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Journal of
Threatened
Taxa

Open Access

10.11609/jott.2022.14.11.22039-22206

www.threatenedtaxa.org

26 November 2022 (Online & Print)

14 (11): 22039-22206

ISSN 0974-7907 (Online)

ISSN 0974-7893 (Print)



ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

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Cover: Mugger Crocodile basking on the banks of Savitri River at Mahad in Maharashtra, India. © Utkarsha M. Chavan.



Population trends of Mugger Crocodile and human-crocodile interactions along the Savitri River at Mahad, Maharashtra, India

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Abstract: In this paper, we report monitoring of a resident population of Mugger Crocodile *Crocodylus palustris* (Lesson, 1831) along a stretch of 3.5 km of the river Savitri on the outskirts of Mahad town of Raigad District in Maharashtra, on monthly basis from 2014 to 2021. This river is increasingly becoming a sink of anthropogenic wastes emerging from adjacent settlements impacting its habitat value, and puts the reptile side by side with humans and human-wastes that could be a cause of rising incidents of crocodile mortality in the recent times here, as also reported from elsewhere. Savitri River has been a fishing ground for local indigenous communities, who also use the river bank for washing clothes and utensils, and for swimming. Such proximity between people and crocodiles creates a potential for negative interaction. This long term study monitored the Mugger population trends for the last eight years at four transect stretches along the river. Counts are suggestive of a healthy viable population of Mugger in this river currently, but a future conflict situation cannot be ruled out. Being generalist feeders, Muggers can sustain themselves on fish, and scavenge on dumped carrion and other anthropogenic organic wastes. With the exception of a few sporadic incidents of aggression by the Muggers at this location, no human casualties have been reported thus far, however, this does not rule out fatal reciprocal interactions in future and hence a few practical mitigation measures have been suggested.

Keywords: Encounter frequency, indigenous community, negative human-mugger interaction, relative density, size-classes, spill over.

Marathi abstract: या शोधनिबंधात, आम्ही महाराष्ट्रातील रायगड जिल्ह्यातील महाड शहराच्या सीमेवरील सावित्री नदीच्या ३.५ किमी. च्या पट्ट्यात अधिवास असलेल्या क्रोकोडायलस पॅलुस्ट्रिस (लेसन, १८३१) मगरींच्या संख्या निरीक्षणाचा २०१४ ते २०२१ ह्या कालावधीसाठीचा मासिक अहवाल सादर करीत आहोत. ही नदी, काठावरील मानवीय वसाहतीमधून सतत बाहेर पडणाऱ्या मानववर्गीय घनकचरा व सांडपाण्याने प्रदूषित होत आहे आणि तिच्या परिस्थितिकीच्या मूल्यांवर प्रतिकूल परिणाम झाला आहे, त्यामुळे इथल्या मगरी मनुष्याच्या सान्निध्यात तसेच मानव निर्मित प्रदूषक घटकांच्या संपर्कात येतात, आणि हेच येथील मगरींच्या मृत्यूच्या वाढत्या घटनांचे कारण असू शकते. सावित्री नदी व तिचा काठ हे इथे वास्तव्यास असलेल्या उपेक्षित काठोडी समुदायांसाठी मासेमारीचे ठिकाण आहे, जे नदीचा वापर कपडे-भांडी धुण्यासाठी आणि पोहण्यासाठी करतात. अलीकडील काळात लोक आणि मगरी यांच्यातील अशा समीपतेमुळे मानव-वन्यप्राणी संघर्ष होण्याची शक्यता निर्माण होते आहे. या दीर्घकालीन संशोधनांतर्गत मागील आठ वर्षांत नदीच्या पात्रात तसेच काठावरील चार निरीक्षण पट्ट्यात मगरींची सांख्यिक गणना केली गेली. सध्या या नदीत मगरींची संख्या व्यवहार्य आणि शाश्वत आहे असे सूचित होते, परंतु भविष्यात संघर्षाची परिस्थिती नाकारता येत नाही. अमूकच वैशिष्ट्यपूर्ण आहाराची गरज नसल्यामुळे मगरी नदीच्या पात्रातील मासे, तसेच इथे टाकलेल्या मानवनिर्मित सेंद्रिय पोषक घटकांचे भक्षण करून आपली पोषणपूर्ती करतात. इथल्या अवघ्या काही आक्रमक मगरींच्या तुरळक घटनांचा अपवाद वगळता, मानवी जीवहानीच्या घटनांची इथे अजून तरी नोंद झाली नाही. तथापि, भविष्य काळात मगर व माणूस ह्या दोन प्रजातींमधील परस्पर घातक संबंध नाकारता येणार नाही, आणि म्हणून त्यावर काही व्यावहारिक संघर्ष-शमन उपाय सुचवले गेले आहेत.

Editor: Perran Ross, University of Florida, Gainesville, USA.

Date of publication: 26 November 2022 (online & print)

Citation: Chavan, U.M. & M.R. Borkar (2022). Population trends of Mugger Crocodile and human-crocodile interactions along the Savitri River at Mahad, Maharashtra, India. *Journal of Threatened Taxa* 14(11): 22118–22132. <https://doi.org/10.11609/jott.7934.14.11.22118-22132>

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Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Author contributions: UTKARSHA MANISH CHAVAN is an asst. professor of Zoology at Bharatiya Vidya Bhavan's Hazarimal Somani College, Chowpatty, Mumbai, India; and has participated in field studies on wildlife of Australia and India. She has also volunteered at The Madras Crocodile Bank Trust and Centre for Herpetology, TN. MANOJ RAMAKANT BORKAR has made seminal contribution to Goa's faunal diversity inventories. His research on the conservation status of Mugger Crocodile in Goa was recognized by the Crocodile Specialist Group of the IUCN. Presently he is a senior faculty at the Department of Zoology at Carmel College for Women, Goa.

Author contributions: UMC has planned and conducted field studies, photo-documentation, and data collation, assisted in analysis and literature survey. MRB has conceptualized the study, supervised field work, analyzed and interpreted the collated data, and written and revised the manuscript.

Acknowledgements: UMC gratefully acknowledges sustained field assistance by Khushboo Chavan, Umesh Awadoota, Riyazuddin Shaikh, Sana Khan, Aawesh Khan, and Mubin Khalife. Assistance in graphical data presentation is attributed to Manish Chavan, Pratiksha Sail, and Sudhir Metkari.



INTRODUCTION

From the global count of 27 crocodilian species (Hekkala et al. 2011; Shirley et al. 2013, 2018; Murray et al. 2019; Stevenson 2019), India is a home to three. Among the three Indian crocodilian species, Mugger or Marsh Crocodile *Crocodylus palustris* Lesson, 1831 is the one with a wide distribution across the Indian peninsula, either as isolated populations or communal aggregations in estuarine and riverine ecosystems (Deraniyagala 1939; Whitaker & Whitaker 1989; Da Silva & Lenin 2010). It is distinguished by its morphology, morphometry, and ethology from the other two species, viz., Salt Water Crocodile *Crocodylus porosus* Schneider, 1801 residing along the shoreline of eastern India and the Gharial *Gavialis gangeticus* Gmelin, 1789 restricted to northern part of the Indian subcontinent. Once common in its range from eastern Iran to Bangladesh and down south to Sri Lanka; the Mugger populations declined drastically due to hunting for meat and hide trade, besides nest predation and poaching. Additionally, changes in land-use and other incompatible encroachments led to shrinking and loss of crocodile habitats in the country. From 1975 to 1982, the species recovery efforts through in situ and ex situ interventions by Government of India under UNDP/FAO direction and thereafter conservation action by NGOs and private individuals have helped the Mugger to recover across its Indian range (De Vos 1984). Interestingly, many former habitats having been repopulated, spillovers have begun leading to conflict situations (Distefano 2008; Pooley 2016). Also, the international (CITES-I listed, IUCN Vulnerable category) and country legislation (IWPA Schedule-I) having accorded a protected status to the reptile, have paid rich dividends to crocodile conservation in India. The expanding demography of a populous country like India has been a major driver of crocodilian habitat degradation, and also brings people in dangerously close proximity to these opportunist predators residing in rivers, tanks, dams and irrigation ponds (Wolch 1996; Kochery 2018).

Though temperamentally *Crocodylus palustris* is believed to be more tolerant of people than its salt water counterpart, and that it is supposedly not a frequent man-eater (Daniel 2002; Sidaleau & Britton 2012), is no guarantee of safety to people who share the habitat with this reptile. CrocBITE reports that between 2008 and 2013, 110 people were attacked by Muggers, out of which approximately one-third of those attacks were fatal for the victims (CrocBITE: Worldwide Crocodilian Attack Database). These numbers though not very

large, provide evidence of the potential hazard and conflict. In shared habitats potential negative Human Crocodile interactions emerge inevitably. Literature on Human-Crocodile Conflict reveals conflict situations across the Mugger habitats in Indian states of Goa, Maharashtra, Madhya Pradesh and Gujarat (Borkar et al. 1993; Whitaker 2008; Rao & Gurjwar 2013; Upadhyay & Sahu 2013; Vasava et al. 2015). Identifying such conflict locations and mitigating a potential conflict is a key to sustained in situ conservation of this species in India (Distefano 2008; Das & Jana 2017).

Despite the perceived threat from crocodiles, until recently it was held that these reptiles are top predators and keystone species, and perform an important role in maintaining the structural and functional integrity of freshwater ecosystems (Thorbjarnarson 1992; Ross 1998; Leslie & Spotila 2001; Glen et al. 2007). In absence of evidence-based justification, these attributions have been questioned recently (Somaveera et al. 2020). Data presented in this paper is a part of long term monitoring of Muggers of Savitri River, which flows through Mahad in Raigad District of Maharashtra in India. Since the objective of this study was to measure Mugger abundance over time, their encounter frequency has been considered.

Besides analyzing the population trends; potential human-crocodile interaction interface at four fixed stretches along the riparian habitat were examined and mitigation measures suggested with a view to change the potential negative interactions into coexistence.

METHODOLOGY AND FIELD PROTOCOLS:

Environmental setting of the river Savitri

Savitri River originates on the crest of Western Ghats in Mahabaleshwar hills and flows towards the west through Raigad District and eventually meets Arabian Sea at Harihareshwar in Maharashtra State, India. Where the river takes a sudden turn towards Mahad is a tidal zone. Out of the total 2,899 km² of water catchment area of Savitri basin, about 2,513 km² area is in Raigad District. The Savitri River basin lithologically belongs to Deccan Trap formation of upper Cretaceous to lower Eocene. The climate of the basin is typical of west coast and characterized with plentiful and regular seasonal rainfall, oppressive weather in summer and high humidity throughout the year. The Savitri basin bears deciduous and evergreen type natural vegetation.

Initial survey

Before the commencement of the long term survey, a pilot survey was conducted at day time during low tide

to determine river conditions such as access to a boat ramp, location of barriers, water depth; all with a view to streamline the nocturnal spotlight survey without compromising on safety. Given that crocodile densities vary within river stretches (Fukuda et al. 2007, 2011), four separate survey stretches with different start and finish points were fixed. During a given survey the adjacent sample stretches were surveyed on consecutive nights, to reduce the possibility of crocodiles moving between sections.

Survey planning

The start and end points of each of the four survey sections have been fixed between the months and over the years, because crocodile abundance and distribution along a river varies over time and space (Fukuda et al. 2007). To minimize the influence of seasonal changes in temperature and water level that affect crocodile behaviour (Webb 1991), repeated surveys over years were conducted every month, ideally within the same week period, however the exact date and time of a survey was decided on the basis of the tide. All crocodile population enumeration surveys were carried out during ebbing at night.

Due consideration was given to the fact that during winter, crocodiles choose to stay in relatively warm waters and can be easily spotted; while in summer they preferred to bask on banks or rest in the bank vegetation and hence making sighting difficult. Surveys always proceeded from down-streams to up-streams and the average speed of boat cruising in the river was 8–10 km per hour. Fixed tasks were assigned to boat driver, spotter and data recorder during every survey.

Crocodile Spotting

The spotter scanned water surface, water edges, banks and vegetation by shining a torch held near eye level standing at the advancing end of the boat. The light was shone in a zigzag manner from one bank of the river to the other to catch the eye-shine of a crocodile.

The study area is a stretch of the river flowing on the outskirts of Mahad city limits. The observation area starts from Kumburli to Smashaan, a distance of 3581 m which is divided into four sampling transects totaling 3.248 km; namely Kumburli, Mohalla, Dadli, and Smashaan (Image 1). Each of these transects differed in their habitat attributes and topography as tabulated (See Table 1 & Image 3)

The data presented here has accrued from monthly reconnaissance visits from 2014 to 2021, along a 3.5 km stretch of river Savitri at four fixed transects, viz.,

Kumburli along Mumbai–Goa Highway (18.0661°N; 73.4138°E), Mohalla near Gandhari River bridge (18.0725°N; 73.4188°E), Dadli on both sides of Dadli Bridge (18.0697°N; 73.4311°E), and Smashaan including Vaikuntha Bhumi near Prabhat colony (18.0669°N; 73.4411°E) (Image 1). Population estimates were based on nocturnal flash count or spot light survey (Fukuda et al. 2012) carried out on monthly basis in identified fixed sampling transects along the river. Since the objective of this study was to monitor the population of Muggers over time, Index of Relative Abundance was calculated based on frequency of sightings. Foot surveys were conducted for studying crocodile behavior and habitat attributes.

At all times observations were made from optimal distances for safety of field crew as well as to avoid breaching the Mugger's basking territory on the river banks, as also in water. Observations were recorded from 0700 to 2100 h. The sizes of Muggers were approximated visually by the same team of observers, based on the reported constant ratio of head length to total length (1:7), and that it changes little across size classes in many crocodilians species including the Mugger (Verdade 2000; Wu et al. 2006; Whitaker & Whitaker 2008; Mobaraki et al. 2021). This value in inches was converted into feet with one inch equaling one foot and was found to be matching with total body length. Only in the months of April 2020 and 2021 the count included hatchlings (up to 0.3 m) at Smashaan; rest at all times the number is of juveniles (<1 m), sub-adults (1–2 m), and adults (>2 m). Species-specific indirect evidences included documentation of fecal pellets, tunnels, tracks or trails and shell fragments of hatched eggs. Regular interactions with locals were held and their narratives recorded. Photo-documentation was accomplished with Digital and DSLR cameras (Nikon P 900 – Digital and Canon 1200 D – DSLR).

OBSERVATIONS AND DISCUSSION

A. Mugger population dynamics in Savitri River, Mahad

The Crocodilian species inhabiting the Savitri River was confirmed to be the Mugger based on presence of the quintessential row of four post-occipital scutes preceding the nuchal scutes (see Image 2B); and also its biometry was found commensurate with the species recorded data. The Mugger population of this habitat was observed and monitored over a linear distance of about 3,581 m of river Savitri meandering along the

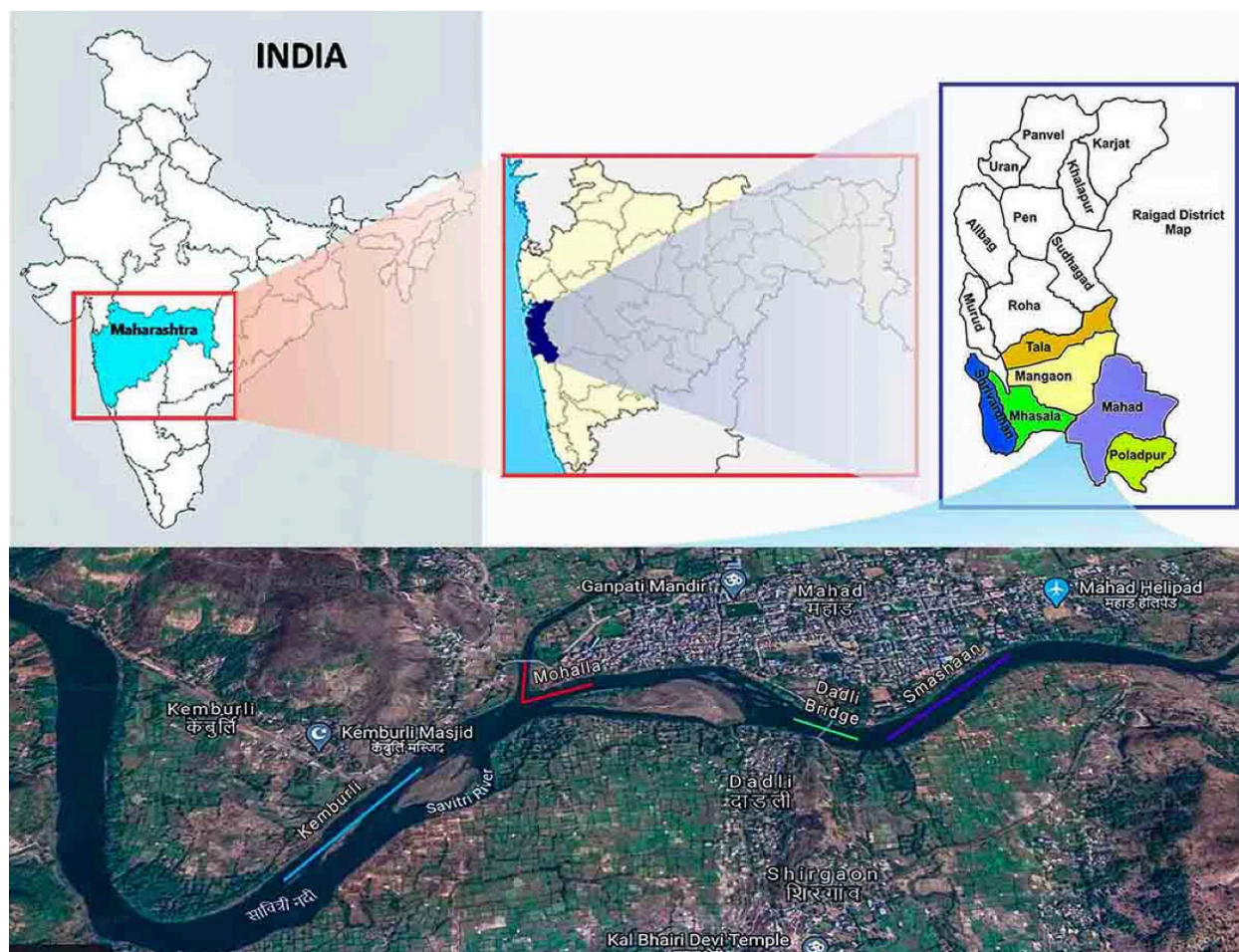


Image 1. Geographic locations of the four transect stretches along the river Savitri of Mahad in Raigad District of Maharashtra, India.

— Kemburli, — Mohalla, — Dadli, — Smashaan

outskirts of Mahad town; the four transect stretches being Kemburli, Mohalla, Dadli and Smashaan. The first observation site is close to Goa–Mumbai Highway, whereas the last observation station is a Hindu crematorium ground of adjacent residential area. The Mugger encounter frequency dominance across the four sample transects was Smashaan >Kemburli >Dadli >Mohalla (Figure 2A,B), with maximum counts recorded at Smashaan. Such preponderance at Smashaan may be attributed to this site meeting requirements of basking grounds as also with the right slope for easy movements in and out of waters.

The general age class hierarchy of Muggers in this river at all four sites was adults >sub-adults >juveniles. The average annual percentage of different size-classes representing different age groups in the Muggers encountered at the four transects during the entire study period has been tabulated (Figure 1).

The counts have been based on sightings, numbers generally peaking during the summer months; except at

Mohalla where more sightings were recorded towards the end of monsoons. The lesser counts were obtained during high water levels and monsoons; and in the latter case could be because of clouded skies when these reptiles withdraw from regular basking sites to backwaters with abundant fish resources, a view that has been corroborated by Smith (1979). The enumeration shows a progressive trend between 2014 till the end of 2021, with highest count of 155 individuals inclusive of hatchlings recorded at Smashaan in April 2020 (Figure 2A).

The preferential residence and basking in Smashaan area leading to higher counts could be attributed to greater fish stocks in the productive waters as can be seen from the basket catch of the fisher folks here, more foraging opportunities on these banks due to anthropogenic organic wastes, and optimal basking sites here. Such a possibility has been corroborated previously by Singh (1993). Despite being a severely disturbed site, that Smashaan is preferentially occupied

Table 1. Sample transects and their habitat attributes.

Sampling transect of the river	Linear distance (in m)	Latitude & Longitude	Depth of water in dry season in feet	Slope of the bank (land to river)	Bank zone character	Predominant flora in riparian bench
Kemburli	1134.81	18.066°N; 73.4138°E	05-25 feet	–35° to –80°	Muddy shoreline interspersed with gravel	<i>Typha angustifolia</i> , <i>Ficus benghalensis</i> , <i>Ficus glomerata</i> , <i>Ficus religiosa</i> , <i>Abelmoschus manihot</i> , <i>Celosia argentea</i> , <i>Alternanthera sessilis</i> , <i>Amaranthus spinosus</i>
Mohalla	771.48	18.0725°N; 73.4188°E	15-25 feet for Savitri and 10-15 feet for Gandhari	–13° to –15°	City side Muddy and opposite side Gravelly	<i>Cassia fistula</i> , <i>Ricinus communis</i> , <i>Amaranthus spinosus</i> , <i>Aternanthera sessilis</i>
Dadli	446.07	18.0697°N; 73.4311°E	35-45 feet	–17° to –22°	Muddy	<i>Cleome viscosa</i> , <i>Clitoria annua</i> , <i>Clitoria ternatea</i> , <i>Colocasia sp.</i> , <i>Cyathocline purpurea</i> , <i>Datura sp.</i> , <i>Ipomoea campanulata</i> , <i>Ipomoea hederifolia</i> , <i>Malachra capitata</i> , <i>Parthenium hysterophorus</i> , <i>Urena lobata</i>
Smashaan	896.45	18.0669°N; 73.4411°E	5-20 feet	–37° to –42°	Muddy with boulders along shore line	<i>Ficus benghalensis</i> , <i>Ficus glomerata</i> , <i>Ficus religiosa</i> , <i>Morinda pubescens</i> , <i>Morinda tomentosa</i> , <i>Mucuna pruriens</i> , <i>Floria vitifolia</i>

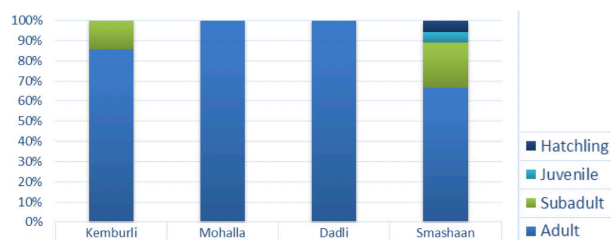


Figure 1. Average annual percentage of various size-classes in Mugger population at each of the four transects (Kemburli, Mohalla, Dadli and Smashaan) in river Savitri from 2014 to 2021. The measurements are in meters which include hatchlings (up to 0.3 m), juveniles (<1 m), sub-adults (1–2 m), and adults (>2 m).

by Mugger is not unusual, given that it is a 'disturbance adapted' species and can thrive very well despite all adverse influences on its habitat (Choudhary et al. 2018).

Discussions with locals suggest that Muggers have been thriving in this river since 1998, when a breeding pair from a private custody of a hobbyist was released at Smashaan area of the river Savitri (Salunkhe Yashwant pers. comm. 2014).

Population size of a species in a defined area provides the information needed to measure ecological change (Thompson 2002) and offers insights about the conservation status of the species (Lettink & Armstrong

2003). A time-series data as accrued here provides insight into the conservation future of this species. Based on the long term data (2014–2021) the population trajectory inferred from encounter frequency and relative density recorded at the four sample transects in this investigation indicate no risk to this viable Mugger population here at present; though a few stochastic oscillations are evident towards April 2020, attributable to a wide range of natural and anthropogenic factors operating here. Nonetheless, these overall trends in relative abundance have a conservation context, since they have been based on four data sets over a period of eight years infusing precision and eliminating potential biases (Holmes 2001; Holmes et al. 2007; Connors et al. 2014). From the view point of conservation future of this Mugger population it is crucial to take into account the age group structure of this population. The average annual percentage of various size-classes in the population over a period of eight years indicate that the number of adults is more as compared to that of sub-adults and juveniles. Such a trend implies a likely 'recruitment deficit' and a probable decline of this population in near future.

Given the deteriorating habitat conditions, there is a possibility that individuals of this population could spill-over into adjacent settlement areas in near future. Crocodilian populations are not randomly distributed

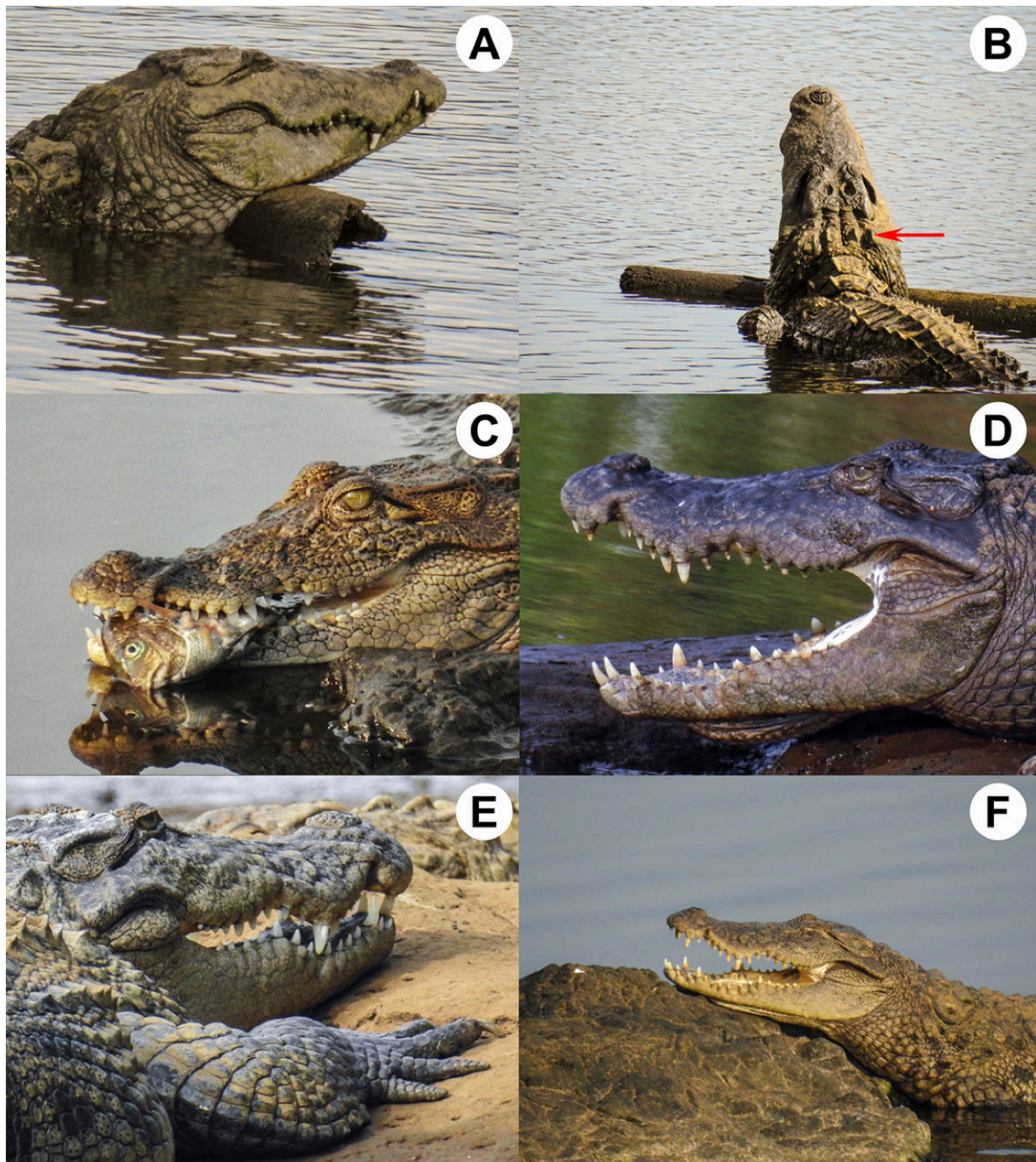


Image 2 (A–F). Mugger Crocodiles *Crocodylus palustris* Lesson, 1831 in the river Savitri at Mahad. Note the snout character (A–C), dentition (D–F) and post-occipital scutes (B) of diagnostic value in specific taxonomy. © Utkarsha M. Chavan.

because they have a tendency to cluster together over smaller areas as observed in this study. Therefore, striving for theoretical distributions in crocodile populations as a means of describing dispersion may not be appropriate (Balaguera-Reina et al. 2018).

Also, a bias in the population size estimation is that

the mean number of animals seen in a survey series will always be below the actual number of individuals present if there is no way to identify each individual (Southwood & Henderson 2003).

B. Muggers and indigenous communities of Mahad:

Modern approach of wildlife management consider people as integral in the habitat of wild animals, and further that such communities which share territory with wildlife influence their spatial use of the habitat, as well as overall eco-dynamics. Further, it is accepted that the attitudes of such communities determine the present status as well as conservation future of this wildlife (Patel et al. 2014; Mir et al. 2015; Hariohay et al. 2018).

The river resources like water and fish are shared by the crocodiles, people and their livestock that makes this riverine ecosystem vulnerable to anthropogenic stressors, and also point to Human-wildlife competition (Image 4). The river Savitri at Mahad is not only a crocodilian habitat but also offers subsistence fishing to the indigenous 'Katkari' or 'Kathodi' communities, who go into the waters for fishing and clam collection regardless of Muggers floating around them (Image 4A–C).

The Katkari community regularly fish in Mugger-infested waters of Savitri (Image 4A–C) raising chances of human-crocodile interaction. Major anthropogenic activities here are water extraction, bathing and washing (Image 4D), livestock grazing on the river bank (Image 4E), sewage water discharged in river (Image 4F), open air defecation along the banks (Image 4G), and cremation wastes' run-off (Image 4H), dumping of animal carcasses (Image 4I), burning of urban wastes dumps along the river bank (Image 4J). Carcass of a juvenile Mugger (Image 4K) and Mugger basking near gunny bag full of waste were also observed during our surveys (Image 4L).

The Mugger population here seems to have been conditioned to human presence, as long as their private space is not violated; and there is admirable level of tolerance between people and the crocodiles. The native community here seems to be at ease with the crocodiles floating dangerously close to them in their precarious fishing grounds in the river, perhaps due to a keen understanding of the reptile's behaviour and know how not to elicit their aggression. As 'river people' elsewhere in southeastern Asia, they associate the crocodilian habitats with good fish stocks and their relationship with the reptile is a mix of vigilance and veneration (Gonzales et al. 2013; Bucol et al. 2014). Such unusual closeness of humans to the potentially dangerous reptile has also been reported of the indigenous people of Philippines, for whom the crocodile is a totemic species (Mangansakan 2008). The fishing communities of Mahad, do not have any pagan rituals unlike the

'Manngé Thapnee' or crocodile worship practiced by the *Gawdas* of Goa who live along the Cumbarjua canal, a Mugger habitat of Goa (Borkar & Mallya 1992), or the Mogri tribals of Gujarat (Fisher & Shah 1971).

C. Ecological Integrity and impact on Mugger habitat in Savitri at Mahad

To ensure conservation future of crocodiles, their habitat integrity is a prerequisite (Vyas & Vasava 2019). Present investigation also has laid emphasis on identifying the drivers of crocodilian habitat deterioration and loss. The river front is regularly subject to erosion and accretion due to seasonal changes in hydrodynamics. In some stretches the Muggers excavate tunnels as heat shelters, rest and nest (De Silva 2016).

Regrettably, the civic authorities have been using this stretch of the river as a sink of urban wastes, dumping huge quantity of unsorted wastes posing threat to the health of this riverine ecosystem. Often during the night-counts, Muggers were seen navigating their way through heaps of litter. Already the river banks at multiple destinations are smothered with mounds of wastes which deprive the Muggers of their basking sites. Though the Mugger is a 'disturbance-adapted' species and can thrive very well despite all adverse influences on their habitat (Choudhary et al. 2018); loss of basking sites can result in abandoning the territory by the reptile (Venugopal & Prasad 2003) further heightening the possibility of a mutually negative interaction between humans and the reptile. Also, these litter dumps are often burnt in the open causing air pollution and the residue ends up in the water, contaminating it (Image 4J).

Sewage from adjacent settlement is also being released in the river (Image 4F) presumably impacting the water quality and altering its hydrochemistry that could be detrimental both to this apex predator as also its aquatic prey-base. In fact on a few occasions dead Mugger juveniles and adults have been found floating in the waters or stranded on the banks (Image 4K & 5C). In absence of any wildlife forensic facility in Mahad, however, the cause of mortality cannot be conclusively established. At Smashaan particularly during the monsoons; the human cremation wastes including ash often drain into the waters (Image 4H). Also, the locals dump the carcasses of livestock (Image 4I) into the river adding to the load of oxygen demanding organic wastes. Regular use of river banks for open air defecation by the impoverished local communities in absence of sanitary facilities adds human wastes to this water body where people also fish (Image 4G).

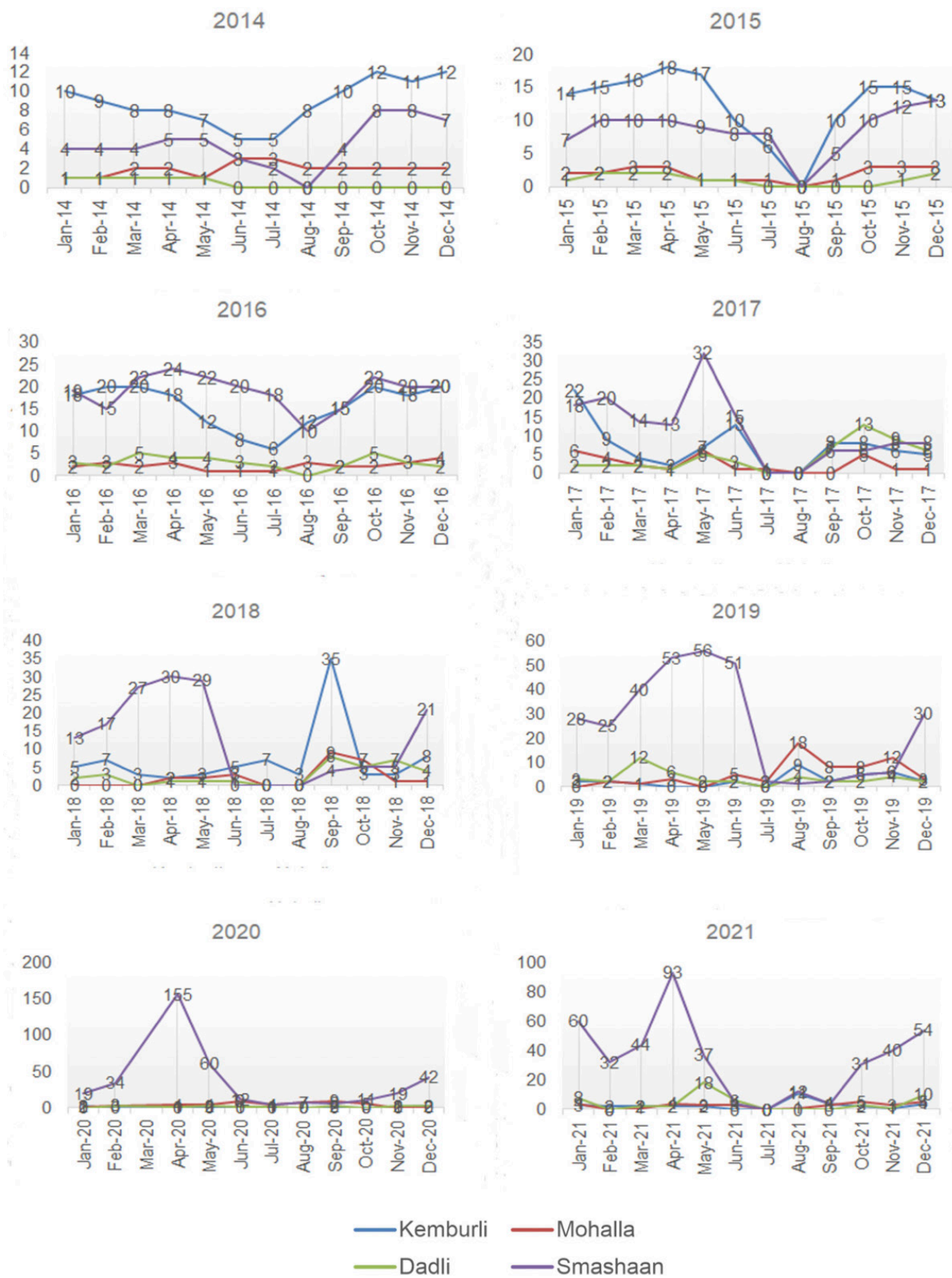


Figure 2A. Encounter frequency of Muggers at four sample transects of river Savitri, Mahad from 2014 to 2021.

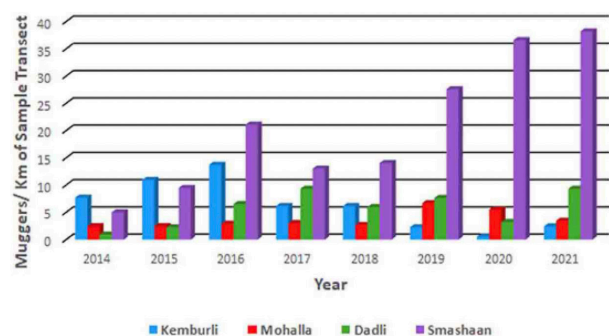
Table 2. Quantification of impacts on Savitri River banks at four locations [- Nil, + Low, ++ Moderate, +++High].

Station		Anthropogenic Impact				
		Garbage Dumping	Boating/ Movement of People	Fishing	Washing, Bathing etc.	Carcass Dumping
1	Kemburli	++	+++	+++	-	+
2	Mohalla	++	+++	+++	+	++
3	Dadli	-	+++	+++	++	++
4	Smashaan	+++	+++	+++	+++	+++

From the foregoing observations it is clear that the quality of crocodilian habitat along the Savitri River is precarious. Quantification of impacts at the four locations along the river front has been tabulated (Table 2). It is an established tenet in Conservation Biology that habitat protection is a prerequisite for conservation of biological diversity and protecting the habitat is a pre-emptive approach to species conservation that can negate the drivers of extinction (National Research Council (US) 1995). The view that loss of habitat is a major factor in species extinctions is also corroborated by Groombridge (1992).

The pragmatic approach shall be to find potential ways to reduce or prevent negative interaction for the better well-being of both people and crocodiles. Such a view has been corroborated by Linnell et al. (2011). Recent works on human wildlife conflict includes a paradigm of coexistence (König et al. 2020), where humans and wildlife co-adapt to live in shared landscapes, and their interactions are sought to be governed by systems that guarantee long-term wildlife population persistence, social legitimacy, and tolerable levels of risk (Carter & Linnell 2016).

In the recent past there has been some debate and discomfort among wildlife biologists on the use of the term "Conflict" and it is suggested that the term is provocative, human-centric and places the burden of blame on the wildlife (Davidar 2018). Hill (2021) opines that rise or exacerbation of 'human-wildlife conflicts' is only a reflection of changing dimensions of human-wildlife interaction that are complex and nuanced. Implicit in this opinion is the understanding that human wildlife interactions need not strictly fall into discrete categories as conflict or coexistence, and that such dichotomous perception though easy to understand is oversimplified and even inaccurate. Further, Frank (2016) argues that 'conflict-coexistence continuum' has no fixed points but socio-cultural and geographical variables that change with time and circumstances. In this paper we consciously and rationally choose to

**Figure 2B.** Mean annual relative density of Mugger at the four linear transects of Savitri River, Mahad, Maharashtra between 2014 and 2021.

use the term 'negative Human Wildlife interaction' to denote all such interactions that may have implications of damage and loss of life to both the sides.

D. Human-Mugger interface at Mahad:

When people and wildlife share habitat and compete for resources therein, their encounters may become reciprocally negative due to spatial overlaps, at worst leading to loss of livelihoods and life. Human-wildlife interaction, is not just a humanitarian issue but also a conservation concern that must be addressed rationally. Incremental episodes of Negative Human Wildlife Interactions (NHWI) have been variously attributed to expanding human settlements and increasing human activities in and near wildlife habitats, recovery of depleted populations of wildlife, and spill-over of a few wild species populations besides large scale environmental changes (Treves 2009).

Perusal of available records and discussions with the locals here revealed that until 2016, no attacks on humans were recorded, barring a few stray incidents when a Mugger caught the leg of a fisherman but immediately released it, perhaps due to lack of predatory drive at the time of incident. Though this caused only superficial injuries to the fisherman, this episode unleashed fear

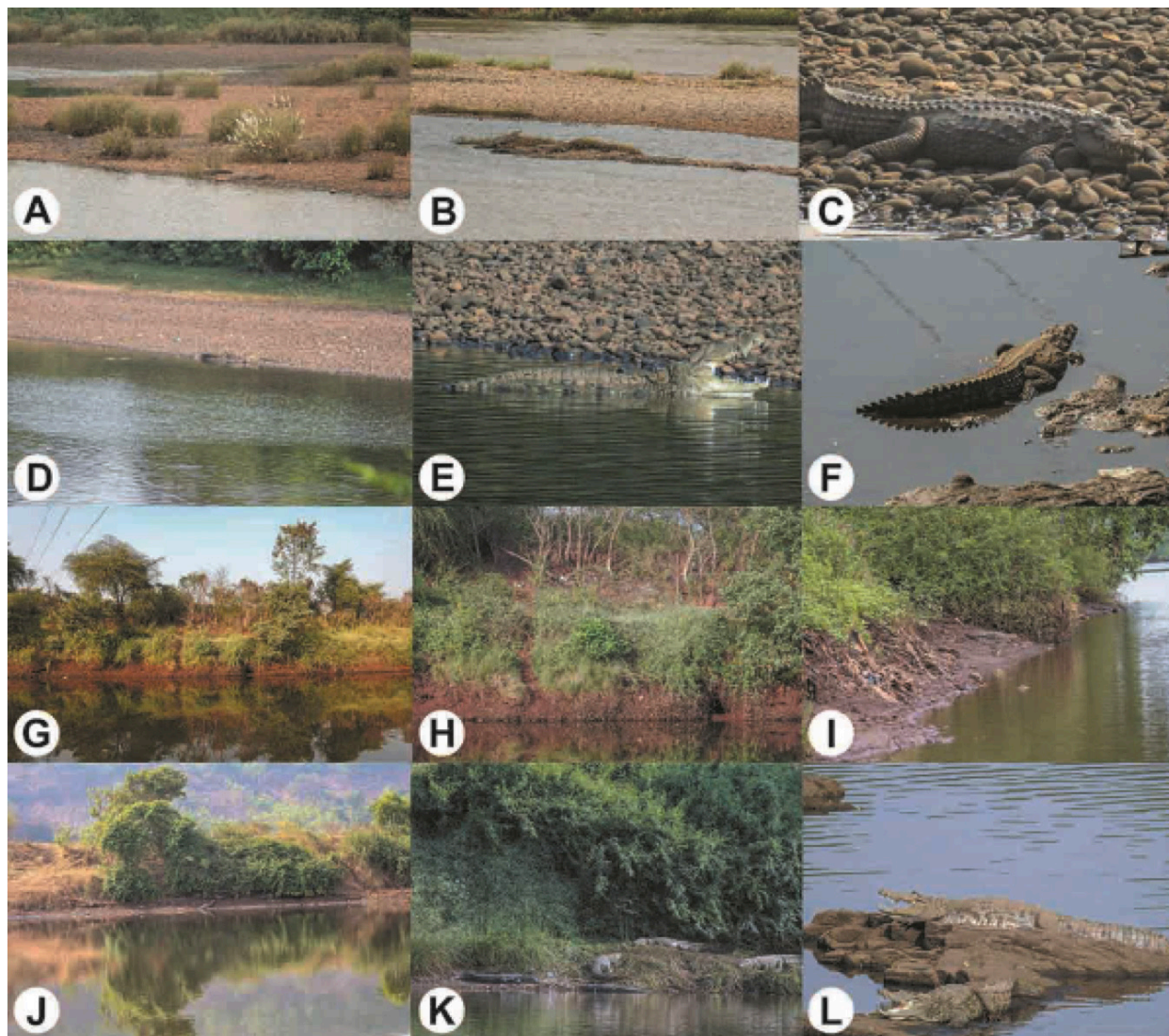


Image 3. Mugger habitats at 1—Kemburli (A–C) | 2—Mohalla (D–F) | 3—Dadli (G–I) and | 4—Smashaan (J–L) in the riparian stretches of River Savitri at Mahad, Maharashtra. Note the differences in vegetation, bank slope and surface character at the four locations. © Utkarsha M. Chavan.

among the people whose livelihoods were linked with waters of Savitri, though the indigenous people continue to fish in those waters in company of Muggers (Image 4A,B,C). Perhaps, the rich aquatic resources in river are excellent food source for both humans and crocodiles (Image 2C). Negative Human-Crocodile interactions (NHCI) have been reported from different parts of the country (Deutsch & Coleman 2000; Whitaker 2007, 2008; Rao & Gurjwar 2013; Upadhyay & Sahu 2013; Vasava et al. 2015; Vyas & Stevenson 2017).

Mugger attacks on humans have been recorded and attributed to several reasons. The known triggers include provocation and fishing (Whitaker & Srinivasan 2020), however, Muggers have also been living in harmony with people as in three districts of Gujarat;

namely Kheda, Anand & Charotar (Vyas 2013) implying conditioning through long term exposure to humans.

It must be emphasized, however, that Mugger Crocodile is responsible for the third highest number of fatal attacks on humans after *C. niloticus* and *C. porosus* (CrocBITE: Worldwide Crocodilian Attack Database), though it never eats its human victim, implying that the basis of such extreme aggression is either defending the territory or protecting the nest or hatchlings; rather than predatory (Sidaleau & Britton 2012).

That dead remains of humans and other animals disposed in river water can also invite crocodile attacks has been suggested (Stevenson et al. 2014). A stray incident has been reported from Dasgaon, a place 7 km away from Mahad, where a person was attacked by

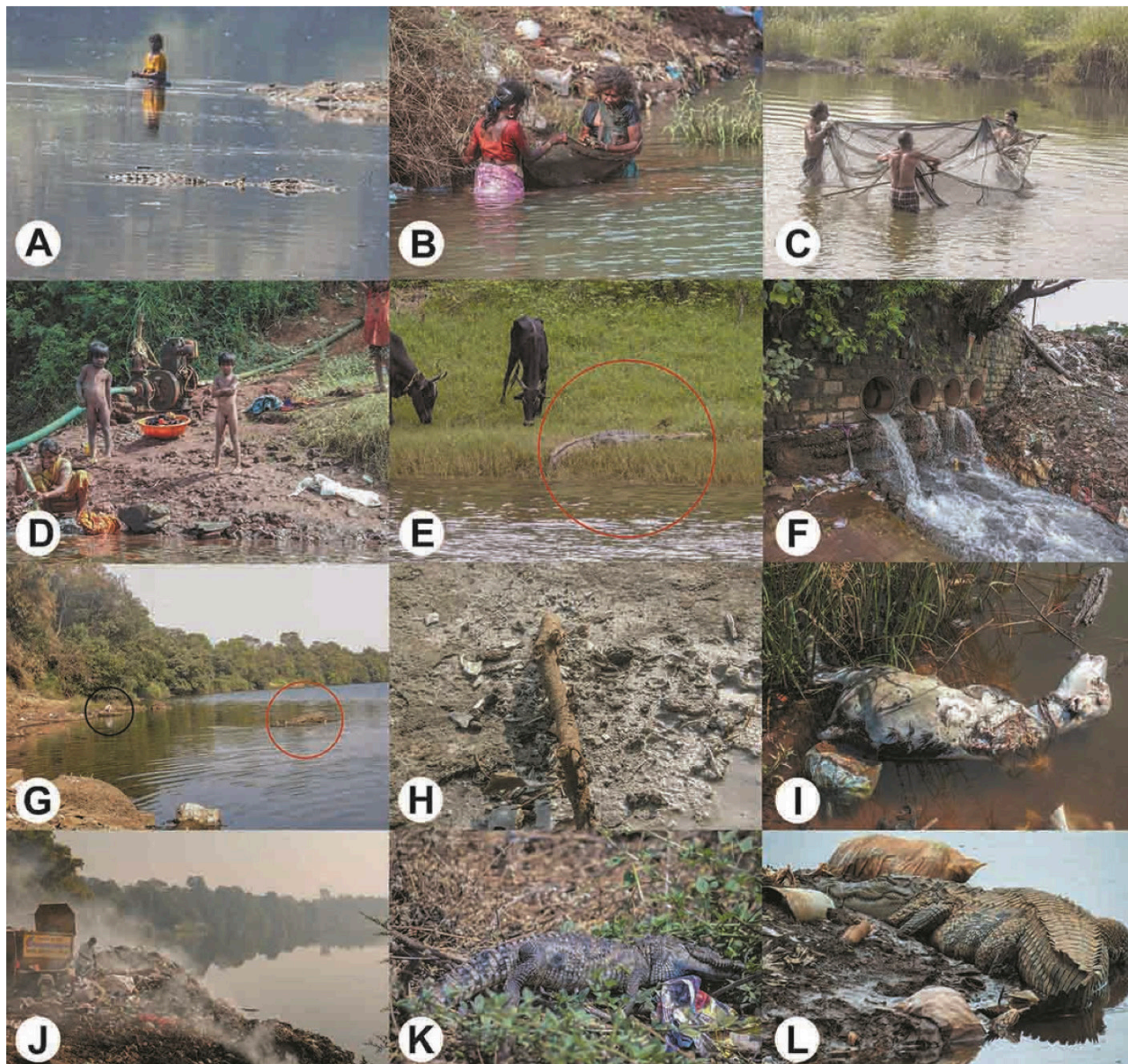


Image 4. Spectrum of anthropogenic stressors on Mugger habitat along the river Savitri at Mahad, Maharashtra, India. © Utkarsha M. Chavan

Mugger during rainy season apparently in defense of its hatchlings. Similar aggression by Muggers has been recorded by Whitaker (2007) from the banks of Krishna River in Maharashtra. Incidentally in the present study, it has been recorded that passersby and onlookers often throw stones for sheer fun and to see basking crocodiles in motion.

E. Negative Human-Mugger Interactions (NHMI) along the river Savitri, Mahad, Maharashtra India.

The rich aquatic resources in mangrove areas, estuaries, and rivers are excellent food source for both humans and crocodiles, making this livelihood option of local communities a reason for potential conflict.

An important objective of this research was to identify a hostile human-Mugger interface if any and mitigate it. Though such episodes entail reciprocal damage both to the wildlife and people, the former is usually branded culpable. This antagonism between humans and wildlife is globally recognized and merits attention from the perspectives of conservation, management and livelihood of local communities (Messmer 2000; Dickman 2010; Bowen-Jones 2012). Across the world unresolved NHWI have been the cause of declining community support for conservation (Hill et al. 2002). Also, retaliatory killing of wildlife is fallout of this threat perception by local community (Inskip & Zimmermann 2009; Mateo-Tomas et al. 2012). Studies have also

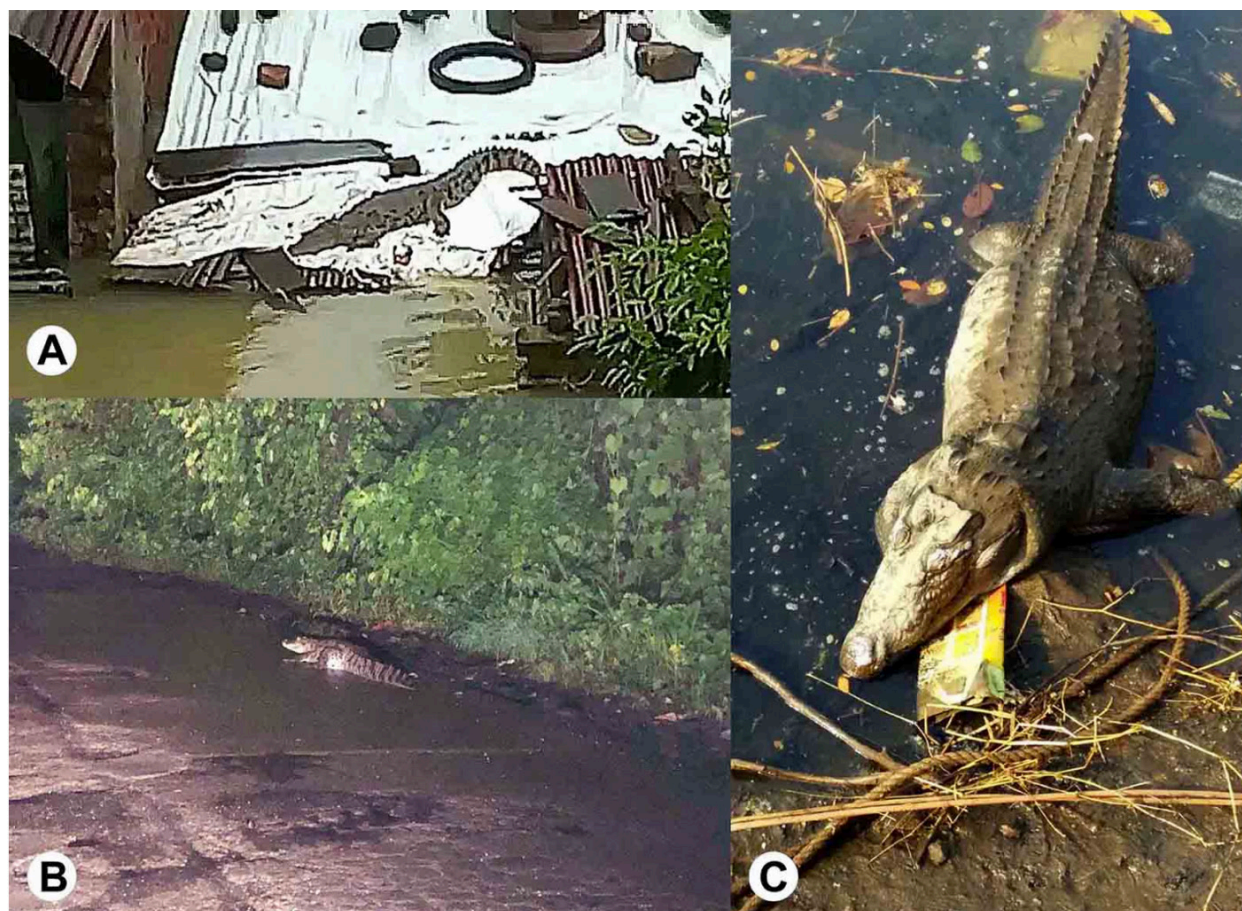


Image 5. Negative human-crocodile interaction interface: A—Mugger stranded on roof top of a house during floods | B—Strayed Mugger vulnerable to road kill an adult | C—Mugger killed by entanglement in fishing net. © Mubin Khalife

shown that there is a correlation between degree of conflict and decline of wildlife (Woodroffe et al. 2005; Michalski et al. 2006). NHWI also has an economic angle in that it takes a toll on life and livelihoods (Rao et al. 2002; Gillingham & Lee 2003; Sahoo & Mohnot 2004). Crop raiding by herbivores and livestock depredation by carnivores inflict significant monetary losses (Mackenzie & Ahabyona 2012; Brara 2013; Schon 2013). Lamarque et al. (2009) have also shown the diminishing financial and human resources implications of NHWI in countries affected by it.

In this study of crocodiles of Savitri River at Mahad; as of now the conflict interface is very subtle, and more than the people the reptile is at the receiving end. Until now there have been no reports of loss of human lives and livestock, despite a close proximity with the crocodiles (Image 4A–C,E). There is an imminent threat to the quality of this Mugger habitat due to incremental anthropogenic pressure. The greatest threat to the integrity of their habitat is from the land-based garbage, sewage, dumping of carcasses, and loss of basking sites

due to human presence and activities (Image 4). The human-Mugger negative interaction interface gets further expanded due to straying of Muggers in human settlements during monsoons. Also during floods that occur intermittently following heavy rainfall here, residential areas get inundated and Muggers have been seen stranded on roof tops of houses (Image 5A) as also stray on roads (Image 5B). Occasionally the adults get entangled in fishing nets and die (Image 5C).

F. NHMI Mitigation and conservation management.

Notwithstanding this hostile interaction potential of the Mugger, these reptiles play a critical role in aquatic ecosystems as indicators of ecological health, ecosystem engineers, apex predators, keystone species, and as facilitators of nutrient and energy transfer across ecosystems (Somaweera et al. 2020). While conventional tourism has reached a saturation point, crocodiles can offer alternative resources for ecotourism promoting sustainable livelihood options for local communities. Borkar et al. (1993) have shown the ecotourism potential

of Mugger in the backwaters of Cumbarjua canal in the adjacent state of Goa, and in Maharashtra State as well there are a few success stories of crocodile safaris at Maldoli creek, Chiplun. Incidentally a similar venture is also in the offing at Powai Lake in suburban Mumbai, for which Maharashtra Tourism Development Corporation (MTDC) has begun the process.

From the view point of disallowing escalation in the negative interactions here, it is important to raise awareness and build capacity of the local community and other stakeholders. Based on several years of field studies here, it is confirmed that the Smashaan area is a potential NHMI interface, though human fatalities haven't been recorded here as yet.

Currently, there is a single signage put up by the Mahad Forest Range Office declaring this area as 'crocodile infested', which also is now rusted and defaced. The forest department must establish a surveillance post here as a deterrence to anti-conservation activity. The facility could have basic rescue equipment as also staff trained in conducting rescue and autopsy. A suitable site here could also serve as an interpretation facility for visitor education.

As for the use of the river waters and banks by local indigenous communities, micro-mapping of such vulnerable areas for NHMI along river Savitri could be a valuable mitigation approach. After identifying such spots, 'Crocodile Excluding Enclosures' could be constructed using indigenous material for safety of people who share the habitat with the reptile. Such approach has been effectively tried in Sri Lanka (Uluwaduge et al. 2018). Poverty alleviation and community development initiatives could help lessen the dependence of locals on this river and consequently move them away from conflict.

Much of the conflict stems from spatial overlap and competition for resources, besides ignorance and fear, and impact of human activity on the habitat.

Areas with significant presence and activity of crocodiles must be mapped and notified by the local civic administration with sign boards in local language along the river banks. Local NGOs like SEESCAP and Srishtiutkarsha that regularly organize awareness programs at Mahad must be engaged by the forest division to sensitize locals towards avoiding risky behaviour and unwarranted machismo towards the reptile. The indigenous communities must be taken into confidence and their livelihood dependence on the river should be compensated with safer and viable alternatives. Sanitation and basic amenities like clean water must be guaranteed under the existing schemes

of the government for socioeconomically disadvantaged population that share the crocodile habitat. Mahad municipality must strictly ban dumping of garbage in the riparian zone in stretches of the river like Smashaan where the reptile has a territory, as also regulate the discharge of raw sewage. The forest department must invoke provisions of the Indian Wildlife Protection Act, 1972 to initiate punitive action. In event of a situation of conflict, a quick response team must be available with the necessary paraphernalia for rescue.

CONCLUSION

The data presented here is accrued from a long-term monitoring programme and has documented presence of a viable Mugger population in river Savitri at Mahad. The Mugger habitat here in some locations is under discrete anthropogenic pressures and there are visible signs of habitat deterioration that could cause a likely spillover in years to come accentuating the negative human-Mugger interaction potential. Currently the reptilian population trends suggest stability, but the present age group distribution raises questions on the optimal recruitment and a likely decline in the population in the coming years. Timely interventions shall be a win-win situation for both, Mugger and people. The state and the community must synergize their efforts to secure conservation future of the crocodile here while encouraging and incentivizing the community involvement.

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Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

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ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

November 2022 | Vol. 14 | No. 11 | Pages: 22039-22206

Date of Publication: 26 November 2022 (Online & Print)

DOI: 10.11609/jott.2022.14.11.22039-22206

www.threatenedtaxa.org

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