



Roads and Railways: An Emerging Threat to the Mugger (*Crocodylus palustris*) Populations of Gujarat, India

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Linear infrastructure, such as roadways, highways, powerlines, railway lines, and canals, is indispensable to the growth of a nation and its economy, but it also has detrimental environmental effects on both terrestrial and aquatic ecosystems (Jackson 2000; Raman 2011). It directly or indirectly causes fragmentation, habitat loss, the spread of invasive alien species, desiccation, windthrow, forest fires, animal injury and mortality, changes in animal behavior, anthropogenic changes including those related to tourism, hunting pressure, unchecked pollution, increased garbage, and other disturbances (Benítez-López et al. 2010; van der Ree et al. 2015).

Andrews and Jochimsen (2007) evaluated the effects of roadways and railways on herpetofauna. These threats have a direct impact on reptilian fauna, including crocodylians, for which crocodile-vehicle collisions (CVC) have been documented for ten species: American Crocodile (*Crocodylus acutus*) in southern Florida, USA (Kushlan 1988; Brien et al. 2008); American Alligator (*Alligator mississippiensis*) in Mississippi (Flynt 2008) and northwestern Florida, USA (Aresco 2009); Australian Freshwater Crocodile (*Crocodylus johnsoni*) in Australia (ABC Radio Darwin 2016); Cuvier’s Dwarf Caiman (*Paleosuchus palpebrosus*) and Schneider’s Smooth-fronted Caiman (*Paleosuchus trigonatus*) in Rondonia, Brazil (Campos et al. 2012); Spectacled Caiman (*Caiman crocodilus*) in the Magdalena Valley, Colombia (Ramos and Meza-Joya 2018); Yacare Caiman (*Caiman yacare*) in Brazil (Fischer et al. 2018); Saltwater Crocodile (*Crocodylus porosus*) in southwestern Sri Lanka (Amarasinghe et al. 2015); West African Dwarf Crocodile (*Osteolaemus cf. tetraspis*) in Benin, Nigeria (Chi 2016); and Mugger Crocodile (*Crocodylus palustris*) in India (Vyas 2011; Sharma et al. 2021).

The Mugger is one of the most adaptable and widely distributed crocodylian species in western Asia, with a range that includes Iran, Pakistan, India, Bangladesh, Bhutan, Nepal, and Sri Lanka (Da Silva and Lenin 2010). It is categorized

as Vulnerable (VU) on the IUCN Red List (Choudhury and de Silva 2013). In India, this species is legally protected under Schedule I of the Indian Wildlife (Protection) Act. However, it has been depleted in Pakistan (Zafar and Malik 2018) and appears to be extinct in Bangladesh, Bhutan, and Myanmar (Da Silva and Lenin 2010). The species survives in some parts of its former range despite threats that include habitat destruction, fragmentation, and alteration, water pollution, and mortality from increasing fishing activity (Stevenson 2019). However, CVC deaths and their consequences for Muggers have been addressed as an emerging threat to the species across its entire range (Vijaykumar 1997; Mobaraki and Abtin 2007; Vyas 2011; Joshi 2013; Vyas and Vasava 2019; Parchizadeh 2019; Vyas et al. 2020; Sharma et al. 2021).

Methods

Gujarat (20°06'–20°42'N, 68°10'–74°28'E), on the western coast of India, is biogeographically and climatically

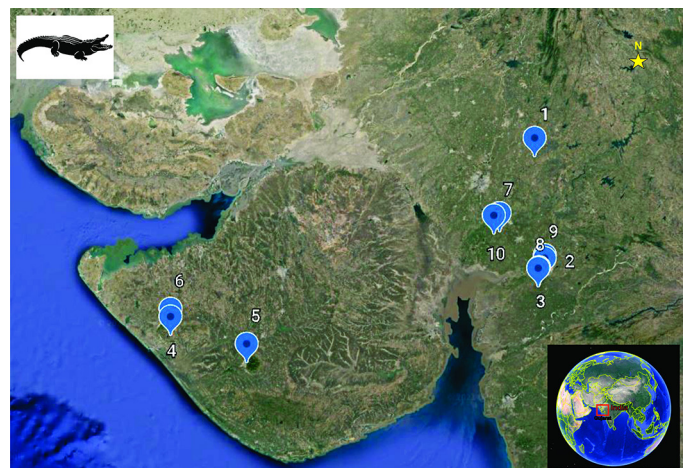


Fig. 1. Map of Gujarat, India, showing locations (1 to 10) where Mugger Crocodiles (*Crocodylus palustris*) were involved in a vehicle collision on either a road or railway track. Collision site numbers and details as in Table 1.

Table 1. Muggers (*Crocodylus palustris*) involved in road and railway collisions in Gujarat, India, in 2020. March–June = summer; July–October = Monsoon. All were juveniles except the two individuals with total lengths ≥ 300 cm killed in March. All died as a consequence of the collision except one juvenile female that was treated successfully and released into the Vishwamitri River (*) and a juvenile male that succumbed to its injuries after treatment (**). See also Fig. 1.

	Date	Location (District) (road or rail) Coordinates	Sex and Size (cm)
1	21 March	Ghodanal-Dabha Vatrak Bridge (Aravalli) (road) 23°12'54.52"N, 73°05'57.05"E	F (300+)
2	25 March	Janbuwa Railway Bridge (Vadodara) (rail) 22°12'26.37"N, 73°10'26.72"E	F (315)
3	23 April	Itola Railway Bridge (Vadodara) (rail) 22°08'55.35"N, 73°09'23.24"E	M (130)
4	21 June	Nr. Ramgadh, Ranavav (Porbandar) (road) 21°48'01.50"N, 69°48'29.38"E	M (105)
5	23 June	Nr. Wilengdon Dam (Junagadh) (road) 21°30'14.90"N, 70°28'46.90"E	M (47)
6	24 June	Nr. Hanumangadh, Ranavav (Porbandar) (road) 21°47'22.02"N, 69°47'59.15"E	F (85)
7	3 July	Nr. Malataj, Malataj-Changa Road (Anand) (road) 22°35'09.13"N, 72°45'07.27"E	F (95)
8	20 August	Nr. Kashipur, Itola Railway Track (Vadodara) (rail) 22°07'05.46"N, 73°08'42.82"E	F (120)
9	8 September	Maretha, Railway Yard (Vadodara) (rail) 22°13'50.27"N, 73°10'31.86"E	F (110)*
10	1 October	Nr. Sojitra, Sojitra-Malataj Road (Kheda) (road) 22°35'07.10"N, 72°44'10.47"E	M (95)**

divided into five subregions; South, Central, North Gujarat, Saurashtra, and Kutch (for further details see Patel and Vyas 2019). We conducted this study around Vadodara in central Gujarat (22°18'33.16"N, 73°11'23.31"E), an area known for a flourishing Mugger population that coexists remarkably with humans (Vyas 2018a, 2018b), and provide new data on CVCs in 2020. We collected data from agencies including non-governmental organizations active in Mugger/reptile

rescues, the state forest department, and media (press/social). We also participated in rescue events to collect photographs and data on victims that include size, age, sex, health, and cause of the event as well as dates and times of the incidents, geolocation, seasonal information, and the number of animals injured/killed. Based on the published literature on Mugger growth and sizes (Whitaker and Whitaker 1984; Mobaraki et al. 2013), we classified Muggers with total lengths (TL)

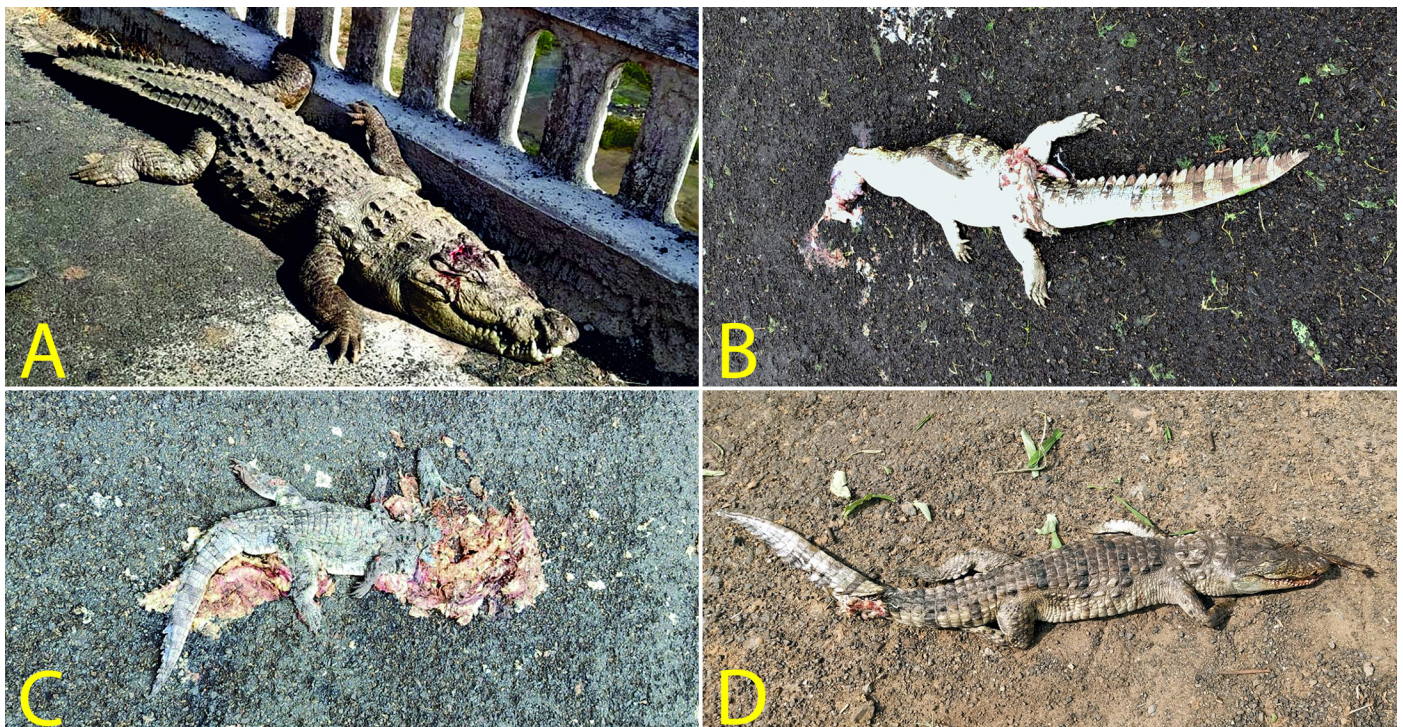


Fig. 2. Muggers (*Crocodylus palustris*) involved in vehicle collisions at various locations in Gujarat, India. Location (approx. size of the crocodile): (A) Ghodanal-Dabha Vatrak Bridge (300 cm); (B) Nr. Ramgadh, Ranavav, Porbandar (105 cm); (C) Nr. Hanumangadh, Ranavav (85 cm); (D) Nr. Malataj, Malataj-Changa Road (95 cm). Photographs by Suresh Patel (A), Dhaval Varigiya (B & C), and Vishal Mistry (D).

<180 cm as juveniles/subadults and those with TL \geq 180 cm as adults. In addition, we obtained information on Mugger rescues for 2020 from “Registered Mugger Rescues” data kept by the Range Forest Officer, Social Forestry Division Karelibaug, Forest Department, Vadodara, as part of overall urban wildlife rescue data.

Results

During the twelve-month study period, we recorded ten CVC incidents in Gujarat (Fig. 1) involving four males and six females, of which eight were juveniles (TL 47–130 cm) and two were large adults (TL >300 cm; Table 1). Six of the ten CVCs occurred on roads (national highways to village roads; Fig. 2) and four were on broad-gauge railway lines; Fig. 3). Two of the juveniles were found alive with injuries (Fig. 4), but after medical attention and recovery treatment, only one recovered and was released into suitable habitat. Six of the CVCs occurred during summer months and four during

the monsoon season; no CVCs were recorded during winter months.

According to the registry of Mugger rescues during 2020, 144 Muggers of various size (50 juveniles + 77 subadults + 17 adults) were rescued from human settlements in and around Vadodara. These included six juveniles rescued from tracks and railway stations without collisions (Table 2). The greatest number of rescues were in August ($n = 27$), whereas only one rescue occurred in February. Most rescues ($n = 81$) were during the monsoon and the least number ($n = 25$) were in winter (Fig. 5).

Discussion

Although documented Mugger CVC mortalities are but a fraction of the overall number of rescues, they cannot be regarded as a negligible threat — instead, the number of rescues and relatively small number of CVCs are indicative of positive mitigation measures. If the six juvenile Muggers



Fig. 3. Muggers (*Crocodylus palustris*) involved in railway collisions at two locations in Gujarat, India. Location (approx. size of the crocodile): (A) Near Janbuwa Railway Bridge (315 cm); (B) near Itola Railway Bridge (130 cm). Photographs by Arivand Pawar.

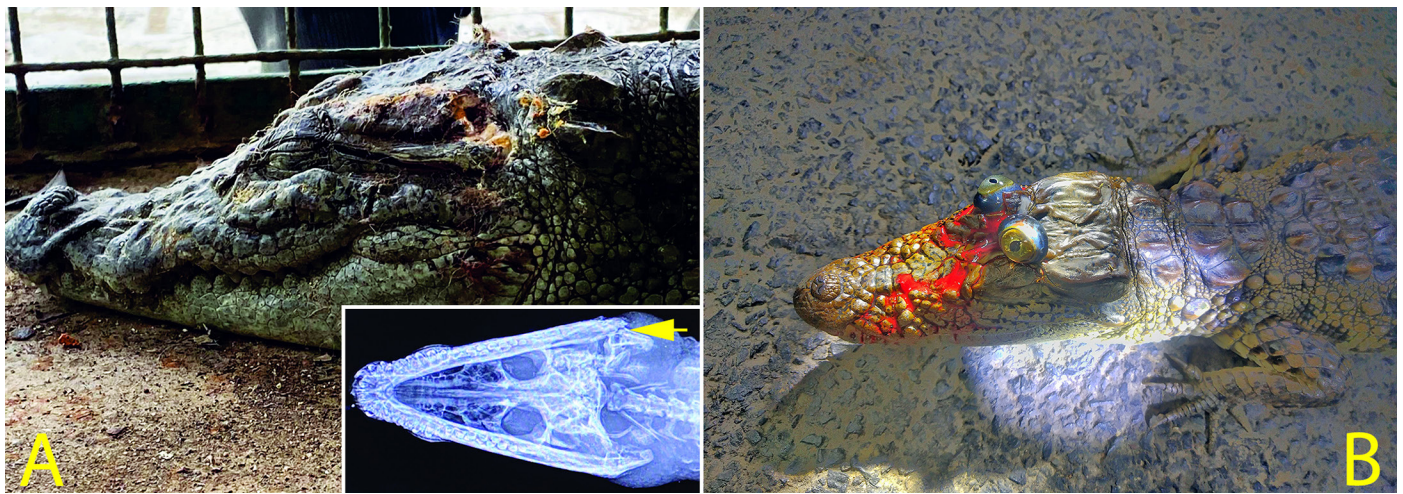


Fig. 4. Muggers (*Crocodylus palustris*) with minor head injuries: (A) On the road at the Maretha Railway Yard, Vadodara, Gujarat, India (inset: x-ray of head with arrow marking fractures at the mandibular joint); (B) near Sojitra, Sojitra-Malataj Road, Kheda, Gujarat, India. Photographs by Hemant Vadhawana (A) and Ajay Mahida (B).

Table 2. Muggers (*Crocodylus palustris*) rescued from railway stations and tracks in Vadodara, Gujarat, India, in 2020.

	Date	Location (coordinates)	Size (cm)
1	10 May	Kelanpur Railway Crossing Gate (22°14'21.83"N; 73°16'12.29"E)	135 cm
2	15 August	Makarpura Railway Line, Makarpura (22°15'11.53"N; 73°10'36.95"E)	150 cm
3	16 August	Makarpura Railway Crossing Gate (22°13'50.79"N; 73°10'32.35"E)	75 cm
4	15 November	Makarpura Railway Line, Nr. Maneja (22°13'46.71"N; 73°10'32.14"E)	90 cm
5	15 November	Makarpura Railway Station (22°14'01.16"N; 73°10'32.87"E)	30 cm
6	24 November	Kelanpur Railway Station (22°14'27.56"N; 73°16'09.59"E)	105 cm

rescued from railway tracks and stations in and around Vadodara had not been rescued promptly, they likely would have become CVC casualties. Fortunately, in light of the sizeable Mugaer population in Vadodara, Mugaer rescues are quite common (Vyas 1994, 2005, 2010, 2012), especially during the rainy season when the Vishwamitri River frequently floods low-lying areas. However, the trends apparent in the ten-year Mugaer CVC data from Gujarat show a gradual increase in deaths (Fig. 6), and CVC incidents affect not only Muggers but many other reptilian species in protected and non-protected areas of Gujarat (Vyas 2000, 2001, 2002, 2004, 2007; Parasharya and Tere 2007; Prajapati 2016; Vyas et al. 2017).

Gujarat is home to some of the fastest-growing economic zones in India, with a variety of ambitious proposed and ongoing inter- and intrastate projects that include expansion of express highways, dedicated freight and highspeed bullet train corridors, and the Narmada Canal Network. Although infrastructure development is inevitable with the growth of any economy, we suggest that this inevitability should not be pursued at the cost of ecological balance, with short-term economic gains taking priority over long-term ecological sensitivity.

Globally, crocodylian CVCs have been documented in 37% of species (Grigg and Kirshner 2015), indicating that the threat is widespread and particularly acute where concentrated crocodile populations intersect with rapidly developing transport corridors. Also, we believe that these few records of CVCs in a relatively small area are but the tip of an iceberg, that a majority of CVCs occur in undocumented localities, and that the prevalence and effects of CVCs are much greater than our data would suggest, not only for a highly visible apex freshwater predator but also for more obscure components of affected ecosystems.

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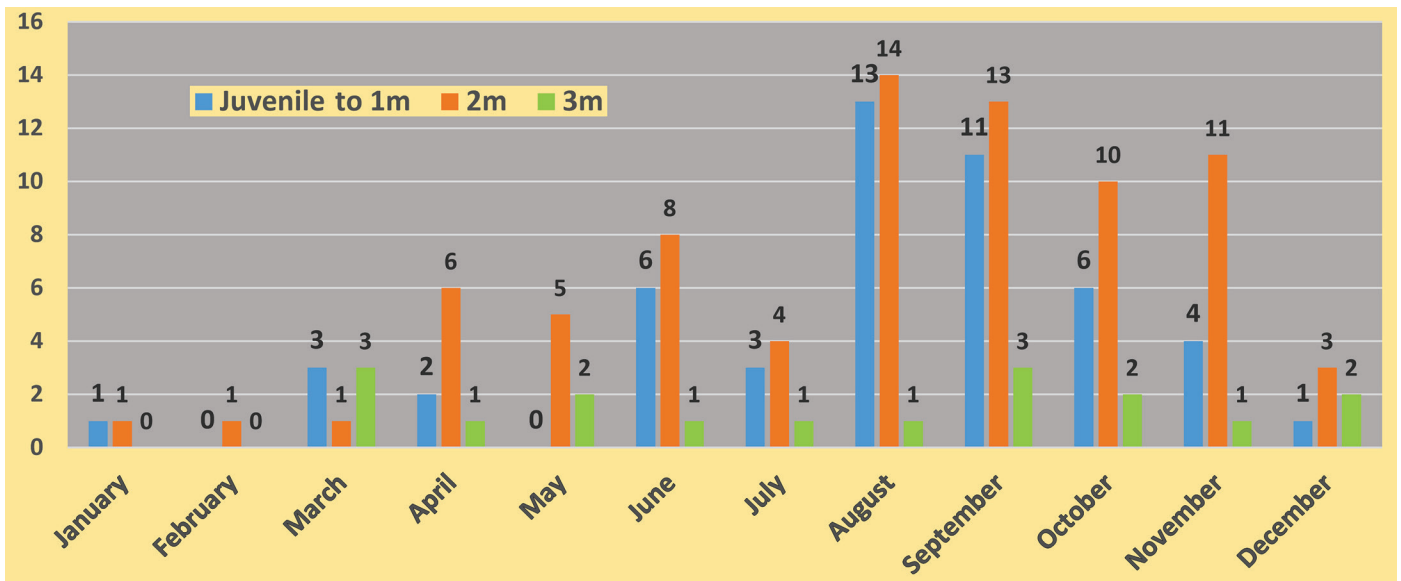


Fig. 5. Muger (*Crocodylus palustris*) rescues by month in urban areas of Vadodara, Gujarat, India, during 2020.

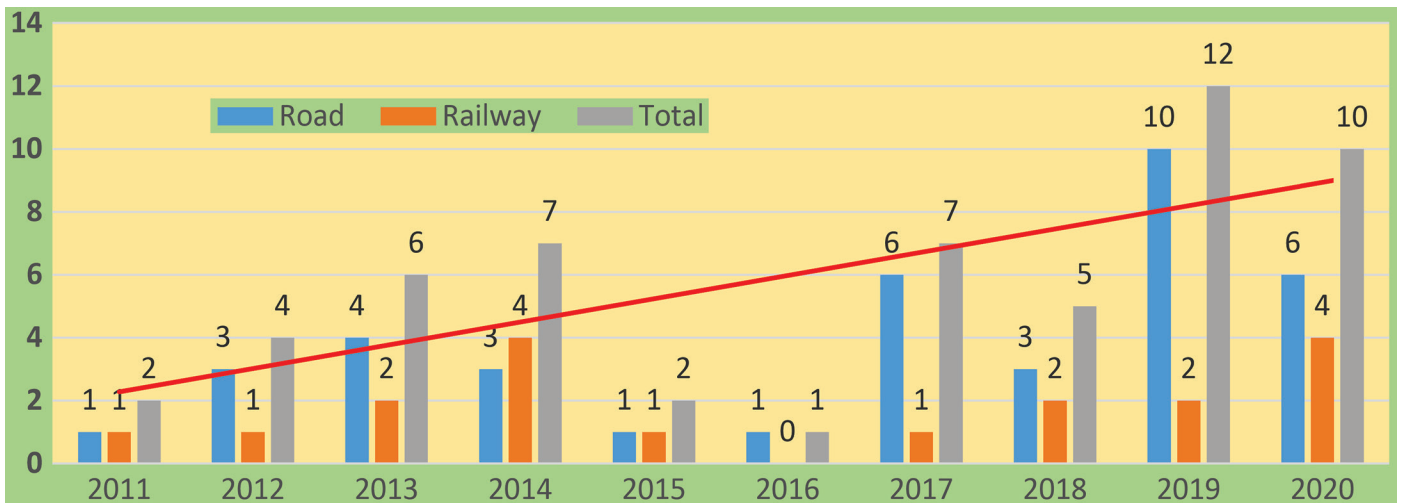


Fig. 6. Ten years of Muger (*Crocodylus palustris*)-vehicle collisions on roads and railways in Gujarat, India.

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