REPTILES & AMPHIBIANS

Status of Mugger Crocodile (*Crocodylus palustris*) and Human-Crocodile Interaction in Surat, India

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The Mugger or Marsh Crocodile (*Crocodylus palustris*), which can be found in forests as well as human-dominated areas, is India's most widely distributed and adaptable crocodilian species (Da Silva and Lenin 2010). This species is a vulnerable reptile in India, and it is legally protected under Schedule I of the Indian Wildlife (Protection) Act 1972; it is also classified as 'Vulnerable' according to the IUCN's threat assessment criteria (Choudhury and De Silva 2013). According to a state-wide survey done in 1995–1996, the Mugger population in Gujarat State, India, is estimated to be around 1,650 individuals (Vijaykumar 1997; Vyas 2010a, 2010b). Since then, no state-wide survey has been conducted, and the current situation of Muggers in Gujarat is unknown. Prior to 1995, surveys were primarily limited to a few protected areas, and only a few were conducted on a regular basis. As a result, there is no current information on crocodile populations in other parts of Gujarat, with the exception of the Vadodara region (Vyas 2010a, 2010b, 2012, 2013) and recent surveys in Anand, Kheda, and Junagadh Districts (Vyas 2013; Upadhyay and Sahu 2013; Vasava 2016a, 2016b, 2017, 2018, 2019, 2020, 2021; Vaghashiya et al. 2018, 2020).

This species is often encountered and appears to be flourishing in numerous bodies of water throughout Gujarat, owing largely to legislative protection and conservation initiatives implemented by the State Forest Department and NGOs (Vyas 2018), but detailed assessments of their populations are still needed. This study reports the status of *Crocodylus palustris* and various negative (attacks) and neutral human-crocodile interactions in Surat, Gujarat, India. It was designed to monitor the urban population of Mugger Crocodiles with the help of interviews (February 2019–December 2021) and direct sightings, in addition to secondary data based on available data from the rescue of Mugger Crocodiles from Surat collected by various NGOs and the State Forest Department. The available records show that crocodile populations, while generally small and isolated, are widespread across Surat (Fig. 1).

Methods

Study Area.—The Tapti River originates in the Satpura Ranges of Madhya Pradesh and merges with the Arabian Sea in Surat, India. The river flows through Surat, Gujarat (Fig. 2), from east to west and is divided into two parts by the Weir-cum-Causeway near the Rander area of Surat. The river becomes an open sewage system carrying enormous amounts of pollution. The study area was a 47-km long section of the river that ranges in width from 300–1,100 m (from Dumas to the Kamrej area of Surat). The secondary data suggested that

Fig. 1. Mugger Crocodile sighted in Tapti River in 2014. Photograph by Rakesh Patel.

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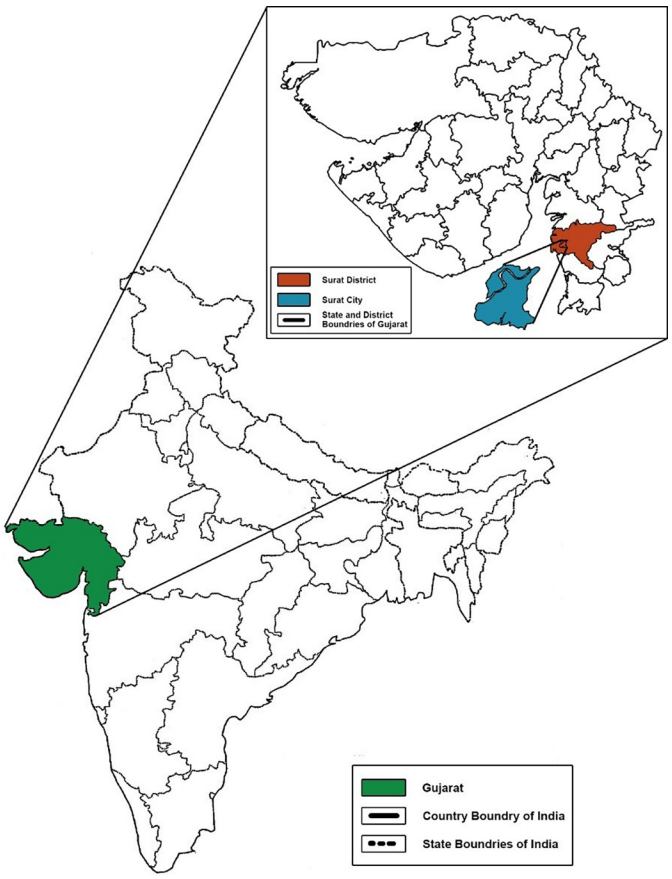

Fig. 2. Map showing the location of the study area in Gujarat, India.

several water bodies such as canal networks, lakes, ponds, and wetlands also had crocodiles present. Therefore, these bodies of water were also surveyed during the study.

Data Collection.—This research is primarily qualitative as we focused largely on people's opinions and experiences. We collected our data using various research methods that included interviews, participant observations, and crocodile rescue data. The primary data (interviews) was collected from a total of 60 respondents who interacted with crocodiles in Surat. A structured interview schedule was chosen because equitable comparisons across applicants may be done by generating a standardized list of questions and evaluation methodologies, thus reducing interviewer biases. It can be carried out by several collaborators while controlling for consistency since the questions are asked of the respondents in a systematic manner and with the same wording defined beforehand. The secondary data were collected from the crocodile rescue data of NGOs and the Forest Department of Surat. Respondents and communities in which human-crocodile interactions had already occurred were chosen. Seasonality has an influence on animal activity and behavior. Hence, to determine the frequency of human-crocodile interaction in various seasons using the secondary data, the seasons were divided into three categories as per the seasonal patterns in Gujarat: (i) winter (November–February), (ii) monsoon (July–October), and (iii) summer (March–June).

For locating and counting crocodilians, most crocodilian biologists prefer "eye-shine" or "spotlight" approaches (e.g., Magnusson 1982; Woodward and Moore 1993), but in this study, due to the extensive width of the river (≤ 1,300 meters), locating crocodiles along the entire river stretch was not possible, hence only daytime survey methods were used for direct sighting of crocodiles. Based on primary and secondary data, survey teams were deployed to conduct daytime surveys at all potential sites. The surveys were carried out on foot along the rivers and other bodies of water. Some parts of the river were inaccessible on foot, so they were surveyed by boat. The teams recorded direct sightings and indirect signs of crocodiles during the surveys. The locations of direct and indirect signs (scat, tracks, and basking sites) of Muggers were recorded with a GPS device (Garmin eTrex 10x). Individuals were observed with Olympus binoculars (10 x 50) and photographs of Muggers and their habitat were captured using a digital camera.

Survey Method.—The current research was conducted utilizing an ex-post-facto method. With an ex-post-facto approach, research is done with a systematic empirical approach in which in which the independent variables are not explicitly addressed because they have already occurred or are innately unmanageable (Robinson 1976).

Surat Municipal Geographic Information System digital data from 2018 were obtained for the Surat City boundary and water bodies from Survey of India toposheets at 1:50000 scale. Using these data, a base map of the study area was prepared. The spatial database was developed in the Polyconic projection system (Lillesand and Keifer 1987). After the survey, we generated a spatial grid of 1×1 km^2 for the entire study area (Buckland and Elston 1993) to get accurate information about human-crocodile interactions. All the map layouts were created using QGIS and Google Earth tools. We developed grids with human-crocodile interactions, where an 'interaction' was defined as when we encountered a crocodile during surveys or when a respondent to the surveys (secondary data) reported they had come into contact with a crocodile. The grids with human-crocodile interactions were then divided into three categories: (i) low interaction zone (1–2 interactions), (ii) medium interaction zone (3–4 interactions), and (iii) high interaction zone (5 or more interactions). This methodology was chosen to conduct zonation of the water bodies into low, medium, and high interaction zones, so wildlife management practices can be applied in areas of need.

Data Analysis.—A regression analysis was used for examining and modelling the relationship (Montgomery et al. 2012) between humans and crocodiles. Chi-Square tests were used to understand whether or not differences between the various segments or categories that the respondents acknowledged (Singhal and Rana, 2015) differed significantly (α =

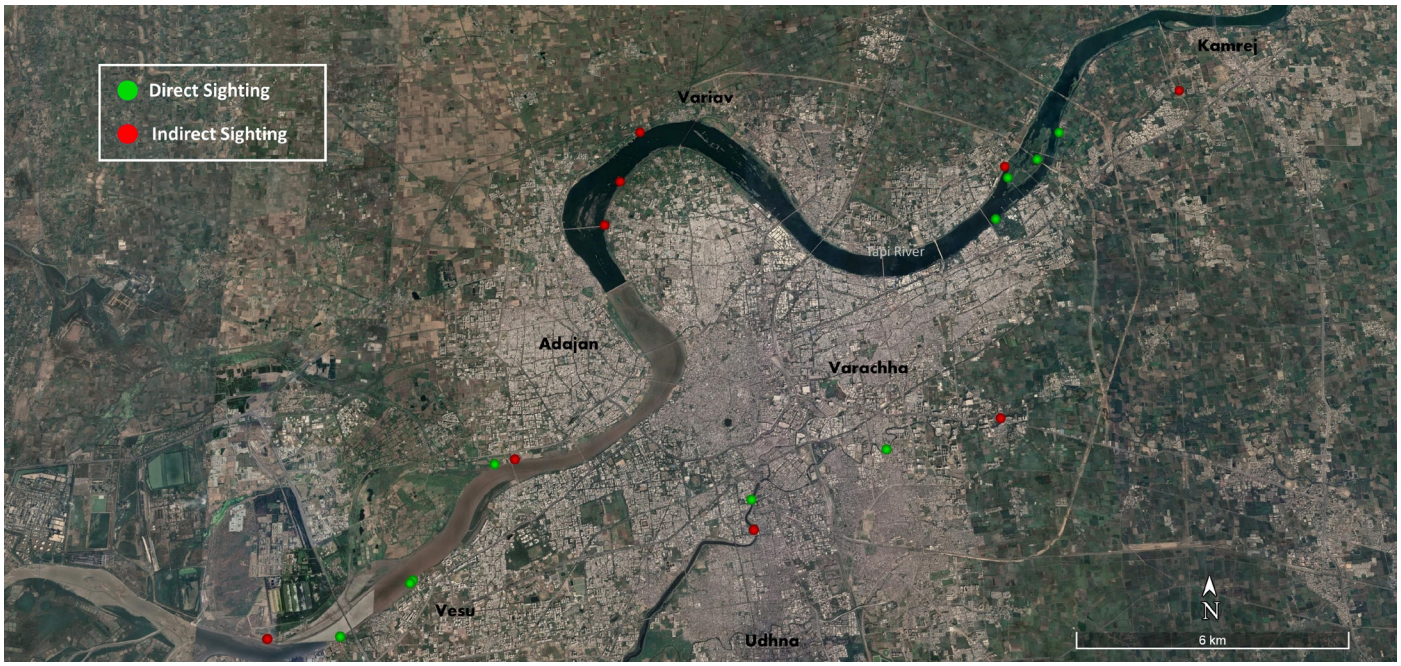

Fig. 3. Direct and indirect sightings of Mugger Crocodile observed during the study along the Tapti River, Surat, Gujarat, India.

0.05). The data obtained on seasonality was analyzed using simple averages and percentages.

Results

We recorded a total of 10 direct sightings of Muggers and 9 sites with indirect signs during the survey (Fig. 3). Crocodiles observed during direct sightings included 3 adults (≥1.5 meters total length), 2 sub-adults (1.0–1.5 meters total length), and 5 without any size estimate due to sightings of submerged crocodiles in water at long distances. During the entire study period, no crocodile conflict (negative interactions; e.g., attacks on humans) was observed.

Frequency of Human-Crocodile Interactions in Surat.— The regression analysis revealed no significant change in the number of crocodile rescues between 2005 and 2020 in Surat (R^2 = 0.0095, p = 0.71). (Fig. 4). We found that human-crocodile interactions between 2005 and 2020 in Surat have increased over time based on the primary data (i.e., data obtained from interviews; y = 0.72x – 1447.01, R^2 = 0.5848, p = 0.0003; Fig. 5). The majority of the survey respondents experienced human-crocodile interactions (58.33%) occasionally (i.e., once or twice a year). However, 35% of the

Table 1. Distribution of frequency of human-crocodile interactions in Surat, Gujarat, India (n = 60).

Frequency of HCI	Frequency	Percentage
Occasionally	35	58.33
Rarely	21	35.00
Daily	4	6.67
Total	60	100

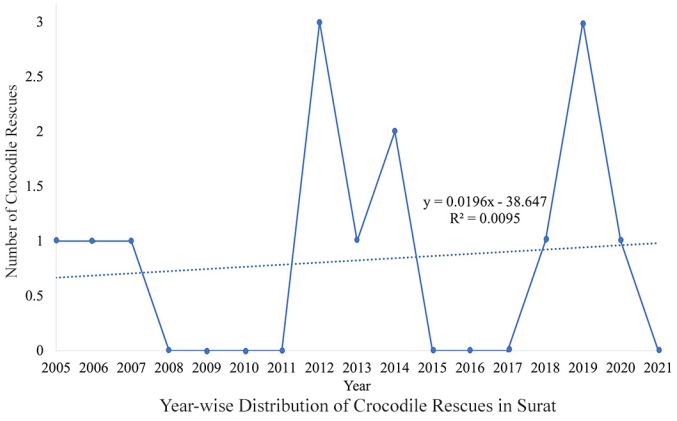

Fig. 4. Timeline showing no pattern in Mugger Crocodile rescues in Surat, Gujarat, India.

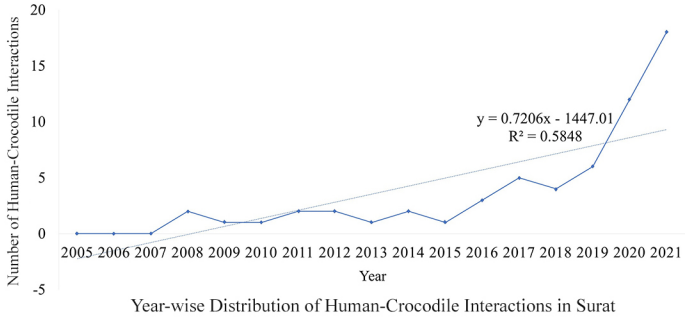

Fig. 5. Timeline showing an increase in the rate of human-crocodile interactions in Surat, Gujarat, India.

Table 2. Areas assigned to various human-crocodile interaction zones in Surat, Gujarat, India.

Categories	Number of Grids	Low interaction zone		Medium interaction zone		High interaction zone	
		No. of grids	% Area	No. of grids	% Area	No. of grids	% Area
Human-crocodile interaction	36	22	61.11	6	16.67	8	22.22

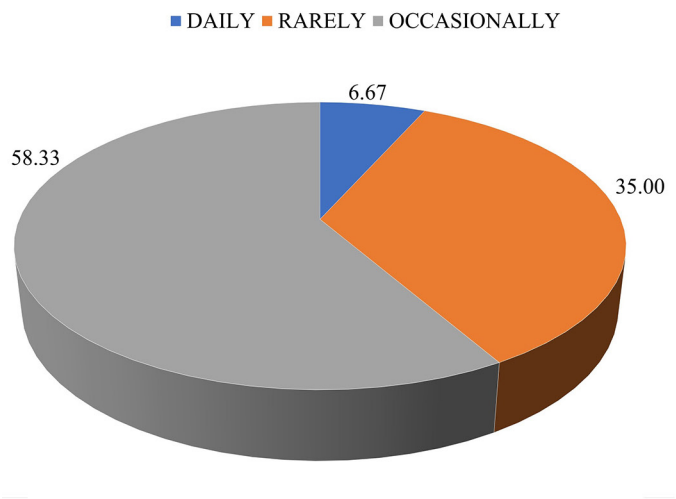

Fig. 6. Pie-chart showing the frequency of human-crocodile interactions in Surat, Gujarat, India. Numbers in the pie chart are percentages (%).

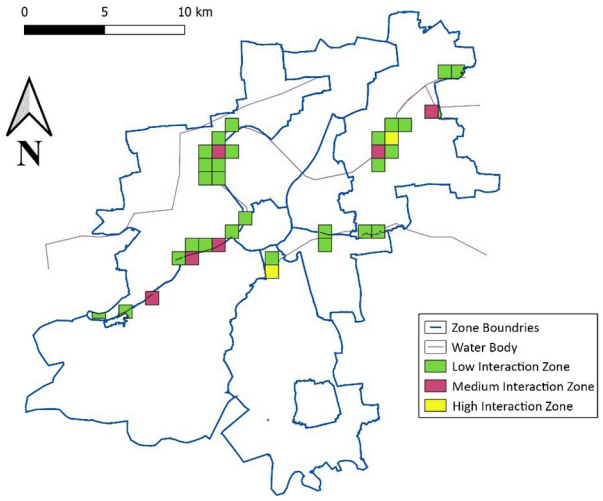

Fig. 7. Spatial distribution of human-crocodile interactions in Surat, Gujarat, India.

human-crocodile interactions occurred rarely i.e., once or twice a month and the fewest human-crocodile interactions (6.67%) took place daily (Table 1; Fig. 6). This difference was statistically significant (x^2 = 24.1, df = 2, p = 0.0001).

Areas Frequently Visited by Crocodiles in Surat.—Around 61.11 % of the grids reported low human-crocodile interaction. Grids categorized in medium and high human-crocodile interactions were 16.67 and 22.22%, respectively (Table 2; Fig. 7). This difference was statistically significant (x^2 = 12.667, df = 2, p = 0.0001).

Seasonality of Human-Crocodile Interactions in Surat.—The majority (n= 46; 76.67%) of the human-crocodile interactions occurred in monsoon season (July–October), about 23.33% (n= 14) in the summer season (March–June), and none took place in the winter season (November–February; x^2 = 55.6, df = 2, p < 0.0001; Table 3; Fig. 8). The results of the study suggested an increase of interactions during the monsoon season, which was similar to the results of surveys conducted in the Bhitarkanika and Sundarbans (Das and Jana, 2018; Khan et al., 2020).

Table 3. Distribution of human-crocodile interactions in Surat, Gujarat, India, by season (n = 60).

Season	Frequency	Percentage
Monsoon	46	76.67
Summer	14	23.33
Winter	0	0.00

Discussion

Human encroachment is one of the main threats to crocodile habitat. The number of interactions between crocodiles and humans is increasing as habitat is reduced and the crocodile

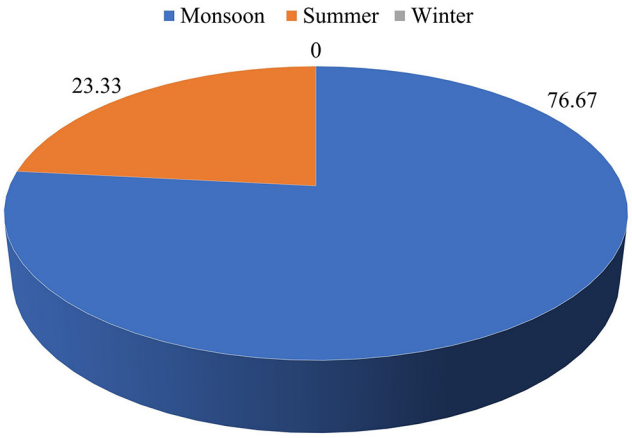

Fig. 8. Pie-chart showing the seasonal frequency of human-crocodile interactions in Surat, Gujarat, India. Note that in winter the frequency is zero.

population grows (Vyas 2005; Whitaker 2008; Vyas and Stevenson 2017; Porras Murillo and Cambronero 2020). That might be because this is crocodile mating season, and so there is an increase in movements in search of food and mates (Khan et al. 2020). In coastal areas, the monsoon is the main fishing season for the fishing community. During this season, fishermen enter bodies of water, increasing their chances of encountering crocodiles (Das and Jana 2018). The results of this study indicate a substantial increase in human-crocodile interactions in the bodies of water of Surat. Environmental factors, water temperature, habitat type, observer ability and experience, type of equipment, and familiarity with the surroundings may all have a negative impact on Mugger sightings, resulting in fewer individuals being reported throughout the survey. Thorough systematic surveys should detect more populations across the Tapti River ecosystem and provide more information on population levels, as well as how this could affect human-crocodile interactions. A systematic multiscale study of Muggers, associated species, and their habitat along the entire stretch of river will yield valuable information regarding the population dynamics and ecology of the species in the Tapti River. The majority of the river stretch was subjected to unregulated fishing and sand mining. Although no major human-crocodile conflict (negative interactions between humans and crocodiles) has been recorded in the area, there is a need to have local awareness campaigns focusing on the vulnerability and ecological value of crocodiles to avoid any negative interactions like attacks by crocodiles on locals, fishermen, and sand mining communities in the future.

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Literature Cited

Buckland, S.T. and D.A. Elston. 1993. Empirical model for the spatial distribution of wildlife. *Journal of Applied Ecology* 30: 478–495.

Choudhury, B.C. and A. de Silva. 2013. *Crocodylus palustris*. *The IUCN Red List of Threatened Species* 2013: e.T5667A3046723. https://dx.doi.org/10.2305/IUCN.UK.20132.RLTS.T5667A3046723.en.

Da Silva, A. and J. Lenin. 2010. Mugger Crocodile *Crocodylus palustris*, pp. 94–98. In: S.C. Manolis and C. Stevenson (eds.), *Crocodiles. Status Survey and Conservation Action Plan*. Third Edition. Crocodile Specialist Group, Darwin, Australia.

Das, C.S. and R. Jana. 2018. Human–crocodile conflict in the Indian Sundarban: an analysis of spatio-temporal incidences in relation to people's livelihood. *Oryx* 52: 661–668. https://doi.org/10.1017/S0030605316001502.

Khan, W., U. Hore, S. Mukherjee, and G. Mallapur. 2020. Human-crocodile conflict and attitude of local communities toward crocodile conservation in Bhitarkanika Wildlife Sanctuary, Odisha, India. *Marine Policy* 121: 104135. https://doi.org/10.1016/j.marpol.2020.104135.

Lillesand, T.M. and R.W. Keifer. 1987. *Remote Sensing and Image Interpretation*. John Wiley, New York, New York, USA.

Magnusson, W.E. 1982. Techniques of surveying for crocodilians, pp. 389–403. In: *Crocodiles. Proceedings of the 21st Working Meeting of the IUCN-SSC Crocodile Specialist Group*. IUCN, Gland, Switzerland.

Montgomery, D.C., E.A. Peck, and G.C. Vining. 2021. *Introduction to Linear Regression Analysis*. Wiley Series in Probability and Statistics. 6th ed. John Wiley and Sons, New York, New York, USA.

Porras Murillo, L.P. and E.M. Cambronero. 2020. Analysis of the interaction between humans and crocodiles in Costa Rica. *South American Journal of Herpetology* 16: 26–33. https://doi.org/10.2994/SAJH-D-18-00076.1.

Robinson, P.W. 1976. *Fundamentals of Experimental Psychology. A Comparative Approach*. Prentice Hall, Englewood Cliffs, New Jersey, USA.

Singhal, R. and R. Rana. 2015. Chi-square test and its application in hypothesis testing. *Journal of the Practice of Cardiovascular Sciences* 1: 69–71. https://doi.org/10.4103/2395-5414.157577.

Upadhyay, J.N. and R.K. Sahu. 2013. Study on *Crocodylus palustris*: co-existence of men, animal and population survey at Kheda Anand district in Gujarat, India, pp. 116–122. In: *World Crocodile Conference. Proceedings of the 22nd Working Meeting of the IUCN-SSC Crocodile Specialist Group*. IUCN, Gland, Switzerland.

Vaghashiya, P.M., B. Dudhatra, and R. Vyas. 2018. Parental behaviour of mugger (*Crocodylus palustris*) at Lal Dhori, Junagadh, Gujarat, India. *Crocodile Specialist Group Newsletter* 37(2): 16–18.

Vaghashiya, P.M., D. Chauhan, and R. Vyas. 2020. Monitoring a Breeding Mugger (*Crocodylus palustris*) Population in the Girnar Wildlife Sanctuary near Junagadh, Gujarat, India. *Reptiles & Amphibians* 26: 211–215. https://doi.org/10.17161/randa.v26i3.14407.

Vasava, A. 2016a. *Charotar Crocodile Count – 2016. 16–17th January 2016*. Voluntary Nature Conservancy, Gujarat, India. https://doi.org/10.13140/RG.2.1.1970.3449.

Vasava, A. 2016b. Charotar's Crocodiles. *Sanctuary Asia* 36(2): 36–41.

Vasava, A. 2017. *4th Charotar Crocodile Count – Counting Crocodiles for Conservation. 7th–8th January 2017*. Voluntary Nature Conservancy, Gujarat, India. https://doi.org/10.13140/RG.2.210821.04325.

Vasava, A. 2018. *5th Charotar Crocodile Count – 2018. Counting Crocodile for Conservation. 6th–7th January 2018*. Voluntary Nature Conservancy, Gujarat, India.

Vasava, A. 2019. *6th Charotar Crocodile Count – 2019. Counting Crocodile for Conservation. 4th–6th January 2019*. Voluntary Nature Conservancy, Gujarat, India.

Vasava, A. 2020. *7th Charotar Crocodile Count – 2020. Counting Crocodile for Conservation. 3rd–5th January 2020*. Voluntary Nature Conservancy, Gujarat, India.

Vasava, A. 2021. *8th Charotar Crocodile Count – 2021. Counting Crocodile for Conservation. 9–10 January 2021*. Voluntary Nature Conservancy, Gujarat, India.

Vijaykumar, V. 1997. Evaluation of restocked mugger crocodiles and its implication in long term conservation and management of the species in Gujarat, India. Unpublished report for the Gujarat Institute of Desert Ecology, Bhuj-Kachchh, Gujarat.

Vyas, R. 2005. Recent notable incidences of conflict between Mugger and humans in Gujarat. *CSG Newsletter* 24(2): 7–8.

Vyas, R. 2010a. Mugger (*Crocodylus palustris*) population in and around Vadodara City, Gujarat State, India. *Russian Journal of Herpetology* 17: 43–50.

Vyas, R. 2010b. The Muggers (*Crocodylus palustris*) of Vishwamitri River: Past and present, p. 32. In: *Herpetology & Environmental Research Project* (HERP), Vadodara, Gujarat, India.

Vyas, R. 2012. Current status of Marsh Crocodiles *Crocodylus palustris* (Reptilia: Crocodylidae) in Vishwamitri River, Vadodara City, Gujarat, India. *Journal of Threatened Taxa* 4: 3333–3341. https://doi.org/10.11609/JoTT.o2977.3333-41.

Vyas, R. 2013. Recent scenario of mugger (*Crocodylus palustris*) population in three districts of Gujarat State, India, pp. 220–226. In: *World Crocodile Conference. Proceedings of the 22nd Working Meeting of the IUCN-SSC Crocodile Specialist Group*. IUCN, Gland, Switzerland.

Vyas, R. 2018. Results of the 2015 Mugger Crocodile (*Crocodylus palustris*) Count at Vadodara, Gujarat, India. *Reptiles & Amphibians* 25: 20–25. https://doi.org/10.17161/randa.v25i1.14221.

Vyas, R. and C. Stevenson. 2017. Review and analysis of human and mugger crocodile conflict in Gujarat, India from 1960 to 2013. *Journal of Threatened Taxa* 9: 11016–11024. https://doi.org/10.11609/jott.3790.9.12.11016-11024.

Whitaker, N. 2008. Survey of human-crocodile conflict in Gujarat and Rajasthan: Trial of conflict mitigation education materials and further information on conflicts. Unpublished report to UNDP/GEF/SGP Project "Community based mitigation of human-crocodile conflict in India."

Woodward, A.R. and C.T. Moore. 1993. Use of crocodilian night count data for population trend estimation. Presented at the Second Regional Conference of the Crocodile Specialist Group, Species Survival Commission, IUCN – The World Conservation Union, held in Darwin, NT, Australia, 12–19 March 1993.