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CAUDATA — SALAMANDERS

***EURYCEA RATHBUNI* (Texas Blind Salamander). OOPHAGY AND CANNIBALISM OF LARVAE.** *Eurycea rathbuni* is a troglobitic spelerpine salamander endemic to the San Marcos Springs of the Edwards Aquifer in Hays County, Texas, USA (Hammerson and Chippindale 2004. IUCN Red List of Threatened Species 2004: e.T39262A10173274). Because of its occurrence in water-filled subterranean caverns, field observations on the behavior and habits of *E. rathbuni* have been limited (e.g., Uhlenhuth 1921. Biol. Bull. 40:73–104), and much of what is known about the species' biology has come from observations of individuals maintained in captivity (e.g., Norman 1900. Amer. Nat. 34:179–183; Uhlenhuth, *op. cit.*; Maruska 1982. Proceeding of the 5th Annual Reptile Symposium on Captive Propagation and Husbandry 5:151–161; Bechler 1986. Proceedings of the 9th International Congress of Speleology 5:120–122; Bechler 1988. Southwest. Nat. 33:124–126).

Audubon Zoo has maintained a captive colony of *E. rathbuni* since 2001 and has been successfully reproducing this species since 2004. An adult breeding group comprised of 10 individuals of unknown sexes is maintained on public display in a 190-L aquarium at the zoo's Reptile Encounter building. Round river stones of varying sizes cover the floor of the exhibit as a substrate and provide potential sites for egg deposition. To facilitate public viewing, fluorescent lighting illuminates the exhibit on a 10-h photoperiod. Water parameters, photoperiod, and feeding frequency remain constant throughout the year.

Eggs are periodically produced throughout the year, although it is unclear which individual or individuals produce them. Eggs from clutches ranging from around 20–60 eggs are usually adhered singly or in small clusters to the surfaces of submerged rocks during each laying event. Eggs have typically been removed from the exhibit as soon as they are discovered and set up in a separate aquarium for hatching and development, but on several occasions, adult *E. rathbuni* were observed predating the eggs before keeper staff could retrieve them. Additionally, on rare occasions when undetected eggs hatched on exhibit, some adults were observed predating the larvae. Due to a lack of discernable physical features to facilitate visual identification, it is also unclear which individual or individuals have been observed consuming eggs or larvae.

The most recent observed case of oophagy by an adult *E. rathbuni* was closely monitored by one of us (RWM) and recorded with video. A clutch of around 20 eggs was laid on 10 February 2018 but could not be retrieved by keepers until two days later. On the morning of 12 February, one of the adults was observed directly above an egg that was adhered to the side of a rock (Fig. 1a). Using suction to detach the egg from the rock, the animal drew the egg into its mouth and then proceeded to reposition the egg inside its mouth for several seconds using chewing-like jaw movements before exuding a large cloud of opaque liquid (presumably the albumin escaping from the ruptured egg; Fig. 1b). The remaining eggs were quickly retrieved and moved to a separate rearing tank to prevent further predation.

Like other troglobitic species of *Eurycea*, *E. rathbuni* is believed to feed on aquatic subterranean invertebrates including crustaceans and snails (Goriki et al. 2012. *In* White and Culver [eds.], Encyclopedia of Caves, pp. 665–676. Elsevier, Waltham). Captive specimens have been reported to accept *Ambystoma* larvae (Uhlenhuth, *op. cit.*), strips of muscle from the tail of crayfish (Norman, *op. cit.*), and *Artemia* shrimp (Maruska, *op. cit.*; RWM et

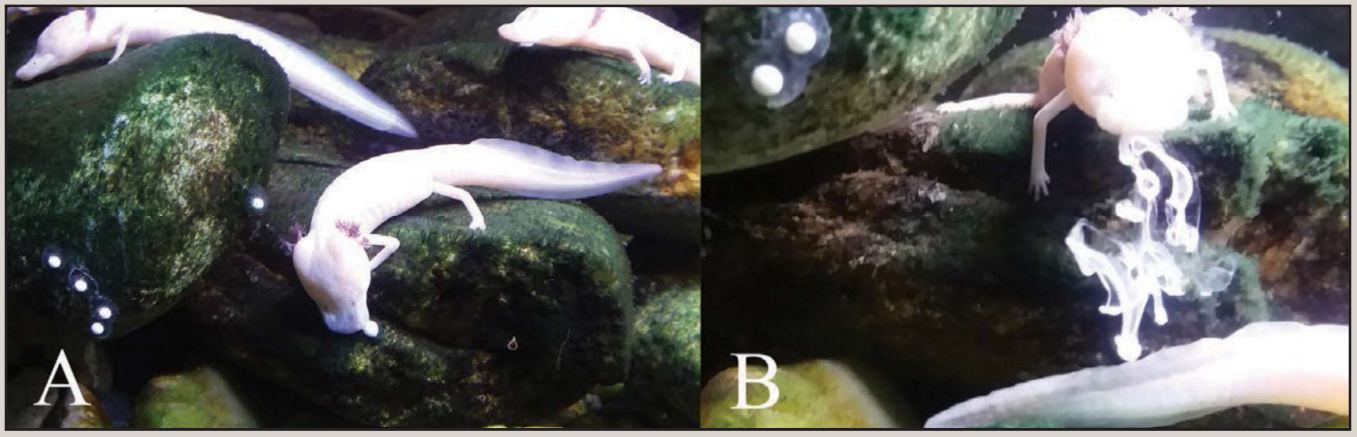

Fig. 1. Oophagy in *Eurycea rathbuni* in a captive setting.

al., unpubl). Oophagy and cannibalism have been documented in several species of plethodontid salamanders (Petranka 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington, D.C. 587 pp.; Chavez. 2017. Herpetol. Rev. 48:791–793) including oophagy in the spring-dwelling *E. sosorum* in captivity (Chavez, *op. cit.*). Given the paucity of available information on the ecology of *E. rathbuni*, it is unclear whether the feeding observations described here for *E. rathbuni* might represent natural elements of its diet and behavioral repertoire or an artifact of captivity. It might not be unreasonable, however, to suspect that *E. rathbuni* might occasionally take such opportunistic food items in nature where prey diversity and availability in aquatic subterranean environments might be limited.

These observations also have important implications for the management and breeding of *E. rathbuni* in captivity. As a vulnerable species with an extremely restricted range that has seen dramatic population declines over the past several decades (Hammerson and Chippendale, *op. cit.*), future conservation measures for *E. rathbuni* may rely on captive-breeding and repatriation as a way to bolster or restore diminished wild populations. If oophagy and cannibalism of larvae by adults pose a significant threat to captive breeding efforts, such behavior may dictate how individuals are grouped and housed to maximize egg and larval survivorship and reproductive success.

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TESTUDINES — TURTLES

***CUORA BOURRETI* (Bourret's Box Turtle). BRUMATION, OVIPOSITION AND INCUBATION.** *Cuora bourreti* is listed as critically endangered (McCormack and Stuart 2016. The IUCN Red List of Threatened Species 2016: e.T163447A115303472; accessed 14 Jul 2018) and populations continue to experience declines in the wild. Recommendations to develop globally integrated captive breeding colonies have been prioritized as a conservation measure for *C. bourreti* (Horne et al. [compilers] 2012. Conservation of Asian Tortoises and Freshwater Turtles: Setting Priorities for the Next Ten Years. Wildlife Conservation Society Singapore Ltd, Singapore. 28 pp.). In North America, the captive zoo population of *C. bourreti* is managed by a Species Survival Plan (SSP) of the Association of Zoos and Aquariums (AZA), with a current population of 83 individuals held in both zoological parks and private collections.

The Smithsonian's National Zoological Park (NZP) maintains a breeding group of *C. bourreti* comprised of two males and one female. All three animals are wild-caught in origin and have been in captivity for over ten years. NZP acquired the female in late 2012, one male in 2013, and the second male in 2014. The *C. bourreti* at NZP are cycled annually by providing seasonal changes in diet, photoperiod, humidity and temperature. During the months of June, July and August, the animals are provided with fourteen hours of daylight, fed three times a week, and misted daily. These parameters are then gradually reduced to eight hours of daylight, mistings once a week, and no feedings during the winter months of December, January, and February. Captives were initially cooled indoors from an ambient temperature of 28° to 18°C in the winters of 2013 and 2014. In the winters of 2015 and 2016, they were brumated in an outdoor greenhouse and cooled below the goal temperature of 10°C, reaching minimum temperatures of 4°C and 7°C, respectively. During brumation, animals were housed individually in 113.5-liter aquaria with large, shallow water bowls (ca. 50 cm in diameter and 5 cm deep), and a PVC hide buried in deep soil and leaf litter substrate for refugia. From March through October, the animals were housed individually in large enclosures (males: 105.4 × 28.5 × 63.5 cm; female: 165.1 × 88.9 × 30.5 cm) with peat moss and soil substrate. Each enclosure had a basking spot providing an 8–10°C gradient within the enclosure, multiple water features, leaf litter, and several refugia. The female was introduced into both male enclosures for breeding two to four times a week during this period.

Nesting occurred as early as February and the female laid two to three clutches of one to two eggs annually (Table 1). The female excavates a shallow ca. 2-cm deep divot in the substrate for oviposition and covers the eggs with leaf litter using her rear limbs. Although this female laid eggs in 2013, hatchlings were not produced from this breeding group until 2017. In 2013, 2014, and 2015, eggs never showed banding or other signs of development. They were incubated in the following methods: inside a small plastic container (ca. 21 × 15 × 8 cm) where the eggs were partially buried in a mixture of moist vermiculite at a 6:5 ratio to water by weight; and in a small (ca. 20 × 17 × 12 cm) suspended incubation container (S.I.M. containers; Squamata Concepts®, Staten Island, New York, USA) with the eggs suspended over saturated vermiculite. In 2016, three eggs banded, but two embryos died within the first month and the third died after 82 days of incubation. The third embryo appeared fully developed and a cause of death was not determined. The successful development of eggs in 2016 and 2017 might be the result of lower brumation temperatures experienced during those winters than in previous years.

In 2017, eggs were incubated using three different methods. One egg from the first clutch, laid in March, was incubated in a large (ca. 33 × 23 × 15 cm) suspended incubation container (S.I.M. Containers; Squamata Concepts, *opt. cit.)* suspended over saturated vermiculite. The second egg from this clutch was incubated in a small plastic container (ca. 21 × 15 × 8 cm) and partially buried in a mixture of moist vermiculite at a 6:5 ratio to water by weight. A second clutch of two eggs laid in April was incubated in the substrate taken from the enclosure where they were laid (peat and soil mixture) inside a small plastic container (ca. 21 × 15 × 8 cm).

Relatively little has been documented on the reproduction of turtles in the genus *Cuora*. The first reported hatchings of *C. bourreti* occurred in 1998 and 1999 and documented eggs (N = 5) from three different females averaging 5.54 × 3.0 cm and incubating for 85–117 days at 24–30°C (Fiebig and Lehr 2000. Salamandra 36:147–156). Here, we document a single female *C. bourreti* producing 19 eggs between 2013 and 2017, including five eggs produced in three different clutches in 2015 (Table 1). Although two other *Cuora* species have been reported to triple-clutch: *C. flavomarginata* (Connor and Wheeler 1998. Tortuga Gazette 34:1–7) and *C. amboinensis* (Ernst et al. 2000. World Biodiversity Database, CD-ROM Series. Springer-Verlag, Berlin), to our knowledge this is the first record of *C. bourreti* triple clutching in a single breeding season. Published accounts on egg production in *C. bourreti* note one or two clutches comprised of one to four eggs annually (McCormack et al.