

Rat Lungworm (*Angiostrongylus cantonensis*) in Hawai‘i: Updated Host Gastropod Records and Distributions on Maui¹

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INTRODUCTION

Rat lungworm (RLW), *Angiostrongylus cantonensis*, is an emerging infectious disease that causes eosinophilic meningitis. The first reported case of angiostrongyliasis in Hawai‘i was in 1961 (Horio & Alicata 1961) and between 2001 and 2016, 85 cases of this disease were reported (Cowie 2017), three of which were fatal. This is nearly four and a half times as many cases (19) as reported from 1959 to 2000 (Cowie 2017). Kim *et al.* (2014) in their state-wide assessment of intermediate hosts (gastropods) for RLW found that 16 of the 37 species tested carried the parasite, including two native species.

The report of recent cases of eosinophilic meningitis from Maui (Cowie 2017) prompted increased interest in identifying the potential host gastropods and developing a better understanding of the distribution of RLW hosts across the island. As such, surveys for gastropods were conducted December 2016–August 2017, and resulted in the collection of 205 non-native land snails representing 21 species from 13 sites across Maui (Fig. 1), all of which were screened for rat lungworm using the non-quantitative PCR approach from Kim *et al.* (2014).

Nine species from these recent collections tested positive for RLW. Of these, two were new island records as hosts for the parasite, and one is a new state record, never having been reported as a carrier of RLW in Hawai‘i. In total, this brings the number of gastropod hosts for RLW in Hawai‘i to 21. Knowing which snails serve as vectors for the RLW and their distributions on each island is critical to developing effective management and educational outreach strategies to protect the public and natural ecosystems.

Collections were made by Norine W. Yeung (NWY), Jaynee R. Kim (JRK), Keahi M. Bustamente (KMB) and Kenneth A. Hayes (KAH). All collected material are deposited in the Bishop Museum (BPBM) Malacology collection. Catalog numbers are BPBM Malacology collection numbers. Latitude and longitude coordinates were recorded by GPS. Many areas are owned privately, therefore, exact locations are kept in the State of Hawai‘i Invasive Species Council and Bishop Museum Malacology databases.

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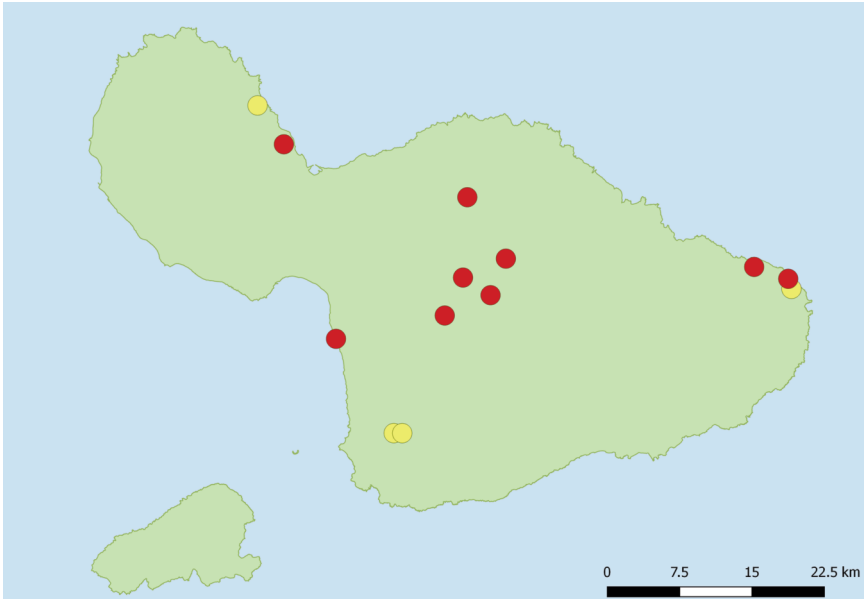


Figure 1. Sites surveyed on Maui as part of this study. Red circles are sites with non-native land snails that were positive for RLW. Yellow circles sites with non-native snails that tested negative for RLW. Map created in QGIS v. 2.18.

Achatinidae

Lissachatina fulica (Bowdich, 1822)

(Fig. 2A)

This species, also known as the giant African snail, was first recorded in Hawai'i in 1936 and is present on all main Hawaiian Islands (Cowie 1997). Wallace & Rosen (1969) first reported this species on O'ahu as a RLW host, and 11.3% (7/62) of the individuals tested were positive in Kim *et al.* (2014), while only 10% (1/10; BPBM 284201) were positive among the 15 collected (BPBM 284187, 284201, 284211, 284219, 284247).

Agriolimacidae

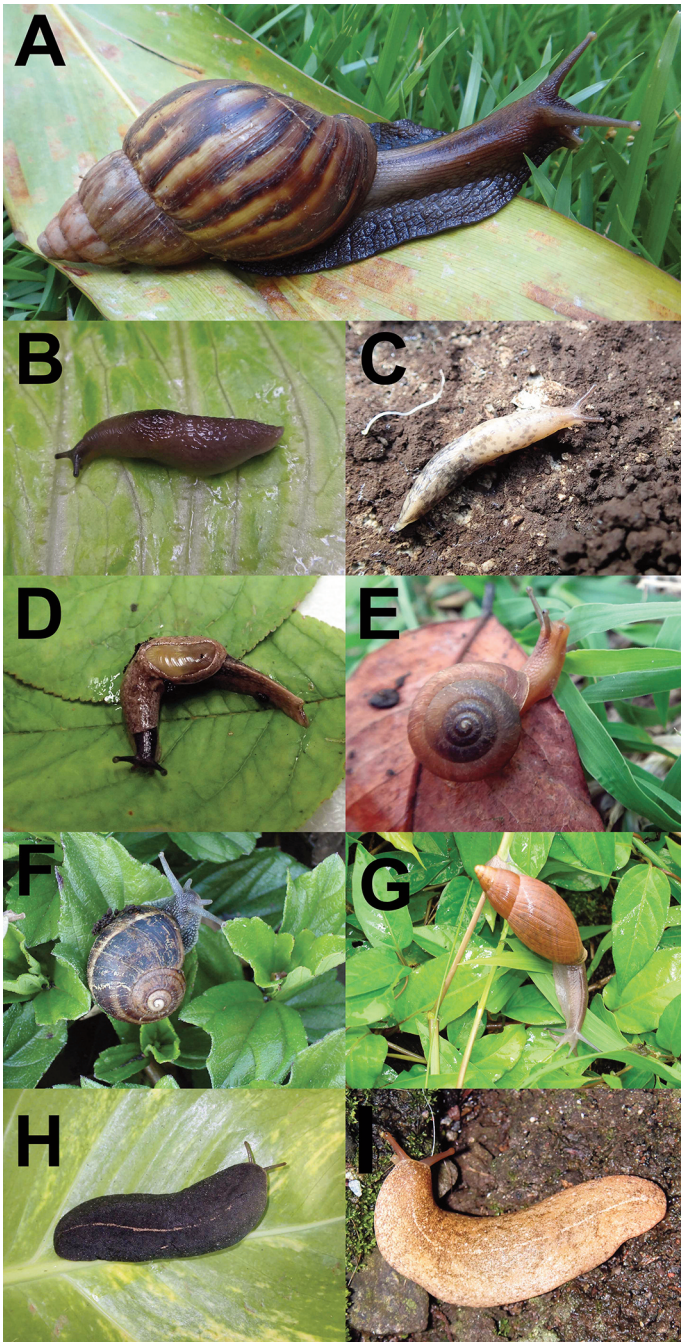
Deroceras laeve (Müller, 1774)

New Island Record for Gastropod Host

(Fig. 2B)

This Western European snail (Kerney & Cameron 1979) was first recorded in Hawai'i in 1897 and considered wide spread on all the main Hawaiian Islands (Cowie 1997). This

Figure 2 (opposite page). **A**) *Lissachatina fulica* (shell length = 10 cm); **B**) *Deroceras laeve* (length = 1.5 cm); **C**) *Deroceras reticulatum* (length = 2.0 cm); **D**) *Parmarion martensi* (length = 4.0 cm); **E**) *Bradybaena similaris* (shell diameter = 1.0 cm); **F**) *Cornu aspersum* (shell diameter = 3.0 cm); **G**) *Euglandina rosea* (shell length = 5.0 cm); **H**) *Laevicaulis alte* (length = 7.0 cm); **I**) *Veronicella cubensis* (length = 7.0 cm).



species was first reported as a carrier of RLW on O‘ahu by Wallace & Rosen (1969), but none of the individuals tested by Kim *et al.* (2014) were positive. In this study, ~56% (10/18) of individuals tested were positive (BPBM 284177, 284191, 284194, 284228, 284234, 284239) from a total sample of 21 individuals collected (BPBM 284177, 284191, 284194, 284228, 284234, 284239, 284252).

***Deroceras reticulatum* (Müller, 1774)**

(Fig. 2C)

This Western European species (Kerney & Cameron 1979) was first recorded in Hawai‘i in 1963 and is found on all main Hawaiian Islands (Cowie 1997, Hayes *et al.* 2012). Kim *et al.* (2014) first reported this species in Hawai‘i as a RLW carrier. Nine individuals were collected (BPBM 284178, 284195) and three out of six (50%) individuals tested positive in this study (BPBM 284178, 284195).

Ariophantidae

***Parmarion martensi* Simroth, 1893**

(Fig. 2D)

First recorded from the islands in 1996 on O‘ahu, then on Hawai‘i Island, and more recently spread to Maui (Cowie 1997; Cowie *et al.* 2008, 2018), but went unnoticed until 2017 when it became anecdotally associated with multiple cases of angiostrongyliasis on Maui (Howe & Jarvi 2017). Hollingsworth *et al.* (2007) first reported this species on Hawai‘i Island as a RLW carrier with 77.5% of specimens screened testing positive. Kim *et al.* (2014) found a similar rate of infection, with 70% of specimens tested being carriers. Fifty-three individuals were collected (BPBM 284202, 284212, 284220) for this study, but only five out of 16 (31%) individuals screened tested positive (BPBM 284202, 284220), a considerably lower rate of infection than found in Hawai‘i Island populations.

Bradybaenidae

Bradybaena similaris* (Férussac, 1821) **New Island Record for Gastropod Host*

(Fig. 2E)

Commonly known as the Asian tramp snail, this species was first recorded in Hawai‘i in 1893 and is considered established throughout the main Hawaiian Islands (Cowie 1997). Similar to the *Deroceras laeve* account, Wallace & Rosen (1969) first reported this species on O‘ahu as a RLW carrier, but none of the individuals tested by Kim *et al.* (2014) were positive. However, twenty-eight individuals were collected (BPBM 284181, 284192, 284235, 284240) for this study, and one of the fourteen (7%) individuals screened was positive (BPBM 284240). It is possible that this species may be less susceptible to *A. cantonensis* infection in general, or just here in the islands, when compared to other species (Kim *et al.* 2014).

Helicidae

Cornu aspersum* (Müller, 1774) **New State Record for Gastropod Host*

(Fig. 2F)

The brown garden snail is native throughout the Mediterranean and Western Europe (Kerney & Cameron 1979, Cowie 1997). It was first recorded in Hawai‘i in 1952 on O‘ahu, and subsequently on Kaua‘i, Maui and Hawai‘i Island, but and is currently considered established only on Maui and Hawai‘i (Cowie 1997). Twelve individuals were

collected (BPBM 284179, 284188, 284193, 284196, 284237) for this study, and of these, 20% (2/10; BPBM 284196) were positive. This is the first record of *Cornu aspersum* as a carrier of RLW in the islands.

Spiraxidae

***Euglandina rosea* (Férussac, 1821)**

(Fig. 2G)

This predatory snail species was first introduced to Hawai'i in 1955 as a biological control agent for the giant African snail *Lissachatina fulica* (Cowie 1997). During this introduction, two species were inadvertently introduced, and it is likely that neither is the true *Euglandina rosea* (Meyer *et al.* 2017). However, here, we refer it to *E. rosea* until this is resolved. It has been reported from all the main Hawaiian Islands, but only as shells on Lāna'i (Hayes *et al.* 2007; Meyer *et al.* 2017). Wallace & Rosen (1969) first reported this species on O'ahu as a RLW carrier and eight of the thirty-nine individuals tested positive in Kim *et al.* (2014). Three individuals were collected (BPBM 284230, 284241, 284256), but only one (33%) of these was positive in this study (BPBM 284230).

Veronicellidae

***Laevicaulis alte* (Férussac, 1822)**

(Fig. 2H)

This tropical leatherleaf was first recorded from Hawai'i Island in 1900 (Cowie 1997), but is currently found on all main Hawaiian Islands and Midway Atoll (Hayes *et al.* 2007, Cowie *et al.* 2008). Wallace & Rosen (1969) first reported this species from O'ahu as a RLW carrier, and 13 of the 44 individuals tested positive by Kim *et al.* (2014) were positive. Notably, one of these individuals had the highest parasite load in that study. Twelve (BPBM 284185, 284209, 284217, 284244) individuals were collected for this study, and two (BPBM 284209) of nine (22%) were positive for RLW.

***Veronicella cubensis* (Pfeiffer, 1840)**

(Fig. 2I)

This species, known as the Cuban slug, was first recorded in Hawai'i in 1985 (Cowie 1997) and is currently found on all main Hawaiian Islands (Hayes *et al.* 2007, Cowie *et al.* 2008). Qvarnstrom *et al.* (2007) first reported this species from Hawai'i as a RLW carrier, and only 2.5% (4/159) of individuals screened by Kim *et al.* (2014) were positive. However, this study found double that rate (5%). Only two (5%) out of 39 individuals tested positive in this study (BPBM 284233, 284259) from 122 individuals collected (BPBM 284186, 284190, 284210, 284218, 284226, 284233, 284245, 284250, 284259).

ACKNOWLEDGMENTS

This study was supported in part by grants from the Hawai'i Community Foundation (via Adam Radford, Maui Invasive Species Council), U.S. Department of Agriculture, Cooperative Agricultural Pest Survey program to NWY and KAH, National Science Foundation grants to NWY, KAH, John Slapcinsky (DEB-1656254, 1656231) and to NWY, KAH (DBI-1561774). We thank Caroline Owens, Amma Boateng, Uduak Udoh, and Megan Paustian (Howard University) for assistance with specimen processing.

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