

Chambal Gharial Ecology Project –2016 Update

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Abstract

Ecological studies (2008-2016) of resident, wild gharial have been conducted in the National Chambal Sanctuary (NCS), north India, utilizing telemetry to record their movements, activities, and behaviours relevant to the die-off of 2007-08, and critical to the long-term conservation of the species. Major project activities from 2013 onward have been: 1) tracking gharial tagged in 2013 (20), in 2014 (7), and in 2015 (10), plus several immature muggers, tagged in 2013, 2) making detailed observations on crèches of gharial hatchlings, attended and guarded by adults, and 3) monitoring nesting as well as hatching success of gharial on the lower Chambal in the NCS.

Long distance seasonal movements of 200+ km are now well documented in the NCS population, indicating the importance of an open, dynamic river ecosystem. Adult females frequently move long distances upstream from monsoonal feeding sites, to breeding and nesting areas. Adult males have small, dry season residences and move less. In contrast, juveniles and subadults live throughout the year in restricted sections (<10 km) of river. GPS loggers incorporated with VHF tracking radios, capable of remotely downloading location data acquired over months, are providing fine scale movement and activity patterns for resident gharial, ranging in size from 2-5+m totl.

The exceptional hatchling care behaviors, exhibited by adult females and males guarding large crèches (100-1000+ hatchlings) have been documented in detail, with game cameras for weeks prior to the onset of monsoon. At nest colonies, one of the larger females is the dominant guardian; she attends groups of young at frequent intervals day and night. Also in attendance, and prominent especially when the young are threatened is a large ghara male who resides near the crèche. At times, both female and male guardians together attend and defend hatchlings. A male guardian is a regular feature of all large (>10 nests) hatchling crèches, but sometimes a male guardian is associated with smaller hatchling groups (2-4 nests/site). In several cases, “alloparental care” by guardian adults, other than one of the presumed parents, occurs. Overall, gharial social interactions and behaviours appear to be decidedly complex and markedly seasonal, and not restricted to particular ages, sizes, and/or sexes.

Nesting sites and hatching success on the lower Chambal (29-163 km from Yamuna confluence) has been tallied from 2010 onwards. Over 6 nesting seasons, 21 nest sites were utilized on this 134 km stretch, but nesting occurred in every year at only 2 sites. Nest location varies with local river topography, changes every monsoon depending on its intensity, occurs on high sand banks, adjacent to deep water, and is communal. In 2015, 153 nests were counted on lower Chambal, of which 124 hatched, producing 4500+ hatchlings. At 2 upstream sites, “industrial scale” sand mining occurred 24/7 from Sept into July, during nesting, incubation, and hatching of 27 nests, of 31 laid. Other immediate threats include water extraction and unregulated fishing with nets.

Introduction: Brief Synopsis of Gharial Conservation

Historically, the gharial (*Gavialis gangeticus*) inhabited the deep rivers of India, Nepal, Pakistan, Bangladesh, Bhutan, and Myanmar, but today the species is limited primarily to isolated pockets in northern India and Nepal (Whitaker & Basu, 1983; Whitaker et al., 2007). A recent rapid decline led to a "critically endangered" status in 2007 (Sharma & Basu, 2004; Choudhury, et al., 2007), followed shortly thereafter by an unexplained mass die-off (Whitaker et al., 2008; Huchzermeyer, et al., 2008). In response, the Gharial Species Recovery Plan was drafted (GCA, 2009), resulting in a CSG Action Plan (Stevenson & Whitaker, 2010) and a national plan for gharial conservation within India (NTRIS-CASMACC, 2011; GSRP, 2011) in which the Chambal River population is highlighted.

These conservation initiatives have their origins in the Indian Crocodile Conservation Project (Bustard, 1999; Choudhury, 1999; Singh, 1999), centered on range-state rehabilitation programs (Singh, 1979; Basu, 1980; Rao & Sharma, 1986). Captive breeding and head starting entailed egg incubation and rearing of all Indian crocodilians (Whitaker & Whitaker, 1984; Lang et al., 1989; Lang and Andrews, 1994; Andrews & Whitaker, 2004). For decades, the Chambal River system has contained the largest, self-sustaining gharial population (Rao, et al., 1995), and this region has been the focus of ecological studies (Singh, 1978, 1985; Whitaker & Basu, 1983; Rao, 1988; Hussain, 1999, 2009), and conservation landscape analyses (Hussain & Badola, 2001). Annual surveys have been conducted (Sharma, 1999; Sharma & Basu, 2004), augmented by recent surveys (Katdare, et al., 2011; Nair et al., 2012a,b). Interactions between mugger and gharial have been commented on at Katarniaghat (Choudhary, 2011) and in the Chambal system (Sharma and Singh, 2015). The Gharial Ecology Project, initiated in 2008 following the mass die-off of the winter of 2007-08, is now in its ninth field season (Lang and Kumar, 2013; Lang, 2016; this report). Recent commentaries on gharial conservation include Stevenson (2015) and Lang (2016).

Background

The Gharial Ecology Project, also known as the Gharial Telemetry Project, and summarized in Lang & Kumar (2013), was designed to investigate the mass die-off of gharials in the 2-4m size class, totalling 110+ individuals in the lower Chambal River, National Chambal Sanctuary (NCS).

Previously, 20 radio-tagged gharials have been tracked successfully through the annual monsoon and dry periods, for an average of 2+ years/animal, since June 2008 through August 2013. Individual gharials show different patterns of seasonal movement and residency, dependent on size/age. Adult males move as far as 80-120 km each to join dry season basking-breeding aggregations (>60 adults), and to locate suitable nesting areas. In contrast, sub-adult gharials moved little, only 10-30 km seasonally, and occupy residencies only 5-15 km. Most sub-adults are sedentary, virtually not moving, either upstream or downstream any time.

In July 2013, project continuation was approved to provide a comprehensive picture of the spatial and reproductive ecology of gharial and mugger living in the NCS. Permission was granted for 25 gharial and 5 mugger to be tagged and

monitored. Support from the international zoo community funded previous tagging and monitoring of radioed animals in 2013 and in 2014.

The overall study demonstrates that individual gharial utilize the entire river for specific habitats as well as corridors, and aims to provide baseline information on the status of gharial populations within the NCS. In 2015, the Gharial Ecology Project continued in two phases: a) monitoring radioed animals throughout the year, and b) capture and tag in November 2015. The tagged individuals serve as indicators of what other members in the population may be doing at different times of year. These animals provide a "window" on the specific daily behaviors and activities of the population as a whole. Detailed behavioral observations are routinely made on all gharial, as well as locating and tracking those with radio tags.

Long Distance, Seasonal Movements

The most exceptional result to date are the extraordinary distances some of the tagged gharial are moving each season, up and down the river, in seasonal patterns related to nesting. One of the tagged gharial moved 210 km downriver to the confluence where she remained during the monsoon. Previously, she moved upriver 100+ km to the site where she nested and protected hatchlings that emerged from her nest in early June (female 24; Table 3). After the monsoon, in late 2015, she moved back 210 km upriver to the same site where she remains, as of March 2016. A subadult female made similar movements to the same nesting site upriver, but returned during the monsoon, a distance of 180 km to the site where she was tagged in 2013 (female 66; Table 1).

Tracking Radio-Tagged Gharial

The international zoo community supported the final monitoring throughout the year for the remaining gharial and mugger tagged in November 2013. Their movements and activities are presented in Tables 1 and 2, and described in the following narrative. As late December 2015, it is noted that nearly all of these gharial and mugger no longer had functioning, trackable radios. Two juvenile gharial (90 & 94) were last recorded in January 2016. In particular, all of these animals were captured and tagged at a wide range of river locations, extending from 35 km downstream to 105 km upstream, or over approximately 70 km of river. Of special interest were 3 adults which included two adult females (50 & 54) and a young adult male (44/46). The movement patterns of these three adults contrasted markedly with the few adult females monitored in earlier groups (described and discussed in previous reports). This result, in turn, suggests that adults generally may show variable movement patterns, presumably related to differences in their sizes/ sexes/ ages and reproductive status.

The movement parameters for the 20 gharial and 2 mugger are shown in Tables 1 and 2. With the exception of the three adults referred to above (ID 44, 50, 54), the remaining 17 gharial consisted of 6 juveniles (4 females, 2 males; Table 1), and 11 subadults (3 females, 8 males; Table 3), ranging in size from 1.4 to 2.8 m total length. The two mugger crocodiles (*Crocodylus palustris*) were juveniles, a male and a female, both less than 2m total length. These animals were captured, tagged, and released at sites ranging from Gohera (103 km upriver from Yamuna-Chambal confluence) to Jagtoli (34 Km upriver from Y-C confluence), in areas frequented by gharial tagged earlier.

In total, for these 20 gharial, 1869 animal-specific locations have been recorded, and 224 instances for the two mugger, or 2093 locations overall during the past 2+ yrs. In general, juvenile gharial were located less frequently than were subadults; animal-specific locations averaged 80 locations/animal for six juveniles and 100 for eleven subadults, ranging from 11 to 143 for juveniles and from 57 to 140 for subadults. In fact, some individuals proved difficult to locate regularly, e.g., ID 92, 96, 40, and 58, while others were reliably located at frequent intervals, e.g., ID 60, 62, 90, 94. The two juvenile mugger were regularly tracked at frequent intervals, with 117 and 107 locations for 82 (upstream at Gohera; = 103 km) and 56 (downstream at Barecha; = 38 km), respectively. Monitoring was spaced evenly throughout the monitoring period, with 4-8 locations per animal per month (Tables 1 & 2).

In brief, nearly all of the tagged gharial exhibited restricted, seasonal movements, similar to the sedentary subadults that were monitored earlier in the 2010 radio-tagged group. The two adult females were the only notable exceptions. One of these, ID 50, though apparently not nesting in 2014, moved extensively up and down 50---64 km of river, from her capture site at Ater upstream to Rhea, at least several times back and forth during the study months. The other female, ID 54, moved mostly downstream to two potential nesting areas, Nachnouli (---18 km downstream) and Dinnpura (---12 km downstream) prior to the monsoon high water, and then during the monsoon shifted upriver +14 km to Gohera, just above her capture site, during the monsoon. Both females nested in 2015. Female 54 nested at Dinnpura (see Figure 47), and female 50 disappeared during the nesting/incubation/hatching period, but reappeared post monsoon back at Ater near where she was tagged. Unlike these two adult females living in the same general area, the young adult male (ID 44) showed no dry season movements, and only shifted +7 km upstream during the monsoonal months of July--September in both years monitored (Table 1).

The majority (11 of 17) of the recently---tagged gharial (4 females=92, 94, 96, 98; 7 male=42, 90, 48, 52, 60, 62, 68) as well as the two juvenile mugger exhibited little or no movements during the study period. Of the remainder (6), two shifted dry season residencies soon after release (40, 58), moving upstream and then showed monsoonal movements, with a seasonal return to previous residences post monsoon a year post tagging. One (80) showed short, downstream monsoon movements both years. Two (64, 76) showed downstream movement the first year, but were

Table 1. Tracking summary for 20 resident wild Gharial (*Gavialis gangeticus*) in National Chambal Sanctuary, 2013-2016

Movements are summarized for 20 gharial tagged in Nov-Dec 2013. Most were tracked biweekly, weekly or more frequently; as of end January 2016, all radios were not functioning. Animal-specific locations from Dec 2013 thru end Jan 2016 totaled 1869; transmitter temperatures were recorded in 2060 instances (external transmitters mounted on tail or neck). Records are across all months, monsoon=Jun,Jul,Aug,Sept; rest=dry

ID	sex	tl	cp	mn	locs	kms	river loc	village locations	trans temp (N)	monsoon	D	shift	home
98	jF	1.8	GH	24	83	8	97 to 105	Ater to Ranipura	14-40 C (93)	no move		none	AT
52	saM	2.5	GH	25	100	6	97 to 103	Ater to Gohera	15-36 C (110)	no move		none	AT
50	aF	3.3	AT	22	44	66	97 to 163	Ater to Rhea	14-40 C (57)	no move	+50	up, +50	AT
54	aF	3.3	AT	23	116	26	79 to 105	NK to Ranipura	15-46 C (130)	upstrm	+14	dwn, +14	DN
96	jF	1.7	MG	9	11	12	93 to 105	Naan to Ranipura	27-32 C (13)	no move		none	GH
42	jM	1.8	MG	23	95	3	88 to 91	Hathkant to NaanTpl	14-38 C (109)	no move		none	MG
48	saM	2.6	MG	23	97	2	89 to 91	Magerpura to NTpl	14-38 C (111)	no move		none	MG
44	aM	4.3	MG	25	125	7	90 to 97	Magerpura to Ater	15-46 C (183)	upstrm	+5	up, +5	NT
94	jF	1.9	KM	26	130	2	73 to 75	Chilongato Murong	15-36 C (125)	no move		none	MU
92	jF	1.3	MU	11	20	4	64 to 68	Udi Bdge to Baroli	15-35 C (21)	no move		none	BA
90	jM	1.4	CH	26	143	4	72 to 76	Lakan to Murong	15-36 C (167)	no move		none	CH
40	saM	2.1	CH	22	57	25	93 to 118	Naan to Harlalpura	19-39 C (47)	variable		up, +24	RN
58	saF	2.6	BR	23	72	41	65 to 105	Barhi to Ranipura	16-35 C (75)	variable		up,dwn,30	BA
60	saM	2.5	GY	25	129	5	49 to 54	Gyanpura to Khera C	14-37 C (132)	no move		none	GY
62	saM	2.8	GY	23	140	5	49 to 54	Gyanpura to Khera C	14-38 C (145)	no move		none	GY
66	saF	2.3	GY	22	100	195	15 to 210	Mahua S. to Tighra	16-40 C (106)	dwnstrm	+180	up, +180	PN
64	saM	2.7	PN	25	118	12	30 to 42	Sashon to Tumrakola	15-40 C (122)	variable	-8	dwn, -8	BC
68	saM	2.6	PG	22	92	11	33 to 44	Barchaulito Kasaua	15-41 C (96)	no move		none	PN
76	saF	2.0	PG	18	89	16	36 to 15	PN to Mahua Suda	15-36 C (104)	dwnstrm	-4	none	JG
80	saF	2.5	JG	25	108	56	0 to 56	Bhareh to Khera	15-37 C (114)	dwnstrm	-23	dwn, -15+	BC

Chambal River loc: GD=Godha; GH=Gohera; MG= Maghera ka Pura; DN=Dinnpura; KH=Khera Ajab Singh; KS=Kasaua; CT=Chikni Tower; TK= Tumrakola; PN= Pituwan ka Nagla; BR=Barchouli; SG=Sashon Ghat; Mahua Sunda=MS; PA=Patharra-Bihar; CF=Y-C confluence; SA=Sahson; JG=Jagtouli; RH=Rhea (upstrm=163)YM=Yamuna; below confl: PD=Pachnada, BW=Bawain; cap/release sites=PN, KH, KS, BR. BA=Baroli, RN=Ranepura, GY=Gyanpura, BD=Badpura, BC=Barecha

legends: tl-m=total length, metres; cp=capture location; mn=months tracked; locs=animal-specific locations recorded; kms= maximum movement distance, in kms; loc to CFL= location on Chambal, relative to confluence (CF; in kms)=0; D = seasonal movement, in kms (minus=dwnstrm; plus=upstrm). Neither 50 nor 54 nested in 2014, but both moved to and remained near nesting areas, upstream for 50, and downstream for 54. In 2015, both nested, 50 near home area, and 54 nested at the same downstream site, which she frequented in 2014 (DN, -14 km from AT ca

Table 2. Tracking summary for resident wild Mugger crocodiles (*Crocodylus palustris*) in National Chambal Sanctuary, 2013-2015

Movements are summarized for 2 mugger tagged in Nov-Dec 2013. These were tracked biweekly, weekly and/or 2-3 times per week; Radios ceased to function by Dec 2015. Animal-specific locations from Dec 2013 thru Nov-Dec 2015 to end sampling period=224; transmitter temperatures= 247 instances (external transmitters mounted on tail). Records for monsoon=Jun,Jul,Aug,Sept; rest=dry.

ID	sex	tl	cp	mn	locs	kms	river loc	village locations	trans temp	monsoon	D	home	shift
56	jF	1.9	MK	24	107	8	97 to 105	Ater to Ranipura	14-39 C (119)	no move		Gohera	none
82	saM	1.7	BC	23	117	49	0 to 49	Bhareh to Gyanpura	14-37 C (128)	variable		KS, JG	none

Chambal River loc: GD=Godha; GH=Gohera; MG= Maghera ka Pura; DN=Dinnpura; KH=Khera Ajab Singh; KS=Kasaua; CT=Chikni Tower; TK= Tumrakola; PN= Pituwan ka Nagla (Philmunnagara); BR=Barchouli; SG=Sashon Ghat; Mahua Sunda=MS; PA=Patharra-Bihar; CF=Yamuma-Chambal confluence; YM=Yamuna; below confl: PD=Pachnada, BW=Bawain; cap/release sites=PN, KH, KS, BR. JG=Jagtouli;

legends: tl-m=total length, in metres; cap=capture location; mn=months tracked; locs=locations recorded; kms= maximum movement distance, in kms, maximum river distance upstream to downstream site; loc to CFL= location on Chambal, relative to confluence (=0); Dkm= seasonal movement, in kms (plus=upstrm; minus=dwnstrm).

stationary the second monsoon season. Finally, a subadult female (66) moved downstream the first monsoon (2014), then upstream 195 km to the large nesting colony at Tighra (=210 km above the Yamuna-Chambal confluence) where another long-distance mover, female 24, nested in 2015. Then, she moved back 190 km downstream during the monsoon.

The two juvenile mugger exhibited variable movements that contrasted with each other. The upstream individual (ID 56; female) resided within ± 5 km of Gohera, where it was located most often. It did not shift residences nor migrate during the monsoon high water (Table 2). The other mugger (ID 82; male) was a dry season resident in the lower section of river. It made a monsoonal movement of ---25 km downstream, then returned to the same dry season residence it occupied prior to the monsoon (Table 2). In general, the movement patterns of the immature muggers were similar to those of the immature gharial with respect to the parameters listed in Tables 1.

Large Gharial With GPS Loggers

Last year, in 2014, for the first time, radio transmitters equipped with GPS loggers which could be remotely downloaded periodically, while still attached to free-ranging, wild resident gharial were utilized. Thus, units were capable of being remotely downloaded at intervals, but also emitted a VHF location signal that could be tracked manually. These tags have been successful in producing very fine scale data on daily locations, resulting in 2-10 records per day, on an almost daily basis, for each tagged gharial. A total of seven GPS tagged gharial were monitored during 2015, and a summary table of results to date is presented here as Table 3. Representative movement maps for GPS tagged gharial are shown in Figures 2-4.

To date, as of March 2016, three gharial (28, 30, & 32) have been successfully tracked and the GPS data downloaded for the previous 15 months since tags were affixed (Figures 1-4). For these three, 3599 animal locations were logged, ranging from 991 for subadult male 28 to 1438 for large ghara male 30 (Table 3). These three gharial have been monitored for 462-466 days, more than a year (=Nov2014 to Mar2016), and daily records were obtained on 859 of 1390 total days, or 62% of the total days with the radios attached. In general, the least successful months for obtaining daily locations are the monsoon months (July through September) and the most successful months are the winter months (November through February) when gharial are basking on land on sunny, warmer days.

Partial location records were obtained for two other gharial equipped with GPS loggers, 931 records for a subadult female (=22) monitored for 301 days (with 213 daily locations or 71% of the total days monitored), and 472 records for an adult female (=26) monitored for 175 days (with 85 daily locations or 49% of the total days monitored). For two additional gharial (20, 24), the GPS loggers failed to allow remote download, and these are noted as "fail" in Table 3, and were only tracked successfully using the regular manual tracking procedure followed for all VHF radioed gharial during the course of study. Five of these large gharial were equipped with both VHF and GPS logging radios (20, 22, 24, 26, 30), and two

Table 3. Tracking summary for 7 resident wild adult Gharial (*Gavialis gangeticus*) in National Chambal Sanctuary, 2014-2016

Movements are summarized for 7 gharial tagged in mid Nov 2014. These larger gharial were tracked manually, utilizing the VHF radios attached to base of tail and/or neck. Tracking frequency was biweekly, weekly, or 2-3 per week, depending on season and daily conditions. In addition, each animal was outfitted with a custom designed GPS logger (Wildlink W510; Advanced Telemetry Systems, Isanti, MN USA) that was scheduled to take location "fixes" and log these, according to a pre-determined daily program, adjusted seasonally to maximize attempted readings when animals were likely to be on land, either basking during the cooler months, or resting on land in evenings and at night during the warmer months.

legends: tl=m-total length, metres; cap=capture location; mn=months tracked; locs=animal-specific locations recorded; kms= maximum movement distance, in kms; loc to Chambal, relative to confluence (CF; in kms)=0; D = seasonal movement, in kms (minus=downstream; plus=upstream). CFL= location on

ID	sex	tl	cp	mn	locs	kms	river loc	village locations	trans temp	monsoon	home	GPSrec	days rec
20	aM	4.1	CH	12	70	61	38 to -10 0 to -13	BA, Gopiakar Gohani (Yamuna)	15-38C (81)	BA, PA	BA, PA	fail	none
22	saF	2.9	AT	12	57	10 (13)*	93 to 103 (92 to 105)*	Naan to Gohera Naan-dwn to RN*	14-40C (71)	no moves	GH	931	213/301
24	aF	3.1	GH	12	16	210	0 to 210	Bhareh to Tighra	23-32C (23)	CF=0	TG	fail	
26	aF	3.2	GH	12	29	11 (19)*	114 to 103 (116 to 97)*	Khndra to Gohera Halapura to Ater*	14-38C (36)	no move	RN	472	85/175
28	saM	3.1	JK	15	10	4 (116)*	34 to 30 (135 to 19)*	Jagtauli to Sahson Pinhut to Kheda*	-----	SA SA	JG KS	991**	282/462
30	aM	5.3	KS	15	89	65 (67)*	-10 to 55 (-9 to 56)*	Gopiakar to KH GP up to KH frnt*	15-40C (99)	CF=0, GP	KH, KS	1438**	298/466
32	aF	3.2	JK	15	25	30 (69)*	55 to 25 (91 to 22)*	Kheda to Kundaul NaanT to Palighar	-----	SA	GY	1170**	279/462

Animal-specific locations from Nov 2014 onward are summarized below, for locations determined manually and also by GPS locations. Periodic downloading of the GPS loggers was attempted during the cool months when animals were on land for hours on sunny days. The Wildlink system downloads via UHF coupled with on-board VHF signal preset for fixed daily times, and depends on proximity of 200-500m and a strong, clear VHF signal when the radio GPS logger is not submerged and out of water. Consequently, downloading is limited to times when tagged gharial can be approached closely, and the radioed individual is out of the water. Records are across all months, monsoon=Jun-Jul-Aug-Sept; rest=dry, and are comparable to the records of radio-tagged gharial and mugger shown in Tables 1 & 2.

gharial in this group (28 and 32) were only equipped with GPS units. The GPS units have a built-in VHF signal that allows limited manual tracking, but the signal has a short range, relative to the regular VHF radios utilized, which do not have GPS downloading capability.

In Table 3, the correspondence between the maximum river distance occupied by each animal is shown for the values determined using the manual tracking method, and the maximum river distance determined for each animal, based on the GPS locations obtained. In the cases of two gharial (22,30), the distances obtained using either method is very close, 10 vs. 13 km for 22, and 65 vs 67 km for 30. GPS determined values were only slightly higher in both instances, +3 km for 22, and +2 km for 30. This difference for Female 26 was almost double, =2X for the GPS determined locations (=19 km) vs. the manual tracking locations (=10 kms). For Female 32, one long trip upstream was not detected manually, but is evident from the GPS records, more than doubling the maximum range of river locations, from 30 km (=manual tracking) to 69 km (=GPS tracking).

In one instance, subadult male 28 was not detected at all for a full season, from Nov. 2014 until September 2015 using the regular manual tracking procedure. However, during the monsoon months, this individual was observed visually at a downriver location for the first time in over 9 months (Figs. 5-8). Shortly thereafter, the GPS records were downloaded, and revealed that this individual had been living in and using a familiar stretch of river being routinely monitored on a weekly basis during this entire 9 month period. During this time, 547 GPS locations were logged, over 290 days, with 163 daily locations determined. Using the conventional manual tracking procedures, it was thought that this individual was no longer in the area or the radio had malfunctioned. In retrospect, neither of these scenarios were correct. This example demonstrates the value of the GPS logging system to successfully record animal locations and activities undetected using other conventional techniques.

For instance, male 28 had a maximum range of upstream vs. downstream river locations that was very limited, from kilometre marker 34 to 30, or just 4 km, based solely on 10 locations using manual tracking methodology (Table 3). In fact, this individual ranged over 116 km of river, and made an undetected upstream visit over several months, with multiple daily stopovers along the way upstream and downstream. The extensive use of a much larger section of river was only revealed when the GPS locations were downloaded and plotted.

Creche Attendance and Hatchling Guardians

During the nesting season in 2015, a concerted effort was made to monitor several large crèches in the lower Chambal with infrared game cameras for continuous 24 hour periods for days at a time in order to determine which adult individuals were acting as protectors and guardians at each crèche, and to characterize the patterns of attendance, care, protection and guarding exhibited by adults remaining in the vicinity of large groups of hatchlings assembled at colonial nesting sites. The emphases during this year's hatching and post hatching period were to make detailed observations, supported with still, video, and remote game camera video clips, without interfering with the natural progression of daily activities. In other words, disturbance by human presence was minimized as much as possible. Creches were observed at safe distances that resulted in minimal, if any disturbance, in most cases. Whenever possible, observations were confined to opposite river banks, at distances of 100+m, so direct disturbance was avoided.

Creches at two sites were sampled with game camera video continuously during hatching, within a week to 10 days post hatching, and later at 2-3 weeks post hatching (Figs. 5-8). Sets of game cameras, modified to take sequential 55 second video clips for 24+ hrs were installed, and changed daily to record complete records of activities at the crèche during the daytime and at night (Fig. 8). Representative stills from this extensive data set are shown in Figures 9-12.

Importantly, these crèche observations indicate two special features associated with the patterns of attendance and guarding of hatchlings. First, one of the nesting females, apparently among the largest at each site, appears to be dominant in protection of hatchlings. She visits the group(s) of young often, but does not remain constantly with them. Only one female seems to do the majority of the guarding, and she actively excludes other females from close approach to the hatchlings, under most circumstances. Typically, the dominant guarding female is assisted in hatchling protection by a large ghara male who associates himself with the crèche of young. When disturbances pose major threats occur to the hatchlings, the male replaces the dominant female at the crèche, and displays his presence with acoustic jawclaps, and loud exhalations that resonatethrough the large, cartilaginous ghara at the tip of his snout. The male assumes "guard" duty, providing protection for hatchlings against potential predators.

Detailed behavioural observations during the breeding and nesting and hatching periods in 2014 and in 2015 at one site upstream, Naangoan Temple nesting colony, strongly suggest that the guardian male at this site is a junior, not yet dominant male, with a ghara that has enlarged in size over the past 3 years. Male 44/46 was tagged in Nov 2014 and so is relatively easy to locate; his river travel is very limited to a small area, e.g., within 7 kms (Table 1). He has not been actively engaged in breeding, but has been the persistent guardian at a relatively large crèche consisting of 13-17 hatched nests in both 2014 and again at the same site in 2015 (Figure 5).

Nesting Success On The Lower Chambal

Nesting effort has been monitored for the past six years on the Uttar Pradesh section of the lower Chambal, in the National Chambal Sanctuary; the river distance above the confluence with the Yamuna is 163 kms. In 2015, several of the radio-tagged females ventured even farther upstream, to a river distance of 210 km above the Yamuna confluence, at Tighra. Consequently, observations were frequently made at Tighra on two large nesting groups (Figs. 13-16). In 2015, a longer river stretch (210 km) was surveyed from Tighra down to the confluence for evidence of nesting.

Within this stretch, 153 nests were located, based on either predation signs prior to hatching and/ or evidence of hatching. Of these, 126 showed evidence of successful hatching, and many groups of young were observed in the vicinity of the numerous nest sites examined within several weeks of hatching. The survey was conducted during daylight hours, from pre-dawn through evening dusk, during 17-20 June, and followed up several weeks later to ensure that all hatched nests were tallied. A summary of nesting (2010-16) is shown in Table 4; in addition, 49 km above the upstream Rhea site were examined and resulted in 66 nests from Barsala to Tighra, with 59 of these producing hatchlings. Male guarding was prevalent at larger communal sites; nest lost from predation occurred at nest sites with relatively few nests, though some of these small groups of nests were guarded by males.

As noted above, during the 2015 nesting season, observations were targeted at larger nest sites, where creches were guarded by both male and female guardians. An effort was made to not disturb these groupings when making observations, by remaining on opposite banks, or at distances from the creche that left the hatchlings and adults undisturbed to determine the natural pattern of care.

Table 4: Spatial distribution of gharial nest sites on lower Chambal River, referenced on distance from Yamuna confluence (=0 km), left is upstrm, right is downstrm. Twenty one nest sites were used during six nesting seasons, producing 38, 76, 80, 62, 96, and 85 nests respectively from 2010-15. The number of nests that produced hatchlings in each year are shown for each location in the bottom panel. For example, the Rhea site (RH) had 11, 20, and 30 total nests, and 11, 19, and 28 nests hatched in 2010, 2011, and 2012, respectively. Bolded,underlined entry indicates that a male was observed guarding hatchlings at nest site, and resided nearby during hatch-post hatch.

distance riverkm	161	133	126	118	107	103	97	91	90	89	87	85	79	74	56	54	49	46	39	38	29			
nesting location	RH	KP	GA	HL	GD	GH	AT	NT	MG	HK	DM	DU	NK	CH	KF	KC	CT	KS	BA	PN	SG		total nests	nest sites
2010	11	2	-	-	4	3	-	-	-	-	-	-	3	3	4	4	-	3	-	1	-		38	10
2011	20	4	-	-	3	3	-	4	-	-	-	-	6	6	7	7	3	7	-	6	-		76	12
2012	30	-	-	-	-	-	-	-	-	-	12	8	-	-	20	-	3	-	-	7	-		80	6
2013	26	2	-	4	8	-	2	-	2	-	-	8	2	-	4	-	-	2	2	-	-		62	11
2014	20	4	3	21	-	-	3	15	-	1	7	-	-	2	13	-	-	3	-	1	1		96	14
2015	16	5	-	15	-	-	3	11	-	-	5	-	-	4	17	1	-	7	-	1	-		85	11
nesting location	RH	KP	GA	HL	GD	GH	AT	NT	MG	HK	DM	DU	NK	CH	KF	KC	CT	KS	BA	PN	SG		nests hatch	hatch sites
2010	<u>11</u>	pd	-	-	4	3	-		-	-	-	-	2	<u>3</u>	<u>4</u>	<u>3</u>	-	pd	-	1	-		31	8
2011	<u>19</u>	pd	-	-	pd	pd	-	pd	-	-	-	-	<u>6</u>	<u>6</u>	<u>3</u>	pd	<u>3</u>	<u>5</u>	-	<u>6</u>	-		48	7
2012	<u>28</u>	-	-	-	-	-	-	-	-	-	<u>11</u>	<u>8</u>	-	-	<u>17</u>	-	pd	-	-	<u>5</u>	-		69	5
2013	<u>24</u>	2	-	4	<u>8</u>	-	2	-	2	-	-	<u>8</u>	pd	-	<u>2</u>	-	-	pd	1	-	-		53	9
2014	<u>18</u>	4	<u>2</u>	21	-	-	<u>3</u>	<u>13</u>	-	1	<u>7</u>	-	-	<u>2</u>	<u>13</u>	-	-	<u>3</u>	-	pd			88	12
2015	<u>16</u>	2	-	6	-	-	<u>3</u>	<u>11</u>	-	-	<u>2</u>	-	-	<u>2</u>	<u>17</u>	<u>1</u>	1	-	7	-	pd		67	10
																			-					

Chambal River locations: RH=Rhea, KP=Kuerapura, GA=Gadarian, HL= Harlalpura, GD=Godha, GH=Gohera, AT=Ater, NT=Naangoan Temple, MG= Maghera ka Pura, HK=Hathkant, DM=Dinnpura MP, DU=Dinnpura UP, NK=Nauchnouli, CH=Chilonga, KF=Khera Ajab Singh, front, KC=Khera Ajab Singh, channel, CT=Chikni Tower, KS=Kasaua, BA=Barecha, PN=Pituwan ka Nagla, SG=Sashon Ghat

Conservation Benefits Of Gharial Ecology Project

The Gharial Telemetry Project has been recognized by the National Tri-State Committee for Coordination of the Conservation in the National Chambal Sanctuary, and the recommendations of the project solicited for incorporation into the National Plan for Gharial Conservation, under consideration for adoption and implementation. The Principal Investigator presented a plenary paper in January 2015 at the Society for Integrative and Comparative Biology (SICB) meeting in Florida, and delivered talks at the U. Florida in Gainesville, St. Augustine Alligator Farm, and in late January 2015, at the Wildlife Conservation Society head office in New York City, based at Bronx Zoo. In April 2015, I visited the Herp Tag Meeting in Atlanta, Georgia and presented a talk on gharial ecology to the Crocodilian AZA group associated with Herp Tag. In late May and early June, I visited the Madras Crocodile Bank, and did a presentation for the Board of Trustees, and discussed the project and conferred with Romulus Whitaker, founding Trustee, and Zahida Whitaker, Director and Founding Trustee at MCBT. Publication in peer-reviewed journals is in preparation, as are popular articles. A summary of recent activities related to gharial conservation is scheduled to appear in the Jan-Mar 2016 issue of Croc Spec Group Newsletter, IUCN.

There is now wide recognition of the importance and significance of the biological findings of the Gharial Ecology Project, and in particular, how these inform and are directly relevant to ongoing conservation and management efforts. This is especially important for the remaining gharial populations in the National Chambal Sanctuary, living in a protected, free-ranging, wild river habitat. The success of efforts to date to continue the study attest to the interest and commitment by the state and central governments, particularly the MoEF and the Forest Departments of Madhya Pradesh, Rajasthan, and Uttar Pradesh for the shared objectives outlined for this project.

Literature Cited

- Andrews, H.V. & N. Whitaker. 2004. Captive Breeding and Reproductive Biology of the Indian Gharial *Gavialis gangeticus* (Gmelin), pp.401-411, In: Crocodiles. Proceedings of the 17th Working Meeting of the Crocodile Specialist Group, IUCN - The World Conservation Union, Gland, Switzerland and Cambridge UK.
- Basu, D. 1980. Baby Croc in a Valley of Death. International Wildlife 10 (1): 3-11.

- Bustard, H.R. 1999. Indian Crocodile Conservation Project, pp.5-9, In: Indian Crocodilians, ENVIS (Wildlife and Protected Areas) 2 (1). Wildlife Institute of India, Dehra Dun.
- Choudhary, S. 2011. Seasonal habitat use and resource partitioning between two sympatric crocodilian populations (*Gavialis gangeticus* & *Crocodylus palustris*) in Katarniaghat Wildlife Sanctuary, India. 82p. Masters thesis in Wildlife Science. Wildlife Institute of India, Dehra Dun.
- Choudhury, B.C. 1999. (Guest Editor). Indian Crocodilians, ENVIS (Wildlife & Protected Areas) 2 (1). Wildlife Institute of India, Dehra Dun.
- Choudhury, B.C., L.A.K. Singh, R.J. Rao, D.Basu, R.K. Sharma, S.A. Hussain, H.V. Andrews, N. Whitaker, R. Whitaker, J. Lenin, T. Maskey, A. Cadi, S.M.A. Rashid, A.A. Choudhury, B. Dahal, U.W.K. Ko, J. Thorbjarnarson, J.P. Ross. 2007. *Gavialis gangeticus*. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2 <www.iucnredlist.org>
- Huchzermeyer, F., P. Martelli, S. Martin, B. Stacy, R. Whitaker. 2008. Gharial Mortality Event in Chambal National Sanctuary 2007/2008. Report of Field Investigations. Crocodile Specialist Group of IUCN. 101p.
- Hussain, S.A. 1999. Reproductive success, hatchling survival and rate of increase of gharial *Gavialis gangeticus* in National Chambal Sanctuary, India. Biological Conservation 87: 261-268.
- Hussain, S. A. 2009. Basking site and water depth selection by gharial *Gavialis gangeticus* Gmelin 1789 (Crocodylia, Reptilia) in National Chambal Sanctuary and its implication for river conservation. Aquatic Conservation-Marine and Freshwater Ecosystems 19: 127-133.
- Hussain, S.A. & R. Badola. 2001. Integrated Conservation planning for Chambal River Basin. Paper presented in the National Workshop on Regional Planning for Wildlife Protected Areas. August 6-8, 2001. India Habitat Centre, New Delhi, Wildlife Institute of India, Dehra Dun. pp.1-20.
- Gharial Conservation Alliance. 2009. Gharial Species Recovery Plan. draft October 2009. pp. 1-45.
- Gharial Conservation Alliance. 2011. Gharial Species Recovery Plan. January 2011. from a Workshop Sponsored and Convened by the Gharial Conservation Alliance, Delhi, 22-24 June 2009.
- Katdare, S., A. Srivathsa, A. Joshi, P. Panke, R. Pande, D. Khandal, & M. Everard. 2011. Gharial (*Gavialis gangeticus*) populations and human influences on habitat on the River Chambal, India. Aquatic Conserv. Mar. Freshw. Ecosyst. 21: 364-371.
- Lang, J.W., & H.V. Andrews. 1994. Temperature-dependent sex determination in crocodilians. J. Exp. Zool. 270:28-44.
- Lang, J.W., H.V. Andrews, & R. Whitaker. 1989. Sex determination and sex ratios in *Crocodylus palustris*. American Zoologist 29: 935-952.

- Lang, J.W. & S. Whitaker. 2010. Application of Telemetry Techniques in Crocodilian Research: Gharial (*Gavialis gangeticus*) spatial ecology in the Chambal River, India, pp.161-171, In: Sivakumar, K. & Habib, B. (Eds.) 2010. Telemetry in Wildlife Science, ENVIS Bulletin: Wildlife & Protected Areas. 13 (1). Wildlife Institute of India, Dehra Dun 248001. India
- Lang, J.W. & P. Kumar. 2013. Behavioral Ecology of Gharial on the Chambal River, India. pp. 1-14. In: Crocodiles. Proceedings of the 22nd Working Meeting of the IUCN-SSC Specialist Group. IUCN: Gland, Switzerland. 2013.
- Lang, J.W. 2016. India—Gharial Ecology Project. Crocodile Specialist Group Newsletter 35(1):10-14.
- Nair, T., J.B. Thorbjarnarson, P. Aust, & J. Krishnaswamy. 2012a. Identifying individual gharials to estimate population size, and determinants of habitat use in the Chambal River, India. p.1-12. In: Crocodiles. Proceedings of the 21st Working Meeting of the Crocodile Specialist Group, IUCN- The World Conservation Union, Gland, Switzerland.
- Nair, T., J.B. Thorbjarnarson, P. Aust, J. Krishnaswamy. 2012b. Rigorous gharial population estimation in the Chambal: implications for conservation and management of a globally threatened crocodilian. J. Applied Ecology 2012: 1-9.
- NTRIS-CASMACC. 2011. National Tri State Chambal Sanctuary Management and Coordination Committee. Ministry of Environment and Forests, Government of India.
- Rao, R.J. 1988. Nesting Ecology of the Gharial in National Chambal Sanctuary. 105p. Report to Wildlife Institute of India. New Forest, Dehra Dun.
- Rao, R.J., & R.K. Sharma. 1986. Gharial Rehabilitation in Madhya Pradesh, India. Tigerpaper 13(1):2-7.
- Rao, R.J., D. Basu, S.M. Hasan, B.B. Sharma, S. Molur, S. Walker. 1995. (Eds). Population and habitat viability assessment (P.H.V.A.) workshop for Gharial. 16-18 January 1995. Zoo Outreach Organization/CBSG. Coimbatore, India.
- Sharma, R.K. 1999. Survey of Gharial in National Chambal Sanctuary- 1993-97. pp.84-86 In: Indian Crocodilians, ENVIS (Wildlife & Protected Areas)2(1).Wildlife Institute of India, Dehra Dun.
- Sharma, R.K. & D. Basu. 2004. Recent Reversals in the Population Trends in the Population of Gharial in the National Chambal Sanctuary in North India: Implications and a Suggested Strategy for the Conservation of One of the World's Most Endangered Crocodilians, pp. 180-186, In: Crocodiles. Proceedings of the 17th Working Meeting of the Crocodile Specialist Group, IUCN- The World Conservation Union, Gland, Switzerland and Cambridge UK.
- Sharma, R.K. and L.A.K. Singh. 2015. Status of Mugger Crocodile (*Crocodylus palustris*) in National Chambal Sanctuary after thirty years and its

implications on conservation of Gharial (*Gavialis gangeticus*). *Zoo's Print* 30(5): 9-16.

- Singh, L.A.K. 1978. Ecological studies on the Indian Gharial (*Gavialis gangeticus* Gmelin, Reptilia, Crocodylia). Unpublished PhD thesis. Utkal University, Bhubaneswar, India.
- Singh, L.A.K. 1985. Gharial Population Trend in National Chambal Sanctuary with notes on radio-tracking. 166p. Final Report. Government of India, Crocodile Research Centre of Wildlife Institute of India. Hyderabad- 500264, India.
- Singh, L.A.K. 1999. Significance and Achievements of the Indian Crocodile Conservation Project. pp.10-16, In: Indian Crocodilians, ENVIS (Wildlife and Protected Areas) 2 (1). Wildlife Institute of India, Dehra Dun.
- Singh, V.B. 1979. The status of the gharial (*Gavialis gangeticus*) in U.P. and its rehabilitation. *Journal of Bombay Natural History Society* 75: 668-683.
- Stevenson, C. & R. Whitaker. 2010. Indian Gharial *Gavialis gangeticus*, pp.139-143 In: Crocodiles. Status Survey and Conservation Action Plan. Third Edition, ed. by S.C. Manolis and C. Stevenson. Crocodile Specialist Group: Darwin, Australia.
- Stevenson, C.J. 2015. Conservation of the Indian gharial *Gavialis gangeticus*: successes and failures. *International Zoo Yearbook* 49: 150-161.
- Whitaker, R. & D. Basu. 1983. The Gharial (*Gavialis gangeticus*): A Review. *Journal Bombay Natural History Society* 79:531-548.
- Whitaker, R. & Z. Whitaker. 1984. Reproductive Biology of the Mugger (*Crocodylus palustris*). *Journal of Bombay Natural History Society* 81(2): 297-316.
- Whitaker, R. & Members of GMTF. 2007. The Gharial: going extinct again. *Iguana* 14: 24-33.
- Whitaker, R., D. Basu, & F. Huchzermeyer. 2008. Update on gharial mass mortality National Chambal Sanctuary. Crocodile Specialist Group Newsletter 27: 4- 8.



Figure 1. Male 30, a 5.3m (totl) "large ghara" male radiotagged with VHF radio on his neck, and another radio with GPS logger affixed to his tail. Tagged in 2014, he was tracked manually at frequent intervals during the intervening 15+mons (as of March 2016). 89 locations indicated a limited range of 65 km, primarily downriver, monsoon movements to the Yamuna River confluence.



Figure 2. GPS plot, with location points shown as green dots, for male 30. Over 466 days, a total of 1438 locations were logged, and are plotted on this Google Earth image of lower Chambal. This animal had two distinct residences, an upstream, dry season site at Khera, Chikni, and Kasaua, and a summer, monsoon residence near the Yamuna River. He ranged 10 km below confluence during this period, but primarily stayed above the confluence in lower Chambal section (Table 3).



Figure 3. GPS plot of dry season locations for male 30, a large ghara, dominant male that maintained a breeding "territory" at Khera Channel, where he was often located.

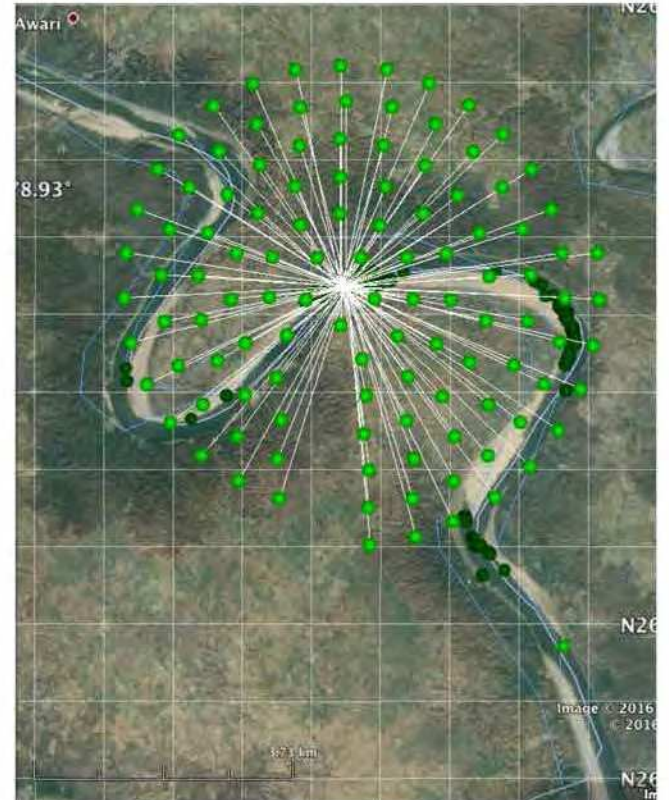


Figure 4. GPS plot, on Google Earth, of multiple occupancies by male 30 of the same location at Khera Channel, during dry season, pre-monsoon period in 2015. This male remained at this site where one female nested, and he acted as guardian for hatchlings when they appeared in early June.



Figure 5. Male 44, a "junior" male, not yet fully grown, and not yet dominant, swims near a large creche of hatchlings at a communal nest site, Naangoan Temple site, where 11 nests hatched in 2015. At this site, 13 nests hatched in 2014. This male was tracked by VHF radio for 25+ mons, Nov13-Dec15. He was the dominant guardian male at this communal nest site in two successive years, 2014 and 2015. He was definitely not the breeding male in the area, where a larger sized, large ghara male is the dominant breeder (Table 1).



Figure 6. Hatchlings remain tightly grouped in a dense creche at nest site where there was communal nesting. Hatchlings spend the early morning and late evenings on land, midday at the shoreline or in the water, and then disperse in shallow water in the nest vicinity at night (see Figures 9-12---game camera night images at creches). After 2-4 weeks post hatching, young actively feeding and widely dispersed at night near the nest site.



Figure 7. A female "guardian" at a nest site typically remains in close proximity to the creche, but she is not necessarily always present. At each nest site, a singular female, one of the larger sized animals, assumes a dominant, guardian role, and appears to actively exclude other females from the area she occupies while attending the creche. Here, a hatchling perches on the female guardian's head while other hatchlings float in the water nearby. Females remain with creches until high water floods the shoreline near the nest site, and then leave the young when adults disperse downriver, or upriver, and away from the nest site.



Figure 8. Batteries of game cameras, modified to record near-continuous, short video clips, were installed at each of two communal nest sites, one upriver and one downriver. These were operated for 3-6 days continuously, 24 hrs early (within a week to 10 days) and late (3 wks) post hatching. Using this set-up, it has been possible to monitor guardians at the creche, and determine who is guarding when among the adults in the nest vicinity. This site, Khara front side, had 17 nests, and all of these hatched, producing 500+ hatchlings in 2015.



Figure 9. (above) Game camera infrared image at creche site: a large-ghara male "guardian" comes ashore amidst a shoreline lined with hatchlings (=small eye shines in distance at shore).
 Figure 10. (below) Game camera infrared image at creche site: a female attending the creche, approaches hatchlings at shore. Other cameras are visible in the distance. Note open jaw position of the young in the water, an effective "fish catching" posture.

Figure 11. (above) Game camera infrared image at creche site: a "guardian" female rests at shoreline while hatchling perches on her back
 Figure 12. (below) Game camera infrared image at creche site: Female "guardian" rests at shoreline, with jaws agape. Hatchlings visible in foreground, and in distance on shore and at shoreline (=small eyeshines in distance)





Figure 13. Close-up telephoto shot of tractors and trolleys, removing sand from Rithora(MP)-Tighra(Raj) sandbank on Madyha Pradesh side of river. Tractors shown here were only some of 35-40 tractors counted at site in late afternoon, early June 2015. Wide angle image of same scene shown in Figure 14.



Figure 14. Panoramic view of sandbar on Chambal River, 5 km below Rajghat, at Rithora-Tighra villages. Here, 35-40 tractors operated almost 24 hours in the several pre-monsoon months of May-June to remove trolley loads of sand, on an industrial scale, to be used for building and construction in major metropolitan areas. This activity is strictly illegal, but widely engaged in by a sand mining "mafia."



Figure 15. At Rithora-Tighra sandbar (see Figs 37-38), there were two large, communal nest sites used by gharial, an upper site with 16 nests and lower site with 13 nests. A total of 25 of 29 nests hatched in 2015; two nests were predated at each site. Shown here is a tractor-trolley in the distance, and two gharial on the shoreline in foreground. Nesting area (upper site) was located just to the right of photo on shoreline (see Figure 40).



Figure 16. Concentration of nests at upper communal site (16 nests; 14 hatched) at Rithora-Tighra. Three females are visible on land near excavated nests (evident as sand disturbances on surface), and one female remains at shoreline. Jackals closely approached unattended nests and scavenged damaged eggs and consumed injured hatchlings. Nest excavation and/or predation by jackals was usually interrupted by guarding females. Sand removal was underway on an industrial scale, almost 24/7 at this season, immediately behind these nests.