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AN UPDATE ON THE WEST AFRICAN *LIMICOLARIA FLAMMEA* (MÜLLER, 1774) IN SINGAPORE, AND ITS DISTINCTION FROM THE CONFAMILIAL *ACHATINA FULICA* BOWDICH, 1822 (MOLLUSCA: GASTROPODA: ACHATINIDAE)

S. K. Tan[1]* and **Martyn E. Y. Low**[2]
[1]*Raffles Museum of Biodiversity Research, National University of Singapore*
Block S6, Science Drive 2, #03-01, Singapore 117546, Republic of Singapore
[2]*Department of Marine and Environmental Sciences, Graduate School of Engineering and Science*
University of the Ryukyus, 1 Senbaru, Nishihara, Okinawa 903-0213, Japan
*(*Corresponding author: dbstsk@nus.edu.sg)*

***ABSTRACT.* —** The West African snail *Limicolaria flammea* (Müller, 1774) was recently recorded from Singapore. Herein, we update the localities in Singapore at which this species has been found. Local authorities have expressed concern regarding the introduction of this species and its possible establishment. As it is uncertain if *Limicolaria flammea* has successfully established a long-term presence in Singapore, its reliable identification and eradication are vital. To facilitate its identification, diagnostic shell characters and figures are provided here.

INTRODUCTION

Several African snails of the family Achatinidae have attained notoriety as pests (Raut & Barker, 2002). Nearly a century after the East African achatinid *Achatina fulica* Bowdich, 1822, was introduced into the Malay Peninsula (see Mead, 1961: 11), the confamilial West African *Limicolaria flammea* (Müller, 1774) was discovered in Singapore in 2006 (Tan & Clements, 2011)—the first record of this species outside its home range of West Africa. *Limicolaria aurora* (Jay, 1839), was hitherto the only member of this genus known to have similarly escaped its home range (Mead & Palcy, 1992).

Herein, we update the localities in Singapore at which this species has been found (see Fig. 1), as additional populations have been found or reported since the paper by Tan & Clements (2011). Officers from the local agency responsible, the Agri-Food & Veterinary Authority of Singapore (AVA), have expressed concern regarding the introduction of this species and its possible establishment. In response to their enquiries on diagnosing this new alien species from the confamilial *Achatina fulica*, we discuss the diagnostic shell characters of both species and provide figures to aid in reliable identification. An unpublished version of the Appendix has been sent to the AVA.

In the next section, we discuss the impact of invasive snail species. A detailed discussion on the shell characteristics that distinguish *Limicolaria flammea* from *Achatina fulica* follows. A summary of the essential characteristics for their identification is summarised in the Appendix. This format was selected as we foresee an increasing interest in the spread of *Limicolaria flammea*, and it is our intention that the Appendix can be printed as a one-page identification guide.

AFRICAN SNAILS AS ALIENS AND PESTS

Many achatinids have attained pest status even within their native range when the habitat is modified for human habitation and farming (Raut & Barker, 2002). The giant African snail, *Achatina fulica*, which has been introduced to many countries, is most notable as one of the worst snail pests known. Besides being a serious plant pest, it presents a possible risk to public health as a vector of parasitic diseases (Kliks & Palumbo, 1992; Raut & Barker, 2002). Although the confamilial *Limicolaria* has not attained the same level of notoriety, the danger it poses is very real. Several *Limicolaria* species are known to occur in abundance in forest edges and modified habitats such as plantations and farms (Raut & Barker, 2002). In an area between Nigeria and Cameroon, the native *Limicolaria zebra* (Pilsbry, 1904) and *Limicolaria numidica* (Reeve, 1848) destroyed leguminous cover crops which were inter-planted with oil palm (Spence, 1938). Even the oil palms were not spared and the palm fruits themselves were eaten. Elsewhere, another congener, *Limicolaria aurora*, has caused damage to a variety of crops in Martinique where it has been introduced (Mead & Palcy, 1992).

In addition to *Limicolaria flammea* being possibly misidentified as *Achatina fulica*, its largely nocturnal habits make detection difficult. Hiding *Limicolaria* snails are extremely difficult to locate and it is known that they spend a considerable amount of time in the soil (Raut & Barker, 2002). On a grassy patch at Chong Kuo Road, under a rock, barely 30 cm across, more than a dozen aestivating snails were located (see Fig. 2), some buried to a depth of more than 5 cm beneath the surface. This discovery would not have been made if it were not for the incidental sighting of empty shells in the area.

It is believed that these snails were introduced into Singapore with exotic plants that were purposefully imported. All encounters were in human-modified habitats except Lentor Avenue and Yio Chu Kang Road (C and D in Fig. 1), which are at the edges of secondary forests. Tan & Clements (2011) have recommended that *Limicolaria flammea* be eradicated swiftly based on the precautionary principle, and it is heartening to know that AVA has taken a commendable interest in this issue, with surveys and searches being carried out. However, the true extent of their pervasiveness and their mode of dispersal in Singapore remain unknown. Readers of this article are encouraged to report sightings of this snail to the corresponding author.

INDENTIFICATION

Figure A1 (see Appendix) illustrates the terms used to describe snail (gastropod) shells in general. These terms are used throughout this article in relation to the differential identification of *Limicolaria flammea* from *Achatina fulica*. The characters that differentiate *Limicolaria flammea* from *Achatina fulica* are summarised in Table 1. Note that small juveniles (shell length < 1 cm) may be difficult to identify with certainty.

Limicolaria flammea. — Adult shells can be up to about 5 cm in length. The anterior end of columella merges smoothly with the anterior end of the outer lip and is never truncated (A in Figs. 3, 4). The columella is also straight (B in Figs. 3, 4). The columellar pillar is pale purple in living or very freshly dead specimens, and fades to white in dead specimens (Fig. 3, upper row). Shell colour is light brown with many reddish-brown to dark brown solidly coloured axial bands and streaks; usually with many thin lines near suture on the body whorl (often obvious on the spire) (Fig. 3, upper row). The shell is rather pupiform and less conical in profile, and relatively narrow (shell length versus shell width), giving it a bullet-like shape in general profile (Fig. 4, upper row).

Achatina fulica. — Adult shells can be up to 15 cm long (but usually less than 10 cm). The anterior end of the columella is always truncated (B in Figs. 3, 4). The columella is concave (B in Figs. 3, 4). The columellar pillar is white in colour, sometimes with a bluish tint in living or freshly-dead specimens (Fig. 3, lower row). Shell colour is generally very pale yellowish-brown, with many reddish-brown to dark brown streaks and mottles. Shells of very small juveniles usually appear uniformly coloured (light brown, without obvious patterns) (Fig 3, lower row). The shell is ovately conical being relatively plump (shell length versus shell width), so giving a teardrop-like shape in general profile (Fig. 4, lower row).

As discussed above, for the purposes of field and non-specialist identification, the most pertinent features for the identification of *Limicolaria flammea* and *Achatina fulica* are provided in the Appendix (which can be used and printed independently of the main text).

Table 1. A summary of the characters that differentiate *Limicolaria flammea* (Müller, 1774), from *Achatina fulica* Bowdich, 1822.

Character	***Limicolaria flammea* (Müller, 1774)**	***Achatina fulica* Bowdich, 1822**
Shell length in adults (cm)	≤ 5	≤ 15; typically 10
General profile	Bullet-shaped	Teardrop-shaped
Columella	Straight	Concave
Columella–outer lip junction	Continuous	Truncated

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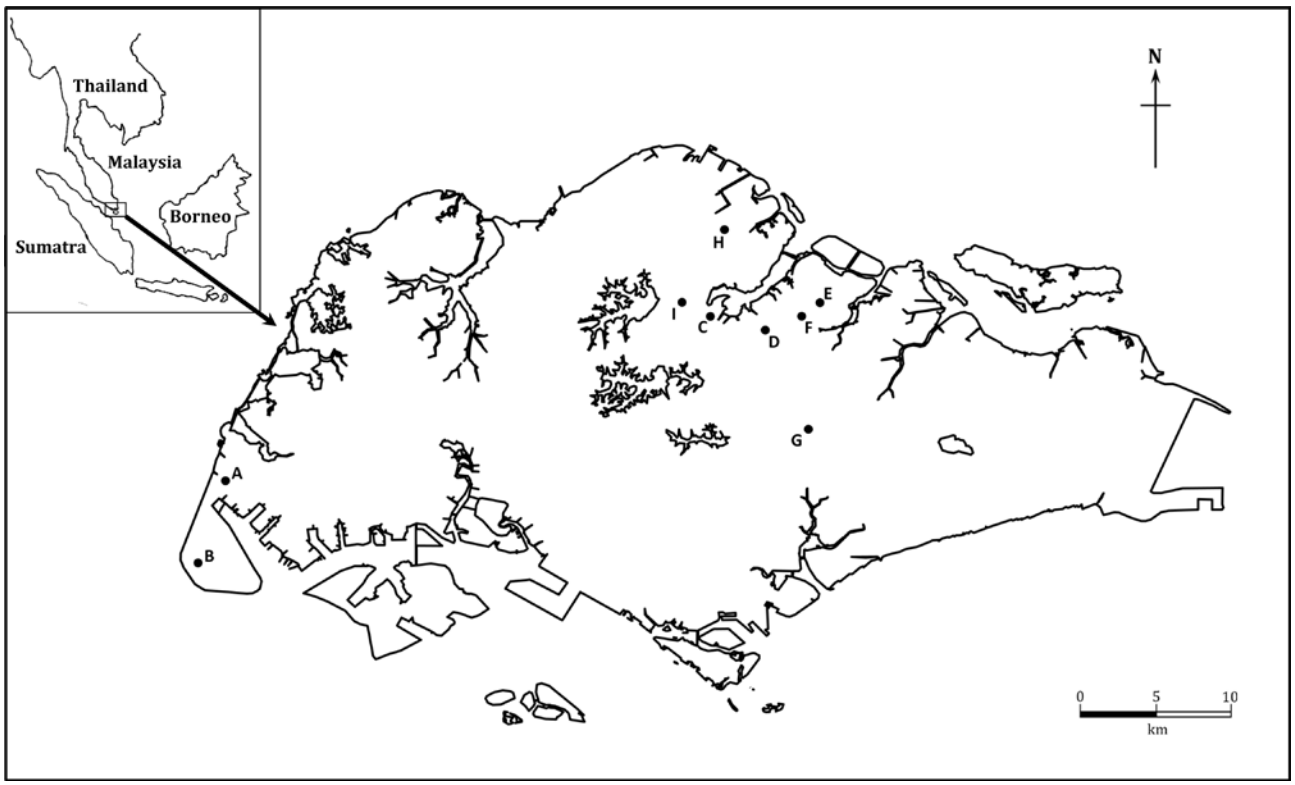

Fig. 1. The known distribution of *Limicolaria flammea* (Müller, 1774) in Singapore in sequential order of discovery: A, Tuas; B, Tuas South; C, Lentor Avenue; D, Yio Chu Kang Road; E, Seletar Aerospace Drive; F, Seletar West Farmway; G, Braddell Heights; H, Yishun Ave 2; I, Chong Kuo Road. Populations at G–I were discovered after Tan & Clements (2011) was published.

Fig. 2. Habitus photographs of *Limicolaria flammea* (Müller, 1774) in Singapore (Chong Kuo Road): A, two buried individuals that were first uncovered after the rock under which they were living was removed; B, a buried individual; C, snails dug up from same patch of soil; D, an aestivating individual showing the epiphragm that temporarily closes the aperture to prevent moisture loss.

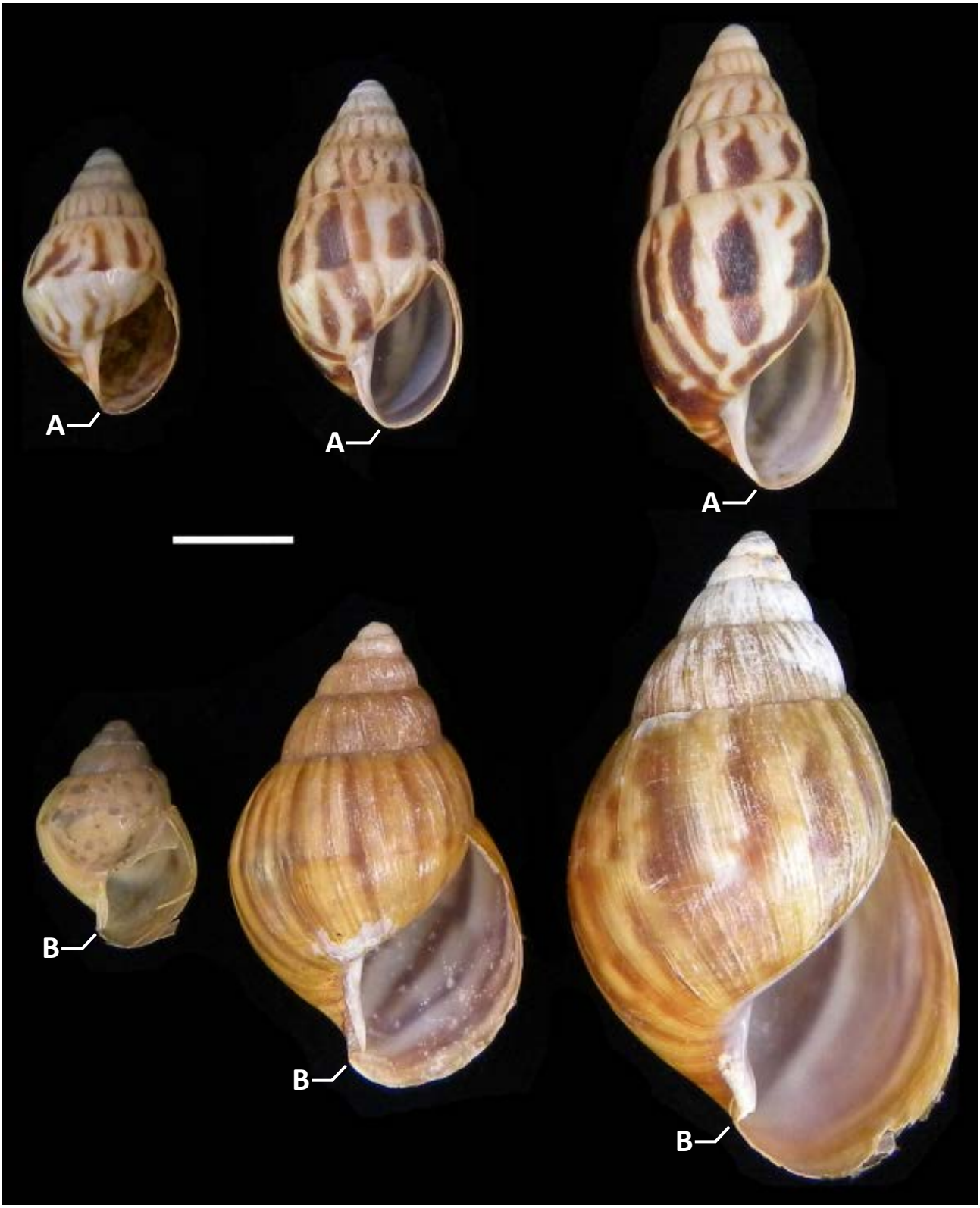

Fig. 3. Growth stages of *Limicolaria flammea* (Müller, 1774) (top row), and *Achatina fulica* Bowdich, 1822 (bottom row) for comparison. Note the straight and continuous columella in *Limicolaria flammea* (A), and the concave and truncated columella in *Achatina fulica* (B). Also note the bullet-shaped general profile of *Limicolaria flammea*, compared to the teardrop-shaped general profile of *Achatina fulica*. Scale bar = 1 cm.

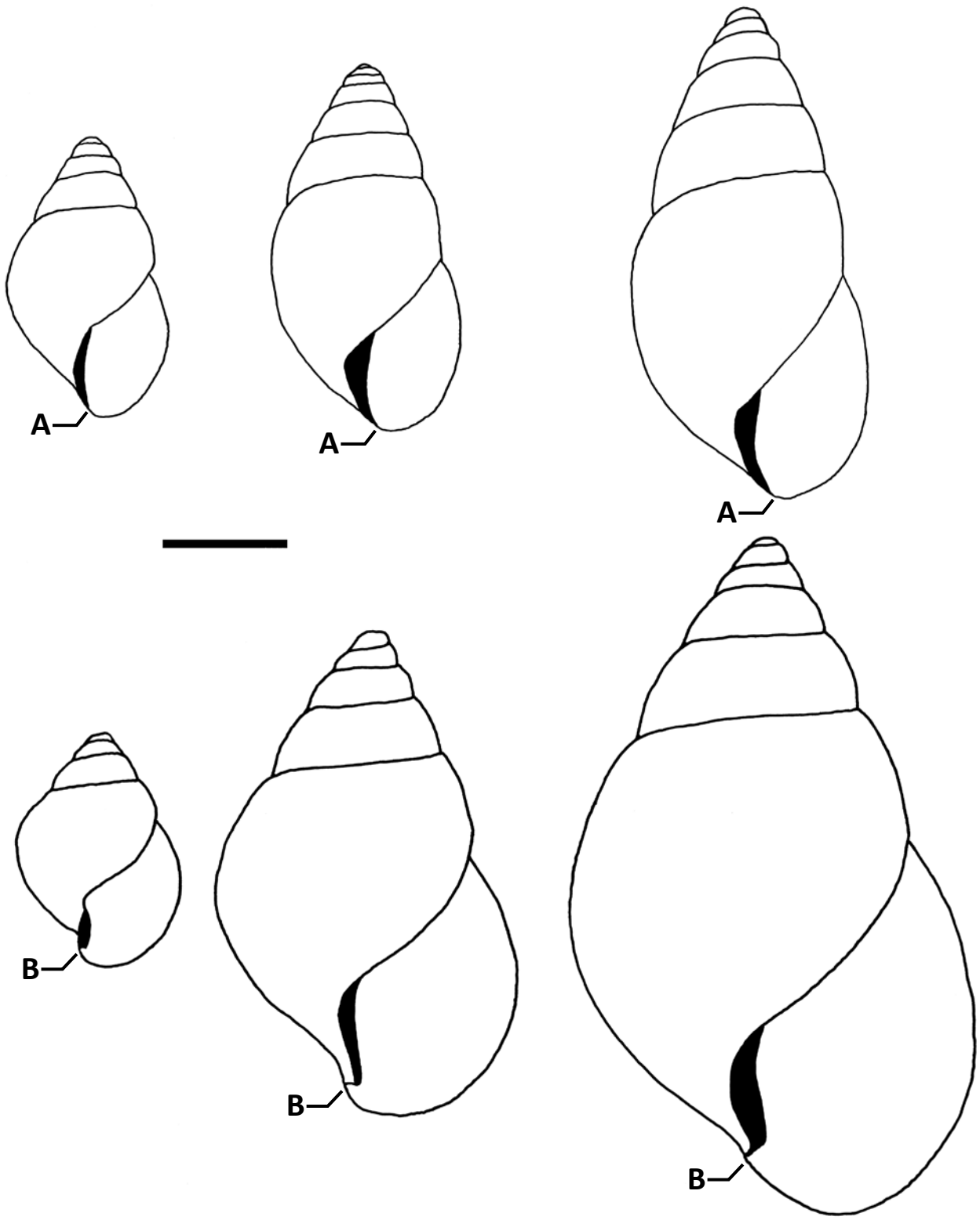

Fig. 4. Line drawings (redrawn after specimens in Fig. 1) of the growth stages of *Limicolaria flammea* (Müller, 1774) (top row), and *Achatina fulica* Bowdich, 1822 (bottom row) for comparison. Note the straight columella pillar that is continuous to the lip in *Limicolaria flammea* (A), and the concave columella that ends in a truncation in *Achatina fulica* (B). Also note the bullet-shaped general profile of *Limicolaria flammea*, compared to the teardrop-shaped general profile in *Achatina fulica*. Scale bar = 1 cm.

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APPENDIX

How to differentiate the newly introduced West African *Limicolaria flammea* (Müller, 1774) from the established East African *Achatina fulica* Bowdich, 1822, in the context of Singapore.

Fig. A1. General characteristics of a snail (gastropod) shell

1. Columella may be continuous or truncated with the outer lip. It may also be straight or concave.
2. General outline is the silhouette of the shell.
3. The shell length is the distance from the apex to the anterior (lowest) part of the outer lip.

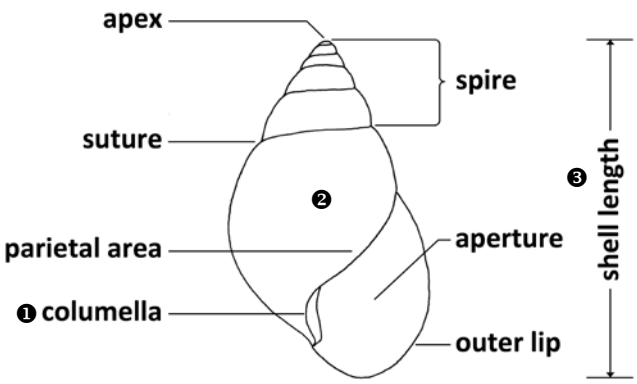
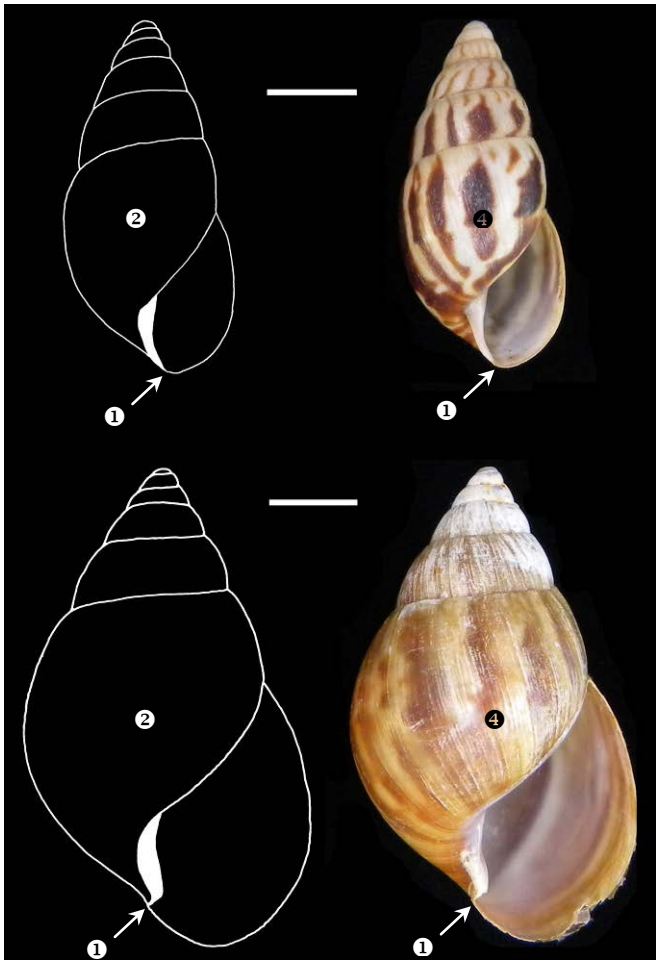


Fig. A2. *Limicolaria flammea* (Müller, 1774)

1. Columella generally straight, continuous with outer lip.
2. General outline is bullet-shaped.
3. Adult shell length usually no more than 5 cm.
4. Colour light brown with solidly coloured reddish-brown to dark brown axial bands and streaks.

Fig. A3. *Achatina fulica* Bowdich, 1822

1. Columella usually concave and always truncated at junction with outer lip.
2. General outline is teardrop-shaped.
3. Adult shell length typically 6 to 10 cm (but up to 15 cm).
4. Colour generally very pale yellowish brown with reddish-brown to dark brown streaks and mottles.



Notes:

1. Small juveniles (shell length < 1 cm) may be difficult to identify with certainty.
2. Scale bars in Figs. A2 and A3 represent 1 cm.
3. This guide applies only to Singapore, where there is no other similar species that can potentially be confused with these two.

First record of *Limicolaria flammea*: Tan, S. K. & R. G. Clements, 2011. *Limicolaria flammea* (Müller, 1774), another potentially invasive African land snail in tropical Asia. *Tropical Conservation Science*, **4**(1): 97–102.

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