Breeding Behaviour of the Canopy Goanna (*Varanus Keithhornei*)

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Introduction

The Canopy Goanna (*Varanus keithhornei*) is a slender, arboreal monitor from north-east Australia (Cogger1996). It is restricted to the tropical rainforest of the upland and lowland regions within the Iron and McIlwraith Ranges of Cape York Peninsula (Irwin 1994). The holotype was one of three individuals collected in 1978 at Buthen Buthen east of Coen, far north Queensland (Czechura, 1980) and due to the absence of convincing evidence, these first specimens were tentatively assigned to the nominate race of *V. prasinus prasinus* (Czechura, 1980). In 1985, Wells and Wellington re-examined these specimens and found sufficient morphological variation to designate them as a new species, *Varanus keithhornei.* Sprackland re-described these same specimens again in 1991 as *Varanus teriae*, however as no reference was made to the previous description of Wells and Wellington the two descriptions have been synonymised as *V. keithhornei* (Covacevich & Couper 1994).

In 1988 the Queensland Reptile and Fauna Park (QRFP) at Beerwah obtained permits from the Queensland National Parks and Wildlife Service to collect two specimens of *V. keithhornei* from the wild. Unfortunately, one specimen sustained injuries during the capture and died shortly after arriving at the park. The second specimen, presumed to be a male, flourished in captivity for the next five years in the absence of conspecifics and at this time a second permit to take was granted to allow for the establishment of a captive breeding program at the QRFP. This species in the wild has an elusive nature, making behavioural and/or reproductive observations virtually impossible; hence, a captive situation offered the best opportunities to observe and record this important information. In November 1993 three specimens, one male and two females, were collected from Iron Range in Cape York Peninsula (Irwin 1996 a).

Captive Management

During the initial stages of housing, the three new specimens were kept on public display. The original male collected in 1988 was paired with one of the new females, while the second pair was housed separately. The first pair was seen to copulate at least twice during their time together, however no nesting behaviour arose from this activity and the male died shortly after from acute leukaemia. It is thought his condition may have contributed to the lack of mating success.

After the death of the original male, the three remaining lizards were moved into off-display housing. This enclosure measured 2.2m high x 2.0m long x 1.4m wide and was maintained at temperatures ranging between 20 and 28°C in winter and 24 and 33°C during summer. A hinged roof and a removable glass panel on the door allowed access to direct sunlight in fine weather. The substrate within the enclosure consisted of hard wood chip and eucalyptus leaf litter. A water bowl provided fresh water at all times (Irwin 1996 a).

Due to the shy nature of these lizards, food initially was left unattended in small feed dishes within the enclosure. However, once established, the lizards would readily take food from the keeper, ensuring that a strict record of the dietary intake of each individual could be maintained. The lizards adapted well to a diet of small rodents and were also offered crickets, beetles, grasshoppers and, very occasionally, small pieces of fruit. Once established, to better replicate wild conditions their diet was modified to consist almost entirely of insects, with a pink mouse only being offered about once every two weeks (Irwin 1996 a, Sprackland 1994 a).

Reproduction

a) Mating and oviposition

Eight weeks after transferring the lizards to the new enclosure, three eggs were found scattered across the floor. These died early during incubation or were, most likely, infertile. Between 1994 and 1997, the two females had produced eight clutches between them. All were hard, often discoloured and failed to hatch. On each occasion, the eggs were laid in various locations with neither female seeming to have a preferred laying site. Numerous nest sites were offered including a termite mound, hollow logs (empty or filled with various substrates such as sand, potting mix or sphagnum moss), an open sandpit and an open sphagnum pit. The various nest sites, where possible, were trialed high above the ground as well as at ground level. During this time none of these nests were utilised for egg deposition and neither female was ever seen to investigate any of these options although they had been observed frantically searching for suitable substrate during the period prior to laying (Irwin 1996 a).

After a female had been mated, she became very aggressive towards the male and other female. Bites and scratches would be inflicted, with the aggression reaching a peak just prior to and following nesting activity. Even during the period of suspected ovulation and mating, small scuffles between the females would occur and, on occasions, aggression would also be shown towards the male. It became clear from this interaction that the smaller of the two females was the dominant animal and due to her persistent aggression, she was removed from the main

enclosure and housed alone. Only once eggs had been laid would a female be removed from the male and replaced by the second female.

In order to reduce the females' frantic searching behaviour prior to laying, a nesting box designed to replicate a rotten log was constructed. The box had internal dimensions of 124mm x 680mm x 245mm. It was totally enclosed, with a hinged lid for keeper access. The entrance was a small, elongated opening 25mm high and 7.2mm wide, positioned 190mm from the bottom of the box. An overhang of 75mm out from the box and 90mm down the side was placed around the entrance to provide extra security for the female (Fig. 1). The nesting substrate consisted of a layer of damp sphagnum on top of a 110mm layer of moist sand. A gap of approximately 30mm was left at the top of the box. A heat pad was placed underneath the box. Due to external temperature fluctuations, the internal temperature of the box varied between 27 - 33°C.

The subordinate female was the first to use this nest box; she deposited four eggs overnight on 23 January 1997. These were placed in the incubator at a 1:1 ratio of vermiculite to water by weight. These eggs, although appearing better than previous clutches, were still discoloured and probably not fertile. They were discarded within a month of laying. The second female also deposited a clutch of eggs but scattered them throughout the enclosure. These eggs were of a similar appearance and also infertile.

As the lack of fertility was thought to be related to inadequate heating, a heat lamp was installed to allow the lizards to obtain higher body temperatures. This produced a basking site between 42 and 47 C and was frequently use by the male. However, it was rarely used by either female even after a second basking position was offered, allowing both occupants to bask simultaneously

The nest box was also modified in two ways. The sandy nesting substrate was replaced with a moist potting mix, as this was though to better replicate the substrate from which *V. prasinus* hatchlings have been seen to emerge in the wild (Sprackland 1989). The under-floor heat pad was also replaced with a strip of heating tape (85mm wide) placed along the inside wall of the box, allowing for a 55mm gap without heat at the box entrance. This modification in the placement of the heat source resolved the original problem of the heat increasing as the female dug down, and gave the female greater options by providing a horizontal thermal gradient within the nest box. It was hoped that these two minor alterations would encourage the use of the box for egg deposition.

Matings were observed on 14, 18, 26 and 28 January 1997. Throughout this period the male was constantly observed on top of the female, sometimes

seeming to be resting in that position. Copulation was obvious as the tail base of the male would be wrapped entirely underneath the female's and on some occasions it was possible to view the hemipene itself. While the female was receptive to the male, the two were constantly in contact with each other, the female never objecting to the close proximity of the male. , As the time of egg deposition approached, the female became less receptive, the male tended to lose interest in her and the pair spent most of their time on opposite sides of the enclosure. Once the eggs were laid, the male actually avoided contact with the female. In this instance, by 3 February 1997 the pair was spending less time together and their individual behaviour returned to 'normal', with each lizard sunning at separate locations for most of the day.

This female first entered the nest box at 4pm on 2 March 1997, 47 days after the first observed mating. It is assumed she did not emerge during the night and remained inside the nest box until 8.30am the next morning. Four eggs were immediately removed from the nest box for artificial incubation. These eggs, unlike previous clutches, were full in appearance with no obvious discolouration (Table 1.). The female did not re-enter the box at any stage after egg deposition, however the male did seem more cautious of her at this time, indicating possible aggression by the female towards him. At no time during courtship, mating or egg development did this female's food intake vary. However, as with all of the previous nestings, the female was ravenous after laying, snatching all food offered to her. This aggressive feeding behaviour lasted for 2-3 days.

The eggs were discovered nestled under the sphagnum moss and marginally dug into the potting mix substrate. The temperature at the site of egg deposition was 33 °C. The surface of the sphagnum had a thermal gradient from the entrance back, which ranged from 23 - 29°C at the time of egg collection. All eggs were adhered, the entire clutch weighing 57g and an average egg weight of 14.3g.

A few days after laying, this female was removed from the enclosure and the subordinate female was placed in with the male. The male immediately showed interest in her. It had been noticed that during the period of separation from the male, this female's abdomen became very slightly distended, possibly indicating ovulation. Although copulation was not observed, at all times the male was lying on top of the female. This female did experience a slight change in feeding pattern when she refused part of the food offered to her three days before laying. She finally entered the nest box at 3pm on 15 April 1997, 44 days after first being introduced to the male. Although she was not present in the box the next morning, three eggs were laid beneath the sphagnum, nestled into and lightly covered in potting mix (Table 1.). These eggs were also laid at the opposite end (the entrance) to the previous clutch and the site temperature was 31°C. All

three eggs were stuck together, the outer two showing a better appearance than the middle egg which was elongated and slightly discoloured. The total mass of the eggs was 44g and average egg weight of 14.7g.

b) Incubation

Both clutches of eggs were placed in plastic containers in a vermiculite to water ratio of 1:1 by weight. Incubation temperature was 29-30°C and humidity was kept as high as possible. Both clutches were also left as single egg masses.

One of the eggs in the first clutch began to discolour during the tenth week. As it was attached to the other three eggs within the clutch, it was feared that this could cause those remaining eggs to also deteriorate. The following technique was utilised to prevent the possibility of contamination of the rest of the clutch should the egg have torn during removal. The clutch was removed from the vermiculite substrate and the 'suspect' egg pierced with a large hypodermic needle. The contents of the egg were off colour and slightly cloudy, possibly indicating a fertile egg which had died during incubation. The major portion of the shell was then cut away from the surrounding eggs, the actual contact points being carefully removed so as not to damage the shell of the viable eggs.

As the cause of the sudden deterioration of this egg was unclear, it was decided to trial a different incubation technique. In the past this alternate technique had been used on Green Python (*Morelia viridis*) eggs with great success (Mannion 1996) and, due to the overlapping distributions of these two species, it was thought that the conditions should be ideal for the *V. keithhornei* eggs also. The three remaining eggs were placed in a large plastic garbage bin half-filled with a vermiculite/water mix at a ratio of 3:1 by weight. The eggs were half-buried and the container sealed with a glass lid. To ensure an even temperature throughout the incubator, a fan was continuously operated to circulate the air. Incubation temperature remained the same, ranging between 29 and 30°C.

On day two of the second clutch's incubation, the substrate mixture appeared too dry; no condensation had formed on the lid of the container. A small amount of water was added to the edges of the mix to avoid physically disturbing the eggs. Day three revealed a small amount of condensation forming on the container lid and it was decided that the mixture was sufficiently moist. By day seven the condensation had increased further, although not to the extent of the first eggs.

After 42 days, the presumed infertile egg in the second clutch began to discolour and it was decided to follow the same procedure that was adopted for the

discoloured egg in the first clutch. However, as the hypodermic needle was inserted it became apparent that the contents of this egg were virtually solid, the difference in viscosity being attributed to egg infertility. Instead a scalpel was used to slice the egg away from the rest of the clutch, revealing its consistency to be similar to gelatine. Again, the attached portions of the shell were carefully removed, resulting in no damage occurring to the viable eggs. This clutch completed the incubation period in the original manner with no further problems being encountered.

c) Hatching and neonate rearing

The eggs of the first clutch began to sweat on the day of hatching. The first hatchling emerged on 20 August 1997, 170 days after laying. The second egg hatched overnight and the last hatchling emerged the following day. All three were in excellent condition and extremely active. At hatching, each lizard weighed 10g and their total length ranged between 232mm and 251mm (Table 2.).

The second clutch swelled due to absorption of moisture from the incubation substrate. Both eggs looked healthy; however, one egg was noticeably larger than the other. The larger, 'normal-sized' egg was first to hatch after 180 days of incubation. This individual weighed 12g at hatching and had a total length of 243mm but did have a considerable amount of yolk sac left unabsorbed. The hatchling was placed into a plastic Tupperware container on moist paper towel and left in the incubator until the sac was absorbed.

The second egg began to sweat, but had failed to hatch by the end of that day. Due to concern over the health of this hatchling, the egg was manually opened to expose a fully formed but extremely small and weak lizard. This individual also had yolk left unabsorbed and was set up in the same manner as the first lizard. During this time breathing appeared laboured and the hatchling barely moved. It died three days after hatching.

All three hatchlings from the first clutch remained in the incubator for one day after hatching and were then placed into an enclosure measuring 500mm x 420mm x 700mm. The front side of the enclosure was set at 45 and fitted with stainless steel wire mesh to allow access to direct sunlight. They were provided with leaf litter substrate and fresh fig branches for climbing, the latter also providing increased humidity. A water bowl provides access to fresh water at all times. The hatchlings have been observed drinking from the bowl and also swimming in it. Mist spraying of the enclosure occurs at least twice daily. These

young lizards, although shy, were not as nervous as their parents and settled well into their captive environment.

The survivor from the second clutch was set up in a similar manner once its health was considered satisfactory. The temperament of this lizard was markedly different. It was extremely nervous when being observed and would not accept food from forceps, hence it was housed separately.

All four hatchlings were very similar in appearance, but were markedly different from their parents' colouration. The markings on the hatchlings were quite vivid, having a black background with distinct silver chevrons across the entire body (Fig. 2.). The head from the eye region forward is entirely silver. As with many varanid species, the juvenile specimens are far more spectacular in colouration and although the body pattern is discernible on the adults, the colours have dulled and merged along the greater part of the body.

The small dead hatchling from the second clutch weighed only 5 grams and was donated to the Queensland Museum. Samples from this lizard are being used for genetic analysis of the *V. prasinus* group.

Discussion

As far as is known, this marks the first successful captive reproduction of *V. keithhornei*. There are no published accounts of its reproduction in captivity, either as *V keithhornei* or *V. teriae*, however a number of the observations recorded here and in earlier papers are similar to those noted for *V. prasinus*, arguably the species most closely related to *V. keithhornei*. These include the raking of prey items during feeding (Greene 1986) and the 'sticky' surfaces of the feet (Czechura 1980).

The behaviour of withholding eggs only to scatter them around the enclosure at a later date has also been observed in captive *V. beccarii*, another closely related species (B. Eidenmuller, pers. comm.), as well as captive *V. tristis orientalis* (Horn & Visser1997) and *V. acanthurus* (P. O'Callaghan pers. comm.). It is possible that the female's behaviour was a searching response for an unoccupied territory in which to lay her eggs. Similarly, the appropriate biotic or abiotic triggers may not have been in place for oviposition, as noted by Horn & Visser (1997).

Adult *V. keithhornei* and hatchling *V. prasinus* have been observed utilising tree hollows in the wild (Irwin 1996 a, Sprackland 1989). These observations, combined with information on the captive breeding of *V. beccarii* and *V. prasinus* (Barker 1985, Eidenmuller 1996, Sprackland 1994 b), resulted in the development of the nesting box which was successfully used by the females at the QRFP.

The detection of a gravid female can be difficult in *V. keithhornei*. In late developmental stages, many varanid species become noticeably distended in the abdomen. This is not the case with *V. keithhornei,* as the abdomen will become only slightly distended and feeding habits will not always alter. This is also said to be true for captive *V. gilleni* (M. Vincent pers. comm.). For many varanids, changed feeding habits can be a reliable indication of when a female is preparing to nest (Irwin 1996 b). Female *V. keithhornei* do not dig test holes and there is no investigation of the nest site until immediately prior to laying. The best guide to determining the time of nesting is if copulation is observed or the male shows a sudden increased interest in the female.

A difference in appearance was noted during incubation between the two egg masses and is likely to be the direct effect of the different methods of incubation adopted for each clutch. The first clutch, which adopted the same technique used at Dallas Zoo for *V. prasinus* (Barker 1985), did not noticeably change in size throughout the entire incubation period whilst the second *V. keithhornei* clutch, incubated using the most common technique for varanid egg incubation, showed a substantial change in appearance. The latter absorbed moisture, significantly increased in size and, a few days prior to hatching, the healthy egg partially collapsed. This scenario has been typical for varanid eggs incubated in this manner at the QRFP in the past (S. Irwin pers comm.; pers obs.). This difference between the eggs' development was also reflected in the hatchlings; the first three being active and strong upon hatching while the second technique produced weak individuals with unabsorbed yolk. It has been suggested that, perhaps due to the drier conditions within the first situation, the developing embryos required the moisture from the egg sack to survive and so absorbed it more quickly (S. Thomson pers. comm.). It has also been suggested that insufficient air circulation toward the end of the development may cause the neonates to emerge before being fully developed. Whether this outcome was a reflection on the physical conditions of the two clutches or the incubation techniques utilised is difficult to determine and requires further investigation.

The period between mating and oviposition is usually 6-7 weeks, which is longer than the 4-6 week period given by Horn (1980, Horn & Visser 1989). However, the 179-190 day incubation period does compare with the periods collated by Horn & Visser (1997) for nine recorded captive breedings of *V. p. prasinus* and *V. prasinus beccarii*. This may be expected due to the close taxonomic relationships between these species and as such, initial predictions of incubation were based on this information.

Because of its arboreal habits and cryptic nature, this species offers many challenges for successful captive maintenance, breeding and public display. It is

hoped that a greater understanding of the requirements of these lizards in captivity will give us a greater insight into their lives in the wild.

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Table 1. Dimensions of *V. keithhornei* eggs at oviposition at QRFP.

Egg No.	Length (mm)	Width (mm)
Clutch 1		
1	49.0	23.0
2	53.0	21.5
3	50.0	22.0
4	51.5	21.5
Clutch 2		
1 (top)	51.1	23.1
2 (middle)	54.1	20.0
3 (bottom)	51.2	21.0

Table 2. Dimensions of hatchling *V. keithhornei* at QRFP.

Lizard No.	Weight (g)	Snout-vent length (mm)	Total length (mm)
Clutch 1			
1	10	100	251
2	10	97	239
3	10	97	232
Clutch 2			
1	12	101	253

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