RESEARCH NOTE

PREDATORY BEHAVIOUR OF NEWLY HATCHED *EUGLANDINA ROSEA*

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Most predatory species tend to be larger than their prey (e.g. Cohen *et al.*, 1993), although many use cooperative strategies to kill and consume prey larger than themselves (e.g. Sugiura, 2010). Because juvenile predators are much smaller than adults, juveniles may use different predation tactics. Predatory behaviour in land snails has been documented in 11 families (Barker & Efford, 2004). However, few studies have focused on differences in predatory behaviour between adults and juveniles.

The predatory snail *Euglandina rosea* (Férussac, 1821) (Spiraxidae) is one such predator that feeds exclusively on molluscan prey (Barker & Efford, 2004). It is native to the southeastern United States and was intentionally introduced to many islands, including the Hawaiian Islands, as a biological control agent targeting the giant African snail, *Achatina fulica* and, although it failed to control *A. fulica*, it has impacted numerous endemic land snail species (reviewed by Cowie, 2001).

Euglandina rosea first locates its prey by tracking the mucus trail, then attacks the prey by biting its exposed soft parts, and finally inserts its head into the prey shell to consume the soft tissue (Cook, 1985a, b; Barker & Efford, 2004; Shaheen *et al.*, 2005). When *E. rosea* eats small snail species, however, it frequently swallows the prey whole (Cook, 1985b). *Euglandina rosea* will eat conspecific juveniles, although laboratory experiments suggested that such cannibalism is rare and only occurs when conspecific individuals are covered in prey mucus (Shaheen *et al.*, 2005). Although prey tracking and feeding behaviour of *E. rosea* has been observed and studied, it is not yet fully understood, and the focus has been on adults rather than juveniles (Cook, 1985a, b, 1989; Barker & Efford, 2004; Shaheen *et al.*, 2005). Understanding the feeding behaviour of juvenile *E. rosea* is important for gaining insight into its complete life cycle, which may ultimately contribute to control and mitigation of the negative impacts of *E. rosea* on native snails, as well as provide insight into the feeding ecology of predatory snails in general.

We conducted laboratory feeding experiments using newly hatched juvenile *E. rosea* to address the following questions. (1) Do newly hatched juveniles eat live prey and, if so, how do they consume their prey? (2) Are small native Hawaiian snails consumed by newly hatched juveniles? (3) Will newly hatched juveniles from a single clutch of eggs readily cannibalize one another?

Adult *E. rosea* collected from various sites on the island of Oahu, Hawaii, during 2009–2010, were maintained in the laboratory with soil and leaf litter (21 ± 3°C). For the experiments we used nine newly hatched *E. rosea* (body weight 0.03–0.04 g, shell height 5.5–6.3 mm, shell width 3.7–4.2 mm) that hatched in late April 2010 from a single clutch laid in early March 2010. Each experimental snail was placed in a plastic container (284 ml, 80 mm diameter, 70 mm height) containing a damp paper towel.

In the first experiment, the prey were juveniles of the introduced species *Bradybaena similaris* (Rang, 1831) (Bradybaenidae), collected on Oahu. Single individuals of *B. similaris*, both larger and smaller (body weight 0.02–0.15 g, shell width 4.7–8.7 mm) than the predators, were presented to the predator hatchlings ($n = 9$) in individual plastic containers. The *E. rosea* juveniles used were <3 days old and had not fed since hatching. The containers were checked regularly for 7 days.

To examine predation by *E. rosea* juveniles on native Hawaiian snails, we used adults of the genus *Tornatellides* (Achatinellidae) from Oahu, because of their small size (body weight <0.01 g; shell height 2.0–2.9 mm) and the fact that they are relatively abundant in the field, even in areas where other native snails no longer occur. A single *E. rosea* was placed with a single *Tornatellides* in each container ($n = 9$). As before, all *E. rosea* juveniles were starved for at least 3 days before the experiment.

Finally, to examine whether starved *E. rosea* juveniles will readily cannibalize each other, four pairs of juveniles were placed in individual containers for 7 days.

Newly hatched *E. rosea* (0.03–0.04 g) consumed *B. similaris* of various sizes (0.02–0.10 g). Five individuals consumed prey smaller than themselves or prey of similar size (0.02–0.04 g) within 2 days. Two *E. rosea* consumed snails larger than themselves (0.06, 0.10 g) within 2 days, although two did not eat larger prey (0.08, 0.15 g) during the 7-day period. The prey-consuming behaviour of *E. rosea* (Fig. 1), after initial contact (Fig. 1A), first involved 'biting' the exposed soft body of the *B. similaris* (Fig. 1B) as it stretched out to crawl, causing it immediately to retract into its shell. The predator then inserted its head into the prey shell aperture and consumed the soft tissues (Fig. 1C). All *E. rosea* ate the endemic *Tornatellides* spp. within 1 day, often immediately following presentation of the prey (Fig. 1D). The prey snail was lifted up off of the substrate (Fig. 1E), manipulated by the everted mouthparts of the *E. rosea* and eaten (Fig. 1F). Following the trial period, empty shells of *Tornatellides* remained in six containers, while no shells were left in three containers, indicating that three *E. rosea* had consumed entire shells as well as soft bodies of *Tornatellides*. In the cannibalism trials no *E. rosea* ate others.

There are similarities and differences in predatory behaviour between adult and newly hatched *E. rosea*. As for adults, when juvenile *E. rosea* were presented with prey much smaller than themselves, they lifted the prey snail up using everted mouthparts and ate it (Fig. 1D–F). However, unlike adults, newly hatched juveniles killed prey larger than themselves (Fig. 1A–C). Because juveniles were not able to lift the large prey up, they instead attacked these snails by biting them, causing retraction of the prey bodies into their shells (Fig. 1B) and cessation of locomotion, thus preventing escape. However, juvenile *E. rosea* did not kill prey three or more times as heavy as themselves. We observed one *E. rosea* attempt an attack on such large prey, ultimately giving up. The large prey snail did not retract its body into its shell despite being bitten by *E. rosea*.

Although adults have been reported to eat conspecific juveniles (Barker & Efford, 2004), our experiments did not indicate that juveniles hatched from the same clutch will readily

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Figure 1. Attacking and feeding behaviour of *Euglandina rosea* juveniles. **A.** An *E. rosea* juvenile (right) attacking *Bradybaena similaris* (left). **B.** *Euglandina rosea* biting the soft body of *B. similaris*. **C.** *Euglandina rosea* (right) inserting its head into the shell to eat *B. similaris* (left). **D.** An *E. rosea* juvenile (left) attacking a *Tornatellides* (right). **E.** *Euglandina rosea* lifting up *Tornatellides* with its everted mouthparts. **F.** *Euglandina rosea* eating *Tornatellides*. Scale bars: **A–C** = 5.0 mm; **D–F** = 2.0 mm.

cannibalize one another. Also, newly hatched juveniles can discriminate between conspecific and other potential prey species (Shaheen *et al*., 2005).

Our feeding experiments indicate that newly hatched juvenile *E. rosea* eat live snails. To our knowledge, however, feeding behaviour of newly hatched juveniles has not been examined in the field. *Bradybaena similaris* is one of the most common introduced land snails in Hawaii, and this and other studies show that *E. rosea* readily preys on all size classes of this species, so this species may be an important component of the diet of *E. rosea* adults as well as juveniles. Small, relatively common endemic Hawaiian snails such as the *Tornatellides* spp. we tested may also commonly be eaten in the field because they still occur in areas where other native species are absent. Many snail species that are endemic to oceanic islands including the Hawaiian Islands are much smaller than *E. rosea* adults or as small as *E. rosea* juveniles (Vagvolgyi, 1975). Therefore, *E. rosea* juveniles as well as adults may have impacted island snail faunas.

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