

APPLICATION OF TELEMETRY TECHNIQUES IN CROCODILIAN RESEARCH: GHARIAL (*Gavialis gangeticus*) SPATIAL ECOLOGY IN THE CHAMBAL RIVER, INDIA

Jeffrey W. Lang and Samir Whitaker

Gharial Conservation Alliance, Madras Crocodile Bank Trust Post Bag 4, Mamallapuram 603104, INDIA.
Email: jeff.w.lang@gmail.com

Abstract

Radio telemetry is an increasingly important and useful tool for conservation biologists and is a widely used field research tool, its value proven on a large variety of species ranging from dolphins to large land mammals such as the African elephant and much smaller animals, such as rodents. In an effort to better understand the seasonal movement of gharial (*Gavialis gangeticus*, Gmelin, 1789) and in light of the unprecedented die-off in the National Chambal Sanctuary in the winter of 2007/08, a radio-telemetry research project was initiated in March 2009. This Madras Crocodile Bank Trust/Gharial Conservation Authority project was based in Garhaita Village, Etawah District, UP, and conducted in collaboration with the Uttar Pradesh Forest Department and the Madhya Pradesh Forest Department. In this report we present a brief synopsis of other crocodilian studies involving radio telemetry, a summary of the results and findings the present study has revealed over the past one year, and a synopsis of our findings in regards to gharial spatial ecology, a subject highly relevant to the die-off and one that will require much more study to comprehensively understand.

Keywords

Chambal, crocodilians, gharial, India, telemetry

Introduction

For millennia, crocodilians have survived and diversified in tropical and sub-tropical environments, where they hold the dubious distinction of being top predators in the water and on land. The secret to their evolutionary success is in large part due to their universal ability to conceal their presence to potential prey, which are ambushed by these sit-and-wait masters at the water's edge. By nature, they are well camouflaged and inconspicuous before they strike and employ cryptic and elusive behaviours to avoid detection. These features present the researcher intent on divulging how they make a living, and what habitats they frequent, special challenges when studying them.

So it is no surprise that with the advent in the 1960s of radio telemetry as a powerful tool with which to identify and track animals, crocodilian biologists have utilized available technologies to learn essential details of the life processes and natural history of this unique reptilian group. The 23 living species of crocodilian are relatives of the dinosaurs and birds and exhibit complex suites of anatomy and behaviours not seen in other reptiles. Universally, crocodiles are difficult to observe and study undetected, have sophisticated learning skills, and generally are disturbed easily. Furthermore, individuals are difficult to recognize, especially when they do show themselves while basking.

Contemporary telemetry techniques are being increasingly utilized in a widening variety of applications in the biological study of animals and have the potential to reveal unparalleled detailed and new information about an individual's activities and behaviours in space and in time. Not surprisingly, a major emphasis has been on spatial ecology, in particular on movement patterns, home ranges, dispersal, and homing abilities. For any given species, these life history parameters are essential components in understanding environmental responses, especially adaptation to changed conditions in a world increasingly influenced by humans. In addition, these features play critical roles in demographic/population processes that are vital to conservation and management.

The objectives of the present paper are two-fold. First, we provide a brief synopsis of radio telemetry as a successful and well established methodology in studies of other crocodilians. Second, we present the preliminary results of a study conducted in the National Chambal Sanctuary (NCS) in 2008-2010. It was initiated in response to the die-off of 2007-2008 in the lower reaches of the Chambal River, near its confluence with the Yamuna. The study presented here has provided detailed information about

gharial spatial ecology, directly relevant not only to the recent mass mortality event, but also to the long term conservation and management of the gharial in the NCS.

Radio telemetry studies in crocodilians: A synopsis

In the 1970s, telemetry studies were initiated on *Alligator mississippiensis* which focused on ecology (e.g., Joanen and McNease 1970, 1972; McNease and Joanen 1974; Goodwin and Marion 1979). More recently, additional telemetry studies have been conducted throughout the species' range (e.g. Rodda 1984a; Taylor 1984; Rootes and Chabreck 1993). Other species in which telemetry has been employed, primarily to study movements and spatial ecology include the following: *Crocodylus acutus* (Rodda, 1984b; Kushlan and Mazzotti, 1989), *Crocodylus johnstoni* (Tucker *et al.*, 1997), *Crocodylus intermedius* (Munoz and Thorbjarnarson 2000), *Crocodylus niloticus* (Hutton 1989; Hocutt *et al.*, 1992), *Crocodylus porosus* (Kay 2004b; Read *et al.*, 2007; Brien *et al.*, 2008), *Paleosuchus trigonatus* (Magnusson and Lima 1991), and *Melanosuchus niger* (Martin and da Silva 1998).

With respect to the design of telemetry systems for tracking, VHF transmitters and multichannel compatible, hand-held receivers with portable Yagi antennas have been employed in the majority of studies to date. Tracking methods with these systems typically entail manual signal reception by observers on foot and/or using a variety of terrestrial vehicles, boats, and aircraft. Recently, satellite tracking technology (e.g., platform terminal transmitters, SIRTRACK - New Zealand) which provide intermittent signal broadcast with GPS fixes of animal positions have been used successfully to track the speed and direction of long distance movements of saltwater crocodiles remotely via computers (Read *et al.*, 2007). It should be noted here that marine, as compared with freshwater environments pose special challenges to signal transmission, and generally require that animals spend some time out of saltwater periodically in order to facilitate location. In addition to tracking transmitters, the ability to relocate individuals has facilitated the additional use of data loggers which archive environmental/physiological parameters for retrieval.

The attachment methodologies for crocodilians are varied, and have involved affixing transmitters to the head, neck, or tail, as well as subcutaneous surgical implants. According to Kay (2004a), neck collars and implants have proven to be the most durable and effective, but radio transmitters have been successfully attached to the nuchal (=neck) scutes in recent studies (Read *et al.*, 2007).

For other species, in particular gharial, the absence of high crests on the nuchal scutes precludes this attachment option, and Singh (1985) describes trials in which various attachment methods, including the use of neck collars, neck mounts, and tail sites were employed with varying degrees of success. He concludes that the best method of attachment was stitching the transmitter on the dorsal surface of the tail just anterior to the double-single scute junction.

Analyses of spatial information, using GPS/GIS approaches have been developed in conjunction with advances in telemetry technologies (Millsaugh and Marzluff 2001). Standardized approaches provide the bases for objective comparisons between populations and species. Several authors discuss the utility of using meaningful home range descriptors, activity centres, and normal movement patterns within the context of spatially constrained, linear habitats such as rivers (Kenward 2001; Kernohan *et al.*, 2001).

In summary, modern telemetric techniques have been proven to be especially valuable tools with which to develop effective conservation and management strategies for crocodilians. This is apparent from the increasing number of studies in a wide variety of species inhabiting diverse aquatic environments. This trend is likely to continue, as new methodologies contribute new, critical data relevant to the specific questions posed. For example, translocation of nuisance crocodiles is often the conventional management solution, but a satellite study of saltwater crocodiles proved conclusively that animals displaced 56, 99, and 411 km (the latter directly across the Cape York peninsula) returned to their capture sites, travelling an average of 7-20 km/day (Read *et al.*, 2007). These results are corroborated by a host of similar findings in other species in which homing of displaced crocodilians has been demonstrated. Additional management concerns which have been informed by detailed and targeted telemetry studies include the (1) design and execution of rigorous survey methodologies, (2) documentation and mitigation of man-made disturbances, (3) evaluation of release/reintroduction schemes, and (4) effectiveness of habitat protection/restoration. For conservation purposes, telemetric studies have allowed researchers (5) to delineate existing populations more accurately, (6) to identify the critical habitats and specific environmental components vital for a species' continued survival, and (7) to manage populations adaptively at sustainable levels. In this connect, this study aimed to:

- Use radio telemetry and ground/water based tracking to quantify seasonal movement patterns, home range characteristics, and habitat use of wild gharial.
- Conduct a variety of related scientific studies in an effort to better understand gharial spatial ecology and general biology to provide inputs for a range-wide gharial species recovery plan.
- Provide data that will allow conservation managers to better evaluate and implement conservation measures such as habitat restoration, captive breeding, and reintroduction.
- Continue to liaise with forest department personnel and other key stakeholders in an effort to better understand the key conservation measures required to maintain/restore habitat and revive wild gharial populations.

Study area and species

The NCS is a 428 km stretch of the Chambal River, ending at the confluence of the Chambal and Yamuna rivers at Pachnada. The sanctuary area is located in a semi-arid zone in northern India in the states of Rajasthan, Madhya Pradesh, and Uttar Pradesh. The

mean ambient temperatures range from 2 to 46 °C, with a mean annual precipitation of 591.2 mm, most of which is received during the south-west monsoon months of May to August. The landscape is dominated by ravine thorn forest, and there is no evergreen riparian forest left – ground cover is generally sparse throughout. The Chambal River itself is a fast flowing river which originates in the Vindhya hill range of Central India. It flows north-east and joins the Yamuna River at Pachnada before eventually flowing into the Ganges River.

This study was focused on a 115 km stretch of river from Pinahat (N26.864170° E78.363723°) to SashonGhat (N26.543776° E79.088323°), which was the affected area of the die-off. This stretch of river, particularly the downstream reaches, was the epicentre (impact area) of the gharial die-off in the winter of 2007/2008. The telemetry study and active tracking of animals have largely been confined to a study site comprising a 30 km stretch of river from Dinnpura (N26.779278° E78.725937°) to the Udi bridge (N26.697508° E78.935026°).

Gharial (*Gavialis gangeticus*) is the only surviving member of its crocodilian family and is a geographically endemic, critically endangered species of South Asian rivers, conferring on it a scientific uniqueness possessed by few vertebrate quadruped taxa anywhere. The species, on the verge of extinction in the early 1970s, with fewer than 300 individuals surviving globally, was slowly recovering in the NCS as a result of concerted in-situ as well as ex-situ conservation action but has recently experienced two dramatic and near-catastrophic population declines. Although gharials do occur in a few other protected areas in India, a PHVA in 1995 assessed the population in the NCS as being the only viable and self-sustaining population in the world.

Methods

Animal capture, restraint, and release

Gharial of the selected size class (2-4 m total length) were very difficult to capture, particularly the larger size class (3.5-4 m TL), and the present study is based solely on 2.7-3.3 m adults and sub-adults. The successful capture strategy employed techniques developed by local fishermen, and entailed setting curtains of mesh netting at the deep water approaches to favoured basking sites. Animals entangled in nets did not struggle, and consequently nets were checked frequently to avoid injury/drowning. Once secured with rope bindings on the limbs and snout, the captured gharial were remarkably sedate and docile, requiring a minimum of additional restraint, but protection from overheating by providing a large shade canopy and frequent wetting are essential while holding animals for tagging. On several occasions, it was necessary to retain animals for 8-10 hours prior to tagging, and under these conditions, the holding procedure that was used was well tolerated. Upon release, all tagged gharial reacted normally and typically showed defensive behaviours briefly and then bounded for the water and swam away quickly. A qualified veterinarian was at hand and assisted in all capture/tagging procedures.

Radio attachment

The rectangular, epoxy encased radio transmitters (60 g, 18 cm × 10 cm × 8 cm) with trailing, flexible whip antennas (30 cm) were attached to the base of the tail just anterior to the junction of the single/double tail scutes. Stainless steel split rings (3, on the bottom edge of each radio) were embedded in epoxy casing and were anchored with a Kevlar fishing line that was inserted with the aid of a trocar style, large gauge needle as a guide, underneath the dorsal skin immediately below the bottom of the transmitter. Three strands of line were threaded through holes drilled at the base of the tail scutes on either side of the radio and then tied to each of the three sets of rings. The knots were dabbed with 5 minute epoxy. They were further secured with metal swages, crimped on line ends. Local anaesthetic was available for use *ad lib*. Radio attachment was completed within 45-60 minutes and well tolerated by all gharial so treated. In addition, a temperature data logger and visual cattle tags were used to provide individual identification, as well as permanent scute markings. Figure 1 shows one of the radios after a full year of attachment, illustrating the effectiveness of the procedure, and Figure 2 shows a fully processed animal, ready for release.

Transmitter function

The transmitters (151 MHz; Advanced Telemetry Systems, USA) were designed to be functional for 2.5 - 3 years and under Chambal conditions have an effective signal range of 0.5-3 km, depending on the local terrain and prevailing weather conditions. Listening posts, on high ground (locally known as *tapu*), were established about every 2 - 3 km along the riverside. The limited vegetation in the river valley and high vantage points facilitated signal reception; the maximum reception range was >5 km under ideal conditions. Daily observations indicate that specific behaviours and activities of an animal correlated closely with the signal strength and signal variation. For example, a swimming gharial can be distinguished from one sitting stationary on land, e.g., basking. Submergence under water results in signal loss at 2-3 m, and continual visual observations while monitoring the signal strength confirmed that submerged animals were detectable even when a gharial surfaced for brief periods, e.g., 1 - 3 minutes. In the dry season, when gharial spend hours submerged, monitoring was extended for 0.5 - 2.0 hours at listening posts in order to adequately track resident gharial when they surfaced periodically while remaining underwater at midday.

By carefully noting signal variations, a variety of animal activities/behaviours can be detected from the signal variation alone and subsequently confirmed by repeated visual sightings. All the above protocols have been incorporated into the routine data recorded at each tracking site. The absence of a signal for a 1-3 day period indicated that an animal was likely no longer present in the area. At all listening posts, the trackers scanned all ten frequencies for signals to prevent bias in anticipating an animal's whereabouts by selectively tracking only known local residents.

Figure 1



Picture taken in March, 2009 of the radio attached to animal number: 59, tagged in June, 2008 illustrating the robust nature of the radio attachment procedure followed in this study.

Figure 2



Tail section of Animal Number 57, after attachment of the radio, data logger and uniquely coded cattle tags. This animal is ready for release.

Disturbances associated with capture/tracking

Capture/tagging activities in mid March '09 extended over two weeks and resulted in disturbance at the two capture sites for the following 4-6 weeks, and typical/normal behaviours, primarily basking, by gharial at these sites were only resumed by tagged as well as untagged individuals in late April/early May. Following this interruption, tagged gharial resumed association with untagged individuals, and regular patterns of activity were exhibited by all resident gharial.

Tracking from listening posts on riverside high ground resulted in minimal/negligible animal disturbance, whereas tracking by boat (technique used initially) was much less productive and appeared to create a much greater disturbance which interfered with radio-location, e.g., gharial submerged on approach, and signal detection was not possible, and there were no visual sightings

"The Chambal gharial populations resident at specific locations appear to be habituated to normal riverside activities, and display finely tuned discrimination abilities when reacting to human activities close to basking and/or nesting sites particularly. Gharial are alert to calls/signals of other sentinel riverbank inhabitants such as shorebirds and wading birds, and typically react to their alarm calls signifying unusual, atypical, often threatening activities. Gharial rapidly head for water if basking, or submerge if in the water until the potential threat wanes or disappears. Habituation to villagers using footpaths, walking with livestock, moving with camels, even crossing of shallow stretches of river on foot/camel is evident, and these activities are ignored and not responded to with escape behaviour."

The capture-tagging forays to affix radios continued for days, and even residual human activities loosely associated with capture, such as tracking/observing, resulted in daily disturbances to normal patterns of basking and submergence by resident gharial.

Frequent major disturbances at some localities appeared to result in resident gharial shifting their "normal" daily locations to nearby, undisturbed areas.

Based on repeated observations reinforcing the summary of disturbance factors (above), the optimum time for capture/tagging would appear to be in the immediate post-monsoon months (Oct-Dec) to avoid interference with important social/reproductive behaviours known to occur from mid-January through the pre-monsoon months (May, June, early July), when nesting, hatching, and parental care of young have been observed in Chambal localities.

Tracking Methodology

The tracking team, based at Garhaita village, consisted of 2 experienced local trackers who also operated an inflatable boat with a 25 hp OBM, and 2 researchers who worked with the trackers to locate tagged gharial along a 30 km stretch of river which was monitored 3-5 days a week. Local transport was primarily on foot and/or by motorbike for river transects. High ground overlooks located at strategic sites provided upstream and downstream coverage. Optimal tracking ranges of 0.5 -3.0 km were obtained by utilizing 4 element Yagi antennas as well as 3-element handheld units with portable field receivers (ATS Fieldmaster 100), depending on the local terrain and weather conditions. The tracking team, logged a total of 241 days of the 412 day tracking period.

GPS readings (Garmin Vista HCX) were taken for determining animal locations by triangulation on constant signals, and when feasible (ie. when tagged animals were visible), these data were collected by waypoint projections using a compass bearing along with a laser range-finder (Bushnell Sport 450).

In addition, hand drawn sketches and marked printouts of satellite maps were maintained for the most important basking sandbanks. Observations/tracking effort, consisting of daily forays of 6-10 hours, were seasonally adjusted to accommodate local weather conditions and, importantly, the seasonal changes in gharial activities – early morning and late afternoon observations during periods characteristic of the warmer, dry months (March–July; Sept–Nov) and midday observations during the wet period (July–Sept) and the winter months (Nov–Feb). Figure 3 illustrates the typical tracking methods, in the backdrop of 'typical' habitat of the study site.

Figure 3



A view of one of the main basking sites, Chilonga, with the tracking team in the fore-ground. Trackers work alone or in pairs decided by a work plan formulated the night before.

Tracking effort

One radio-tagged gharial (59) has been monitored for over 22 months (9 months from June '08 to Feb '09 intermittently, followed by 13 months regularly). The ten gharial outfitted with radio transmitters (151 MHz; individual frequencies) have been tracked for approximately 50% of the total days (2432 of the total gharial days tagged, which were 4120) between release in mid-March 2009 and 30 April, 2010. For the ten gharial monitored for 13 months, locations for 1795 daily monitoring gharial days were recorded, for an average of 180 tracking days during the mean 412 days tagged per animal, or approximately 44% of the days monitored. A total of 1812 daily locations were recorded for the ten monitored gharial during the 13-22 months of the study. In addition to daily tracking locations, detailed observations were made of environmental parameters, water levels (river) and gharial activity and behaviour throughout the daylight hours, including the morning and afternoon. Photos of gharial groupings, including those which included tagged gharial, were taken frequently, daily to weekly, to further document gharial locations and habitat usage. A summary of the tracking effort is presented in Table 1.

Table 1 : Summary of the Tracking Effort

Sex	ID	Length (mts)	Days Tagged	Days Monitored March 2009 to April 2010																Total	Not Found	Track Days
				M	A	M	J	J	A	S	O	N	D	J	F	M	A					
F	61	2.9	412	17	18	25	24	24	14	16	23	22	24	27	23	16	15	288	47	241		
F	53	2.3	410	8	15	24	28	23	4	10	18	20	18	20	19	21	11	239	45	194		
M	55	2.1	412	15	17	21	27	8	7	15	23	23	25	27	24	19	16	267	53	214		
F	69	3	409	8	16	23	26	23	5	12	16	20	17	21	14	25	23	249	57	192		
F	75	2.5	410	10	17	24	27	22	5	11	16	20	20	24	17	12	18	243	62	181		
F	63	3.3	412	3	-	-	-	13	11	21	20	23	24	25	15	20	21	196	77	119		
F	57	2.9	417	18	19	24	24	19	12	21	16	19	18	18	19	11	13	251	61	190		
F	49	2.9	409	14	12	23	22	13	5	12	15	18	17	20	15	15	19	220	48	172		
F	51	2.8	410	15	13	23	28	22	6	14	19	18	19	24	21	17	16	255	58	197		
M	59	2	419	15	14	17	18	26	4	16	17	20	21	22	8	14	12	224	129	95		
TOTAL				123	141	204	224	193	73	148	183	203	203	228	175	170	164	2432	637	1795		
June 2008-March 2009																						
M	59	2	255				5	4				8	4					21	4	17		
TOTAL				123	141	204	229	197	73	148	183	211	207	228	175	170	164	2453	641	1812		

Result

Movement Patterns and Spatial Ecology of Chambal River Gharial

During the dry season/low water conditions, normal activities consisted of loose aggregations of gharial of all sizes at particular deep water areas, pools with riverside sand banks, sandbars and exposed mid-river sand islands. This 'clumped' distribution of gharial is characteristic of all months of observation, except the high water/monsoon months of July, August, September and October.

Table 2 : Summary of dry season and monsoon residency, maximum movement distances, summed distances moved and trips recorded for ten telemetered Gharial, Chambal River

ANIMAL DETAILS										SUMMARY			
ID	Sex	Total length mts	Track Days	Cap Site	Primary Dry Season Residence	Secondary Monsoon Residence	Max (km) Dist. Loc	Loc max		Distance (km) movement	Min # trips	UP STR	DWNST R trips
61	F	2.9	241	CH	CH	CH	< 2km	CE-MR		3.2	0	0	0
53	F	2.3	194	NK	DN	NK	6.9	DN-NK		28.5	8	4	4
55	M	2.1	214	CH	CH	PG	4.2	CH-PG		31.3	13	7	6
9	F	3	192	NK	DN	NK	6.9	DN-NK		73.5	16	8	8
75	F	2.5	181	NK	DN	NK	6.9	DN-NK		125.5	23	11	12
63	F	3.3	119	CH	CH	PG	6.0	MR-PG		10.2	3	1	2
57	F	2.9	190	CH	CH/BR	BR	14.3	CH-BD		66.2	11	5	6
49	F	2.9	172	NK	CH/BD	PG	21.5	MR-UD		55.9	10	3	7
51	F	2.8	197	DN	DN	NK	16.4	DN-PG		54.5	15	8	7
59	M	2	112	NK	NK	NK	16.4	DN-PG		99.6	18	9	9
8F2M			1812				X = 10.2			X = 54.8	X = 11.7	X = 5.6	X = 6.1
TOTAL							(2 - 16.4)			(3-100)	(0-23)	(0-9)	(0-12)

X= MEAN VALUE

Abbreviations : CH – Chilonga, NK – Nakhnoli, BD – Badpura, PG – Pachai Gaon, DN – Dinnpura, UD – Udi Bridge, MR – Murong, CE – Chilonga East Sandbank, AK – Akon ki muariyan, BR – Baroli, LK – Lakhanpura rock pool, BS – Baswara

Synopsis

The radio-tagged gharial monitored for 13 months (Mar '09 – Jan '10) exhibited individually distinct patterns that ranged from residency at a single location (61 at Chilonga) to wide-ranging movements upstream as well as downstream, which were exhibited by a gharial (59 at Nakhnoli) whose residency was loosely centred at the midpoint, 6 km below the furthest upstream location and 10 km above the furthest downstream location. The home range of the radio-tagged animals has, for the most part, been within the 30 km stretch that formed the main study site, although some animals (63 and 49) have been found outside this range. The 3.3 m female (63) has been recorded 22 km upstream of Dinnpura, and another female (49) has been recorded about 5 km downstream of the Udi bridge. Summaries of the residency patterns are presented in Table 2, and further details of individual patterns, as well as size estimators during the dry season and monsoon months, are shown in Table 3.

Table 3 : Activity centres, home range estimates, river direction and summed movements of ten telemetered Gharial in dry season vs. monsoon on a 30 km stretch of Chambal River, Udi-Dinnpura, Uttar Pradesh and Madhya Pradesh States, India

SEX	ANIMAL ID	SEASON	DRY SEASON AND MONSOON RESIDENCES		HOME RANGE		RIVER MOVEMENT DIRECTION	SUM ALL MOVEMENTS (KM)
			CENTER	RANGE	DISTANCE (KM)	AREA (HA)		
F	61	D	CH	CE-CH	1.3	38	NONE	3
	61	M	CH	CE-MR	3.2	159	NONE	
F	53	D	DN	DN-AK	2.4	70	DOWN STR	29
	53	M	NK	MR-KA	5.4	269	DOWN STR	
M	55	D	CH	CH-LK	2.1	59	DOWN STR	31
	55	M	PG	CH-PG	4.2	208	DOWN STR	
F	69	D	DN	DN-KA	5	141	DOWN STR	74
	69	M	NK	MR-KA	5.4	269	DOWN STR	
F	75	D	DN	DN-NK	6.9	197	DOWN STR	126
	75	M	NK	MR-KA	5.4	269	DOWN STR	
F	63	D	CH	CE-MR	3.2	91	NONE	10
	63	M	PG	MR-PG	6	301	DOWN STR	
F	57	D	CH(2009)	LK-CH	2.1	59	DOWN STR	66
	57	M	BR (2009)	PG-BD	10.1	503	DOWN STR	
	57	D	BR (2010)	BS-BD	6.7	189	UP & DOWN	
F	49	D	CH (2009)	NK-PG	9.5	268	DOWN STR	56
	49	M	PG (2009)	MK-PG	6	301	UP STR	
	49	D	BD (2010)	RP-BR	5.2	148	DOWN STR	
F	51	D	DN	DN-AK	2.4	70	DOWN STR	54
	51	M	NK	NK-PG	9.5	472	DOWN STR	
M	59	D	NK	NK-AK	4.5	127	UP STR	100
	59	M	NK	NK-PG	9.5	472	DOWN STR	

Abbreviations : CH – Chilonga, NK – Nakhnoli, BD – Badpura, PG – Pachai Gaon, DN – Dinnpura, UD – Udi Bridge, MR – Murong, CE – Chilonga East Sandbank, AK – Akon ki muariyan, BR – Baroli, LK – Lakhanpura rock pool, BS – Baswara

Seasonal trends

Most tagged gharial showed well-defined seasonal patterns of residency, with upstream primary (low water/dry season) location(s) and downstream secondary (high water/monsoon months) residences to which each moved during August-October, returning to its primary residence upstream in subsequent months. Two tagged gharial (49 and 57) varied this seasonal pattern by remaining at downstream locations and/or visiting these during the post-monsoon, dry season as well.

Two other gharial (75 and 69) with upstream residencies shifted frequently between their primary residencies and nearby localities, presumably in response to high water fluctuations that inundated mid-river islands at Dinnpura. Seasonal shifts to monsoon residencies during the high water months of August-Sept-Oct involved shorter distances (4-7 km) or longer distances (14-16 km), by gharial from dry season primary residencies at Dinnpura as well as those residing at Chilonga.

Distance trends

Three gharial tagged at Chilonga had their primary residency at Chilonga, and either did not move downstream (61) or made shorter movements to secondary residencies downstream (55 and 63). Three Dinnpura residents (53, 69 and 75) moved shorter distances (7 km) to secondary residences, while another Dinnpura resident, 51, shifted a longer distance (16 km) to its secondary

downstream residence. Two other Chilonga residents (49 and 57) moved downstream and back upstream with less obvious seasonality, involving longer downstream shifts in residency. These gharial appeared to have shifted their dry season residencies in 2009 to locations downstream in 2010 and resided at or near their secondary residencies downstream that were occupied during the 2009 monsoon.

The mean for the ten monitored gharial was 10.2 km but varied from < 2 km for a Chilonga resident (61) which was not recorded anywhere else (location tracked on 241 days through the 412 tagged days over 13 months) to 16-21 km for three wide-ranging residents (49@CH, 51@DN and 59@NK). The total recorded movements for the 10 radio tagged gharial also showed considerable individual variation. These distances ranged from 3 to 100 km, with an average of 55 km. Likewise, the minimum number of trips upstream and downstream recorded averaged 11.7 trips, ranging from 0 to 23 trips, roughly equally divided between downstream high water movements and upstream return movements.

Transit patterns typically involved a series of short movements between specific locations, with stopovers at transit locations as short as 1-2 days and as long as several weeks. For example, 57 shifted in late January from Baroli to Chilonga, a river distance of 11 km, in 1-2 days. A number of recorded movements showed relatively short transit times of 1-4 days for distances of > 10 km. The typical transit patterns are illustrated by the travel narratives of two gharial (51 and 57) which are presented in detail below.

Movement summaries for two selected individuals

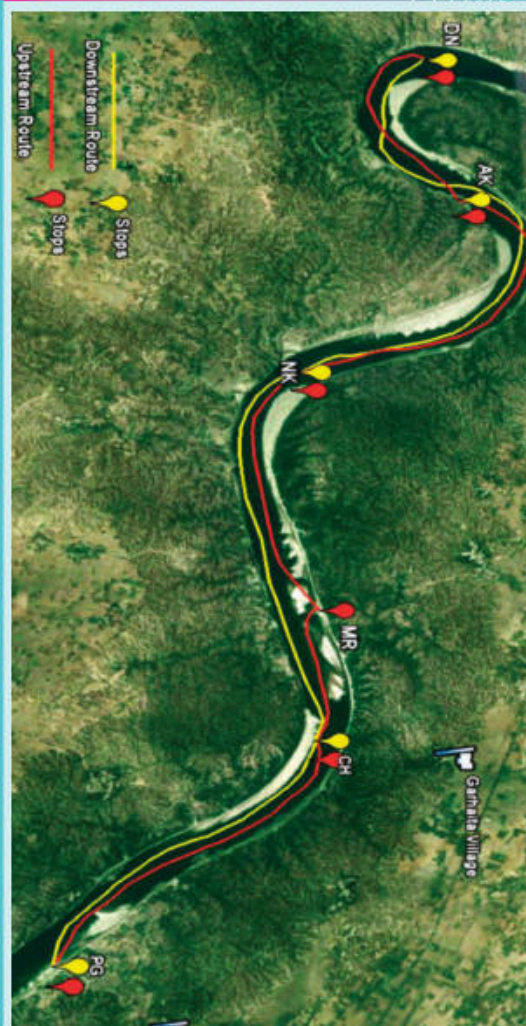
To illustrate the movement patterns of these two animals, the residency and movement patterns have been superimposed on satellite imagery, and the resulting outputs have been shown for these two animals (51 and 57). Downstream routes are denoted as yellow lines with downstream stops marked as yellow balloons; upstream routes are denoted as red lines with upstream stops marked as red balloons.

Movement Summary (2009 - 2010) – ID: 51 (2.8m female, captured at Nakhnoli)

This individual (51), a resident of Dinnpura and Akon Ki Mauriyan during the months of May-July, has been tracked for a total of 255 days till date (30/04/10). During the tracked days, it was found on 197 days (or 77% of the time). The total number of days this animal has been tagged is 410, and it has been tracked for 48% of the total number of tagged days. During the months of May-July, 51 moved from Dinnpura to Akon, a distance of 2.4 km, several times but remained resident in this general area. In early August, 51 made a downstream transit, first to Nakhnoli (6.9 km) and then to Chilonga (5.3 km from Nakhnoli) – a total distance of 12.2 km. The transit time from Nakhnoli to Chilonga was 1 day, and Chilonga was used as a temporary residence for 15 days. September saw another downstream movement by 51, from Chilonga to Pachai Gaon, a distance of 4.2 km which was covered in a single day. Pachai Gaon was used as a temporary residence for about 4 days. Following the residence at Pachai Gaon, 51 moved back upstream to Chilonga in October, again covering a distance of 4.2 km. Chilonga was again used as a temporary residence for a further period of 15 days. 51 then moved upstream to Murong and spent 2-3 days resident at this site. In early November, 51 moved upstream from Murong to Nakhnoli, covering a distance of 3.4 km with a transit time of 2-3 days. In mid-late November, 51 again moved upstream, back to its May-July residence just below Dinnpura at Akon and Karot 4.5 km upstream of Nakhnoli. Figure 4 is an overview map of the movements made by 51.

In late December, 51 moved upstream 2.4 km to Dinnpura and was resident there for 2 days, following which there was a 6.9 km transit downstream to Nakhnoli. The downstream movement to Nakhnoli coincided with a rise in water levels and submergence of some basking sites at Dinnpura. 51 was resident at Nakhnoli and nearby sites just upstream during late January and early February and returned to Dinnpura briefly for 3 days before shifting 5 km downstream

Figure 4



Movement map for Animal Number 51 showing a summary of major movements made from March 2009 to May 2010

to Karot where it resided all of April. The total distance traveled by 51 over this 13 month period was 54.5 km, the sum of all its recorded transits. It made a minimum of 15 trips, 8 up and 7 downstream (Table 2).

Movement Summary (2009 - 2010) – ID: 57 (2.9 m female, captured at Chilonga)

This individual was observed to use the Chilonga basking site fairly exclusively during the months of May, June and July. During this period, the animal was tracked for a total of 57 days and was recorded exclusively at Chilonga (it was not recorded for 12 of the 57 tracking days – it was not found for 21% of the tracking days). In early August, the animal left Chilonga and moved downstream to another well used basking site at Badpura. The transit time for this move was 5-6 days, and the distance covered was 14.3 km. 57 used Badpura as its primary residence for a period of 15-20 days.

In mid-September, 57 moved upstream to a site near the village of Baswara, where it was resident for a period of 10-15 days. The distance travelled over this transit was 6.7 km. In early October, levels of disturbance were observed to increase at the Baswara site, and 57 left Baswara and made another upstream transit to Pachai Gaon, a distance of 3.4 km. The Pachai Gaon site was used as another temporary residence, and the animal spent ~15 days at this site. Figure 5 is an overview map of the movements made by 57.

Late October to early November saw 57 making another downstream transit from Pachai Gaon to Baroli, a distance of 6.9 km, with a transit time of about 5 days. Baroli was used as another significant temporary residence site, and 57 spent the months of November and December and most of January there. In late January, 57 left Baroli and moved upstream to Chilonga, with no recorded stops along the route, over a transit time of 1-2 days. This distance travelled was 11.1 km, and the animal remained at Chilonga for 3 days, returning to Baroli to the same locality it had occupied previously. It remained there till mid-March, when it shifted downstream 3.2 km to Badpura, stayed there one day and then returned to Baroli through the rest of March and all of April. The total distance recorded travelled by 57 over this 13 month period was 66.2 km, the sum of all major transits it made during this time. It made a minimum of 11 trips, 5 upstream and 6 downstream (Table 2).

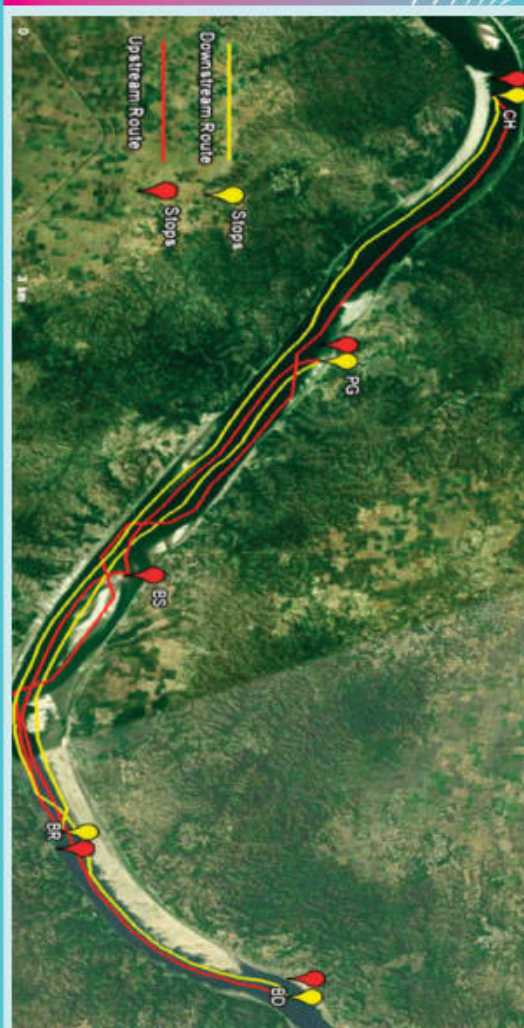
Seasonality of movement patterns observed

The details of individual gharials' seasonal patterns of residency (dry season vs. monsoon) with respect to the main centre of activity, home range size and area estimates, the direction of movement and the summed movement totals are presented for the ten telemetered gharial in Table 3. Each gharial had a well defined activity centre from which it made excursions, typically return trips, periodically.

Home ranges consisted of all tracked locations and were larger during the monsoon months. River lengths (between most distant points of home range) averaged 4.0 km (range 1.3 to 7.3 km) in the dry season vs. 6.5 km (range 3.2 to 10.1 km) during the monsoon. The home range area (river length $\times$ river width seasonal) averaged 92 ha (range 38-208 ha) in the dry season and 322 ha (range 159-503 ha) during the monsoon. The predominant movement direction was downstream during both seasons. The trip frequency, reflected in the summed movements, was not obviously related to either the size or extent of home range estimates. The tracker observations strongly suggest that many short trips were directly in response to water level changes (e.g., dam releases inundating basking sites and/or specific human activities close to basking areas that directly interfered with the daily basking routine).

Although the seasonal patterns of residency summarized here were notably consistent for all the gharial monitored, four individuals (59, 57, 49 and 63) showed departures from the general pattern. Two (57 and 49) shifted their dry season residences

Figure 5



Movement map for Animal Number 57 showing a summary of major movements made from March 2009 to May 2010

downstream during 2010, close to where they initially shifted during the monsoon from previously occupied upstream residences. Another (59) had an activity centre that did not shift seasonally but tended to move upstream during the dry and downstream during the monsoon. Finally, the largest female (63) disappeared coincident with the nesting/hatching periods in 2009 and again in 2010.

Discussion

The preliminary results of this study indicate that the telemetry methods we employed have provided sufficient data to reveal the seasonal residency patterns of the Chambal gharial in some detail. The major findings in brief are the following: (1) each gharial displayed its own individual spatial preference for specific areas of the river stretch we studied; (2) activity centres and home ranges varied seasonally, (3) the primary direction of movement was downstream during the monsoon and upstream post-monsoon, and (4) significant individual differences were evident as variations of the general pattern common to all. However, the study results to date are limited because (a) the 2009 monsoon was late and did not result in the usual high water levels and (b) the absence of larger gharial (3.5 to 4+ m total length) limits the findings to the 2-3.3 m residents only.

Previous studies of gharial movements have been primarily focused on tracking released juveniles (1-2 m total length) as part of various head-starting/reintroduction programmes within India and Nepal (Singh 1985; Ballouard and Cadi, 2005). These efforts have met with varied success which has been difficult to assess because the resident, wild populations have not been studied and/or reintroductions have been made in river stretches devoid of an established resident population. In general, although some reintroduced/released gharial remain near release points, many have been resighted >10 km away, predominately at downstream locations.

The movement patterns of wild, resident gharial determined utilizing telemetry at a Chambal locality upstream from the study area in the present study have been reported by Singh (1985). One juvenile moved downstream a total of 9 km in 35 days upon release, moving 6 km in 15 days and a further 3 km in 20 days. Another juvenile translocated 60 km upstream moved 14 km downstream, where it remained after 4 months, still 46 km upstream of its capture site. In a previous study (Bustard and Singh 1983), based solely on sightings of 4 uniquely marked adults (2 males, 5.4 and 6.6 m total length; 2 females, 3.6 and 4.6 m total length) in Satkosha Gorge, a 22 km stretch of the Mahanadi River in Orissa, India, home range river lengths of 19.2, 12.8, 10.4, and 11.6 km, respectively, were estimated based on numerous re-sightings. The maximum recorded movements in this study were 28, 44, 23 and 43 km, respectively.

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