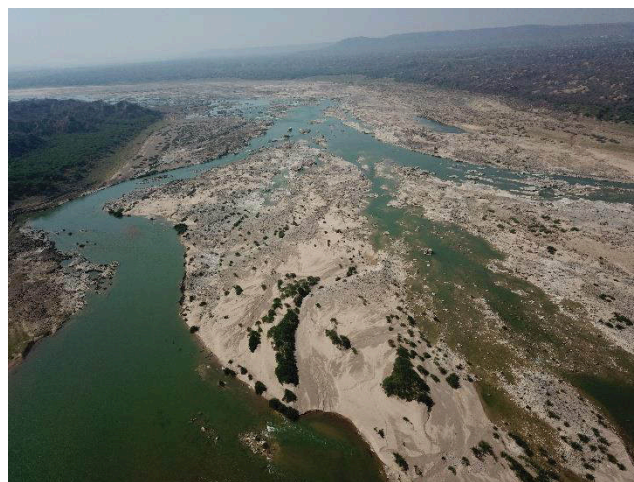


PROGRESS 2020-2021

GHARIAL ECOLOGY PROJECT



In collaboration with Madras Crocodile Bank Trust, Gharial Local & Global Foundation,
Uttar Pradesh Forest Department, Madhya Pradesh Forest Department,
Rajasthan Forest Department & Ministry of Environment, Forest, and Climate Change

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PROGRESS REPORT. GHARIAL ECOLOGY PROJECT 2020-2021

Summary: The Gharial Ecology Project (GEP) is now in its 15th field season (2022), since its initiation in 2008, following the mass die-off of Gharial (*Gavialis gangeticus*) in the winter of 2007-08. Our research, supported by the international zoo community and private donations, is sanctioned under the NGO umbrella of the Madras Crocodile Bank Trust (MCBT). The GEP programs are facilitated by the State Forest Departments of Uttar Pradesh, Madhya Pradesh, and Rajasthan, as well as the Ministry of Environment, Forests, and Climate Change, Government of India. The GEP is the present-day avatar of the Gharial Conservation Alliance, and our media presence has increased through active Facebook and Instagram pages, a dedicated YouTube Channel, and soon to be inaugurated new website, now under construction. What follows is a brief summary of recent activities, updating Lang et al. (2018, 2021).

The GEP has three main goals: 1) to develop a comprehensive assessment of gharials in the National Chambal Sanctuary (NCS), 2) to identify and protect the species' critical riverine habitats, and 3) to reduce threats and challenges to the species' continued survival. Gharials are Critically Endangered (=CR) with an estimated 650-700 mature adults globally; 550+ are resident in the NCS. Project activities are conducted primarily by a small core staff (3-4) of Indian biologists / naturalists, with periodic inputs from its Senior Scientific Advisor, Professor Jeff Lang. Active, productive collaborations with Indian colleagues are encouraged locally and regionally.

Covid constraints. With the onset of pandemic restrictions in early 2020 on international travel, Jeff's seasonal visits, usually three trips per year, to the Chambal were initially delayed, then cancelled. From early 2020, he has stayed in touch with the field team via frequent phone and internet contacts daily/weekly.

Now, with travel to India open, Jeff returned to Chambal on 11 March 2022, working with Jai and the team til early May, with second return trip scheduled for mid June.

The GEP field crew, consisting of Jailabdeen A., Pankaj K., Anand K., and "Guddhu" K., plus Ashutosh T. have all been observing in-country lockdowns and precautions, wearing masks, practicing social distancing, riding individually on motorbikes, and related precautions. In 2020 and again in 2021, the annual seasonal surveys have still been possible, despite travel restrictions, for doing total population counts in the winter months, and for doing post-hatching surveys for nest / hatchlings counts at crèche sites in mid summer, during the pre-monsoon. The outreach programs for capacity building, teacher-training, and community development have been limited to nearby UP localities, but MP and Rajasthan gatherings were conducted, despite the pandemic conditions, in 2020 and in 2021.

Comprehensive surveys. In 2021 January to March, various surveys were conducted to make additional actual counts of gharial in the National Chambal Sanctuary (NCS), in the manner similar to those conducted previously years. In the upper Chambal, there are an estimated ~380 gharial, specifically 29 males, 210 females, 102 subadults, 26 juveniles, and 21 yearlings. In the lower Chambal, ~1320 gharial were directly observed and tallied by the static survey. These consisted of 73 males, 461 females, 399 subadults, 248 juveniles, and 140 yearlings. Adjusted for accuracy in size categories, these counts included 71 mature males (with ghara) plus 31 "near-mature" males, 671 reproductive and "near reproductive" females, 501 subadults, 274 juveniles, and 161 yearlings.

In early 2019, and again in 2020, the entire gharial population with the NCS (bottom ~425 km, from Pali to Pachnada) was counted and estimated at ~1700 individuals (not counting the annual crop of hatchlings). In the upper Chambal, there are an estimated 400+ gharial, specifically 35 males, 285 females, 25

subadults, 48 juveniles, and 23 yearlings. In the lower Chambal, 1274 gharial were directly observed and tallied by static survey. These consisted of 66 males, 415 females 428 subadults, 261 juveniles, and 104 yearlings. Adjusted for accuracy in size categories, these counts included 80 mature mates (with ghara) plus 59 "near-mature" males, 525 reproductive and "near-reproductive" females, 435 subadults, 295 juveniles, and 151 yearlings.

In 2021, 422 nests were recorded in the NCS. Of these, 295 nests hatched successfully, and 98 nests were predated. Egg collection continues by the Uttar Pradesh (UP) and Madhya Pradesh (MP) Forest Departments to provide hatchlings for rearing centres at Kukrail (UP) and Deori (MP). In 2021, 30 nests were collected for these centres, 6 for MPFD and 24 for the UPFD. Fortunately, key staff liaise closely with our GEP field staff to identify suitable collection sites at the known nesting areas, and to receive assistance with nest location and egg transfers. Early detection and collection are advised to minimize damage and disturbance in this regard.

A total of 31 nesting locations were tallied in 2021, with the number of nests varying from 1 to 44, with a median of 16 nests/site (1-5 nests=10 instances; 6-10 nests=7; 11-15 nests=4; 20-30 nests=7; and >30 nests=3 sites). The four largest nesting sites (29, 38, 39, and 44 nests) had high levels of predation (11, 8, 10, and 12 nests predated, respectively). Guardian males were recorded at 20 of the 31 sites. Sites with fewer nests (1-7 nests) had only about a third (5 of 15) of the overall instances of guarding by a male, whereas sites with more nests (9-44 nests) had an associated protective male, in all but one instance (15 sites with a male, out of a total of 16 sites).

In 2019, we tallied 469 nests overall, with 185 in the upper stretch, and 284 nests in the lower Chambal. Of these, at least 297 nests hatched, and 172 were lost, either to predation or egg failure. In 2020, we counted 250 nests at 17 sites in the

lower stretch of the Chambal, and 180 of these hatched at 16 sites. Overall, there were 401 nests counted in 2020, of which 297 hatched, and 105 were lost.

The relative importance of the Chambal gharial population is evident. With realistic estimates of all the other populations included, the total number of adult gharials globally likely remains under 1000 today. Consequently, the NCS population constitutes about 80% of the world total. Nesting in the NCS likely exceeds 85% of the global total annually. Presently, the NCS population is the only remaining population residing in an open riverine, largely protected habitat. Importantly, it is self-sustaining, definitely stable, and appears to be on the increase in recent years. However, major threats loom large, including widespread and uncontrolled water extraction, rampant riverside sand mining at many nesting sites, and ubiquitous illegal net fishing throughout the NCS.

Tagging and tracking. The GEP field team, with the direction and leadership of Jailabdeen A. had another successful catch and tag session on the Chambal in late 2021. The trackers and Jai work with an experienced group of local fishermen from Pachnada who have been netting and handling gharial since 2008 when the project started. Kishore, his son Pinto, and relatives Shiv Singh, Santaram, and Prem Narian spend long hours setting nets, patiently waiting for gharial to become entangled, then expertly capture and restrain each gharial. A total of 26 resident wild gharial were tagged with radio transmitters, including 7 with Iridium satellite transmitting tags that convey GPS location information (for more detail on these units, see a following section of this report). The primary area of focus within the NCS was the midsection stretch, from Dang Basai above Dholpur (on the Gwailor-Agra road) to Reha (at the Raj-UP border), and downstream, just above our Garhaita village base, between Udi and Jaitpur, NW of Etawah. The majority of tagged gharial were females (19 of 26), including 12

adults or 'near' adults (>2.9m total length), and 7 sub-adults (<2.9m). Two younger, "big ghara" males were also tagged (4.6m and 4.9m total length), as well as 5 sub-adult males.

In late 2019, and again in late 2020, our field tracking team joined forces with a trusted cadre of local fishermen to capture and tag gharials with radios for tracking. In both years, we have conducted capture operations in both the downstream and in the upstream stretches of the NCS, separated by about 250 km. In November-December 2019, we caught 27 gharial, and radiotagged 14, including one with an Iridium (satellite) tag, and the rest with VHF radios in the downstream. In the upstream, in early December 2019, we tagged 10 large gharial, including a 4.8m "big ghara" male, and outfitted that animal and another female with satellite tags as well.

In November-December 2020, the field team caught and tagged 13 additional gharial downstream, and 13 upstream, including 8 gharial with satellite tags. One of these was in the downstream, a female, and the remainder in the upstream, including 6 females and another "big ghara" male, 5.3m total length. Altogether, as of end of March 2021, we are monitoring a total of 9 Iridium tagged gharial, outfitted with GPS loggers. These units communicate daily location "fixes" of each animal several times a week via satellite link to the internet. A "kml" file is produced for each individual which can be visualized as map locations in Google Earth.

To date, noteworthy new findings, using this methodology, have included: 1) documentation of behavioral interactions among the multiple males resident at or near the upstream breeding groups, 2) discovery of multiple nests on an upstream tributary (Kuno River) not previously known to be used seasonally by Chambal gharial, 3) tracking a downstream resident female up into the mid stretches of the NCS, where she subsequently bred and likely will nest nearby in 2021, and 4) recovery after 7 years, of a juvenile marked in 2013 with radio in the downstream.

Now a sub- adult resident in the upstream, this female appears to have shifted its residency from downstream to upstream, over a total distance of 260 km. Examples of specific spatial findings are detailed on our FB page, as these seasonal movements occur, showing the travel routes and schedules.

Iridium Satellite Tracking. For the past three years (2019-2021), the Gharial Ecology Project (GEP) field team has outfitted resident Chambal gharial, primarily larger adults, with GPS logging radio transmitters that log location information as GPS points, and transmit this information on each individual animal, remotely via satellite link (Iridium system---Advanced Telemetry Systems, Isanti, MN) to an internet node. Spatial data is then available as .kml and .txt files that delineate an animal's whereabouts for many months to 1-4 years. We have been routinely "double-tagging" larger gharial with an Iridium GPS unit, as well as a conventional VHF tracking radio transmitter, to facilitate daily tracking.

In late Nov-early Dec 2019, we tagged 3 gharial, a single adult female in the downstream section of NCS, and two gharial, a "big-ghara" male (5.3m total length) and an adult female in the upstream, near our 'new' upstream base at Baroli. Of these three, two of the units are still functioning and providing weekly locations for the upstream male and the downstream female. The third unit functioned on the upstream female for half a year, well into the summer 2020 monsoon. The locations of this female, that nested in March, revealed an entirely "new" tributary that the Chambal gharial were using for nesting and monsoon movements, in the Kuno National Park, a Protected Area for cheetah-lion re-introductions in the future.

In 2020, we tagged an additional 7 gharial in the upstream, and 1 in the downstream with Iridium tags. These units were smaller (350 gms vs 600 gms), with 25% the power of the 2019 units (AA cells in 2020 vs. D cell in 2019). On average, these smaller units only lasted 6 months (ranged 3-12 months), but did

reveal that all of the 2020 gharial so tagged showed very restricted activity-home ranges of river stretch, ranging from 6 to 20 km in total extent. The upstream animals remained near their capture/release sites, as did the downstream female.

In 2021, larger units with D cells were again deployed with 7 gharial, but at least two of these units were damaged presumably due to their large size and weight; each of the two gharial repeatedly bit at the tail-mounted radio that ultimately failed. Subsequently, several “C” cell, with 50% the power of the D cell units, are being trialed, with a projected intermediate “radio-life” of 18-30 months. A key factor with all of these Iridium units is that the in-built VHF function be minimized, and set to broadcast only 1-2 hrs daily, so that the power available for the location-transmit function be maximized, prolonging the “radio-life” of the D cell units to 3-4 years, with a few locations daily throughout the entire run period. We have routinely employed a second, 2 or 3 stage VHF radio transmitter, in conjunction with an Iridium unit, both attached dorsally at the base of the tail.

Seasonal and annual movement-activity patterns. In order to provide a brief snapshot of the data capability of the Iridium units, here are some details re: the number of data points (GPS location, date, time), number of transmissions (typically every 2-6 days), and the total stretch of river occupied by tagged gharial. The “big-ghara” male, tagged 6 Dec 2019 at Baroli near our upstream base, has occupied only 6.5 km stretch of mainstream Chambal, based on 1228 data points, with 72 transmissions, thru 28 Feb 2022. In contrast, a downstream adult female has moved back and forth over two years, over a total stretch of 166 km of Chambal, nesting >100km upstream from where she was captured, but then returning each monsoon, and moving upstream again post monsoon the entire >150+km, and then back again. In the second year, she nested in the downstream, near where she was captured. She also moved relatively far distances from her breeding sites to her nesting sites. Her seasonal movements are based on 1472 locations, with 234 transmissions to date, thru end Feb 2022.

Both of these animals are carrying functioning Iridium transmitters, two years post tagging as of March 2022, and predicted “radio-life” of the units is another 12-18+ months (operational until late 2023-early 2024). The third unit deployed in late 2019 was operational for only 8 months when the gharial was “lost.” However, this animal with the Iridium tracker revealed a previously unknown tributary was being used as a nesting and seasonal foraging area by Chambal gharial. This is the Kuno National Park where the radioed female moved during nesting, a distance of 60 km upstream from the Chambal confluence. This unit provided 310 data points, with 57 transmissions, revealing a stretch of river utilized as 24 km along the Chambal, and 62 km up into the Kuno National Park.

For the 2020 smaller capacity Iridium units, collected data points ranged from 357 to 651 locations over 81 to 126 transmissions. The upstream gharial that were tagged only occupied relatively short stretches of river, ranging from 7 to 23 km; the single downstream female occupied just 10 km of river length. One of these radios failed soon after deployment, and another stopped functioning in 4 months, with 279 data points and only 66 transmissions.

Creche counts. In recent years, frequent (almost daily) counts of hatchlings visible in creches have been made until each large group of hatchlings disperses, in an attempt to document survivorship of hatchlings in the days post hatch. Generally, each creche tends to remain grouped near the nesting site as long as the water levels remains low, prior to the start of monsoon rains and river edge flooding. Representative counts at large and small creches are available for 2020 at 6 sites and for 2021 for 9 sites. As listed, NH=date nest hatched, with number of nests hatching; PD=predated nests; and HC=hatchlings counted each day observed.

In 2020, observations were made at sites with 1, 2, 7, 14, 25, and 36 nests. Nest predation was highest at the sites with the most nests. And hatchling counts declined from a high of 1000 to 644 when recording was no longer possible.

Several sites with only 1-2 nests showed relatively high survivorship. The drop in hatchling numbers by the end of 3-4 weeks post hatching are difficult to interpret, simply as losses due to predation, since creches tend to organically disperse and spread over greater shoreline distances, as the hatchlings grow and begin to

feed regularly. Ultimately, the adult female guardian abandons the creche, and then it disperses quickly. In 2021, sharp declines in hatchling numbers are not obvious, and survivorship of hatchlings appears to be relatively high, in comparison with 2020. Nest predation is high when overall nest numbers are high, and hatchling mortality is most evident at a site with few nests (n=3; Korth).

Hatchling survival. Since 2018, we have been doing pilot studies with small groups of hatchlings during their first 6 months of life to get a better idea of how many of these survive as they grow, and learn more about how these young gharial behave. Small "back-pack" radios have facilitated locating tagged individuals within crèches, but so far none of these have been tracked thru the actual monsoonal high water that peaks on the Chambal in mid August. Recently, we outfitted 3-4 month old young with backpack radios in the post monsoon period, September-October. Survival of these young gharial has been about 60% after 3 months, and appear to be lower than the 90% levels of survivorship we have documented for 9-12 month old gharials. In contrast, the first 4-6 weeks for a hatchling appear to be particularly perilous, and our observations of crèche size indicate that at least half of the crèche disappears, presumably directly through predation, before the onset of monsoonal high water.

Head-starts vs. wild juveniles. Starting in late 2018, we have been working in collaboration with the MPFD to track head-started 2-4 yr old juvenile gharials, reared at the Deori EcoCentre facility near Morena in Madhya Pradesh. In comparisons of wild resident vs. reared "head-starts," matched for size/age, wild juveniles had higher rates of survival and showed well-defined and stable patterns

of residence, without notable residency shifts and/or long dispersals. In contrast, fewer "head-starts" survived, and were more likely to shift residences and/or move long distances. Furthermore, released captive-reared gharial were more likely to be predated by muggers (subadults and adults). In fact, we were able to track several subadult muggers for several months before they eventually voided the "head-start" radios in feces. "Head-starts" also showed atypical behaviors, and had distinctly different activity patterns, during the first few months following release, than those of wild residents living alongside them.

Kuno connection. Discovery of the importance of the Kuno National Park as seasonal gharial habitat, through its connections with the NCS has spurred a new found interest by the Madhya Pradesh Forest Department (MPFD) in gharial conservation and protection in this specially designated and protected area. The Kuno NP is now being used as an additional release site for "head-started" juvenile gharial, from the Deori EcoCentre rearing facility. We have been able to partner with the MPFD, and radiotag a small cohort of these animals being released in this upstream tributary, and in the mainstream Chambal nearby.

In December 2020, we tagged 11 head-starts, 6 for release in Kuno, and 5 for release at the Baroli sandbank on the main Chambal. At the end of March 2021, all 11 of these juveniles are actively being tracked, with most remaining near release sites. Post monsoon 2021, a few of these tagged "head-starts" were located near the release site in Kuno NP, but at least one from Kuno had moved into the mainstream Chambal. Several of the "head-starts" released near Baroli in the upstream Chambal, above the Kuno confluence, were tracked post monsoon. Overall, indications are that only about half of those released as "head-starts" were evident a year later post release. Widespread movements and/or mugger predation are suspected as factors leading to this result.

Also, in 2021, none of the recently tagged adult or subadult gharials, primarily females, from the mainstream Chambal ventured into the Kuno for nesting. Notably, water levels are markedly lower than in 2020, and so Kuno nesting may be restricted to only some “wet” high water years, and used periodically, rather than routinely. In October 2021, at least one subadult female resided well within the Kuno NP, but there is little evidence of a resident gharial population in Kuno.

Outreach Activities. In 2021, Dr. Ashutosh Tripathi, the GEP Outreach Coordinator, spent 53 days full time as Consultant, planning, producing, and conducting various outreach programs and activities. During April-May, covid restrictions curtailed gatherings such as class groups and community meetings. In March, World Wildlife Day was celebrated on 3 March with a village program in Kasaua, the site of gharial creches each year, with a particularly defensive male guardian. International Day of Action for Rivers was held on 14 March with a clean-up campaign in nearby Khera Ajab Singh, another village close to a traditional large nesting site. World Sparrow Day was celebrated on 20 March, and capacity building for the UP Forest Department was held on 21 March.

Public activities were very limited in April-May, due to covid, but in June, World Crocodile Day was feted with an extensive online quiz competition and related activities. Finally, in Nov-Dec, ten programs including a drawing competition, were held primarily in riverside communities close to Udi and Etawah. On Dec 14, Chambal River and Gharial Awareness was held in Gatti Village, UP.

The previous year, in 2020, Dr. Tripathi conducted two capacity building programs in Rajasthan and Madhya Pradesh, visited and conducted 20 village community programs hosted international wildlife week events, and started a model village program, featuring organic farming and recycling activities. The Outreach coordinator also worked with colleagues to develop additional games and

activities, as well as short videos with conservation messages. Readings with environmental themes have been videotaped, with Hindi translations.

Drones deployed. We have been using DJI quadcopter drones to create 2D and 3D maps of riverine habitats, using geo-referenced JPEGs. Drone imagery facilitates species identification (mugger vs. gharial), quantification of numbers present, as well as accurate estimates of animal sizes. With regard to finding and counting nests, aerial methodology is reliable when colony size is mid-range, >5 but <20 nests. In general, drones are well tolerated by gharials on land or in the water at >50m height, but disturbances increase rapidly at lower altitudes. Within large crèches, counting hatchlings accurately is possible with drone-acquired imagery. Related software has allowed 3D imagery of nesting banks for detailed analyses of nest placement, relative to water levels, and nearby nests.

Upstream base, downstream office. Our new upstream base at Katrinapur, a small riverside village, is located within a 15 minute walk to the Baroli sandbank on the Chambal River. It took shape in late 2019 as a stand alone office-workroom with adjoining bath-toilet facilities, and was completed by late 2020, with additions in late 2021 and early 2022. Its proximity to the two major breeding and nesting areas on the upper Chambal make it possible to conduct detailed behavioral observations every day, and this location also facilitates day trips to adjacent mainstream stretches, as well as tributary river habitats. Previously, this upstream location was a focal point for gharial surveys and releases of captive-reared juveniles from Deori EcoCentre, by the MPFD. Downstream, we have established an Indian NGO called "Gharial Local and Global," with a local Etawah office that serves as headquarters for our Outreach programs. In Uttar Pradesh, India's most populous state, the town of Etawah serves as a regional centre, and is located just 40 km from our riverside village base at Garhaita. Long term plans involve sourcing in-country support for the GEP thru this Chambal-based NGO, while continuing our affiliation with MCBT.

Gharial genetics. In collaboration with LaCONES, a novel 15 marker panel has been developed which is much more informative (0.43) than previous markers. With a new panel of markers, a genetic bottleneck event in the Chambal population is clearly evident. Furthermore, detailed parentage analyses are now possible and are currently underway, to understand the relationships among all participants in each creche. Preliminary results show evidence of multiple paternity, likely at low levels, and importantly document that multiple males likely sire hatchlings at some nest sites, suggesting that alloparenting by guardian females and males may be widespread amongst the large gharial creches assembled at nest sites.

It is now clear that previously published marker studies on gharial have not been sufficiently informative, and have led to premature conclusions, not supported with robust genetic data. With a panel of 8 markers, 96 gharial samples from the NCS have revealed lower average number of alleles (3.2) per marker, and lower polymorphic information content (0.34), than that revealed by Jogoyya et al. 2013 for the captive gharial population studied. In light of the new markers developed at LaCONES, a re-evaluation of previous reports is now underway.

Gharial Dietary Niche. For stable isotope analyses, utilizing C/N signatures, 181 scute samples were collected by the GEP team from 2009 thru 2019, over >300 km of NCS. All size classes of individuals (hatchling to big ghara males) have been included. Around 100 fish samples, as well as representative river-dwelling vertebrates, have been included in the on-going analyses. Our objective is to understand any ontogenetic and/or sex differences in the dietary niche of gharial.

We hypothesized that ontogenetic change in body size would be matched with a shift in diet, and it could be revealed from stable nitrogen and carbon isotope ratios in keratinized scute tissues of gharials. Initial results suggest that the seasonal patterns evident are related to monsoonal watershed inflows that vary strongly from year to year, and are closely coupled to river location. Dietary niche shifts in

gharials will have important implications for the ecosystem level management and long-term viability of the population. The Chambal river ecosystem at present is one minimally impacted by control structures that alter seasonal dynamics of high-water vs. low-water riverine habitats.

Gharial communication. Jailabdeen A. has continued his PhD research studies of acoustic signaling amongst "big ghara" males. These signals consist of underwater POPs in stereotypic patterns, primarily with "timing" variations, which are individually distinctive as well as context-dependent. At one site frequented by a breeding male, with few females (<10 in 2017) vs. many (>30 in 2018), "recruiting" pops directed at females predominated in both years. In contrast, in 2018, when other males were present, the main acoustic signal was a "challenging" pop. At this site, overall pop frequency almost doubled in 2018 (182 vs 101), relative to 2017. Then in 2019, frequency declined (120 vs. 182), almost half as many as in 2018. In short, adult male gharial are signalling using fine structure temporal patterning of POPs, very different than the frequency-based vocal signals described in other crocodylian species. How the POPs are produced as well as perceived are open questions, ripe for further studies.

Jai is also investigating chemical signaling via secretions produced in the gular and cloacal glands. Pheromone samples from wild gharial of various sizes, ages, and sexes have yielded complex mixtures of distinctive chemical compounds. Collaboration with LaCONES, an Indian Government research lab in Hyderabad, is facilitating this research initiative. Such secretions are presumably responsible for the noticeably strong, musky smell made by large male gharials during breeding, but the roles of pheromonal communication in other aspects of gharial behaviors are largely unknown. Jai will complete his PhD in early 2023.

Films, videos, media. The GEP has active Facebook and Instagram pages, with frequent posts about recent events and activities. Select GEP media are now available in Hindi, and are being translated into other regional languages as well, such as Tamil. These are freely downloadable on the GEP YouTube channel. Animal Logic produced a 7 min video called "Boop the snoot" including GEP behavioral footage; an edited version is on YouTube. A recent 3:30min short on Chambal gharial natural history appears on our FB and on the MCBT website, and is now available in English, Hindi, Nepali, Burmese, Sinhala, Bengali, Malayalam, Tamil, and Urdu, as well as Spanish, French, German, Czech, Norwegian, Dutch, and Chinese. This video summarizes the major findings from the GEP studies on the Chambal over the past decade and a half.

The GEP team worked collaboratively with the Gaia People, a Delhi production house in April and June 2019, to produce an episode about Chambal gharial natural history for the second season of *On the Brink*, an Indian TV series, coproduced by the Habitats Trust. The program is 26 minutes, and features Pankaj K. and Jailabdeen A. and was aired on Earth Day in April 2021, and distributed throughout the Pacific Region. The GEP has been very fortunate to work closely with a talented Indian film maker, Kalyan Varma and associates, and currently is teaming up with these cinematographers to make a series of documentaries, focusing on the resident gharial in the NCS.

Recent magazine articles that have featured stories about the GEP include a historical account of gharial conservation at the MCBT by one of its founders, Zahida Whitaker (2020). In a three part series in the *Wall Street International* travel magazine, Gehan de Silva Wijeyeratne (2020) highlighted findings of the tracking studies using telemetry on gharial, as well as the Chambal River birds and related landscapes, and the challenges of conducting research in the NCS.

Gharial elsewhere. Recent field work in Katarniaghat Wildlife Sanctuary, arguably the second most important gharial population remaining, by Gaurav Vashistha and his colleagues has documented the tenuous nature of continued nesting by gharial there (Vashistha et al. 2021a,b). In short, increased vegetation on riverside sandbanks has limited nesting opportunities in recent years. He relates the change to a channel shift, resulting in less seasonal monsoonal flooding. To solve the problem, vegetation removal was attempted but proved largely unsuccessful, whereas sand addition to create new sandbanks resulted in increased nesting. Long term prospects for gharials living in such river-reservoir settings is not favorable, due to the unidirectional movements imposed by reservoir dams. At Katarniaghat as well as at the Corbett Tiger Reserve, juvenile recruitment remains the unresolved threat to the long-term sustainability of both "pocket" populations (Vashistha et al. 2022). On a brighter note, gharial studies in Nepal have now documented a sixth breeding population for gharial globally, with the discovery of nesting on the Babai River, on a protected stretch within the Bardiya National Park (Bashyal et al. 2021). In addition, we continue to collaborate actively with Phoebe Griffith and Nepalese colleagues at Chitwan National Park, working on that critical gharial population (Griffith et al. 2020), as well as with Phoebe as she completes a DPhil at Oxford focusing on the Chitwan work, and gharial related topics (Griffith et al. 2022).

Future prospects. Hopefully, as covid restrictions are relaxed, and regular international travel resumes between India and the rest of the world, our regular seasonal exchanges will be possible. In the interim, the GEP field team headed by Jailabdeen A. and Pankaj K. will continue to conduct field studies in both the upstream and downstream stretches of the NCS, and develop strong ties with our upstream partners such as TigerWatch, based in Rajasthan, and the Forest Department in Madhya Pradesh. Our focus in the near term will be to document gharial life history patterns of those residing in the upstream Chambal, for

possible comparisons with our prior observations in the downstream Chambal, during the past decade, and to continue to monitor gharial throughout the NCS.

International Funding. We are extraordinarily fortunate to have the continued support of the City of Prague / Prague Zoo and the generous contributions of donors to CrocFest through the Gladys Porter Zoo. The Summer CrocFest (June 2021) at Zoo Tampa provided additional support for the Gharial Ecology Project, and we gratefully acknowledge the invaluable funding received to date, literally making gharial conservation on the Chambal an on-going joint venture and a distinct reality. The international zoo continues to contribute support via the CrocFest events, as well as direct support; Berlin Zoo, Montgomery Zoo (Alabama), and the Los Angeles County Zoo have provided substantial funding in the past two years. We have begun to garner CSR funding from Indian industry, and gratefully acknowledge the extraordinary logistic and operational funding provided by the Astral Pipes Foundation, as we solicit additional CSR support.

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Fig. 1 During the 2020 & 2021 "pandemic" years, the GEP field team carefully observed isolation and mask protocols when tracking and conducting behavioral observations in riverside localities. Special permission was granted to GEP that allowed us to move freely during lock downs. Here, Pankaj, our lead tracker, sits at the Khera Ajab Singh nesting site near a guardian male gharial, surrounded by hundreds of hatchlings.



Fig. 2 Jailabdeen A., Project Co-Ordinator for Gharial Ecology Project (GEP), was the leader during the long two year period of lockdowns and social distancing, in 2020-2021. Here, he retrieves a quadcopter used for two main annual surveys---population counts throughout the 425+ km in late January, and nest counts in the post-hatch period, during late June, just prior to the high water rise at the start of the July-Aug monsoon.



Fig. 3 Guddhu, our newest recruit as a regular tracker, listens for the beeping signals of a radio-tagged gharial, near our downstream base at Dinnpura. This locality has been used year after year by 15-40 gharial for communal nesting. Downstream nests tend to hatch one to two weeks later than nests upstream.



Fig. 4 Anand, a long time tracker with the GEP, checks for nests likely to hatch in the next several days by tapping on the sand surface above the buried eggs, 12-18" inches deep. If babies are ready to hatch, they vocalize loudly in response to taps on top of the nest. Daily checks allow the team to document the hatch synchrony, day-wise, at each communal nest site.



Fig. 5 Anand (gray shirt) and Guddhu (blue shirt) harvest vegetables with their kids, from kitchen gardens at the Chambal riverside, near Sashon Village. Masks were commonplace throughout the pandemic, and most villagers were restricted to their village areas and not allowed to move around as they did normally.



Fig. 6 Pankaj, our lead tracker and researcher, works in the family garden, riverside, with his two sons, Krishna and Dev. Riverside cultivation is an essential source of locally consumed vegetables, but limited to the immediate perimeters of each village. Local vendors also visited villages with carts of local produce for sale, going house to house within villages.



Fig 7 Raghuvendra, nicknamed "Guddhu," receives his vaccination for covid at a local clinic. All GEP trackers were vaccinated as soon as this was feasible, in early 2021. Normally working together in pairs, the team members each adopted an individual schedule of river tracking, riding a motorbike alone during 2020-2021.



Fig. 8 Pankaj sits by himself, in his field shed, near the riverside gardens, and records behavioral observations keyed to his images, both still and video, shot with his Nikon P1000 ultrazoom camera. Binoculars & scopes are regular field gear used during routine tracking. Trackers distinguish specific gharial behaviors, such as swimming or basking on land, based on radio signals.



Fig. 9 View of a rock shelf at the riverside along upstream Chambal River, with riverfolk collecting rocks and boulders for construction. Riverside consumption of local resources, especially sand and boulders sales, which increased dramatically during the pandemic.



Fig. 10 View from Rajasthan side of Chambal at the Tighra-Rithora turn, below Dholpur, of an entire sandbank that has been "removed" by tractors and trolleys 24/7 throughout recent years, except high water months in July-August, beginning in 2015. By 2019-2020, the 40+ gharial nests previously laid at the shoreline were no longer possible at this site. Details at this site are shown in Figs. 153-158



Fig. 11 When villagers working in the larger cities were forced to return "home" during the pandemic, riverside activities needed to generate "lost" income increased everywhere along the river, within the protected National Chambal Sanctuary. A villager uses a truck inner tube as a personal "raft" with which to spread nylon netting across river stretches.



Fig. 12 Villagers from Rajasthan, upstream near the Kali Devi Sanctuary cross the Chambal on foot, carrying head- loads of wood to fuel cooking fires. Villagers spent lots of time riverside during the pandemic months, collecting firewood and grasses for local consumption and cash sales, as well as subsistence fishing and hunting of waterfowl, etc.



Fig. 13 View from the upstream confluence of the Parvati River (right side of image), flowing westward from the MP-Raj border to meet the Chambal River flowing northward from its headwaters in Rajasthan. Gharial nesting occurs on the east facing bank, bottom center, and upstream along the Parvati. The bridge from MP to Rajasthan at Pali, is shown in distance, top center on horizon. Tourist camps on the banks of the Chambal (left, shoreline) operate under private ownership, with Raj FD permission.



Fig. 14 Looking downstream from upstream location on the Parvati River, showing a few deep pools with shallow, rocky connecting channels. The Parvati River is protected on only one side, the Madhya Pradesh side of the river (shown right in this image). The left side is in Rajasthan, and totally unprotected. Hence, riverside cultivation, sand and rock removal is common on the unprotected Rajasthan shoreline. Gharials nest at several locations on the Parvati, and these are on unprotected shoreline in Rajasthan.



Fig. 15 View of the island at Baroli, an upstream area used annually for communal nesting, 15-40+ nests by resident gharial. Our upstream base is located near this traditional nesting site, studied over decades by the MPFD staff. Looking upstream, the area in the foreground was the main residence of the big ghara male, tagged with an Iridium satellite GPS radio unit.



Fig. 16 Upstream view of Dang Basai rapids, showing gharial communal nesting area on sandy shorelines in center. The river crossed a large, rocky shelf above this site. Several radio-tagged females breed here and also nested at this site. Upstream movements were recorded above these rapids, but many adults stopped their upstream movements.



Fig. 17 Dr. Ashutosh Tripathi pauses while listening for evidence of radio tagged gharial in lower stretch of the Kuno River just upstream from the boundary of this Protected Area tributary that joins Chambal just below our upstream base. Female gharial from the mainstream Chambal moved up into the Kuno to nest, in "wet" years when water levels allowed.



Fig 18 Dr. Hari Mohan Meena, a collaborator based in the upstream National Chambal Sanctuary (NCS), tracks radio tagged gharial near the Baroli nesting area, in the post monsoon, Sept-Oct, when water levels are still relatively high and aquatic habitats extensive. This location is just a 15 minute walk from our base at Katrinapur, in the upstream NCS.



Fig. 19 Since 2009, we have relied on Deepu Mishra who has been our dependable driver, base manager, as well as purchasing agent, and jack of all trades. Here, Jailabdeen and Deepu prepare to document the gharial population residing at the Baroli site, near the upstream base, with drone imagery.



Fig.20 Pankaj, tracker and researcher, accompanied by Deepu, listen for radio-tagged gharial at Baroli, the island (shown in Fig 15) which is the center of the "home range" of the big ghara, breeding male resident at the site, and radio-tagged in Dec 2019.

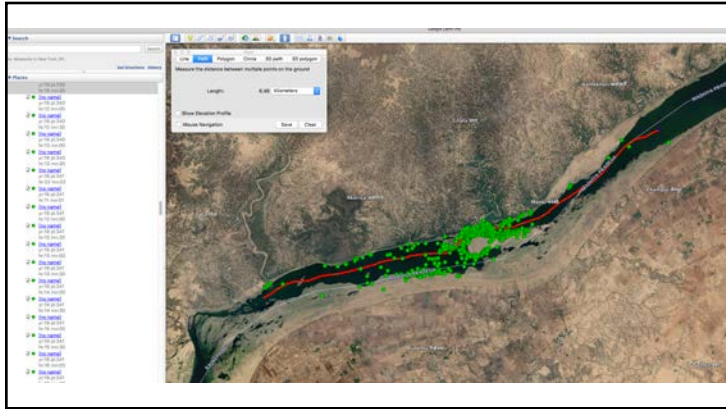


Fig. 21 Plot of GPS locations for the Baroli male, tagged in Dec 2019 and followed via Iridium satellite transmissions (72) for 1228 datapoints, thru end Feb 2022. He moved only a few km over that period, even during the two monsoon seasons (2020&2021). The red line traces 6.5 km along the Chambal, from the uppermost location to the farthest downstream. The main center of his activity is shown in Fig. 20.



Fig. 22 Head-on view of the Baroli male, showing the Iridium satellite tag (brown rectangle with GPS platform visible, black patch) in position on dorsum at base of tail, nestled between double scute rows. This unit, built by Advanced Telemetry Systems, has a useful 'life' of about 3-4 years, based on a few daily fixes (GPS locations) transmitted for download every 4-7 days to a user-friendly internet site.



Fig. 23 Side view of Baroli male during breeding in Feb 2021, showing two transmitters on base of tail. One unit is the Iridium GPS satellite radio, and the other radio is a conventional VHF tracking radio. Two units are routinely used on large adults, to facilitate both remote tracking as well as manual tracking to ensure frequent monitoring of activities & behavior.

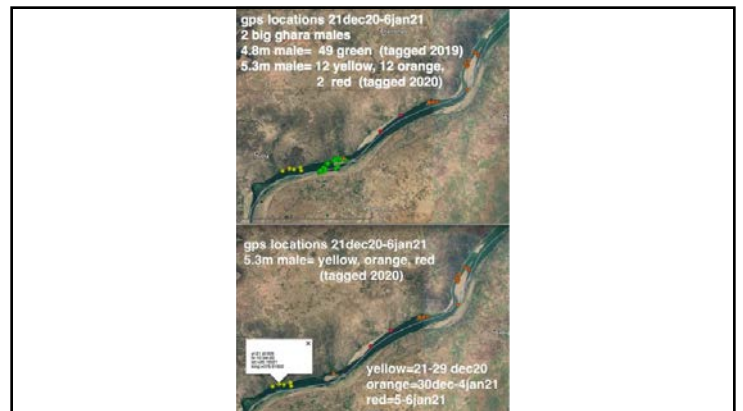


Fig. 24 Spatial patterns of two "big ghara" males in residence near the upstream base at Baroli. One male, shown in Figs. 22&23, has remained near his capture site, while the larger male, tagged in Dec 2020, moved back and forth between the Baroli nesting site, and another site 10 km downstream.

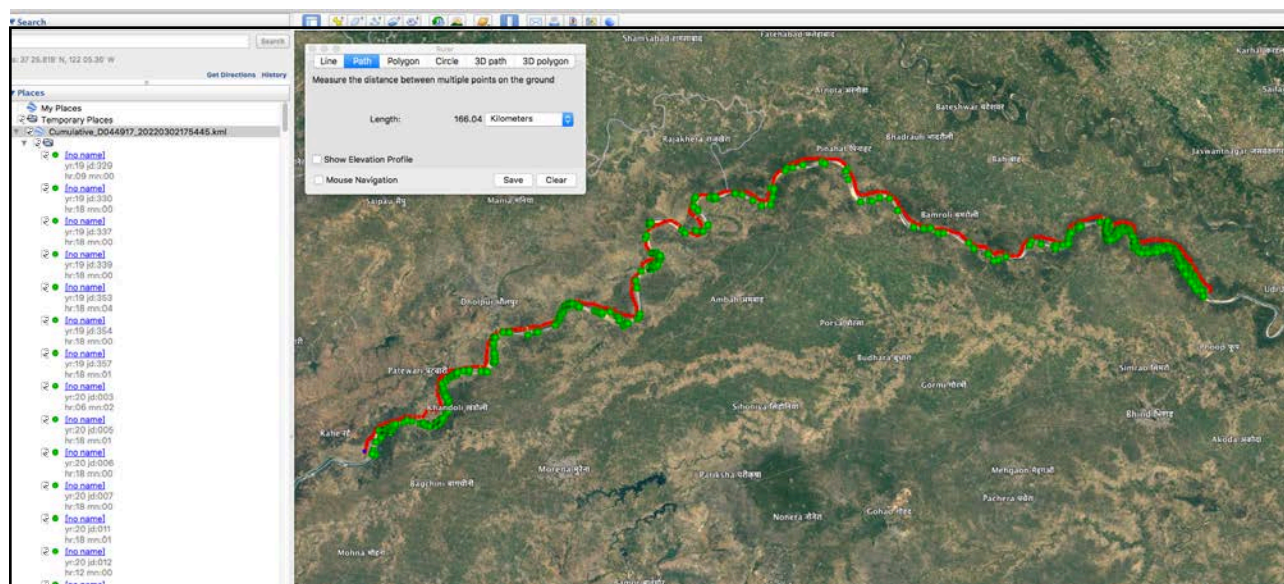
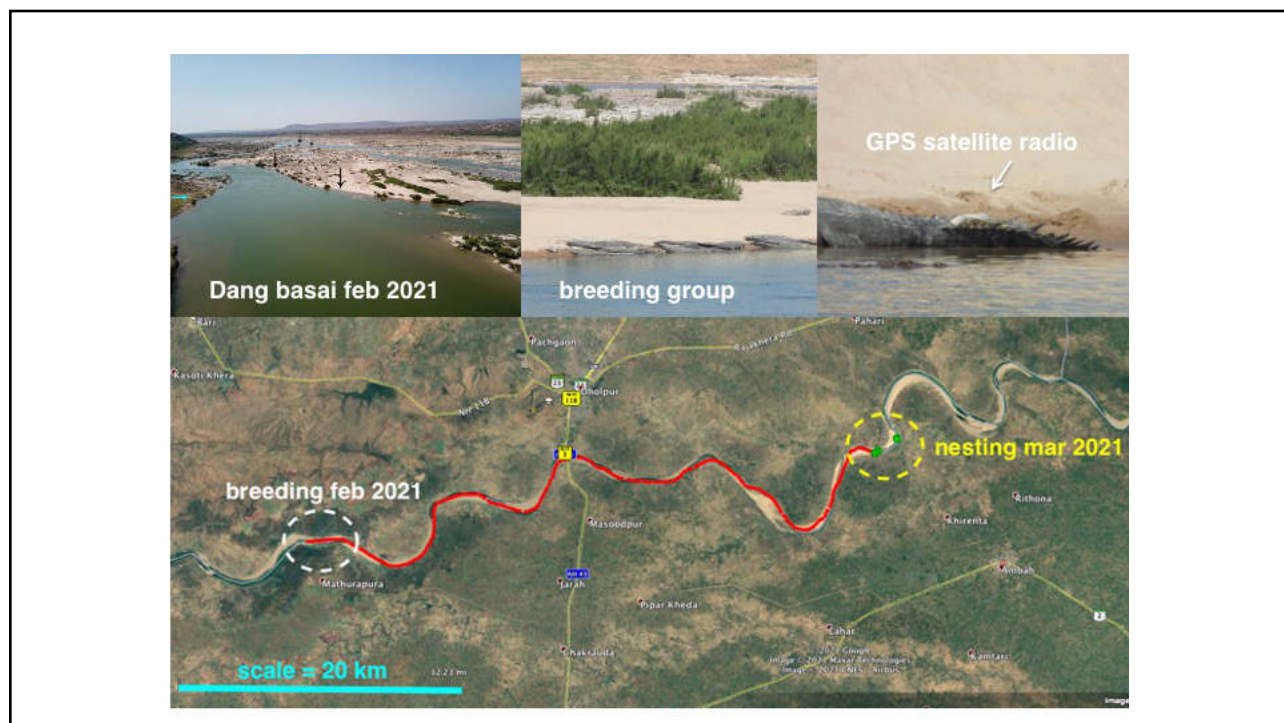


Fig. 29 In Dec 2019, a female gharial was captured at Dinnpura, near our downstream base at Garhaita, and she has been tracked with an Iridium satellite unit through June 2022. She moved back and forth over a distance of 166 km, nesting upstream >100 km from her capture point, then moved back downstream during monsoon. Her extensive back and forth seasonal movements are based on 1472 locations, thru Feb 2022.

Fig. 30 (below) In 2021, the Dinnpura (DN) female, captured at a downstream site near where she had nested previously, moved >150 km upstream to a breeding site in Feb-Mar, then nested at a midstream site, ~100 km above her previous nesting site. In 2022, she again moved upstream, but bred and nested downstream.



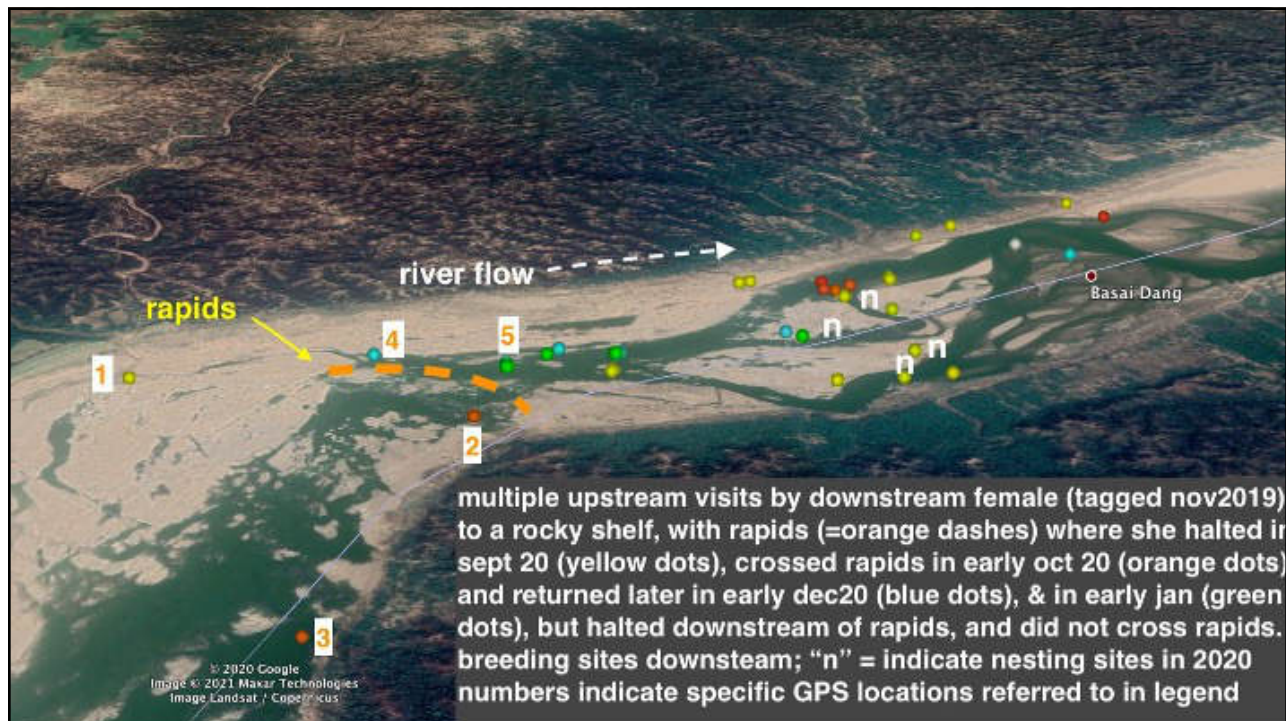


Fig. 31 Extensive upstream movements by the DN female, radio-tagged with an Iridium satellite GPS unit in Dec 2019, have been documented during the past two years. The radio unit is still functioning, as of June 2022, and has provided to date, a total of 1610 locations, based on 256 transmissions over 30+months. To date, this female has moved back and forth over a river distance of >166 km multiple times in the two years of tracking.

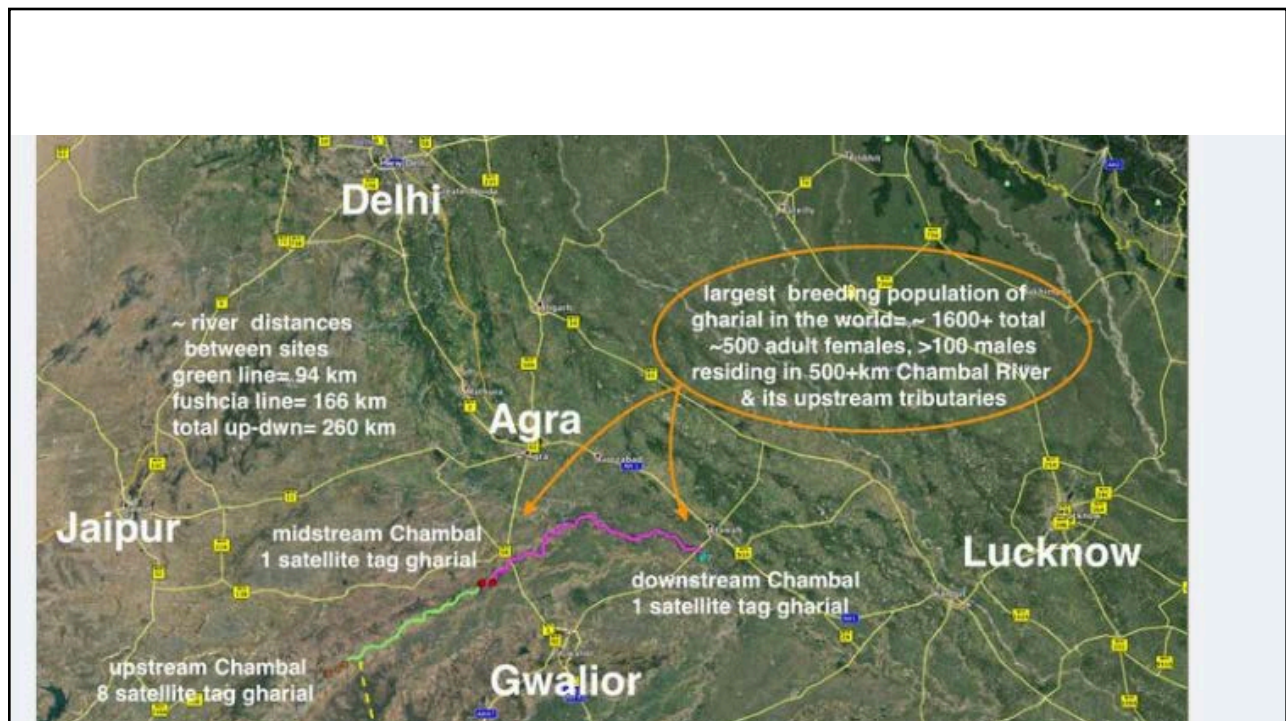


Fig. 32 Overview of the location of the mainstream Chambal River, both upstream, midstream, & downstream stretches that are routinely being monitored for annual population surveys, as well as nest counts during the breeding, nesting, hatching seasons (Feb-Jun) before the high water, monsoon months of Jul-Aug-Sep.

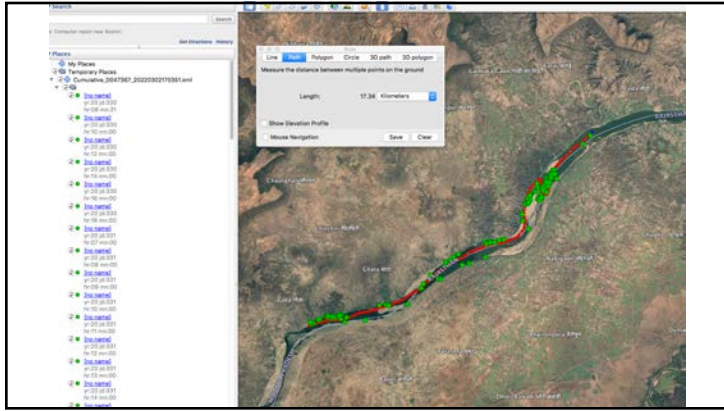


Fig. 33 In Dec 2020, 8 gharial were radio-tagged with smaller capacity Iridium GPS units, and tracked for 6-14 months. Seven of these were residents in the upstream stretch of NCS, near the Baroli base. Above are the cumulative locations, totaling 564 data points, with 126 transmissions, over a 17 km stretch of mainstream Chambal for a 3.6m female (56/49). This female nested at Nadigoan, another communal nesting site just downstream from the Baroli site.

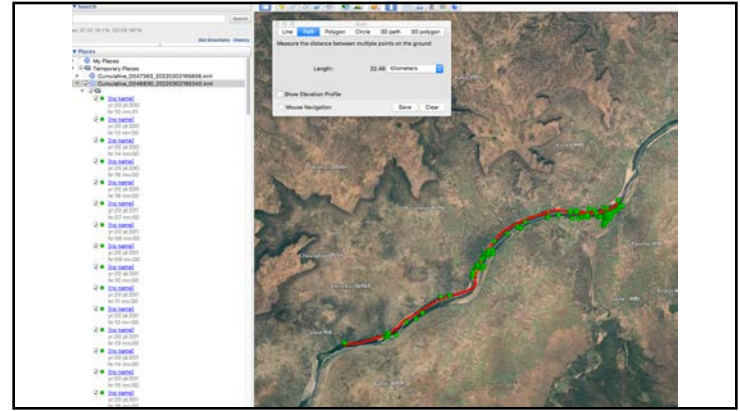


Fig. 34 Comparable record for female 82/33, with total length of 3.4m, tagged in Dec 2020 (same as in Figs. 32 thru 35). The cumulative locations, totaling 393 data points, with 93 transmissions, ranged over a 23 km stretch of mainstream Chambal. Following breeding, this female spent considerable time at the Kuno- Chambal confluence (upper right locations), but did not venture upstream into the Kuno for nesting in 2021, as some other females did in 2020.

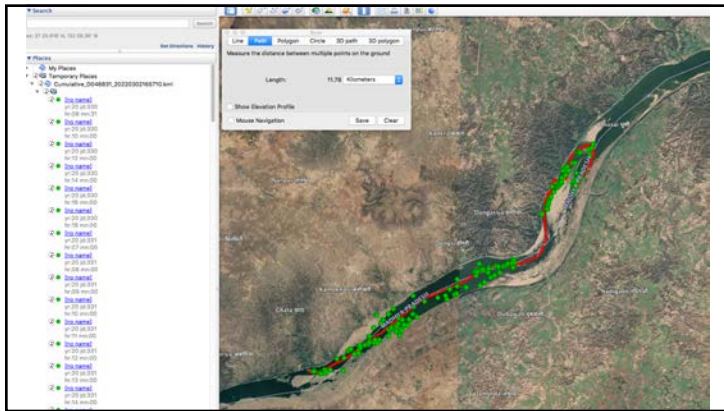


Fig. 35 Comparable record for female 84/39, with a total length of 3.1m, tagged as animals in Figs 32-35. The cumulative locations, totaling 420 data points, ranged over 12 km of mainstream Chambal. This subadult female was not large enough to be nesting, but had activity/movement patterns similar to those older, larger females that were likely nesting in 2021.

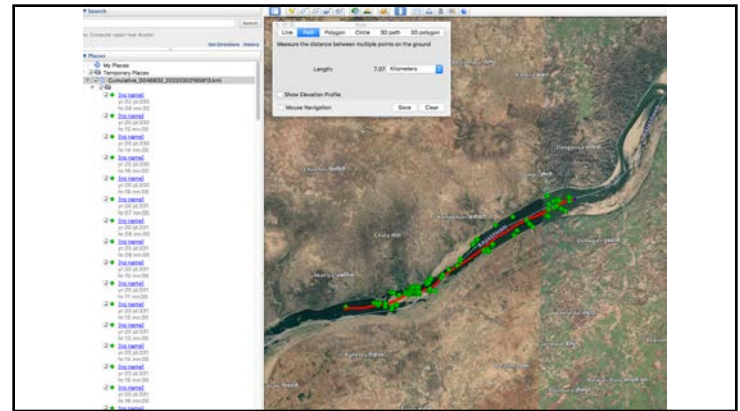


Fig. 36 Comparable record for female 86/35, with a total length of 3.3m, tagged as animals in Figs. 32-35. The cumulative locations, totaling 381 data points, ranged over only 7 km of mainstream Chambal. This female spent considerably more time upstream at the Baroli nesting site where she nested in 2021.

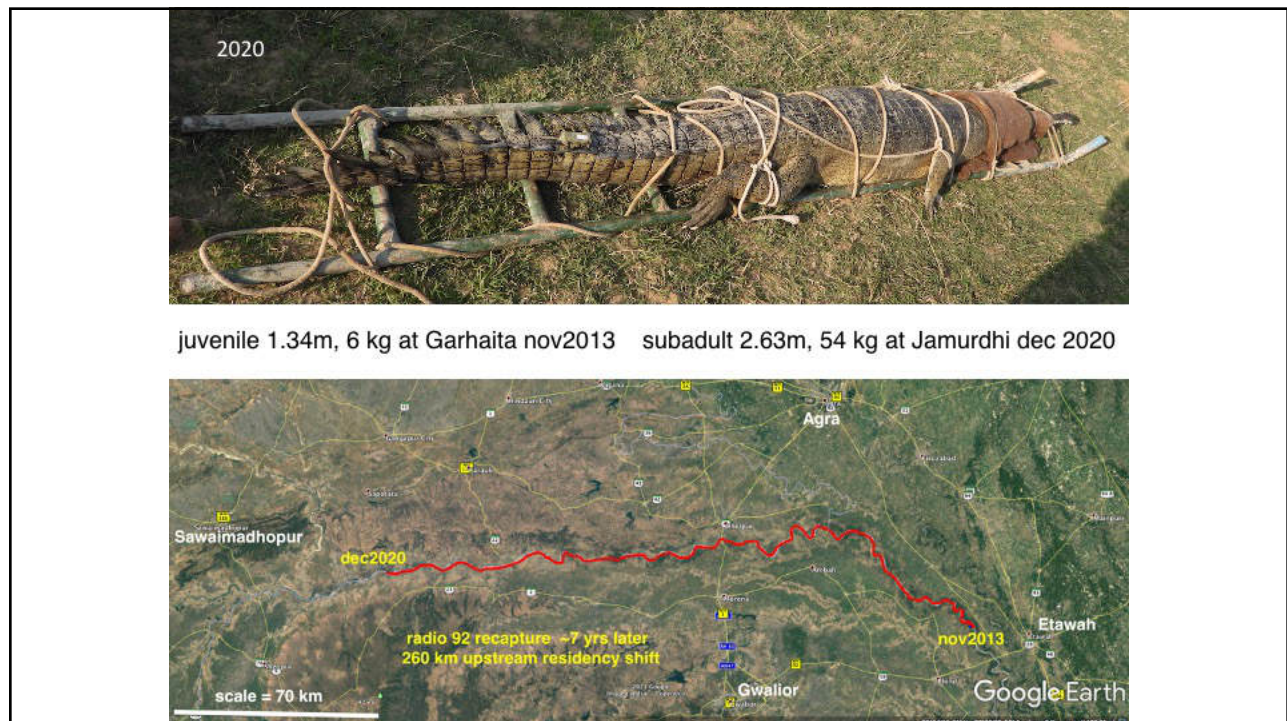


Fig. 37 Although more than 100 gharial, ranging in size from juveniles to adults, have been marked since 2008, in the lower Chambal (within 125 km of the Yamuna confluence), few of these have been encountered in the upstream Chambal (above Dholpur). In Dec 2020, a gharial tagged as a juvenile in Nov 2013 was recaptured just below Baroli in the upstream, a total shift in residency of 260 km when recapped ~ 7 years later upstream.



Fig. 38 Images taken in 2013 when the gharial was tagged as a 6 kg, 1.3m juvenile (lower left, upper left). When it was recaptured 260 km upstream in 2020, it measured 2.6m total length, and weighed 54 kg.



Fig. 39 Detailed behavioral observations have been conducted in the upstream Chambal, for comparison with data collected downstream. Here, in late Feb 2021, at the Baroli sandbank, the resident breeding male basks near a sandbar with 30+ females basking in the late afternoon. Peak breeding occurs within a few days, when females approach a dominant male to initiate courtship and breeding.



Fig. 40 A female approaches the resident dominant male, in his breeding arena, and initiates courtship. Receptive females remain close to the breeding male and mating usually follows in shallow shoreline areas. During peak breeding, the dominant male is courting and breeding non-stop day and night, but especially in the late afternoon and evenings, & early mornings.



Fig. 41 "Big ghara" males compete for opportunities to breed, and eventually establish a breeding arena near favored basking sites along a residential stretch of shoreline. Prior to peak breeding, males contest their dominance, presumably based on body size, and such contests, as in Figs. 42-45, result in scarring on the snout, often extensive as shown here, and /or punctures or tears in bulbous knob at tip of snout.



Fig. 42 Young males, nearing full adulthood as "big ghara" dominant breeders, are characterized by an enlarging protuberance on the end of the snout that encapsulates the nares in a cartilagenous growth, known as the "ghara." In Chambal, a male acquires a ghara within a few years, once he reaches ~4.5m in total length and acquires a breeding residence.



Fig. 43 The dominant Baroli male, radio-tagged as in Figs. 22-23, approaches a sub-dominant male with small "ghara" (above, right side) that is basking with a large group of breeding sized, adult females. On approach, the smaller, subordinate male quickly moves away, and submerges to avoid confrontation.



Fig. 44 Here, the sub-dominant male, with small ghara, rapidly moves away from approaching dominant male (see left side, Fig. 42). Most such confrontations are quickly resolved by rapid retreat of the smaller, subordinate. Typically, these small males remain on the periphery of basking groups, but sometimes they attempt to "hide" in groups of other similar-sized individuals, most of whom are reproductively active females.



Fig. 45 "Body surfacing" by a dominant "big ghara" male involves his sudden rapid swimming, accompanied with splashing and head held above the water surface, as shown above, for at least 3-4 body lengths, usual parallel to shoreline where other gharials are basking. It is often initiated when a challenger male appears or is detected in the area.



Fig. 46 Continuation of "body surfing" behavior that results in sudden disturbance, with lots of splashing adjacent to an area where most gharials are basking. This behavior appears to be an "assertion" display intended to broadcast a strong "dominance" signal to all those in the surrounding vicinity.



Fig. 47 This is the first of 4 stills taken from a video clip showing the dominant, "big ghara" male doing a "tail-wag" to punctuate a chase or patrol, usually performed in response to the presence of another male, either challenger or intruder, in the area. The tail-wag display was only observed to be performed by large ghara males with established residencies which remained as basking and breeding sites for years. Younger males, not yet having a "residency," were observed moving up and down river stretches, presumably assessing future breeding opportunities.



Fig. 48 A "tail-wag" consists of a deliberate, stereotypical and exaggerated lifting of the tail, from the substrate, high into the air, and then dropping it down suddenly with force, against the ground. Figs. 46-49 are still-frames from a video clip showing this dramatic behavior, performed by a resident, dominant male, usually near gharials basking on land.



Fig. 49 This frame is the third still in a sequence shown in Figs. 46-49. Here, the dominant male drops his tail down, with a big splash, as he moves onto land. A "tail-wag" by a dominant male is used to punctuate the chase of a sub-dominant nearby, or to conclude such an encounter in which the performer prevailed.



Fig. 50 The resident, dominant male assumes a basking position on land, at the conclusion of a "tail-wag" aimed at either another subordinate male gharial (as in Figs. 42-43) or possibly at an adult mugger crocodile (shown here just ahead of the dominant male at the shoreline). In some cases, resident male gharial chase mugger crocodiles out of basking areas.



Fig. 51 "Big ghara" male gharial engage in contests that appear to determine dominance and access to breeding opportunities near favored basking sites. Size appears to be the determinant of victory in such encounters. Here, two nearly-equal sized animals, ~5m in length, swim in parallel, making large circles in open water.



Fig. 52 Circular swimming leads to one individual, here the slightly smaller of the two, moving onto the back of the other, possibly attempting to push his opponent underwater as he moves onto its back. The process is leisurely, taking many minutes, and can last at least an hour or more.



Fig. 53 Although the appearance here is one of deliberate "head to head" contact, or "dueling" as it has been called, the actual activity involves one individual trying to get into a position of moving over the back of the other. Here, the smaller gharial (noted by slight difference in ghara size/shape), is trying to move on top of the larger individual.



Fig. 54 As the contest concludes, the larger gharial (now with head held highest, in foreground) moves onto the back of the smaller, and succeeds in gaining a favorable, dominant position, relative to that of the smaller gharial (shown here on left). This contest lasted for more than 45 minutes in open water in midriver at the Tighra-Rithora turn, below Dholpur.



Fig. 55 Each "big ghara" male is characterized by a distinct, individually unique ghara in size and shape. In effect, each "ghara" acts as a signature marker of the identity of its bearer. Such a distinction allows the GEP field team to keep close track of individual breeding sized male gharial, up and down the NCS. In general, the large male gharial that are effectively breeding along the Chambal are long-term residents of small river stretches, favored for basking/nesting.



Fig. 56 This male has a distinctive "shortened" lower jaw, probably related to an injury or net encounter. Such special features, in concert with a unique size / shape to each ghara, establish an individual identity for each "big ghara" male, and allow us to map out the residential stretches of river each male inhabits.



Fig. 57 In this sequence (Figs. 56-57), a large male is able to corral a much smaller female into shallow water, prior to mounting her to complete a mating. During peak breeding, courtship and mating are accomplished for 20+ females in a breeding group in just a few days, and occurs throughout the 24 hours.



Fig. 58 Courtship and mating occur in shallow water, usually in 1-2m depth, and may last only minutes or continue for hours, at all times of day or night. Each breeding male establishes a small breeding arena, and displays often at that site, and when patrolling.



Fig. 59 In Nov-Dec 2020, the GEP field team, working under the direction of Jailabdeen and Pankaj, caught and tagged 13 gharial in the downstream Chambal, as well as 13 gharial upstream, and were able to equip 8 larger gharial with Iridium satellite radio-tags. Here, they restrain a 5.3m male caught at Nadigoan, just below the upstream Baroli base.



Fig. 60 Safe capture and tagging these larger gharial is paramount, and the GEP field team has worked with a 5 person fishermen team from Pachnada for more than a decade. The teams use walkie-talkies to communicate, and spend long hours strategizing net arrangements in order to successfully capture the larger gharial. Cool weather coupled with sunny days ensures that gharial will cross nets for basking.



Fig. 61 Close-up of the "big ghara" of male 60/93, shown being restrained in Figs 58-59. The distinct POPs produced by large males is thought to be dependent on the structural features of the ghara, but the actual mechanics of the acoustic sound production have not been studied, to date.



Fig. 62 Jailabdeen with the help of an assistant takes a pheromone sample from the chin gland of a subadult mugger crocodile. Chin gland and cloacal gland samples from each captured gharial have been collected, and flash frozen for chemical analyses.



Fig. 63 Jailabdeen (left), assisted by Deepu, Himani, and Prem Narian, attaches a satellite transmitter on one of the females during the 2020 tagging session. Both radios are clearly visible attached to the top surface at the base of the tail. Strong, braided fishing line is used to secure the radios beneath the skin.



Fig. 64 With each individual captured, measurements are taken, as well as a weight, and samples collected for DNA and pheromone analyses. Scutes are clipped in distinctive combinations to denote each individual. The whole process from capture to release typically occurs within several hours, on same day of capture.



Fig. 65 During the catch-tag operation each season, the field team interacts with local villagers using the river, and are able to talk with them about the importance of protecting the gharial, and also teach them about differences between gharial and mugger.



Fig. 66 The field crew enjoys the last morning on the river, as the 2020 season closes. (left to right) Guddhu, Kishore, Himani, Pinto, Santaram, ShivSingh, Pankaj, Anand, Deepu, Prem Narian.



Fig. 67 Early morning Dec 2021, Santaram prepares the two country boats for the hard work of setting the nets around the basking sites. In 2021, the GEP crew was led by Jailabdeen and Pankaj, as in 2020. Lockdown restrictions related to the pandemic made working on the river more challenging in terms of moving from site to site, and securing permissions.



Fig. 68 Catch-tag operations in 2021 were centered on the mid-stretches of the Chambal, in contrast to previous years working upstream, and earlier years working downstream. At this site, near the Raj-UP border of the National Chambal Sanctuary (NCS), nets were set early in the morning to allow gharial to cross the nets as they emerged on shore to bask. Then, basking individuals were chased into the nets by approaching them from the river banks.



Fig. 69 In late 2021, catch-tag operations yielded a total of 26 resident wild gharial that were tagged with radio transmitters, including 7 with Iridium GPS units, as in previous years. Of these, most were adult and subadult females (19 of 26), but also included two "big ghara" males, 4.6m and 4.9m total lengths.



Fig. 70 Steel ladders helped us restrain & transport gharial from capture sites to camp site for tagging. The head was covered, including the eyes so that the animal remained subdued during handling. Gharial rarely struggled, once restrained, and were usually released within 2-4 hours post capture.



Fig. 71 Pankaj pulls a gharial entangled in netting to the side of the country boat, before lifting it into the boat, or slowly pulling it to the shore. Nets were attached to floats, and were checked regularly to ensure that no animals were held long underwater. Multiple nets were set to surround basking sites in an effort to prevent gharial from escaping nets.



Fig. 72 Slow and easy are the buzz words when nets were removed from the fine, sharp teeth used by gharials to catch, handle and swallow slippery fish. Extra time spent securing the long, powerful jaws paid off with few, if any, accidents or mishaps due to poor techniques for handling animals.



Fig. 73 Each catch-tag operation had its share of camp fire stories. The field teams spent 15-20+ days each early winter, since 2013, living riverside. Meals were cooked on location at each site, and the teams moved every several days, usually going downriver. Provisions were procured locally by road and foot.



Fig. 74 Campfires not only provided food, but light and warmth on chilly evenings and cool mornings. Night time on the Chambal is for resting & sleeping. Netting started at dawn, and by evening, nearly all of the gharial had already been tagged and released.



Fig. 75 Hatchlings remain in the riverside creches for 1-4 weeks post-hatch, before dispersing into smaller groups, as the water levels rise on monsoon rains. A back-pack radio attached to a hatchling allows us to monitor hatchling activity & behavior before the creche dissolves, as well as keep track of these young survive in the first few weeks of life.



Fig. 76 In 2020 and again in 2021, creche counts were made for about a month before creches dispersed. Nest predation is highest at sites with most nests. About half of the hatchlings are no longer evident by the time the creche dissolves, but losses vary from one year to the next. For small groups of hatchlings, survivorship can be very low, or relatively high.



Fig.77 Hatchlings that survive into the monsoon may well number about half of those alive pre-monsoon. The low percentage that survive post-monsoon, are generally double or triple the size of hatchlings, in overall length and weight. Pilot studies in 2020 and 2021 suggest that survivorship is already high for those hatchlings still alive by end Sept-early Oct.



Fig. 78 Hatchlings surviving into the post-monsoon months of late Oct-early Nov are already 0.6-1m in length, and may be seen feeding voraciously along shallow shorelines at night. Approach & capture are possible, and pilot studies are planned to radio-tag hatchlings at 6 months of age to study survivorship.



Fig. 79 In 2018, GEP field team collaborated with Madhya Pradesh FD to tag and release "head-starts" reared in captivity at Deori for Chambal release. Tracking radios were attached to juvenile gharial, 1-2m in length prior to release. In brief, captive reared young showed lower survival, and were predated by subadult and adult mugger crocodiles.



Fig. 80 A small batch of "head-starts" were tagged in early 2018, for simultaneous release in an area where wild resident juveniles of the same sizes/ages were tagged. Captive reared releases were more likely to move upstream and downstream from the release sites, and were more often predated by mugger crocodiles, than were wild tagged juveniles.



Fig. 81 In late 2020, additional "head-starts" were released upstream in the Kuno National Park where they were effectively "soft-released" into several deep pools not connected via river channels to the mainstream Chambal. Others were tagged for release in the mainstream Chambal at Baroli.



Fig. 82 In late 2018, another group of "head-starts" were released in the downstream Chambal, a total of 15 captive reared vs. 8 wild resident juveniles, same sized. Captives moved widely upon release, then settled in residencies near release sites. But more were lost to predation by mugger crocodiles.



Fig. 83 Aerial view of the Kuno River at Palpur locale where "head-starts" from Deori EcoCentre were released during winter months. Some were held in temporary pens within the deep pool visible above.



Fig. 84 View of enclosure constructed as holding pen for "soft release" of captive-reared juveniles from the Deori EcoCentre, Madhya Pradesh Forest Dept. In Dec 2020, 11 "head-starts" were tagged, 5 for release at Baroli on the mainstream Chambal, and 6 were released at this site in Kuno National Park.



Fig. 85 A subset of "head-starts" retained in a soft release enclosure at Palpur, Kuno River were tagged and subsequently tracked through the high water of the 2021 monsoon. Of the six tagged, several were located in the Kuno, and at least one tagged gharial had moved from the Kuno River into Chambal River.



Fig. 86 Aerial view of shoreline in Kuno National Park. On lower left shoreline, a subadult mugger crocodile is basking on land. A juvenile gharial basks at shore, to the right of square rock, at site just downstream. Mugger predation on juvenile gharial is evident in both upstream & downstream stretches of Chambal.



Fig. 87 Aerial view of Katrinapur, the small village where our upstream base is located. Agricultural fields surround the village, and grazing land adjoins the Chambal River channels, visible in far horizon.



Fig. 88 Aerial view of the Kuno River in full flood in monsoon 2021. During the dry season, most of the year, except during July-Sept, flow is limited to shallow riffles connecting the few deep pools. This tributary to the Chambal provides intermittent nesting sites in wet years for gharial, and may provide safe, semi-isolated "refuges" for release of head-started juveniles reared to 1-2m in captivity.



Fig. 89 View at Palpur, Kuno National Park, during the 2021 monsoon, showing deep pool (foreground) where "head-starts" were released earlier in Dec 2020----compare with Fig. 86.



Fig. 90 View of Baroli "island" during peak monsoon flooding of Chambal River channel, showing flooded riverside pastures and low ground used for grazing. Compare with Fig. 20 taken post monsoon in 2020. Baroli island is the center of activity for big ghara male with satellite GPS tag shown in Figs. 51-53.



Fig. 91 In late January of 2020 and 2021, the GEP field team did population surveys aided by drone imagery of main basking sites utilized by gharial in the NCS. View above is looking downstream on the Paravati River, showing gharial basking on the left bank which is unprotected and in Rajasthan, while the MP bank (right side in this view) is protected as part of the Natioal Chambal Sanctuary (NCS). Nesting occurs on both banks along this upstream tributary, so protection of shorelines is warranted.



Fig. 92 Drone imagery is being used in conjunction with "on the ground" observations, noting the size of individual gharial, in addition to numerical counts at selected "basking sites" that are used year after year by gharial at various riverine locations. These allow us to verify our stationary population counts, and augment size estimates with quantifiable data. In Figs. 92 above and 93 below, large adult size can be estimated to nearest 0.1m regardless of position in or out of the water.



Fig. 93 In this image, and in Fig. 92, counts of gharial present, and their relative sizes can be quantified if manual counts and drone imagery are synchronized at selected sites. Previously, the field team relied on repeated stationary counts, supported by ground level imagery of various sized gharial at basking sites. Figs. 92 & 93 are of basking groups at Dang Basai.



Fig. 94 Drone imagery of a basking group below Khera Ajab Singh, on a sand point during midday. Resolution is sufficient to allow species identification and also estimates of the total lengths of individuals. In general, gharial tolerate drone heights of 50m or more, but are noticeably disturbed at lower heights.



Fig. 95 During hatching in 2020 and in 2021, the team used drone imagery to document nest numbers and provide quantifiable imagery of creche sizes, and the guardianship of adults at various nesting sites. This image of a portion of the Kasaua nesting site clearly showed a guardian male in attendance, and opened nests along the shoreline.



Fig. 96 At some larger creche sites, such as Khera Ajab Singh, on the lower Chambal, hatchlings formed multiple assemblages, each attended by a guardian adult. In this image, two females attend creches adjacent to each other, and the shoreline shows evidence of multiple nests having been excavated.



Fig. 97 Drone imagery has been useful throughout the entire length of the NCS, including its tributaries. This female is guarding a creche of several nests laid on the shore upstream in the Parvati River, along the unprotected Rajasthan side, just opposite the other side of the river, NCS protected in Madhya Pradesh.



Fig. 98 In this image of the shoreline at Khera Ajab Singh, a large communal nesting site in the lower Chambal River, multiple nest craters are evident on the high, steep embankment above the shoreline where a large creche with an attendant guardian adult is assembled on the shoreline.



Fig. 99 Pankaj, the principal tracker and field man on the GEP team, listens for any signals of radioed gharial, on the Sashon-Chakar Nagar bridge crossing the Chambal. The river is in full flood, within 4m of the bridge underside, having risen ~ 7-9m in mid river, and inundated vast low lying areas riverside.



Fig. 100 A view from riverside during the dry months from Oct thru June before and after monsoonal high water during July-Sept. The bridge in Fig. 102 shows in the distance, revealing the extent of the lower Chambal flooding at the peak of the monsoon rains.



Fig.101 Aerial view of Sashon bridge shown in Fig. 102, showing the water level rise during peak rains, and the extensive flooding in the lower Chambal in August-September. River levels rise some 25-30 feet during the peak monsoon. During such periods, the gharial avoid the main channels, and prefer to use edges and back channels, where flow is minimal.



Fig. 102 Another view of the Sashon bridge during peak monsoon, showing the recently constructed UP Forest Department "rest house" complex entirely surrounded with high water, with the exception of a connecting roadway. Gharial utilize side channels and nullas as waterways to stay out of main flows.



Fig. 103 Aerial view from the Dacoits' Temple, below Garhaita village, half way to the Chambal River. During peak monsoon, flooding is extensive in all low lying areas, including many back channels connecting nullas to the mainstream Chambal. All of the flooded areas visible here are completely dry during most of the year.



Fig. 104 Another view, further eastward, looking southward toward the MP bank of the mainstream Chambal showing the extensive flooding of connecting nullas which remain dry for most of the year. Gharial move extensively in these back channels when the river is in flood, and avoid river areas where there is strong flow.



Fig. 105 Aerial view of Garhaita village, looking to the north, toward the Udi-Bah road and traintrack. The road visible in lower right leads to the temple shown in Fig. 106 and on to the Chambal River. Wooded areas in the ravines are privately "owned" by village families who harvest wood for fuel/cash.

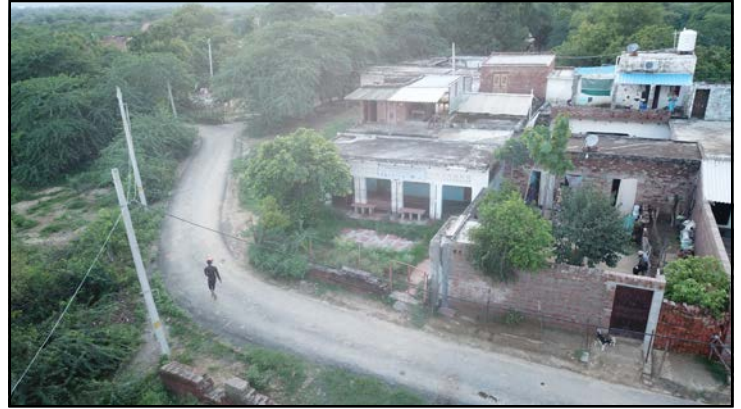


Fig. 106 View of the Garhaita base, rented house on left side here, with rooftop terrace for sleeping, and protected first floor for offices and work space, plus kitchens and living accommodations for field team. Local families have been especially hospitable in allowing us to base GEP operations in this village.



Fig. 107 View of the upstream base, to right of large tree, center of image. The large single room facility with attached bath-toilet, provides living and cooking areas, as well as work space for periodic visits by the GEP team to upstream sites for tracking and surveys.



Fig. 108 Final construction phase involved painting the exterior and finishing windows and doors on the upstream base at Katrinapur. This facility now allows the GEP field team to live and work close to the Chambal at Baroli sandbanks, a traditional breeding and nesting site for resident gharials.



Fig. 109 In 2020-2021, Astral Foundation supported the Gharial Ecology Project with Corporate Social Responsibility (CSR) funding, primarily for upgrading our infrastructure and base facilities, as well as field equipment for tracking and observing gharial. A high end computer work station plus NAS backup facility at our Garhaita base enables us to archive & analyze field data, back it up, and share it among GEP team.



Fig. 110 Computer tablets (10" RealMe) allow field trackers to communicate with images, record notes and back up the daily inflow of field observations. Two tablets were purchased with Astral funding, and in-house, online training has significantly improved data transfer and storage, and daily exchange of information amongst all team members.



Fig. 111 A new field motorbike, a Honda Shine, was acquired with Astral funding, and is presently housed at our upstream base at Katrinapur. Daily tracking is only possible by accessing multiple waypoints along the riverside, and strategically observing & recording information about radiotagged gharial and censusing gharial numbers at selected favored basking sites.



Fig. 112 Our 13+ yr old 25 hp Mercury boat engine has needed multiple overhauls and repairs lately, to power our 2 jonboats as well as an older inflatable. Astral funding provided a major upgrade, with the purchase of a new two stroke, 25 hp petrol boat motor to power any of the three project boats.



Fig. 113 Consistent and reliable power is required at both upstream and downstream bases, due to often irregular mainline power, especially during monsoon. Astral funding has provided a 5KVA genset for each base that will allow 24 hr power service with an inverter, for recharge and to provide backup service.



Fig. 114 A mini-split air conditioner was installed in the computer room at the Garhaita base, providing a climate control facility for operating electronics and for storing photographic and imaging gear during the monsoon. Unit allows both cooling and heating, and can be operated with assistance of generator when power is not available.

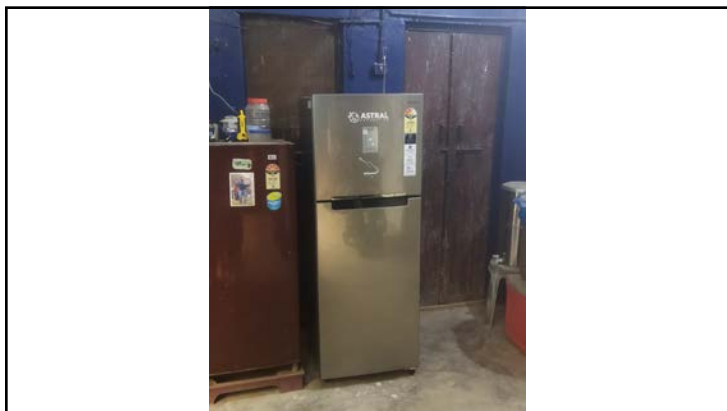


Fig. 115 The Godrej fridge purchased in 2009 is still running, but now an energy efficient larger unit is operating at each base, thanks to Astral CSR funding. The new Samsung fridge is capable of either freezing and/or cooling, and with better insulation, operates with less power, and for longer "powerless" periods.



Fig. 116 A Kent RO water filtration system has been installed at our Garhaita base to insure abundant supply of clean drinking / cooking water, especially during intensely hot, pre-monsoon season in May-June. The unit is capable of filling 30 litre bottles quickly, so that fresh water is always available.



Fig 117 As part of the Model Village program, Rajesh Gupta describes the process of preparing a vermi compost at home for organic farming in Gohra village, October 2020



Fig 118 Dr. Rajesh Gupta, working with Dr. Ashutosh Tripathi, GEP Community Outreach Coordinator, in the innovative Model Village community program, sharing the model village theme of planned work.



Fig. 119 The local Ranger, Uttar Pradesh Forest Dept, is discussing the impact of illegal fishing in the protected National Chambal Sanctuary, and sharing guidelines for volunteers to inform frontline guards.



Fig 120 An open air meeting during the pandemic days in late 2020 at the Nandgoan Interpretation Centre, for volunteers to aid in preventing wild animal attacks, especially of crocodiles, in the NCS.



Fig. 121 Capacity building workshop, organized at Palighat Rest House, Rajasthan, near the upstream confluence of the Chambal and Parvati Rivers, held in Oct 2020. Dr. Ashutosh Tripathi discusses human crocodile interactions, and how best to prevent attacks on people and livestock by muggers.



Fig. 122 Dr. Dharmendra Khandal, from Tiger Watch, a community based NGO at Ranthambore Tiger Reserve, describes the innovative approaches he and his colleagues have taken to involve local communities in Chambal River conservation.



Fig 123 Mr. Arvind K. Jha talks to the assembled group outside during the pandemic in Oct 2020, at Palighat about the Indian Wildlife Protection Act of 1972. This capacity building program was organized by Dr. Ashutosh Tripathi, GEP Outreach Coordinator, to provide conservation specifics to frontline FD staff.



Fig. 124 Dr. Hari Mohan Meena, collaborator with GEP for training presentations, discusses details related to conducting drone surveys and aerial mapping techniques. Gharial Ecology Project staff are incorporating drone imagery as part of surveys of gharial population numbers and nest counts.



Fig. 125 In Oct 2020, a Capacity Building Workshop was organized for the Madhya Pradesh Forest Dept frontline staff, working along the Chambal River, by Dr. Ashutosh Tripathi, GEP Outreach Coordinator. It was held over two days at the Deori EcoCentre, a facility near Morena, and close to the Chambal. For many years, a "head-start" rearing program, with eggs/hatchlings from wild gharial nests, has been on-going, rearing 2-4 yr old juveniles for release.



Fig. 126 Dr. Hari Mohan Meena, collaborator with GEP, shows frontline staff the operational details for conducting drone surveys, using conventional DJI quadcopters to count crocodilians, both gharial and muggers, and also to survey riverside sand banks and shorelines for nests, and basking animals, as well as destructive activities such as sandmining.



Fig. 127 Hari shows MPFD staff how a quadcopter is oriented in flight, and how to control the movements remotely. The Gharial Ecology Project (GEP) has been using drone imagery to monitor gharial populations, as well as document important changes to sandbanks along the river, especially those used every year for nesting by gharials and turtles.



Fig 128 Dr. Ashutosh Tripathi summarizes years of conservation-related behavioral studies conducted by the GEP along most of the 425 km long National Chambal Sanctuary (NCS) since these studies were initiated in 2008, following die-off of >100 gharials. This MPFD workshop was conducted in late 2020 during the pandemic lockdowns throughout India.



Fig 129 In 2021, school outreach programs conducted locally in riverside villages on the lower Chambal in Etawah and Agra districts focused on providing info on river conservation and important river animals. Here, kids in Barechha village indicate whether they know the difference between mugger and gharial.



Fig. 130 In Bareh, at the confluence of the Yamuna and Chambal, a group of locals assembled on the steps of the Snake Temple, listen to Dr. Tripathi describe how male and female gharial guard the hatchlings for an extended period in large creches that form before monsoon waters rise every year.



Fig. 131 In Choti village, mostly young kids attentively listen to an awareness program being presented by Dr. Ashutosh Tripathi, and his assistant. At these meetings, usually a light snack is offered, and this incentive tends to increase the number of villagers willing to come and listen to talks/presentations.



Fig. 132 At Jagtauli, another riverside village in the National Chambal Sanctuary, riverfolk listen as well as discuss the "do's and don'ts" of activities at the water's edge, with livestock as well as themselves. Mugger crocodiles occasionally attack people as well as livestock, especially close to frequented areas for washing, bathing, drinking, and also cremations.



Fig. 133 Video presentations (note screen on wall, left) are an important component in community programs, and an essential teaching tool for local population. Here, in Bhoya village on 10 Nov 2021, Ashutosh introduces a Hindi version of a documentary showing the Gharial Ecology Project team in action.



Fig. 134 Village video shows often attract a large crowd and are an excellent venue for introducing discussion of the importance of gharial in the river ecosystem, and why crocodylians and turtles should be saved. This is a program in Kundol village conducted on 22 Nov 2021, and attended by ~30 villagers, mostly men.



Fig. 135 Some programs attract women and young girls, especially during the daytime. Here, in Nov 2021, a young helper distributes handouts with diagrams showing the difference between gharial and mugger crocodiles, and what foods they eat. This group is in Madaiyan Badhpura village.



Fig. 136 Another river village, Sahua Pura was visited by the Gharial Ecology Project Outreach team, and a crowd gathered to listen to Ashu's talk and watch the slide and video presentations. Many of these visits are also coordinated with school classroom visits. This program was conducted on 26 Nov 2021.



Fig. 137 In the Januani UPS, classes were engaged in a drawing competition, and prizes were awarded. Here, on 24 Nov 2021, local teachers use materials from the GEP program to question students.



Fig. 138 In mid March 2021, on International Day of Action on the River, the GEP team was engaged with villagers to clean up discarded materials on the river. Here the team is collecting non-degradable waste for disposal off-site. For many locals, dumping trash in the river is a quick, easy disposal solution, since seasonal flooding tends to move waste downstream.



Fig 139 On World Environment Day, celebrated in early June 2021, greenery was planted around the Sashon Rest House in the presence of Honorable Executive Magistrate, with FD staff attending.



Fig 140 World Sparrow Day, in March 2021, involved a competition with masks and wings. Here the skit performers are pictured with the school director. The GEP Outreach team has been quick to use such events to draw attention to Chambal conservation.



Fig 141 In Kasaua village, a local cattle guard working for the UPFD describes threats to wildlife along the river, and how to protect important sandbanks used by gharial. Gatherings such as these usually involve sharing stories of how wildlife from the sanctuary can damage or destroy nearby croplands, and how to minimize these disturbances.



Fig 142 In March 2021, a Capacity Building Workshop was conducted near Etawah for the UPFD staff and frontline guards. Jailabdeen talked about mapping using drones, and how research focused on turtles and gharials is used to further their conservation. Marking techniques were described, and survey methodologies discussed.

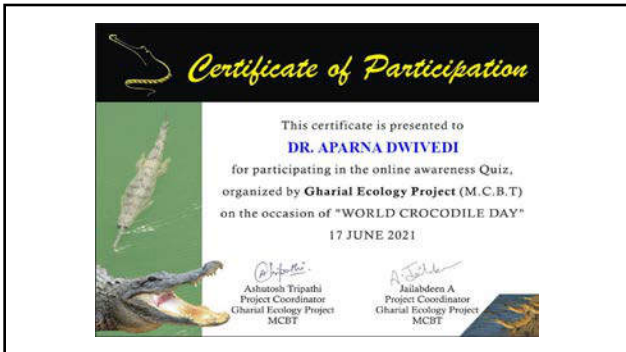


Fig. 143 On World Crocodile Day in mid June, an online quiz was conducted, and participation prizes awarded. Participation involved hundreds of contestants and drew attention to the social media postings on Insta-gram and on Facebook, for the Gharial Ecology Project.



Fig 144 In Gaati village, a curious onlooker asks Ashu what the purpose of the mid Dec 2021 rally is, as he confronts a marching class of middle schoolers, dressed with gharial masks and waving banners illustrating scenes with gharial. These images were taken by GEP team members during their regular research involving tracking, observing, monitoring.

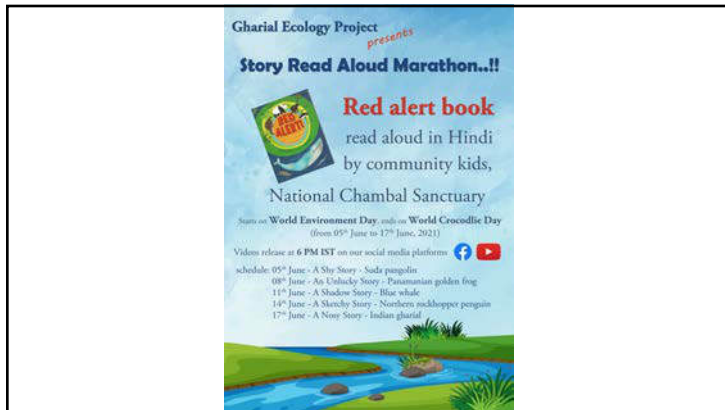


Fig 145 An online resource developed by the GEP Outreach Director, Dr. Ashutosh Tripathi, to promote story telling in Hindi, focused on short segments out of the book by Catherine Barr, entitled "Red Alert." Red-listed species that are critically endangered are featured, with a story about the unique and different characteristics of each group. Each story is read by a young Hindi speaker, while the text and pictures are shown, page by page, in a YouTube video clip.



Fig. 146 An online "quiz" format, developed to encourage internet participation, and intended to generate interest and curiosity about the weird and wonderful morphological and behavioral adaptations of crocodylians, species by species. Hundreds of participants earned a certificate indicating they were part of this activity open to anyone online.



Fig. 147 In the The Red Alert book, the gharial is prominently featured, along with a listing of its most distinctive characteristics. The account was written in conjunction with advice from Dr. Jeff Lang, Senior Advisor to the Gharial Ecology Project, and used in this reading exercise developed especially for the young readers and "listeners" living on the Chambal.



Fig. 148 On the upstairs terrace of our Garhaita base, next-door neighbors read aloud from the Red Alert book to learn about Critically Endangered species in need of conservation attention. Few locals recognize the unique features of the wild resident gharial living nearby, and often confuse these with the more familiar, but dangerous mugger crocodile.

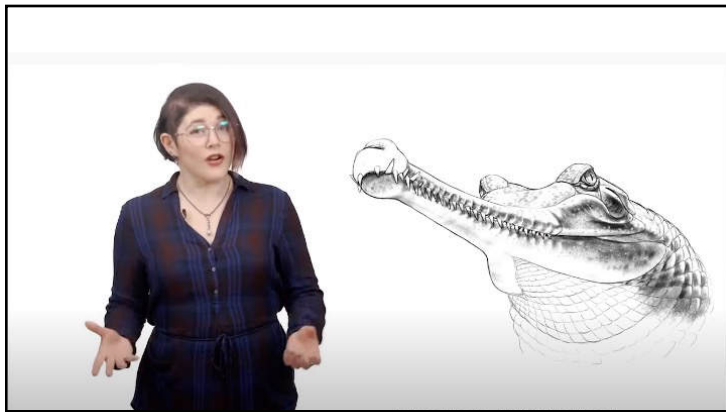


Fig. 149 "Don't Boop the snoot" is the name of a YouTube video produced by Animalogic. It examines the weird, wonderful traits of the gharial, using behaviors illustrated with some clips from the Gharial Ecology Project. "POPs" are acoustic signals that large adult males with a ghara make as individually-specific signals. An edited version is available on our GEP YouTube channel, along with related gharial videos.

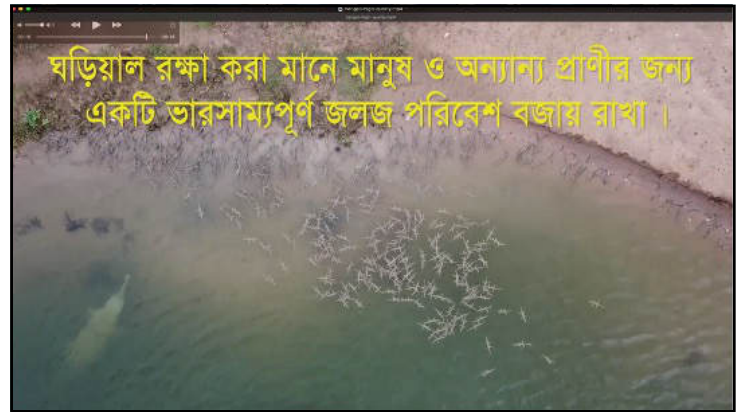


Fig 150 Gharial natural history features and facts are summarized in a 3:30 min video translated with text in many languages, including regional Indian scripts, as well as Nepali, Burmese, Sinhala, Spanish, Czech, German, French, Norwegian, Dutch, etc. Other videos are included for viewing on Gharial Ecology Project's YouTube channel.

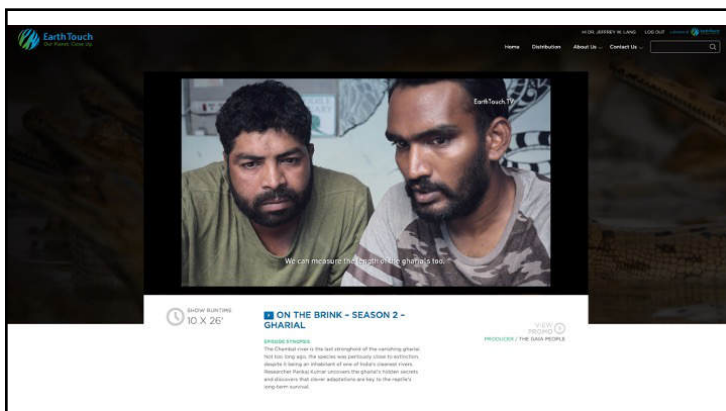


Fig. 151 Project team members Pankaj Kumar, our main tracker/researcher, and Jailabdeen A., our Project Coordinator, are featured in an On the Brink episode on the Chambal gharial population, and the in-depth efforts to learn for the first time, details of gharial life history, ecology, and behavior.

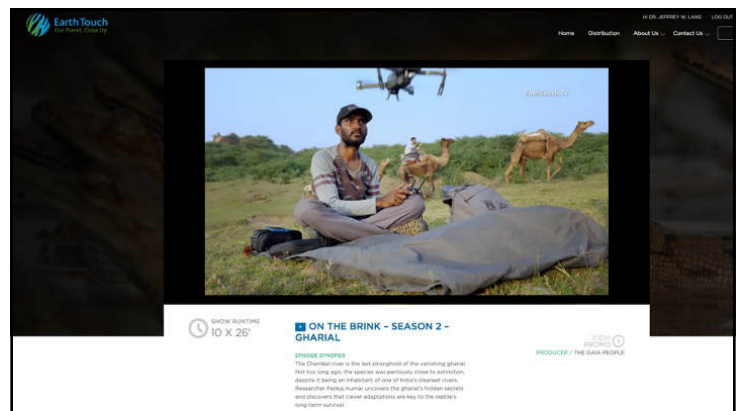


Fig. 152 The On the Brink program, running for 25 minutes on prime time Indian TV, and now available on streaming platforms, accurately summarizes the recent new information learned during the past 15 years of study on gharial in the National Chambal Sanctuary (NCS), funded by the international zoo community and NGO efforts by CrocFEST & others.

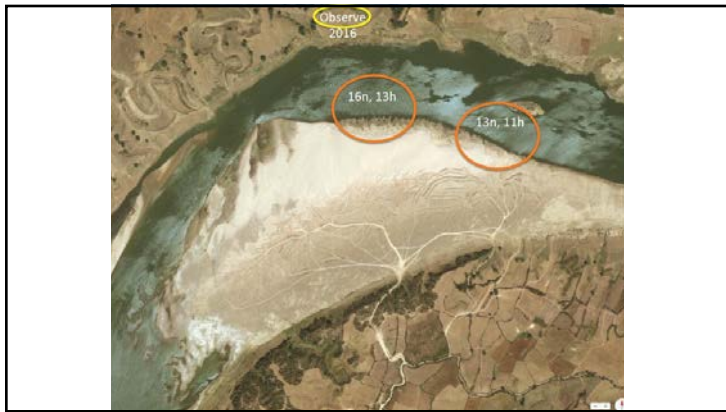


Fig.153 Loss of nesting sandbanks is increasingly a big problem along the protected shorelines of the NCS. At this sandbank, the Tighra-Rithora riverbend below Dholpur, 20-40+ nests were laid every year. In 2016, 29 nests were observed, of which 24 nests hatched.



Fig. 154 In 2017-2020, industrial-scale sand mining was occurring via the tracks and trails visible in Fig. 78, on a 24/7 schedule in all but the several months of the monsoon rains. By late 2020, the 3-4m depth of the monsoon rains. Compare Fig 153 BEFORE with Fig 154 (above) AFTER removal of entire sandbar by sandminers.



Fig. 155 Image taken in 2018, during nesting period of large group of basking gharial, along shoreline previously used for nesting, and then under direct threat from industrial-scale sand removal. Sand was transported via well-established tracks off the beach onto high ground, where it was transferred to lorries for trucking to construction sites far from the NCS.



Fig. 156 Aerial view of the denuded sandbar area shown in Figs 154, looking from upstream to downstream, from foreground to distance, in this image---across Fig. 154, from left to right. Note island in mid river in distance in this image, for comparison with mid river "island" in upper right on Fig. 154, between "Chambal" & "Madhya Pradesh."



Fig 157 At the height of removal, dozens of wagons pulled by tractors, operated 24 hrs a day, 7 days a week, for 10+ months in all but 2 monsoon months. Such industrial scale sand mining is run by a "sand mafia" technically "illegal," but privately sanctioned. The entire sandbank visible in this image was gone by early 2020, compare Figs. 153 vs. 154 (above).



Fig. 158 View of the Tighra-Rithora sandbank, MP side where sandmining continued unabated for years until the entire expanse was removed, below water level from an average depth of 3-4m of sand covering the entire river turning. One result is deposition of sand downstream, with markedly shallow water now prevailing for many kilometers downriver.



Fig. 159 Besides sand mining and water extraction, the mainstream Chambal is now becoming more accessible by road, from many crossings, such as this bridge under construction at Mandrayal-Sabargarh in the upstream NCS, crossing between Rajasthan & MP. At other localities upstream, bridges are planned or are under construction. Illegal sand removal increases when bridges and roads connect the river to roads. At present, four bridges are under construction in NCS.



Fig. 160 Several major connections across the NCS are presently nearing completion in the downstream Chambal, including this bridge at Mahua Suda, just upstream from the Yamuna-Chambal confluence. This locality near the confluence has many shallow sandy areas, and is favored by juveniles year-round; adults in large numbers visit stretches near the confluence to feed where the swirling waters make fishing easy.