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NESTING BEHAVIOR OF *Crocodylus palustris* AND POTENTIAL SURVIVAL ADVANTAGES LINKED TO DIFFERENT NEST STRUCTURES IN A SANCTUARY PREMISES IN HARYANA, INDIA

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ABSTRACT: The present studies endeavour to focus attention on the Tunnel behavior of Indian Marsh Mugger in "Bhor Saidan Crocodile Sanctuary" in Kurukshetra district of Haryana state in India. The Sanctuary premises are spread over an area of about 25-30 Acres with a good marshy land. The marsh mugger (*Crocodylus palustris*), also known as the mugger crocodile or the broad-snouted crocodile, is a species of crocodilian native to the Indian subcontinent. An extensive one-year study identified four distinct types of crocodile nests, each with unique features and specific functions. These nests were categorized as Funnel Nests, Simple Tunnel Nests, Chamber Nests, and Tunnel Nests with Doorsills. Each type served a different purpose: Funnel Nests were primarily used by adult crocodiles for resting, while Chamber Nests were utilized for egg laying. The Tunnel Nest with a Doorsill provided a dual function, offering a hiding place for hatchlings in their early days and preventing water from entering the nest hole. The study extensively examined nesting behavior and recorded physical parameters such as ambient temperature and humidity, correlating these factors with the nest architecture. The findings indicated that the choice of nest site and type significantly impacts the species' survival.

Key words: *Crocodylus palustris*, Nesting behaviour, Survival, Nest

INTRODUCTION

The marsh mugger (*Crocodylus palustris*), also known as the mugger crocodile or the broad-snouted crocodile, is a species of crocodilian native to the Indian subcontinent. Although some older records still hold true, the ecology of this species has not received as much attention as it once did. The IUCN Red List 2004 classifies the mugger as Vulnerable (VUA1a C2a). Even when dry, they can move quickly across short distances and have incredibly strong jaws that can bite with great force. Depending on their age, their nutrition changes. Adults eat fish, amphibians, reptiles, birds, and small mammals like monkeys; juveniles eat insects, crabs, and small fish (Gupta & Bhardwaj, 1993; Britton, 1995). Mugger crocodiles are a hole nesting species. As with other hole nesters, egg laying takes place during the annual dry season. Nests can be found in many different types of settings; females have even been observed to build their nests within or at the entrance of their burrows. Mugger crocodiles primarily inhabit freshwater environments like marshes, ponds, lakes, irrigation

canals, and reservoirs, but they can also be found in saltwater lagoons. As indicated by their scientific name, *Crocodylus palustris*, which means "crocodile of the marshes," they predominantly reside in marshy areas. During the dry season, these crocodiles dig burrows in the mud to escape the heat and may travel long distances overland in search of water if their current habitat dries up.

During the dry season, which spans from December to February, the female crocodiles create nesting holes. They generally prefer sloping banks but may choose other sites as well. Once a female selects a suitable location, she often uses it for breeding over multiple years. After mating, the female deposits her eggs—typically around 28, though this can range from 10 to 48—into the nest she has prepared. This egg-laying occurs between February and April.

Although it hasn't been seen in the wild, certain mugger crocodiles in captivity have been reported to lay two clutches in a single year (Whitaker & Whitaker, 1984). The incubation period is brief, usually ranging from 55 to 75 days. The mugger crocodile's sex is determined by its incubation temperature. It is the most adaptable of all three of India's crocodilians, found in dams, streams, and saline lagoons (Whitaker and Whitaker 1984). During the early seventies, while the mugger population in india were reportedly decling. The mugger crocodile (*Crocodylus palustris*) has the widest distributional range compared to any of the Asian fresh water crocodilian species (Whitakar and Whitakar, 1989). Of the 21 species of crocodilians that are found in the warm subtropical and tropical regions of the world, three occur in the Indian subcontinent (Singh,1999) namely the Gharial (*Gavialis gangeticus*) the Saltwater or Estuarine crocodile (*Crocodylus porosus*) and the mugger (*Crocodylus palustris*). Most muggers are available in holy tanks in southern India and Srilanka along with rivers like Chambal, Yamuna, Ganga and Mahanadi in Orissa.Yet, Muggers are in abundance in various Zoos and Mamllapuram Crocodile Park in TamilNadu. However, "Bhor Saidan Crocodile Sanctuary" in Kurukshetra district in Haryana is a unique system providing ideal conditions for studying behavior of Muggers. Bhor Saidan crocodile sanctuary is loomed in village Bhor Saidan. It is believed that about 1960, 2-3 muggers came here in the flood, residing in the village pond. At that time the pond had a very ideal environment for crocodiles in the form of water body, terrestrial platform, and marshy plant growth inside water, a huge earth mound for egg laying, etc. The pond was situated in 3 acres area at that time. After sometime population increased through breeding which became a problem for villagers. They started attacking human as well as pets. Then the administration became alert and declared the crocodile breeding centre under crocodile conservation project. It was declared a wildlife sanctuary in 1982 under Wildlife Protection Act, 1972 by the Government of Haryana, with a total area of 8 acres.

REVIEW OF LITERATURE

The Mugger is a hole-nesting species, with egg-laying taking place during the annual dry season. Females become sexually mature at approximately 1.8-2 m, and lay 25-30 eggs (Whitaker and Whitaker 1989). Nests are located in a wide variety of habitats, and females have even been known to nest at the opening of, or inside, their burrow. In captivity, some Muggers are known to lay two clutches in a single year (Whitaker and

Whitaker 1984), but this has not been observed in the wild. Incubation is relatively short, typically lasting 55-75 days (Whitaker 1987). Whitaker and Whitaker (1989) provide a good review of the behaviour and ecology of this species. Like a number of other crocodilians, C. palustris is known to dig burrows. Whitaker and Whitaker (1984) referred to Mugger burrows in Sri Lanka and India (Gujarat and South India) and noted that yearling, sub-adult and adult Mugger all dig burrows. In Iran they are sometimes known to dig two burrows close to each other, which may be used by one or more crocodiles (Mobaraki 2002). These burrows are presumably utilized as an effective refuge from hot daytime ambient temperatures. These burrows play a critical role in the survival of crocodiles living in harsh environments (Whitaker et al. 2007), allowing them to avoid exposure to excessively low and high temperatures for long periods of time, which may be lethal (Lang 1987). In crocodiles, the temperature at which eggs are incubated determines the sex of the offspring. There are typically specific temperature ranges that influence whether an embryo will develop into a male or female.

· · **Temperature Ranges**:

- ·**Low Temperature Range**: Generally, lower temperatures (often below a certain threshold) tend to produce females.
- **Intermediate Temperature Range**: Intermediate temperatures usually result in males.
- **High Temperature Range**: Higher temperatures can also influence the production of females, though this can vary between species.
- The emerging juveniles are roughly 30 cm long and their mother will aid them by opening up the nest and carrying them to the water.

MATERIALS AND METHODS

Study site: It is amazing to note that there is a "Crocodile Sanctuary" in Kurukshetra district in Haryana. The Crocodile sanctuary came into existence in 1982 when a "Temple Tank" having 25-30 muggers was upgraded as "Sanctuary" by Govt. of Haryana. Actually this sanctuary is located beside a village, namely "Bhor-Saidan Crocodile Sanctuary "in Kurukshetra district and hence its name "Bhor Saidan Crocodile Sanctuary." In contrast to vast area, required to generate account on natural history of Marsh Mugger in India focusing attention on the vast basins of rivers like Yamuna, Ganga, Chambal, and Mahanadi, the present Crocodile Sanctuary site is an ideal site, bypassing frustration of tracking and boating and yielding no substantially clues. The present study site is, namely, "Bhor Saidan Crocodile Sanctuary." Bhor Saidan village is a part of "Pehowa Sub -Divisional Block" of Kurukshetra which is 157 Kms away from Delhi on NH-1 in the North. This Sanctuary has a glorious past directly related with conservation of biodiversity through religious ethics, rituals, preachings and bindings. According to the Sadhus now in charge of the Temple, their Guru brought Muggers around 250-300 years ago to the tank and inspired the villagers to have affiliation with the Muggers by way of "Food-Offerings" and "Worship". The study is an ideal habitat in a limited dimensions providing virtually the best location for understanding the basics of behavioral patterns of Marsh Mugger. The main physical attribute of the Sanctuary include a vast sheet of marshy wetland and an earth mound. This mound is the site of "Tunnels."*Bhor Saidan* sits on an ancient archeological mound on the banks of dried up river bed

of Sarasvati River that dried up due to the movement of tectonic plates. Curator Archaeologist of Shrikrishna Museum in Kurushketra, Rajesh Purohit, discovered Painted Grey Ware culture (1200 BCE to 600 BCE)) pottery from the Vedic period of Mahabharata.

Country	India
State	Haryana
District	Kurukshetra district
Founded by	Bhurisrava (Kaurava hero)
Government	
• **Type**	Panchayati raj
• **Body**	Gram panchayat
Languages	
• **Official**	Hindi
Time zone	UTC+5:30 (IST)
Website	www.haryanaforest.gov.in

Topography: The main topographical features are: (i) circular water body and (ii) mound of settled soil. The water body is approximately 1.25 m deep in the center, artificially fed by a feeder originating from Bhakra-Saraswati Canal. This water level is maintained throughout the year. The mound is circular in shape, 243.60 m in circumference and 5 m in height. The soil is settled and has grassy patches. The circular canal is interrupted at one place by a longitudinal stretch of earth which provides a passage to approach the mound. The various tunnels scattered round the mound are significant features of the sanctuary and have been dug by the crocodiles.

Flora and Fauna: The aquatic flora consists of *Nelumbium speciosum*, *Ipomoea*, *Pistia* and *Eichhornia* species. The submerged weeds are *Valisneria*, *Hydrilla*, *Chara* and *Potamogeton*.The nektonic fauna comprises of fishes, mainly *Labeo rohita* and *Channa punctatus*. Birds like the weaver bird (*Ploceus philippinus*) and cattle egret (*Bubulcus ibis*) nest on the nearby trees.

Climate: The altitude of the study area is around 230 m MASL. The maximum temperature recorded during June was 460 C and minimum in winter (December-January) was 40 C. The mean annual rainfall is 1200 mm. The relative humidity ranges from 100 % during monsoon to 14 % in summer.

Methods: This sanctuary will be very little known. Keeping this in view, systematic surveys will be initiated to study nesting behaviour of *Crocodylus palustris*. Nests were actively monitored along the river banks through extensive field surveys conducted once in two days. Once the nests were located the nesting sites were thoroughly examined and the associated flora and fauna around the nest was documented. Further the nest dimensions viz. Shape of the nest, length of the nest, nest width, nest height at the entrance and in the middle

were recorded using standard graduated measure tape. All the nests were explored strictly during the non-breeding season to avoid any kind of conflict. The nests were first checked for the presence of any individual inside the nest and in case of their absence only further exploration was done.

RESULT AND DISCUSSION

A total of 09 active nests are recorded. Nests are not uniformly distributed but they are aggregated in one particular area. Distances between successive nests are perhaps not uniform. An accurate measurement could not be taken because of the inaccessibility of terrain. Based upon their architecture as well as probable function, the nests are defined as 1. Simple Tunnel Nest, 2. Funnel Nest, 3. Chamber Nest, 4. Tunnel Nest with Doorsill.

The physical dimensions of the nests can be correlated to with the most important physical properties i.e. temperature. In Chamber Nest the temperature decreases as we measured more and more inside the nest and becomes stable in chamber area. The temperature was found to be 29.5°C in chamber, which is a female biased temperature. This has been seen in all the chamber nests we observed. Similarly the temperature remains more or less constant in all the seasons. It implies that the female perhaps has sense about the temperature maintenance. Similarly we also correlated the physical dimensions with each other of other nests. However the significance of the dimensions could not be interpreted. Nevertheless, these dimensions are probably needed to maintain the specific function.

The locations of these nests and their proximity to water differed from each other. For instance, the Funnel Nests and Tunnel Nests with doorsills were closer to the water compared to the other two types. Each nest type had distinct functions. Funnel Nests were primarily used by adult crocodiles for resting, as only adults were observed around these nests. Eggshell fragments found in nests with storage chambers suggested that these nests were mainly utilized by adult females for laying eggs. Hatchlings were commonly found near Tunnel Nests with doorsills, which likely provided a safe hiding spot for these vulnerable young crocodiles, protecting them from both inter- and intra-specific threats until they grew to the size of a yearling. Additionally, the doorsills helped prevent water from entering the nests, which were situated closer to the water. Despite rising water levels during the monsoon, these nests remained safe from flooding. The purpose of simple Tunnel Nests remains unclear.

Being ectothermic, crocodilians' activities, especially their breeding behavior, are significantly influenced by temperature. A noticeable gradual decrease in temperature was recorded in Chamber Nests. By comparing the dimensions of the nests with their length, significant findings emerged, highlighting the importance of nest architecture for the species' survival success. The different functions of the nest holes were correlated with their individual structures.

- Type-I nests known as ‘Simple Tunnel Nests,’ are straight, tunnel-shaped nest holes that measure 11 to 12 feet in length and are excavated in the soil with an arena. The arena helps keep the nest away from the

water, thereby preventing water from entering. Over time, a noticeable variation in the length of the arena has been observed, likely to further prevent water intrusion.

- Type-II nests are characterized by their straight tunnel structure with a funnel-shaped entrance, and are thus called 'Funnel Nests.' These nests are 11 to 12 feet long and feature a funnel-shaped entrance. The upper side of these nest holes is covered with vegetation, including *Lantana camara, Calotropis gigantea*, and various grass species, which nearly obscures the entrance. A dense layer of this vegetation is found in front of the nest hole, providing a basking area. This type of nest is commonly used for resting in the evening. During these periods, the crocodile assumes a still posture with its head tucked inside the nest hole, which is distinct from its basking behavior. No tail movement is observed during this resting time.
- Type-III Chamber Nests are characterized by a 13 to 14-foot-long tunnel that ends in a spherical structure known as the storage chamber. Unlike other nests, this tunnel is not entirely straight. It is also known as storage chamber. This nest type features an arena in front of the entrance, and both the length and slope of the arena show considerable variation. There is indirect evidence suggesting that this nest is likely used for egg laying and rearing hatchlings in the early stages. Such evidence includes eggshell fragments, tracks of both adults and hatchlings, and observations of an adult (possibly female) moving in and out of the nest during and after the breeding season. Compared to Type-I nests, Type-III nests have a longer arena. The extended length of the arena may help prevent water from entering the nest and provide additional space for the female to guard the nest.

- Type-IV (N=1) Tunnel Nest with Doorsill; it is the nest just like that of the simple tunnel nest, but it has a vertical structure termed as 'doorsill' in front of the entrance. It has been observed that this doorsill is 1 foot in height from the surface of ground.

The dimensions of this type of nest are same as that of the Simple Tunnel Nest. The possible role of doorsill is to avoid the entry of water inside the nest since the height of this doorsill increases as the water level is elevated in monsoon and it is broken down to a considerable extent in summer when the water level goes down. Another reason can be inferred by comparing the overall structure of all the nests, that there is no arena in front of this nest as seen in Simple Tunnel Nest. This nest type may be the modified form of Simple Tunnel Nest when the boundary of nest is shared by water and also no place in front the entrance to leave it as an arena.

CONCLUSION

This study demonstrates that the Marsh Crocodile can differentiate between the needs for various types of nests for distinct functions. The dimensions of the nests indicate that these four different types are vital for the survival of these crocodiles, as each serves a unique role in their life cycle. Analysis showed that they build nest to protect the developing eggs and incubate them with the warmth of decaying vegetation. When they hatch she might carry them from the nest to safe shallow water where they can find food, and even guard them for a while to scare off any predators that might eat them while they are small. Such research is extremely valuable for the conservation of this species, particularly when creating artificial breeding centers.

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