Int. Zoo Yb. (2003) **38:** 145–152

Observations on the husbandry, breeding and behaviour of the Indian python *Python molurus molurus* at the National Zoological Park, Washington, DC

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Social behaviour and reproductive biology are reported for a group of 3.2 Indian pythons *Python molurus molurus* at the National Zoological Park, Washington, DC. Details of the python enclosure and the conditions provided for artificial incubation are also described. Twenty-two fertile eggs were laid by one wild-hatched ♀ and the clutch was removed for artificial incubation in two slate-bottomed aquariums. Ambient temperature during incubation ranged from 26·7 to 32·2°C, while temperatures in the aquariums ranged from 27·2 to 32·2°C. Sixteen young hatched successfully. Temperature appears to play a critical role in hatching success and coloration of the hatchlings, and this parameter is discussed.

Key-words: behaviour, breeding, husbandry, incubation, Indian python, pattern anomaly, Pythonidae, Serpentes, temperature

In 1932 Francis G. Benedict studied the reproductive biology and maternal brooding behaviour of the African rock python *Python sebae* by comparing environmental and skin temperatures of a ♀ snake at the National Zoological Park, Washington, DC (Washington NZP) (Benedict, 1932). Nearly 70 years later we report on the reproductive biology of the Indian python *Python molurus molurus* at the same institution.

The Indian python was once commonly exhibited in private menageries and zoos. The availability, impressive size and appearance, and tractable nature of the species contributed to its popularity (Minton & Minton, 1973). Increasing human pressures have resulted in a drastic reduction in many wild populations and in 1972 the *Indian Wildlife Act* was passed by the Indian government to provide partial *in situ* protection for this species (Whitaker, 1978). The Burmese python *Python molurus bivittatus,* which was placed on Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) in 1973 (IUCN, 1979), has been consistently bred in private reptile collections and zoos, which has led to snakes showing a variety of unusual colours and patterns (see Bechtel, 1995), probably as a result of fluctuating temperatures during incubation and mixed subspecific parentage. The nominate form has been less widely bred. Accounts of reproduction in both the Burmese and Indian forms in captivity describe behaviour, thermoregulation, eggs and growth (Forbes, 1881; Acharjyo & Misra, 1976; Van Mierop & Barnard, 1976, 1978; Acharjyo & Mishra, 1980; Marcellini & Peters, 1982; Michaels, 1986; Deeming,1989; Kalaiarasan & Rathinasabapathy, 1991; Johansen, 1993; Sekar & Jagnnadha-Rao, 1995; Vyas, 1995). The Indian python was the first large constrictor to be listed on the *U.S. Endangered Species List* (24 June 1976). *Python molurus* was listed as Vulnerable in the *IUCN Red Data Book* (IUCN, 1979) and the species is listed as Lower Risk (near threatened), LR(nt), in the *2000 IUCN Red List of Threatened Species* (Hilton-Taylor, 2000). *Python molurus* was placed on Appendix I of CITES in 1973. Washington NZP has concentrated on breeding

programmes for *P. m. molurus* and *P. m. bivitattus*. In this paper the social behaviour and reproductive biology of *P. m. molurus* are described.

HISTORY OF BREEDING GROUP

In October 1975, Washington NZP acquired 3.2 snakes on breeding loan from the senior author. Two ♂♂ and one ♀ were collected in the wild as juveniles but their provenance was unknown. A pair of first-generation captive-hatched juveniles (hatched July 1974 by a private breeder) was added to the group. The wild ♂♂ were *c.* 3 m total length after 5 and 7 years in captivity; the wild ♀ reached 4 m total length and exceeded 50 kg mass after 6 years in captivity.

HOUSING AND HUSBANDRY

Upon arrival at Washington NZP, the Indian pythons were placed in an enclosure measuring 4 m × 3·2 m × 3·3 m high. The facility was constructed of concrete with a viewing window measuring 3·2 m × 1·3 m. The top was covered with heavy-gauge wiremesh screening and partially covered with glass to retain heat and humidity. A pool (1·3 m wide and 0·4 m deep) was situated near the rear right-hand corner with a facade of rockwork rising 40 cm behind it; all snakes soaked in the pool regularly. The temperature in the exhibit fluctuated between 29 and 32°C annually; temperatures rose several degrees around midday. A natural photoperiod was provided through skylights. Artificial lighting and supplemental heat lamps were placed over the viewing window and suspended in a wiremesh cage to protect the snakes from thermal burns. The enclosure was cleaned and sprayed with water every day.

Food was offered every other week and consisted mostly of rats and rabbits. During the breeding season (December–March), the snakes fed infrequently or stopped feeding completely. Chickens or other fowl were occasionally accepted during this period. All three ♂♂ tended to stop feeding a few months before the ♀♀. Males were often defensive during this time, directing strikes towards the keepers. After oviposition, the wild ♀ refused food.

OBSERVATIONS

The terminology used to describe social behaviours follows Barker *et al.* (1979).

Head-up posture During the breeding season, but seemingly not associated specifically with courtship or combat, all snakes would raise their heads and anterior trunks in a vertical position 30–60 cm above the substrate. The head of the snake pointed directly upwards but the context for this behaviour could not be determined.

Courtship and copulatory behaviour The snakes were placed in the exhibit on 7 November 1975 and courtship leading to copulation occurred 1 week later in the 2.1 wild snakes. The ♂♂ initiated dorsal anterior advances with their heads pressed to the ♀'s body, as described by Gillingham & Chambers (1982). During January and February, all snakes were *in copulo*. Although breeding behaviour occurred among all snakes, more than one ♂ often followed the wild ♀ and attempted copulation; the captive-hatched ♀ was never courted by more than one ♂.

Scent-marking Both sexes scent-marked during the breeding season by expelling uric acid and a clear pungent liquid onto the substrate. When the ♀♀ did so, the ♂♂ would trail them by directing rapid tongue-flicks onto the substrate or lifting their heads and anterior trunks vertically while following the ♀. Copulation or ♂ combat as described by Barker *et al.* (1979) frequently followed these activities. Males often pressed their head along the ♀'s dorsum and moved their heads in a jerky side-to-side motion on the ♀'s body. Simultaneously, ♂♂ attempted to align

their bodies along the length of the ♀'s body.

Spur use As described in Barker *et al.* (1979) and Gillingham & Chambers (1982), ♂♂ erected their spurs perpendicular to the body wall and vibrated them on the ♀'s dorsum. Often, the ♀ became quiescent as the ♂ placed his vent region in apposition to her cloaca. Male Solomon Island boas *Candoia bibroni* used their spurs to position the ♀'s vent to facilitate copulation (Murphy *et al.*, 1978) and this was also observed in the snakes at Washington NZP. Males tried to insert the hemepenis by sliding their tails around the ♀'s vent: rigorous spur vibration occurred throughout the sequence until intromission was achieved.

Intromission and coitus Both ♀♀ often raised their tails and gaped cloacae in response to a ♂'s copulatory attempts. Occasionally, a discernable muscular pumping motion in the posterior portion of a ♂'s trunk occurred after insertion of the hemipenis. During this period, ♂♂ often intertwined their tails around a ♀'s tail and lifted it in a vertical plane. Copulation ranged from 10 minutes to several hours, much shorter than the average time of 6 hours 45 minutes described for *P. m. bivittatus* by Gillingham & Chambers (1982). Occasionally, two pairs were observed copulating in a group.

Behaviour of gravid ♀ The gravid ♀ refused all food for at least a month prior to oviposition. Shortly before egg-laying the ♀ often coiled tightly in the area where eggs were ultimately deposited and rotated her body so that the ventral scales were exposed. The ♀ quickly assumed the usual coiled position if disturbed. Ecdysis occurred 7 days prior to egg-laying and the ♀ continually moved around the enclosure during this period. For a week prior to laying, muscular contractions of the posterior trunk occurred and small amounts of uric acid and faecal material were expelled.

EGGS AND INCUBATION

On 22 March 1976, the wild ♀ laid 22 eggs and coiled tightly around the adherent egg mass (Plate 1). The other ♀ failed to lay eggs even though she was courted and mated by the ♂♂. The clutch was removed for artificial incubation; fertility was determined using a bird-egg candler. Average mass and measurements were as follows: 245·9 g mass, 100·9 mm length and 68·7 mm width (Table 1).

Eggs were incubated in two slate-bottomed aquariums measuring 50 cm × 25 cm × 32 cm deep and 75 cm × 32 cm × 30 cm deep (Plate 2). The bottom of each aquarium was covered with pea gravel *c.* 80 mm deep; eggs were placed on the surface of sterile plant potting soil in small crockery (130 mm wide × 80 mm high) and plastic (100 mm × 80 mm high) cups

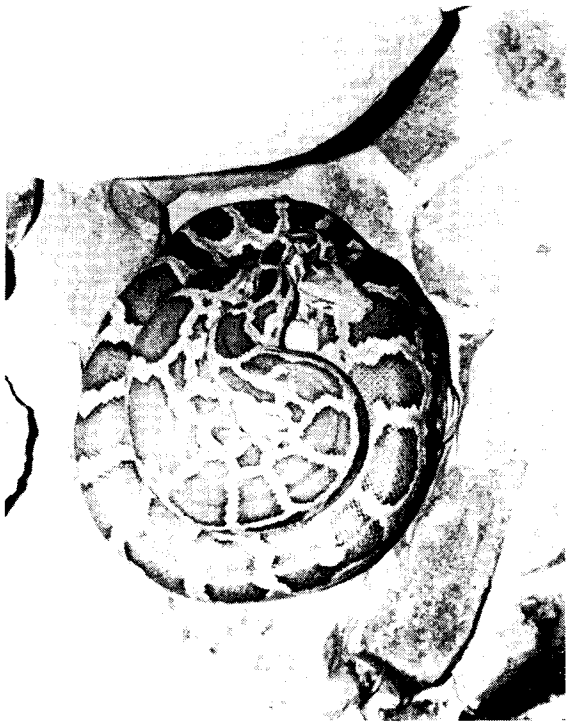

Plate 1. A ♀ Indian python *Python molurus molurus* brooding eggs before they were removed for artificial incubation at the National Zoological Park, Washington, DC. *Trooper Walsh.*

EGG	MASS (g)	LENGTH × WIDTH (mm)	HATCHING DATE	INCUBATION TIME (days)	COMMENTS
A	276·9	105 × 75		78	opened 8 Jun; well-developed embryo
B	262·2	106 × 61		78	opened 8 Jun; well-developed embryo
C	268·9	104 × 58		7	sent to laboratory for biopsy
D	266·4	102 × 68		78	opened 8 Jun; well-developed embryo
E	248·4	103 × 62	5 Jun	75	
F	244·6	100 × 74		11	sent to laboratory for biopsy
G	234·9	91 × 70	9 Jun	79	
H	258·2	105 × 72	5 Jun	75	
I	253·0	102 × 69	15 Jun	85	
J	265·0	102 × 71		86	pipped; opened 16 May; fully formed
K	244·6	100 × 74	7 Jun	77	
L	263·8	106 × 79	22 May	61	
M	218·0	95 × 69	30 May	69	
N	234·9	103 × 69	24 May	63	
O	258·1	109 × 68	31 May	75	
P	235·9	102 × 72	28 May	67	
Q	238·9	101 × 66	30 May	69	
R	253·2	103 × 72	31 May	70	
S	262·4	101 × 76	4 Jun	74	
T	256·1	102 × 66	6 Jun	76	
U	190·1	91 × 63	4 Jun	74	
V	176·8	88 × 62	1 Jun	71	

Table 1. Egg measurements, hatching dates and incubation times for Indian python *Python molurus molurus* eggs at Washington NZP.

which were placed on the gravel in two longitudinal rows. Water was added to the aquariums until it reached the top surface of the gravel but no water was placed in the cups. The aquariums were covered with glass to maintain adequate humidity and placed in an enclosed room where the ambient temperature ranged between 26·7 and 32·2°C. Because the temperature fluctuated, additional heat was provided by 120 W heat tapes placed lengthwise under the aquariums. The tapes were not thermostatically controlled so when daily temperatures in the aquariums fluctuated from a minimum of 27·2°C to a maximum of 32·2°C this caused water to condense onto the glass. Eggs were not handled unless they deteriorated. Two eggs died early in incubation and biopsy revealed a variety of bacteria, including high concentrations of *Pseudomonas* (eggs C and F, Table 1).

Three eggs were removed *c.* 78 days after oviposition (eggs A, B and D, Table 1) because they were discoloured and malodorous; all contained well-developed embryos. Egg J was pipped but the hatchling was unable to cut through the egg shell. The remaining 16 eggs hatched (average incubation period 72·5 days) giving a hatching success of *c.* 73%. Three eggs were opened manually to assist the hatchlings. All possessed large yolk sacs which were absorbed within a few hours. Unusual egg-brooding behaviour has been observed by four ♀ *P. m. bivittatus* and two *P. m. molurus* (T. Walsh, unpubl. obs). When the hatchlings in the eggs at the top of the clutch began to pip, ♀♀ loosened their coils around the egg mass or left the mound completely. As the eggs at the top began to hatch, liquid from these eggs drained on the lower eggs. The liquid seemed to act as a solvent to loosen the adherent eggs which allowed the neonates on the bottom and in the centre of the egg mass to cut through their eggs easily without

encountering adjacent eggs. Water did not dissolve this bonding agent. Cloudsley-Thompson (1994: p. 114) mentioned that newly hatched pythons returned to egg shells at night when the ♀ coils around the egg mass and warms the neonates by shivering; these behaviours were never observed in the snakes at Washington NZP.

HATCHLINGS

The 16 hatchlings appeared to be healthy and alert, averaging 141·7 g in mass. Several showed pattern abnormalities: light-coloured spots within the darker dorsal blotches and a light-coloured dorsal stripe encompassing two-thirds of the length of the trunk (Table 2; Plate 3). Within 1 month of hatching sexing was achieved using cloacal probing, as described by Ross & Marzec (1990): there were 7.9 snakes.

Each hatchling was maintained in a 37·85 litre aquarium with a heat tape under one end and containing a hide box. The photoperiod maintained using artificial lights was 10:14 hours light:dark. The aquariums were covered with glass to increase humidity and reduce heat loss.

Initial ecdysis ranged between 8 and 22 days (average 12·2 days) and first feeding began 3–70 days (average 21·8 days) after hatching. Most of the snakes fed unassisted after their first shed but a few were disinclined to feed immediately (Table 2). The snakes were offered food at 5 day intervals. Eleven hatchlings accepted live mice *Mus musculus* initially; the remaining snakes were offered live chicks. [The feeding of live vertebrates is not legal in many countries.] Three snakes were assisted to feed on small mice until they began to feed independently.

DISCUSSION

Based on our observations, breeding *P. m. molurus* and *P. m. bivittatus* in captivity is comparatively simple but a suitable temperature must be provided for artificial incubation. Males should be

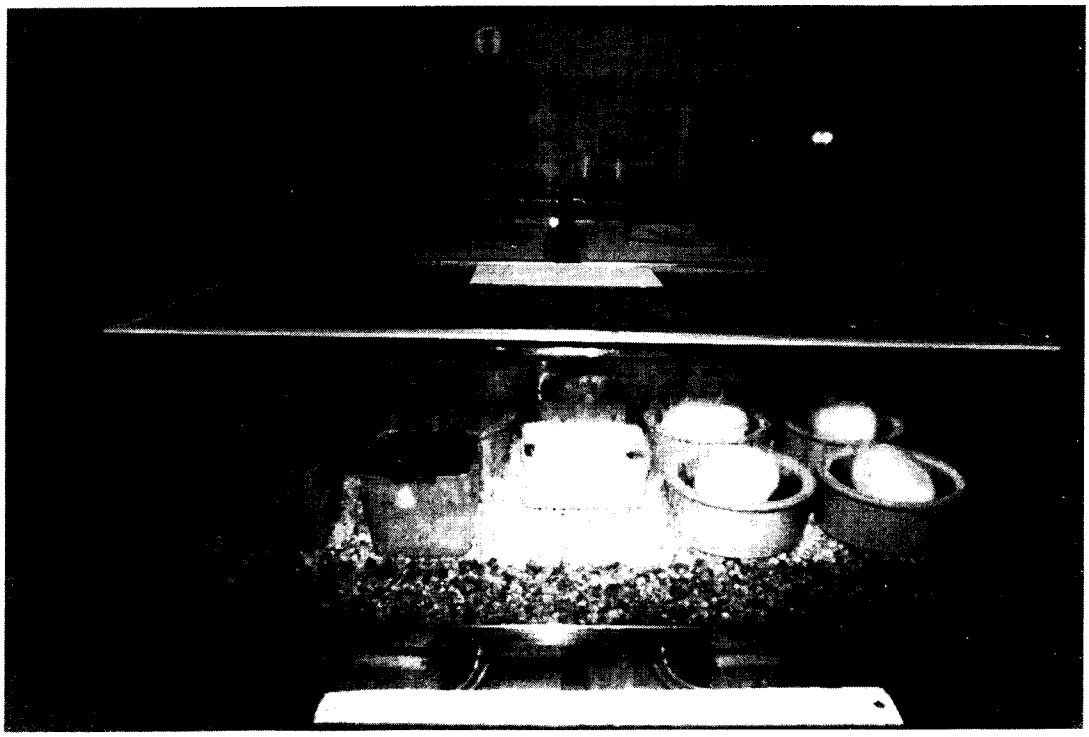

Plate 2. Slate-bottomed aquarium used to incubate Indian python eggs at the National Zoological Park. *Trooper Walsh.*

HATCHLING	SEX	MASS (g)	TIME (days) HATCH TO FIRST SHED	HATCH TO FIRST SELF-FEED	FIRST SHED TO FIRST SELF-FEED	PATTERN
E	♀	145·0	14	18	4	
G	♀	138·5	10	13	3	few dorsal spots
H	♂	137·5	15	60	45	many dorsal spots
I	♂	114·5	14	70	45	
K	♂	152·4	12	14	2	stripe
L	♀	156·9	9	9	same day	few dorsal spots
M	♀	134·0	9	17	8	
N	♀	140·0	10	10	same day	few dorsal spots
O	♂	162·2	9	13	3	
P	♂	143·0	8	3	5 before	
Q	♀	139·0	8	29	21	
R	♂	157·2	9	15	6	one dorsal spot
S	♂	161·6	11	18	7	
T	♂	164·3	17	16	1 before	few dorsal spots
U	♂	116·9	10	18	8	
V	♂	108·5	22	26	4	few dorsal spots

Table 2. Sex, mass and time intervals between significant events for 16 *P. m. molurus* hatchlings.

removed from the breeding colony prior to and reintroduced during the breeding season, which extends from December to February in the wild (Wall, 1912; Smith, 1943; Daniel, 1983). Wagner (1976) reported successful reproduction in *P. m. bivittatus* at the Seattle Zoo using this procedure. Ecdysis appears to stimulate courtship (Radcliffe & Murphy, 1984).

Plate 3. Indian python hatchling no. 14 showing anomalous pattern. This specimen is listed as hatchling K in Table 2. *Trooper Walsh.*

Clutches are laid *c.* 2 months after conception (Pope, 1961; Wagner, 1976; Ross & Marzec, 1990). Pope (1961) recorded 16 clutch sizes of between 15 and 54 eggs but it was not clear in which subspecies these observations were made. Daniel (1983) recorded clutch sizes ranging between eight and 100 eggs (largest 107 eggs) in north India, where eggs were laid between March and June. Vinegar (1973) described two clutches of 44 eggs in captive breedings between subspecies.

Hutchison *et al.* (1966) reported that ♀ *P. m. bivittatus* which brooded their clutches were maintained at ambient temperatures of 32–33°C. Vinegar (1973) found that a temperature of 30·5°C was optimal for artificial incubation but higher temperatures were not tested. Maternal incubation periods for captive *P. molurus* have ranged from 57 to 66 days (Pope, 1961), while incubation periods for artificially incubated clutches ranged between 60 and 93 days (Vinegar, 1973; Wagner, 1976). Vinegar demonstrated that eggs incubated at a lower temperature (27·5°C) hatch later and have a lower hatching success than those incubated at a higher

temperature (30·5°C). Eggs incubated at 23°C did not hatch and embryonic development was curtailed. The incubation time for eggs from the Indian python ♀ at Washington NZP varied widely (61–85 days; mean 72·5 days). This variation and loss of some eggs may have been the result of fluctuating ambient room temperatures caused by air-circulation patterns in the vicinity of the aquariums.

Pattern abnormalities in *P. molurus* with mixed subspecific parentage have been correlated with low incubation temperatures (Vinegar, 1973, 1974); these pattern aberrations caused by unsuitable temperatures have also occurred in *P. sebae* (Branch & Patterson, 1975). The anomalies in our pythons were similar to the specimen illustrated by Vinegar (1974: fig. 1A). We postulate that these abnormalities were caused by temperatures as low as 26·7°C with a daily variation of as much as 5°C.

ACKNOWLEDGEMENTS

We thank Dale Marcellini and Michael Davenport for assistance in the preparation of this manuscript. Betsy Smith from the National Zoological Park, Washington, DC, cultured eggs for bacterial organisms. Judith A. Block read an early draft of this paper.

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Manuscript submitted 16 March 1999; accepted 14 August 2000

Int. Zoo Yb. (2003) **38:** 152–159

A co-ordinated captive-breeding programme for Rothschild's or Mountain peacock pheasant

Polyplectron inopinatum

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In the late 1980s a co-ordinated captive-breeding programme was initiated for Rothschild's or Mountain peacock pheasant *Polyplectron inopinatum* after it was discovered that the species was probably being smuggled from Malaysia to Singapore and being sold on from there. Under a captive-breeding agreement that was set up in 1991, ownership of wild-caught birds would remain with the Malaysian government as would 50% of any progeny: the other 50% would be owned by the holder of the birds as long as they continued to participate in the programme. Thirty-two Mountain peacock pheasants were removed from the wild over a number of years and *c.* 450 birds have hatched and been reared in captivity from sixteen of these original founders. This article describes basic husbandry and breeding procedures for *P. inopinatum*, as well as the success achieved by the co-ordinated captive-breeding programme.

Key-words: aggression, captive-breeding programme, consortium, co-operative programme, hand-rearing, husbandry, Malaysia, mountain peacock pheasant, studbook

The Rothschild's or Mountain peacock pheasant *Polyplectron inopinatum* was first described by Rothschild in 1903 (Rothschild, 1903). The species is found in the main mountain range of peninsular Malaysia, inhabiting the upper unlogged dipterocarp forest between 900 and 2000 m in altitude. Insects, spiders, white