HUSBANDRY

Propagation of the South American Bushmaster (*Lachesis muta muta*) at the Jacksonville Zoo and Gardens

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Photographs by the author except where indicated.

"Coiled in a mound on the forest floor, its calligraphic black and tan colors blending with the surrounding debris, was the most magnificent snake I'd ever seen in nature. The snake's behavior was not exaggerated, no lunging strikes, no frenzied escape efforts, but a powerful sensation of measured readiness, like Clint Eastwood's squint in *High Plains Drifter:* 'Don't come closer'" (Greene 1997).

The Jacksonville Zoo and Gardens (JZG) acquired 1.1 South American Bushmasters (*Lachesis muta muta*) in December 2003. This pair reproduced in 2007 and 2008. This was the first breeding of Bushmasters by JZG and the techniques that were utilized to produce the two clutches are described here in detail. During the first year of breeding, the International Species Information System (ISIS.org) listed 60 *Lachesis m. muta* in numerous zoological facilities. After contacting the Association of Zoos and Aquariums (AZA) Bushmaster Studbook Keeper on the potential breeding of the pair, it was determined to be highly desirable.

Female South American Bushmaster coiled around her clutch at the Jacksonville Zoo and Gardens in 2007.

Biology

The Bushmaster is endemic to tropical rainforests and lower montane wet forests of Central and South America (Campbell and Lamar 2004). Possibly the longest of all vipers, accounts of animals reaching lengths over 3.6 m are rare, but most adults commonly exceed 2.0 m in length (Campbell and Lamar 2004). Bushmasters are like no other pit viper in the western hemisphere, in that they are the only genus that is oviparous (Savage 2002). They possess no rattle, but they will alert a perceived intruder to the danger that awaits by vigorously vibrating their tails against the substrate or the enclosure. Campbell and Lamar (1989) described this species as crepuscular and nocturnal. Mehrtens (1987) described it as secretive and given to sheltering in fallen logs or near exposed root systems. According to Greene (1997), Bushmasters feed exclusively on rodents throughout their lives. de Souza (2007) reported that wild Bushmasters do not have a regular breeding season.

Propagation in 2007 and 2008

At JZG, the Bushmasters are housed in an exhibit measuring 5.0 x 2.1 x 2.7 m. Artificial rockwork lines the interior walls and partially encompasses land areas near and around the water feature. The water basin is a 38-liter pool fed by a stream that stretches across 75% of the enclosure. The stream divides the upper and lower areas of the exhibit. A re-circulating pump submersed in the pool supplies the stream with water flow. Substrate consists of sphagnum moss in the lower front tier of the exhibit and cypress mulch covers the upper tier near the service door. Many live plants are maintained in the exhibit to provide hide areas and aesthetics. Species include Pothos (*Epipremnum* sp.), Philodendrons (*Philodendron* sp.), Rubber Plants (*Ficus elastica*), Peace Lilies (*Spathiphyllum* sp.), and bromeliads *(Neoregelia* sp.) (http://plantinfo.umn.edu/). The exhibit also is home to Blue Poison Dart Frogs (*Dendrobates azureus)* and Green and Black Poison Dart Frogs (*Dendrobates auratus*).

The photoperiod for the exhibit is maintained at a constant 12-hr daytime/12-hr nighttime. Temperatures are 24–28.5 °C and the basking spot is never above 29 °C. Exhibit temperatures are maintained by 90- and 250-watt spot lamps along with a heating ventilation and air conditioning (HVAC) duct directly over the exhibit. The latter provides fresh air in the enclosure. Each end of the habitat has a 19 x 19-cm mesh-covered vent for air exchange. Daily spraying of half the enclosure with reverse osmosis (RO) water keeps the humidity elevated. Exhibit moisture also is supplemented by a Pro Mist® misting system. Two misting heads mounted on the screen overhead project mist toward the moist side of the enclosure twice daily for ten-minute intervals. In January–March 2007, the exhibit was sprayed more frequently with the RO water hose to stimulate reproductive activity.

Possible copulation was observed in early morning on 4 March 2007. The male was chin-rubbing on the female in late March, but no other breeding attempts were reported by keeping staff. Minimal

The 2007 clutch before the last egg was added.

Table 1. Egg morphometrics.

	2007		2008	
Egg #	**Weight (g)**	**Size (mm)**	**Weight (g)**	**Size (mm)**
01	89.5	77 x 42	85.9	82 x 39
02	83.0	75 x 43	83.4	73 x 44
03	90.1	87 x 40	88.6	79 x 44
04	87.2	86 x 38	83.9	71 x 45
05	81.8	70 x 43	80.5	70 x 44
06	86.7	79 x 42	83.9	69 x 46
07	89.7	83 x 43	79.7	66 x 45
08	80.3	73 x 43	88.5	71 x 45
09	80.0	68 x 45	85.6	68 x 45
10	83.2	62 x 41	78.2	68 x 42
11	80.4	70 x 44	84.0	69 x 45
12	81.8	63 x 45	81.6	72 x 45
13	79.1	67 x 43	84.6	82 x 39
14	84.6	73 x 46	84.4	77 x 42
15			84.0	71 x 46
16			86.2	71 x 43
Mean	**84.1**	**73.8 x 42.7**	**83.9**	**72.4 x 43.7**

disturbance of the adults during the spring was maintained to avoid complications with reproduction or oviposition. The female began to refuse prey on 16 May and did not feed even though prey was offered each week. Her weight increased from 5.0 kg in January 2007 to 5.4 kg in June 2007. She was palpated during the first week of June, as her body seemed distended. During palpation, the body of the female was taut and no obvious egg bulges were visible. The herpetology staff watched for a pre-egg laying shed from the female; shedding occurred on 22 April 07 and again on 7 July 07.

On 13 June, the female was very active during the day, unusual behavior for an animal that is rarely known to move during daylight hours. A five-gallon bucket with a concrete bark design was cut in half (top to bottom) and served as a secure site for oviposition. The hide area was positioned near the exhibit service door to aid in the removal of the female and eggs. At 1600 h on 14 June, she attempted to lay a clutch of eggs inside the hide box. The next morning at 1000 h, keepers gently tubed the female and extracted a clutch of 13 eggs. Each egg was carefully separated from the clutch, weighed and measured, and labeled with a number 2 pencil. The incubation egg chamber consisted of a 12-quart Rubbermaid® storage container with a 1:1 mixture by weight of water to vermiculite.

The female was taken to the animal hospital where she was radiographed for egg retention. She was found to have withheld two eggs, one just before the cloaca and another far back in the oviduct. This brought the clutch total to 15 eggs. The dam proceeded to lay

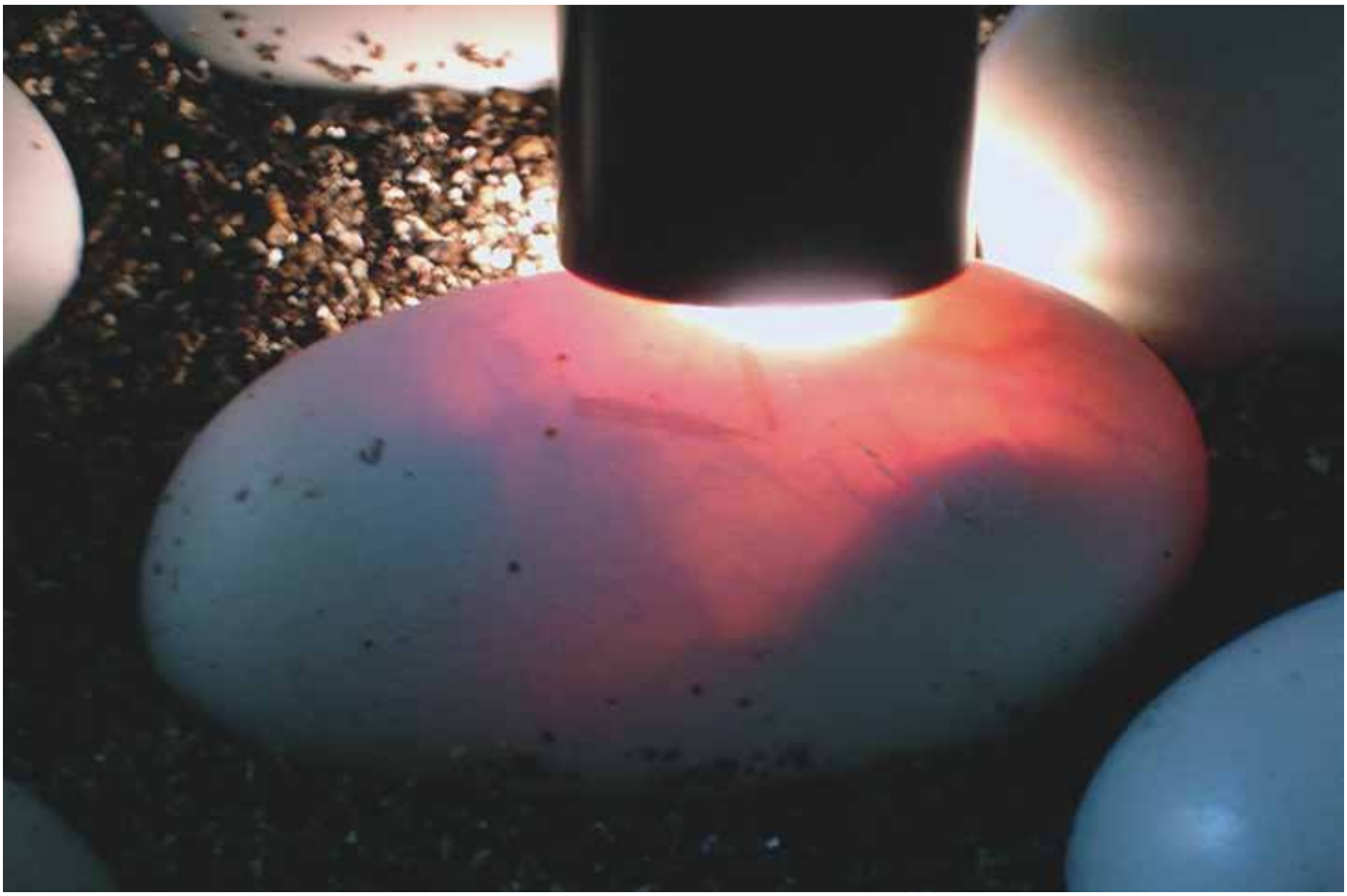
The female laid a 14th egg while being radiographed for egg retention.

the 14th egg during the hospital procedure. She was given an intramuscular injection of 0.5 ml of the hormone oxytocin to encourage deposition of the retained egg, and was placed back on exhibit. Over the course of the next two days she was administered 0.5 ml of oxytocin daily without result. A decision was made by the veterinary team to intervene surgically for the safety of the dam. The operation successfully removed the egg, but it could not be incubated. In an effort to minimize the surgical site, the egg had amniotic fluid and yolk drained; nevertheless, it appeared to be fertile with good size and color. The weight of the female was 4.4 kg after oviposition, down just over 1.0 kg from her pre-oviposition weight.

The incubator was set at 30 °C (Boyer et al., 1989) and four sealed 1.9-liter bottles of water were placed in the bottom of the incubator to keep temperatures steady in the event the incubator should fluctuate. Only three days into incubation, the HVAC system of the building that housed the incubator failed and the eggs were at 32 °C for a short time. The incubator was moved to a building with more stable temperatures to limit further unforeseen mishaps. Six days into the incubation period, a decision was made to reduce temperatures to 25.5 °C from the current incubator setting of 30 °C (Ripa 2007). Incubation temperatures were slowly reduced but could not be maintained. Temperatures fluctuated from 25.5 °C during early incubation to 27.2 °C just before hatching. Moisture was monitored by weight of the clutch, and RO water was added when the egg chamber was not equal to the box weight at the start of incubation. Candling of eggs was utilized for observation of tissue development. Eggs were not handled or removed from substrate while candling. As development progressed, more caution was taken during candling, since the eggs contained venomous neonates.

Half of the eggs began to dimple at what would be a week before hatching. After 76 days of incubation, egg #7 pipped on the afternoon of 30 August 2007. Over the next three days, the remainder of the clutch emerged, with the last neonate hatching on 2 September 2007. Each hatchling was weighed as it emerged from the egg. Neonates from eggs 4, 5, 6, 9, 11, and 14 hatched overnight, and the numbers of the eggs from which they emerged could not be determined. Neonate weights were 63.5–72.4 g. Each individual was housed separately in a 12-quart Rubbermaid® container with a 0.4-liter water dish and a 1.2-liter Gladware® storage container that had a 5.1-cm hole cut in the middle for access. This container was half filled with sphagnum moss and kept moist to offer a humidity chamber. This reduced the chance of the enclosure becoming soaked by over-misting or from a spilled water bowl. Each unit had a double row of 0.5 cm-holes either drilled or melted with a soldering iron encircling the top of the container. This provided airflow throughout the unit and kept humidity levels stable. Hatchlings moved back and forth from the humidity chamber to resting on or behind it.

The rack system housing the containers was kept locked with two aluminum poles that prevented the drawers from being opened. These were held in place by eyehooks at the top and bottom with



A small flashlight was used to candle eggs to monitor tissue development.

Table 2. Hatchling data. Neonates marked with an asterisk (*) hatched overnight, and the numbers of the eggs from which they emerged could not be determined.

Egg #	Date	Weight (g)	First Shed	Sex
07	31 AU 07	70.3	19 SE 07	0.1
13	01 SE 07	63.5	19 SE 07	1.0
01	01 SE 07	71.5	19 SE 07	0.1
08	01 SE 07	66.1	19 SE 07	1.0
12	01 SE 07	66.9	19 SE 07	1.0
10	01 SE 07	66.8	19 SE 07	0.1
02	01 SE 07	68.0	19 SE 07	1.0
04*	02 SE 07	65.3	19 SE 07	0.1
05*	02 SE 07	70.1	20 SE 07	0.1
06*	02 SE 07	67.6	20 SE 07	0.1
09*	02 SE 07	64.4	19 SE 07	0.1
11*	02 SE 07	64.6	19 SE 07	1.0
14*	02 SE 07	68.0	19 SE 07	1.0
03	02 SE 07	72.4	19 SE 07	0.1
Mean		**67.5**		**6.8**
05	29 AU 08	65.2	13 SE 08	0.1
16	29 AU 08	65.9	13 SE 08	0.1
02	29 AU 08	68.1	13 SE 08	0.1
08*	29 AU 08	64.4	13 SE 08	0.1
09*	30 AU 08	67.0	14 SE 08	0.1
11*	30 AU 08	70.4	14 SE 08	0.1
01	30 AU 08	63.8	15 SE 08	0.1
12	30 AU 08	67.1	14 SE 08	0.1
15	30 AU 08	66.1	15 SE 08	0.1
06	30 AU 08	71.6	15 SE 08	0.1
03*	31 AU 08	63.5	15 SE 08	1.0
04*	31 AU 08	71.3	15 SE 08	0.1
07*	31 AU 08	61.3	15 SE 08	1.0
10*	31 AU 08	68.6	15 SE 08	0.1
14*	31 AU 08	65.6	13 SE 08	1.0
13	02 SE 08	67.4	16 SE 08	0.1
Mean		**66.7**		**3.13**

folding hasps covering the crimped ends of the poles. Padlocks prevented removal. The unit was kept at a steady 26.6 °C with no thermal gradient. Radiant heat tape was installed in the back of the unit but was not needed as drawers reached and maintained the recommended temperatures without it. All of the juveniles completed their first shed at just under three weeks of age. We observed no difficulties in ecdysis, which we attributed largely to the style of the enclosures.

Juveniles were reluctant to accept frozen/thawed (f/t) mice as first meals, and live prey items were used to elicit a feeding response. After several live mice were consumed, almost all of the offspring were switched to f/t adult mice from forceps. Prey items were offered every 7–14 days. Some individuals fed readily at each opportunity, whereas others fed only every second feeding. Many of the juveniles would strike the prey and not let go. Very few would bite and release, leaving the prey for later consumption. The first stools of some juveniles contained shed fangs, and two pairs were found in a few instances. Surprisingly, these fangs were 0.5–0.8 cm long when passed.

Probing of the juveniles was completed at 3–5 months of age. Females were probed at 3–5 subcaudal scales and males at 7–9 subcaudals. Each animal was micro-chipped with a Trovan® PIT (passive integrated transponder) tag on the left side just above the cloaca. Over the next year, all animals were placed in AZA facilities.

The breeding of the pair was approved again in 2008. The female's viability was a concern after having an egg surgically removed. However, her overall body condition was good and her weight was 4.8 kg in early 2008. Consequently, we proceeded, anticipating another clutch. The male was observed pursuing the female in early March after he was returned to the exhibit. During mid-March, the male was extended over the female and stimulated her caudal region with his tail. Because we tried to disturb them as little as possible, we did not witness copulation, but the female began refusing prey during the second week in May.

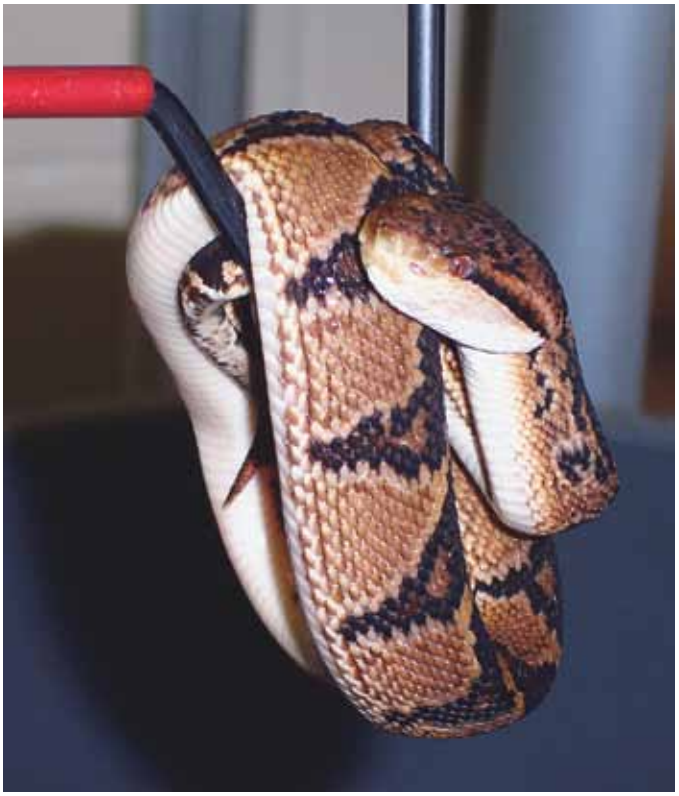
On 11 June, she was active and seemed uneasy, and the posterior half of her body was distended. The suture site from the egg removal in 2007 appeared to have abscessed, so the veterinary staff was notified. The next day she was taken to the hospital where radiographs confirmed that she was gravid with at least 15 eggs.

Each hatchling was housed separately in a 12-quart container with a 0.4-liter water dish and a 1.2-liter storage container with a 5.1-cm hole for access.

After 76 days of incubation, egg #7 pipped on the afternoon of 30 August 2007 and the hatchling emerged on 31 August.

Further examination of the abscess would not be possible until after oviposition. Her weight at that time was 5.5 kg, and she was nearing the oviposition date of the previous year. A larger hide box was constructed from half of a large plastic flowerpot covered with sphagnum moss. This was introduced to the exhibit in late May, although the female chose not to occupy the hide. On 17 June, she coiled next to the hide box and began oviposition in the late afternoon.

On the morning of 18 June, she was removed from a clutch of 16 eggs and radiographed for egg retention. All eggs had been passed, and the abscess appeared to be scar tissue protruding from the suture site. Exploratory surgery by our veterinarian found no complications. All of the eggs had good color and size. Data were collected on each egg. Again, the incubator was set at 25.5 °C but would not drop below 27 °C throughout incubation. Daily temperatures of the building rose as the heat of the summer intensified during July and August and fluctuated from 27–27.8 °C. Water was added over the course of incubation as egg box weight dropped. Six eggs were dimpled on 21 August. At 71 days of incubation, three eggs pipped in the afternoon of 28 August and hatchlings emerged the following morning. This clutch varied less than one gram in average neonate weight from that in 2007 despite the fact that the animals in the second clutch hatched and shed earlier (possibly attributable to higher incubation temperatures?). The majority of the young switched readily to f/t prey, but a few difficult feeders held out for live prey. Those that fed ravenously appeared ready to eat each time the unit was maintained.



A young Bushmaster is hooked from its enclosure for servicing.

Hatchlings were able to move in and out of a humidity chamber made from a container with moist sphagnum moss.

After two large clutches from this pair, we determined that a non-reproductive year was appropriate, especially since they are now well represented in the captive gene pool. In general, more data on captive husbandry and reproduction of Bushmasters are necessary to establish standardized guidelines for their propagation. Wild populations are increasingly threatened by habitat loss and persecution, and zoological institutions must be able to respond effectively if the species' survival comes to depend on captive populations.

A five-month-old Bushmaster feeding on a frozen and thawed prey item.

Acknowledgements

Many professionals have contributed to the success of our efforts. In particular, we thank Donal M. Boyer of San Diego Zoo for sharing his knowledge on Bushmasters. Dean Ripa was extremely gracious for answering emails and taking a phone call during the incubation of the first clutch. Dr. J. Andrew Teare lent his expertise in surgery. I also thank the staff of the Herpetology Division at The Jacksonville Zoo and Gardens: Mark Beshel, Karl H. Betz, Andy E. Price, Steve Gott, and Dino Ferri. Their tireless efforts and diligent recording of data made this paper possible.

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SUZANNE L. COLLINS, CNAH

Although this individual is a wildtype living in nature, Corn Snakes (*Pantherophis guttatus*) have been captive-bred for decades. Those snakes, with at least 30 different color and pattern morphs, certainly qualify as "domestic" reptiles.