

*Research article*

## **Morphometry, nutrition and health of the marsh crocodile (*Crocodylus palustris*) conserved in the Chittagong zoo, Bangladesh**

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### ABSTRACT

The crocodiles are one of the largest living reptiles representing the majority of the ancient classes of reptilians which are far reaching and dependent on the deep oceanic environments of the tropical and sub-tropical locales. In expansion to their biological significance and recognizable proof as the key stone old species, they serve exceptionally critical economic role for human civilization. Crocodile meat is not only delicious, it is anti-arthritis, anti-inflammatory, anti-arrhythmic, anti-thrombotic, anti-atherosclerotic, and anti-carcinogenic for human being. However, most of the populations of the species have been depleted in their ranges due to over harvesting for diversified employment settlement with special regard to their highly valued skin and oil. Consequently, out of 23 living species, nearly half of them are recorded in several categories of Red Data List as debilitated species and currently facing severe threats for survival. The purpose of the Chittagong zoo, Bangladesh is recreation, exhibition, conservation, education and research on wildlife. The current study aimed to focus the morphometry, habitat, nutrition, health and reproduction of the marsh crocodile (*Crocodylus palustris*) conserved in the Chittagong zoo, Bangladesh.

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## 1. INTRODUCTION

Crocodile is a reptilian animal found almost all over the world except Europe (Silva and Lenin, 2010). They originated about 175 thousands of years ago and till date they have been an integral part of the biodiversity in different geographical locations throughout the world (Walker, 1968, 1972; Whetstone and Martin, 1979; Delfino et al., 2020). There are 23 crocodylian species under 3 families in the world. They are long lived animals and the available information suggests that freshwater crocodiles can live more than 40 years (Vyas, 2012). Keeping a

crocodile is a long term commitment, and many people purchase a crocodile in the belief that they will leave it away once it grows quite large. Compared with many other animals, crocodiles grow rapidly to large adult sizes and increase in length to at least 20 to 30 times from hatchlings and 1,000 times in weight by 10 to 20 years (Mitra, 2005). In any case, development rates may shift essentially between people depending upon temperature, recurrence of nourishing, quality of nourishment and social factors. Despite these varieties, all crocodiles appear a reasonably similar development pattern, i.e.,

initial growth rates are quick, frequently for a few a long time, but gradually start to decrease as the creature matures (Vyas, 2014).

Crocodiles play an important role in the wetland ecosystems (Whitaker and Whitaker, 1989). They help keep the balance in the complex web of life in freshwater and estuarine ecosystems (Rao, 1994). Besides, crocodile meat is a low-fat, low cholesterol and high protein meat. Crocodile meat is not only delicious, it is good for heart, lungs, blood circulation and it is known to remedy of asthma and coughing (Mitchell et al., 1995; Hoffman et al., 2000). It is rich in omega 3 fatty acids, which many other meats do not contain in great quantity. Omega-3 normalises and regulates cholesterol triglyceride levels by lessening the protein action that causes the liver to metabolize fat. It is anti-arrhythmic, anti-thrombotic, anti-atherosclerotic, and anti-inflammatory. Crocodile meat is believed to have anti-carcinogenic and anti-arthritis properties reducing the symptoms of inflammatory diseases such as asthma and arthritis (Zhang et al., 2011; Lu et al., 2012; Xiao and Wang, 2014; Jeyamogan et al., 2017; Poapolathep et al., 2020). Despite many promising features, the species is threatened by unregulated hunting for skins, habitat destruction, death in fishing nets, egg collection and illegal hunting (Choudhury and Silva, 2015). Despite the truth that a number of populations exit all through its run, they are disconnected and their numbers are less. A few populations have already been terminated from Bangladesh. It was, therefore, to survey the current status of crocodiles, human crocodile interaction, and the causes of decline of crocodiles and to build up awareness among local people for conservation of crocodiles in the Chittagong zoo, Bangladesh.

## 2. MATERIALS AND METHODS

### Study area

The study was undertaken in Chittagong zoo, Chittagong, Bangladesh. Chittagong zoo is a zoo in Chittagong Bangladesh located about three kilometres north-west of the city, alongside at the entrance of Foy's Lake, opposite the foothills of the mountains of USTC Medical College. In 1988, MA Mannan, former Deputy Commissioner of Chittagong district and some other elites of the city, initially took initiative to establish a private zoo at Foy's Lake for the

purpose of recreation, education and research on zoo animals. It is arranged at uneven arrive of Foy's lake, south-khulshi, Chattogram. Afterward, on February 8, 1989 the zoo was opened for the guests. At first 4.90 sections of land of arrive was designated by the Bangladesh government which a while later expanded to 6 sections of land. Within the damp season, the zoo is hot, harsh, and cloudy and the dry season is warming, humid and generally clear. Over the study of the year, the temperature regularly shifts from 58 to 90°F and is seldom underneath 53-93°F. The average rainfall of this area is 0.5 inches in February to June and 17.8 inches from July to September.

### Preparation of questionnaire

Before collection of data, a structured questionnaire was prepared in accordance with objectives of the study. A random sampling survey was conducted using the questionnaire. Later on, the questionnaire was validated. The questionnaire included both open and close ended questions on habitat, behavior, food, nutrition, reproduction, hazard, common diseases, treatments and local people's perception about crocodile.

### Data collection

The data was collected by using primary data collection method from zoo curator, zoo attendant, and other people working in the zoo area and also from group discussions. The survey was carried out in Chittagong zoo from 15 to 17 February, 2020 for adult crocodiles and 19 to 21 February, 2020 for the juveniles. Information related to the population, morphometry, habitat and distribution of crocodiles were collected. The sites of the habitat of crocodiles were visited in zoo and interview was conducted in the study area. All the information was compiled and analyzed to prepare the manuscript.

## 3. RESULTS

### Demography

The marsh crocodile (*Crocodylus palustris*) in the Chittagong zoo lives in fresh water where the depth of water is 3 feet. There are two adult crocodiles with a length of 2.5 meters for the female and 3.0 meters for the male. They are 30 years old and brought from Safari Park, Cox's Bazaar, Bangladesh. The weight of the female

and male was 600.0 kg and 700.0 kg, respectively. The length of the adult crocodile's tail was 1.8 meters. The hatchling weighed 300g. There were 14 young in the zoo and their average age was 9 years.

### **Morphometry**

The adult crocodiles of the zoo were grey to brown with little banding. The colour of the juvenile was light tan with black cross banding on body and tail. The size was medium to large. Their snout was broad in appearance and enlarged scutes were present around the throat. They had intense senses, which was a developmental advantage that made them effective predator. The eyes, ears and nostrils were found on beat of the head, permitting them to lie down within the water, nearly completely submerged and covered up from prey. The tail was long and massive, and the skin was thick (Murray et al., 2019).

Overall, its external morphology was a sign of its aquatic and predatory lifestyle. In the zoo, it was seen that its body enabled it to swim swiftly. It tucked its feet to the side while swimming made it faster by decreasing water resistance. They had webbed feet which they utilized to move them through water, but permitted them to create fast turns and sudden move within the water to start swimming. Webbed feet were an advantage in shallow water, where they moved around by strolling. The nostrils were closed amid submergence. They had soft integument on their stomachs and sides, whereas their dorsal surfaces were heavily clad with large bony structure within the skin called osteoderms. The steel plated skin had scales and was thick and tough providing some sorts of protection (Caldwell, 2009). They had unique body form that allowed their eyes, ears, and nostrils to be above the water surface while most of the animal was hidden below. The adults had 64 and the juveniles had 50 teeth. They are cable of supplant each of their 80 teeth up to 50 times in their life expectancy of 35 to 75 a long time (Scully, 2002)(Scully, 2002). They had perceivable molars, incisors and canine teeth and dental pulp stem cell in their dental shelf powerful jaws with many conical teeth and short legs with clawed webbed toes. Their tongues were attached to the roof of their mouth, so they could not move it. This made it impossible for them to stick it outside of their

narrow mouths. The tongue played no part of feeding. As they spent much time underwater, the tongue helped to keep the throat closed, protecting it airways. They had salt glands on their tongue. They had no sweat glands and released heat through their mouths. In the zoo it was seen that they used to sleep with their mouths open and panted like a dog. The crocodiles within the zoo were fed by snatching and, they had advanced sharp teeth for puncturing and holding onto flesh, and effective muscles to shut the jaws and hold them closed. In any case, it was an advantage instead of a drawback to the crocodile since the properties of the teeth permitted them to hold the prey with the slightest plausibility of the prey creature getting away. Cutting teeth, combined with the especially tall nibble constrain, would pass through substance effortlessly sufficient to take off an elude opportunity for prey. The jaws might nibble down with monstrous constrain, by distant the most grounded chomp of any animal (Bates and Falkingham, 2012). The space for the jaw muscle within the cranium was exceptionally huge, which was effortlessly unmistakable from the exterior as a bulge at each side. The muscle was very hardened. It was nearly as difficult as osseous matter to touch, as on the off chance that it was the continuum of the cranium. Another characteristic was that most of the brawn in a crocodile's jaw was organized for clamping down. In spite of the solid muscles to shut the jaw, they had amazingly little and powerless brawn to unlock the jaw.

### **Vision, hearing, sense**

The crocodiles of the Chittagong zoo had very good night vision. They had vertical-slit shaped pupils which helped to protect their eyes during daylight. In the eyes, they had tapetumlicidum which reflected incoming light back onto the retina, thus utilizing the small amount of light available at night to be best advantage. In expansion to the security of the upper and lower eyelids, they had a nictitating layer or 'third eyelid' that might be drawn over the eye from the internal corner whereas the covers were open. The eyeball surface was in this way secured beneath the water whereas a certain degree of vision was still conceivable. They had exceptionally sharp hearing. They may listen their babies calling from interior their eggs. Their tympanic films were concealed by level

folds that could be raised or brought down by muscles. So the crocodiles might listen well. Within the mouth cavity of the crocodiles, the upper and lower jaws were secured with tactile pits which were obvious as little, dark dots on the skin. These sense organs were known as domed pressure receptors. In the zoo areas, they responded to the slightest disturbance in surface water, detecting vibrations and small pressure changes as small as a single drop. This made it possible to detect danger and intruders, even in total darkness.

The sense of scent was moreover exceptionally well created of the grown-ups and adolescents. They utilized olfaction within the egg earlier to bring forth. They had as it were one olfactory chamber and they recognized both air-borne and water-soluble chemicals utilized for their olfactory framework. When over water, they upgraded their capacity to distinguish unstable odorants by gular pumping, a muscular development of the floor of the pharynx. Within the zoo, they were seen to shut their nostrils when submerged.

### **Behavior**

Crocodiles are the foremost social reptiles. In any case, there was a certain shape of chain of command in crocodiles which was seen within the zoo. The biggest and heaviest male were at the best, having get to the most excellent lolling location, whereas females had need amid a gather bolstering of a huge carcass. They utilized to appear toleration in bunch feedings and tended to gather in certain zones. The male crocodile was forceful towards each other amid mating season, to pick up access to females. Crocodiles are also the most vocal of all reptiles. In the zoo, they produced a wide variety of sounds during various situations. The most common specific vocalization was made during the season. They quarreled during feeding. They also produced different distress calls and in aggressive displays to their own kind. Specific vocalizations included threat call, hatching call, chirping and bellowing. They used to follow trick to hunt any prey, holding up for arriving any angle or small creatures to come near, they usually rushed out to sudden attack. But in Chittagong the zoo, the crocodiles are in enclosed condition and they cannot perform hunting. Sometimes they eat fish, amphibians, mollusks, birds and reptiles in the water. What a

crocodile eats changes significantly with size and age. Crocodiles have the foremost digestive juice in their stomach of any vertebrate. They can effectively process osseous matter, corniculate and trotter.

### **Thermoregulation**

The crocodiles of the zoo used to thermo regulate by alternately sunning themselves and retiring to shaded areas or cooler water. Larger individuals maintained stable body temperatures in the preferred range of 30-32°C (86-90 °F) for several hours, even overnight. As a result, these individuals enjoyed increased metabolic efficiency. The complex social relations between individuals were expressed as dominance hierarchies that allowed dominant animal's better access to preferred sunning and nesting sites. The crocodiles also dug burrow into the banks of lakes where they remained. Burrows extended for several metres in length and ended in a chamber where individuals sought refuge from drought or cold.

### **Communication**

The crocodiles vocalized to communicate. In the zoo, the young used several squeaking and grunting sounds, and the adults used to grunt, growl, and hiss. In addition, members of both sexes produced a loud roar during the breeding season. They tensed the muscles of their body so that the head and tail raised high outside of the watery area. The flanks used to vibrate so violently that water was sprayed high into the air from each side. Sounds, including roars, could be provoked by loud noise. They responded to gunshots, motors, and even people mimicking crocodile sounds. They used to communicate using chemical signals. Glands in the mandible and cloacae excreted oily chemicals that had a poorly understood function in communication.

### **Habitat**

In the study area of the zoo, crocodiles were reared under enclosed area where there were both land and water and the area was covered by hard wire fencing system. Two enclosed area were found where front one was for adults and another behind was for the juveniles. The depth of the front areas water for adults was 3.0 feet and for young 1.0 foot.

### **Diets and feeding**

In the zoo, the crocodiles were fed normally once a week. The amounts of feed used to depend on the age and the reproductive state of crocodiles (Table 1). They were provided chicken and beef which were given 8% of their body weight to the grown-up while for the youthful as it were 5%. In each week, grown-ups were given 6.0 kg meat and the adolescents were given 1.0 kg at a time. They teared the flesh by strong sharp teeth and surprisingly, swallowed the whole meat. They captured water

animals in their jaws with a sideways movement of the muzzle. They had sensitive pressure receptors located in pits in the scales around the mouth that detected motion. These structures assisted in the capture of prey in the dark. To catch land animals, the zoo crocodiles floated passively or remained motionless at the edge of the water where prey habitually drank. They drank water what was supplied in the enclosure of the zoo.

Table 1. Feeding schedule for the young and adult crocodiles at Chittagong zoo, Bangladesh.

Parameter	Adult	Young
Age	30 years	Around 9 years
Diet	Chicken meat and beef	Chicken, beef
Percentage	8% of live weight	5% of live weight
Amount	Around 6 kg	Around 1 kg
Frequency of feeding	Once in a week	Once in a week
Feeding style	Tearing flesh and swallow it	Swallow whole meat

### Reproduction

The 2 adult crocodiles of Chittagong zoo was brought from the Safari park, Cox's Bazaar and then the female became matured and they bred by laying eggs. The 14 young crocodiles were born from the mother. In the zoo, the female one reached sexual maturity at 6 years old while males matured at 10 years old. Nests were given during the dry season (December to February). They were most commonly found on sloping banks. The female laid 20 eggs and 14 eggs were hatched. Eggs hatched after a moderately brief period of 55 to 75 days, and the adolescents were around

30cm long at birth. Research into the impacts of temperature upon sex of the developing life produced male-only embryos at 32.5°C, with a more noteworthy rate of females delivered underneath and over this. Female-only embryos were delivered between 28°C and 31°C.

### Diseases

Numerous bacterial, viral and parasitic infections influenced crocodiles in conjunction with hepatic maladies (Table 2). The disease and treatment schedules were different according to age and sex.

Table 2. Disease prevalence and treatment for the young and adult crocodiles at Chittagong zoo, Bangladesh.

Diseases	Adult	Juvenile
	Parasitic infestations	Osteomalacia
	Psittacosis	
	Salmonellosis	
	Campylobacter enteritis	
	Adenoviral hepatitis	
Treatment	Fenbendazole and other antibiotics are administered orally with feed.	Calcium supplements are given with food. Vitamin and mineral mixture are given with feed.

### Common hazards

In the zoo there are many hazards mentioned in the Table 3. As crocodiles are instinctive predators and unusual creatures, to diminish the chance of crocodile's assault, discernment on its conduct is critical. As least control measures any individual working close over the top crocodiles over 1.5 meters in length was went

with by another competent individual who acted as a spotter or guarder. Children beneath the age of 16 were not permitted on walled in area of the crocodiles. The space where they used to stay was not sufficient enough for them. So they quarreled and fought among themselves. It made stress to them. Besides these, public used to disturb crocodiles and threw stones towards

them. They also made a noisy environment around the crocodile enclosure.

Table 3. List of animal, human and environment hazards for young and adult crocodiles at Chittagong zoo, Bangladesh.

Animal hazards	Human hazards	Environmental hazards
<ul style="list-style-type: none"> <li>• Physical size</li> <li>• Breeding cycle</li> <li>• Territoriality</li> <li>• Sexing of crocodile</li> <li>• Sexual maturity</li> <li>• Temperament</li> <li>• Treatment in captivity</li> </ul>	<ul style="list-style-type: none"> <li>• Behaviour</li> <li>• Age</li> <li>• Training</li> <li>• Skills</li> <li>• Behavioural knowledge</li> <li>• Individual characteristics</li> <li>• Experience</li> </ul>	<ul style="list-style-type: none"> <li>• Enclosure design</li> <li>• Physical location</li> <li>• Season</li> <li>• Location to crocodiles</li> <li>• Number</li> <li>• Fencing construction</li> <li>• Hazardous substances</li> </ul>

### Lifespan

Measuring crocodile age is questionable, in spite of the truth that a few procedures are utilized to infer a sensible figure. Therefore, the most common strategy is to degree lamellar development rings in bones and teeth. Each ring compares to alter in development rate which regularly happens once a year between dry and damp season. The crocodiles of the zoo appeared that their lifespan was between 30 to 40 years.

## 4. DISCUSSION

### Habitat

The mugger crocodiles occur in the southern Iran, Pakistan, Nepal, India and Sri Lanka, where they inhabit freshwater lakes, rivers and marshes, and prefers slow-moving, shallow water bodies but probably extinct in Bangladesh (Chaudhuri and Chakraborty, 1973; Choudhury and Silva, 2015). They are also known to thrive in artificial reservoirs and irrigation canals (Da Silva and Lenin, 2010). In the Chittagong zoo, it was found that as they preferred body temperature ranging from 29 to 34°C, they were protected from climate extremes, i.e., the enclosures were provided with adequate shade. To minimize the possibility of escaping enclosed crocodiles, gates and doors were provided around the enclosure. Indoor lightings in the enclosure for crocodiles were adequate to facilitate proper cleaning, routine health check-up, hygiene and maintenance. Lights were switched on only for 11 to 13 hours a day to stimulate natural day length. Adults were reared in 3 feet depth and juveniles in 1-foot depth of water. In Indian zoos, the crocodiles are reared in fresh water and coastal saltwater lagoons or

in human made reservoirs. The usual depth of this water reservoirs are around 5.0 meters (Taigor et al., 2010). The crocodiles do not migrate seasonally, inhabiting the same locality in wet or dry season (Whitaker and Whitaker, 1989). They also make burrows on lands.

### Food and nutrition

As crocodiles are carnivores (Martill, 1986; Magnusson et al., 1987; Sah and Stuebing, 1996; Platt et al., 2006, 2013; Pauwels et al., 2007; Wallace and Leslie, 2008), they mostly prefer meat, i.e., poultry meat and beef. The adults eat up to 8% and the young juveniles eat 5% of their body weight in a week (Taylor, 1979a; b). But in the wild condition, they feast on fish, birds, frogs and crustaceans. In Dhaka zoo of Bangladesh, crocodiles are provided small animals that have already been killed for them such as rats, fish or mice. They are also provided with different kinds of meats. They also eat live locusts. In another crocodile farm in Mymensingh, Bangladesh, the young crocodiles eat only minced poultry meat and beef. They are reared in temperature controlled chamber. The young crocodiles are very sensitive to smell of human. At least two assigned persons are needed to supply feeds to the young daily. If the person changes, they stop eating and subsequently die (Lang, 1987). Adult crocodiles are supplied cow meat, poultry meat and fish as their feed. In comparison to other zoos in Bangladesh, in Chittagong zoo, there is no big difference in the feeding habit. Only a little difference was seen in the amount of feed that is supplied to crocodiles in enclosed condition of zoo. The crocodiles of other nations such as Australian saltwater crocodiles are entirely carnivore. Fish, birds, and warm blooded animals that wander close the water's edge are all eaten. The grown-up crocodiles will eat

nearly anything that comes as well near. The younger crocodiles eat small fish and insects (Bhatnagar and Mahur, 2010).

Larger crocodiles may go for long term without eating a meal (Chaudhuri and Chakraborty, 1973; Yeragi and Yeragi, 2015). In extreme situation, they can close and live off their own tissue for a long division of time. But mostly eat much more often than that. On average crocodiles eat about 50 full meals a year. The food does not need to be chopped to a size that is easy to eat which is similar to Chittagong zoo. After providing meat, they tear the flesh by strong and sharp teeth and swallow easily. Young crocodiles are fed once or three times per week. They are provided vitamin supplements to their diets for more benefits. Sometimes crocodiles eat stones in the wild to help digestion. But they eat them in captivity if stones are in the enclosure. In the zoo, they are not offered stones as part of their diet, they eat them if they needed. Uneaten foods are removed within 24 hours to stop it decomposing. They drink water *ad libitum* according to their body weight and environmental temperature. When the weather is hot to maintain thermoregulation system, they drink much water as they need.

### Health

In the study area it was found that, the juvenile crocodiles were suffered from osteomalacia and then Ca<sup>++</sup> drug was given mixing with feed. After continuing several weeks, the crocodiles were cured. Conversely, parasitic, bacterial and viral diseases were found in the adults where fenbendazole, antibiotic and vaccines were given (Thorbjarnarson et al., 1989; Huchzermeyer, 2002; Huchzermeyer and Van Wyk, 2003; Leslie et al., 2011; Brioudes et al., 2014). Adenoviral infection also affected crocodile young beneath 5 months of age. Clinical signs of the disease were dormancy and anorexia related with tall mortality, particularly amid winter months when extra push components utilized to play a part in infection movement. Constant adenoviral hepatitis was a cause of hindered improvement of crocodiles. The liver was the foremost commonly influenced organ. Be that as it may, other organs were too included, counting digestion tracts, pancreas and lungs.

### Reproduction

Nesting is common practice in crocodile biology (Ogden, 1978; Kofron, 1989; Mazzotti, 1989; Platt and Thorbjarnarson, 2000; Charruau and Hénaut, 2012). In the zoo, the crocodiles were found to lay eggs either in holes or mound nests. A hole nest was usually excavated in sand. Courtship used to take place in an arrangement of behavioral intelligent that incorporate an assortment of nose rubbing and easy going show that takes a long time (Garrick and Lang, 1977; Dunn, 1980; Marais et al., 1994; Rivas and Owens, 2002; Tisdell and Nantha, 2007).

Mating continuously took part in water, where the match could be watched mating a few times. Females constructed or burrow a few trial homes which showed up inadequate and deserted afterward. Egg-laying usually took place at night for 30-40 minutes (Whitaker et al., 1984). Females were highly protective of their nests and young. The eggs were hard shelled, but translucent at the time of egg-laying (Whitaker et al., 2007).

### 5. CONCLUSION

The Chittagong Zoo has recently been a unique source of recreation, exhibition, conservation, education and research related to the marsh crocodiles for the researchers from schools, colleges, and universities who are guided by the veterinary officers and curators. Visitors gather information pertaining to the habitat, nutrition, reproduction and health of the crocodiles. Modernization of the zoo by establishing well as equipped veterinary hospital will explore new horizon for conservation of the marsh crocodiles.

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