Status of Mugger Crocodile (*Crocodylus palustris*) in National Chambal Sanctuary after thirty years and its implications on conservation of Gharial (*Gavialis gangeticus*)

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Abstract

During thirty years of observation from 1984 sighting of mugger crocodiles (*Crocodylus palustris*) have increased more than 12-times from 33 and their spatial distribution have expanded to the entire river in National Chambal Gharial Sanctuary (NCS). In this period sighting of gharial has increased less than two-fold from 605. Reducing water level in upper reaches of Chambal and certain or several other critical changes in the habitat prior to 2008-09 may have triggered and intensified ecological and behavioural changes. As a result, from 2011 onwards sighting of mugger crocodiles in the stretch of river downstream of Rajghat have surpassed sightings in upper reaches of the river. The programme on conservation of gharial (*Gavialis gangeticus*) in river Chambal, now over 35 years, warrants review and fresh planning because of intensified human dimensions and threat from the fast-growing population of mugger crocodiles.

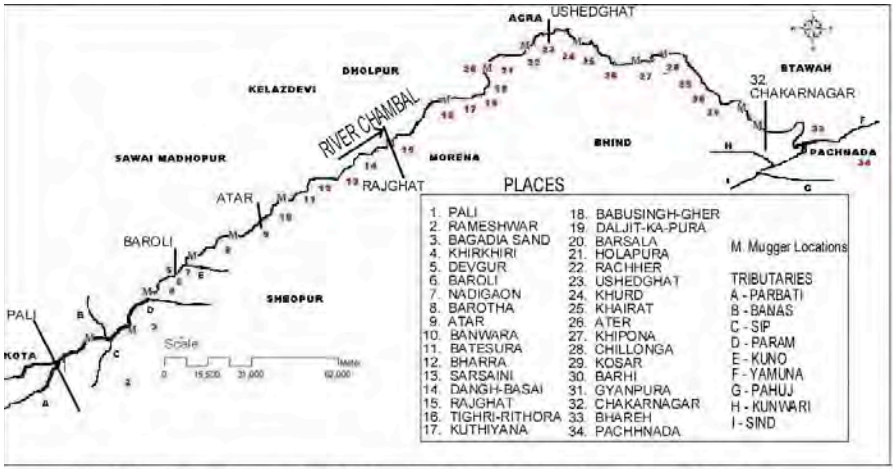

Fig 1. National Chambal Sanctuary over River Chambal with major locations of mugger sighting during 2014

Introduction

The programme for conservation of Indian crocodilians (FAO, 1974; Bustard 1981, 1999; de Vos 1982; Singh 1984) is one of the best examples of *in situ* and *ex situ* management that gradually expanded and became the trend setter for several first-time activities in the wildlife sector in India (Singh 1999). After forty years the highly regarded crocodile scheme appears to be languishing due to its own successes (Singh 2014b).

Now, the endangered Gharial (*Gavialis gangeticus*) in NCS needs a fresh set of conservation actions in view of impending threats from the sympatric mugger (*Crocodylus palustris*). Singh (1991) ascribed mugger crocodiles as one of the factors for non-survival of gharial in its niche in river Mahanadi, Odisha, and gone to the extent of commenting that disappearance of gharial from all its range in the peninsular India may have been due to competitions in the long past with an 'evolution-young' and 'more-versatile' mugger which returned to or invaded the perennial rivers in geological times.

In the present paper, we have examined thirty years data on status of mugger crocodile in river Chambal and infer from spatial distribution that niche transfer from gharial to mugger have started here. In this context, we have taken forward some of the suggestions from Singh (2014a) for river Mahanadi and offer a few management prescriptions that could slow down dominance of mugger crocodile and protect populations of gharial in Chambal.

National Chambal Gharial Sanctuary

The National Chambal Sanctuary (NCS) (Fig.1) was constituted in 1979 encompassing a stretch of 572km of river Chambal within the administrative functions of the states of Rajasthan, Madhya Pradesh and Uttar Pradesh. The objective was for ensuring the best possible future for gharial in India.

In 1983 Government of India established the Crocodile Field Research Unit at Deori campus of NCS in Madhya Pradesh. From this time onwards annual monitoring of gharial and incidental collection of ecological and biological data on other wetland fauna have been possible. Some of the work are described in Singh and Sharma 1984, 1985; Singh 1985; Rao and Singh 1987 a,b,c; and Sharma and Singh 2014. One of us (RKS) has remained consistently associated with the research work in NCS.

Sympatric Gharial and Mugger

Mugger crocodiles (*C. palustris*) were usually very few when they occurred in habitats known for gharial population (FAO 1974; Singh 1985:82; Singh 1991; Rao and Choudhury 1993). A general consensus was reached at Katerniyaghat Symposium on Crocodile Conservation in 1979 (Singh and Choudhury, 1982) that captive reared mugger crocodiles will not be released in any gharial

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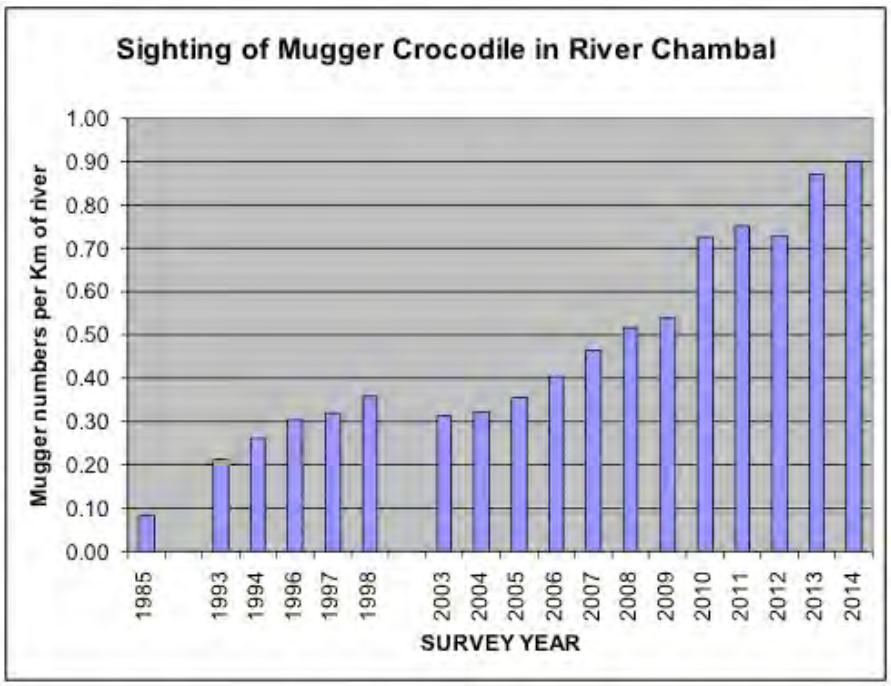

Fig 2. Sighting-Trend of Mugger Crocodile (*Crocodylus palustris*) in River Chambal during the period 1984-85 to 2014

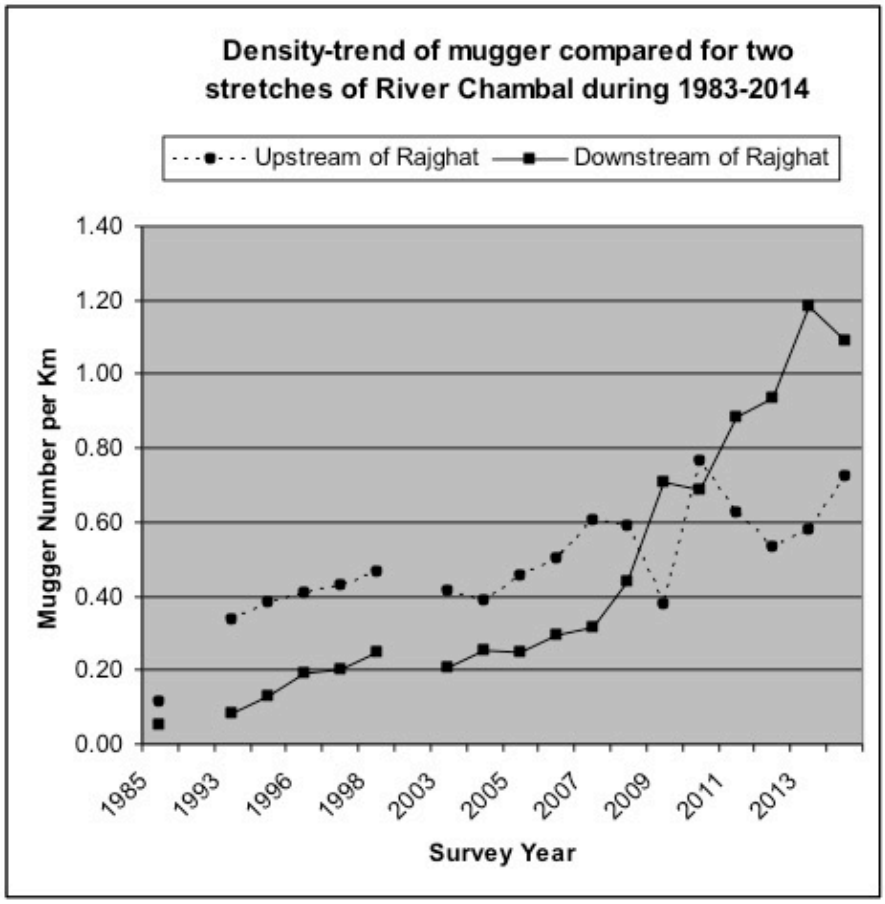

Fig 3. Density-Trend of Mugger Crocodile (*Crocodylus palustris*) compared for two broad stretches of River Chambal during the period 1984-85 to 2014

habitat, a view that has been consolidated from time to time (Singh 1985:116-117; Rao 1992; Rao and Choudhury 1993).

Mugger in Chambal: Literature overview

The NCS includes a stretch of River Chambal from Jawahar Sagar Dam to Kota Barrage, and then after a non-sanctuary zone of 18km, the sanctuary continues from Keshoraipatan to Pachhnada (Singh 1985: 4-5). The status of mugger in the main river of Chambal prior to 1984 is sketchy. Whitaker *et al* (1974) and Dr H. R. Bustard (in FAO 1974) approached the river from Kota and reported about the 'presence of mugger crocodile' in river Chambal at Gandhi Sagar Dam and Jawahar Sagar Dam in Rajasthan. Dr Bustard (in FAO, 1974, page-3) quoted Col. K.K. Singh who shot about a hundred crocodiles on a boat journey from Kota to Pali, and there were 50-60 gharial. Although no date can be traced to this event, it was apparently during the young days of Col. Singh, a few decades before 1974, when Dr. Bustard talked to him. Allowing possible favor shown in discussion for gharial perhaps there were equal or more numbers of mugger in the hunt in river upstream of Pali.

In February-March 1984, we (LAKS and RKS) surveyed Chambal from Kota barrage to Pali with participants from Rajasthan and Madhya Pradesh (Singh 1985:129-135). The survey team neither sighted nor collected any recent evidence of either gharial or mugger crocodile. All information referred to 'three to four years before 1984'.

Although the limits of NCS start at Kesoraipatan, about 18km downstream the Kota barrage, the river downstream of barrage was nearly dry or had very little water and the rocky bed was exposed. Water flow improved after the confluence of Chambal and Kali Sindh (Singh 1985: page 130), which is 82km after the barrage. On the whole, the river didn't permit a smooth experience of survey by boat. Singh (1985:

Table 1. Mugger crocodiles sighted in size class less than 60cm during 'day-survey' of River Chambal

Year	Numbers of Mugger Crocodiles <60cm sighted	% of mugger less than 60cm in total sightings
1993	07	7.7
1994	07	6.4
1995-96	06	4.8
1996-97	09	6.7
1997-98	12	7.8
2003	08	6.1
2004	11	7.9
2005	15	9.7
2006	18	10.2
2007	03	1.6
2008	07	3.3
2009	06	2.7
2010	09	3.0
2011	08	2.6
2012	07	2.4
2013	12	3.4
2014	22	5.8

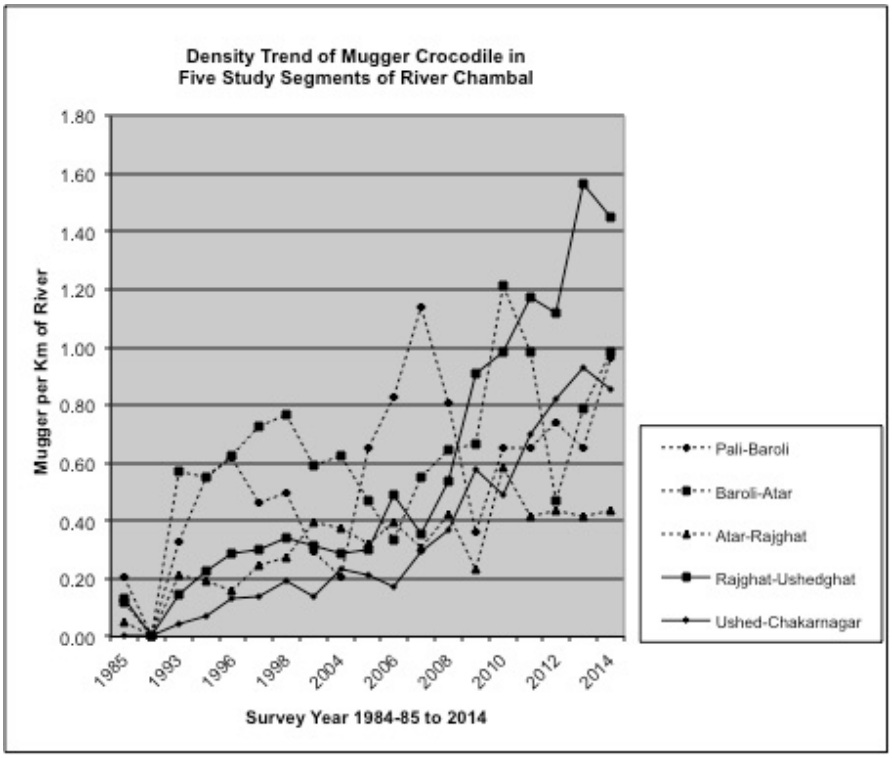

Fig 4. Density Trend of Mugger Crocodile (*Crocodylus palustris*) in five 'study segments' of River Chambal during the period 1984-85 to 2014

page 131) mentioned that the river downstream of Keshoraipatan near Miana / Dhiroli (115km from Kesoraipatan) appeared to have good potentialities to form mugger stretches.

Methods

Sources of information for this paper are drawn from our survey started in 1983-84 and continued in subsequent years when one of authors (RKS) remained associated all along. The study area focused for the present paper is from Pali to Chakarnagar, a river length of 395km (Fig.1).

The method for survey of the river habitat of Chambal is basically the same as described in Singh (1985) and Sharma and Singh (2014). On-boat-surveys were carried out from upstream towards downstream during day time. In the year 2006 sighting of <60cm crocodiles was 10.2% of the total. In other years sightings were less than 10% (Table-1). Therefore, all data presented in this paper refer to crocodiles above 60cm body length. Published information on mugger sightings (Sharma 1993, 2006; Sharma and Mathur 1999; Sharma *et al* 1995, 2013) in which one of us (RKS) is associated, are used to complete time series data, where required.

Data on mugger sightings are compiled under five 'study-segments' namely, Pali-Baroli (58km), Baroli-Atar (51km), Atar-Rajghat (94km), Rajghat-Ushedghat (76km) and Ushedghat-Chakarnagr (116km) (Table-2). These segments confirm to certain landmark locations and/or distinct navigable stretches of the river. Rajghat is the point where the bridge across Chambal marks continuity of National Highway Number-3. This location is 15km from the research base at Deori in Morena District, and is a major hub of human activities on the banks of Chambal. Therefore, for more focused analysis and interpretation the study segments are clubbed under two 'stretches', Pali to Rajghat in the upstream including three segments and Rajghat to Chakarnagar including two segments in the downstream. These two 'river stretches' are 203km and 192km in length. Pali is considered as the zero-km point for distance reference.

Results

In the past thirty years mugger sighting has gradually increased in Chambal (Table-2, Fig.2). It was

Table 2. Numbers of mugger (above 60cm body length) sighted in five 'study segments' of River Chambal during the period 1983-84 to 2014

	Segments upstream of Rajghat (203km)			**Segments downstream of Rajghat (192km)**		
Year	**Pali-Baroli (58km)**	**Baroli-Atar (51km)**	**Atar-Rajghat (94km)**	**Rajghat-Usedghat (76km)**	**Usedghat-Chakarnagar (116km)**	**Entire length of river**
Distance (km) in reference to Pali	**0-58**	**58-109**	**109-203**	**203-279**	**279-395**	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1983-84	Survey not done		6	13	0	19
1984-85	12	6	5	10	0	33
Total 1984-85	**69.7%**			**30.3%**		
1993	19	29	20	11	5	84
1994	32	28	18	17	8	103
1995-96	36	32	15	22	15	120
1996-97	27	37	23	23	16	126
1997-98	29	39	26	26	22	142
Total in 1997-98	**66.2%**			**33.8%**		
2003	17	30	37	24	16	124
2004	12	32	35	22	27	128
2005	38	24	30	23	25	140
2006	48	17	37	37	20	159
2007	66	28	29	27	34	184
2008	47	33	40	41	43	204
2009	21	34	22	69	67	213
2010	38	62	55	75	57	287
2011	38	50	39	89	81	297
2012	43	24	41	85	95	288
2013	38	40	39	119	108	344
2014	56	50	41	110	99	356
Total in 2014	**41.3%**			**58.7%**		

33 crocodiles in 1984-85 and 356 in 2014. In 1984-85 for 12.0km river there was one sighting of mugger, in 1997-98 the length of river reduced to 2.8km for one sighting, and in 2014 it was one mugger every 1.1km of river (Table-3)

Sightings upstream of Rajghat have gradually decreased from nearly 70% of total in 1984-85 to 66% in 1998 and 41% in 2014 (Table-2). When the two stretches of river namely Pali-Rajghat (PR) and Rajghat-Chakarnagar (RC) were compared, the density of mugger described as numbers per km of river were PR:RC:: 0.11:0.05 in 1984-85, 0.46:0.25 in 1997-98 and 0.72:1.09 in 2014 (Table-3, Fig.3), suggesting gradual and relative increase in RC-segment (Rajghat-Chakarnagar).

In RC-segment (Rajghat-Chakarnagar) on an average only one mugger sighting was recorded over 19.2km of the river in 1984-85, and 4.0km in 1998 but in 2014 it was one sighting every 0.9kilometer (Table-3). From the year 2009 the rate of mugger sighting along RC-segment surpassed that in PR segment. From 2011 onwards the higher density of mugger became clear in RC segment (Fig.3). In 2011 there were 170 out of 297 or nearly 57% of total sightings downstream of Rajghat (Table-3). In 2014 the RC segment recorded 209 out of 356 or approximately 59% of the sightings.

Between 1984-85 and 2014 each of the five study segments recorded different patterns of increase in sighting (Table-2, Fig.4), and in 2014 the RU-segment (Rajghat-Ushedghat) of 76km provided the highest sightings, 110 out of total 356, or 31% of total sightings (Table-2). In 1993 this stretch recorded 11 out of 84 or 13% sightings, and in 1998 it was 26 out of 142 or 18% sightings.

Discussion

There are two distinct inferences from data on sighting of mugger in NCS for thirty years from 1984. First, sightings have increased in the entire river, and second, sightings in the stretch of river downstream of Rajghat have surpassed the stretch in the upstream. Both these observations point towards growing dominance of mugger in Chambal.

Table 3. Trend of density of mugger in River Chambal during 1984-85 to 2014

Year	Numbers of mugger			Average distance (km) of river for sighting one mugger			Mugger density (Numbers of mugger per km)		
	Entire river 395km	Pali-Rajghat 203km	Rajghat-Ch.Nagar 192km	Pali-Rajghat	Rajghat-Ch.Nagar	Entire river	Pali-Rajghat	Rajghat-Ch.Nagar	Entire river
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1984-85	33	23	10	8.8	19.2	12.0	0.11	0.05	0.08
1993	84	68	16	3.0	12.0	4.7	0.33	0.08	0.21
1994	103	78	25	2.6	7.7	3.8	0.38	0.13	0.26
1995-96	120	83	37	2.4	5.2	3.3	0.41	0.19	0.30
1996-97	126	87	39	2.3	4.9	3.1	0.43	0.20	0.32
1997-98	142	94	48	2.2	4.0	2.8	0.46	0.25	0.36
2003	124	84	40	2.4	4.8	3.2	0.41	0.21	0.31
2004	128	79	49	2.6	3.9	3.1	0.39	0.26	0.32
2005	140	92	48	2.2	4.0	2.8	0.45	0.25	0.35
2006	159	102	57	2.0	3.4	2.5	0.50	0.30	0.40
2007	184	123	61	1.7	3.1	2.1	0.61	0.32	0.47
2008	204	120	84	1.7	2.3	1.9	0.59	0.44	0.52
2009	213	77	136	2.6	1.4	1.9	0.38	0.71	0.54
2010	287	155	132	1.3	1.5	1.4	0.76	0.69	0.73
2011	297	127	170	1.6	1.1	1.3	0.63	0.89	0.75
2012	288	108	180	1.9	1.1	1.4	0.53	0.94	0.73
2013	344	117	227	1.7	0.8	1.1	0.58	1.18	0.87
2014	356	147	209	1.4	0.9	1.1	0.72	1.09	0.90

The reasons for overall improvement in sighting of mugger (Fig.2) in NCS could be due to cumulative results of good natural recruitment in upper reaches followed by dispersal towards downstream, restocking of captive reared muggers, or release of mugger crocodiles rescued from other areas. There are not enough records to support or dismiss these possibilities. Records on release of mugger in river Chambal are very casual or fragmentary (Rao and Choudhury 1993, The Hindu 2013). Because of some communication gap or the absence of an alternate choice, 28 muggers that originated from eggs collected in NCS were released near Pali in 1984 (Singh 1985:82). With emphasis on gharial and growing human dimensions the magnitude of threat from mugger was growing unnoticed.

1. Niche transfer from Gharial to Mugger

When first assessed, the river upstream of Pali already had good potentialities for growth of mugger population in 1984-85. It was not navigable and there were no gharial population, so river surveys in subsequent years usually started from Pali downstream. It is possible that with passage of time and reduction in water depth the fast-growing mugger population in upper reaches of Chambal dispersed downstream. Behaviour linked to territoriality and resource partitioning mugger crocodiles may disperse (Singh 1992).

Katdare *et al* (2011) warned that National Chambal Sanctuary appears drifting towards fragmentation and isolation. The team surveyed 104 km of river Chambal from Pali in the downstream during three consecutive winter seasons in January 2008, December 2008 and December 2009. In this survey 87% of the gharial was sighted in the downstream termed as HPRA (High Population Recorded Area), and 59% of total mugger sightings were in the upstream. Such different patterns of gharial and mugger distribution point favourable conditions for mugger in the upper reaches of Chambal and that water depth influenced the spatial distribution of both the species in the study area of Katdare *et al*; (2011). In this context emphasis on environmental flow assessment in river basins hold high significance (Dyson, *et al* 2008).

Abundance of gharial in Chambal is discussed by Nair (2010) with statistical quantifications to habitat attributes including the influence of basking sites and greater water depth. Hussain (2009) and Hussain *et al* (2011) discussed about the impact of modifications happening to river morphology and highlighted the importance of water depth and the minimum water flow required in an ideal gharial habitat. Taigor (2007) and Taigor and Rao (2008, 2010) have highlighted how various human dimensions like sand-mining, fishing and agriculture were becoming prominent in Chambal and were not favourable for gharial conservation.

In 1984 (Singh 1985:113) there were a total of 605 gharials and the density was 1.42 gharial/km. At this time there were 33 mugger sightings with a density of 0.0776 mugger/km. By the year 2014, according to our present study the gharial sighting increased to 1088 from 605 in 1984-85, or increased by 1.79-fold while the mugger population increased from 33 to 390 or by 11.8-fold during the same period. By 2015 (RKS *pers. obs.,* and Saxena 2015), the gharial population has increased to 1150 or 1.9-fold but mugger population increased to 402 or 12.2-fold. Sharma and Basu (2004) highlighted the declining trend for gharial population in Chambal between 1998 and 2003. Our time series data indicate the possible appearance of some ecological scenario that developed towards steep rise in sighting of mugger crocodiles in lower Chambal around 2005-2009 (Fig.3 and Fig.4) onwards. This may be the time from when habitat fragmentation and reduction of water depth started becoming more acute in the upper reaches. Although the root cause is not yet clear, one major happening is also from December 2007 onwards when there are mortality of a large number of gharial without any clear reason (*For example,* Chauhan 2007; CSE 2008; GCA 2008; WWF-India 2008, Lang and Kumar 2013). Habitat-vacation of lower Chambal by gharial following mass mortality, and the new pattern of spatial distribution in mugger population indicate possible link between the two happenings. As a result, by the year 2014 the study segment Rajghat-Ushedghat, although only 76km or 19% out of total 395 study area, recorded 31% mugger sightings that too in lower Chambal.

These discussions indicate that transfer of niche from gharial to mugger has already started. The transfer appears to be the combined result of overall increase in mugger population in upper Chambal, decreased water flow leading to shifting of muggers towards downstream, and settlement of muggers in lower Chambal without much resistance, as gharials had vacated some space due to mass mortality. The link between gharial mass mortality and flourishing of mugger population in lower Chambal need further study. Gharials are timid but the strength for defending "basking and nesting resource" may be their group-basking behaviour, which is breaking down because of fragmentation of water flow.

2. Management of Overpopulated Mugger

One of the reasons for non-survival of gharial in river Mahanadi is the growth of mugger population in 'gharial niche' (Singh 1991, 2014a). The inferences from our study on mugger in NCS are alarming for the future of gharial. The National Gharial Sanctuary should not be surrendered to mugger crocodiles. Although mugger crocodile is known to lead peaceful coexistence in places used by cattle and people (Singh 1983) with growing human dimensions and increased human-interface chances for accidents increase. A few suggestions are made for managing overpopulated mugger in Chambal.

- The interface of mugger with humans for tourism, fishing has to be avoided or reduced.
- Research pertaining to mugger may be encouraged under provisions of the Wildlife (Protection) Act, 1972.
- Natural nests of mugger should be left for natural process. There should not be any egg collection with the intention for preventing depredation.
- If any wetland sanctuary outside Chambal can accommodate mugger attempts should be made to capture adult muggers from Chambal for such purpose. Captive breeding of mugger should not be encouraged.
- Tourists going for boating in river Chambal need to be educated. People must not hang their feet or hand out of the boat into water when the boat is moving. They must not throw unused meat or fish at camping places. They must not feed muggers. Such actions may create nuisance muggers for future. The carrying capacity for tourism in the river sanctuary should be properly judged (Singh 2013).

Since *G. gangeticus* are the oldest crocodilians and sole surviving member of an evolutionary line, it may be expected that the concept of "species senescence" (Simpson, 1953) may be operating with the gharial (Singh 1991). By 1974 gharial had come to near extinction because there were no quantitative data (Bustard 1999). Now data are available, and warnings are also made sufficiently ahead from field research on gharial as well as their ecological associates like *Platanista gangetica* (Sharma and Singh 2014) and *C. palustris* (this paper). Therefore, the programme on conservation of *G. gangeticus* in river Chambal, now over 35years, warrants review and fresh planning as there is intensified human dimensions and threat from the fast-growing population of mugger crocodiles. Rivers outside the Gangetic and Brahmaputra systems, which may have supported gharial population in historical or

evolutionary time could be surveyed for allowing gharial population to grow.

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