Natural history of the rough-scaled python, *Morelia carinata* (Serpentes: Pythonidae)

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ABSTRACT

Although the rough-scaled python *Morelia carinata* of north western Australia is one of the most morphologically distinctive python species worldwide, it remains virtually unstudied. Our fieldtrips have increased the number of animals seen in the wild from 2 to 12, and the 5 animals brought into captivity produced 7 clutches totalling 71 viable offspring over a period of 6 years. In this paper we provide quantitative information on reproduction and growth of these captive animals, as well as qualitative information about behaviour and dietary habits. Reflecting their close phylogenetic relationship with green tree pythons *Morelia viridis* from northeastern Australia, captive rough-scaled pythons are sedentary animals that spend most of their time tightly coiled in arboreal or saxicolous ambush sites. Females produce relatively small clutches of 10 to 14 eggs, which hatch as large, slender-bodied offspring averaging 406 mm snout-vent length (SVL) and 16.9 g in weight. Growth is rapid, with captive males attaining sexual maturity at around 1000 mm SVL and approximately 18 months of age; females mature at 1400 mm and 30 months. Many hatchlings were reluctant to accept mammalian prey unless anuran or avian scent had been added beforehand, suggesting that frogs may be an important dietary component of juvenile snakes in the wild. In turn, frog-eating may render these snakes vulnerable to the imminent invasion of cane toads *Rhinella marina* into the northwestern Kimberley. Continued maintenance of captive stocks can provide for potential future reintroduction to the wild if toads (or some other threatening process) imperil existing wild populations of rough-scaled pythons.

Key words: captive breeding, conservation, Kimberley, life-history, reptile, snake

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Introduction

Our knowledge of reptiles lags far behind that of mammals and birds. The discovery of a new or rarely-seen mammal or bird species brings considerable publicity, whereas many new reptile species are discovered every year. For many reptile taxa, we have only anecdotal information about major aspects of their biology. This situation is perhaps not surprising when the animal in question is a small drab lizard found only in a part of the world far from any major scientific institutions, but in fact our ignorance extends much further. In this paper we review available information on one of Australia's most spectacular reptiles: a python that until 1994 was known from only two specimens, both collected in a remote part of the Kimberley during surveys by the Western Australian Museum. These specimens were killed at the time of collection, so that no behavioural or ecological data are available on this species. However, general head and body morphometrics and the unique keeled nature of the body scales indicated that the two specimens clearly belonged to an undescribed species. The taxon was formally described as *Morelia carinata* by Laurie Smith (1981).

Apart from their collection localities in sandstone gorges near the Mitchell and Hunter Rivers in far northwestern Australia, nothing was known of these snakes. This situation stimulated the Australian Reptile Park to initiate a project to observe rough-scaled pythons in the field, and ultimately to maintain and breed animals in captivity. With support from Western Australian wildlife management authorities, these objectives have been achieved. Data are still limited, but are sufficient to clarify several facets of the biology of these distinctive reptiles.

Information from Fieldwork

Until recently, all known specimens of *M. carinata* have come from areas around the Mitchell Plateau, a deeply dissected sandstone escarpment in the Kimberley region of tropical Western Australia. The pythons do not occur on Mitchell Plateau itself, but on the much older King Leopold sandstone that overlays this lateritic geological unit. The python's dissected gorge/monsoon rainforest habitat occurs within this sandstone and to the west of Mitchell Plateau. In 2006, a specimen of *M. carinata* was found on Bigge Island off the northwestern coast.

Beginning in 1983, one of us (JW) undertook several trips to the north Kimberley in search of *M. carinata*. Ten such trips, of 1 to 4 weeks in duration, were conducted and resulted in the discovery of 10 rough-scaled pythons (i.e. approximately one snake capture per 35 person days in the field: Weigel and Russell 1993; Weigel 2005a;

Porter 2010). Including the two initial specimens from the Western Australian Museum collectors, the 12 snakes mostly have been found on rock ledges and in caves ($n = 6$) or in trees ($n = 4$) rather than on the ground ($n = 2$). Two snakes were closely associated with fruit-bearing trees (one in the branches, one beneath the tree on the ground), possibly reflecting selection of ambush sites for frugivorous birds or mammals (as has been suggested for *M. oenpelliensis*: Barker and Barker 1994). One snake was rescued from the coils of a large (2.2 m long) olive python *Liasis olivaceus*. All 12 specimens were encountered within or at the periphery of small isolated pockets of monsoonal rainforest within 100 m of permanent freshwater, suggesting this habitat is an essential part of the snake's ecological requirements. Although there are no reports of reproductive activity in the field, our observations of three adult snakes (one female, two males) in close proximity (separated by approximately 5 m) in August 2002 is highly suggestive of a dry-season mating period. Detailed studies on other *Morelia* species have reported aggregations of adult animals in association with courtship and mating (*M. spilota* – Slip and Shine 1988a; Shine and Fitzgerald 1995; Pearson *et al.* 2002; *M. kinghorni* – Fearn *et al.* 2005).

Incidental observation of snakes at the time of capture suggest that the rugose scales of these animals may serve to camouflage them, particularly amongst the exposed roots of the abundant *Ficus* species (mostly about the same thickness and colour as *M. carinata*) and the exposed sandstone surfaces that are prevalent in this area. A similar ecological advantage has been postulated for rattlesnakes with keeled scales (Klauber 1997) where the keels reflect light differently to smooth scales, making them appear less reflective. Rugosity is particularly effective at enhancing camouflage in species with disruptive colour patterns, such as the rough-scaled python. In addition, rugose scales may assist with climbing, particularly amongst the rock ledges and crevices widespread in the species' habitat (rough scales are seen also in arboreal snakes such as *Hoplocephalus* and *Tropidechis*: Shine 1991).

Two newly captured animals displayed a spectacular defence display unlike that exhibited by any other python species (Figure 1). When approached, the snakes extended the fore part of the body towards the threat and opened the mouth to full gape, clearly displaying the extremely long teeth so distinctive of this species, while the head was rhythmically waved slowly from side to side. The mouth and body were held in this position for at least 5–10 seconds. Despite this superficially aggressive behaviour, even newly captured animals are generally quite placid on handling and in most (but not all) cases, were disinclined to bite.

Information from Captive Maintenance of Animals

The low encounter rate with wild rough-scaled pythons makes it virtually impossible to gather detailed information in the field without adopting logistically difficult methods such as radiotelemetric monitoring. Thus, we applied to the Western Australian Department of Conservation and Land Management (now the WA Department of Environment and Conservation, DEC) to collect 5 pythons and maintain them in captivity at the Australian Reptile Park. Our aims were to obtain information about general behaviour and reproduction, and, if breeding was successful, to provide hatchlings for distribution to other wildlife agencies and zoological parks, for possible use in reintroduction to the wild should such an approach be deemed to have conservation value.

Permits were approved and issued for the project in 1998 and 5 rough-scaled pythons (3 males, 2 females) were collected in 1999 and 2000. All have been maintained at the Australian Reptile Park since that time, and all specimens are still alive at the time of writing. Over the ensuing years, those 5 animals produced 71 viable progeny, with all individuals contributing to the captive gene pool. An additional 33 hatchlings have been produced by the captive-bred offspring of these five founders.

General behaviour

Rough-scaled pythons are placid and generally lethargic animals, typically remaining in a tightly coiled ambush position within their cage for up to 7 days at a time without apparent movement. Activity (moving about the cage) is most prevalent during the night with two peak active phases; the first two hours after enclosure lights are switched off and again the final few hours of darkness before the beginning of the daylight period.

Feeding

One of the original rough-scaled pythons disgorged a rock rat when captured (Weigel 2007). Most captive-bred hatchlings readily accepted recently killed domestic mice as food. Those that refused rodents continued to do so until mice were scented by rubbing with live striped marsh frogs *Limnodynastes peronii*, or with day-old Japanese quail *Coturnix japonica*. We have never observed overt tail-luring for prey in *M. carinata*, although this behaviour is common in juveniles of the closely related

Figure 1. Defensive posture of newly-captured rough-scaled python, *Morelia carinata.* Photograph by John Weigel.

M. viridis (Murphy *et al.* 1978) and has been reported in *M. spilota* also (Simon *et al.* 1999). Once feeding voluntarily, specimens were offered food items approximately once per week regardless of age.

Sloughing

The pattern of sloughing in captivity resembled that of other similarly-sized python species, being largely dependent upon the rate of food intake. During reproduction, gravid females executed a pre-lay slough at 22–28 days prior to oviposition, again equivalent to most python species of similar size. The freshly sloughed skin is similar to those of most other Australian python species but is thicker than that of *M. viridis* (J. Weigel, unpubl. data).

Sexual dimorphism

As with many other Australian python species, females appear to attain slightly larger body sizes than males. The two captive females measured 1700 mm and 1790 mm total length at last measurement, while the three males ranged from 1470 mm to 1600 mm. The cloacal spurs of adult males are smaller, relative to body length, than in any other Australian pythons that we have examined. Seven males (1500–1600 mm in length) had spur sheaths of 1–2 mm in length, and spurs of 1.5–2 mm. Four females (1700–1800 mm long) had spur sheaths 0.5–1 mm long, and spurs 0.25– 0.5 mm in length. Interestingly, *M. carinata* differs markedly in this respect from its close relative *M. viridis*, which has very large spurs in males.

Reproductive behaviour

All five wild-caught snakes have bred successfully in captivity. The snakes were kept in large enclosures (1200 x 800 x 1200 mm high), each containing an elevated natural timber perch plus multiple hide boxes. Snakes used the perches regularly but were rarely observed in the hide boxes. The enclosure floor was covered with unprinted newspaper and the furnishings were completed with a water bowl. Heating was provided by incandescent lights and heat pads, providing a thermal gradient ranging from 34–36°C at the hottest point to a low of 24–26°C. A photoperiod equivalent to that of Gosford, New South Wales, was maintained throughout the year. During a 15–16 week period from late May to mid-September, we lowered enclosure temperatures by 4–6°C during the day and around 10°C at night to provide a nocturnal minimum of around 16°C, to simulate tropical dry season conditions (see Weigel 2005b, 2007 for additional husbandry information).

Courtship and mating were recorded in July and August each year (corresponding to the mid-dry-season in the field), with oviposition in late October and early November (which equates to the late dry-season or "build-up" in their natural habitat). Courtship behaviour appeared relatively passive and mating was a brief affair when compared to other *Morelia* species (J. Weigel, unpubl. data). Oviposition occurred 81–89 days after mating (mean = 85.8 days). We never observed male-male combat in our captive animals, despite experimenting with housing multiple males with mature females during the mating season (late July to late August). At the time of the pre-lay slough, nest boxes measuring 300 x 200 x 200 mm high with 100 mm access holes were installed and filled with 20–30 mm of slightly moist sphagnum moss. In all instances oviposition occurred at night or very early morning and always took place within the nest boxes. When females were discovered after oviposition, they were always tightly coiled around the clutch (Figure 2). Temperature within the nest boxes was maintained at 29–30°C, perhaps accounting for the lack of observed thermal shivering by captive females. Eggs were removed from the females (generally in one tightly adherent mass) and incubated at 30.5–31.5°C using a no-substrate incubation technique whereby the eggs are enclosed within a container and suspended on a perforated plastic platform above a shallow pool of warm water. This system maintains a nearly constant 100% humidity around the eggs while allowing unfettered gaseous exchange across the eggshell (Weigel 2007).

Figure 2. Adult female rough-scaled python, *Morelia carinata,* coiled around her freshly-deposited eggs. Photograph by John Weigel.

Reproductive output

The original two captive females produced a total of 7 clutches, with a range of 10–14 (mean = 11.2) eggs per clutch. Hatching success was 100% for four of the seven clutches, but 70 to 90% in the other three; thus, overall hatching success was 90% (71 of 79 eggs produced viable offspring). Mean egg mass per clutch ranged from 29.5–33.5 g (overall mean = 30.8 g). Hatching occurred in late December and early January 58–63 days after oviposition (mean = 61.8 days), with all eggs within a clutch typically hatching on the same day. The 31 viable hatchlings for which we obtained detailed size data were very slender-bodied (see Figure 3); they averaged 403.5 mm SVL and 16.5 g, with ranges of 365–443 mm and 13–19 g. Males and females did not differ significantly in mean body sizes at hatching (SVL: $F_{1,24} = 0.002$, $P = 0.96$; tail length: $F_{1,24} = 0.21$, $P = 0.65$; mass: $F_{1,24} = 0.96$, $P = 0.34$), nor in tail length relative to SVL (interaction $F_{1,27} = 0.97$, $P = 0.33$, intercepts $F_{1,28} = 0.52$, $P = 0.48$) or mass relative to SVL (interaction $F_{1,27} = 0.31$, $P = 0.59$, intercepts $F_{1,28} = 1.01$, $P = 0.33$).

Figure 3. Young rough-scaled python, *Morelia carinata,* showing elongate morphology. Photograph by John Weigel.

About half of these offspring were transferred to other zoological facilities for captive maintenance, and a studbook is being maintained for this species at the Australian Reptile Park in accordance with recommendations of the Australasian Regional Association of Zoological Parks and Aquaria, with a view to coordinating regional breeding of this species. However, all data on captive specimens in the present paper derive from observations made at the Australian Reptile Park.

Growth rates

Figure 4 shows body sizes of our hatchling snakes at 12-month intervals. Growth was rapid, with both sexes reaching about 1000 mm SVL within 24 months of hatching. Based on courtship behaviour, males attained sexual maturity (1000 mm SVL) at around 18 months and females a year later, at a length of 1400 mm SVL. Growth rates of the two sexes were similar for the first year of life (comparing mean SVLs, at 12 months: $F_{1,8} = 0.19$, $P = 0.68$) but females tended to grow faster thereafter (Figure 4); the size disparity between the sexes was statistically significant at 24 months of age ($F_{1,3} = 27.93$, $P < 0.01$).

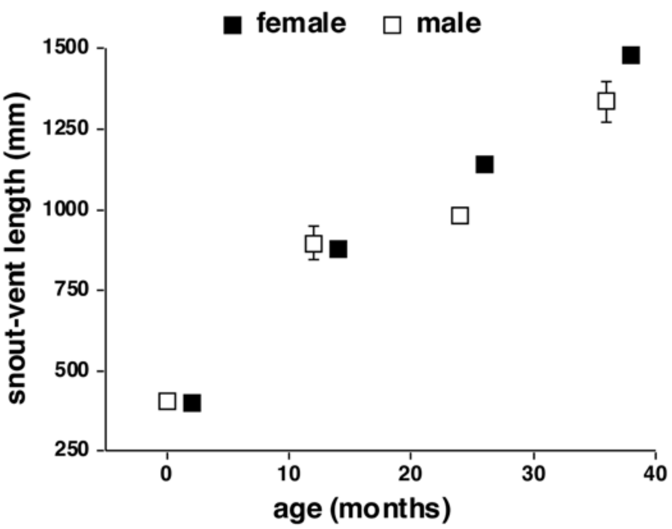

Figure 4. Growth rates of captive-hatched rough-scaled pythons. Symbols show mean values, and error bars show one standard error on either side of the mean.

Offspring of the original breeding founders have also successfully reproduced in captivity. At the time of writing, a total of 33 healthy offspring have been produced by F1 generation snakes at the Australian Reptile Park, some of which have been distributed to experienced reptile hobbyists with a view to further proliferating the species in captivity. The original five founding snakes are still reproducing after 11 to 12 years in captivity. The second female collected was apparently fully mature when located in the field, suggesting (based on growth rates in captivity) that she was already at least 3 years old at collection – in turn suggesting a minimum current age of approximately 14 years.

Comparisons with Other Python Species

Biochemical analysis on tissues from our captive rough-scaled pythons indicate that they belong within the genus *Morelia*, as a sister-group to the green tree python *Morelia viridis* of tropical Queensland, New Guinea and Indonesia (Rawlings *et al.* 2008). *Morelia carinata* resembles *M. viridis* in general body size and shape, particularly the distinctive broad head and narrow neck, arboreality, and the habit of adopting a tight resting coil for long periods. Sedentary habits and reliance upon ambush predation appear to be characteristic of all *Morelia* species (Slip and Shine 1988b; Shine 1991; Wilson *et al.* 2006). Differences include the rugose scalation and grey-brown colours of *M. carinata* along with its ability to change colour on a day-night cycle (but without a pronounced ontogenetic shift), and the relatively longer spurs of adult male *M. viridis*. In addition, caudal luring has not been observed in rough-scaled pythons but is commonly utilised in green tree pythons.

The seasonal timing of reproductive activity in our rough-scaled pythons accords well with available information on other pythonid species from tropical Australia. In all species that have been studied in detail, mating occurs in the coolest time of year (mid-dry season), with oviposition about two or three months later, and hatching in about another two months (e.g. Shine 1991; Madsen and Shine 1996; Wilson *et al.* 2006). Hatchlings thus emerge from their eggs shortly before the onset of the annual monsoonal rains.

Published data on reproductive output of Australian pythons, based primarily on dissection of museum specimens and captive breeding (Shine and Slip 1990), suggest that rough-scaled pythons are similar in this respect to their relatives also. For example, the average clutch size of captive rough-scaled pythons was 11.2 with a range of 10–14, which is similar to that of *Morelia viridis* with an average of 12.3, range 6–19 (Shine and Slip 1990). Mean hatchling SVL in *M. carinata* of 403.5 mm in this study is larger than that seen in most pythonid taxa similar in adult body size to rough-scaled pythons (e.g. <350 mm in *Morelia viridis*, *M. spilota, Antaresia maculosus, A. childreni, A. stimsoni*). Indeed, the hatchlings of *M. carinata* are about as long as those of the larger python taxa such as *Aspidites ramsayi* (390 mm), *Liasis fuscus* (420 mm) and *Liasis* *olivaceus* (440 mm: Shine 1991a). However, neonatal M. *carinata* are much more slender-bodied than are most of these other taxa (Figure 3); for example, hatchling *L. fuscus*, although averaging almost the same length as our hatchling rough-scaled pythons, weighed more than twice as much (means of 34.9 vs. 16.5 g: Madsen and Shine 1996).

Conserving the Rough-scaled python

As well as providing quantitative data on captive behaviour and reproduction of M. *carinata*, our data clarify some issues relating to conservation planning for this poorly-known species. First, the success of scenting rodent food items with anurans suggests that this species may be vulnerable to the inevitable invasion of cane toads *Rhinella marina* into their habitat. Toads are still spreading westwards across tropical Australia; they reached the Darwin area in the wet-season of 2004–05, and crossed into Western Australia in 2009. At current rates of range expansion, these large toxic anurans will reach the rough-scaled pythons' range in the near future. Anecdotal reports from other regions suggest that toads will colonise even relatively inaccessible areas. Toad invasion has caused catastrophic declines of several species of previously-abundant large predators, notably varanid and scincid lizards (Doody *et al.* 2009; Price-Rees *et al.*, 2010; reviewed by Shine 2010). However, initial predictions that toads will also cause significant mortality of anuran-eating snakes (Phillips *et al.* 2003) have not been borne out by detailed studies in the Darwin region (including, on *Morelia spilota*: Brown *et al.* 2011). Green tree pythons remain common in areas invaded by cane toads many decades ago (Wilson *et al.* 2006). Although there are no convincing cases of toads actually causing extinction of predator species, even a major decline in python abundance could be of substantial concern given the apparent rarity of these animals and the small geographic area over which they are found. There seems little hope of eradicating or slowing cane toads before they reach the north Kimberley, so the priority must be urgent action to safeguard wild populations in any way possible.

How can this be achieved? One option may to conserve snake populations on islands (such as Bigge Island) where toad invasion may be less likely, and more easily controlled. Surveys of the islands of the north Kimberley thus are an urgent priority, as is the development and implementation of protocols for quarantine, and detection of toad arrival. Pearson (1993) speculated that "..there are no immediate direct threats to the species, although cattle (both domestic and feral), weeds and frequent fire may be degrading habitat". While much of the area occupied by M. *carinata* is very rugged and beyond the reach of cattle, weeds such as *Passiflora foetida* are choking many of the small and highly fragmented monsoon rainforest patches in the north Kimberley (see McKenzie *et al.* 1991). Fire also has a major impact, causing the contraction of rainforest pockets (e.g. Clayton-Greene and Beard 1985; Russell-Smith and Stanton 1992). Thus, habitat management in mainland as well as island areas is critical.

Our success in captive husbandry and breeding of rough-scaled pythons suggests an additional option: to maintain captive stocks of these animals. Such stocks might then enable subsequent reintroduction of pythons if future developments in biological control are successful in eliminating toads. Although this is a tactic of last resort, and may depend upon the eventual development of management techniques to deal with other threatening processes (e.g. a successful biological control for cane toads), we see no other feasible option. The distinctive appearance of rough-scaled pythons, and their hardy nature in captivity, suggest that many zoos would be willing to maintain captive animals if wildlife authorities decide to adopt this tactic.

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