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Received: 6 August 1997
Reviewed: 21 April 1998
Revised and Accepted: 28 May 1998

Chelonian Conservation and Biology, 1998, 3(1):96–99

Reproductive Ecology of the Indian Softshell Turtle, *Aspideretes gangeticus*, in Northern India

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The Chambal is a major river of northern India and is part of the Gangetic river basin. The river flows for about 600 km along the state boundaries of Madhya Pradesh, Rajasthan, and Uttar Pardesh. In 1983, the "Ganga Action Plan" was launched to clean the river Ganges. In this program large numbers of softshell turtles, *Aspideretes gangeticus* (Fig. 1) and *A. hurum*, were released into the river to feed upon carcasses of animals and humans which were commonly dumped into the river (Basu, 1985). Under a "Hatch and Release" program, eggs were collected from the Chambal and transported to rearing centers at Lucknow and Varanasi, where they were hatched and headstarted.

With the help of the existing facility a study was carried out on the nesting ecology of the Indian softshell turtle, *A. gangeticus*, in the Chambal river. Information on the reproductive biology of this species is sparse, including few studies on its sexual cycle (Rao and Shaad, 1985; Rao, 1986).

Study Area. — The Chambal river is perennial and flows in a northeasterly direction (Fig. 2) in northern India. A major portion of the river flows through topography characterized by ravines. The study area was located in the National Chambal Sanctuary at Etawah District in Uttar Pradesh State. It was 5.4 km in extent, reaching from 78°54' 36"E to 78°57'18"E and 26°46'36"N to 26°48'N. The river flows 102 m above sea level in this area. The river has many side channels with seasonal streams. Water level in the river fluctuated from 4 to 25 m depth and ambient temperature ranged from 4 to 47°C during the year 1992. Various softshell

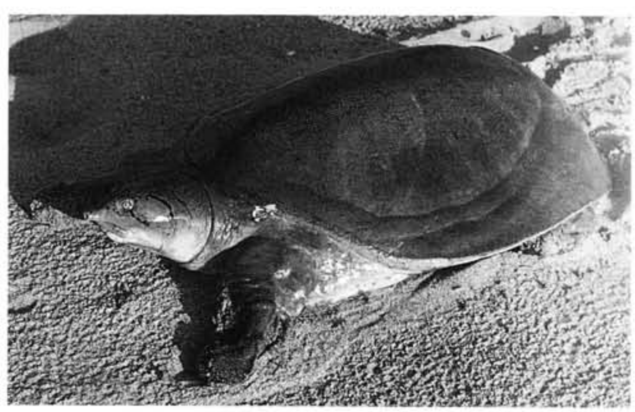

Figure 1. Indian softshell turtle, *Aspideretes gangeticus*. Photo by B.C. Choudhury.

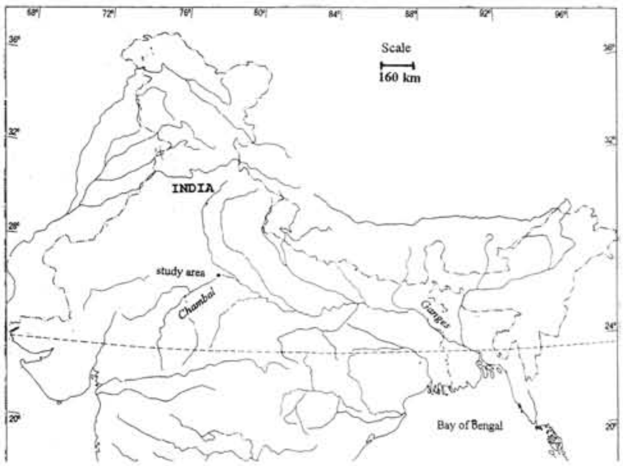

Figure 2. River Chambal and location of study area in northern India.

and hardshell turtle species, gharials, and Gangetic dolphins were commonly seen. Nesting sites of *A. gangeticus*, *A. hurum*, *Chitra indica*, *Hardella thurjii*, *Kachuga tentoria*, *K. kachuga*, and *Lissemys punctata* were present within the study area. The banks of the river are used for cultivation 6 months per year and nesting sites were close to the fields.

Materials and Methods. — The survey was carried out from July to October 1992 by camping in a boat used for the egg collection program. Water level in the river and rainfall was recorded daily based on local Central Water Commission gauges. The study area was searched for nests daily during the nesting season by walking along the banks. Nests were found by following the tracks of nesting turtles, by claw marks, and the appearance of nest sites. Nests were excavated and nest parameters measured, including depth and width of the chamber, length and diameter of the neck, clutch size, and egg diameters. Nest site parameters such as soil type, vegetation covering the nest, slope orientation of the nest, distance from water, and the height above water level were recorded. Although the nesting study was focused at the study area, data on 3 additional clutches were collected from outside the site.

Clutch volume was calculated using the formula for volume of a sphere, $\pi/6*d^3c$, where **d** is the mean egg diameter of the clutch and **c** is the clutch size. Nest volume was calculated by using the formula for volume of an ellipsoid, $4/3*\pi*abc$, where **a**, **b**, and **c** are the three different perpendicular radii measured from the center of the nest.

Nest predation was recorded and nest locations were plotted. The predator species was identified from the way the nest had been excavated and from the tracks of the animal. Fourteen nests found in the study area were used for the incubation study. To avoid detection by predators eggs of these nests were placed in plastic netting bags, a thermistor probe was placed at the center of each nest, and the nests were concealed at the nest sites.

Temperatures were recorded with a digital temperature recorder; round-the-clock temperatures were recorded at 3-hr intervals once every month, and the time when the soil temperature would be minimum and maximum was determined for each month. Maximum and minimum nest temperatures were recorded weekly for all nests. Nest temperatures for nests exposed to northern, southern, and western orientations were monitored and compared.

Soil moisture was measured three times during October, January, and June. Soil samples were taken from the nest depth close to the nest site in all the nests and sealed in plastic bags. The samples were weighed within 24 hrs to the nearest gram, dried to constant weight in a heated wooden box, and then weighed again and the average percentage moisture content calculated.

Eggs were inspected for chalking to determine fertility. Nests were checked daily during the hatching season. Unhatched eggs were opened and the stage of the embryos categorized as "well-developed but dead" (WDD) or as "no discernible embryo or infertile" (NDE/IF) based on visual appraisal. When the eggs hatched the hatchlings were measured and weighed. Times taken for hatchlings to absorb the yolk sac, flatten the plastron, and initiate locomotion were recorded. Ninety-two hatchlings from 8 clutches were randomly selected for an orientation experiment, others were allowed to reach the water unimpeded. The hatchlings were separated into two equal, randomly selected groups. One group was released on the main river and the other was released on the side channels. This study was carried out between 1500 to 1800 hrs, with the time lapse between hatchling emergence and release being less than one hour. The behavior of hatchlings and the numbers reaching the river successfully were recorded for 2.75 hrs after release.

Results. — In the study area 49 nests were found during the 1992 nesting season; the first was recorded on 31 July, the last on 30 October. Peak nesting was observed during late August. Nest and nest-site parameters are described in Table 1. A significant positive Spearman rank correlation existed between clutch size and nest volume ($p < 0.05$, $n = 38$). A similar correlation was observed for clutch volume and nest volume ($p < 0.01$, $n = 38$). Clutch volume was significantly smaller than nest volume (Mann-Whitney U test, $p < 0.001$, $n = 38$). No correlations were observed between nest and nest-site parameters and clutch size or egg size. There was a significant difference in predation on side channels and banks ($\chi^2 = 4.5$, df = 1, $p < 0.05$) with more losses on side channels. There was no significant difference in predation between nests in the open and those covered by vegetation,

Table 1. Nest and nest site parameters for *Aspideretes gangeticus*.

	n	Mean	SD	Range
Depth of nest (cm)	49	22.6	3.4	17–31
Width of chamber (cm)	49	14.7	1.9	11–20.5
Height of chamber (cm)	49	11.2	5.1	8–20.5
Length of neck (cm)	49	10.4	1.8	7–16
Width of neck (cm)	49	9.0	1.5	6–16.5
Clutch size	49	19.2	4.8	6–47
Mean egg diameter (cm)	42	3.1	0.1	2.8–3.4
Distance from water (m)	49	110	9.8	8–300
Height above water (m)	49	15	2.1	1–25
Nest volume (cm^3)	48	1278	6.1	656–3600
Clutch volume (cm^3)	49	324	5.4	94–600

Table 2. Incidence of predation on nests in the open vs. those covered by vegetation.

	Depredated		Intact	
	n	%	*n*	%
Open	15	47	17	53
Covered	4	24	13	76
Overall	19	39	30	61

but predation was least in covered nests and most in open nests (Table 2). The most common predator of covered nests was the monitor lizard, *Varanus bengalensis*, while the jackal, *Canis aureus*, also preyed on some nests.

Nest temperatures for three different slope orientations (north, south, and west) were not significantly different (Fig. 3), but the number of well-developed dead embryos differed significantly ($\chi^2 = 18.04$, df = 2, $p < 0.001$). The number of NDE/IF eggs in different slope orientations were also significantly different ($\chi^2 = 19.75$, df = 2, $p < 0.001$), with southern orientation nests showing the highest egg mortality (Table 3). Incubation time ranged from 251 to 310 days, with a mean of 276.6 days (Table 3). Soil moisture during October was 14% ($n = 6$) in nests under vegetation and 10% ($n = 6$) in open nests; open nests had 7% moisture in January ($n = 4$) and 1% in June ($n = 4$).

Hatchlings had a mean weight of 10.86 g (SD = 1.01, $n = 56$). The mean yolk sac diameter in live and dead hatchlings, respectively, were 1.12 cm (SD = 0.178, $n = 53$) and 1.53 cm (SD = 0.102, $n = 21$); these were significantly different (df = 66, $p < 0.001$). The mean time taken for hatchlings to initiate locomotion after hatching was 22 sec (SD = 2.4, $n = 15$). Hatchlings released on banks and side channels demonstrated significantly different orientations to the river ($\chi^2 = 23.06$, df = 1, $p < 0.001$), with more hatchlings becoming disoriented on river banks than on side channels.

Discussion. — Nesting of *A. gangeticus* was first recorded on 31 July 1992 in the study area and the last nesting was observed on 30 October 1992. There are reports of nesting in the region from August to October (Rao, 1990) and outside the region during November and December (Das, 1995). In the study area, nesting coincided with the first floods in the river. Nesting was not observed during

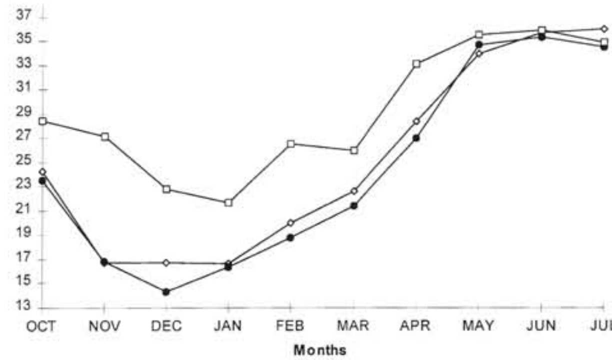

Figure 3. Temperatures (°C) in nests with different slope orientation exposures: open squares = southern, open diamonds = western, solid dots = northern.

floods but there was an increase in nesting frequency soon after the water level dropped. Nests were mostly found in loam or clay soil on slopes.

Nests were flask-shaped cavities with a narrow neck leading into a well-defined chamber. The nest chamber was either broad and shallow or deep and narrow. Nest shapes varied but appeared to be proportional to the clutch size laid. Nest volume was greater than clutch volume, which allows the nest some space above the topmost eggs. This air space may play a role in hatching success. In many chelonians, relationships have been demonstrated between egg size and clutch size (Moll, 1979). However, during this study no correlation was observed between egg size and clutch size, and among many well-studied reptiles there is no clear tendency for larger eggs to occur in smaller clutches (Jameson, 1988).

Jackal (*Canis aureus*) and monitor lizard (*Varanus bengalensis*) are the predominant predators of the nests. According to local people, hyenas, feral dogs, porcupines, ratel, and mongoose also feed on the eggs. Predation by *C. aureus* was more widespread than *V. bengalensis* and its nest search pattern could have caused the variation in frequency of predation on side channels and on banks. The results suggest that a "two dimensional" search pattern (on banks) was less successful than a "linear" search pattern (on side channels); similar observations were also made by Congdon et al. (1983) for the American emydid turtle *Emydoidea blandingii*.

Table 3. Incubation and hatching data for *A. gangeticus*.

Clutch Number	Protected (+) or not (–)	Clutch Size	Age of Nest when found (d)	Orientation of Nest	Incubation Period (d)	Temperature Range (°C)	Number Hatched	Percentage Hatched	Well-Developed Dead (WDD)	Not Developed Infertile (NDE/IF)
1	+	14	2	S	295	16.5–35.4	13	93	1	0
2	+	15	3	W	310	13.8–37.0	0	0	12	3
3	+	11	2	W	291	14.0–36.3	11	100	0	0
4	+	15	3	W	288	14.8–35.1	14	93	0	1
5	+	17	1	N	287	12.1–36.3	15	88	0	2
6*	+	17	1	S	285	19.0–37.2	0	0	4	13
7	+	20	1	E	270	17.5–36.4	18	90	0	2
8	+	14	2	S	283	19.0–36.5	0	0	12	2
9	+	15	1	–	251	13.0–35.3	15	100	0	0
10*	–	16	2	S	253	18.6–38.0	0	0	7	9
11	–	18	1	N	253	12.8–36.0	18	100	0	0
12	–	10	1	–	253	14.4–36.2	9	90	0	1
13**	–	47	1	E	–	–	–	–	–	–
14**	–	28	1	S	–	–	–	–	–	–

* Disturbed by local people in mid-February 1993
** Depredated by jackal before hatching

Differences in hatching success between nests having northern, southern, and western slope orientations suggests that the exposure influences development and survival of the embryo, but the nest temperatures in the three orientations were not significantly different. There were some differences in nest temperatures in different slope orientations but lack of statistical significance could be due to insufficient samples. There was no increase in nest temperatures after a period of low and fluctuating temperatures and this might cause intermittent development of the embryo (Ewert, 1984). After the month of May, the nest temperatures exceeded 35°C and such heat is not conducive for development of the embryo; the optimal period for development would have been between March and May. The increase in number of NDE/IF eggs in nests 6 and 10 (Table 3) suggests that disturbance of the eggs could have adverse effects on further development. In southern facing nests the numbers of well-developed but dead embryos were high (Table 3), probably due to high temperatures experienced by these eggs during incubation. The yolk volume remaining in dead hatchlings was greater than that in live hatchlings. It could be inferred that the embryos died well before hatching and that the fully-developed embryo aestivates, using some of the yolk reserves until hatching. Soil moisture varied considerably in the nests during the incubation period. During summer, low soil moisture could have caused mortality of embryos by desiccation.

Hatching, even of nests laid at different times, took place simultaneously when there were rains after summer in July. It is probable that moisture acts as a "hatching releaser." Results from the locomotion study suggest that hatchlings orient themselves by the gradient of the substrate, moving downwards until they reach water. Thus, nesting on slopes (banks) would be advantageous to the hatchlings. Hatchlings that had to make a long journey to the river took intermittent refuge under bushes and cracks in the soil; when water flowed during subsequent rains they were swept into the river.

From this study it would be reasonable to recommend protection of nests in order to increase hatching success in the wild population, since predation of nests is high. These measures may be taken to augment the natural population in the wake of large scale collection of nests for re-introduction programs.

Acknowledgments. — I thank WWF - India for providing me a honorarium through the Conservation Corps Volunteer (CCV) program and J.W. Lang for financial support through the "Reptile Egg and Incubation Project." My heartfelt thanks to D. Basu and other staff of the Uttar Pradesh Forest Department for their help. Thanks are also due to H. Andrews, I. Das, and R. Whitaker for their encouragement.

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Received: 28 August 1997
Reviewed: 26 April 1998
Revised and Accepted: 30 May 1998

Chelonian Conservation and Biology, 1998, 3(1):99–102

Morphometrics of the Fossil Box Turtle, *Terrapene innoxia* Hay 1916, from Florida

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The fossil turtle species *Terrapene innoxia* was described by Hay (1916) from a series of shell elements collected by E.H. Sellards from Wisconsin (Rancholabrean) Pleistocene deposits at "Vero, St. Lucie County, Florida" (the site is actually in Indian River County). The series consists of a complete carapace, the holotype (Florida Geological Survey [FGS] 7080, now United States National Museum of Natural History, Smithsonian Institution [USNM] 8824), a second almost complete carapace (FGS 7079), several carapacial fragments (FGS 7081–84), and two plastral elements (FGS 5471, 7085). Hay's (1916) description of *T. innoxia* was vague and barely separates it from other North American box turtles: "Carapace thin, relatively narrow, highest at middle of length, sloping hardly more rapidly backward than forward; nuchal bone not excavated; hinder