

Noteworthy observations on food and feeding behaviors of mugger crocodiles (*Crocodylus palustris* Lesson) at Lal Dhori, Girnar Wildlife Sanctuary, Gujarat, India

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Abstract

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Mugger Crocodiles (*Crocodylus palustris*) are apex predators of freshwater aquatic ecosystems throughout South Asia whose natural history and ecology are incompletely known. We present some noteworthy observations on feeding behavior, hunting strategy, and diet of the species based on seven observations during the last four years as part of a long-term monitoring study in Junagadh, Gujarat, India. We found Muggers of this region feeding on the domestic dog (*Canis familiaris*), Indian rock python (*Python molurus*), Indian flap-shelled turtle (*Lissemys punctata*), several species of fishes, as well as cannibalism events. Moreover, we review and discuss some published observations of the species.

Key words: Cooperative hunting, crocodilians, dietary habits, ethology, Saurashtra

Introduction

The geographical distribution of crocodilians encompasses tropical, sub-tropical, and warmer temperate wetland regions of the world (Grigg and Kirshner, 2015). Some primarily inhabit temperate low plains and forest areas and take advantage of upland hilly forest habitats (Brazaitis and Watanabe, 2011). These giant ectothermic carnivores depend on external heat sources to regulate their body temperature (Grigg and Kirshner, 2015), with metabolism and behavior depending on environmental conditions. Therefore, behavior of these animals varies from place to place, under the influence of the localized ecological conditions. Crocodilians are generally considered specialized nocturnal predators that hunt in water or at the water's edge (Neil, 1971). The Marsh Crocodile or mugger (*Crocodylus palustris* Lesson) is widely distributed in India (Mobaraki et al., 2021), protected under Schedule I of the Indian Wildlife (Protection)

Act, 1972, and considered a nationally 'Vulnerable' species (Choudhury and de Silva, 2013). Following conservation measures, the species remains reported throughout most of its historic range, being one of the most highly adaptable crocodilian species in South Asia (de Silva and Lenin, 2010). In Gujarat State, this species is commonly found in many water bodies due to the legal protection and assured preservation measures taken by the State Forest Department and non-government organizations (Vyas, 2012) and due to development of new agricultural irrigation systems (Vasava et al., 2015; Vyas, 2023). Currently, this large carnivorous is flourishing in many water bodies throughout the state (Vasava et al., 2015; Vyas, 2023; Vyas et al., 2023).

However, more information is needed on the diet and feeding behavior of this crocodile. General accounts of feeding and breeding behaviors were provided by Whitaker and Whitaker (1978a, 1978b, 1984, 1989),

Lang et al. (1986) and Lang (1987); further behaviors include cooperative herding of fish to shore (Dinets, 2015), cannibalism (Reddy, 1978; Vaghashiya et al., 2020), parental care (Dharmkumarshinji, 1947; Vaghashiya et al., 2018, 2020), homing (Vyas and Bhavsar, 2009; Vyas, 2010) and use of tools (Dinets et al., 2015).

Since 2016, we have studied the reptilian fauna of Girnar Wildlife Sanctuary (GWS), Gujarat, India (Patel et al., 2019), including monitoring a small population of mugger crocodiles for further understanding the ecology of the species (Vaghashiya et al., 2018, 2020; Vyas and Vaghashiya, 2022). We made a few unusual observations of mugger feeding behavior at Lal Dhori, Junagadh, Gujarat, India, between July 2019 to June 2023, during our ongoing study of the species (see: Vaghashiya et al., 2018, 2020). Here, we present details of those observations and review and discuss some published observations of mugger crocodiles.

Material and Methods

Girnar Hills (100–1,100 m asl) constitute the largest hill complex in the Saurashtra Peninsula and is a famous pilgrimage place of the State. This region falls in the semiarid zone (Champion and Seth, 1968), and its vegetation is characterized as dry mixed deciduous teak forest (Barqi, 2000). The surrounding forested area is a prime habitat for small satellite populations of Asiatic Lions *Panthera leo persica* (Singh, 2017). Therefore, the entire area, encompassing about 278.87 km², is now a wildlife sanctuary. This sanctuary has diverse, rich flora and fauna, and it is well studied, including for amphibians and reptiles (Giri et al., 2009; Patel et al., 2019), birds (Patel and Bagada, 2022) and mammals (Singh, 2017). The sanctuary comprises several perennial and non-perennial waterbodies of varying sizes, and all these waterbodies contain small numbers of muggers, with some having active breeding populations (Vaghashiya et al., 2018, 2020). The Lal Dhori (21°32'17.87"N, 70°30'9.79"E) is a small water body having around 500 m² area and is located in the base of Mt. Girnar in Bhavnath, Junagadh city, Gujarat, India. The water body is part of a protected area with a small mugger crocodile breeding population.

The present study is based on observations made during several sessions of fieldwork between June, 2019 to August, 2023. Ideally one field trip was made per week, with each field session varying from 2 to 4 hours and generally conducted during late morning to afternoon and sometimes at late evening. Observations were recorded using digital SLR cameras (either with Canon 70D or Canon 750D) with telephoto lenses (either Canon EF 100–400 mm or Tamron 18–300 mm).

Results

We noted muggers of Lal Dhori feeding on the domestic dog (*Canis familiaris* Linnaeus), Indian

rock python (*Python molurus* (Linnaeus)), Indian flap-shelled turtle (*Lissemys punctata* (Bonnaterre)), conspecifics (hatchling and juvenile) and several species of fishes. Here, we present in chronological order all significant observations in detail, along with the feeding behaviors of muggers.

Observation 1: On 23 July 2019, in the evening, we noticed an adult mugger crocodile (approx. over 2.5 m) feeding on an adult stray dog (*Canis familiaris*) at Lal Dhori (Fig. 1A). We did not know how the mugger caught the dog; parts of the dog were left uneaten.

Observation 2: On 10 December 2019, in the evening, we observed a juvenile mugger (approx. <1 m) floating dead in a corner of Lal Dhori. We were unable to find the reason for the death, but we assume it might have died due to interspecific interactions between animals. In the late evening, a large adult mugger grabbed the dead mugger (Fig. 1B) and consumed the entire animal within a few minutes. The large mugger was over double the size of its prey.

Observation 3: On 9 June 2021, we observed a large adult mugger (approx. 3 m) swimming with over a dozen fresh hatchlings on the opposite banks of the water body. The size of the hatchlings indicated them to be one or two days old. With the mugger and its hatchlings there was also a partially eaten Indian rock python (*Python molurus*) of > 2 m length floating along with the flock (Fig. 2). The hatchlings were not just biting and feeding on the python but also used it as a basking object. The next morning, we did not find remains of the python.

Observation 4: On 11 June 2021, in the evening, a subadult mugger (approx. 1.5 m) was seen actively foraging where the water was shallow (depth ~15 cm). The animal curved its body, slowly moving toward the edge with continued undulation of its tail, and formed a small 'C' shape in the water. As it neared the bank, it increased the intensity of tail wagging and started splashing its tail. As it did so, a good number of fishes and frogs tried to escape from the small water area, and the mugger grabbed a few (Fig. 3). This behavior was repeated three times and lasted for a total of 28 minutes. Another subadult mugger behaved in the same manner twice at an approximate distance of 10 m.

Observation 5: On 11 June 2021, in the evening, a large female was observed swimming with a few hatchlings (Fig. 4). It slowly approached the bank, came out, and grabbed a fresh hatchling that was being attacked by several weaver ants (*Oecophylla smaragdina* (Fabricius)) (as videographically documented) (Fig. 5). Then, she returned to water, gently clapped her jaws with side-to-side head movements, and finally engulfed the hatchling after several jaws clapping (Fig. 6).

Observation 6: On 23 March 2023, at noon, an adult Indian flap-shelled turtle (*Lissemys punctata*) was emerging from the water onto land near a large basking mugger. The mugger suddenly captured the turtle (Fig. 7) and devoured it within a few minutes.

Observation 7: On 10 June 2023, a sub-adult Indian flap-shelled turtle was scavenging on a dead fish in the corner of the water body (Fig. 8A) when a mugger hatchling emerged from the water to eat the fish (Fig. 8B). However, the turtle immediately

changed its position, disappearing under the water and then emerging next to the hatchling and attacking it (Fig. 8C). Finally, the mugger hatchling got tired due to constant biting and disturbance from the turtle and left the fish to the turtle (Fig. 8D).

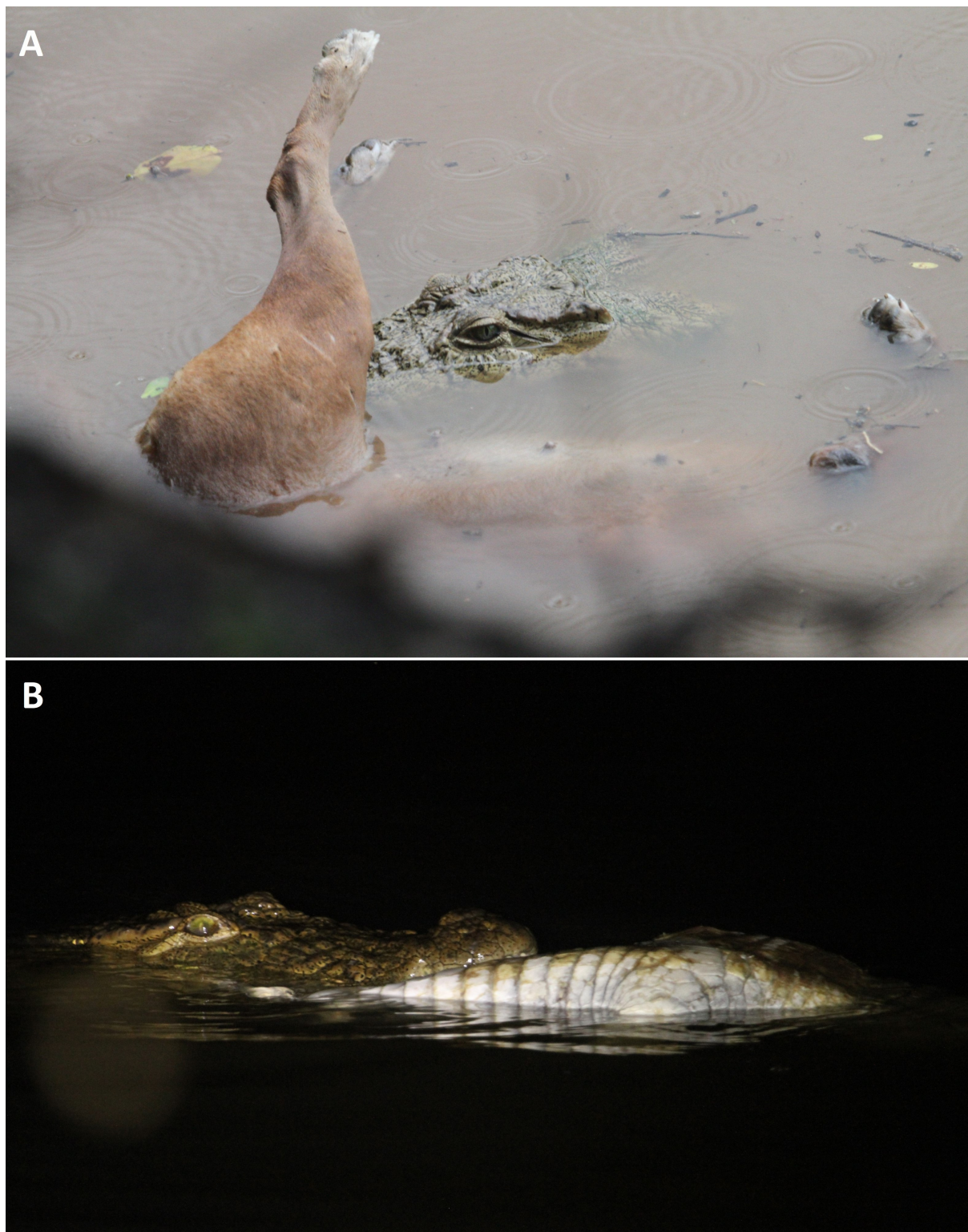


Figure 1: An adult mugger crocodile (*Crocodylus palustris*) feeding on an adult stray dog (*Canis familiaris*) (Date: 23 July 2019); (A) a large adult mugger (*Crocodylus palustris*) with prey as a sub-adult mugger (Date: 10 December 2019), (B) at Lal Dhori, Girnar Wildlife Sanctuary, Gujarat, India.



Figure 2: (A, B) An adult mother mugger (*Crocodylus palustris*) with over a dozen fresh hatchlings and carcass of an Indian rock python (*Python molurus*) at Lal Dhori, Gimnar Wildlife Sanctuary, Gujarat, India (Date: 9 June 2021).

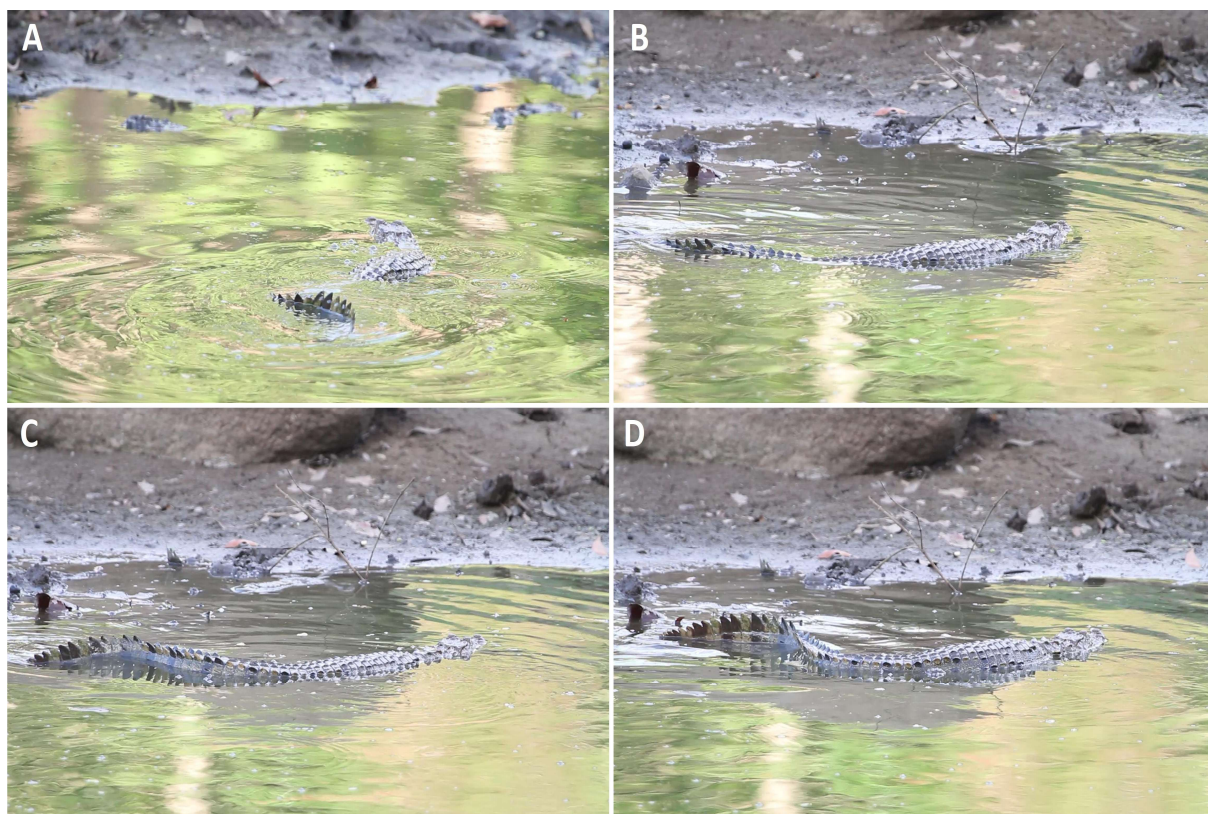


Figure 3: Sub-adult mugger (*Crocodylus palustris*) swimming toward the bank area (A), the body posture in curve position (B) with continued tail wiggling movements (C) and finally, tail splashing for capturing prey from the narrow escape water area (D) at Lal Dhori, Girnar Wildlife Sanctuary, Gujarat, India (Date: 11 June 2021).



Figure 4: The large female (*Crocodylus palustris*) with its a few hatchlings (red arrows indicate hatchlings) at Lal Dhori, Girnar Wildlife Sanctuary, Gujarat, India (Date: 11 June 2021).

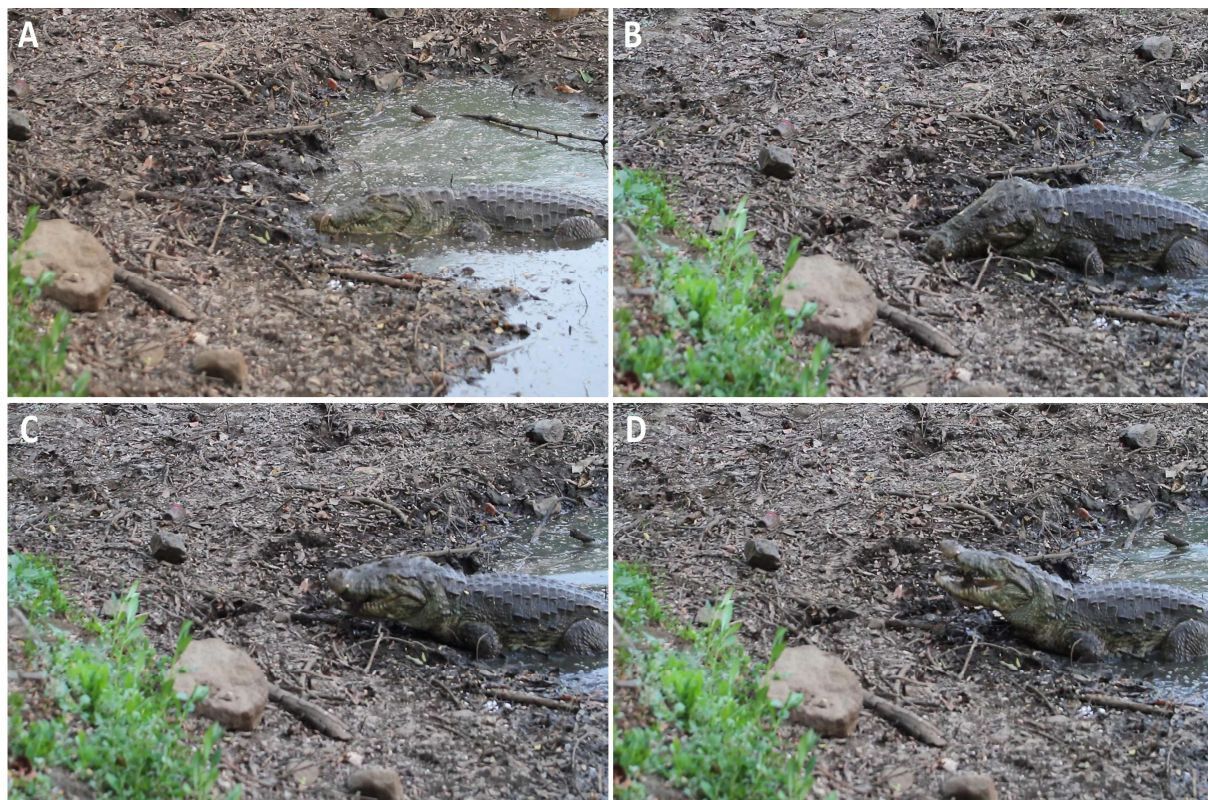


Figure 5: The large female (*Crocodylus palustris*) observing weaver ants praying on the hatchling (A), she emerges out of the water and grabs the poor hatchling from the edge of the water body (B), the hatchling with debris in her jaws (C), and she sifts the hatchling in jaws (D) at Lal Dhori, Girnar Wildlife Sanctuary, Gujarat, India (Date: 11 June 2021).

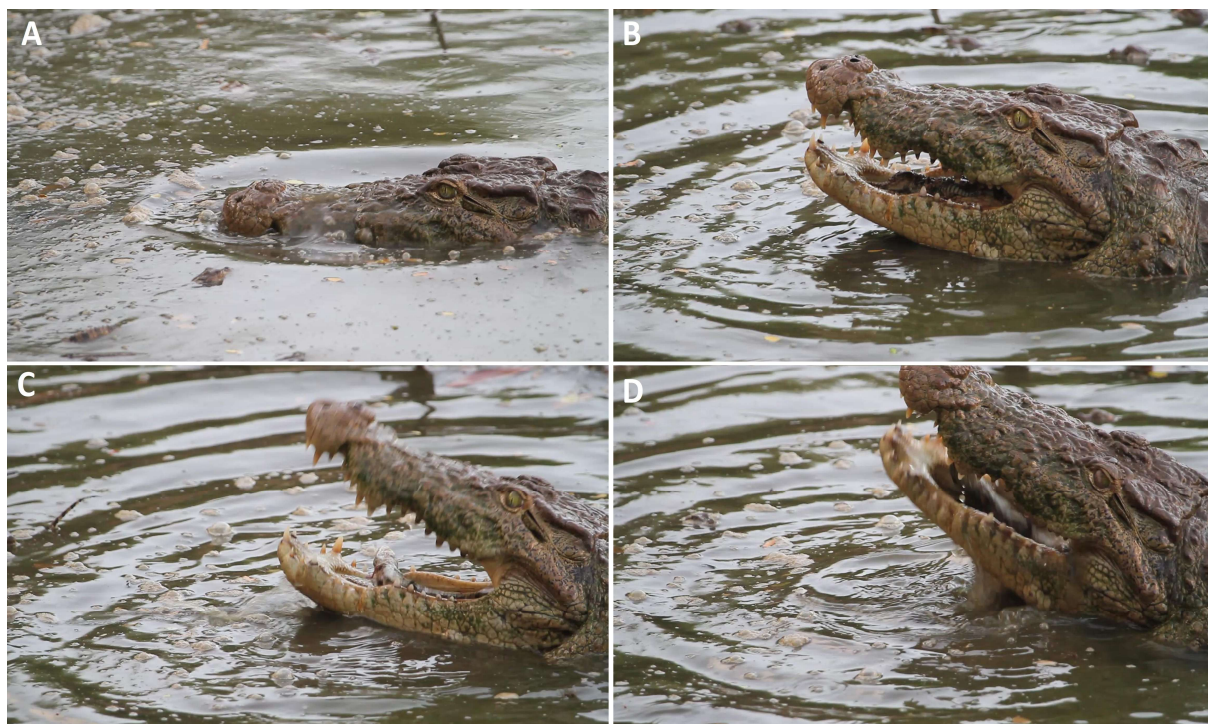


Figure 6: The large female (*Crocodylus palustris*) with a hatchling in her mouth (A), the jaw clapping with the head movements (which depicted through waves created in the water) and few hatchlings around, her open jaw with a dead hatchling on the lower jaw (B and C), and finally she engulfs the dead hatchling (D) at Lal Dhori, Girnar Wildlife Sanctuary, Gujarat, India (Date: 11 June 2021).



Figure 7: The mugger crocodile (*Crocodylus palustris*) with its prey as Indian flap shell turtle (*Lissemys punctata*) at Lal Dhori, Girnar Wildlife Sanctuary, Gujarat, India (Date: 23 March 2023).

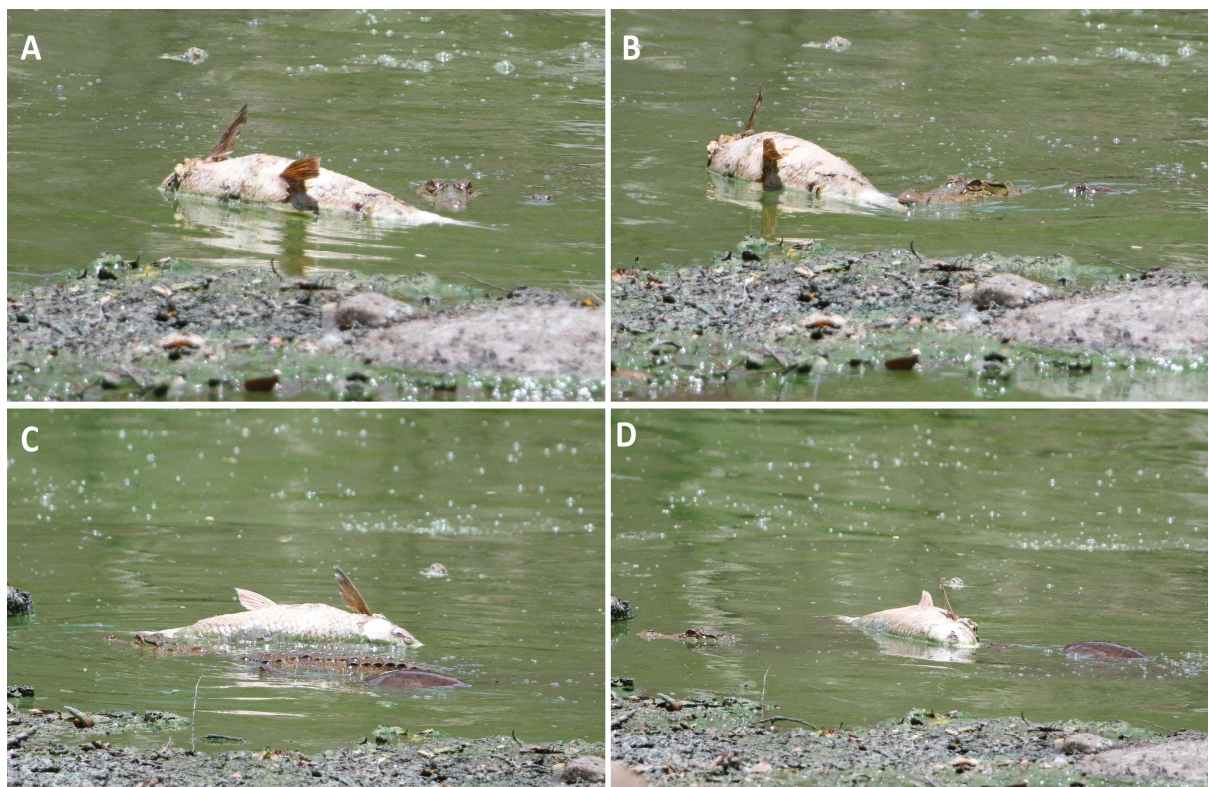


Figure 8: A sub-adult Indian flap shall turtle (*Lissemys punctata*) was scavenging on a dead fish at the same time, and a hatchling of mugger (*Crocodylus palustris*) emerge to scavenge fish (A), creating a disturbance by sub-adult Indian flap shell turtle (B and C), mugger hatchling leaves the fish (D) at Lal Dhori, Girnar Wildlife Sanctuary, Gujarat, India (Date: 10 June 2023).

Discussion

All these observations confirm that the mugger is an opportunistic apex predator that feeds on a diversity of animals (Whitaker and Whitaker, 1984; Vyas, 2020, 2021). Devouring dogs is among the usual habits of muggers: there are several reports of muggers preying and scavenging on dogs and livestock (Daniel, 2002; Vyas, 2012; Chavan and Borkar, 2022). Few reports, however, also list chelonians and pythons in the diets of mugger crocodiles (Ranjitsinh, 1989; Daniel, 2002; Bhatnagar and Mahur, 2010; de Silva et al., 2011; de Silva, 2013; Murugan et al., 2020). Their prey preferences change according to the age or size as hatchlings and juveniles prefer small fishes, crustaceans, insects, etc., while the adults feed on a large variety of invertebrates and vertebrates, including mammals, birds, reptiles and large fishes (Whitaker and Whitaker, 1984; Halliday and Adler, 1989; Stevenson, 2019). Therefore, a wide range of food items have been reported in their diet (Santiapillai and de Silva, 2001; Alderton, 2004; Vyas, 2010; Choudhury and de Silva, 2013).

The devouring of a juvenile mugger by an adult mugger is not the only example of cannibalism in this species and could be a result of the scarcity of resources in specific ecosystems. We that the female adult mugger in our fifth observation came to know that the hatchling was in trouble most probably through the distress call (Lang, 1987). The acoustic communication between hatchlings and parents among crocodilians is well reported (Campbell, 1973; Brazaitis and Watanabe, 2011; Vergne et al., 2012). The hatchling appeared to be attacked by the predatory weaver ants (*Oecophylla smaragdina*). The female gently grabbed the hatchling with her jaws and brought it into the water. She repeatedly tried to revive the hatchling by very gentle jaw-clapping, creating pressure along with side-by-side head movements. Finally, the female engulfed the hatchling after she realized that it was not alive. All the hatchlings of that female were hatched the previous night, which would have attracted the weaver ants. It is well-documented that fresh crocodile hatchlings are vulnerable to predators such as ants and other small invertebrates (Somaweera et al., 2013). A possible reason for this instance of cannibalism could be that leaving the dead hatchling may have attracted other predators to that area which may have endangered the other surviving hatchlings as well. Also, eating the hatchling is the use of a good source of nutrition (Maritz et al., 2019).

Cannibalism is not rare among crocodilians (Somaweera et al., 2013) and has been recorded in several species, including *Caiman crocodilus* (Linnaeus) (Staton and Dixon, 1975), *Crocodylus acutus* Cuvier (Richard and Wasilewski, 2003), *C. moreletii* Duméril and Bibron (Cedeño-Vázquez et al., 2016), and *Alligator mississippiensis* (Daudin)

(Delany et al., 2011). Cannibalism has been recorded in muggers in captivity (Reddy, 1978) and in wild populations (Lal Dhori, GWS, Gujarat: Vaghashiya et al., 2020; Katerniaghat Wildlife Sanctuary, Uttar Pradesh: Ugemuge et al., 2023). Some plausible reasons for cannibalism in these animals can be stress or competition among conspecifics, which can affect the frequency of cannibalism (Fox, 1975; Melo et al., 2003; Pereira et al., 2017; Maritz et al., 2019). It is a common behavior playing an essential role in the ecology of species by affecting the population size, age structure, and dynamics (Polis and Myers, 1985; Maritz et al., 2019). However, we did not find any plausible reason for the female to kill the hatchling, and we considered that the incident uses the nutrition in the hatchling and not invite any scavengers or predators.

The hunting and feeding activities by subadult muggers drive small numbers of fish in confined water areas toward shore for easy hunting. Crocodiles can be divided into two groups based on hunting strategy: chasers and ambushers. The chasers prey in shallow water with a potent splash of their, and the ambushers wait in the deep waters and try to snatch the fish (Balavand, 2022). Earlier, Whitaker and Whitaker (1984) noted similar feeding behaviors in the species during the day at Hiran Lake, Gujarat, and during the night at Amaravathi Reservoir, Tamil Nadu, in the dry season. Similar behavior was also reported in saltwater crocodiles, *Crocodylus porosus* Schneider, by Mikloukho-Maklay (1982). The present observation of subadult muggers herding fish to shore at Lal Dhori is similar to those recorded by Dinets (2015) and Stevenson (2019).

We know many crocodile species have excellent cooperative hunting skills (King et al., 1998; Dinets, 2015; Chavan and Borkar, 2023). For example, the mugger crocodile is known for its strategic cooperative hunting (Dinets, 2015). Earlier, one of the authors (RV) observed collective hunting behavior (unpublish observations), on three different occasions. All these occurred during summer when water levels are low. On 24th May 1987, the first author and B.C. Choudhury observed collective hunting behavior with two dozen large adult muggers at Kamaleshwar Dam (= Hiran Dam) in Visavadar, Gujarat. Two dozen muggers were swimming in a semi-circle, and gradually all these animals tightened the circle by swimming toward the middle. They observed such behaviors repeatedly for more than 40 minutes. On 29–30 May 2017, one dozen subadults were cooperatively hunting at 'Vagol Nalah' Gir Forest (upper catchment areas of Kamaleshwar Dam, Gir Sanctuary and National Park). On the third occasion, collaborative hunting was observed at night with nine subadult muggers in Dobhoo village pond in May 2018. Such cooperative hunting is only possible through some form of communication among the crocodiles, either vocally or through body signalling, or both, and crocodilians have both kinds of communication (Garrick et al., 1982). A captive

experiment by Weldon et al. (1990, 1992) showed *Alligator mississippiensis* is capable of locating food through the use of chemical clues, and muggers have similar sensory structures in their lower jaws (Ashanani and Pilo, 1995); hence, it is possible that muggers are also capable of detecting fish in a similar manner.

The interaction between mugger hatchlings and subadult Indian flap-shall turtles shows food competition between the two. It is a usual phenomenon since both are scavengers. Here, the mugger's hatchling avoids competition with the turtle, and leaves the fish or may be due to its inexperienced nature.

Earlier, crocodylians were thought to be lethargic, senseless, and dull reptiles. But now we know crocodylians exhibit flexible multimodal gestures, advanced parental care, and highly coordinated hunting tactics (Doody et al., 2013) as well as intraspecific communication (Vergne et al., 2012; Reber, 2018). Recent opportunistic observations of hunting and parental care show that crocodylians, especially mugger crocodiles, have spectacular multifaceted behaviors.

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Author contributions

RV: conceived and designed the study, analyzed the data, authored or reviewed drafts of the paper and approved the final draft. DC: field data collection, prepared figures and approved the final draft. PV: field data collection and approved the final draft. HP: conceived and designed the study, prepared figures, authored or reviewed drafts of the paper and approved the final draft.

Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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