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SEXUAL MATURATION IN *VARANUS SALVATOR* (LAURENTI, 1768), WITH NOTES ON GROWTH AND REPRODUCTIVE EFFORT

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In captivity, *Varanus salvator* attains sexual maturity when they are just over one metre in total length and 50 cm snout-vent length. Maturity can be attained at the end of two years. Males and females tend to grow throughout the breeding season. Egg-laying seasons are closely synchronized with those in the wild. No significant difference was noticed in clutch and egg sizes of younger females when compared to those of older and larger females.

INTRODUCTION

Little is known about the age at which the water monitor lizard (*Varanus salvator*) attains sexual maturity. Determining the age of wild-caught animals is difficult. Most captive specimens are wild-caught and lack sufficient life history data. Vogel (1979) estimated the age at maturity to be three to four years in the case of females and four to five years in the case of males. Authors have assumed age at maturity to be three years (Andrews & Gaulke, 1990; Daltry, 1991). Some smaller species like *V. bengalensis* mature at the end of the second year or beginning of the third year (Auffenberg, 1983, 1988).

For *V. salvator*, size at maturity has been noted previously. Vogel (1979) reported 1.4 m total length for females, 1.7 m for males in the wild and 1.2 m as the minimum size of a female breeding in the Zurich Zoo (Honegger, in Vogel, 1979). A wild-caught pair consisting of a 1.4 m female and a 1.5 m male, both of unknown age, bred in captivity at the Ahmedabad Zoo (David, 1970). Jasmi et al. (1986) designated wild-caught animals over 1.6 m in total length as adults, and a smaller size class of 1.3-1.6 m as subadults. Luxmoore & Groombridge (1990) report that size at maturity may vary between populations and could be dependent on the maximum adult size attained. Hairston & Burchfield (1992) reported two females of unknown age and total length 1.5 m and 1.6 m that bred at the Gladys Porter Zoo, and 1.6 m and 1.8 m total length for breeding males. However, it is not mentioned if these females had previously nested. In *V. olivaceus*, males and females appear to mature when just over a metre in size (Auffenberg, 1988). Of the 37 wild-caught males sampled by him, sperm was detected in the seminiferous tubules of animals with total length of 1.2 m and snout-vent length over 0.45 m.

The results of a captive breeding programme at the Madras Crocodile Bank indicate that *V. salvator* in captivity reach sexual maturity when males and females are just over a metre in total length, and 50 cm snout-vent length at the end of the second year. In this paper, I present observations and measurement data of two groups of captives that have been monitored from the time of hatching. In the discussion, I relate these findings to conservation and management programmes based on captive populations of *V. salvator*.

MATERIAL AND METHODS

The study animals consisted of captive-bred *V. salvator* maintained at the Madras Crocodile Bank (see Andrews & Gaulke, 1990; Daltry, 1991). All animals were individually marked by tail-notching and housed in a small enclosure. Initially, as hatchlings, the animals were measured (total body length, TBL; snout to vent length, SVL) and weighed every month for the first year, and subsequently at intervals of two or three months. The first group (Group 1) comprising four males and 11 females, were all captive-bred at the Madras Crocodile Bank in 1988 and 1989. Incubation and growth records of this group in the first year have been reported by Andrews & Gaulke (1990). On April 14, 1990 animals of this group were measured, weighed and moved to a large breeding enclosure (Enclosure 1), which housed a large-size wild-caught male from the initial breeding group. These animals were measured and weighed again on July 6, 1990 (Daltry, 1991). Several females from this group laid eggs in 1990. In October 1990, the large wild-caught male was transferred to a separate enclosure. The second group (Group 2), offspring of animals belonging to Group 1, comprising six males and two females, were hatched in captivity in 1991. This second group of animals were
maintained in a separate enclosure. One of these females nested in this enclosure in 1993.

RESULTS

1990 Nesting - 1991 Hatching

Egg incubation extends for seven to nine months in this species; an increase in incubation temperature reduces the incubation period (Andrews & Gaulke, 1990). Two clutches laid by two females of Group I in 1990 went undetected until the following year. On March 31, 1991, three hatchlings were noticed in the enclosure, and on April 16 eight more hatchlings were observed emerging from a burrow. All 11 hatchlings were transferred to a hatching pen. Excavation of the burrow revealed 11 hatched egg shells with longitudinal cracks all around and an opening at one end.

The second clutch hatched on April 22, 1991. Eight hatchlings were observed emerging from a burrow at 0730 hrs and were immediately removed. On closer examination, the hatchlings revealed the presence of an egg tooth, fresh umbilical scars and a few of them had extended umbilical cords. On excavating the burrow, eight freshly hatched egg shells and one whole egg was found which had completely dried out. Considering the extended incubation period, these two clutches were probably laid in July or August 1990.

1991 Nesting - 1992 Hatching

During the 1991 breeding season, mating among the two- and three-year-old males was noticed in April and May. Between May 31 and July 15, four females were observed nesting. Eggs were removed, measured, weighed and candled to determine fertility rate, and fertile eggs were incubated. Each female was measured and weighed immediately after she had nested. On July 15, 1991, all the animals of Group I were measured, weighed and transferred to a new, larger breeding enclosure (Enclosure 2).

On March 4, 1992, 25 hatchlings were recovered from Enclosure 1 and seven hatchlings were recovered from Enclosure 2. The recovery of these 32 hatchlings indicate that two females had nested in Enclosure 1 before being transferred to Enclosure 2 and another female of the same group (Group 1) had nested in Enclosure 2 immediately after the transfer.

Sexual Maturation in Females

In 1990, the exact sizes of the two-year-old females that nested could not be determined, because the animals could not be identified. However, measurements and weights of all the animals taken at the onset of the breeding season (April, 1990), and during the egg-laying season (July, 1990), show that sizes of the two-year-old females during the egg-laying season (n = 6) ranged from 108 cm to 125 cm (mean 113.8 cm) TBL; 45 to 49 (mean 46.5 cm) SVL, and 1.3 to 2.5 kg (mean 1.87 kg) weight. The two-year-old females that nested for the first time in 1991 and 1993 were 114.5 cm TL and 47 cm SVL, and 123.5 cm TL and 48 cm SVL (Table 1). Egg-laying by the two females in 1990 and the results of 1991 and 1993 breeding season show that female Varanus salvator reach sexual maturity at the end of two years.

Continual growth monitoring helped ascertain age and size at maturity. Measurements taken in April and July 1990 (a 76 day interval) show that females continue to grow even during the breeding season (Table 2).

Sexual Maturation in Males

Although mating activity was observed among members of Group I, it was not possible to determine whether the two-year-old males fertilised the females of this group in 1990, due to the presence of the old, wild-caught male from the initial breeding stock. This was later determined when one of the females of Group 2

<table>
<thead>
<tr>
<th>Female code</th>
<th>Year hatched</th>
<th>TBL (cm)</th>
<th>SVL (cm)</th>
<th>Wt. (g) after laying</th>
<th>Date laid</th>
<th>Clutch size</th>
<th>Egg wt. (g) range</th>
<th>Clutch wt. (g)</th>
<th>% body wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1989</td>
<td>114.5</td>
<td>47.0</td>
<td>1700</td>
<td>31.591</td>
<td>11</td>
<td>64.15-58.4</td>
<td>678.4</td>
<td>39.90</td>
</tr>
<tr>
<td>07</td>
<td>1988</td>
<td>124.0</td>
<td>50.5</td>
<td>2325</td>
<td>9.691</td>
<td>12</td>
<td>64.7-52.9</td>
<td>689.5</td>
<td>29.65</td>
</tr>
<tr>
<td>04</td>
<td>1988</td>
<td>132.5</td>
<td>54.5</td>
<td>2320</td>
<td>10.691</td>
<td>14</td>
<td>62.65-47.10</td>
<td>768.6</td>
<td>33.12</td>
</tr>
<tr>
<td>02</td>
<td>1988</td>
<td>133.0</td>
<td>53.3</td>
<td>2520</td>
<td>15.791</td>
<td>9</td>
<td>65.9-59.9</td>
<td>563.2</td>
<td>22.34</td>
</tr>
<tr>
<td>11</td>
<td>1991</td>
<td>123.5</td>
<td>48.0</td>
<td>2350</td>
<td>21.693</td>
<td>8</td>
<td>78.8-60.8</td>
<td>520.3</td>
<td>22.14</td>
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</table>
TABLE 2. Growth and size of female *Varanus salvator* recorded in April and July 1990 in the second year, and July 1991 in the third year.

<table>
<thead>
<tr>
<th>Female code</th>
<th>Year hatched</th>
<th>TBL (cm)</th>
<th>SVL (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1989</td>
<td>14/4</td>
<td>84.0</td>
<td>33.3</td>
</tr>
<tr>
<td>02</td>
<td>1988</td>
<td>11/5</td>
<td>111.0</td>
<td>45.0</td>
</tr>
<tr>
<td>03</td>
<td>1988</td>
<td>12/4</td>
<td>75.7</td>
<td>30.5</td>
</tr>
<tr>
<td>04</td>
<td>1988</td>
<td>12/0</td>
<td>109.0</td>
<td>45.0</td>
</tr>
<tr>
<td>05</td>
<td>1989</td>
<td>12/4</td>
<td>85.3</td>
<td>32.8</td>
</tr>
<tr>
<td>07</td>
<td>1988</td>
<td>10/2</td>
<td>104.7</td>
<td>43.7</td>
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<tr>
<td>08</td>
<td>1988</td>
<td>10/12</td>
<td>106.5</td>
<td>41.5</td>
</tr>
<tr>
<td>09</td>
<td>1989</td>
<td>12/0</td>
<td>102.0</td>
<td>40.0</td>
</tr>
<tr>
<td>10</td>
<td>1989</td>
<td>12/12</td>
<td>106.5</td>
<td>42.8</td>
</tr>
<tr>
<td>12</td>
<td>1989</td>
<td>12/4</td>
<td>97.9</td>
<td>40.2</td>
</tr>
<tr>
<td>17</td>
<td>1989</td>
<td>12/0</td>
<td>69.2</td>
<td>27.4</td>
</tr>
</tbody>
</table>

TABLE 3. Growth and size of male *Varanus salvator* recorded in April and July 1990 in the second year, and July 1991 in the third year.

<table>
<thead>
<tr>
<th>Male code</th>
<th>Year hatched</th>
<th>TBL (cm)</th>
<th>SVL (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>06</td>
<td>1988</td>
<td>14/4</td>
<td>115.0</td>
<td>46.4</td>
</tr>
<tr>
<td>07</td>
<td>1988</td>
<td>14/4</td>
<td>104.0</td>
<td>42.7</td>
</tr>
<tr>
<td>11</td>
<td>1989</td>
<td>14/4</td>
<td>84.0</td>
<td>33.3</td>
</tr>
<tr>
<td>13</td>
<td>1989</td>
<td>14/4</td>
<td>77.6</td>
<td>31.0</td>
</tr>
</tbody>
</table>
(hatched in 1991) nested in June 1993 in a different enclosure, which housed both males and females of the same age group. The sizes of the males from this group \( (n = 6) \) were TBL = 111 to 133.6 cm, SVL = 46 to 55.5 cm, weight = 1.5 to 3.35 kg. Table 3 shows size and growth at one, two and three years of age. Thus the results of the 1993 breeding season demonstrate that both males and females can attain sexual maturity at two years of age.

**DISCUSSION**

The above observations and results clearly demonstrate that male and female *V. salvator* are sexually mature when they are just over a metre in total length and 50 cm in snout-vent length, at the end of their second year.

In the first three years of growth there was no marked difference in size between females, and males \( (n = 4) \) grew 5.0 - 7.1 cm (mean 5.63 ± SE 0.50) in 76 days, while females \( (n = 10) \) grew 1.3-7.0 cm (mean 4.42 ± SE 0.65), in the same period. Within the year (358 days), the same males \( (n = 4) \) grew 8.0 - 9.5 cm (mean 8.90 ± SE 0.32), while the same females \( (n = 10) \) grew 1.0-13.0 cm (mean 7.99 ± SE 0.93). Comparisons of growth rates between the sexes show no significant differences (Mann-Whitney *U*-test; \( U = 3, P > 0.05 \), in both cases).

Enhanced feeding regimes under captive conditions may result in early sexual maturity, in which case sexual maturity will be dependent on growth, rather than age. This feature has been demonstrated for various species of crocodilians (Andrews, *unpubl. obs.*). Bustard & Singh (1981) reported that captive *Crocodylus palustris* under optimum husbandry conditions exhibit rapid growth, thereby leading to early onset of sexual maturity. They also demonstrate that breeding can be hastened and sexual maturity is dependent on growth, rather than age. Nichols & Chabbeek (1980) reported that enhanced feeding leads to faster growth rates, resulting in early breeding in alligators. Joanne & McNease (1975) have also reported that sexual maturity is dependent on size rather than age for alligators. However, this aspect is still to be tested in *V. salvator* when comparative information from the wild becomes available.

The oviposition cycle in *V. salvator* has been discussed by several authors. At the Nandankanan Biological Park, Orissa, eastern India, eggs were laid in July for two years in captivity by a female (Biswa & Acharjyo, 1977) and by another in June in the same Park (Acharjyo & Mohapatra, 1980). Khan (1969) reported that different wild individuals in the Malay peninsula are reproducitively active throughout the year, with a peak from September to October. Erdelen (1991) thought that it is likely that *V. salvator* in south Sumatra reproduce continuously throughout the year, with egg-laying peaking at the same time as in the Malay peninsula, as reported by Khan (1969). Gaulke (1992) found considerable variation in the breeding season between wild populations found in the various islands of the Philippine archipelago. For example, nesting in May was observed in one island and in November in another. Hairyson & Burchfield (1992) reported marked oviposition cycle differences in two breeding females in captivity. These females laid eggs in December, April, July, August and September. Authors have also reported multiple clutches by the females in a single year, a phenomenon reported by Andrews & Gaulke (1990).

At the Madras Crocodile Bank, where the rainy season starts in June, the 1991, 1992 and 1993 egg-laying seasons closely synchronize with that reported by Smith (1935), namely, eggs being laid in June at the onset of the rainy season in Thailand. A female in captivity was also reported to have laid 14 eggs in June (Whitaker, 1978). June has also been reported as the egg-laying season coinciding with the south-west monsoon season in north-east India, Bangladesh and Andaman and Nicobar Islands (Whitaker & Khan, 1982). Biswas & Kar (1981) also reported that in north-east India, egg-laying in the wild occurred in June. Keatzer (1973) also reported egg-laying in July. Similar findings of eggs being laid from May through July in the north-eastern India population (R. Ghosh, *pers. comm.*) are known.
**GROWTH AND REPRODUCTION IN VARANUS**

*V. salvator* has the largest distributional range of all the varanids (Gaulke, 1991). It is also the most exploited species for skin and meat throughout its range. (Das, 1989; Luxmoore & Groombridge, 1990). Habitat destruction also poses a major threat for the species' survival (Andrews & Gaulke, 1990; Erdelen, 1991).

Previous observations in captivity have demonstrated that the species can be bred in captivity with a high degree of success (Andrews & Gaulke, 1990). Considering the growth rate of the species, hatching survival rate and their ability to breed in two years under captive conditions, the species can easily be made a resource for skin and meat. In countries of tropical Asia, captive-breeding for farming can be taken up under eco-development programmes for the benefit of local people, thereby reducing the pressure on wild populations.

Captive-breeding can also serve as a conservation tool, and for maintaining gene pools. Besides farming, offspring raised to the appropriate size can be re-stocked in habitats where populations have been decimated. Thus, besides facilitating a better understanding of the biology of *V. salvator*, captive breeding can greatly aid in the management and conservation of the species.

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