arrival at the Australian border. This will be a government-supervised biosecure facility where the snails can be held while species is verified.
- A subset of the hatchling snails within each imported consignment will be subject to species verification by molecular identification. This will entail the development, validation and standardisation of a molecular procedure that meets the department's requirements for sensitivity and specificity. The protocol for the application of this procedure will be described in the Approved Arrangement and will be based on the anticipated size of a consignment.
- Having verified the species of hatchling snails within a consignment (as above), the consignment may be released from biosecurity control. It will be a condition of the import permit that imported hatchling snails are for breeding purposes only and must not be used for human consumption.

6.2 Certification for species verification and biosecurity

A veterinary health certification will be required for live garden snails (*C. aspersum*) exported to Australia. This certificate must be signed by an Official Veterinarian. The department may review these conditions if there is reason to believe that the animal health or phytosanitary status of an exporting country has changed.

The certificate must provide details of:

- The packaging of the live garden snails for export to Australia, including details of the labelling
- The addresses and, where applicable, the identification numbers of establishments at which the live garden snails for export to Australia were raised
- The names and addresses of the exporter and the consignee
- Species of the live garden snails for export to Australia within the consignment.

The Official Veterinarian of the source country must certify in English and also in a language understood by the Official Veterinarian of the approved country, if required, that:

- The live garden snails for export to Australia are *C. aspersum*
- The live garden snails for export to Australia have been continuously resident in the exporting country since hatching
- The live garden snails for export to Australia have been sourced from an approved snail farming establishment. To be approved, this must be a commercial establishment that is not incorporating field (wild) snails into their stock. These establishments must be government certified for basic quality standards for food safety and general hygienic operation.

The current Quality Standard document(s) applicable to the commercial operation must be attached to the import application.

- The live garden snails for export to Australia must not be field collected
- The live garden snails for export to Australia were prepared and/or stored at the following establishments <insert list>
- The live garden snails for export to Australia have been subject to effective separation controls to ensure the prevention of inadvertent or deliberate substitution, and the prevention of comingling with, or contamination by, animal material not eligible for export to Australia
- The live garden snails for export to Australia have been prepared for export and packed on <insert date> and the bags, wrappers or packing containers were clean and new
- The live garden snails for export to Australia were not exposed to contamination prior to export
- The live garden snails for export to Australia will be transported in a clean packing container sealed with a seal bearing the number or mark <insert mark>. The container contains only garden snails eligible for entry into Australia.

7 Appendices

7.1 Appendix A: hazard identification

Under the World Organisation of Animal Health (WOAH) Code, hazard identification is a categorisation step, identifying biological agents dichotomously as hazards or not. The risk assessment may be concluded if hazard identification fails to identify hazards associated with the importation.

A set of questions distils the key considerations for hazard identification for this biosecurity import risk review, including:

- Are there any pathogens that can infect *C. aspersum* that could be imported along with the snail?
- Are these pathogens present in Australia?
- Can the introduction, establishment and spread of pathogens introduced in imported infected *C. aspersum* which have escaped/been released into the environment, cause adverse outcomes in Australia if a significant outbreak eventuated?

Hazard identification identified 14 pathogens (to genus group) which could infect *C. aspersum*, were exotic to Australia and which could have significant adverse consequences in Australia. Of these, eight pathogens (to genus group) were then retained for further review.

The results of the hazard refinement process, including the reason for removal or retention of each identified hazard are summarised in Table 6. The diseases retained for review include:

- *Angiostrongylus* spp., including:
 - *Angiostrongylus (Aelurostrongylus) abstrusus*
 - *Angiostrongylus cantonensis*
 - *Angiostrongylus chabaudi*
 - *Angiostrongylus vasorum*
- *Brachylaima* spp., including:
 - *Brachylaima aspersae*
 - *Brachylaima cribbi*
 - *Brachylaima llobregatensis*
 - *Brachylaima mascomai*
- *Crenosoma vulpis*
- *Dicrocoelium dendriticum*
- *Phasmarhabditis* spp.
- *Riccardoella limacum*
- *Tetrahumena* spp., including:
 - *Tetrahymena rostrata*
 - *Tetrahymena limacis*
- *Troglostrongylus brevior*

Table 6 Hazard identification

Agent	Agent species	Known susceptible species	Adverse consequences in Australia	Exotic to Australia	Retained for further review
<i>Alloionema appendiculatum</i> Nematode	n/a	Snails in the families Helicidae (including <i>C. aspersum</i>), Agriolimacidae, Hygromiidae, Succineidae Slugs in the family Arionidae	Could potentially infect native snails and slugs.	Unknown	No. Refer to Department of Climate Change, Energy, the Environment and Water
<i>Angiostoma aspersae</i> Nematode	n/a	<i>C. aspersum</i> Salamanders: <i>Lyciasalamandra antalyana</i> <i>Lyciasalamandra luschani</i>	Little information on this species. Could potentially infect native snails and slugs.	Yes	No Sparse information available. Hosts are salamanders. Very restricted distribution.
<i>Angiostrongylus</i> spp. Nematode	<i>Angiostrongylus (Aelurostrongylus) abstrusus</i>	Felines <i>Felis catus</i> <i>Acinonyx jubatus</i> <i>Panthera onca</i> <i>Felis concolor</i> <i>Panthera leo</i> <i>Panthera tigris altaica</i>	Yes Domestic cats are affected by this species. The introduction of new strains/genotypes could have adverse consequences to domestic cats.	No	No
	<i>Angiostrongylus cantonensis</i>	Rodents ²⁴ rat species with <i>Rattus norvegicus</i> and <i>R. rattus</i> identified as responsible for greatest distribution Accidental hosts: Humans, Australian native fauna, domesticated and wild animals	Yes	No	No. However, some details included in chapter on <i>Angiostrongylus</i> spp.
	<i>Angiostrongylus chabaudi</i>	Felines	Yes Domestic cats are affected by this species.	Yes	Yes
	<i>Angiostrongylus mackerrasae</i>	Rodents <i>Rattus fuscipes</i> <i>Melomys cervinipes</i> <i>Rattus leucopus</i>	No	No	No

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Agent	Agent species	Known susceptible species	Adverse consequences in Australia	Exotic to Australia	Retained for further review
	<i>Angiostrongylus vasorum</i>	Canines <i>Canis lupus familiaris</i> <i>Cerdocyon thous</i> <i>Ducicyon azarae</i> <i>Ducicyon. vetulus</i> <i>Fennecus zerda</i> <i>Vulpes vulpes</i> Paratenic hosts: lizards, mice, rats	Yes This species infects canids. Domestic dogs, dingoes and foxes would be at risk of infection.	Yes	Yes
<i>Brachylaima</i> spp. Trematode	<i>Brachylaima aspersae</i>	Rodents Known definite host: mouse (<i>Mus musculus</i>)	Yes Little information available on this species. Only one known host. It could potentially infect native rodents and other animals.	Yes	Yes
	<i>Brachylaima cribbi</i>	Birds, mammals, reptiles Known definitive hosts: Bird: emu (<i>Dromaius novaehollandiae</i>) chicken (<i>Gallus gallus</i>) pigeon (<i>Columba livia</i>) little raven (<i>Corvus mellori</i>) black bird (<i>Turdus merula</i>) starling (<i>Sturnus vulgaris</i>) Mammal: mouse (<i>Mus domesticus</i>) sheep (<i>Ovis</i> spp.) cat (<i>Felis catus</i>) Reptile: Shingleback lizard (<i>Tiliqua rugosa</i>)	Yes, but already present. The origin of this species has not been established. It is therefore possible that new strains / genotypes are introduced.	No	Yes
	<i>Brachylaima llobregatensis</i>	Rodents	Yes	Yes	Yes

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Agent	Agent species	Known susceptible species	Adverse consequences in Australia	Exotic to Australia	Retained for further review
		Known definite hosts: <i>Crocidura russula</i> <i>Mus spretus</i> <i>Mus musculus</i>	Little information available on this species. Known hosts are all rodents. It could potentially infect native rodents and other animals.		
	<i>Brachylaima mascomai</i>	Rodents Known definitive host: <i>Rattus norvegicus</i> <i>Rattus rattus</i> <i>Mus musculus</i> <i>Crocidura russula</i> <i>Meriones unguiculatus</i> <i>Apodemus sylvaticus</i>	Yes Little information available on this species. Known hosts are all rodents. It could potentially infect native rodents and other animals.	Yes	Yes
<i>Crenosoma vulpis</i> Nematode	n/a	Fox (<i>Vulpes vulpes</i>) Coyote (<i>Canis latrans</i>), Dogs (<i>Canis lupus familiaris</i>) Badgers (<i>Meles meles</i>)	Yes Domestic dogs, dingoes and foxes would be at risk of infection.	Yes	Yes
<i>Cryptobia helicogena</i> Protozoan	n/a	Snails <i>C. aspersum</i> <i>Helix pomatia</i>	Yes Could potentially infect native snails and slugs.	Yes	No Sparse information available.
<i>Dicrocoelium dendriticum</i> Trematode	n/a	Livestock including sheep, cattle, llama Rabbits, pigs, dogs Humans	Yes The role of <i>C. aspersum</i> as an intermediate host is unclear. This parasite has a broad host range, can impact livestock and can also infect humans. It could potentially infect native animals.	Yes	Yes
<i>Phasmarhabditis</i> spp. Nematode	<i>Phasmarhabditis hermaphrodita</i>	Snails in the family Helicidae (including <i>C. aspersum</i>) Slugs in the families Limacidae, Agriolimacidae, Arionidae, Milacidae, Vaginulidae	Yes Could potentially infect native snails and slugs.	Yes	Yes
	<i>Phasmarhabditis californica</i>	<i>C. aspersum</i>	Yes	Yes	Yes

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Agent	Agent species	Known susceptible species	Adverse consequences in Australia	Exotic to Australia	Retained for further review
			Little information on this species. Could potentially infect native snails and slugs.		
<i>Rhabditis maupasi</i> Nematode 10	n/a	<i>C. aspersum</i>	No, but could potentially infect native snails and slugs.	Unknown	No Sparse information, no evidence of animal biosecurity impact, referred to Department of Health and Aged Care as <i>C. aspersum</i> for human consumption can carry parasite.
<i>Riccardoella limacum</i> Mite	n/a	<i>C. aspersum</i> <i>Arianta arbustorum</i>	Yes Could potentially infect native snails and slugs	Yes	Yes
<i>Tetrahymena</i> spp. Protozoan	<i>Tetrahymena limacis</i>	Slugs in the Arionidae, Milacidae and Limacidae families Snails in the Bradybaenidae, Daudebardiidae, Helicidae, Hygromiidae, Succineidae, Vitrinidae and Zonitidae families.	Yes Could potentially infect native snails and slugs.	Unknown	Yes.
	<i>Tetrahymena rostrata</i>	Snails and slugs Snails in the Helicidae (including <i>C. aspersum</i>) Oleacinidae and Zonitidae Slugs in the Agriolimacidae and Arionidae families	Yes Could potentially infect native snails and slugs.	No	As part of <i>Tetrahymena</i> spp. chapter.
<i>Tetratrichomonas limacis</i> Protozoan	n/a	Snails and slugs <i>C. aspersum</i> <i>Limax flavus</i> <i>Deroceras agreste</i> <i>Limax maximus</i> <i>Helix pomatia</i> <i>Otala lacteal</i>	No information but could potentially infect native snails and slugs.	Unknown	No
<i>Troglostrongylus brevior</i>	n/a	Felids	Yes	Yes	Yes

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Agent	Agent species	Known susceptible species	Adverse consequences in Australia	Exotic to Australia	Retained for further review
Nematode			Domestic cats would be at risk of infection.		

n/a: not applicable.

7.2 Appendix B: species of garden snail

Table 7 Comparison of snail species in Australia and worldwide

Snail species	Morphology	Origin	Present in Australia	Is this species farmed?	Is this species field collected?	Comments	References
<i>Cornu aspersum</i> = <i>Helix aspersa aspersa</i> Common garden snail Petit gris	Shell size: 25–35 mm diameter x 25–35 mm height Shell colour: light brown to dark brown with darker coloured bands and yellow fleck Shell shape: round and globose Whorls: 4–5 Large and rounded aperture Closed umbilicus	Mediterranean region Now also found in: Africa Asia Europe North America Oceania South America	Yes	Yes Sizes of farms vary from cottage industry or hobbyists to large scale commercial production. No commercial farms in Australia, only cottage industry.	Yes Farm raised in countries where it has been intentionally introduced such as eastern Europe, South America and Asia. Field collected, due to overharvesting and agricultural chemicals has become rare to find in the wild in places like the Republic of Türkiye.	<i>Helix</i> snails constitute 70% of world market (<i>Helix aspersa</i> 40%). Most suitable and easily grown species to farm in Italy. Invasive pest of agricultural crops in the Americas, south-eastern parts of Australia, New Zealand, South Africa and elevated areas (>1,000 m). High change of wild caught snails being contaminated with heavy metals presenting risk to humans.	(Conte, 2015; Begg, 2003; Blacket <i>et al.</i> , 2016; Begg, 2006; Nordsieck, 2022a; Murphy, 2001; CABI, 2015)
<i>Helix aspersa maxima</i> = <i>Cornu aspersum maximum</i> Gros gris	Shell size: 45 mm diameter Shell colour: similar to <i>C. aspersum aspersum</i> Weight: 20–30 g Bigger than <i>C. aspersum aspersum</i>	North Africa	No	Yes Commercial	No	Growing conditions have been adapted to support breeding of these snails in Europe.	(Aude <i>et al.</i> , 2019; CABI, 2015)

Importation of live garden snails (*Cornu aspersum*): Biosecurity Import Risk Review

Snail species	Morphology	Origin	Present in Australia	Is this species farmed?	Is this species field collected?	Comments	References
<i>Helix pomatia</i> Roman snail, Burgundy snail, escargot de Bourgogne	Shell size: 38–50 mm or 1/3 size of snail Shell colour: brown with 4–5 light brown bands Shell shape: round spiral Whorls: 4–5	Central and Southeast Europe Now also found in: North America, South America Asia	No	Yes 160 farms in Sardinia (Italy) for <i>Helix</i> genus under the support of the International Institute of Snail Farming (2,000 members). 9,800 kg produced in Italy 200. Sizes of farms vary from cottage industry or hobbyists to large scale commercial production.	Yes Field collected, but due to overharvesting and agricultural chemicals has become rare to find in the wild. Difficult to breed on a large scale due to artificial conditions of a farm. Commercial. Exploitation prohibited in Western Europe (still occurring in Eastern Europe).	Most popular in Europe and North America. Meat is considered most juicy and tasty. In places like Central Romania, 50–150 families at a time make collection an annual even. <i>Helix</i> snails constitute 70% of world market (<i>Helix pomatia</i> 28%).	(Animalia, 2022; Ligaszewski <i>et al.</i> , 2007; Ligaszewski and Pol, 2021; Ligaszewski <i>et al.</i> , 2009; Conte, 2015; Thompson and Cheney, 1996)
<i>Helix lucorum</i> Turkish snail	Shell size: 35–60 mm width x 25–45 mm height Shell colour: brown tip with white spherical spiral bands Shell shape: heavily depressed Weight: 20–25 g	Eastern Black Sea region through Asia Minor Southern Romania and Bulgaria Italy Introduced in Austria	No	No	Yes Field collected in the Republic of Türkiye – regional standards suggested such as size, diameter, weight and time of year (after copulation).	Most popular in Europe and North America. <i>Helix</i> snails constitute 70% of world market (<i>Helix lucorum</i> 22%).	(Nordsieck, 2022b; Conte, 2015; Neubert, 2011)
<i>Helix cincta</i>	Shell size: 37 ± 4 mm diameter Shell colour: light brown with thin bands	The Republic of Türkiye North East Mediterranean from Italy to the Middle East	No	No	Yes	Not consumed in the Republic of Türkiye but a main export item.	(Yildirim <i>et al.</i> , 2004; Giusti <i>et al.</i> , 2015)

Importation of live garden snails (*Cornu aspersum*): Biosecurity Import Risk Review

Snail species	Morphology	Origin	Present in Australia	Is this species farmed?	Is this species field collected?	Comments	References
	Shell shape: compressed last turn with rough surface Short brown peristome						
<i>Cantareus apertus</i> = <i>Helix adanensis</i> = <i>Cornu apertus</i> Green snail	Shell size: 15–30 mm diameter Shell colour: olive green (juveniles), light brown shell (adults), no banding Whorls: 4–5 Aperture extremely large relative to body (larger aperture than <i>C. aspersum</i>)	Mediterranean region (Europe and North Africa) Introduced to Australia (WA) and North America	Yes Declared pest	No	Yes	Not consumed in the Republic of Türkiye but a main export item.	(Blacket <i>et al.</i> , 2016; Yildirim <i>et al.</i> , 2004)
<i>Cepaea nemoralis</i> English garden snail	Shell size: 20–26mm diameter Shell colour: yellow, pink or brown with 1–5 bands Distinguished from <i>C. hortensis</i> by its brown apertural lip (opening of the shell)	Central and Western Europe Introduced to North America	No	No	Yes	Ease of culture, near worldwide availability and hardiness has led to them being cultured for human consumption.	(Dees, 1970; Pearce <i>et al.</i> , 2010; Rosin <i>et al.</i> , 2013; Ozgo and Schilthuizen, 2012; Whitson, 2005)
<i>Cepaea hortensis</i> Smaller banded snail	Shell size: 20 mm diameter Shell colour: yellow to brown with 1–5 thin chestnut brown stripes Distinguished from <i>C. nemoralis</i> by its white apertural lip (opening of the shell)	Central and Northern Europe, extending more north than <i>C. nemoralis</i> North America	No	No	Yes	Least popular of the large European snails.	(Cowie and Jones, 1987; Pearce <i>et al.</i> , 2010; Dees, 1970; Thompson and Cheney, 1996)

Importation of live garden snails (*Cornu aspersum*): Biosecurity Import Risk Review

Snail species	Morphology	Origin	Present in Australia	Is this species farmed?	Is this species field collected?	Comments	References
<i>Eobania vermiculata</i> = <i>Massylaea vermiculata</i> Chocolate-banded snail	Shell size: 22–35mm diameter Shell colour: white, green or yellow with darker chocolate colour bands Whorls: 5–6	Mediterranean region The Republic of Türkiye	Unsure Introduced to South-eastern Australia; appears locally extinct. On National Priority Pests list 2019.	Yes 4,420 kg produced in Italy 2002. Sizes of farms vary from cottage industry or hobbyists to large scale commercial production.	Yes collected	Quite difficult to raise in captivity. Important export item for the Republic of Türkiye. 8.5% world market.	(Conte, 2015; Yildirim <i>et al.</i> , 2004)
<i>Otala lactea</i> Milk snail	Shell size: 27.5–36 mm diameter x 16–25 mm high Shell colour: light brown (almost white) with speckled dark brown lines along the shell whorls Shell shape: non globular, slightly depressed	Northern Africa Spain South America	No		Yes	None	(White-McLean, 2022b; Dees, 1970)
<i>Otala punctata</i>	Shell size: 33–39 mm wide x 20–24 mm high Shell colour: dark brown with lots of white flecks along whorls	Mediterranean South Africa North America	No		Yes	None	(White-McLean, 2022b; Barbara and Schembri, 2008)
<i>Theba pisana</i> White garden snail	Shell size: 12–25 mm width x 9–20 mm height Shell colour: creamy white shell with diverse range of pale-dark brown markings.	Mediterranean Atlantic coast of Europe Southwest England and Wales	Yes		Yes	Serious agricultural pest worldwide, and in Australia, particularly in South Australia.	(Cowie <i>et al.</i> , 2009; Dees, 1970; Leonard, 2003; Caetano <i>et al.</i> , 2021; CABI, 2020; ALA, 2022)

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Snail species	Morphology	Origin	Present in Australia	Is this species farmed?	Is this species field collected?	Comments	References
	Uninterrupted spiral bands, dotted lines or small radial smudges	Introduced to Australia and USA				Mainly consumed in the Iberian Peninsula (Spain and Portugal). 4,000 tonnes per year consumed in Portugal. Growing and large economic market. Important export item for the Republic of Türkiye.	
<i>Achatina achatina</i> Common African snail	Shell size: 180 mm length x 90 mm diameter Body size: 300 mm length and 250 mm height (largest snail species worldwide) Shell colour: brown with striped pattern 'tiger snail' Shell shape: conical	West Africa	No	Yes Commercial Cottage industry	Yes 18.2% of farmers in Nigeria obtain snails from wild. Very few farmers (<4%) start with eggs or hatchlings. Market makes up 30% of snails that are farmed.	Snails purchased from the market are hand-picked from their natural habitat. Preferred source of snails for consumers as it is widely believed they taste better. Snails are taken from wild before reaching sexual maturity – threatens survival. High change of wild caught snails being contaminated presenting risk to humans. Hardest species to farm due to stable conditions it is accustomed to in the wild but by far most popular in West Africa (2 nd and 3 rd most popular <i>Archachatina marginata</i>	(Chah and Inegbedion, 2013; Nyoagbe <i>et al.</i> , 2016; Ngenwi <i>et al.</i> , 2010; Cobbinah, 1993)

Importation of live garden snails (*Cornu aspersum*): Biosecurity Import Risk Review

Snail species	Morphology	Origin	Present in Australia	Is this species farmed?	Is this species field collected?	Comments	References
						and <i>Achatina fulica</i> respectively).	
<i>Achatina (Lissachatina) fulica</i> Giant African land snail	Shell size: 200 mm length x 120 mm diameter Shell colour: brown with darker bands across spiral Weight: 250 g	East Africa	No An outbreak occurred in QLD in 1977 but was quickly eradicated. A single animal was also found in QLD in 2004. On National Priority Pests list 2019.	Yes Commercial Cottage industry	Yes 18.2% of farmers in Nigeria obtain snails from wild. Very few farmers (<4%) start with eggs or hatchlings. Market makes up 30% of snails that are farmed.	Snails purchased from the market are hand-picked from their natural habitat. Preferred source of snails for consumers as it is widely believed they taste better. Snails are taken from wild before reaching sexual maturity – threatens survival. High chance of wild caught snails being contaminated presenting risk to humans. Causes considerable economic damage to crops.	(Chah and Inegbedion, 2013; Nyoagbe <i>et al.</i> , 2016; Government, 2019; Cobbinah, 1993)
<i>Archachatina marginata</i>	Shell size: up to 210 mm length x 130 mm in diameter Shell colour: brown to yellow, striated 'woven' look Shell shape: more rounded than other African species Weight: 500 g	African rainforest belt / West Africa	No	Yes Commercial Cottage industry	Yes 18.2% of farmers in Nigeria obtain snails from wild. Very few farmers (<4%) start with eggs or hatchlings. Market makes up 30% of snails that are farmed. Largely rudimentary and its demand is met by hunting	Snails purchased from the market are hand-picked from their natural habitat. Preferred source of snails for consumers as it is widely believed they taste better. Snails are taken from wild before reaching sexual maturity – threatens survival.	(Chah and Inegbedion, 2013; Nyoagbe <i>et al.</i> , 2016; Jimoh and Akinola, 2020; White-McLean, 2022a)

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Snail species	Morphology	Origin	Present in Australia	Is this species farmed?	Is this species field collected?	Comments	References
					from their habitat in the wild.	High change of wild caught snails being contaminated presenting risk to humans. Highest yield out of the three main species farmed in Nigeria.	
<i>Elona quimperiana</i> Quimper snail	Shell size: 30 mm diameter Shell colour: translucent Shell shape: flat and smooth Slightly reflected apertural margin	France Spain	No	No	Yes	None	(Raven, 2022)
<i>Sphincterochila candidissima</i>	Shell size: 13.3–20.5 mm Shell colour: pure white	Mediterranean Spain	No	No	Yes	None	(Moreno-Rueda, 2008; Yanes and Fernandez-Lopez-de-Pablo, 2017)
<i>Iberus alonensis</i>	Shell size: 30 mm diameter Shell colour: creamy light brown		No	No	Yes	Only in Spain Threatened Unlikely important	(Thompson and Cheney, 1996)

8 Glossary

Term	Definition
ALOP	Appropriate Level of Protection
Approved Arrangement	<p>Approved arrangements, previously Quarantine Approved Premises and Compliance Agreements, are voluntary arrangements entered into with the Department of Agriculture, Fisheries and Forestry.</p> <p>These arrangements allow operators to manage biosecurity risks and/or perform the documentary assessment of goods in accordance with departmental requirements, using their own sites, facilities, equipment and people, and without constant supervision by the department and with occasional compliance monitoring or auditing.</p> <p>Further detail at Approved Arrangements.</p>
Approved Arrangement site	<p>A site where a biosecurity industry participant undertakes biosecurity activities covered by an Approved Arrangement. For biosecurity industry participants that undertake mobile biosecurity activities, the biosecurity industry participants Approved Arrangement site is the location from which the mobile activities are based.</p> <p>Further detail at Approved Arrangement site.</p>
Approved Country	An approved country is one assessed by the Department of Agriculture, Fisheries and Forestry based on relevant factors such as history of trade and knowledge of the competent authority, history of reporting to WOAHP for notifiable animal diseases, history of compliant trade to Australia, and verification activities which may have been undertaken historically.
BIRA	Biosecurity import risk analysis
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
DCCEEW	Australian Government Department of Climate Change, Energy, the Environment and Water
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
Heliculture	Synonymous with heliciculture and means the science of snail rearing (or farming)
IPPC	International Plant protection Convention
ISPM	International Standards for Phytosanitary Measures
ISPM 11	Pest Risk Analysis for Quarantine Pests
The department	Australian Government Department of Agriculture, Fisheries and Forestry
WOAH	The World Organisation for Animal Health

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