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Basking Behaviour and Use of Riparian Tunnels by Mugger Crocodiles *Crocodylus palustris* (Lesson, 1831) of Savitri River at Mahad, Maharashtra, India

Chavan Utkarsha Manish[1] and Borkar Manoj Ramakant[2*]

[1]Department of Zoology, Hazarimal Somani College, Chowpatty, Mumbai, India
[2]Biodiversity Research Cell, Department of Zoology, Carmel College for Women, Nuvem 403604, Goa, India

**Corresponding Author*

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Abstract: This study has recorded observations on maintenance behaviour pertaining to basking and use of tunnels by Mugger crocodiles *Crocodylus palustris* (Lesson, 1831) of river Savitri at Mahad in the Indian state of Maharashtra. The Mugger shuttles between the land and water guided by a circadian rhythm, primarily to regulate its body temperature. This amphibious reptile was seen to be meeting its thermal preferences by a combination of heat-seeking and heat-avoiding behaviours that largely revolve around immersion in water, basking and retreating in tunnels. The ascendance from water body to bask on dry ground also included intermediate postures taken by the Mugger like pre-basking, surface basking and shallow water basking; and the relative amount of time spent in each of these behaviours varied seasonally. Also, the Mugger crocodiles were seen to excavate separate tunnels on the river banks for purpose of resting and nesting. These observations recorded over a span of nine years are discussed in the context of ethology. The study also documents behaviour of Mugger with conspecifics and other species that share its habitat. It is emphasized that understanding of crocodile behaviour helps in discernment of species-specific natural history, and is also important from the perspective of its conservation management.

Keywords: Mugger, *Crocodylus palustris*, Behaviour, Savitri River, Basking, Tunnel, Conservation Management

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Introduction

The Mugger or Indian Marsh Crocodile, *Crocodylus palustris* (Lesson, 1831) once a widely distributed reptile, is now restricted to the Indian subcontinent and Iran; where they occupy freshwater habitats such as rivers, lakes and marshes. In India and Sri Lanka, Mugger crocodiles are also found in man-made reservoirs, irrigation canals and ponds, and even in estuarine waters (Whitaker and Whitaker, 1989); and are a species of conflict concern (Borkar *et al*., 1993;

Distefano, 2008; Whitaker, 2008; Rao and Gurjwar, 2013; Upadhyay and Sahu, 2013; Vasava *et al*., 2015; Pooley, 2016). Once decimated to the point of no return, the Mugger has recovered and is now found in good viable populations across India (De Vos, 1984; Jacobson, 1999; Singh, 1999; Da Silva and Lenin, 2010; Gour *et al*., 2022).

While the focus of crocodilian researchers is mainly on ecology and conflicts, little attention has been given to its ethology. Crocodilian ethology in India is still in its nascence, and understanding of some dimensions of their behaviour has been accrued only through observing captive animals (Desai *et al*., 2022).

Their prolonged relative stillness offers a difficult challenge to behavioural biologists; added to the fact that they are extremely shy, less vocal, elusive and get easily disturbed. An interesting aspect of behavioural studies is to understand how the species adapt to their environments, and combine their innate and learned behaviour to increase their survival chances amidst hostile and dynamic environmental settings.

Much of the crocodilian behaviour is perceived as stereotype and more in the realm of innate responses, but careful and long periods of *in situ* observations reveal that these behaviours too have plasticity suggestive of a learning ability. Conventionally the behaviour of crocodiles is categorized based on its primary functions of maintenance, social interaction and reproduction (Lang, 1987a). Since optimal occupancy and utilization of resources within a habitat is a function of species' behaviour in that habitat, ethology provides useful insights for conservation management. As behaviour is species-specific, conservation management must focus on constructing ethogram of the species of interest.

The results of the present study are based on long term *in situ* observations of Mugger in an important natural riverine habitat in the state of Maharashtra, India. Attention in this study was on basking behaviour and tunnel use of the Mugger crocodile. Also, on the basis of our other observations, some inferences can be drawn on the extrinsic drivers of their site fidelity, hierarchy and tolerance of conspecifics, besides interspecific interactions.

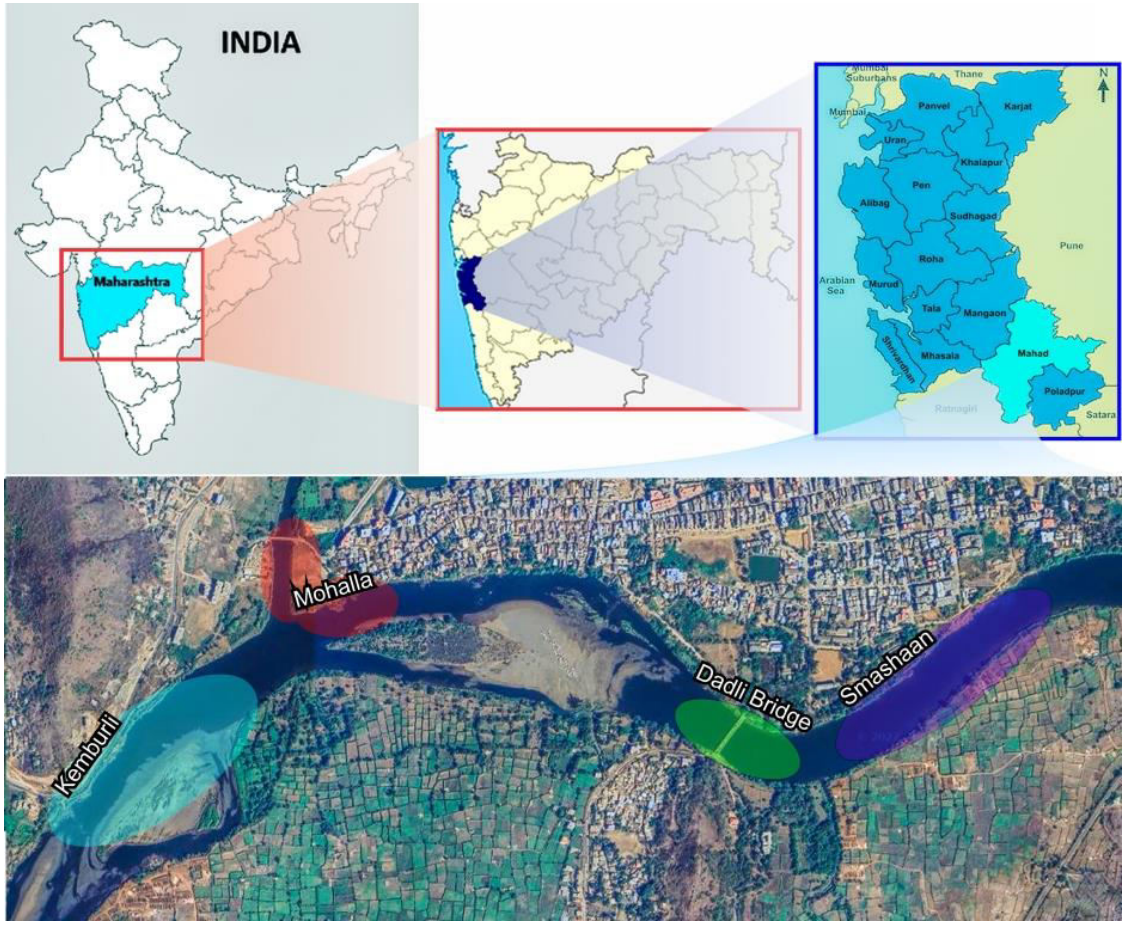
Materials and Methods

We have been monitoring Muggers of Savitri River at Mahad since 2014 by direct observations in field (Chavan and Borkar, 2022). Long hours of observations were made by using binoculars (Model-Galileo 30x60); either by sitting on bank elevation or in a boat for understanding patterns of their basking, tunnel constructs and use. Observations were conducted through all seasons and individuals were observed for minimum 20 min at a stretch. For basking behaviour, all basking sites were mapped and visited regularly. The wariness, distribution patterns during basking were observed. Between submergence in water and emergence for basking, preponderance of intermediate phases were observed across seasons. The riparian stretches along the river were scanned for tunnels, and on encountering tunnels, the area was thoroughly checked for active and abandoned nests and other indirect evidences. Photographs and videos were captured by digital and DSLR cameras. Information was also collected by interviewing the locals.

Results and Discussion

Sites monitored:

The data presented here is a part of a long-term monitoring study on Mugger population of Savitri River that flows through Mahad town of Raigad district of Maharashtra, India (Fig. 1). All the observations on use of terrestrial habitat such as basking, tunnel excavation and occupancy were carried out along the riparian stretches corresponding with four principal segments of the river. Muggers were observed for basking and tunnel retreat at four observation stations (Tables 1, 2; Fig. 2); namely Kemburli on Mumbai-Goa highway (18°03'58" N and 73°25'18" E), Mohalla, residential area near highway (18°04'21" N and 73°25'08" E), Dadli, a bridge on Savitri River joining Mahad City to Dadli village (18°04'11" N



Kemburli: , **Mohalla:** , **Dadli:** , **Smashaan:**

Fig. 1: Geographic locations of the four bank-stretches along river Savitri of Mahad in Raigad district of Maharashtra, India.

and 73°25'52" E) and Smashaan, an area of Hindu crematorium (18°04'01" N and 73°26'28" E) (Fig. 1) (Table 1).

Kemburli is on Mumbai-Goa Highway; the highway side bank has a steep slope and four basking spots and three tunnels each, whereas opposite bank has three basking sites (Fig. 2A). Here, the river has two islets, which also serve as basking sites for Muggers.

There is a moderate slope in Mohalla stretch of the river that has two basking sites towards the city-side of River Savitri and three basking sites on the opposite side. At Mohalla, Gandhari River meets Savitri River; Muggers being found in both the riparian tracts. For Gandhari River at Mohalla, there are two basking sites each towards the city side and the opposite bank (Fig. 2B).

Dadli region has three basking sites adjacent to city-side and one on opposite side (Fig. 2C). With a considerable slope here, the Dadli stretch has 15 tunnels on city-side bank.

Both the banks at Smashaan region have gentle to moderate slopes with five main basking spots at city-side bank, and six main basking spots on the opposite side (Fig. 2D). The entire Smashaan area has about 30 tunnels (Table 1).

Basking Behaviour of Muggers at River Savitri at Mahad, Maharashtra:

Direct evidence of Mugger's presence in Savitri is best offered by individuals basking in the riparian stretch adjacent to the water body. Though Muggers share space and resources with conspecifics, they show site fidelity and generally

Table 1: Details of Basking sites in the four study stretches of the Savitri River

Name of Bank-Stretch	Latitude and Longitude	Name of River	Depth of water in peak summer	Slope of the Bank (Land to River)	Bank Zone character	Number of Tunnels
Kemburli	18°03'58"N 73°24'50"E	Savitri	05-25 feet	–35° to –80°	Muddy shoreline interspersed with gravel	3
Mohalla	18°04'21"N 73°25'08"N	Savitri and Gandhari	15-25 feet for Savitri and 10-15 feet for Gandhari	–13° to –15°	City side Muddy and opposite side Gravelly	0
Dadli	18°04'11"N 73°25'52"E	Savitri	35-45 feet	–17° to –22°	Muddy	15
Smashaan	18°04'01"N 73°26'28"E	Savitri	5-20 feet	–37° to –42°	Muddy with boulders along shore line	30

Table 2: Site codes of basking areas on the four bank segments of Savitri River

SITE CODE	BANK STRETCH OF THE RIVER
OKB	Opposite Kemburli Basking area
KI2B	Kemburli 2nd Islet Basking area
KIB	Kemburli Islet Basking area
KB	Kemburli Basking area adjacent to highway
MB G	Mohalla Basking area adjacent to city (Gandhari River)
OMB G	Opposite Mohalla Basking area (Gandhari River)
MBB S	Mohalla Boulder Basking area adjacent to city (Savitri River)
MB S	Mohalla Basking area adjacent to city (Savitri River)
OMB S	Opposite Mohalla Basking area (Savitri River)
DI	Dadli Islet
ODB	Opposite Dadli Basking area
DB	Dadli Basking area adjacent to city
OSB	Opposite Smashaan Basking area
SBB	Smashaan Boulder Basking area adjacent to city
SB	Smashaan Basking area adjacent to city

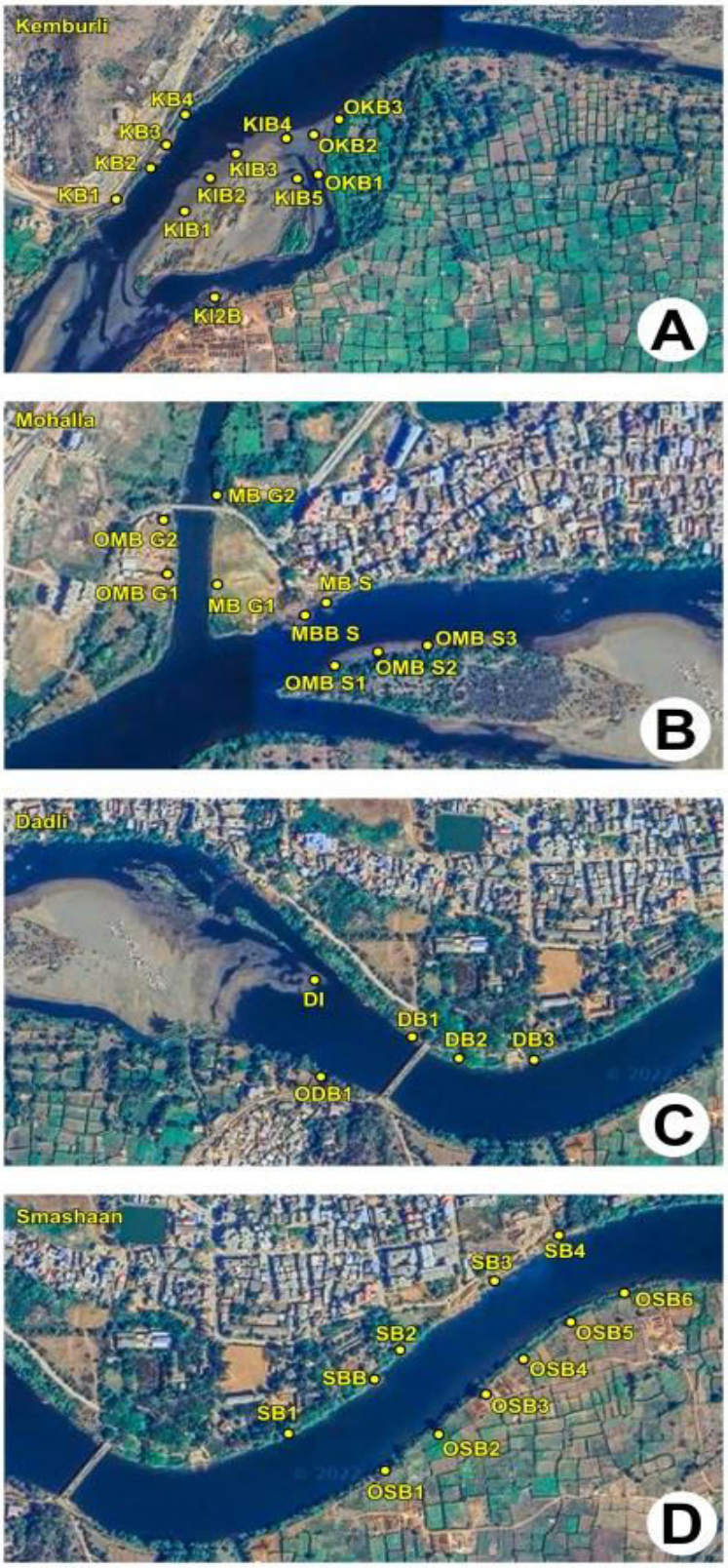


Fig. 2: (A) Kemburli Basking Area (B) Mohalla Basking Area (C) Dadli Basking Area (D) Smashaan Basking Area. See Table 2, for Site codes of basking areas.

males defend their territory, just as females display intolerance to intrusion in nesting sites (Whitaker and Whitaker, 1984; Lang *et al*., 1986; Mobaraki *et al*., 2013; Combrink *et al*., 2016; Vaghashiya and Vyas, 2018).

In this study, regular emergence from water to bask mid-water on raised substrata or adjacent dry land was commonly observed (Fig. 3). Kumar *et al*. (2019) have also observed Muggers basking on rocky mid-river islands of Betwa in Madhya Pradesh, and on a few occasions basking on muddy area. Crocodilians are ectothermic animals and need to regulate their body temperatures with respect to the environment. Whereas basking primarily aids temperature regulation, it also puts social interactions to test. These reptiles have a thermal preferenda but heat up faster than they cool down (Grigg *et al*., 1979). Hence, they use a combination of thermoregulation and basking techniques (Lang, 1987a, b; Gupta and Sri Hari, 1989; Whitaker and Whitaker, 1989; Tibbo, 1991; Venugopal and Prasad, 2003) to attain desired body temperature by means of heliothermy i.e. basking in sun (Pough, 1983), and thigmothermy i.e. absorbing heat from warm surface (Huey, 1982). For both, they find a place where they can either use heat from land, sun or even water.

Water can serve as a heat source as well as a heat sink (Lang, 1987b) depending on the difference in temperatures between the body and the water. For both, basking and thermoregulation they come out of water and take refuge at places such as grass, rocks, and soil (Venugopal and Prasad, 2003). Interestingly, Smith (1979) opines that behavioural drives other than thermo-regulation play role in terrestrial activity. The ability of reptiles to thermoregulate is often achieved behaviourally (Ross *et al*., 1989; Seebacher and Grigg, 1997). Basking and shuttling between land and water, and exposure to the sun and shade have long been recognized to be of thermal significance in crocodiles (Seebacher *et al*., 1999).

Seebacher (1999) has shown a clear relationship between posturing and heat transfer affecting changes in body temperature of Fresh water crocodile (*Crocodylus johnstoni*) and reported that between diving (0% exposure) and basking (100% exposure) there are intermediate positions that the reptile exhibits.

In the present investigation it was observed that though there is some extent of basking site-fidelity by Muggers, individuals shifted within the basking space through the day; depending on the right combination of shade and sun during the afternoons. Similar observations have been reported by others (Tibbo, 1991; Venugopal and Prasad, 2003). Mahur *et al*. (2010) report that Mugger crocodiles mostly basked on rocks as compared to grass or soil, and further that they chose rocks away from water to bask. These workers further record that the crocodiles basked more with their snouts oriented towards water, than away or parallel to the water line.

However, in our study it was observed that the crocodiles prefer basking spots near water line, perhaps as a strategic advantage to quickly slip into the waters on being disturbed (Fig. 3). It was also seen that the Muggers at Smashaan and Kemburli stretches were more tolerant of conspecifics and utilized the available space, basking very close to each other; most of the times their bodies touching (Figs. 3A-D, G, H). This is interesting, as such crowding indicates compromised territoriality of hierarchical individuals in the population. Probably, such crowding is a tradeoff against augmented populations in limited habitat. Defended areas also include basking spots and maintenance of exclusive territories is difficult in high density populations is a view corroborated by Lang (1987a). High density populations occupying small territories have also been reported by Lo´pez-Sepulcre and Kokko (2005).

In our field investigations it was noticed that the Muggers bask on moist soil during summer months (Fig. 3E), but also changed their locations during the day according to the sunlight and shade available. However, during winters they preferred to use boulders and rocks in water near the banks

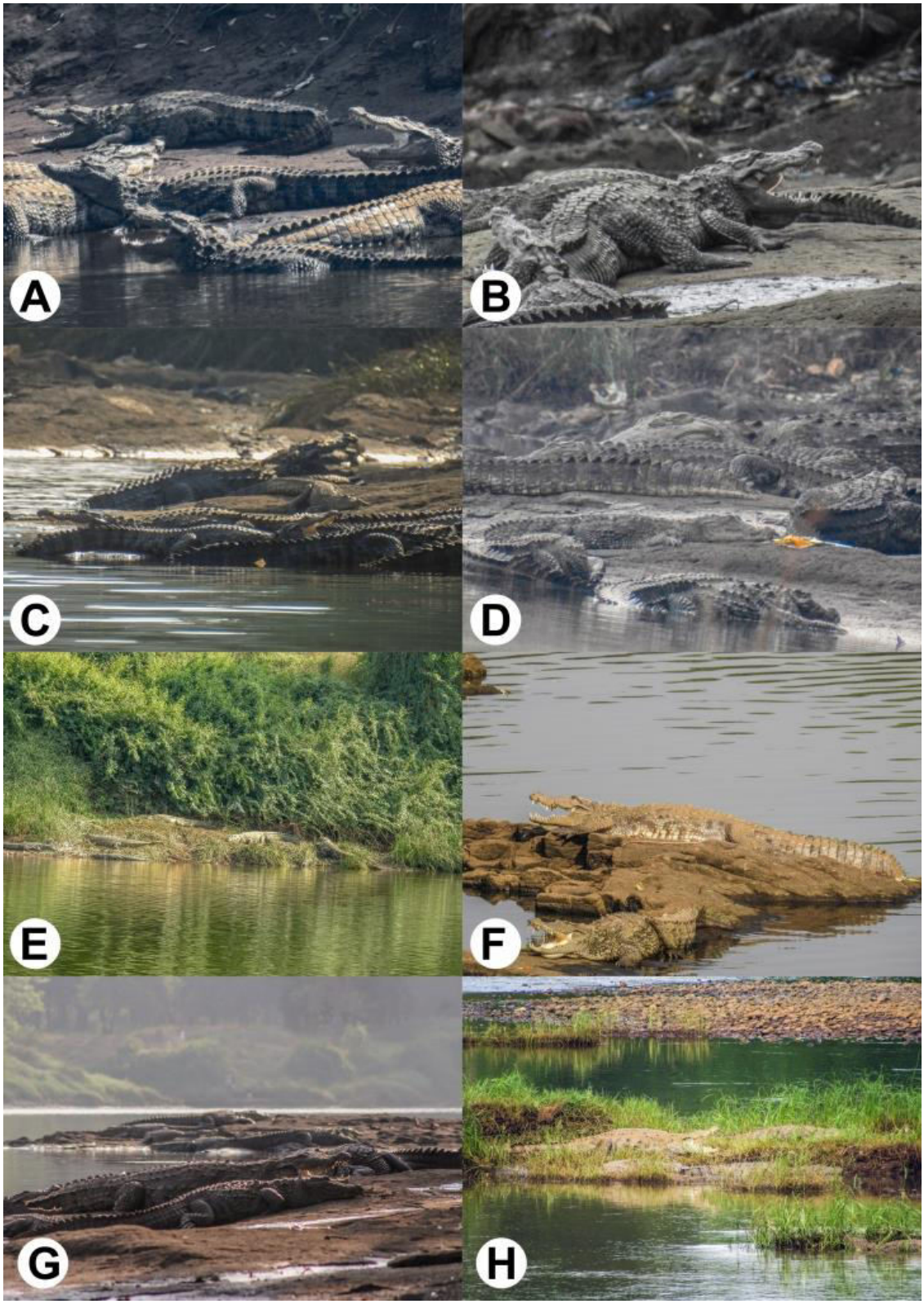


Fig. 3: Dry Basking: 3A-D and G. Muggers basking without any specific orientation in close proximity of each other, suggesting rollback of territoriality, 3E and H. Muggers basking along the riparian vegetation, 3F. Muggers basking on mid-water boulders.

(Figs. 3F, G), rather than emerge out. Seebacher and Grigg (1997) reported that *Crocodylus johnstoni* similarly prefers rocks for basking. The basking locations also appear to be temperature dependent and during very hot summers the crocodiles preferred basking on the grass or *Typha* plants growing near banks.

At Kemburli, Mohalla and Smashaan there is neither apparent preferred orientation nor strict private space that the individuals claim. At Kemburli and Smashaan the basking individuals show total disarray and crowding to the extent of resting on each other (Figs. 3 A, B) in a show of extreme tolerance towards conspecifics. Our separate studies on the population trends of Muggers here indicate greater abundance in this stretch as inferred from greater sighting frequency at Smashaan (Chavan and Borkar, 2022) corroborative of such crowded basking pattern here.

At Dadli, basking Muggers are infrequent but the area is known to have many excavated tunnels, which these reptiles use for resting (Figs. 4 A-C). The bank character at this site is more suitable for excavation than for basking.

Though largely tied up with the water body, Muggers can reach safe places by climbing considerable height. In one instance during rainy season when the Mohalla stretch was inundated due to extreme precipitation, a Mugger was even seen stranded on a roof top of a house near the flooded river (Chavan and Borkar, 2022). Dinets *et al*. (2013) reported that juveniles of several species of crocodilians across American, African and Asian continents have the ability to climb trees. Further these authors reported that Australian freshwater crocodiles climb steep river banks, the ability of climbing decreasing with size and mass. This is divergent from our observation that crocodiles of any size can climb and take refuge or rest as seen from the tail drag imprints of large crocodiles in tunnels nearly 15 feet above the ground (Figs. 4 A-C).

We have observed four distinct types of basking behaviours in Muggers; First type is 'Dry basking' when the Mugger is completely out of water and its body is fully exposed (Fig. 3). Second type is 'pre-bask' when two-third of Mugger's body is submerged in water, with its snout on land (Figs. 5 A-C). The third type is 'surface bask', when Mugger floats still without any movement on the surface of water (Figs. 5D-E). The fourth type is 'shallow water basking'. In this the Muggers bask with their entire length of the dorsal surface above the water in line with upper jaw (Figs. 5F-H). Both pre-bask and dry ground basking are commonly seen (70%), whereas surface basking (5%) is not as frequently seen as compared to shallow water basking (25%). Smith (1975) recorded that *Alligator mississippiensis* pre-bask in the shoreline and does not emerge directly from deep water to the land. However, Seebacher (1999) reported an array of intermediate postures of *Crocodylus johnstoni* before emerging from water to land, while Muggers studied by us did not necessarily show any such transitory postures and emerged directly from water onto land or even retreated back from pre-bask postures.

Basking substrates at the study site include rocks and boulders, barren soil, soil with vegetation and also debris and discard like pipes (Figs. 5B, 6). Maximum crocodiles were seen basking on the banks of Smashaan region. Such preferential occupancy could be because Smashaan region provides a gentle to moderate slope on both the banks of the river, besides the riparian vegetation here also offers shade during summer. The region also has few boulders near lower bank which are used by the Muggers for basking.

An interesting aspect of the Muggers in the investigated stretch of the river Savitri is their less wariness towards obvious disturbances. It was not uncommon to witness feral cattle and animals like feral dogs, as well as birds like the Wooly-necked Stork (*Ciconia episcopus*), Eurasian Spoonbill (*Platalea leucorodia*), Black-headed Ibis (*Threskiornis melanocephalus*), Little Egret (*Egretta garzetta)*, Intermediate Egret (*Ardea*

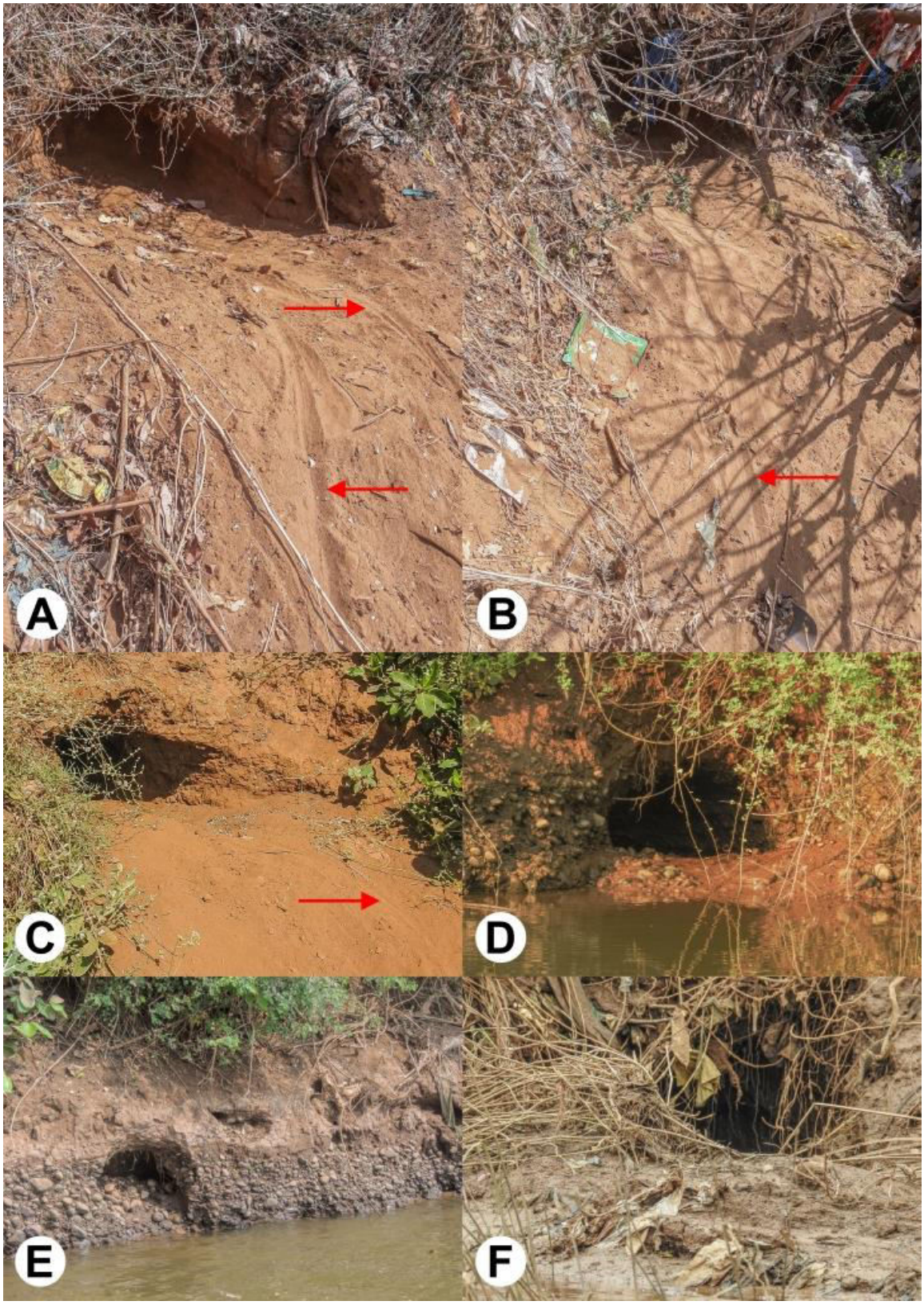


Fig. 4: Resting and Nesting Tunnels: Fig. 4A-C (resting) and Fig. 4 D-F (nesting). Resting tunnels are generally built high above the ground from 5 to 20 feet. Red arrows in 4 A-C shows tail drag marks of Mugger exiting from the tunnel.

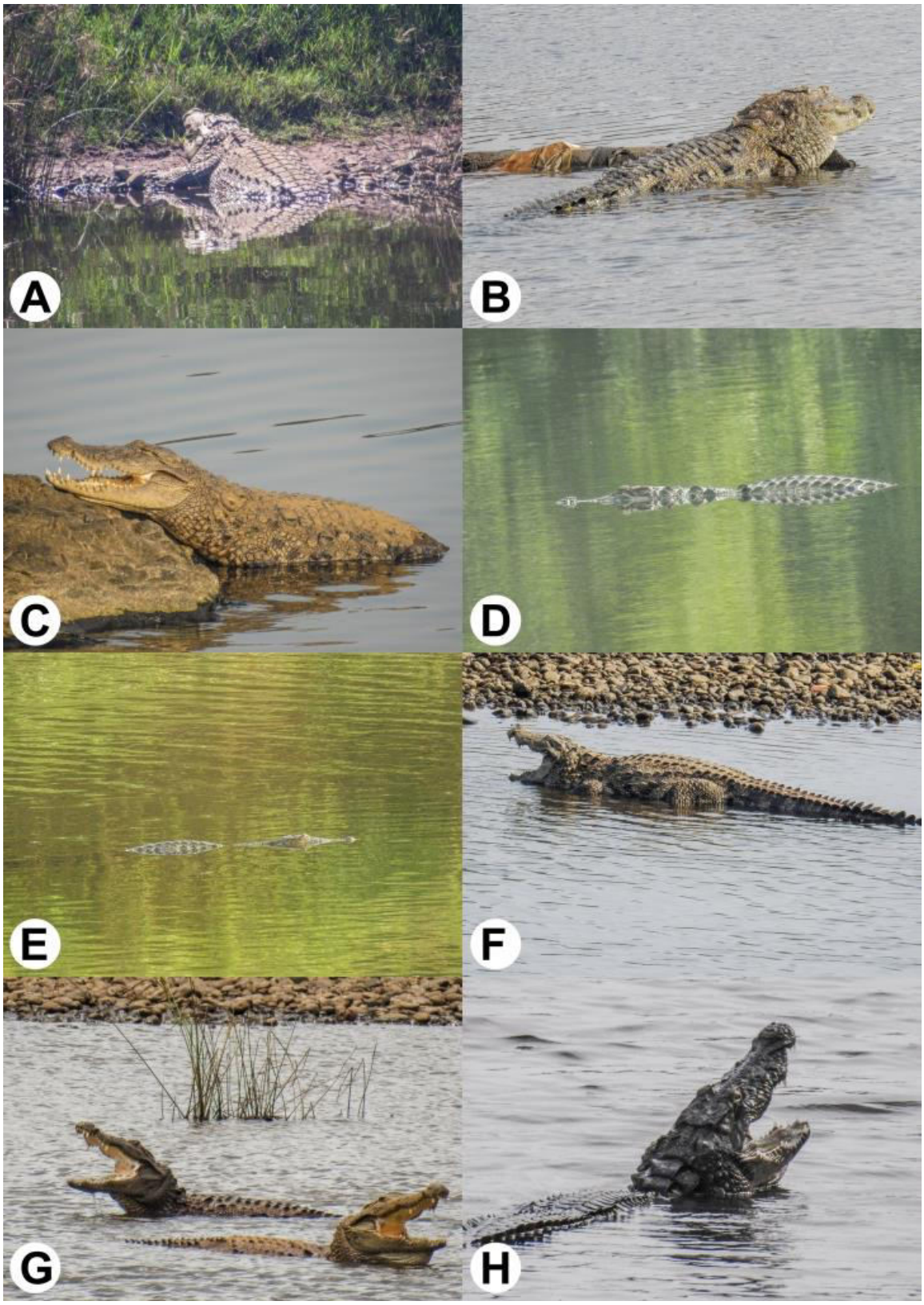


Fig. 5: Pre-basking (A-C), Surface Basking (D-E) and Shallow water basking (F-H)

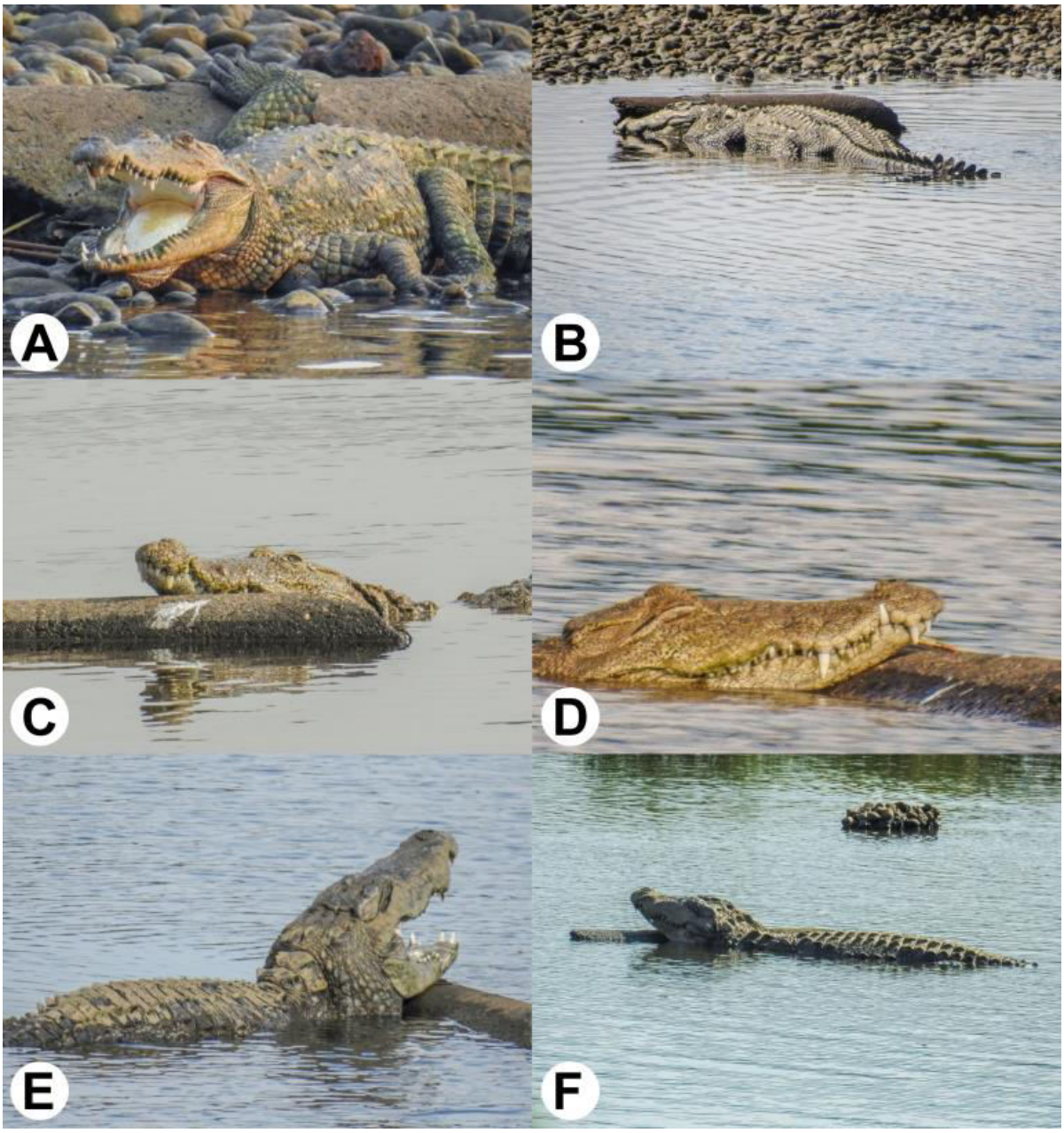


Fig. 6: Muggers using pipe for thigmothermy and to rest.

intermedia) and Cattle Egret (*Bubulcus ibis*), Grey Heron (*Ardea cinerea*), Night Heron (*Nycticorax nycticorax*) and Pond Heron (*Ardeola grayii*) forage in the immediate vicinity of the basking crocodiles (Figs. 7A-D). Also, the indigenous *Katkari* community fishing in these waters in close proximity of surface-basking crocodiles is an intriguing sight (Fig. 7E). It was observed here that Muggers can be approached at very close distance, without being alarmed by human presence most of the times (Fig. 7F). It is known that repeated exposure to humans in a neutral context leads to habituation that reduces their wariness (Price, 1984; Lamichanne *et al*., 2022). The crocodiles were mostly observed crawling on land, often with high walk.

Except at Dadli, the banks of other three stretches provide good basking sites for Muggers. At Mohalla and Kemburli, Muggers were seen dry basking during winter months, whereas in summer they prefer shallow water basking. Generally, it was observed that during the

Fig. 7 A-D: Basking Muggers habituated to humans and other non-human species.

summers Muggers take intermediary positions for basking. The seasonal differences in preponderance of various basking postures of Muggers are presented in Figure 8.

Our observation that basking is a regular perennial activity of Muggers is in agreement with that of Gupta and Sri Hari (1989). During the summer, Muggers were seen basking for a couple of hours each before and after sunrise and sunset. They were either fully or partially submerged in water during noon and afternoon hours, and if out of water then resting in shades of riparian vegetation. This basking pattern of warmer months is corroborated by Lang (1987b) in *Crocodylus novaeguineae* and *Crocodylus porosus* in Papua New Guinea, *Caiman crocodilus* in Venezuela, *Gavialis gangeticus, Crocodylus porosus* and *Crocodylus palustris* in India.

During winter months they were often seen basking in open spaces of the river bank. The adults and ones presumably in higher levels of hierarchy were seen occupying spaces of their choice and defended it against the competing sub-adults and juveniles, latter being compelled to

occupy whatever space was available. The larger individuals were seen changing their basking spots after certain periods of time; which eventually reshuffled the arrangement of the entire basking aggregation at that place.

While basking on the banks, the Muggers gape at regular intervals without any obvious threat perception or provocation (Figs. 3F, 5C, F-H, 6A, E, 7A, B, D, F), though the same was never seen during surface bask. Gaping during basking is common in many species of crocodilians and is speculated to be a thermoregulatory behaviour (Guggisberg, 1972; Spotilla *et al*., 1977; Smith, 1979; Steel, 1989; Huchzermeyer, 2003). Also, Downs *et al.* (2008) reported gaping to be more prevalent after long periods of basking, though we could not confirm the same in our study. Crocodiles at high temperatures may lie with their mouths agape, which increases evaporative cooling (Loveridge, 1984; Branch, 1998 a, b). However, there are differing opinions on the role of gaping in crocodiles (Kofron, 1993).

Though primarily the functional reason for this behaviour seems to be thermoregulatory and particularly towards heat loss, congruent with the observations by Spotilla *et al*. (1977). Recent observations though suggest that gaping is a complex behaviour that must be viewed beyond mere thermoregulatory benefits. Carl *et al.* (2020) opine that unprovoked 'mouth gaping' is very common behaviour across extant species of crocodiles and yet its purpose remains largely speculative in absence of experimental evidence. Hypotheses on advantage of mouth gaping vary from threatening/agonistic behaviour towards non-crocodilians (Brien *et al*., 2013), giganto-thermy (Grigg *et al*., 1998), dominance behavior toward conspecifics (Thorbjarnarson and Herna´ndez, 1993; Ray and Walley, 2003), invitation for birds to pick decaying meat/leeches trapped between teeth (Guggisberg, 1972), and increased airborne gustatory sensitivity (Kofron, 1993). Mishra *et al.* (2018) reported age group related differences in basking postures and preferences, with young crocodiles basking on the surface of water**,** and juveniles and sub-adults oriented with their mouths towards the water line with little or no contact with water. At Kotmi Sonar in Chhattisgarh, these authors have also observed that adults and big sized crocodiles bask away from but parallel to the water line. On the contrary, in our study basking individuals were seen orienting themselves variously with respect to the water body.

Tunnels:

Cott (1975) concluded that crocodilian thermoregulation is affected both by habitat selection and behavioural adaptations. Crocodilian species like the Mugger use burrows or tunnels as refuge during cold and dry periods (Ross *et al*., 1989). Excavation and occupancy of tunnels by Muggers to avoid extreme sunlight during summer months and rain during monsoon has been reported by many workers (Bayani *et al*., 2011; Gupta, 2011; Zafar and Malik, 2018). In our field study, the Muggers were seen building nests at the entrance of these tunnels. Such association between tunnels and nesting has been established (Mazzotti, 1983; Whitaker and Whitaker, 1984)

Zafar and Malik (2018) have reported that Mugger crocodiles live in the holes (presumably tunnels) nearest to water bodies. Of the four types of tunnels excavated by Muggers as reported by Bayani *et al*. (2011); only simple tunnels measuring 12-14 feet long were found at all the four sites observed in this study. The nests were either outside of the tunnel entrance or immediately inside. The nesting tunnel with somewhat crescent-shaped opening differs from the resting counterpart, in that the former has barricading of stones at the mouth and the passage is at an angle to avoid inundation. Some modifications of habitat around the nesting areas such as clearance, trails and runways have been reported (Lang, 1987a).

Dadli having the steepest slope amongst the four riverine stretches studied, has many resting and nesting tunnels. Although for personal safety and to keep the tunnels inviolate, we did not

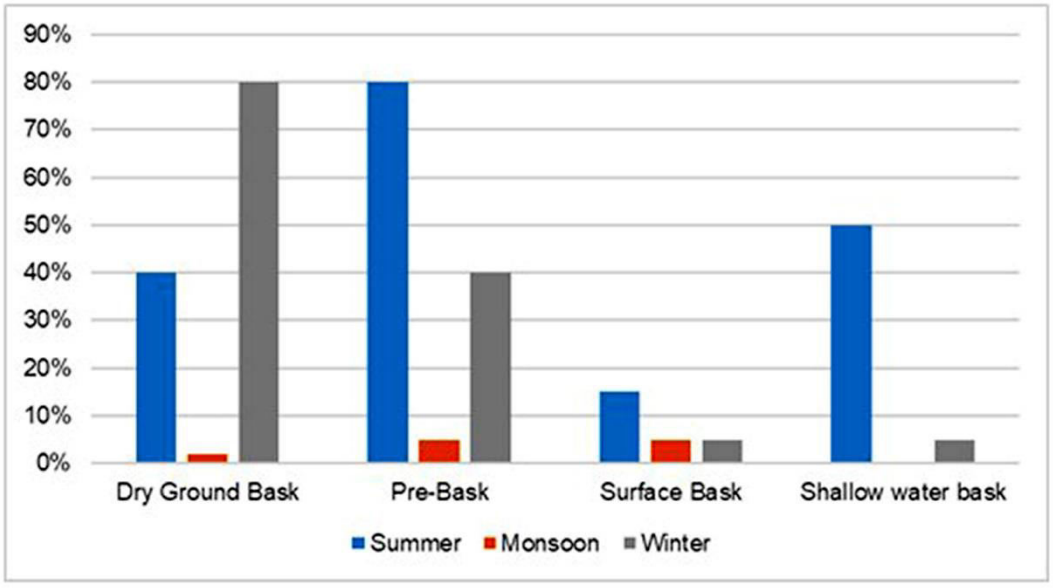


Fig. 8: Seasonal differences in basking types in Muggers of Savitri River, Maharashtra.

photo-document Muggers inside the tunnel, yet indirect evidences of tunnel occupancy such as imprints of tail drag and belly-crawl on the soft mud outside were seen during summer months (Figs. 4A-C). Also, the local indigenous communities who fish in this stretch of the river, confirmed presence of numerous hatchlings during monsoons.

Gupta (2011) reported that older Muggers show a tendency to occupy tunnels at higher levels on the earth mound and very young crocodiles prefer tunnels at the lower rim of the mound at the level of water; and further that their stay in tunnels is guided by diurnal photo-periodicity in consonance with temperature regimes. Also a few tunnels always remain unoccupied and may be excavations of the previous season.

Conclusion

The data presented here on two crucial behaviours viz., basking and tunneling has accrued from a long-term monitoring study on Muggers of river Savitri at Mahad, in the Indian state of Maharashtra. This crocodile habitat is facing imminent threats from the fast pace of urbanization, pollution and proposed linear infrastructure, and must be left inviolate. Basking is maintenance behaviour crucial to the reptile's temperature regulation and site fidelity, whereas tunnel construction and occupancy addresses both maintenance and reproduction. These behaviours have species-specific nuances and are critical to understanding Mugger's natural history as well as to fine-tune strategies for its conservation management.

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