Learning from a Limited Dataset; Behaviours of the Indian Gharial (*Gavialis gangeticus*)

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Introduction

Literature was reviewed from the archives of the Madras Crocodile Bank Trust (MCBT) and Web of Science, where the following search terms were used; gharial, gharial conservation, Indian gharial, gharial in India, gharial in Nepal, gharial threats and gharial extinction. This gives the historical context for the introduction and discussion, and an insight into the research that has already been carried out and how it could be further developed with technological advances.

The Indian gharial is the sole representative species of an ancient lineage of crocodilians, the Gavialidae (Choudhury, 1981). Since the 1970s the species has been the subject of a number of conservation initiatives which have had varying degrees of success. The longest running scheme 'Project Crocodile' was funded largely by the Indian Government, but in 1996 in spite of some indications to the contrary (Singh, 1991; Stevenson, 2015) funding was withdrawn and the project ended. The range of the species has vastly retracted over its former area (Biswas, 1970; Choudhury *et al*., 2007) and whilst the population is at present thriving in some regions, some remain extremely small. These isolated populations are confined to five key areas in India and Nepal, meaning that the species is highly vulnerable to stochastic events.

Satellite GPS data can provide key insights into previously unknown behaviours and is particularly valuable in understanding cryptic or difficult to observe species. However, it is important that the lure of pioneering technology be resisted lest it lead to reverse engineering questions of interest. The vulnerability and uniqueness of the gharial make it a prime candidate for GPS tracking. The gharial ecology project has been responsible for the current tracking efforts, and to date a small number of animals have been tagged. This paper discusses some of the interesting points that the tracking of these animals has raised, the limitations of having only a small number of animals tagged and considerations for planning a tracking programme to ensure funding gives the maximum return on investment.

The data presented here was collected from three satellite GPS tagged individuals residing in the Chambal sanctuary, northern India, between late 2014 and early 2016. Remote tracking for the gharial is useful as the species is notoriously shy when it comes to observation by boat. The mapping of this data revealed some unique behaviours amongst crocodilians, however, the paucity of data means that some of the points that are discussed herein are intended as a spring board for further study or future consideration when undertaking similar studies. If, in future further individuals are tagged then this existing data can be added to analyses accordingly.

The gharial ecology project on the whole has revealed a great deal more about their behaviour, interactions with their environment and life history (Lang and Whitaker, 2010; Lang and Kumar, 2013). Whilst this data is useful in developing a greater understanding of the species and its relationship with its habitat it remains problematic applying it to populations beyond the immediate study area of the Chambal. However, the data is invaluable in terms of planning for a longer term recovery and in consideration of alternative possibilities. The data presented here was mapped using the open source program QGIS.

Methods

Three individuals were tagged on the Chambal in late 2014, and the data were then collected over approximately 24 months. These individuals were wild caught individuals of various sexes; a large adult male, a sub-adult female and a sub-adult male. They were affixed with a telemetric tracker that returned satellite ‘pings’ every 30-45mins, trackers did not return pings when the animals were submerged however, and the limitations this leads to are discussed further down in this report.

The large amount of recordings that gave a zero reading meant that the three data sets needed to be cleaned before analysis. The nil returns were removed and the columns which held the year, month, day, hour and minute values were merged into one column to give a single value for the timestamp.

QGIS was used to create maps of the data – basic points maps and heatmaps to show specific usage and

frequency of usage were generated. The data was mapped onto a Google Earth satellite map using the quick map plugin on QGIS. This data used to produce movement animations and heatmaps to show which areas of the river were used most frequently. In order to produce animations and heatmaps the time manager plugin and the heatmap plugin were both used. An Indian coordinate reference system (CRS) was applied to the final map to ensure data points were correctly located.

Results

The three individuals that were tracked showed very different movement patterns as shown in Figure1 below. The most restricted movements were those of the sub-adult female, whereas the sub-adult male showed a propensity to travel relatively long distances in short time periods. In March 2015 it travelled 120 km in just a few days. The large adult male mirrored the range of the sub-adult female for much of the duration, but also travelled to the region around the confluence of the Chambal with the Yamuna (see also, Fig. 3).

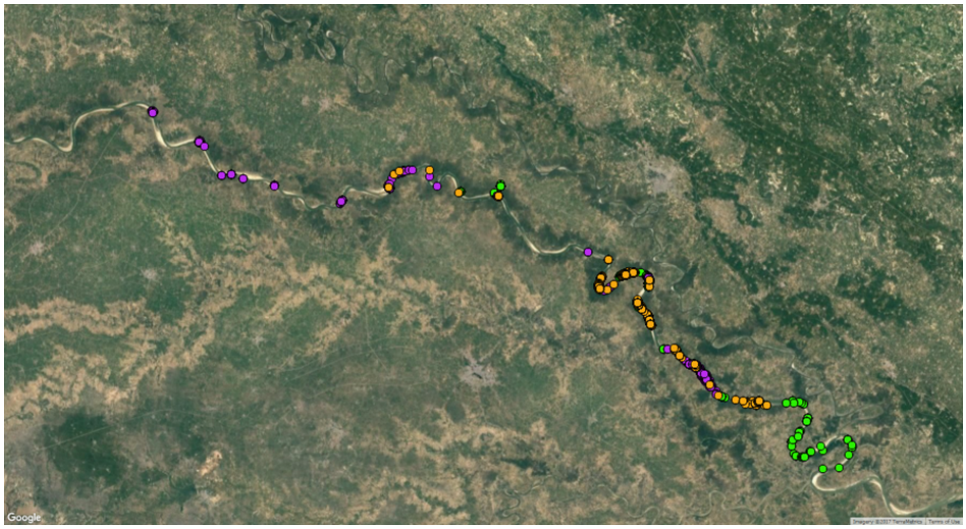


Figure 1. Range of the three individual gharials over the monitoring period covered in this report. (Adult male – green, Sub-adult female – orange, Sub-adult male – lilac)

Research has shown that gharials prefer undisturbed habitat, however, the large adult male showed high usage and the sub-adult female to a lesser extent – females have been observed to prefer less disturbed areas previously - of sandbanks near heavily farmed areas, see Figure 2 below.



a. b.

Figure 2. a. Heatmap movements of the sub-adult female along the Chambal, darker red circles show areas of higher usage, this is an area surrounded by agricultural land; b. showing the usage of a sandbank adjacent to agricultural land, the blue spot shows the sub-adult male, pink shows adult male and orange sub-adult female, all three utilised the sandbank but visits from the adult male and sub-adult female are more frequent, with more patrolling behaviour from the adult male.



Figure 3. Heatmap showing usage of sandbanks in a highly populated region of the Chambal – the Yamuna confluence.

Discussion

The initial process of cleaning the data removed nil returns. The GPS trackers returned a latitude/longitude fix at set times during each day – these increased or decreased seasonally. However, once the animals submerged in the water the tracking devices that were used no longer returned a location fix to the satellite, resulting in nil return for the latitude/longitude coordinates. Out of approximately 5300 returns per animal over the recording period of 18 months, the useable data was only around 30%. Combined with three differently sized and gendered animals this means that it is very difficult to draw useful conclusions from the data set. This indicates that for future studies it is imperative that the technology needs to be capable of working underwater to avoid this issue and maximise on any investment.

With accelerometers attached to the animals, it would be possible to discern when the animals are hunting. The data which we currently have shows that there is a correlation between the time of day and the activity, the animals were likely to have a location fix returned in the morning. Gharials prefer to bask at different times of the day seasonally and tracking data could highlight variations in this between animals of different sizes and genders. Separate temperature recordings may be useful in discerning where the animals were – air and water temps for each day – even if other data were not available, as temperature data was returned for each fix regardless of whether the animal was underwater or not. Significant variation between air and water temperature if this data were available could make a larger proportion of the data set useable. The study of activity patterns as they relate to the varying temperatures of both air and water would also be interesting in considering differences between populations in different regions or countries. Any variations, if found, between populations may be local adaptations and therefore useful when considering which animals would be best suited to a particular reintroduction site.

The sub-adult male travelled the greatest distances along the Chambal, and in the course of one month - March – it travelled approximately 120 km along the river. March coincides with the end of mating season and the beginning of nesting season that may be a significant factor in this long-range movement. Additional GPS tagged animals in this size class would have the potential to shed light on whether this is an anomalous individual or whether this is a trend amongst these sub-adult males. If a pattern emerges it should be possible to start understanding the drivers behind the issue.

Dispersal is an important area for future study, especially as researchers have suggested that the carrying capacity for gharials in the Chambal sanctuary may only be in the hundreds. With the population now numbering in the thousands this could be a reason why younger males are moving greater distances along the river. The main goal of dispersal is to establish a new territory for hunting and mating, finding that there are no potential mates further afield however might provide an explanation as to why a sub-adult male would travel such a long distance, only to return in a relative short space of time. The young female however did not exhibit this behaviour preferring to stay in the vicinity of the communal nesting sites during breeding season. However,

this may be an anomaly, and a larger number of tagged sub-adult females could serve to understand whether they too exhibit the long-distance travelling behaviour that may be indicative of a desire to disperse.

The multi-day gaps in the data also mean that when the animals do travel long-distances, we do not know how far they are travelling in this time span. Gaps of multiple days – assuming that there is no tracking device fault – implies that in these periods the animals are spending only a short amount of time basking. It would be useful to understand when they travel, whether they rest overnight in unfamiliar areas or when they hunt on these journeys. If multiple animals were tracked it would be possible to learn whether they are travelling alone, or if young animals move together or if not together, at broadly similar junctures. It may also be possible to extrapolate from the data – assuming trackers do not return location pings when the animals are underwater – that time periods when no pings are returned represent fishing or at least moving.

As the species has proved adaptable to the lake environment that arose from the dam building project near Corbett National Park, this is another area that could lead to interesting studies – whether the species is also adaptable to disturbance. Understanding how the species responds to the pressures of disturbance would be important when considering sites for future reintroduction of the species to locations from which they have been extirpated. Confirmation of whether the species is adaptable to human perturbation or not would help to inform choices of locations for future reintroductions. Some of the data included here has shown that individuals may travel to or even frequently bask in areas that are infringed on by human activity.

Limitations

The sample size is the key limiting factor in studying the species at present, for statistical use the sample size (n) would need to be; n =30. However, as males and females are likely to disperse along, and use the river in different ways this further limits the useability of the data for in depth analysis.

One of the important points which these datasets highlight is the need to ensure questions are not reverse engineered in order to make use of technology. Whilst technology can provide extremely useful data it may not be the best use of limited to funds to use technology, particularly if the funding only allows for the purchase of a small quantity of it. With the gharial, netting the species from the wild population can be difficult and is more likely to result in random individuals varying in gender and/or size being captured. To overcome this issue, tagging animals from captive-bred populations would allow selectivity; only male or female individuals of the same size are tagged prior to release. In tagging animals selectively by size class or gender as previously discussed, this would allow studies to understand the behaviour of not just individuals but groups of similar animals.

Further work

An interesting study could look at temperature versus activity, this would require trackers which would ping above water too.

Future considerations for the data may include incorporating it into species recovery planning using a spatial PVA package RAMAS GIS to allow the inclusion of the GIS landscape data from the telemetry project, however, there is an associated cost with the purchase of the package.

As suggested in the discussion section with the correct technology – accelerometers, depth measurement – a great deal more could be revealed about the animals' behaviour, and what their optimum habit needs might be. Therefore, suggested key priorities for further movement research are:

- Increasing the number of individuals tracked in order to ensure individual behaviours are not anomalous.
- Looking at the link between temperature and activity.
- Understanding how gharials behave and interact with their habitat on both a daily and seasonal basis.
- The use of movement data to inform species recovery planning and selection of sites for reintroduction.
- Analysis of data to understand if long-distance movement may be driven by overpopulation at key sites.

References

Biswas, S. (1970) 'A preliminary survey of the gharial in the Kosi river', Indian Forester Vol. 96, 705-710

Choudhury, S. (1981) 'Some studies on the biology and ecology of *Gavialis gangeticus*, the Indian gharial',

University of Lucknow (Unpublished PhD thesis).

Choudhury, B.C., Singh, L.A.K., Rao, R.J., Basu, D., Sharma, R.K., Hussain, S.A., Andrews, H.V., Whitaker, N., Whitaker, R., Lenin, J., Maskey, T., Cadi, A., Rashid, S.M.A., Choudhury, A.A., Dahal, B., Win Ko Ko, U., Thorbjarnarson, J & Ross, J.P. (2007) '*Gavialis gangeticus*.' The IUCN Red List of Threatened Species 2007: e.T8966A12939997.

Lang, J.W. & Kumar, P. (2013) 'Behavioural ecology of gharial on the Chambal River, India', World Crocodile Conference, Proceedings of the 22nd Working Meeting of the IUCN-SSC Specialist Group, 42-52.

Lang, J.W. & Whitaker, S. (2010) 'Application of telemetry techniques in crocodilian research: Gharial (*Gavialis gangeticus*) spatial ecology in the Chambal River, India', in Sivakumar, K., and Habib, B. (Eds.) 'Telemetry in wildlife science', ENVIS bulletin: Wildlife & Protected Areas. Vol 13(1) 161-171.

Stevenson, C. and Whitaker, R. (2010) 'Indian Gharial *Gavialis gangeticus'* in Crocodiles: Status Survey and Conservation Action Plan. Third Edition, ed. by S.C. Manolis and C. Stevenson. Crocodile Specialist Group: Darwin. 139 – 143.

Stevenson, C. (2015) 'Conservation of the Indian Gharial Gavialis gangeticus: successes and failures' Internation Zoo Yearbook, Vol.49(1), Zoological Society of London, 150-161.

Whitaker, R. (1992) 'Crocodilian conservation on the Indian subcontinent' (Unpublished report for the ISRAG action plan).

Supplementary reading list

Andrews, H.V. & McEachern, P. (1994) 'Crocodile conservation in Nepal', IUCN Nepal and USAID, NGO Environmental management programme.

Archarjyo, L.N. & Singh, L.A.K. (1987) 'Twinning abnormality in *Gavialis gangeticus* (Reptilia, crocodilia)', Journal of the Bombay Natural History Society, Vol. 86(3) , 248-249

Brandt, L.A., Beauchamp, J.S., Jeffery, B.M., Cherkiss, M.S. and Mazzotti, F.J. (2016) 'Fluctuating water depths affect American alligator (*Alligator mississippiensis*) body condition in the Everglades, Florida, USA'. Ecological Indicators 67: 441-450.

Bustard, H.R. (1976) 'Operation Gharial', CHEETAL; The Journal of Wildlife preservation society of India Vol. 18(3&4), 3-6

Bustard, H.R. & Singh L.A.K (1982) 'Movement of wild gharial *Gavialis gangeticus* (Gmelin) in the River Mahanadi, Orissa (India)', British Journal of Herpetology, Vol.6, 287-291

Choudhury, B.C. (1987) 'Crocodile conservation – The Indian experience', Vivekananda Kendra Patrika, 72-78

Das, A., Das, A.K. & Dutta, S.K. (2013) 'An assessment of assisted recovery of *Gavialis gangeticus* in the river systems of Northeast India',Proceedings of the World Crocodile Conference, 22nd Working Meeting of the Crocodile Specialist Group of the Species Survival Commission of the IUCN, 29-35

de Vos, A. (1982) 'Evaluation of India's crocodile project' Technical report for the FAO India.

Hussain, S.A. & Choudhury, B.C. (1991) 'Ecology of *Gavialis gangeticus* Gmelin in National Chambal Sanctuary', Technical report for the Wildlife institute of India, New Forest, Dehra Dun

Hussein, S.A. (2009) 'Basking site and water depth selection by gharial Gavialis gangeticus Gmelin 1789 (Crocodylia, Reptilia) in National Chambal Sanctuary, India and its implication for river conservation', Aquatic conservation: Marine and freshwater ecosystems.

Mohan, A. (2015) 'Sand mining in India', Sustainalytics, Amsterdam, Netherlands, available from http://www.sustainalytics.com/sand-mining-india (accessed 09/07/2016)

Maskey, T.M. & Mishra, H.R. (1981) 'Conservation of gharial *Gavialis gangeticus* in Nepal', in; Wild is Beautiful, ed. Majupuria, T.C., Lovely composing house, Neela Mahal, Jullundur City (Punjab), 185-196

Nair, T. & Katdare, S. (2013) 'Dry-season assessment of gharials *(Gavialis gangeticus)* in the Betwa, Ken and Son Rivers, India" Proceedings of the World Crocodile Conference, 22nd Working Meeting of the Crocodile Specialist Group of the Species Survival Commission of the IUCN 53-65

Rao, M.V.S. & Bustard H.R. (1980) 'Observations on the hatching sequence of the Indian gharial *Gavialis gangeticus* Gmelin', Comparitive physiological ecology, Vol.5(4), 342-345

Rao, R.J. (1988) 'Nesting ecology of the gharial in National Chambal Sanctuary', REPORT for Wildlife institute of India, New Forest, Dehra Dun.

Rao, R.J., Tagor, S., Singh, H. & Dasgupta, N. (2013) 'Monitoring of Gharial (Gavialis gangeticus) and its habitat in the National Chambal Sanctuary, India' Proceedings of the World Crocodile Conference, 22nd Working Meeting of the Crocodile Specialist Group of the Species Survival Commission of the IUCN 66-73

Sharma, R.K. & Dasgupta, N. (2013) 'Status and population trends of Gharial in Chambal River, National Chambal Sanctuary', Proceedings of the World Crocodile Conference, 22nd Working Meeting of the Crocodile Specialist Group of the Species Survival Commission of the IUCN, 74-77

Singh, L.A.K. & Bustard, H.R. (1977) 'Studies on the Indian gharial *(Gavialis gangeticus* Gmelin)(Reptilia, crocodilia)V: Preliminary observations on maternal behaviour', Indian Forester, Vol. 103(10), 671-678

Singh, L.A.K (1979) 'Gharial research and conservation', Wildlife Newsletter, Vol. 6(1) 7-8

Singh, L.A.K. & Bustard H.R. (1982) 'Congenital defects in the gharial *Gavialis gangeticus* (Gmelin)', British Journal of Herpetology, Vol. 6(1), 215-219

Singh, L.A.K. & Bustard. H.R.(1982) 'Growth and behaviour of a blind gharial *Gavialis gangeticus* (Gmelin)' Journal of the Bombay Natural History Society, Vol. 79(3), 681-684

Stevenson, C. & Whitaker, R. (2010). 'Indian Gharial *Gavialis gangeticus*', in Crocodiles; Status Survey and Conservation Action Plan. Third Edition, ed. by Manolis, S.C. & Stevenson, C., Crocodile Specialist Group: Darwin, 139-143

Vyas, C.M. & Sharma, R.K. (1990) 'Effect of basking on growth of gharial' (UNPUBLISHED REPORT FOR NATIONAL CHAMBAL SANCTUARY)

Whitaker, R., Basu, D., Rajamani, V.C. & Balakrishnan, V. (1974) 'Gharial Survey Report', Madras Snake Park Trust, Madras India Technical report in Herpetology review, Vol. 6(1), 2-3

Whitaker, R. & Mahadev, E. (1976) 'Gharial Survey Report', The New York Zoological Society, New York.

Whitaker, R. & Basu, D. (1982) 'The gharial (*Gavialis gangeticus):* A review', Journal of the Bombay Natural History Society, Vol. 79(3), 531-548

Whitkaker, R. (1992) 'Crocodilian conservation on the Indian sub-continent', ISRAG action plan

White, P. (1984) 'Social behaviour in *Gavialis gangeticus',* (UNPUBUBLISHED REPORT FOR MADRAS CROC BANK, St Olaf College)

Yadev, S.K., Nawab, A. & Khan, A. (2013) 'Conserving the Critically Endangered Gharial (*Gavialis gangeticus)* in Hastinapur Wildlife Sanctuary, Uttar Pradesh: Promoting better coexistence for conservation', Proceedings of the World Crocodile Conference, 22nd Working Meeting of the Crocodile Specialist Group of the Species Survival Commission of the IUCN 78-82