Deaths of mugger crocodiles *Crocodylus palustris* falling from small dams in Gujarat, India

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The mugger or marsh crocodile (*Crocodylus palustris*) is one of the most adaptable and widely distributed crocodilian species in south Asia (Choudhury & de Silva, 2013). In India it is considered 'Vulnerable' under IUCN Red List criteria and is protected under Schedule I of the Wildlife (Protection) Act, 1972. In the Indian state of Gujarat, the mugger population is facing various threats, including water pollution, habitat loss and encroachment, river-side developments, tourism, and the pet trade (Vyas, 2010). Some of the recently noted direct threats to the species involve the trade of crocodile parts as aphrodisiacs (Vyas, 2017), crocodile-vehicle collisions (Vyas, 2011, 2014; Vyas & Vasava, 2019; Vyas et al., 2020a), and entanglement or ingestion of discarded plastic waste (Vyas et al., 2020b).

In this account we document the sudden and tragic deaths from 2000 to 2020 of 11 mugger crocodiles at five small dams (Table 1 & Table 2) in the Saurashra region of Gujarat State. It would appear that these deaths resulted from falls caused by flash-flood waters over the dam walls. In 2019, five cases were recorded at the Willingdon Dam involving individuals (2M:3F) ranging in length from 1.66 to 2.51 m (snout to tip tail length) which were found dead having fallen from the reservoir (Table 1; Fig. 1). Earlier, on 25th August 2018, a large male mugger, measuring 2.4 m in length was found in a severely injured condition near the base of the Willingdon dam. The injured animal had a large hump on its back and its snout covered in blood clots. Due to the severity of injuries, the animal was unable to move and given the location where it was found it can be assumed to have fallen from the dam. This is consistent with the fact that on the previous night water had overflowed the 13 m retaining wall of the dam. Soon after the injured animal was found, it was shifted to a nearby local veterinary facility for further treatment and clinical care (Dr Vaibhasingh Dodiya, College of Veterinary Science and Animal Husbandry Junagadh, with advice from a renowned crocodile expert veterinarian Dr Gowri Mallapur). An X-ray showed signs of multiple injuries and fractures to vertebrae and ribcage (Fig. 2A to C). Unfortunately, the injured animal did not recover and died after three weeks of intensive care and treatment.

In the past, similar mugger deaths have been recorded at three other man-made water bodies (Vyas, unpublished records); Dhola Dhuna dam, Gothadad dam (Barda hills) and Singoda dam (Gir forest) (Table 1). The last two water bodies are known to hold breeding populations of the species;

 Table 1. Dead or injured mugger crocodiles (C. palustris) found at various small dams in Gujarat (India)

No	Date	Mugger total body length in cm	Gender	Condition
	Dhola Dhuna dam			
1	2nd September 2000	200	Female	Dead
	Gothadad dam			
2	20th August 2001	250	Male	Dead
	Singoda dam			
3	8th August 2012	300	Male	Dead
4	14th September 2015	210	Female	Dead
	Willingdon dam			
5	25th August 2018	240	Male	Badly injured*
6	7th August 2019	185	Female	Dead
7	9th August 2019	200	Male	Dead
8	11th August 2019	180	Female	Dead
9	17th August 2019	251	Male	Dead
10	27th August 2019	166	Female	Dead
	Hasnapur dam			
11	27th August 2020	227	Female	Dead

*animal died after 3 weeks of intensive treatment

Gothadad dam contains over 12 muggers and Singoda dam contains over 66 muggers. This makes Singoda dam home to the second-largest mugger population within Gir Wildlife Sanctuary & National Park (Vyas, 2019). Victims may have been washed out during flooding and been killed when washed over the high dam walls. In the absence of roller brackets, or where the brackets are damaged, these muggers seem likely to have hit the hard ground directly leading to trauma and ultimately death.

Crocodile movements across aquatic habitats are influenced by water level and are seasonal (Campos et al., 2006; Campbell et al., 2013). Large hydroelectric dams modify water-level regimes (Magilligan & Nislow, 2005) but there hasn't been any specific research demonstrating the impact of fluctuations in the water-levels of large-dams on the movement of crocodilian fauna. However, there have been reports of the movement patterns of Nile crocodile (*Crocodylus niloticus*) after the construction of Pongolapoart dam, South Africa (Champion & Downs, 2017) and the effects of dam construction and operation in the Brazilian Amazon on Table 2. Salient features of small dams in Gujarat (India) where dead or injured muggers (C. palustris) have been found

Name of the Dam, District	Geo-coordinates	Height (m)	Area of reservoir (km²)	River	Use of water body	Remarks
Dhola Dhuna Check dam, Jamnagar	21°50'43.24"N; 69°44'18.02"E	7.5	0.6	Kileshwari River	Percolation, water conservation	Barada Wildlife Sanctuary, no water roller backets
Gothadad dam, Porbandar	21°46′44.64″N; 69°43′57.27″E	8.5	2.5	Bileshwari River	Percolation, water conservation	Barada Wildlife Sanctuary water roller backets damaged
Singoda dam Juna- gadh	21° 1'21.52"N; 70°46'37.06"	14.7	5.5	Singodi River	Percolation, water conservation, irrigations	Gir Sanctuary & National Park, water roller backets damaged
Willingdon dam, Junagadh	21°30′16.82″N; 70°28′49.16″E	12.9	1.5	Kalwa River*	Water supply for Junagadh City	Girnar Wildlife Sanctuary, water roller backets damaged
Hasnapur dam, Junagadh	21°34′13.16″N; 70°31′8.03″E	11.5	4.25	Lol River*	Water supply for Junagadh City	Girnar Wildlife Sanctuary, water roller backets damaged

*a tributary of Uben River



Figure 1. A. Willingdon dam on the outskirts of Junagadh city, on 17th August 2020, **B**. A 2.5 meter-long mugger (*C. palustris*) found dead after falling over 13 m from the dam wall, **C.** Local forest staff and volunteers of an NGO making efforts to recover the crocodile's dead body for postmortem diagnosis

the movements of the dwarf caimans *Paleosuchus trigonatus* and *Paleosuchus palpebrosus* (Campos et al., 2017) and black caiman Melanosuchus niger (Campos, 2019). Crocodilians are long-lived and most species are strongly territorial by nature (Lang, 1987). Consequently, dam construction may severely disrupt home ranges, possibly resulting in individuals dispersing into nearby water bodies or catchment areas where they are at increased risk of death from dam turbines or floodgates (Campos, 2015). Furthermore, changes in water levels may reduce opportunities for nest building (Magnusson & Lima, 1991; Mourão & Campos, 1995; Campos, 2019). Even though the water-filled dams displace crocodilians from their home ranges, most individuals eventually re-established themselves near their original sites which increases their risk of mortality from encounters with dam turbines and floodgates.

Larger dams, certainly those in Amazonia, directly affect local populations of crocodiles (Benchimos & Peres, 2015). And yet, the impact of smaller dams or man-made reservoirs on crocodilians remains little known. In the case of our study,



Figure 2. The injuries of a 2.4-meter-long male mugger (*Crocodylus palustris*) that fell from the Willindon dam in 2018 **A.** The crocodile with a humped back, **B.** X-ray in dorsal view (red arrow shows bones facture and red circular marks gastroliths), **C.** Lateral view of multiple fractures on the spinal vertebrae and rib-cage (red arrow shows same bone facture as in B.)

the numbers of accidental deaths associated with such dams is relatively small but this is an emergent threat that requires further research so that it can be properly quantified and appropriate conservation actions identified.

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