Tracking Behavior in the Snail *Euglandina rosea*: First Evidence of Preference for Endemic vs. Biocontrol Target Pest Species in Hawaii

Author(s): Brenden S. Holland, Taylor Chock, Alan Lee and Shinji Sugiura
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RESEARCH NOTE

Tracking behavior in the snail *Euglandina rosea*: First evidence of preference for endemic vs. biocontrol target pest species in Hawaii

Brenden S. Holland¹, Taylor Chock², Alan Lee³, and Shinji Sugiura¹⁴

¹Center for Conservation Research and Training, Pacific Biosciences Research Center, University of Hawaii at Manoa, 3050 Maile Way, Gilmore 408, Honolulu, Hawaii 96822, U.S.A.
²Whitman College, 345 Boyer Ave., Walla Walla, Washington 99362, U.S.A.
³Depauw University, P.O. Box 37, Greencastle, Indiana 46135-0037, U.S.A.
⁴Department of Forest Entomology, Forestry and Forest Products Research Institute (FFPRI), 1 Matunosato, Tsukuba, Ibaraki 305-8687, Japan

Correspondence, B. S. Holland: bholland@hawaii.edu

Abstract: The predatory snail *Euglandina rosea* (Férussac, 1821) is native to the southeastern U.S.A. and has been widely introduced as an attempted biological control agent for agricultural pest gastropods, often targeting the giant African snail *Achatina fulica* Bowdich, 1822. However, *E. rosea* may impact native land snails rather than *A. fulica*, particularly in Hawaii. Laboratory prey preference trials for *E. rosea* were conducted using three prey taxa, including the endemic endangered Oahu tree snail *Achatinella lila* Pilsbry, 1914, the giant African snail *A. fulica*, and the introduced Asian trampsnail *Bradybaena similaris* (Rang, 1831). Trials were conducted in the laboratory on branches of ohia lehua trees, *Metrosideros polymorpha*, an important habitat component for Hawaiian tree snails. Y-shaped ohia branches were used to simulate tree snail habitat and test *E. rosea*’s ability to track and pursue prey via slime trails on branches, and to evaluate prey choice by offering trails of two different species simultaneously and slime trail vs. water. *Euglandina rosea* significantly favored branches with slime trails vs. water, choosing the branch with slime trail 90% of the time (*P* < 0.001). Predatory snails exhibited no significant preference between *B. similaris* and *A. fulica* (*P* = 0.820), or *B. similaris* and *A. lila* (*P* = 0.260). However, *E. rosea* showed a significant preference for native *Achatinella lila* over invasive *Achatina fulica* (*P* = 0.040), the intended target species of the biological control program.

Key words: Hawaiian tree snails, predatory snails, *Achatinella lila*

_Euglandina rosea* (Férussac, 1821) is a carnivorous, terrestrial pulmonate snail native to the southeastern U.S.A. that preys exclusively on gastropod molluscs (reviewed in Barker and Efford 2004). *Euglandina rosea* was introduced to Hawaii and many other Pacific islands as a biological control method, targeting primarily the terrestrial agricultural pest species *Achatina fulica* Bowdich, 1822, the giant African snail (Mead 1979, Cowie 2001). Together with a number of other infamous, attempted bio-control programs in Hawaii that failed to control the intended pest species, this effort backfired catastrophically (Howarth 1991, Henneman and Memmott 2001, Holland et al. 2008), and has led directly to range reductions and extinctions of the native terrestrial island snail fauna (Clarke et al. 1984, Cowie 2001, Lydeard et al. 2004). *Euglandina rosea* was first released in Hawaii in 1955 by the Board of Agriculture and was subsequently introduced throughout the Pacific and Indian Oceans by officials in French Polynesia, Samoa, Mauritius, Micronesia, and elsewhere (Mead 1979, Griffiths et al. 1993, Civeyrel and Simberloff 1996, Cowie 2001). *Euglandina rosea* has since become a primary destructive agent of native Hawaiian and other island snails including arboreal species (Christensen 1984, Cowie 2001). The conservation and resource management community in the Hawaiian Islands has been intent on finding effective ways to attract, capture, and kill *E. rosea* for a number of years (Brenden Holland, pers. obs.). Although very little is presently known about the prey tracking and feeding behavior of this species in Hawaii, gaining understanding of these underlying mechanisms and strategies will provide important information that ultimately should be applicable to control efforts.

As in many animal groups, gastropods track and locate mates and food resources by detecting and following chemical trails (Chase 1986, Clifford et al. 2003, Shaheen et al. 2005). Trail tracking behavior is known from both predatory and non-predatory snails. Predatory snails have been shown to follow mucous trails in terrestrial, marine, and aquatic ecosystems (Chase 1986, Levri 1998, Davis 2005). At the present time, although an important topic, the underlying physiological and biochemical basis for prey mucous trail recognition by *E. rosea* is poorly understood and warrants further investigation.
Euglandina rosea feeds on slugs and other snails by tracking their prey through detection of small, water-soluble components in prey slime using specialized elongated lips (Clifford et al. 2003). Although most commonly encountered on the ground in Hawaii, E. rosea is known to climb trees in pursuit of prey (Davis et al. 2004), including of course, tree snails (Hadfield et al. 1993). Therefore, as in experiments focusing on tracking behavior in snail-eating flatworms (Sugiura and Yamaura 2009), studies of trail tracking behavior of E. rosea were conducted on tree branches. However, E. rosea behavior has previously not been observed on such materials, but has been studied on polyethylene sheets or glass plates (Cook 1985, Clifford et al. 2003, Shaheen et al. 2005). In addition to Achatina fulica and Achatinella spp., E. rosea have also been observed to prey on the common introduced snail Bradybaena similaris (Rang, 1831) (Davis and Butler 1964). The Oahu tree snail Achatinella lila Pilsbry, 1914 was included in the trials as a representative of the endemic Hawaiian malacofauna.

Laboratory prey trail preference choice trials were conducted on y-shaped ohia lehua (Metrosideros polymorpha) tree branches to simulate arboreal conditions where the native tree snails live and where Euglandina rosea tracks and hunts native tree snails. Y-shaped branches stripped of leaves were suspended 15 cm off the lab bench to simulate the arboreal environment. Snail trails were carefully placed from the beginning of the y-junction to the tip of each branch without overlap (Fig. 1), yet at the y-junction the two trails were close enough that E. rosea could taste both trails simultaneously with their specialized sensory palps (Fig. 1). The sides (left or right of the y-junction) of the prey trails were randomized during each set of trials to avoid any directional bias that may have resulted from light sources or other visual or magnetic cues that could affect the snails’ choice of direction. Branches were changed between trials. On the occasions when branches were reused, branches were vigorously scrubbed in scalding water and detergent, then rinsed and air dried, effectively removing all traces of slime trails. Fresh trails were produced prior to each pairwise trial. For each trial series, 20 E. rosea individuals were used (Table 1); each predatory snail was used only once per day.

Ten tree branches were used. Tree branch dimensions were as follows: mean length of straight element, labeled A, was 8.75 cm (SE 3.06), mean length of split elements after y-junction was 9.79 cm (SE 2.31) the average angle between branches B and C was 40° (Fig. 1). Foliage was removed before trials began, and snail mucous trails were removed between trials, or new branches were used. Dimensions of y-junction of branches used was such that as Euglandina rosea moved along the straight portion to the junction, it was allowed to choose which direction, either B or C (Fig. 1), to pursue. Point A shows the starting point for predatory snails, arrows show direction of travel. Within each of the four pairwise trials, B and C were randomized, to account for any inherent left-right bias in E. rosea. Prey choice experiments in pairwise trials were conducted with pairings of Achatina fulica vs. Achatinella lila, A. lila vs. Bradybaena similaris, B. similaris vs. A. fulica, and A. fulica vs. water.

All Euglandina rosea specimens were collected from the same locations in the Waianae Mountain range in Hawaii on the island of Oahu. Individual weight and shell length was recorded upon arrival to the lab. Euglandina rosea specimens (N = 52) were kept in plastic terraria in the laboratory (22 °C) and were fed Bradybaena similaris collected from various locations around the University of Hawaii (UH) at Manoa campus approx. once a week (Table 1). Previous studies indicate that trail following by E. rosea was not influenced by hunger (Clifford et al. 2003), but regular feedings were conducted to maintain the health of the specimens. The common Achatina fulica (N = 5) were also obtained on the UH campus. Achatinella lila (N = 5) occurs in the central Koolau Range on Oahu, and were kept in environmental chambers in the UH Tree Snail Conservation Lab. Achatinella lila was kept under permit by the USFWS and no individuals were harmed during these trials.

Since prey were not consumed by Euglandina rosea in these trials, one important consideration in our experimental design was the possibility that, since Achatina fulica is substantially larger than the other two experimental prey
species, its slime trail could be wider, potentially causing confounding factors by the amount of trail material, rather than the intended variable. However, the tree branches used were standardized by their width to approx. 5–6 mm in diameter (within the width range of labial palps), so that branches were narrower than prey foot width, limiting prey size as a factor in the preference experiments.

To place slime trails on branches, Achatina fulica, Achatinella lila, and Bradybaena similaris were placed on the branch in an active state with foot protruding and were allowed to crawl along the length of the branch, with occasional directional prodding if the snail was inactive. Because of A. fulica’s large size relative to the tree branch, individuals occasionally required manual assistance to remain upright as they crawled along the length of the branch. Each trial was considered complete once Euglandina rosea made a choice and crawled to the tip of the branch furthest from the y-junction (Fig. 1). In all cases, slime trails were applied to branches, then prey snails removed, and predators immediately placed at the y-junction for the choice trial. Efforts were made to present fresh mucous trails to predators, normally less than 15 minutes old.

Three trials with 20 Euglandina rosea each were conducted with two prey species presented one at a time. In addition, an experiment was performed using 20 E. rosea with Achatina fulica slime on one side of the branch and tap water on the other (Fig. 1). These trials were a control to ensure that E. rosea was following mucous rather than following the branch for an opportunity to hydrate. Tracking frequencies were analyzed using a two-tailed binomial test (Iwai et al. 2010).

The results of the control trial showed clearly that Euglandina rosea pursued the Achatina fulica path significantly more often (18 out of 20 replicates) than the water path, supporting that E. rosea was indeed attracted to slime rather than water (Table 2).

However, no significant preference between Bradybaena similaris and Achatina fulica was observed, with nine predatory snails selecting A. fulica and 11 choosing B. similaris out of 20 replicates (two-tailed binomial test: P = 0.820). In trials between B. similaris and Achatinella lila, Euglandina rosea chose B. similaris 13 times and A. lila 7 times out of 20 trials (P = 0.260), suggesting that E. rosea had no preference between B. similaris and A. lila (Table 1).

Finally, in trials of Achatinella lila vs. Achatina fulica, the native Hawaiian tree snail was chosen 15 times out of 20 (P = 0.040). While not strongly significant, the results show for the first time that Euglandina rosea preferred an endemic, endangered species rather than its intended biocontrol target.

Previously published laboratory choice and gut content studies of field-collected individuals indicated that adults of Euglandina rosea preferred snail species much smaller than themselves (Cook 1985, Griffiths et al. 1993, Meyer and Cowie 2010). Whether E. rosea can discriminate among prey snail species using mucous trails had until now remained unclear although E. rosea has been known to discriminate between conspecific and prey snail trails (Clifford et al. 2003). Our trail-choice experiments indicated that E. rosea can discriminate between Achatinella lila and Achatina fulica trails.

Interestingly, Euglandina rosea showed no preference between the Oahu native Achatinella lila and introduced Bradybaena similaris. Implications here suggested that in areas where both prey species are present, neither had any immediate survival advantage over the other. However, B. similaris develops, matures, and reproduces at a much faster rate than Achatinella spp., giving the introduced species an advantage over the live bearing and late maturing Achatinella spp. There are forest regions on Oahu where both species co-occur, such as Puu Hapapa, where the majority of the E. rosea used in this study were collected. The E. rosea used in this study may have fed on both species in the wild and were therefore locally adapted to feeding on these prey. This could be a confounding factor causing preference of locally available prey over Achatina fulica though no preference was exhibited.

<table>
<thead>
<tr>
<th>Species</th>
<th>N</th>
<th>Shell length (cm)</th>
<th>Shell width (cm)</th>
<th>Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achatina fulica</td>
<td>5</td>
<td>53.36 (14.59)</td>
<td>28.8 (7.41)</td>
<td>21.03 (12.3)</td>
</tr>
<tr>
<td>Bradybaena similaris</td>
<td>10</td>
<td>8.35 (1.37)</td>
<td>4.66 (0.73)</td>
<td>0.16 (0.10)</td>
</tr>
<tr>
<td>Achatinella lila</td>
<td>5</td>
<td>15.83 (3.75)</td>
<td>7.76 (0.41)</td>
<td>0.76 (0.16)</td>
</tr>
<tr>
<td>Euglandina rosea</td>
<td>52</td>
<td>34.92 (9.54)</td>
<td>15.83 (3.75)</td>
<td>2.84 (2.07)</td>
</tr>
</tbody>
</table>

Table 2. Trail preference results showing the number of times each prey trail was chosen by Euglandina rosea. Each trial series consisted of 20 replicates, table includes P values from two-tailed binomial tests, where P values with asterisk (*) were statistically significant.

<table>
<thead>
<tr>
<th>Trial series</th>
<th>Total number of times chosen</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Achatina (11) vs. Bradybaena (9)</td>
<td>0.820</td>
</tr>
<tr>
<td>2</td>
<td>Achatinella (7) vs. Bradybaena (13)</td>
<td>0.260</td>
</tr>
<tr>
<td>3</td>
<td>Achatinella (15) vs. Achatina (5)</td>
<td>0.040*</td>
</tr>
<tr>
<td>4</td>
<td>Achatina (18) vs. water (2)</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>
for B. similis vs. A. fulica. Future studies on prey preference in E. rosea might take prey ranges into account, and test prey collected from areas where B. similis is present but species of Achatinella are absent, as well as areas where Achatinella spp. are present but B. similis is absent, to evaluate the possible role of local adaptation in prey choice.

In the Hawaiian Islands, the geographic distribution of Euglandina rosea ranges from sea level to mountain peaks and ridges at about 1000 m, whereas Achatina fulica occurs in lower elevation habitats, likely allopatric with Achatinella lila. In addition A. fulica is a ground-dwelling species and has not been observed to climb ohia trees. Therefore it is highly unlikely that E. rosea would encounter a choice between native tree snails and African snails in the field.

Although resource managers in Hawaii have long speculated as to whether native island snails might be preferred to the intended biocontrol target species Achatina fulica, this is the first study to conclusively document this phenomenon. The data presented here provide the first concrete evidence that, when offered fresh mucous trails of the giant African snail and an endemic Oahu tree snail, there is a clear preference for the tree snail. In addition, in unpublished laboratory trials, we observed that even when Euglandina rosea attempted to attack larger A. fulica adults, it usually failed, due presumably to the large size disparity. Yet surprisingly, well-intentioned agriculture agency personnel from island nations where A. fulica is present periodically propose release of E. rosea as a solution. This study provides strong support against continued release of E. rosea, for any reason.

Knowledge of prey preferences of Euglandina rosea may ultimately help in the design and construction of attractant traps for E. rosea that could be used throughout the Pacific islands to control and ultimately exterminate E. rosea to preserve native and endemic fauna.

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**LITERATURE CITED**


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