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Behaviors in the Cuban Crocodile (*Crocodylus rhombifer*)

"Andrew Odum of the Toledo Zoo has observed a male Cuban crocodile (*Crocodylus rhombifer*) attacking and pushing around a large ball and approaching it while blowing bubbles used in courtship. Altogether, from the observations to date it would appear that crocodilians do not provide strong evidence for play behavior. However, the nature of their housing in captivity may preclude play, and young animals have not been studied sufficiently in either captivity or the field. Animals in warm, nutritionally adequate, and ecologically appropriate settings need to be studied."
—Gordon M. Burghardt, *The Genesis of Animal Play*, 2005 [p. 283]

The Cuban Crocodile (*Crocodylus rhombifer*) has a long history of being maintained in captivity and observed in the wild. It is, as discussed below, one of the most unusual crocodilians in a number of respects. Here we review behavioral studies of this species, add some new observations made at the Smithsonian National Zoological Park (SNZP), and make some comparisons with findings on other species of crocodilians. Some recent findings stimulated this review.

Burghardt (2005) mentioned that reports of play behavior in crocodilians are limited; one of the first was on an American Alligator (*Alligator mississippiensis*) snapping at dripping water by Lazell and Spitzer (1977). The scarcity of reports may be due to the fact that researchers do not expect these reptiles to play and therefore do not spend time looking for signs that they do so. However, it may be fruitful for zoo and aquarium workers to start looking carefully for examples that their captives might indeed play. We advance this suggestion based on our observations on a colony of seven adult *C. rhombifer* in the collection at SNZP (Fig. 1), some of which have shown object play with cinderblocks and a removable intake drain pipe.

To begin, we follow this "abbreviated definition" by Burghardt (2014) on play—"Play is repeated, seemingly non-functional behavior differing from more adaptive versions structurally, contextually, or developmentally, and initiated when the animals are in a relaxed, unstimulating, or low stress setting." Object play is the most common type of play reported in crocodilians and is being observed with increasing frequency as more captive crocodilians are being provided with unique objects (Dinets 2015).

In addition, a new appreciation of crocodilian "intelligence" is fast becoming an integrated part of crocodilian husbandry; their intelligence and ability to learn allows them to be managed in captivity more safely through conditioning and provisioning of enrichment features that stimulate natural and play behaviors and thus are beneficial to the animals and contribute to public education and scientific study. A caveat: Burghardt (1996) published an important paper on controlled deprivation and enrichment which relates to the need for studying captive animals more naturalistically and questioning the 'enrichment' vocabulary.

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Overview of Behaviors

Many crocodilians, especially *C. rhombifer*, are in serious danger of extinction (see IUCN Red List; Ramos 2000; Brazaitis 2011, for examples). Amazingly, De Sola (1930) mentioned that 50–60 *C. rhombifer* were killed weekly for hides. We may never know their complete behavioral repertoire. Here is what we do know to date about their intelligence and complex activities.

Crocodilian Play.—Dinets (2014) described three types of play (Locomotor Play, Object Play, Social Play) for crocodilians. In our crocodiles at SNZP, we have not seen examples of locomotor play similar to those described by Dinets (2015).

We describe two examples of object play in the present paper: moving a cinderblock and chewing a copper pipe. Dinets (2015) also showed a picture of a male *C. rhombifer* playing with pink *Bougainvillea* flowers that were floating in the pools where the animal was kept in Zoo Miami (Florida, USA) by carrying and pushing

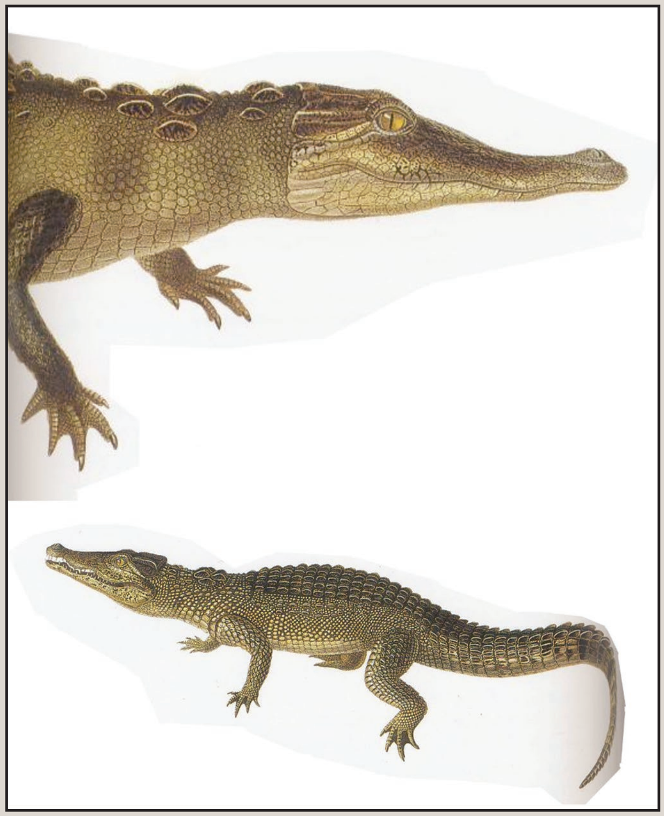


Fig. 1. Illustration of American Crocodile (*Crocodylus acutus*) [top] and Cuban Crocodile (*C. rhombifer*) from *Historia fisica, politica y natural de la isla de Cuba*, by Ramón de la Sagra in 1839–1856. See Alexander (2006) outlining possible future of this taxon. Hybridization between these two species is a serious threat to the Cuban Crocodile (see Weaver et al. 2008).

them around for several days. Burghardt (2005) referenced a male *C. rhombifer* at the Toledo Zoo moving around a large ball and blowing courtship bubbles. Burghardt concluded that this behavior was not courtship as the animal also attacked the ball.

Dinets (2011a,b) described his observations on courtship. A 2.2-m *C. rhombifer* at Zoo Miami roared and vibrated its body, suggesting production of brief infrasound, in HOTA (head oblique, tail arched) posture. A 1.7-m long female in the same enclosure showed mutual courtship behavior and mating. He also mentioned that the female rode around the pool on the male's back on four occasions lasting up to a minute. Dinets (2015) reexamined his observations of courtship with *C. rhombifer* and concluded that the female riding on the back of the larger male was not courtship and that instead it might be a form of play developed by the pair during many years of living together. Even though these animals have been living together for years, we have never seen this type of interaction where females rode on the back of males at SNZP.

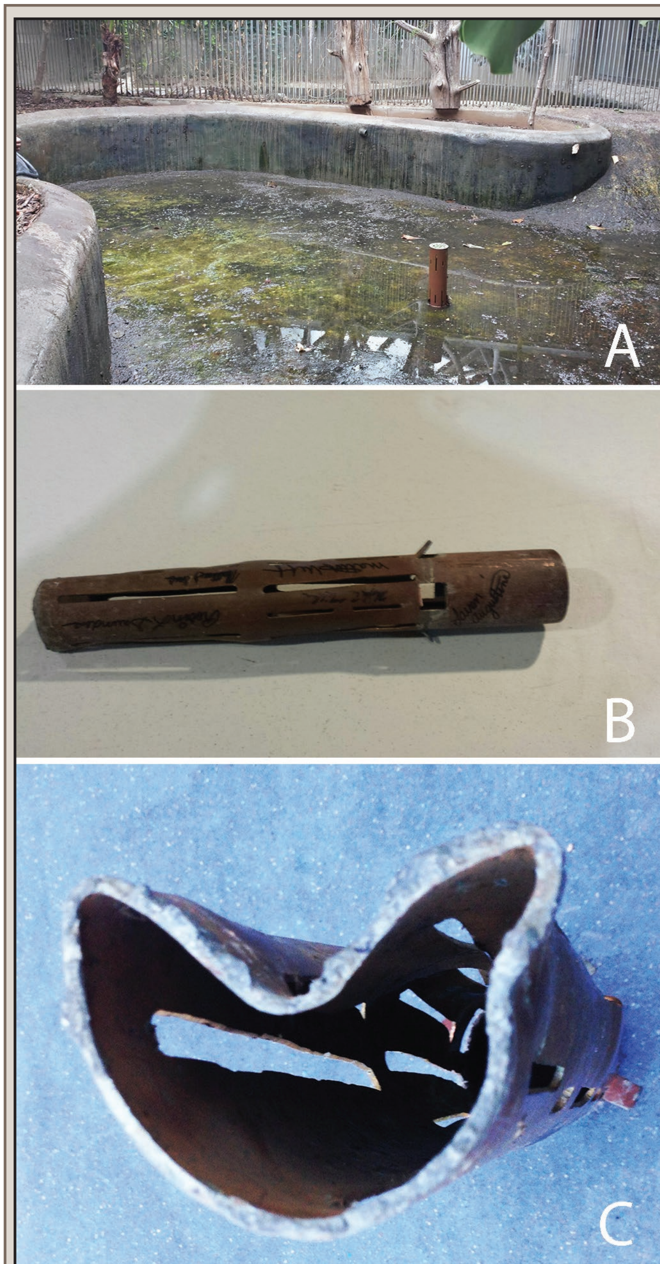
Fig. 2. Adult female *Crocodylus rhombifer* at SNZP showing extraordinarily agile predation attempt to snatch dead rabbit from tongs. Grigg and Kirshner (2015) describe jumping and "tail walking." See text.

Signaling.—Dinets (2013) characterized *C. rhombifer* as a species inhabiting mostly fragmented aquatic habitats, listing signal components as HOTA posture, infrasound, vocal sounds, and slaps. In the SNZP animals, we have seen headslaps by the male while in the pool in the center exhibit and roaring from both males on land. When hatchlings (N = 7, from two clutches) were restrained for medical exams and held by caretakers, the two oldest ones continued emitting distress calls for over two years and the five youngest ones began calling shortly after emerging from the eggs. Long-distance signals such as bellows, roars, headslaps, and infrasound pulses are important components of crocodilian communication channels but only recently have there been increasing accounts by a number of researchers interpreting various sounds while looking at a broader cross-section of crocodilian taxa. Examples include publications by Gans and Maderson (1973), Herzog and Burghardt (1974), Garrick and Lang (1977), Staton (1978), Garrick and Garrick (1978), Lang et al. (1986), Garrick et al. (1987), Vergne et al. (2007), Vergne and Mathevon (2008), Senter (2008), Vergne et al. (2009), Vergne et al. (2011), Vergne et al. (2012), Kumar et al. (2012), Roberto and Robinson (2013), Dinets (2013), Mathevon et al. (2013), Sicuro et al. (2013), and Bonke et al. (2015). Mathevon et al. (2013) presented an interesting finding (the crocodilian "language" with crocodiles and caimans sharing the same acoustic code), suggesting that these signals support a "crocodilian identity." Calls recorded from other species (*Melanosuchus, Caiman*) elicit a response from juvenile Nile Crocodiles (*C. niloticus*). They used calls from Nile Crocodiles, Black Caimans (*Melanosuchus niger*), and Spectacled Caimans (*Caiman crocodilus*).

Dinets (2013) reported that *C. rhombifer* frequently roars but rarely headslaps, and the roars sounded identical to those of *C. moreletii*. In his study, captive males produced numerous advertisement calls; a roar was included in all, though only one included a headslap.

Ajay Kartik from the Madras Crocodile Bank Trust/Centre for Herpetology, India provided an excerpt from his presentation at the Crocodile Specialist Group (CSG) meeting in Cambodia recently: 1) Vocalization in crocodilians appears to have a correlation to habitat (Lang 1987), and species that inhabit open water seem to rely less on vocal communication than species that inhabit vegetated, marshy habitat; 2) Previous workers have described the vocalizations of *C. rhombifer* as "roar-like hisses," "low volume bellows," and "guttural grunts" (Varona 1966; Neill 1971; Herzog 1974); 3) the frequency of vocalization for *C. rhombifer* at the Trust was higher during the early morning (0700–0900 h) and late evening (1700–2100 h). The timings conform with the general activity pattern of the group, which is inactive during the warmer parts of the day; 4) this group was observed to make two distinct types of vocalizations.

As an aside, two adult male *Alligator mississippiensis* of equal size in an outdoor exhibit at Dallas Zoo began roaring virtually every time a jet plane passed overhead throughout the year except during cold weather but were unaggressive to each other (JBM, pers. observ.). When a propeller-driven plane or helicopter passed by, the alligators were not stimulated to roar. Beach (1944) described alligators which were aggressive to conspecifics - roaring accompanied by aggressive locomotion. A smaller male was attacked by the roaring alligator.



PHOTOS BY MATTHEW EVANS (A–B) AND KYLE MILLER (C)

Fig. 3. A) Copper intake drain pipe in pool at SNZP. B) Same pipe after being crushed by *Crocodylus rhombifer*. C) End of crushed pipe.

Feeding in Cuban Crocodiles.—Ditmars (1933) had a healthy respect for the appetite of the Cuban Crocodile. Bindi Irwin, daughter of the late Steve Irwin of "The Crocodile Hunter" fame, and her mother Terri asked biologist Matt Evans to feed a Cuban Crocodile at SNZP to compare this behavior to other crocodilians in the family-owned Australia Zoo collection (see Grigg and Kirshner 2015 showing photos of Estuarine Crocodiles [*Crocodylus porosus*] jumping out of water to grab prey during demonstrations for tourists on boats in Australia). Evans planned to give a feeding demonstration that showed the incredible agility and predatory instinct of *C. rhombifer*. A dead rabbit was held on long tongs and was to be offered to one of the crocodilians over the fence (1.5 m high). One of the females launched her body so high and rapidly against the fence that she grabbed the rabbit from the tongs with her entire head over the top of the fence before Evans could react. He was certain that she was going to climb over the fence so he successfully pushed her back with the tongs with the rabbit still held in her jaws (Fig. 2). It was truly a stunning example of raw power during a feeding episode.

Cooperative Behavior.—Grigg and Kirshner (2015) discussed whether feeding aggregations could be properly called cooperative behavior (groups of animals working together for same outcome) and gave some interesting examples of *C. niloticus* feeding on a pelican and antelope. They rightly suggest that more research needs to be done to determine whether feeding aggregations are cooperation or not. Mike Hileman (pers. comm.) reported that a colony of *C. rhombifer* living at Gatorland in Florida has exhibited what researchers believe is true pack-hunting behavior, remarkable since crocodiles have usually been assumed to be solitary hunters. Mike Hileman (pers. comm.) confirms this behavior in his group and has also observed them working together to attack the handlers (see also Alexander 2006; Dinets 2015). Brazaitis (in Murphy 2013a) described something similar. A pair of *C. niloticus* was kept with several other species at the Wildlife Conservation Society's Bronx Zoo and the two cooperated by executing a pincer movement to jump out of the water at him every time he entered or began to exit the exhibit. We can assume that these crocodiles were not viewing Brazaitis as prey, but rather their aggressive attack behaviors may have been territorial. We have not seen evidence of cooperative behavior in our group of *C. rhombifer*.

Aggressiveness of Cuban Crocodiles—This taxon is considered to be an aggressive and highly territorial species of crocodilian (Wise 1994; Trutnau and Summerland 2006; Targarona et al. 2010), indicating that social interactions would likely include high incidences of agonistic behaviors and possibly similar behaviors to *C. porosus* (Brien et al. 2013). Murphy (2013a,b) presented historical illustrations and literature accounts of assaults and other interactions by and toward crocodilians (including *C. rhombifer*) and pleaded for improved programs in zoos and aquariums for crocodilian conservation. All crocodilians are spectacular and important predators and some do on occasion kill and eat humans. As an example, Dinets (2013) pointed out that *C. rhombifer* are very smart, fast, and aggressive and are potentially dangerous to humans. Many years ago, JBM visited George McDuffie in Cincinnati, Ohio, who kept a two-meter specimen in a large stock tank, covered with a divided heavy metal top. The crocodile was resting quietly in the water. As George lifted the lid to show off his prize possession, the crocodile exploded from the tank with open mouth and only the tail tip still in the water and directed the attack toward George's face. The reptile nearly succeeded but George, with the unexpected grace of a ballet dancer, fell backward just out of reach. The ominous sound of snapping jaws was quite loud. What was amazing was that the crocodile leapt without a running start.

Behler and Behler (1998) characterized this crocodile as stocky, powerfully built, large head and jaws, aggressive and "extremely dangerous and untrustworthy." Read the amusing account of six escaped *C. rhombifer* at the zoo by Behler's coworker Peter Brazaitis in the book *You Belong in a Zoo!* Barbour and Ramsden (1919) translated Juan Gundlach's account where the latter wrote that they have killed human beings. In 1995, CrocBITE, the Worldwide Crocodilian Attack Database, published a note that an elderly spear-fisherman was attacked, killed, and partially consumed by a *C. rhombifer* in the Zapata Swamp.

Behavioral Observations at SNZP

We have watched many social interactions in our SNZP *C. rhombifer* throughout the years—linear social hierarchy, courtship approach with bubble blowing and head-slapping, body vibrations and vocalization, body alignment, pre-copulatory behavior, coitus, nest construction, oviposition, female defense of the nesting site toward conspecifics (and artificial hatching of eggs) (see Augustine and Watkins 2015, Augustine et al. 2015a, Augustine et al. 2015b for history). A male and two adult female *C. rhombifer* are housed on exhibit between a pair of *C. rhombifer* and a female True Gavial (*Gavialis gangeticus)* in the Reptile Discovery Center (see Murphy and Xanten 2007, Augustine et al. 2015b for description). The pair consists of a captive-hatched female (F_1) approximately 35 years old and a captive-hatched male approximately 30 years old. The trio consists of two females, a younger animal which was captive-hatched in 1980 and an older wild-caught female estimated to be 57 years old and still successfully producing viable neonates as of 2015. The male in this trio was captive-hatched in 1970. Weigl (2014) described one female that lived more than 48 years in the USA. All three SNZP females seasonally breed and lay eggs (Augustine and Watkins 2015). See also Thorbjarnarson (1996) who provided information on female size and reproductive parameters, egg mass, clutch size, and clutch mass.

Experiments were designed to determine whether operant conditioning could be used as a tool to facilitate shifting (moving from one enclosure to another) of these animals (Davenport 1995) for medical reasons (see Huchzermeyer 2003 for a superb book on medical management) and safely feeding these aggressive reptiles and these were successful (Augustine and Baumer 2012; Hellmuth et al. 2012; Kuppert 2013). Brazaitis and Watanabe (2011) described reproductive behavior including nest building and showed two courtship photographs of the SNZP *C. rhombifer*. Ferguson (1985) published an extensive chapter on reproductive biology and embryology, including comparative data on nests, eggs, and hatchlings of *C. rhombifer*. A detailed study on social behavior and reproduction (linear social hierarchy, male-male agonistic interactions, male-female courtship patterns) in *C. rhombifer* has been completed at SNZP and is being prepared for publication.

PHOTO BY MEHGAN MURPHY, SNZP

Fig. 4. Business end of a *Crocodylus rhombifer* at SNZP. The green color of the teeth in the back of the mouth is caused by algae growth. Vladimir Dinets has watched small fishes clean algae growth off the teeth in American Crocodiles.

The enclosures at SNZP are divided by metal bar fencing. In July 2014, three cinderblocks (painted black, white, and original gray color) were placed along the fence line in the middle exhibit as a part of this operant conditioning program (see Augustine et al. 2015b for additional information). The next morning, the black block was found in the pool. It was returned to the original position by keepers and moved back to the pool by the crocodiles an additional six times over the next few months. Once, a keeper (KM) saw the male pick up the block and drop it into the pool (Augustine et al. 2015b).

One morning, the pool was completely dry (see fig. 2 in Augustine et al. 2015b showing pipe on far left next to cinderblock). A copper intake drain pipe had been removed from the drain receptacle by a *C. rhombifer* and was clearly crushed by its jaws (Fig. 3). The damage clearly showed the biting power necessary to inflict such changes to the pipe (21 cm long, 76 mm in diameter and 6.3 mm thick with a series of openings on the side; weight was 2.0 kg). Small pieces of the pipe were protruding from the openings and bent nearly 90° from the longitudinal axis of the pipe. Ultimate tensile strength or tensile strength is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. Copper pipe is almost pure copper and may be manufactured from any of five copper alloys. While we are unable to determine whether alloys were added to the pipe, copper values (99.9% Cu) listed in Wikipedia (Ultimate Tensile Strength) are Yield Strengths —Megapascals (MPa) 70; Ultimate Strength—MPa 220; Density (g/cm^2)—8.92. As a comparison, structural steel is 250 MPa, 400500 MPa and 7.8 g/cm^2, respectively. Copper is a relatively soft metal and the crocodile may have been stimulated to bite it since it was shiny, somewhat malleable and provided biofeedback as water flowed as a steady stream into the pipe.

Erickson et al. (2012) measured adult bite forces and tooth pressures in all 23 extant crocodilian species at St. Augustine Alligator Farm in Florida and Crocodylus Park in Darwin, Australia (see Grigg and Kirshner 2015). They analyzed the results in ecological and phylogenetic contexts and concluded that these reptiles generate the highest bite forces and tooth pressures known for any living animals. Crocodilians have canine and molar-like teeth. Bite forces strongly correlate with body size, and body size changes are a major mechanism of feeding evolution in this group. Erickson et al. (2012) presented a table (anatomical measurements, and bite-force performance for extant Crocodylia) that shows dental measurements and pressure generation—*C. rhombifer* show a range of estimated caniniform bite forces (RCBF) of 1392–3127 N used to initially contact and seize prey and range of estimated molariform bite forces (RMBF) of 917–2035 N used to crush prey. On the other hand, Erickson et al. (2012) described a *C. porosus* individual of 6.7 m likely capable of a molariform bite force of approximately 27,531 N to 34,424 N (6187–7736 lbs). A Newton (N) is a unit of force.

Crocodylus rhombifer prey upon a variety of animals, but mostly fish and turtles (Dinets 2013). To deal with turtle shells and bones, these reptiles have massive teeth in the back of their jaws. We carefully checked the empty pool to locate shed or broken teeth after the pipe (and crocodiles) was removed; no teeth were found. We visually examined open mouths during basking at the front of the exhibit in close proximity to us and the dental arcade for all three crocodiles appeared intact (Fig. 4).

Neill (1971) summed up the challenges when dealing with *C. rhombifer* in captivity by saying that in proportion to its size the species is one of the most difficult of crocodilians to handle and has an exceptional impulse to fight when molested. In comparison at Dallas Zoo years ago, a youthful and relatively inexperienced JBM had to jump on the backs of a two-meter American Crocodile (*Crocodylus acutus*) and a similarly-sized *C. porosus* every few days to apply topical ointment for a serious skin infection for several months. Had the patient been a *C. rhombifer* with the same medical issue, it would have had to cure itself.

Acknowledgments.—We dedicate this paper to crocodilian biologist Kent A. Vliet from the University of Florida, who has studied these reptiles for his entire career. His research interests include crocodilian biology, social behavior of reptiles, reproductive biology, and energetics of development and allometry of metabolism. He is a major player in the IUCN Crocodile Specialist Group. We greatly enjoy pictures and films of Kent swimming with eyes just above the water line studying American Alligators.

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HERPETOCULTURE NOTES

CROCODYLIA — CROCODILIANS

***CROCODYLUS RHOMBIFER* (Cuban Crocodile). SUSPENSION INCUBATION.** Suspension incubation, a technique where eggs are suspended above a moistened medium, has previously been used to incubate reptile eggs in captivity (Köhler 2005. Incubation of Reptile Eggs. Krieger Publishing, Malabar, Florida. 214 pp.). In 2009, Squamata Concepts® (Staten Island, New York 10305, USA) released a commercially-available suspended incubation container (S.I.M. [Suspended Incubation Method] Container). This container elevates the eggs on a plastic grid above the incubation medium, preventing direct contact with the substrate. The purported benefits of S.I.M containers over conventional incubation techniques are shorter incubation times, fully absorbed yolk sacs, and larger hatchlings (J. Andragna Jr., pers. comm. *In* Baumer et al. 2012. Herpetol. Rev. 43:597–599). Some of these purported benefits, such as reduced incubation time, have been demonstrated with *Sauromalus ater* at the Bronx Zoo (Baumer et al. 2012, *op. cit.*).

Since 2012, seven Cuban Crocodile (*Crocodylus rhombifer*) hatchlings have been produced by a single breeding pair of adults maintained at the Smithsonian's National Zoological Park; two in 2012 and five in 2015. Ten out of 26 eggs laid in 2012 showed initial signs of development. Eight of the original 10 eggs were set up for incubation in a small plastic container (ca. 21 × 15 × 8 cm) without air holes and partially buried in a 1:1 mixture of vermiculite to water by weight; the remaining two eggs were placed in a small S.I.M. container (ca. 20 × 17 × 11 cm) suspended over saturated vermiculite. Two different incubators were used to incubate the two groups of *C. rhombifer* eggs in 2012. Eggs in the S.I.M. container were incubated inside a Grumbach compact S84 model incubator (Lyon Technologies Inc. Chula Vista, California 91911, USA), whereas the eggs placed in a 1:1 mixture of vermiculite were incubated in a GOf 110-watt reptile incubator (GOf, Savannah, Georgia 31415, USA) with a Big Apple proportional thermostat (Big Apple Pet Supply, Boca Raton, Florida 33432, USA). Both containers were vented for gas exchange weekly for the first month, increasing in frequency as the eggs developed, to