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Husbandry and Breeding of the Crocodile Monitor *Varanus salvadorii* Peters & Doria, 1878 in Captivity

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Abstract - Due largely to its impressive size, *Varanus salvadorii* has become a mainstay in zoological exhibitions. Yet, despite its popularity in captive collections, little data exists on its husbandry and reproduction in captivity. This article describes experiences with the captive husbandry and breeding of *V. salvadorii* at two zoological parks in Madrid, Spain.

Introduction

Endemic to New Guinea where it inhabits dense lowland tropical forests, the crocodile monitor lizard *Varanus salvadorii* has rarely been observed in the wild (Horn *et al*., 2007). Wild populations of *V. salvadorii* are threatened by the effects of habitat fragmentation caused by uncontrolled logging and mining activities, as well as over-collection for food and the exotic pet trade (Koch *et al*., 2013).

Since 2001, the legal export of live *V. salvadorii* specimens from Indonesia to the European Union has been curtailed as a way of preventing declines in wild populations (UNEP-WCMC, 2009). However, some countries such as Spain, France, Germany, the Czech Republic, and the United Kingdom continue to receive wild-caught specimens by importing them via intermediate countries such as the United States (UNEP-WCMC, 2012). Given the continued demand for live specimens, breeding this endangered species in captivity may be one of the best options for reducing the number of specimens taken from the wild.

For many years, there have been limited data available on the successful reproduction of *V. salvadorii* in captivity (Philippen, 1994; Schmicking & Horn, 1997). Some earlier reports documented successful breeding behavior including copulation, oviposition, and even hatching, but most of the eggs received had been infertile. Until recently, successful reproduction of *V. salvadroii* in zoos had been limited to the Honolulu Zoo (1997-1999), Fort Worth Zoo (1997-1999), and Gladys Porter Zoo (1992), but in the last few years, some reports on the husbandry and breeding of *V. salvadorii* have presented interesting and promising results (Waterloo & Bayless, 2006; Mays, 2007; Trout, 2007), with the Denver (Trout, 2007) and Houston (Mays, 2007) Zoos successfully reproducing specimens in their collections.

In an effort to present useful information that can be used to increase captive breeding and reduce the capture and removal of specimens from the wild, this article describes husbandry and successful reproduction of *V. salvadorii,* in captivity.

Care in Captivity

Naturaleza Misteriosa at the Madrid Zoo & Aquarium

The Naturaleza Misteriosa at the Madrid Zoo & Aquarium currently maintains a breeding group of adult *V. salvadorii* in two adjoining enclosures each measuring

Figures 1 & 2. *Varanus salvadorii* terraria at Naturaleza Misteriosa at the Madrid Zoo & Aquarium.

3 x 1.5 x 2 m (L x W x H) (Figs. 1 & 2). The breeding group is currently comprised of one male (M1) (Fig. 3) and two females (F1 and F2). Females are housed together in a separate, adjacent terrarium from the male. Males and females are only introduced for mating purposes and housed together for periods of two to four weeks. Both females are rarely introduced to the male at the same time since female F1 has shown aggression towards the male and female F2. During introductions for breeding, the male or female is lured into the other sex´s enclosure with food to avoid handling and related stress.

The terraria are equipped with heated floors, an automatic misting system, ultraviolet lighting and a single basking area. Ultravitalux lamps (300W) are used to generate basking spots of 35-40° C. Ambient temperatures are maintained for most of the year at 28-32° C, decreasing slightly in the winter months. Humidity levels are increased from the months of May to August through four to six 3-minute misting sessions per day; humidity levels are kept lower during the remaining eight months of the year, with only two to three misting sessions daily. A 50-100 cm deep layer of cocopeat or coconut fiber is offered as substrate because of its ability to retain humidity. Live plants are avoided because they are immediately destroyed by the animals. Each enclosure features a dense area of thick branches and a large pool of water measuring 90 x 120 x 30 cm (324 L).

Figure 3. Male M1 in the terrarium

The diet offered to captives is quite varied, comprised mainly of poultry (chicken, chicks, quail) and rodents (rats, mice), but rabbit, duck, turkey, fish and crayfish are also offered on occasion. For behavioral enrichment, fresh or cooked eggs are sometimes buried in the soil, which are quickly found and unearthed. Young animals feed primarily on newborn rodents and small portions of poultry. Adults are fed twice weekly, and juveniles are fed two to three times per week. Food offerings are increased during the mating period.

Parque Temático de la Naturaleza Faunia

Several specimens of *V. salvadorii* have been maintained at the Parque Temático de la Naturaleza Faunia in Madrid, Spain since 2008. At the Parque Temático de la Naturaleza Faunia, up to 1.3 specimens have been housed together in a 5.5 x 2.5 x 3 m enclosure. The terrarium is equipped with an automatic misting system, ultraviolet lighting and two basking areas. Ultravitalux lamps (300W) are used to generate basking spots of 35-40° C. The enclosure also features a water

basin measuring 100 x 50 x 50 cm. A dense area of thick branches connects with two different resting rocks located 1.5 and 2 m from the floor. All other husbandry parameters are identical to those described for the Madrid Zoo & Aquarium.

Behavioral Observations

We have found the behavior of *V. salvadorii* in captivity to be particularly interesting. Captive specimens of *V. salvadorii* are typically nervous, elusive, and shy away from human contact, and some can even respond aggressively to human presence. As we have seen in other reptile species, each specimen of *V. salvadorii* has unique behavioral patterns that clearly distinguish it from other individuals. Through daily husbandry routines and human activity, all specimens at the Madrid Zoo & Aquarium have become very comfortable with human presence and rarely exhibit stress or assume defensive postures. The males are very curious and peaceful towards humans; two of the females are calm as well, but one female (F1) has remained highly nervous and irritable.

Adding new objects to the enclosures provides opportunities for the animals to investigate them, opening up a wide range of possibilities for behavioral enrichment. At the Parque Temático de la Naturaleza Faunia, a target training program has been developed to enhance the animals' physical abilities as well as enable veterinary procedures such as blood extractions and other treatments. Progress was slow, but some results have been achieved. Today, these captives are stronger, faster, and can be handled without any danger, even by veterinarians and strangers.

Captive Reproduction

Madrid Zoo & Aquarium

In April 2009, female F1 (Fig. 4) at the Madrid Zoo & Aquarium was introduced to the enclosure of male M1. Initially, both animals were tolerant of one another; however, by the end of the month, the female began to show signs of dominance and aggression towards the male. During this time, there were observed attempts by the male to copulate with the female, but successful copulation was not observed. Without definitive proof of successful mating, and with increased aggression by female F1, it was necessary to separate her from the male in the first week of May and move her back with female F2 (Fig. 5). In late June there were episodes of aggression by female F1 directed toward female F2; therefore, it was decided to house each female separately. For three days, female F1 refused food, which is unusual for the species and especially for this female. Gravid female varanids often refuse to eat, especially as egg laying approaches; sometimes they may accept food, but end up regurgitating it hours later. These signs are often suggestive of imminent ovoposition.

On 2 July 2009 female F1 laid a clutch of 10 eggs, which were partially buried in the soil next to a fallen tree trunk. All eggs were removed and buried in a plastic container with vermiculite mixed with water to an approximate ratio of 1:1 by weight, and placed inside an incubator constructed from a modified refrigerator. Maximum and minimum temperatures inside the incubator were recorded every 12 hours; incubation temperatures ranged between 28 and 30.5° C.

By the second week of incubation, six eggs became

Figure 4. Female F1 in the terrarium.

Figure 5. Female F2 in the terrarium.

dark in appearance, showing signs of infertility. It was decided to move each egg to its own plastic container and isolate them from the remaining eggs which still looked viable. These six eggs were discarded some days later. After 185 days of incubation, the first two eggs hatched; a third egg hatched nine days later after 191 days. On day 200 the remaining egg was manually opened, as its appearance began to worsen. Inside the egg was a dead, fully-developed embryo, with an everted and deformed abdomen.

In late September 2009, female F1 was introduced to the enclosure of male M1, where they were housed together for a month. No successful copulations were observed during this period. The female did show aggression towards the male on several occasions, causing in some cases bite wounds that required veterinary care. Thus, it was once again necessary to separate the pair.

In early January 2010, female F1 laid a clutch of 10 eggs, which were scattered atop the substrate throughout the enclosure. The eggs were laid one at a time over the course of the night and following day. Incubation parameters were similar to the previous event, except that the eggs were incubated in individual containers from the beginning. After the first 15 days of incubation, six eggs were visibly darker and turgid, indicating they were not viable, and were discarded. The first two offspring hatched after 185 days of incubation (Figs. 6 & 7). Two additional hatchlings emerged two days later, resulting in a total of four healthy offspring.

Female F1 was introduced to the terrarium of male M1 on three different occasions in 2010. Two of these introductions in June and August lasted less than a day due to excessive aggression that the female showed towards the male. The third introduction lasted for one week during early September 2010.

During the first week of November 2010, female F1 laid a clutch of 10 eggs which were once again scattered throughout the enclosure. Unlike in previous events, digging behavior was not observed in the days leading up to oviposition. Eggs were incubated individually at temperatures ranging from 29.5-30.5° C. Eight out of the ten eggs showed signs of infertility after 15 to 21 days of incubation and were discarded. The two remaining eggs hatched after 155 days of incubation (Fig. 8).

Figures 6 & 7. *Varanus salvadorii* hatching, 2010. Photographed by **Jairo Cuevas.**

Figure 8. Hatchling *V. salvadorii* emerging from egg, 2011. Photographed by **Jairo Cuevas**.

Figure 9. Closeup of hatchling *V. salvadorii*. Photographed by **Jairo Cuevas**.

Figure 10. Hatchling *V. salvadorii* shortly after emerging from its egg. Photographed by **Jairo Cuevas**.

Figure 11. Juvenile *V. salvadorii* bitting a handling glove. Photographed by **Jairo Cuevas**

Parque Temático de la Naturaleza Faunia.

A group of one male (M2) (Fig. 12) and three female (F3, F4, F5) *V. salvadorii* have successfully lived together in the same terrarium at the Parque Temático de la Naturaleza Faunia for two years without any signs of aggression. In July 2010, male M2 began pursuing the females in an effort to copulate with them; copulation was observed between the male and all three females. In late August, one of the females (F3) began to dig in a hollow log filled with humid cocopeat, and deposited five eggs, of which only one was fertile. Over the next several days female F3 became lethargic and unresponsive. Veterinary radiographs confirmed the presence of a retained egg within the oviduct which required surgical removal. This female died on 1 September 2010 from complications related to the dystocia.

Figure 12. Male M2 at the Parque Tematico de la Naturaleza Faunia. Photographed by **Jairo Cuevas**.

The single remaining egg incubated for seven months at temperatures between 28-30° C before it began to deteriorate in early March 2011. Dissection of the egg revealed a dead, fully developed embryo.

Female F4 died in 2011 due to an ovarian cyst, reducing the *V. salvadorii* breeding group at Parque Temático de la Naturaleza Faunia to female F5 and male M2. In November 2012, the breeding female F1 from Madrid Zoo & Aquarium was transferred to the Parque Tematico de la Naturaleza Faunia due to problems with aggression directed towards male M1, the father of all offspring produced to date. In March 2013, this female was introduced to female F3 and male M2, but showed aggression towards the new male, so it was necessary to separate her from this new group. In early July 2013, male M2 began attempting to copulate with female F3, so it was decided to once again introduce female F1 to the group. Aggression was not observed between female F1 and the male, and copulations were observed over the next 10 days. In early August, courtship and copulations ceased. On 10 September, female F1 scattered a clutch of four infertile eggs on the soil surface without showing any apparent signs of nest-building.

Discussion

Varanus salvadorii is a difficult species to breed in captivity because very little is known about its biology. Some zoos have successfully bred this species, but the results have not always been as favorable as they could be. For example, infertile eggs, aggression, incubation difficulties, and reproduction-related pathologies are a

few challenges frequently experienced with this species. Based on our experiences with *V. salvadorii* at the Parque Temático de la Naturaleza Faunia and the Madrid Zoo & Aquarium, it is possible to develop a breeding program for *V. salvadorii* with groups of individuals maintained together all year long, or with groups of individuals that are housed together and only introduced during the breeding season.

Although individual *V. salvadorii* may experience difficulties adjusting to each other's reproductive cycles, temporary separation of the male may increase chances of successful reproduction when reunited with females during the mating season. Caution should be taken when females are housed together with males, as aggression can occur. It is possible that females respond aggressively to repeated attempts by males to mate with them throughout the year when they are not receptive. Our experiences suggest that aggressive behavior by the female towards the male is inhibited when females are reproductively cycling and receptive to copulation.

In North American captive collections, male and female *V. salvadorii* experience several hormonal peaks throughout the year which define the ideal time for reproduction (Long, 2005). While hormonal fluctuations occur throughout the year in males, females maintain a consistent pattern of estrogen peaks, especially during the months of January, March, June, July, and August. Ultrasound data from captive individuals indicated that estrogen peaks coincide with an initial phase of follicular growth which reaches its height one month after the beginning of vitellogenesis (Long *et al*., 1999). Thus, if these findings are applicable to captives held in other parts of the world, the months of February, April, July, August and September could be months when females are most fertile, and thus the months in which animals should be paired for breeding.

Our findings from Madrid generally agree with Long *et al*. (1999), but successful mating has also occurred in October. Higher temperatures and humidity levels, and longer daylight could be responsible for triggering the three distinct mating periods that have been observed in *V. salvadorii* at the Madrid Zoo & Aquarium (September-October and April-June) and one at the Parque Temático de la Naturaleza Faunia (July-August). These reproductive periods are likely reflective of the conditions inside the terrariums rather than the weather patterns or climate of Madrid.

This article adds additional information to what is known about the husbandry and reproduction of *V. salvadorii* in captivity. It is hoped that this information will be useful to other keepers and institutions seeking to keep and reproduce this species in captivity.

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