Notes on the breeding behaviour of the Crocodile monitor (*Varanus salvadorii*) in captivity

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VARANUS salvadorii is the longest monitor lizard in the world, with some reports stating this species may reach 4.5 metres in total length (Schultze-Westrum, 1961; Redmond, 1980; Bayless, 1998; Horn, 2004a). The natural habitat of this large arboreal species consists of lowland dense jungle and tropical rainforest in New Guinea (Schultze-Westrum, 1961; Horn, 2004a), where the species occurs in both provinces of Papua and Iran Jaya (Bayless, 1998; Horn, 2004a). Crocodile monitors, as they are commonly known, are apex predators and, like many other large varanids, ambush hunters. Although their natural diet is not clearly understood, prey is likely to consist of mammals, birds, reptiles, fruit bats (flying foxes), and marsupials ('Cuscus') – prey is attacked both on the ground, and by dropping on it from above, causing severe and massive trauma before being eaten (Bayless, 1998). The largest known Crocodile monitor belongs to the Gladys Porter zoo in Brownsville, Texas – this individual, a long-term wild caught male in 2005 measured 3.4 m (Hairston Adams, pers. comm.). Approximately 7.6 to 15 cm of its tail is missing, and yet it is considered verifiably the longest known example of this species reported, in captivity or from the wild. As an arboreal species, even a 3.3 meter long specimen would probably not weigh very much, as two-thirds of its size is its tail. The average life span of captive specimens has varied from 18 years (H. G. Horn, pers. comm.) to 20 years (Bennett, 1998).

Breeding Group

From 1994 to early 1997, the principal author maintained a small (1:2) group of Crocodile monitors. The male, approximately 2 years old and about 1 metre long, was acquired in October 1994; the two females, acquired in late 1995, were long-term captives and averaged 1.8 m in total length. All three lizards were taken to the local veterinarian to be x-rayed to determine their sex. Sexing Crocodile monitors, like most varanids, is not without complications. Many 'males' have consequently laid eggs, and combat occurs with no sexual bias (H. Adams, pers. com.). My original notion that I might have had a 1.2 group was based upon behaviour of the lizards, as both females rarely ventured to the ground for any length of time, were shyer, and would 'soak' in the water for an hour or more at a time (Horn, 2004b).

Rats were the only prey taken with eagerness by the females, as apposed to the male, which seemed more willing to feed on any prey available, with mice, rats, and chicks taken with equal eagerness. Hissing cockroaches were offered, but never accepted. The females slept in hide boxes, and basking occupied a majority of their day. The male however, was quite restless. Excursions to the ground were common, as was digging. In the wild, females of *Varanus* species tend to have smaller home ranges, appear to be shy, and may encounter limited prey (Phillips, 1995; pers. obs.). Our lizards are housed separately in individual cages measuring 2.6 m x 2.6 m x 1.3 m, and also given access to an outdoor enclosure (Figure 1).

For the purpose of breeding, a large cage was constructed in June 1996, measuring 3m x 2.6m x 1.3m. Introduction of the lizards to the new enclosure occurred in July 1996, and was without complication. All three were placed in the enclosure at the same time, thus reducing the possibility of territorial disputes. Their activity during the first hour consisted of exploring, with some digging. Shortly after, all three animals sought out the hide boxes created for them above ground. Wild Crocodile monitors have been noted to sleep in tree holes many metres above ground

(Philipp, 1999). Roughly one week later, all three lizards began sharing the same hide box, tightly squeezed together, and thereafter this became standard behaviour, only changing when I separated them after the first female was observed to be gravid. At no point did I witness any aggression, or fighting by any of these lizards. In general this was a perfect 1.2 group of *V. salvadorii*. Feeding was accomplished using 30.5 cm long hemostats, the diet consisting mostly of small rats, mice, and chicks. On average feeding occurred 3 times a week with small meals – sufficient to maintian a healthy appetite. Food was usually placed near the monitor as this helped keeping each of them occupied with their own meal. Of the three animals, the females in particular would seize their food and climb to highest secure spot, before consuming it. Crocodile monitors process food faster than any monitor I have ever kept, with faeces usually being evacuated within 12 hours. Rats appeared to be their preferred prey and were consumed with much eagerness.

Breeding Conditions

During August 1996 I began to increase humidity, rainfall, and ambient air temperatures. The average temperature was 29°C (85°F) during the day, with a night time low of 21.1 to 24°C (70–75°F). Humidity was in the range of 80–85%. To stimulate breeding, I increased humidity to almost 100%, and increased night-time temperature lows to between 26.6 and 29.4°C (80–85°F). Average air temperature during the day was also increased to approximatley 35°C (95°F). Basking site temperatures remained the same throughout, from 43 to 49°C (110–120°F). Photoperiod was maintained on a constant 12/12-hour on/off cycle, with lights switched on at 07:00 hr. Breeding activity began in September 1996, within 30 days after making these adjustments. It appeared to me that copulation only occurred in the hide boxes above ground – copulatory behaviour may have happened on the ground, but it was never observed there. When copulation was observed, it would usually last up to 60 minutes, and may have continued into the night due to the fact that on a few occasions, both the male and female would appear to be 'engaged' close to the time when lights were switched off, usually from 18:45–19:00 hrs.

Breeding behavior was a non-violent affair, with the male pursuing the female and tongue-flicking her hindquarters (rear legs, tail base), neck, and the shoulder region – where pheromone pores are more frequent in the Varanidae (Andreas *et. al*., 1999). Head-bobbing was not observed, although a 'jerky' side-to-side lateral motion was. The male would also gently scratch the female's shoulders and hindquarters. Within 50 days, around mid-October, I awoke in the morning to find that one of the females (Figure 2) had constructed a large nest on the ground, and was lying on top of it – presumably a form of guarding behaviour – when the lights were turned on. The dimensions of the mound were roughly 1.3 m across and 0.6 m high. The male and other female were emerging from the hide box to bask and warm-up. When I entered the cage, the nesting female lunged at me immediately. This was the first and only time I witnessed any aggression from any of the animals in this group. I decided to remove the remaining female and male to their original cages. Unsure of what to do, I left the female, and cage conditions the same (temperature, humidity, etc.). Approximately 3–4 days later the female began to exhibit normal behaviour. She no longer showed aggression, and resumed her usual routine of basking and relative calmness, and it was at this time I entered the enclosure to retrieve the eggs.

By the time the eggs were removed, their general condition was poor. Mould was present, and a light tint of grey colouring was observed on the shells of all four. Each of them measured approximately 5 cm in length. Later that day I cut them open only to find a semi-solid yellow mass resembling a 'jelly like' substance. By the first week of November 1996, the second female had also laid a clutch of four eggs – however, these eggs were scattered about the cage, and were of a similar light grey colour. The second female did not show any signs of aggression, or maternal care of her clutch, as had the first female. Once again, when cut open, the same solid yellow mass was present. Both females began to feed within days of depositing their clutches.

Figure 1. Sub-adult *Varanus salvadorii* in naturally designed outdoor enclosure. Photograph © M. K. Bayless.

During late December of 1996 the first female was taken to the veterinarian for a check-up as I was planning to begin breeding them again in early January 1997. During the visit, x-rays showed a blockage in her oviduct, so surgery was necessary. Prior to the visit, nothing abnormal was observed with this female, diet, defecation, and general behaviour were all normal. Following surgery, this female failed to recover and died soon thereafter. By mid-January 1997, the remaining female and the male were maintained together in the breeding enclosure. For the next few months breeding behaviour was not observed, and temperatures were returned to pre-breeding conditions by mid-February 1997.

Initiaton of the breeding program was resumed during the first week of March 1997, with the same aforementioned temperature and humidity levels. Copulation was witnessed once during this month and lasted until around the middle of April, following which I began to look out for changes in behaviour of the female and indications of egg-laying (e.g. digging, aggression). None of these were observed, so I decided to have the animal examined by a veterinarian. By this time, however, it was late April and well past the 30–40 day egg-laying time line. The x-rays showed an oviductal blockage, and extensive liver damage. As with the other female, her behaviour appeared normal throughout, but by the first week of May this lizard had also died. Shortly thereafter, the male died as well. Necroscopy showed that both had extensive damage to the liver, identified by the veterinarian as possibly a form of cancer.

Whatever killed these three monitors was never observed in any of the other varanids I had in my collection at the time, which leads me to suspect that it might have been a species' specific illness. The abrupt end was a major loss, and left me with many unanswered questions.

DISCUSSION

Success in future breeding initiatives for *V. salvadorii* would seem to require individuals to be maintained in small groups, from a relatively early age. The 1.2 group I kept was ideal, although the addition of another male at some point may have introduced a possibly beneficial element of 'competition'. All three lizards were wild caught; the male, however, was still small when first imported. The females were wild caught at an older age, and had probably been maintained in captivity for at least a short time before I acquired them (despite assurances that they were both long term captives). Numerous authors have noted aggression between conspecifics; however when given ample room, and plenty of hide boxes this species can coexist with others without incident.

My own recorded observations of *V. salvardorii* indicate that females do not noticeably distend when gravid, as described for cerain other varanids (Bennet, 1995; Bayless, 1998; R. Faust, pers. comm.). Research has also stated that most reptiles from New Guinea breed year-round, with the possible exception of Boelen's python (*Morelia boeleni*), a species of the cooler highlands (O'Shea, 1996). Small clutch size presumably helps in enabling this arboreal species to continue moving around in trees, in contrast to the more stoutly-bodied terrestrial forms, in which clutch

size is typcally larger. Hatchling Crocodile monitors are large, with total lengths in the range of 30.5 to 40.6 cm, and larger than those of *Varanus komodoensis*; a female may produce 15–25 eggs a year, but only lay 4–6 eggs every 3–4 months (Bennett, 1995, Hairston Adams, 1996; Horn, 2004a).

Breeding size is apparently key to the successful captive reproduction of *V. salvadorii*, with sexually mature animals in the 1.5 to 2.1 metre size range, provided they are obtained at a young age. Over-crowding will most likely lead to aggression and health problems, and expsoure to low humidity and poor diet may result in kidney and liver problems. In our experience the UVB light radiation is an essential addition to the over-all health and condition of captive animals, as they naturally receive a higher level than terrestrial varanids. Relatively high temperatures would also seem important; in the wild, Crocodile monitors appear to live where the temperature never drops below 21.1°C.

Figure 2. Adult female *V. salvadorii*; this individual laid 4 eggs in a constructed nest. Photograph © B. Waterloo.

The diet of wild Crocodile monitors is in much need of research (Brandenburg, 1983; Bayless, 1998; Horn, 2004a). Insects appear to be of no interest to either younger individuals or adults. All of the *V. salvadorii* I have maintained myself (8) refused insects as food, no matter what the age of the animal. Cockroaches, crickets, and even earthworms were never looked at twice. Rats, mice, chicks, and the 'turkey diet' (R. Faust, pers. comm.), however, were eaten without exception. The skull morphology and teeth of *V. salvadorii* would seem to suggest that this species kills its prey with maybe one or two well placed bites, with perhaps large marsupials and fruit bats forming a major part of the natural diet. Birds may also be accepted as prey, although in my experience only the male showed an interest in birds of any kind. Over-feeding is likely to cause problems. Dissected examples of wild-caught *V. salvadorii* have shown only small fat deposists (H.-G Horn, and R. Nye DVM, pers. comms.) whereas in captive animals fat accummulaitons are presumably larger. What does this say about captive husbandry and the proper diet of captive animals? In our opinion, *V. salvadorii* should always be kept a little hungry – although feeding responses can be 'exciting' for the keeper, it is best to keep this species a little more trim than would otherwise seem preferable. The weight of breeding females may be increased with the addition of more (1–3) prey items during the weekly feeding schedule. Keeping males also on the lean side, and females a little more 'heavy', should increase productivity, and consequently healthier offspring – as similarly noted by Auffenberg (1979) in *Varanus bengalensis*. The viability and health of the offspring is presumably based on the overall health of the female parent, as often seen in mammals.

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Footnote: The Editor has been informed that following submission of this article, its co-author, Mark K Bayless, sadly passed away (November 1st 2006). Of his friend and colleague, the senior author (B. Waterloo) writes: "Mark's work with varanids was well-known and his articles have been referenced in numerous books. Mark was a great friend, apart from our mutual interest in varanid biology. He was friendly to anyone with an interest in varanids."