Factors influencing basking site selection and basking behaviour of freshwater turtles in a disturbed landscape

by

Srinjan Majumdar
Enrolment no: 50BB24A73028

Master's Dissertation

Submitted to Academy of Scientific and Innovative Research

For the requirement for partial fulfilment of the degree

Master of Science
in
Wildlife Science

Under the supervision of

Dr. Abhijit Das, Scientist-E (Supervisor)
Dr. GV Gopi, Scientist-F (Co-Supervisor)

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

AcSIR

July 2026

CERTIFICATE

This is to certify that the thesis by **Srinjan Majumdar** entitled **"Factors influencing basking site selection and basking behaviour of freshwater turtles in a disturbed landscape"** is an original and independent research work submitted to the **Academy of Scientific and Innovative Research**, for the award of the degree of **Master's in Wildlife Science**.

Srinjan Majumdar has put one semester of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.

Dr. Abhijit Das
Supervisor

(Dr. Ruchi Badola)
Dean
Faculty of Wildlife Science

पत्रपेटी स 18 चन्द्रबनी देहरादून-248001, उत्तराखण्ड भारत
Post Box No. 18, Chandrabani, Dehradun-248001, Uttarakhand, INDIA
ई.पी.ए.बी.एक्स .+91-135-2640111 से 2640115, फैक्स :0135-2640117
EPABX +91-135-2640111 to 2640115, Fax : 0135-2640117
ई-मेल/E-mail wii@wii.gov.in, वेब/website . www.wii.gov.in

DECLARATION

I hereby declare that the work conducted under the thesis entitled **"Factors influencing basking site selection and basking behaviour of freshwater turtles in a disturbed landscape"**, is a record of original and independent research work done by me and subsequently submitted for the award of the degree of **Master's in Wildlife Science** at the **Academy of Scientific and Innovative Research**. This research work has been carried out under the guidance and supervision of **Dr. Abijit Das**, **Scientist- E**, and co-supervision of **Dr. GV Gopi**, **Scientist- F** of Wildlife Institute of India, Dehradun. The work has not formed the basis for the award of any other degree, diplomá, or any other qualification. I also declare that the thesis embodies my own work, analysis, observation, understanding and the particulars given in it are true to the best of my knowledge.

Srinjan Majumdar

Srinjan Majumdar

Enrolment No: 50BB24A73028

Place: Dehradun

Date: 15th July

Dr. Abhijit Das

Supervisor

Dr. GV Gopi

Co- Supervisor

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE OF PLAGIARISM CHECK

It is certified that the Master's dissertation thesis titled **"Factors influencing basking site selection and basking behaviour of freshwater turtles in a disturbed landscape** submitted by **Srinjan Majumdar** has been examined by us for plagiarism check as per UGC (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations. The following inferences are drawn from this check:

a) Thesis has significant new work/knowledge as compared to already published work or work under consideration for publication elsewhere.
b) No sentence, equation, diagram, table, paragraph or section is found to have been copied verbatim from previous work unless it was placed under quotation marks and the source was duly cited.
c) The work presented is original work of the author (i.e., there is no plagiarism) and there is no fabrication of data or result by manipulating research materials, equipment or processes, or by changing or by omitting data or results such that the research is not accurately represented.

The similarity indices as reported by the software Drillbit are as follows:

Software used	Date	Total world count	Similarity index
Drillbit	15.07.2026	20934	6%

The similarity index came as above. Scientific names, measuring units (SI) and references have been excluded from documents.

15/7/26

Mr. Manohar Pathak
Librarian

Dr. Abhijit Das
Supervisor

पत्रपेटी सं. 18, चन्द्रबनी, देहरादून-248 001, उत्तराखण्ड, भारत
P.B. No. 18, Chandrabani, Dehradun-248 001, Uttarakhand, INDIA
ई.पी.ए.बी.एक्स. :+91-135-2640114, 2640115, 2646100, फैक्स : 0135-2640117
EPABX : +91-135-2640114, 2640115, 2646100, Fax : 0135-2640117
ई–मेल/E-mail : wii@wii.gov.in, वेब/website : www.wii.gov.in

C O N T E N T S

LIST OF TABLES

LIST OF IMAGES

LIST OF FIGURES

A C K N O W L E D G E M E N T S

I would like to acknowledge Director of WII and Dean of WII for making this study possible. I thank all the faculties especially Dr. Abhijit Das and Dr. Gopi G.V. – My guides, who played a very important role in the formulation of the question and tweaking of the methodology part to ensure higher detections, which was a problem during the reconnaissance phase. I would like to thank them for their continuous support during my field session and even beyond that. I would like to thank Dr. Abhijit Das for all his inputs and support from the period when this study was supposed to be conducted in a different area altogether, to a very shaky phase in my dissertation when everything became uncertain, to regaining composure in my question but at a different site this time. I would like to thank Dr. Gopi GV for both academic inputs as well as mental and emotional support during "certain" observations on field. Emotional support from a supervisor is not something one typically expects, but he was always there whenever I needed it, and I cannot express how grateful I am for this. I would like to thank Dr. Sutirtha Dutta- Our course director and someone who helped me from the time of formulation of the topic till 24 hours before the presentation of thesis, along with that, for helping out during a very stressful situation just before the starting of my fieldwork. Without Dr. Sutirtha and Dr. Gopi GV's help regarding the permissions and re-formulation of the questions, I cannot imagine what would have been the status of this thesis. I would also thank Dr. Bivash Pandav and Dr. JA Johnson for providing inputs and support whenever possible at that particular stage before fieldwork and Dr. Amit Kumar- our assistant course director. Along with this, I thank all other professors as well who took time

out of their busy schedule to teach us through these 1.5 years of intense coursework, providing us with knowledge, critical thinking, sometimes gossip, and a lot of joy that we gained in (as well as out) of the classrooms - especially Dr. Bivash Pandav, Dr. Suresh Kumar, Dr. Bilal Habib, Dr. Sutirtha Dutta, Dr. JA Johnson, Dr. Gopi GV, Dr. Abhijit Das to name a few.

It was a very intense coursework with nonstop classes, nonstop assignments and nonstop field. Except of the last one, the others made the coursework occasionally incredibly hectic. And the reason all 18 of us could survive without losing sanity, I think almost all would agree with me, is because of the friends, our batchmates. Hostel life was new for me and most definitely I was a bit stressed regarding how to manage such a shift. But there is some charm and comfort in knowing that the moment you feel something going downhill, be it academics based or be it emotional or psychological state based, you always have the option of walking into someone's room and just talk (or maybe mimic) until you start feeling better again. I was also lucky to have 2 of my 3 neighbouring rooms being occupied by Rock lovers, Afterall the best way to release all the stress is to scream and head bang on rock→Death metal spectrum, either until you cough out blood or your spinal cord finds it hard to hold your skull without shaking. This reminds me, I cannot thank certain people enough who were never with me but were always blasting in my ears, since without them for the longest time I have not known any other form of outlet- Thanks to Chester Bennington, Serj Tankian, Kurt Cobain, Chris Motionless, Marko Saaresto, Corey Taylor, Rupam Islam and many more.

But I digress, oh yes, speaking about friends while we all have been good friends to each other, obviously you end up creating a smaller subset of friends with whom you end up making a lot of memories, with whom you end up sharing all your insecurities regarding how

you feel you are eating up a seat in WII which could have been used better by someone else, and in the end, those are the ones for whom one "might" cry when leaving this institute. I will like to thank all my batchmates for supporting me in this journey and I would like to specially thank that smaller group of friends- Shreyas Prashant, Joshika Komarla, Himani Pawar, Bryan Rana Thompson, Mencho Sena, and Gayathri Varma. And, Smriti Sharma from Freshwater MSc as well.

I sincerely thank the Rajasthan Forest Department for their help throughout the study period, be it Ranger Deepak Meena inviting me for fish dinners to keep the carnivorous Bengali in me alive, to taking me to the more undisturbed areas of Chambal which were not part of my study area also. I would like to thank the DFO, Ashish Vyas for his continued support and interest in my project and the forest guards who helped me throughout- Kumar Singh, Sajjan Gurjar, Kanhaiya and the others, along with my boatman Ajay, as well as the MP forest Dept.

I would also like to thank the team of WCT (Wildlife Conservation Trust), particularly Tarun Nair, Batan Singh and Munna Lal for their continued inputs and support for my study.

A lot of problems were faced during this dissertation, starting from shifting of methodology to completely shifting the study site. But in the end, I got to admit, this thesis is almost 100 pages long. That would not have been possible, this amount of data and these many analyses definitely would not have been possible to do if the study site was not Chambal. But getting to all these findings was not an easy work. Because of the delayed start of field, my study also concluded late compared to most of my batchmates. This resulted in me being unable to do most of the analyses that could prove my hypotheses and give rise to even more questions to analyse more, by the time of submission of draft thesis- the version based on which you are marked. This sealed my fate that under no circumstances can I hope for good marks for my dissertation, regardless of what all new findings I come out with in the final submission. Thus, finally I have to thank me, for not blaming myself for too long for the incomplete draft based on which I will be marked, rather using that to fuel myself to make sure to present all the objectives and findings in the final submission, exactly the way I had imagined in field while collecting data. And since I am thanking myself, I have to thank my better half as well- Sneha Pandey for all the love, concern and patience. And obviously, the most important, my parents without whom nothing at all would have been possible. Afterall, my parents only put the cascade of events into motion.

EXECUTIVE SUMMARY

Ectothermic animals such as Freshwater turtles rely on behavioural thermoregulation-basking, to maintain proper body temperature. It is the time of the day when turtles are exposed to predators and disturbance. Anthropogenic disturbance might hamper the basking behaviour resulting in a cascading consequence affecting body temperature, metabolism, locomotion and ultimately survival. The Chambal River is home to a great diversity of freshwater reptiles while anthropogenic disturbance is very high along the river primarily due to sand mining, illegal fishing, agriculture, livestock grazing and presence of humans.

Boat-based surveys with habitat characterization at macro and micro scale were performed to understand the impact of anthropogenic disturbance to basking site selection for turtles. In macro scale, *Nilssonia* and *Batagur* showed strong avoidance against highly disturbed stretches. The effect was buffered in the presence of mid-river basking sites. At micro scale, *Nilssonia* basking site selection was driven by type of Site (shoreline vs Mid river sites) and distance from waterline, while disturbance was not a predictor in the top model.

Behavioural observations were done from morning till evening. Basking duration for identified *Nilssonia* individuals were seen to decrease by 1/3rd under high disturbance, while basking bouts were also shorter. *Nilssonia* individuals spend more time basking on mid-river sites away from the disturbed shoreline, while the basking bouts were significantly longer on

sandbars as compared to disturbed sandbanks. Thus, mid river sites buffer the negative effect of disturbance both in site selection and behavioural aspects.

Since mid-river basking sites have limited area, crowding on such sites result in increased negative social interactions. The impact of disturbance was highest on juvenile *Nilssonia* as they were repeatedly removed from mid river basking sites by larger *Nilssonia*. Thus, juveniles basked for significantly lesser duration during high disturbance phases as they were unable to utilize mid river basking sites. After the removal of disturbance, it was observed that basking bouts were equally long on sandbank and sandbars and time spent on mid river basking sites were also lowered. This suggests that usage of mid-river sites cannot be simply attributed to thermal properties of the site, but is also, at least partially driven by disturbance at banks. Based on individual ID, the study also revealed how disturbance may impact different individuals in different manners.

Thus, mid river basking sites are critical habitat features that allow turtles to bask away from the disturbed shoreline under high disturbance. Even though they buffer the effect of disturbance, it cannot completely remove the negative impact of disturbance. Thus, regulation or removal of disturbance should be first priority for conservation of these species, followed by protection of these critical habitats (primarily from sand mining). The study also suggests to focus on multi-species, multi-scale response to understand how disturbance might be affecting various aspects of its habitat usage and behaviour, along with focusing on individual level responses to develop effective conservation strategies.

I N T R O D U C T I O N

Anthropogenic disturbance has been a field of wildlife science that has been studied in very great detail, particularly due to its application in wildlife conservation, as well as ecology of the organism in question. Disturbance can affect the survivability of an organism majorly in 2 ways- one is the direct impact, through hunting or habitat loss and modifications, both of which directly affects the survivability (Benitez-Lopez et al., 2017), and the other is the indirect way which imposes no direct impact on survivability but can affect particular aspects of an animal's behaviour or ecology which results in a cascade of detrimental effects, ultimately leading to reduced survival (Heppard & Buchholz, 2019). For example, change in time activity budget (Riddington et al., 1996), change in activity peaks (Gaynor et al., 2018), alteration of movement (Doherty et al., 2021). Basically, disturbance usually first affect the behavioural aspects of an organism which do not have any detrimental effect directly but can impact more crucial behavioural activities such as time spent in foraging, time spent in thermoregulating, time spent near nests (particularly for birds) which results in physiological implications such as higher stress levels (Desai et al., 2024), reduced movement, reduced protection to eggs or hatchlings (Weston et al., 2011) and inability to maintain a proper body temperature (Heppard & Buchholz, 2019), all of which alters the ecology of an organism and may result in physiological impacts, which thereby results in reduced survivability.

The impact of Anthropogenic Disturbance may vary from species to species as well as between different locations (Irwin et al., 2010). Thus, it is important to know exactly in what ways an organism might be affected to develop proper conservation measures. The question arises, exposure to anthropogenic disturbance do not always result in direct deaths or habitat modifications, yet they are impacted by approach of humans also. This is believed to be due to animals perceiving exposure to humans as predation risk and therefore employing anti predator strategies as a response (Frid & Dill, 2002). Predators themselves also influence prey not only through consumption, but also by changing the perceived risk associated with particular places and times (Palmer et al., 2022). Flight Initiation Distance (FID) is the most widely used metric to quantify disturbance. At what distance, does an organism respond to disturbance by flying away or by abandoning its activity is a cost benefit analysis (Ydenberg & Dill, 1986) where if the cost of not responding to the disturbance is perceived to be higher than the benefit of the activity that it is performing, the animal might choose to respond to the disturbance in some way. Animals may tend to shift away from highly disturbed areas if lesser disturbed alternative areas are available. Thus, the presence of alternate sites might be crucial to reduce the detrimental effect due to disturbance (Gill et al., 2001). Else, in the absence of such less disturbed habitat the animals have no choice but to utilize the disturbed habitat itself, but might respond in other aspects such as altered behaviour (Mukherjee et al., 2018) or physiological responses (Amo et al., 2006).

Anthropogenic disturbance may also reorganise temporal behaviour of wildlife. It has been seen that mammals increased their nocturnality by 1.36 in response to human disturbance (Gaynor et al., 2018). For ectothermic animals, shift in activity patterns might have higher detrimental effect, as they require exposure to sunlight for temperature regulation. If that is impacted due to anthropogenic disturbance, the effect might be highly detrimental (Amo et al., 2006, Heppard & Buchholz, 2019).

Human activity can produce spatial and temporal heterogeneity in perceived risk, causing animals to alter habitat selection or activity schedules. Thus, habitat for performing a particular activity might be present, but may be functionally absent for the animal due to perceived risk from humans. Avoidance of these resources by animals, might lead to reduction of effective resource utilization, even though the resource is available. Disturbance may result in disturbance-induced habitat compression (Gilbert et al., 2022) which is a phenomenon where animals utilize only a subset of available habitat to avoid disturbance. This may result in concentration of animals in more secure areas, which can alter density, aggression and competition. Thus, human disturbances may also result in changes in social context of an organism (Gilbert et al., 2022).

As already discussed, disturbance may affect different taxa or different individuals differently. Multiple taxa have been studied for impact of disturbance, with mammalian and avian studies being disproportionately higher-

Mammals: Because of the integration of telemetry and camera trapping data, mammalian studies provide a large variety of inputs as to strategies employed by organisms to different forms of disturbance. Ungulates have been seen to alter their habitat selection and time activity budget, shifting to higher time spent in performing vigilance in highly disturbed areas (Ciuti et al., 2012), while both herbivores and carnivores have been seen to alter their diel activity pattern under anthropogenic disturbance (Gaynor et al., 2018). Mammalian movement is also seemed to reduce in landscape with higher footprint (Tucker et al., 2018), while in other cases it might result in higher movements as well, due to escape. Thus, mammalian studies show that disturbance can affect at multiple scales. At smaller scale, they might affect time spent in vigilance, escape behaviour, etc. while at daily or seasonal scale, they might affect the activity pattern whereas at landscape scale, disturbance may affect activity patterns, sociality and movement. Thus, just the presence of animals in a disturbed area do not mean they are not responding to disturbance. Responses might be shown in smaller scales which might have cascading detrimental effects.

Birds: Like mammals, impact of disturbance on birds is also greatly studied. Avian studies are mostly focused on flight initiation distance, alert distance and return rate to nests. Disturbance might impact behaviour in terms of reducing feeding time under high disturbance, which might have direct effect on survivability. Individual based modelling showed that disturbance may reduce survival when birds cannot compensate for lost feeding opportunities, whereas the impact is buffered under high food availability (Stillman et al., 2007), which is in line with Gill et al., 2001's argument that resource (alternate options) availability may buffer the negative effect of disturbance. Nesting behaviour is also well known to be affected by human disturbance which directly impacts the survivability of eggs/hatchlings (Beale & Monaghan, 2004, Steven et al., 2011). Anthropogenic disturbance may result in nest departure and reduced incubation period. Thus, even in avian studies, the conclusion remains the same. Disturbance may have different impacts on different scales, thus presence or absence of an organism in highly disturbed area does not mean it is not affected by disturbance, there may be several other responses that is being shown due to disturbance and have significant impact on survivability.

Reptiles: Compared to mammals and birds, reptiles are far less highlighted in studies related to impact of anthropogenic disturbance, primarily because of most reptilian species being elusive (Larson et al., 2016). Most of these studies come from basking reptiles and crocodilians that look into how disturbance might affect distribution and basking behaviour. Thermoregulation is a procedure by which living organisms maintain their body temperature. This is essential for survival as body temperature drives most of the internal mechanisms such as metabolism, enzymatic activity, etc, which in turn regulates energy production, nutrition assimilation and locomotion (Chessman, 2024). All in all, Thermoregulation is one of the most essential processes to ensure survival of an organism (Bulté & Blouin-Demers, 2010). While homeothermic animals such as Mammals primarily thermoregulate by Physiological thermoregulation (sweating, shivering) to maintain almost constant body temperature despite of environmental fluctuations, reptiles, Amphibians and Fishes are poikilothermic and to maintain body temperature within the optimal range, they resort to behavioural thermoregulation. The most well-known example of such behavioural thermoregulation is Basking.

Basking is a form of thermoregulation whereby animals expose themselves to the surrounding environmental conditions, and stay almost motionless to maintain their body temperatures. Both homeotherms and poikilotherms are known to perform basking, though it is most important for poikilotherms as they lack other means of thermoregulation. Besides thermoregulation, evidences exist to prove that basking might also aid in ectoparasite removal and cooling (Chessman, 2024). During basking, the animals are directly exposed to the predators as well as to anthropogenic disturbance. Thus, time spent in basking in a disturbed landscape is also a cost benefit analysis where if the cost of prolonged basking and exposure to disturbance/predators is higher than the benefit of thermoregulating, the animal might choose to terminate basking (Batabyal et al., 2017).

Most of the literature connecting anthropogenic disturbance with reptilian behaviour has emerged from studies on basking lizards. It is known that FID of basking lizards is affected by type of disturbance, distance from refuge, body temperature, etc (Cooper Jr et al., 2011, Cooper Jr et al., 2009). In certain species, it has been observed that the FID do not vary under different disturbance levels, but the body condition was comparatively poorer in higher disturbed areas compared to lower disturbed areas, which might be because of inefficient basking as lizards in highly disturbed areas had to perform higher frequency of anti-predatory strategies (Amo et al., 2006), since basking is also known to play a major role in removal of ectoparasites. Reptiles show population level and behaviour level responses to disturbance but the directionality and magnitude of these effects were found to have very high variation, owing to variation in responses to disturbance by different species (varying strategies at different spatial and temporal scale) (Gill et al., 2001).

In the context of Freshwater turtles, it's a common sight to see turtles coming out from water onto the surrounding substrate that is available, and bask for several minutes to a few hours even, depending upon the physiological requirements. Basking is also the time when these are most susceptible, to predators and to disturbance (López et al., 1992). While exposing themselves to predators reduce their survivability, disturbance also triggers the flight response preventing turtles from performing their natural basking behaviour (Selman et al., 2013), which again reduces the survivability as improper basking may lead to lethargic responses and sluggish locomotion, preventing the animal from effectively searching for food and avoiding predators. Thus, where to bask or basking site selection can be considered a crucial part within the basking behaviour, as thermal needs, physiological limitations and exposure to threats all might play an important role in selection of where to bask.

Basking site selection, primarily for Crocodilians and lizard species is well studied, but lesser so for freshwater turtles. Habitat variables such as slope, substrate, Water depth, shade cover, disturbance index, etc. has been seen to drive basking site selection. Lamber et al., 2013 found the effect of substrate, disturbance level, slope and water depth next to the basking site. Peterman & Ryan, 2009 found substrate and vegetation cover to be significantly associated with turtle basking sites. Vignoli et al., 2015, found water turbidity and presence of emergent vegetation to be significantly associated with basking site selection of a pond turtle. Capula et al., 1994 found *Emys orbicularis* preferring mid pond islands over shore of the pond after the installation of islands in a pond that lacked it. The reason behind this was suggested to be security from predators on banks. Erdelyi et al., 2021 found substrate, vegetation cover and diameter of logs to be significantly associated with basking site selection where smaller bodied turtles preferred thinner branches. Hill & Vodopich, 2013 found turtle basking site selection to be negatively correlated with degree of disturbance. Thus, what factors drive selection and to what degree varies from species to species and also between sites. And as is evident from the provided examples, very few of such studies exist for turtles, especially for riverine turtles.

The general basking behaviour is comparatively well studied from a thermal perspective, primarily for lizard and crocodilian species, but also for turtles. The study of basking behaviour majorly focuses on basking peak, basking duration, emergence and retreat rates and thermal requirements. Several species of crocodilians and turtles are known to show unimodal basking peak around the middle of the day during winters, which shifts to bimodal basking peak, one in early morning and later towards the evening during the summers (Moore & Seigel, 2006; Dave & Bhatt, 2021). Basking duration is the time period for which an animal basks in a day. Basking duration of *Chrysemis picta* is known to be negatively correlated with body size, either due to higher heat absorption rates or higher wariness (Lefevre & Brooks, 1995). For animals that cannot be individually identified and are unmarked, it is not possible to know the entire basking duration since turtles might retreat during a disturbance and resume basking after the disturbance has passed, the resumption of basking can take place at the same basking site or may shift to some other basking sites. Thus, for basking studies for unmarked species duration of one continuous basking event is counted. (Moore & Seigel, 2006).

Predictive models had shown disturbance might result in a 0.34ºC reduction in body temperature which amounts to 8% reduction of metabolic rate (Heppard & Buchholz, 2019). This might have large scale implications towards the physiological and locomotory capabilities of the organism, ultimately reducing its fitness.

Another important concept that has been looked into for other taxa such as birds (Tracy-Smith et al., 2012, Pickerell, 2015) but not that much with respect to aquatic reptiles are river islands or Mid river basking\nesting sites. These are basking\nesting structures such as sand bars, mud bars, gravel bars or rocks jutting out of water, which are not connected to the main shoreline and are surrounded by water on all sides. These kinds of structures are characteristic of braided river channels. Scientific studies have shown how these sand bars serve as a refugia for nesting birds and Softshell turtles (Dieter et al., 2014, Tracy-Smith et al., 2012, Dixon, 2009), by virtue of it being isolated from the mainland, thus preventing disturbance and predators from crossing over to the sandbars (Pickerell, 2015). If these mid river sites serve as refugia for basking animals or if the presence of mid river basking site, buffers the effect of disturbance has not been looked into, but it has been seen that Gharial encounter rate is driven by presence of mid Channel Islands (Hussain, 2009, Choudhary et al., 2018). Though for turtles, this has not been looked into even though it was seen that formation of mid river basking sites resulted in turtles shifting their basking site from shoreline to the mid river sites (Capula et al., 1994). Thus, basking site selection and impact of disturbance on basking are some of the topics that has been studied globally but riverine turtles have been largely overlooked in that aspect.

In Indian context, studies relating basking to disturbance are very few and performed mainly on crocodilians. While response of disturbance towards other taxa, such as mammal and birds are well studied, following the exact trend as that of the global context. In terms of birds, it has been quantified in Rajasthan that anthropogenic disturbance was the greatest contributor to destruction of *Grus Antigone* nests (Kaur et al., 2008), which is one of the most conclusive pieces of evidence of direct impact of anthropogenic disturbance by direct mortality. Faecal glucocorticoid levels (an indicator of stress) in *Panthera tigris* were found to be consistently higher in tourism zones (Tyagi et al., 2019), indicating Tigers are having physiological responses to anthropogenic disturbance.

Basking site selection studies with response to disturbance for reptiles are rare in India, with most studies conducted on muggers and Gharials. Chowdhury et al., 2018 found basking site selection to be driven by Land use pattern and intensity for Gharials, while for muggers, disturbance was not a predictor in the best-fit model. Evidences exist that anthropogenic disturbance may in fact affect muggers in an indirect fashion by affecting the physiology. Desai et al., 2024 found muggers in more disturbed areas seemed to have much higher faecal glucocorticoid metabolite levels indicating chronic stress. While higher levels may also be due to environmental factors, because of consistently high levels throughout the year, the possibility of disturbance playing a role cannot be ignored. While published literature for turtle species of India and their response to disturbance is absent, Jani et al., 2009 found turtle abundance to be negatively correlated with disturbance. While *Pangshura tentoria* did not respond to disturbance as such, *Chitra indica* and *Nilssonia hurum* were negatively affected by disturbance. Even though certain species of turtles are well studied in terms of nest site selection (Sirsi et al., 2017), nesting behaviour (Pareek et al., 2026) and response of nesting behaviour to disturbance in India, the same has not been done for basking. While nesting is of higher conservation priority for these species whose population is declining, as discussed till now, inability to bask properly may also result in decrease in fitness, which also needs to be studied to ensure proper health of an individual.

The importance of alternate basking sites or sandbars are not well studied in India, regarding basking of turtles, even nesting studies are infrequent. It is known that Softshell use sandbars for basking through natural history records (Krishnaswamy, 2015). Chowdhury et al., 2017 and Hussain, 2009 found gharial encounter rates to be positively correlated with presence of alternate basking sites at a macro/segment level. Gharials were seen to tolerate moderate amounts of disturbance under the presence of mid river basking sites (Chowdhury et al., 2017). It has been seen when water levels are too low, the sandbars may become connected to the main shore. Then the sandbars that were being used for nesting by skimmers due to absence of disturbance paves the way for disturbance to expand upon the sandbar as well resulting trampling by livestock, dog depredation, etc (Patel, 2020, June 17). Similar pattern may be expected to be observed for turtle basking as well, whereby sandbars or any other mid river basking sites serve as buffers to an otherwise highly disturbed landscape.

The reason turtles have been overlooked this much in India despite having a lot of cultural roots associated with turtles is because Turtle conservation in India started as a by-catch of gharial conservation. It’s only in the recent few years; people are becoming aware of their critical status of this species and important research is being done. But still, most of the studies are focus on nesting behaviour and population assessment, in terms of information about basking, it is still lagging behind.

Literature Gaps:

- Basking Site Characterization and Documentation of Basking Behaviour for turtle species of India is almost non-existent in published scientific literature, despite of India having one of the highest species richness of Turtles globally.
- Impact of anthropogenic disturbance on basking site selection and basking behaviour (both direct and indirect) of freshwater turtles are not known in the Indian context. Even though globally, research on the topic exists, they are very infrequent.
- Even though natural historical observations suggest the importance of mid river basking sites, if they actually serve as buffers under high disturbance has not been researched upon.

Disturbance may affect basking site selection and behaviour in various ways and at various scales-

Macro scale avoidance: Animals respond to the general disturbance regime or persistent disturbance, and may avoid the more disturbed areas altogether. Evidences exist for these kinds of responses in population level, whereby population/habitat usage is lower in the more disturbed regions (Choudhary et al., 2018).

Micro scale avoidance: The most widely studied response and a lot of literature exist to suggest that reptiles do respond to immediate or localized disturbance events, mostly responding with higher lag time before coming out to bask, or abandonment of basking at a site (Moore & Seigel, 2006).

Basking Site Shift: In a disturbed region, animals might shift to other basking structures and resume basking. These alternate basking structures could be the opposite shoreline, or islands and rocks in the middle of the water body. (Heppard & Buchholz, 2019, Gill et al., 2001).

Emergence and Retreat Rate: Hourly emergence and retreat rates refer to the number of emergence-to-bask incidents and retreat-from-basking incidents every hour. In an undisturbed environment, it would be expected that emergence-to-basking will be higher when the environmental temperature reaches an optimum value and will be lower before and after that time. Retreat rate will be expected to be the highest when the environmental temperature lowers beyond the optimum, i.e. when the Sun is about to set. While in highly disturbed areas, animals might have to retreat from and resume basking several times throughout the day because of the high frequency of disturbance. As a result, the hourly emergence and retreat rates will be different (Mukherjee et al., 2018).

Basking Duration: Literature evidences prove that higher disturbance reduces the average basking duration which might have negative effect in thermoregulation (Mukherjee et al., 2018).

Though Chambal is the most studied river in terms of turtle ecology, the studies are mostly focused on nesting ecology. While nesting is the most important event in the lifespan of an organism and conservation of nesting sites is essential to increase the numbers of these endangered species, basking is the second most important event that determines survivability of these species and is needed almost regularly. Thus, understanding the basking ecology of the turtle species of Chambal and the conservation of basking sites is equally important for sustaining their population, but is severely understudied in India. This thesis aims to understand what are the drivers behind basking site selection, how these turtles respond to disturbance and if presence of mid river basking sites is buffering the impact of disturbance.

O B J E C T I V E S

Objective 1: To understand the factors that drive basking site selection and impact of disturbance and mid river basking sites on site selection

Sub-objective 1.1: To understand which factors drive Basking Site Selection (in both macro and micro scales)

Explanation: It is known from previous literature that various macro and micro habitat variables drive basking site selection of turtles. This objective is solely to understand what factors drive basking site selection and to what magnitude. Macro scale variables refer to segment level variables, whereas micro scale variables refer to point level variables.

Sub-objective 1.2: To understand how disturbance and presence of alternate basking sites influence habitat usage for basking

Hypothesis 1a: Turtles will avoid basking in segments with higher disturbance pressure

Explanation: Turtles might show various responses to different degrees of disturbance. These responses may be different for different species and responses might vary between disturbances at different scales, such as **Macro-scale avoidance/Segment level avoidance**, according to which Turtles avoid basking in particular segments of river, because of the disturbance pressure being higher in those segments.

Hypothesis 1b: Turtles will be utilizing disturbed segments for basking, if alternate/mid river basking sites are available

Explanation: Presence of mid river basking sites, may provide the turtles an opportunity to utilize these basking substrates while still being away from the disturbed shoreline. Thus, presence of mid river basking sites, may buffer the impact of disturbance.

Objective 2: How disturbance and presence of alternate basking sites influence basking behaviour and social interactions

Sub-Objective 2.1: How disturbance and presence of alternate basking sites influence basking behaviour

Hypothesis 2a: Under high disturbance, the basking duration will be lower (if turtles are individually identifiable)/ Under high disturbance, the basking bouts will be lower (if unidentifiable)

Explanation: Different species may have different responses to disturbance. Certain species may avoid selection of disturbed areas for basking while others may use disturbed areas for basking and may respond to disturbance by terminating basking, thus reducing the total duration of basking.

<u>Hypothesis 2b</u>: Under high disturbance, turtles will be utilizing the mid river basking sites more than the shoreline basking sites, as compared to less disturbed days

Explanation: Reduction of basking duration may affect the body temperature, physiological and locomotory capabilities. Thus, even if turtles bask in a disturbed area, if alternate options are available in the area, they might prefer to bask away from the disturbed shoreline (Gill, J.A. et al. 2001).

<u>Sub-Objective 2.2:</u> To understand Individual level responses to disturbance

Explanation: Individual level response to disturbance can give more insight into ecological and management-related implications. Since it was possible to identify individuals of *Nilssonia gengetica* and due to lack of such studies, individual level responses were looked into.

<u>Sub-Objective 2.3</u>: To understand social interactions during basking

<u>Hypothesis 2c</u>: Number of aggressive interactions will be positively correlated to the number of basking turtles on a basking site

Explanation: Since mid-river basking sites are few and smaller in size as compared to the shoreline, they can be considered as point basking habitats, whereas the shorelines provide large stretch of basking habitats but is under high disturbance. Thus, social interactions might be increasing due to crowding (Gilbert, N.A. et al. 2022), in this case, turtles might be getting into direct conflicts with each other for the utilization of mid river basking sites.

STUDY AREA

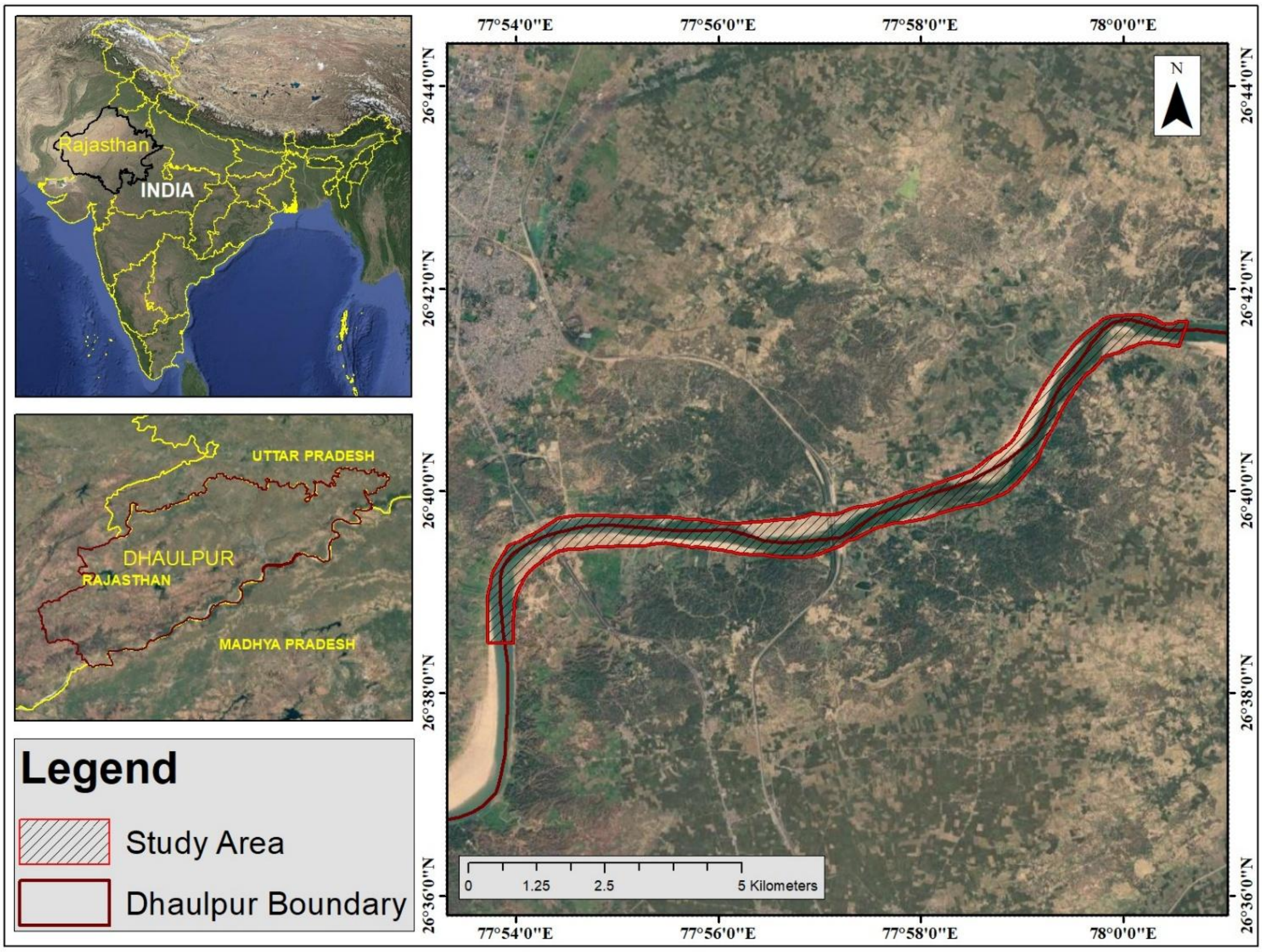

Figure 1: Map of Study Area

Image 1: Photo of Study Area

Chambal River is the largest tributary of Yamuna River, originating in Madhya Pradesh, travelling along the border of Madhya Pradesh and Rajasthan and into Uttar Pradesh to finally meet with Yamuna River. August to October is the flooding season of Chambal which accompanies the Southwest Monsoon, after which the water levels steadily decline till the lean season during April – June. The diurnal temperature ranges from 30-37 °C during the Summer season and 20-25 °C during the winters. Alongside being a culturally and historically rich region, the surrounding vegetation is of the tropical thorn, scrub and riverine type. The Chambal River boasts long stretches of deeply cut ravine habitats, which serve as nesting sites for Vultures and Bonelli's eagle, also as shelter for majestic mammals such as Leopard and Striped Hyaena. Once upon a time, these areas served as shelter for the famous Chambal rebels - Phulan Devi and Paan Singh Tomar, alongside others. The river also holds a huge diversity of native and migratory birds starting from Indian cormorant to Pelican, Comb headed Duck to Indian Skimmer and black bellied tern.

A 400-kilometer stretch was notified as the National Chambal Sanctuary, from downstream of Jawahar Sagar Dam in Rajasthan to Panchnada in Uttar Pradesh in 1978, primarily for the protection of Gharial, Gangetic Dolphin and Freshwater turtles. The National Chambal Sanctuary holds one of the largest populations of Gharials and is one of the last remaining habitats for the critically endangered *Batagur kachuga*. The shoreline morphology transitions from rocky in the upstream stretch to sandy in the downstream areas. Mid river sand bars, rocks, gravel bars and islands are present along the entire stretch which serve as important nesting and basking habitats for reptiles and birds alike.

Chambal is one of the least polluted rivers because of the lack of industries along the shore. Despite these conservation efforts, certain stretches are rampant with illegal activities such as mining, fishing and garbage disposal. Sand mining has been the biggest threat to basking and nesting habitats for turtles and gharials alike, while fishing and garbage disposal are reduced to localized problems because of the measures taken by the forest departments. Agriculture and livestock grazing along the banks within the protected area itself is a very common sight which results in human and livestock presence along the shores, creating disturbance for basking reptiles. Alongside this, another bigger problem for the Chambal ecosystem are the dams built upstream of the sanctuary area, namely, Gandhi Sagar Dam,

Rana Pratap Sagar Dam, Jawahar Sagar Dam and Kota Barrage. The earlier mentioned water levels are under natural conditions, but in the recent times, due to untimely release of water particularly during heavy monsoon season, the flooding season has been altered or extended while the lean period has been delayed or shortened. This altered hydrological patterns alter the emergence of sandbars and sandbanks which is important not only for basking, but for other crucial activities such as nesting as well. Washing away of Skimmer eggs due to untimely release of water has been one of the biggest concerns for the conservation of the species, which is also true for the other bird and reptilian species as well (Debata, S. et al. 2019).

Image 2: Illegal Sand Mining

Image 3: Agriculture

Image 4: Livestock

Image 5: Illegal Fishing

Image 6: Human Presence on Shore

Image 7: Accumulation of Garbage

This study was performed particularly along a roughly 14 kilometre stretch of the Chambal River in the districts of Morena, Madhya Pradesh and Dhaulpur, Rajasthan, stretching from Kamare ka Pura to Rithora Khurd. The primary reason for choosing this particular stretch was because of the accessibility to boat services. Furthermore, this stretch is known to have high density of Softshell and Hardshells alike. Though almost the entire shoreline is disturbed, the disturbance varies greatly between the segments. Along with that, this stretch consists of areas with no mid river basking structures and segments with sandbars, gravel bars, islands, rocky outcrops and smaller jutting rocks as well. Thus, the selected stretch provided the disturbance and habitat mosaic along with the logistical backing that was needed for this study.

A short introduction to the turtle species observed during the study:

Nilssonia gangetica- Large-bodied softshell turtle which is known to be a scavenger as well as a predator, though it might also feed upon aquatic vegetation. It has a flat body with a leathery carapace and tubular nostrils. Males can grow as big as 3 feet, while females can be larger (Wildlife Institute of India, 2025). They can be individually identified on the basis of head markings, though the markings may change with the age. Often observed basking on banks and mid channel basking sites, they are known to be highly sensitive to disturbance (Subba, A. et al. 2026). IUCN status- EN

Batagur kachuga- Large bodied hardshell turtle, herbivorous in nature. Females may grow up to 2 feet in length whereas males are usually smaller. During the breeding season, the head and neck of the male *B.kachuga* develop orange/red, blue and yellow coloration. Earlier found at several places along south and southeast Asia, its population has decreased drastically and Chambal River is one of the last remaining river systems holding a good population of these turtles. IUCN Status – CR

Pangshura tentoria circumdata- Small bodied hardshell turtle which derives its name from the spine like projection on its carapace that gives it the appearance of a tent. Females can grow up to 25-30cm in length, while males are around 10cms. The particular subspecies is characterized by orange pleuro-marginal ring on its carapace and is distributed in Upper and central drainages of Ganga. IUCN Status- LC

Other species that were observed but not included in analysis because of low amount of data were:

Batagur dhongoka- Large bodied hardshell turtle, primarily herbivorous, differentiated from *B.kachuga* based on 3 black stripes on its carapace. They bask infrequently. IUCN Status- CR

Chitra indica- One of the largest freshwater turtles, it is a Softshell turtle and primarily a carnivore. It is an ambush predator and digs itself into sandy substrate waiting for prey to pass by, at which point it extends its neck at very high velocity to capture the prey. It is identified by lines diverging from the neck, forming a 'V'. IUCN Status- EN

Lissemys punctata andersonii- These are habitat generalists known to inhabit ponds, floodplains and river systems. They are named Flapshell turtles because of the presence of femoral flaps on its plastron that guards the limbs when retracted. This particular subspecies is identified by the yellow spots on its carapace. IUCN Status- VU

Image 8: Lissemys punctata andersonii

Image 9: Batagur kachuga

Image 10: Nilssonia gangetica

Image 11: Pangshura tentoria circumdata

Image 12: Batagur dhongoka

Image 13: Chitra indica

O B J E C T I V E 1

F I E L D   M E T H O D S

Reconnaissance: During the reconnaissance period, multiple boat rides were conducted to select the survey area, and number of basking turtles by time of the day were recorded to figure out the peak basking hours. Based on this, the survey area was chosen to be a 14-kilometer stretch of Chambal River extending from Kamare ka Pura to Rithora Khurd which was seen to support a good density of hardshell and softshell turtles alike. Further upstream, the shoreline becomes very steep and basking incidences are greatly reduced. Areas further downstream were not included, as surveying that much of an area would result in the survey period going beyond the peak basking hours, thus reducing detectability. The peak basking time was observed to range between 11:00AM – 2:00 PM. Feasibility of 2 methods were checked during the reconnaissance for turtle basking surveys – one on foot (Vignoli, L. et al. 2015), the second via boat (Chaudhary et al., 2018). Both methods are widely used in scientific literature, but it was decided very early-on that boat-based surveys will be conducted- not because of logistics but because of the threats from sand mafias. As sand mining is a rampant business along the Chambal shoreline in the area, the only feasible and safest way to cover the entire stretch was by boat. Observations were done from strategic locations across the study area based on accessibility, to check if boat-based surveys result in lower detection of basking sites compared to scans from fixed points. Based on this, *Lissemys* *punctata* and juvenile *Nilssonia gangetica* were found to have imperfect detections via boat-based surveys, primarily due to short duration of basking. Thus, data for *L.punctata* and juvenile *N.gangetica* collected during boat surveys were not used for analysis.

Turtle Basking Surveys –. Boat based surveys were conducted across the 14km segment of Chambal starting from 11:00AM, ensuring a steady pace at 5kph, keeping the trajectory of the boat along the middle of the river. Thus, the boat surveys extended from 11:00AM – 2:00PM, i.e. the peak basking period. The reasoning behind keeping a steady speed was because turtles were observed to respond to sudden stopping and resumption of boat more severely as compared to a steadily moving boat. While boat-based surveys are one of the most widely used methods for survey of riverine reptiles, disturbance due to the boat is a valid concern. Thus, to maximize encounters, a viewing angle was estimated that would aid in increasing detection even if the turtle retreats upon the boat approaching closer, for the observation would have been recorded beforehand itself, because of the viewing angle.

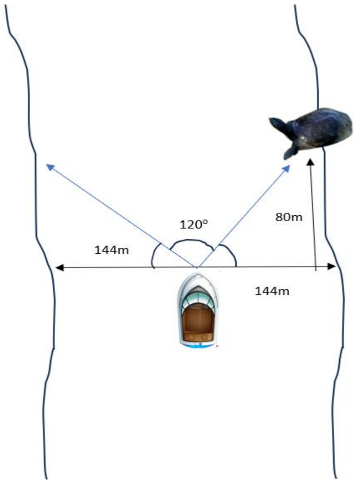

Figure 2: Calculation of Viewing Angle

During the reconnaissance, turtles were approached head on with a boat to calculate the average **Flight Initiation Distance (FID)** keeping the starting distance constant at 250 metres. This was conducted only for *Nilssonia gangetica* as they are generally known to be sensitive to disturbance and they have a good population to experiment this method upon. This FID was used to calculate the viewing angle during the surveys. The average FID for *Nilssonia gangetica* within the tourism zone (the first 6.5kilometer stretch) was 80 metres upon approach by a boat. For a conservative estimate, the viewing angle was calculated as 180-2*(tan inverse of 80 upon half of average channel Width which is 144 metres) resulting in a viewing angle of 120 degrees. Beyond the tourism area, the average FID for *Nilssonia gangetica* increased to around 120 metres, and the Average channel width was 298 metres, resulting in a viewing angle of 100 degrees. These trials were restricted to no more than 10 in both tourism and non-tourism areas, to reduce disturbance on the turtles. The boat surveys were conducted only on those days when no other tourist boats were launched before the survey timing, as that would result in turtles abandoning basking because of the disturbance due to tourist boats. Thus, because of these criteria, the survey days were mostly restricted to weekdays. The sky had to be clear and Sunny during the survey days, to maximize encounters and reduce the chance of the weather changing midway into the survey.

5 boat-based surveys were conducted between 26th Feb – 8th March, one survey a day. The reason for doing the surveys within quick succession was because the lean season of Chambal was still approaching, as a result, the water level was supposed to go down more, which could change the availability of habitat. During each boat survey, the shoreline and mid river basking sites were scanned for basking turtles using a binocular (Zeiss Terra ED 42) within the viewing angle. The GPS location (using Locus Map App), Species and number of basking turtles were collected for each basking incidence, along with photographs (if needed) for later reference.

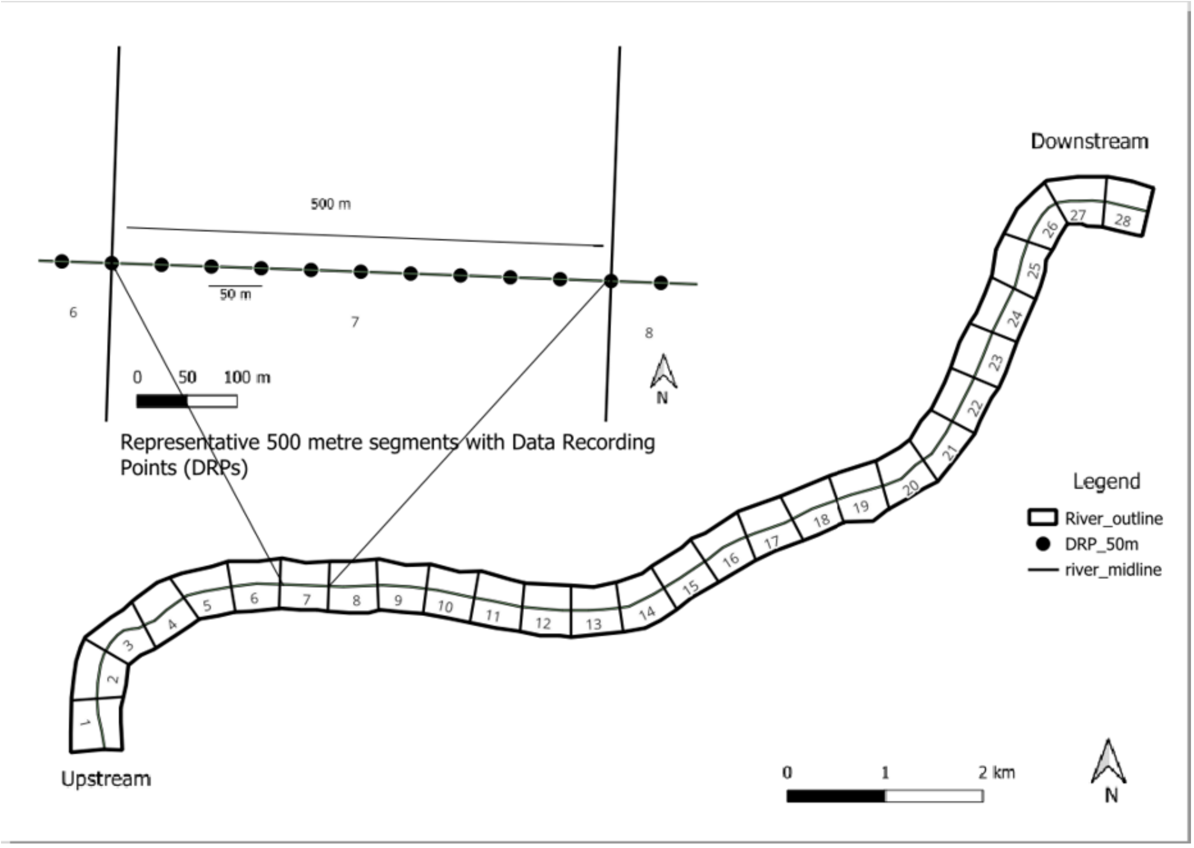

Figure 3: Schematic representation of Study Area for macro and micro scale habitat characterization

Habitat availability for *Nilssonia* and *Batagur* was quantified at every 50 metres interval on both the banks and if any mid river sites are present, for them as well. Since it was not possible to walk along several stretches of the bank, primarily because of threat due to the sand mafias. Points were generated at 100 metres intervals along the middle of the river using QGIS. Later on, these areas were approached either by foot or by boat to collect habitat variables. This was done opportunistically whenever the threat due to sand miners were absent and no animals were seen basking in the vicinity. The habitat variables that were expected to play a part in basking site selection were collected. These were:

- **Slope** (using LABART Digital inclinometer) – Slope was expected to play a role in basking site selection by primarily acting upon physiological restraints. (Chaudhary et al., 2018)

- **Substrate** – Collected ocularly. The 4 types of substrates that were mainly covered are: Sand, Mud, Rock and Gravel. Substrate selection is one of the most important phenomena in basking site selection as it directly impacts thermoregulation (Meek & Luiselli, 2022).
- **Depth Profile** (DepthTrax 1H Depth Sounder) – Depth was collected twice, once at a distance of 10 metres from the shoreline and then at 50metres from the shoreline. The depth profile was then calculated by subtracting the values and dividing by (50-10) to get a unit for per meter increase in depth. Animals might choose basking habitats based on where they can easily retreat into deep waters. Thus, depth profile might play a role in basking site selection (Hussain, 2009).
- **Grass Cover** (using ocular estimation) – Presence of grass on basking substrate may provide shade if grown long enough or provide moisture.

A buffer of 10 feet was created on both the banks, as turtles were not seen basking beyond 10 feet towards the interior in the landscape. While at the habitat availability point, a random number generator was used to generate a random number between 1-10 and I would take that many numbers of steps inwards from the waterline.

- **Distance from water** – A bamboo pole was inserted at the waterline and the point on bank where I reach after walking that many numbers of steps. Using Nikon Forestry Pro II Rangefinder's 'HOR' mode, the horizontal distance of the point was calculated from waterline by taking the bamboo poles as reference.
- **Height from water** – A red tape was applied 1 foot from the base of both the bamboo poles, and the height of the availability point was calculated by subtracting the height of red tapes on both the bamboos, using 'Hgt' mode of the Rangefinder.

- **Disturbance** presence/Absence (if disturbance is present, it is attributed to the closest availability point).

Habitat usage was quantified by approaching the locations where turtles were seen basking either by foot or by boat later on, with the help of GPS location and photographs (if taken). The same habitat variables were also collected for each usage site.

Extrapolating Macrohabitat variables: For *Nilssonia* and *Batagur*, the entire river segment was divided into 500 metre segments and the properties of the segment were calculated by averaging out the 50 metre habitat availability points within each segment. No literature backing could be found to support defining segments as 500 metre stretches for turtles, neither does daily movement information exist for these species. The basis of selecting 500 metre as a segment was primarily because similar studies have been done on Crocodilian species in 2km or even 1km segments, thus for turtles, it was decided to reduce the segment length to 500 metres. This was used to extrapolate segment-level factors from microhabitat availability points itself, such as:

- **Substrate composition (% Sand, % Rock, % Mud, % Gravel)-** These percentages do not include habitat availability points on mid river basking sites, as because that is treated as a separate variable in itself. Also, as part of one of my objectives, it is assumed that mid river basking sites are functionally different from basking sites along main shore, by virtue of it being surrounded by water on all sides and having the potential to buffer the negative impact of disturbance, by providing alternate basking structures.

- **Presence of mid river basking sites**- mid river basking sites can be defined as basking platforms, formed of sand (sandbars), mud or gravel in the middle of the river surrounded by water on all sides. But since the aim of the study is to look at species specific drivers, the definition of mid river basking sites is considered more flexible, to align with species biology and field observations. For example, mid river structures such as sand bar, mud island and gravel bars all were considered mid river basking sites for *Nilssonia*, because they were either seen basking on the structures or on the same substrate at least. In case of *Pangshura tentoria*, they were never seen basking on sand or sandbars throughout the study period, not only during surveys. In that case marking presence of sandbars as presence of mid river basking sites for *Pangshura* may be ecologically incorrect. Thus, for the different species, mid river basking sites were defined differently based on the field observations:

  Pangshura- mid river rocks

  Batagur- large mid river rocks (>=1.5 feet radius of basking platform)

  Nilssonia – gravel bar, sand bar, mud bar, rocks
- **Mid River Depth** – extrapolated by averaging the mid river depth at 50 metre intervals along with the microhabitat quantification.
- **Disturbance** – Within each segment during each boat-based survey, start and end point of disturbance and category of disturbance were recorded. This was averaged out for the 5 survey days to generate average proportion of shoreline that is disturbed due to human presence, due to livestock presence and due to sand mining. Average escape distances were calculated for *Nilssonia gangetica* towards each of these disturbance categories (primarily because *Nilssonia* was seen to utilize diverse range of habitats, and thus it was easier to observe escape distances of *Nilssonia* to

disturbances as compared to *Batagur*, for which sightings were low and to *Pangshura*, for which escape distance to sand mining cannot be calculated as they were never observed to be basking on sand). It was seen that the average escape distance in case of human and livestock disturbance ranged around 20-25metres, whereas in case of sand mining, turtles would run away even when the tractors are at a distance of 90-100metres, which is 5times the distance for human and livestock. Thus, to calculate disturbance index, the average proportion of shoreline under disturbance was weighed with the escape distance, that is disturbance due to human= average proportion of area under disturbance due to humans * 1, disturbance due to livestock= average proportion of area under disturbance due to livestock * 1 and disturbance due to sand mining= average proportion of area under disturbance due to mining * 5 and these were summed to generate a disturbance value for each segment as per the 5 survey days.

For *Pangshura*s, the length of segments was reduced. Field observations suggested that *Pangshura*s were present in localized areas and not uniformly distributed throughout the study site and by virtue of their smaller size as compared to the other species studied in this thesis, the segment was reduced to 200metres for macrohabitat level selection. The same habitat variables were collected and extrapolated as segment level characteristics. During each boat-based survey, location of basking turtles was collected with GPS and were later geocoordinated to different segment IDs.

STATISTICAL ANALYSIS

Sub-objective 1.1: Using ggplot2 package of R, response variable, that is, number of turtles of a particular species seen in a segment were plotted against predictor variables to choose the variables that were to be run for analysis.

Using library *GlmmTMB* package, mixed effect generalized linear models were run with random effect of day and segment to account for variability between days, during the 5 surveys. In case of either of the random effect variance being close to zero, the random effect was removed from the model. Candidate models and intercept only models were run based on ecological understanding and field observations, which were then selected based on AICc using model.select function of package *MuMIn*, following the information theoretic approach. In case of Delta AICc being less than 2, model diagnostics were run to choose the best fit model. For Microhabitat usage analysis, habitat availability and usage points with substrate rock were removed, as each rock served as a unique basking structure in itself with different values of slope, distance and height form water. Thus, including rocks with sand, mud and gravel would result in a scale mismatch of how the habitat parameters vary. For *Batagur* genpois family was used while for Pangshura and Nilssonia, negative binomial was used.

Sub-objective 1.2: Using *GLMMTMB* package in R, hypothesis testing approach was used. Thus, an interactive model between disturbance index and mid river basking sites were used to test the hypothesis for different species. For *Batagur* genpois family was used while for Pangshura and Nilssonia, negative binomial was used

R E S U L T S (Sub-objective 1.1)

Batagur kachuga Macrohabitat Usage

Table 1: Model selection table for factors affecting Batagur kachuga encounter rate at segment scale

Model	Predictor(s)	AICc	ΔAICc	Weight
Hydrology	as.factor(MidRiverRock) × Disturbance + River Depth	200.3	0.00	0.502
Interaction	as.factor(MidRiverRock) × Disturbance	201.6	1.25	0.269
Global	Mud + Sand + Rock + River Depth + as.factor(MidRiverRock) × Disturbance	203.4	3.08	0.108
Mid-river basking	as.factor(MidRiverRock)	204.4	4.08	0.065
Additive	as.factor(MidRiverRock) + Disturbance	205.3	4.97	0.042
Depth	River Depth	208.1	7.75	0.010
Major basking substrate	Rock (%)	211.8	11.48	0.002
Disturbance	Disturbance	212.3	11.94	0.001
Substrate use	Mud + Sand + Rock	213.6	13.25	0.001
Null	Intercept	226.4	26.08	0.000

Based on the information-theoretic approach, for *Batagur* encounter rate Hydrology and Interaction models seem to be the best-fit model (Del AICc <2). The Interaction model is a nested model within the Hydrology model. Both the models consist of an interaction term between disturbance and presence of mid river basking sites, with the model Hydrology having an extra predictor- River Depth. Thus, Confidence interval of the additional predictor in the model Hydrology, i.e. River Depth was checked during model summary, to see if the 95% confidence interval range excludes zero, i.e. no effect (Arnold, 2010).

Table 2: Model summary table for Batagur kachuga encounter rate (exponentiated co-efficients)

Predictor	**Estimate**	**95% CI**	**Z value**
Intercept	0.368	0.054–2.501	-1.023
MidRiverRock present	0.497	0.067–3.689	-0.684
Disturbance	0.366	0.143–0.935	-2.100
River depth	1.054	1.001–1.110	1.988
MidRiverRock × Disturbance	2.827	1.080–7.401	2.117

The additional predictor (River depth) shows that the 95% confidence interval excludes 0 (or 1 after back transformation). Thus, even though the addition of River depth as a predictor does not improve the AIC by more than 2, Hydrology was chosen as the best-fit model based on the confidence interval criteria.

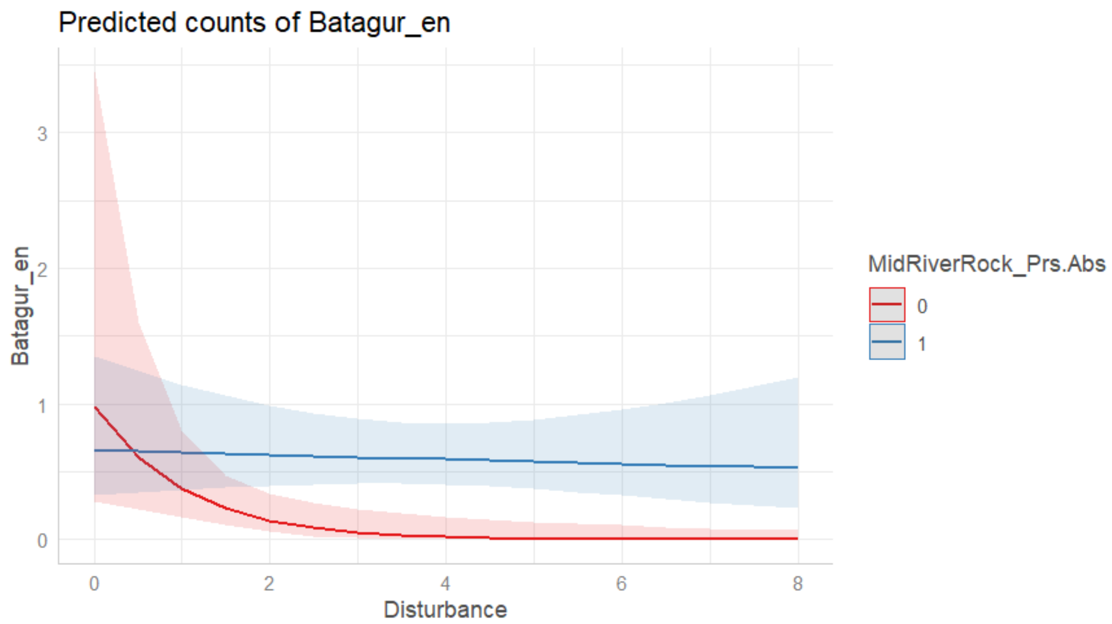

Figure 4: Predicted count of Batagur kachuga with interaction effect of Disturbance and mid river basking site

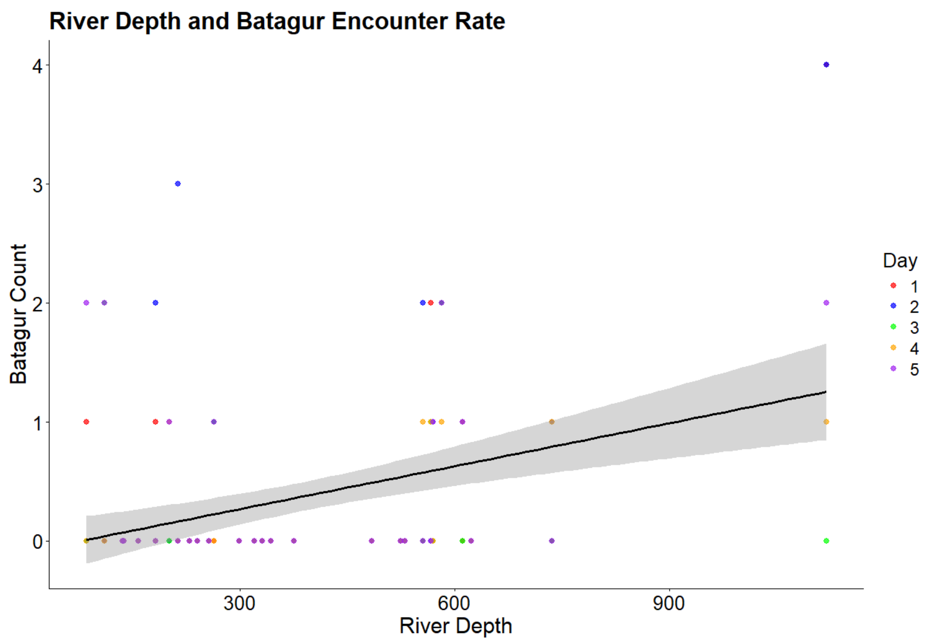

Figure 5: Plot of Batagur kachuga encounter rate with River Depth

According to the Hydrology model, *Batagur* encounter rate is weakly positively associated with River Depth, while *Batagur* encounter rate is strongly negatively associated with Disturbance, while positively associated with interaction effect of mid river basking site and Disturbance. Thus, in the absence of mid river basking sites, *Batagur* encounter rate falls in a steep fashion, while in the presence of mid river basking sites, the encounter rate remains more or less stable. Random intercept variance was 0.034 (SD = 0.186) for Day and 0.483 (SD = 0.695) for Segment. The model explained 61.5% of variation with fixed effects alone (Marginal $R2= 0.615$) while both fixed and random effect together explained 71.7% of variation (Conditional $R2=0.717$).

Pangshura tentoria **Macrohabitat Usage**

Table 3: Model Selection Table for Factors Affecting Pangshura tentoria Encounter Rate at Segment Scale

Model	**Predictor(s)**	**AICc**	**ΔAICc**	**Weight**
Rock	as.factor(Middle Rock) + % Rock	615.3	0.00	0.429
Hydrology	as.factor(Middle Rock) + % Rock + River Depth	616.3	1.01	0.259
Global	as.factor(Middle Rock) + Disturbance + % Rock + % Mud	617.4	2.05	0.154
Shore rock	% Rock	618.4	3.08	0.092
Mid rock	as.factor(Middle Rock)	620.8	5.48	0.028
Additive	as.factor(Middle Rock) + Disturbance	620.9	5.62	0.026
Interaction	as.factor(Middle Rock) × Disturbance	622.4	7.06	0.013
Disturbance	Disturbance	630.8	15.45	0.000
Null	Intercept only	831.5	216.20	0.000

According to the information theoretic approach, the top 2 models – Rock and Hydrology appear to be the best fir model with del AICc<2. The model Rock is nested within the model Hydrology with Middle Rock presence and % Rock being common predictors in both the models, while River Depth is an additional predictor in the model Hydrology.

Table 4: Model Summary Table for Hydrology (exponentiated co-efficients)- Pangshura tentoria

Predictor	Estimate	95% CI	Z value
Intercept	0.009	0.001–0.105	-3.724
Middle Rock presence	7.315	1.120–47.769	2.078
% Rock	1.137	1.038–1.245	2.761
River Depth	0.928	0.802–1.073	-1.013

The additional predictor (River depth) shows that the 95% confidence interval includes 0 (or 1 after exponentiating, as in this case). Thus, based on the confidence interval criteria of Arnold, 2010, the predictor River depth does not add any information into the model to justify its inclusion. Thus, Rock was chosen as the best-fit model based on the confidence interval criteria and parsimony.

Table 5: Model summary table for Pangshura tentoria encounter rate (exponentiated co-efficients)

Predictor	Estimate	95% CI	Z value
Intercept	0.004	0.0004–0.037	-4.849
Middle Rock presence	9.036	1.395–58.513	2.310
% Rock	1.115	1.028–1.209	2.633

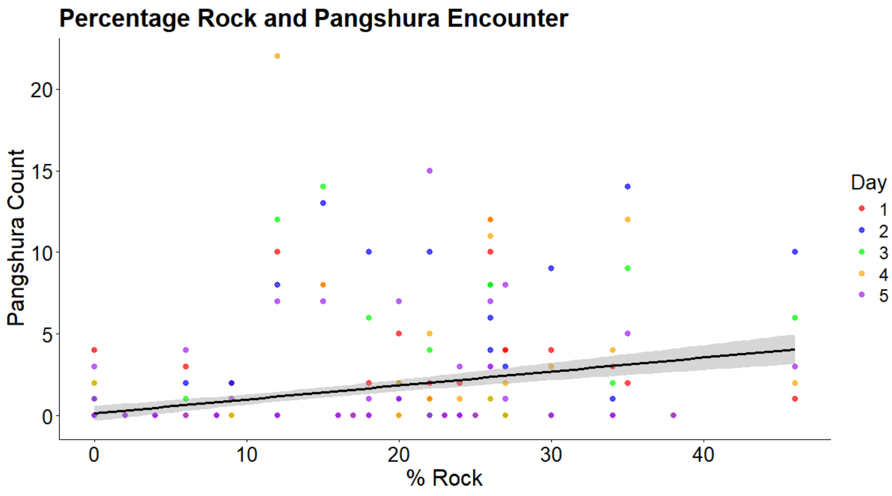

Figure 6: Plot of Pangshura tentoria Encounter Rate with Percentage Rock

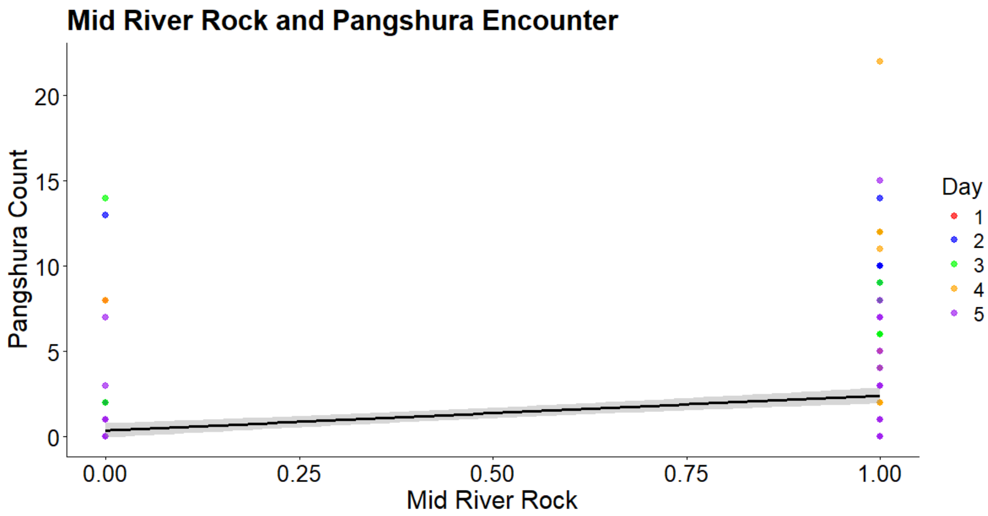

Figure 7: Plot of Pangshura tentoria Encounter Rate with Mid River Basking Site

According to the Rock model, *Pangshura* encounter rate is positively associated with % Rock and Presence of mid river rocks as basking sites. Random intercept variance was 7.879 (SD = 2.807) for Segment. The model explained 32.8% of variation with fixed effects alone (Marginal R^2= 0.328) while both fixed and random effect together explained 96.2% of variation (Conditional R^2=0.962).

Nilssonia gangetica Macrohabitat Usage

Table 6: Model Selection Table for Factors Affecting Nilssonia gangetica Encounter Rate at Segment Scale

Model	**Predictor(s)**	**AICc**	**ΔAICc**	**Weight**
Interaction	Disturbance × as.factor(Mid river basking sites)	365.6	0.00	0.772
Additive	Disturbance + as.factor(Mid river basking sites)	371.0	5.46	0.050
Disturbance	Disturbance	371.1	5.53	0.049
Mud	% Mud	371.7	6.15	0.036
Global	% Rock + % Sand + % Gravel + as.factor(Mid river basking sites) × Disturbance + River depth	372.4	6.79	0.026
Rock	% Rock	372.4	6.85	0.025
Gravel	% Gravel	373.8	8.26	0.012
Sand	% Sand	374.1	8.51	0.011
Mid-river basking	As.factor(Mid river basking sites)	374.3	8.76	0.010
Hydrology	River depth	374.4	8.83	0.009
Null	Intercept only	426.8	61.17	<0.001

According to the information theoretic approach, the best model to explain *Nilssonia* habitat use consists of an interactive effect between Disturbance and presence of mid river basking sites.

Table 7: Model Summary Table for Nilssonia gangetica Encounter Rate (Exponentiated Co-efficients)

Predictor	**Estimate**	**95% CI**	**Z value**
Intercept	4.137	0.942–18.173	1.880
Disturbance	0.386	0.217–0.687	-3.238
Mid river basking sites present	0.304	0.037–2.475	-1.113
Disturbance × Mid river basking sites	2.232	1.136–4.385	2.330

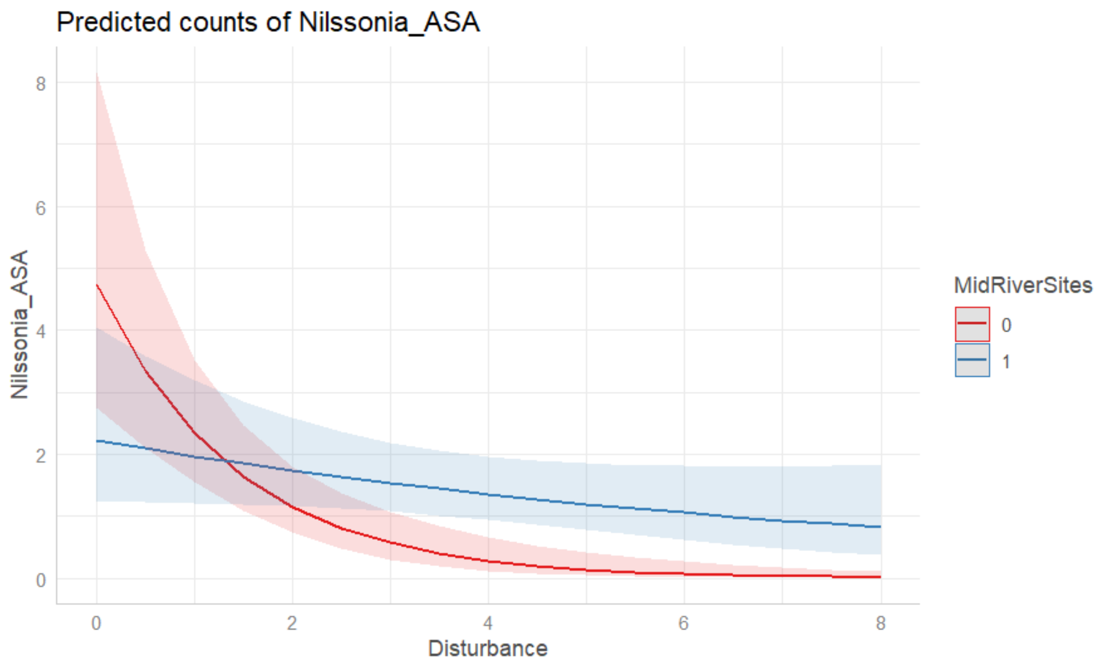

Figure 8: Predicted count of Nilssonia gangetica with interaction effect of Disturbance and Mid River Basking Site

According to the model, *Nilssonia* encounter rate is negatively associated with Disturbance while interaction effect of disturbance and presence of mid river rocks as basking sites has a positive effect. Random intercept variance was 1.42 (SD = 1.192) for Segment. Thus, in the absence of mid river basking sites, *Nilssonia* encounter rate declines sharply, while in the presence of mid river basking sites, the encounter rate remains more or less stable, even though the standard deviation for both the fitted lines seems to be very high. The model explained 33.8% of variation with fixed effects alone (Marginal R2= 0.338) while both fixed and random effect together explained 71.4% of variation (Conditional R2=0.714).

Microhabitat Variables Driving Basking Site Selection of *Nilssonia gangetica*

Table 8: Model Selection table for Nilssonia gangetica Microhabitat Selection

Model	Predictors	AICc	ΔAICc	Weight
m_rsf3	as.factor(Site) + as.factor(Substrate) + Distance	229.1	0.00	0.635
m_rsf4	as.factor(Site) + as.factor(Substrate) + Distance + Grass	231.2	2.01	0.233
m_rsf5	as.factor(Site) + as.factor(Substrate) + Distance + Grass + Depth profile	233.2	4.04	0.084
m_rsf1	as.factor(Site) + as.factor(Substrate) + Grass + Distance + Depth profile + Slope + Disturbance	234.6	5.43	0.042
m_rsf2	As.factor(Site) + as.factor(Substrate) + Grass	238.7	9.57	0.005

Based on the Model Selection Table, the m_rsf3 model was chosen to be the best model compared to the other models as per the information- theoretic approach.

Table 9: Model Summary Table for Nilssonia gangetica Microhabitat Selection

Predictor	Estimate	Std. Error	Z value
Intercept	1.4459	0.5260	2.749
Shore site	-3.8848	0.6537	-5.943
Mud substrate	0.6893	0.7367	0.936
Sand substrate	1.4076	0.7204	1.954
Distance	-0.0122	0.0048	-2.554

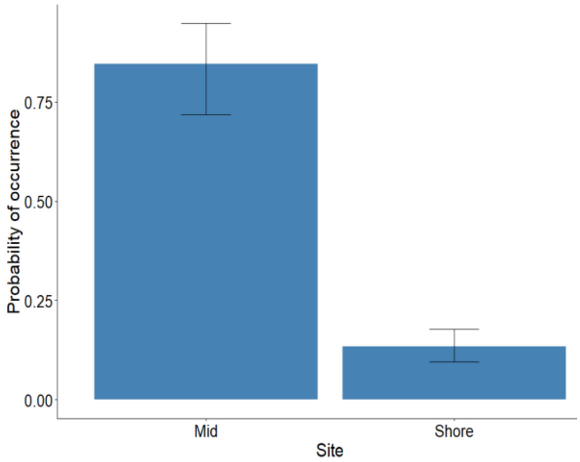

Figure 9: Nilssonia gangetica Microhabitat Selection with Site (Mid-River vs Shoreline)

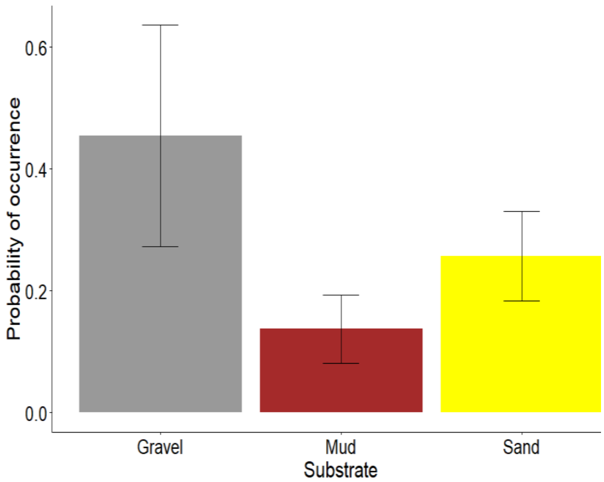

Figure 10: Nilssonia gangetica Microhabitat Selection with Substrate

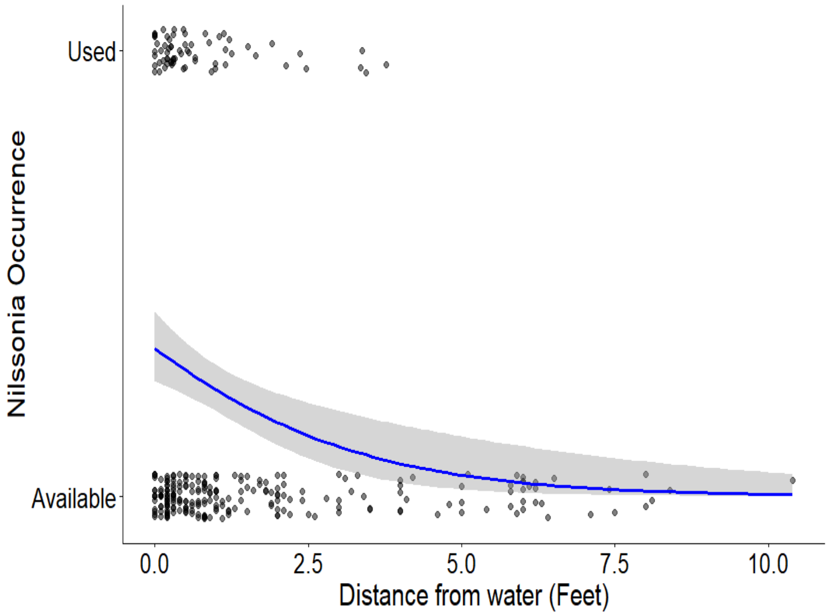

Figure 11: Plot of Nilssonia gangetica Occurrence with Distance from Waterline

The best fit model explains *Nilssonia* occurrence as a function of Site, Substrate and Distance from waterline. The probability of occurrence versus Site graph shows that the probability that a site will be utilized for basking by *Nilssonia* is very high if the site is a mid-river site as compared to the shoreline. The model summary also suggests strong selection of Mid river sites (or strong selection against Shoreline site). The probability of occurrence versus Substrate graph shows that probability of a site being occupied is highest for Gravel followed by Sand, followed by Mud. The model summary suggests Occurrence of *Nilssonia* is explained by Substrate. The Occurrence versus Distance from waterline suggests *Nilssonia* basking sites are usually close to water. The model summary also suggests strong negative correlation of Distance from water with *Nilssonia* Occurrence. The model explains 36.2% of variation (R2=0.362).

R E S U L T S (Sub-objective 1.2)

Effect of Disturbance and Mid-River Basking Site on *Batagur kachuga* Macrohabitat Usage

*Table 10: Disturbance*Mid River Basking Site Model for Batagur kachuga Encounter Rate*

Predictor	**Estimate**	**Standard Error**	**Z value**	***P* value**
Intercept	-0.1422	0.9967	-0.143	0.887
Disturbance	-1.1646	0.5409	-0.539	0.590
MidRiverRock Present	-0.6323	1.1738	-2.153	0.031
MidRiverRock Present × Disturbance	1.1288	0.5590	2.019	0.043

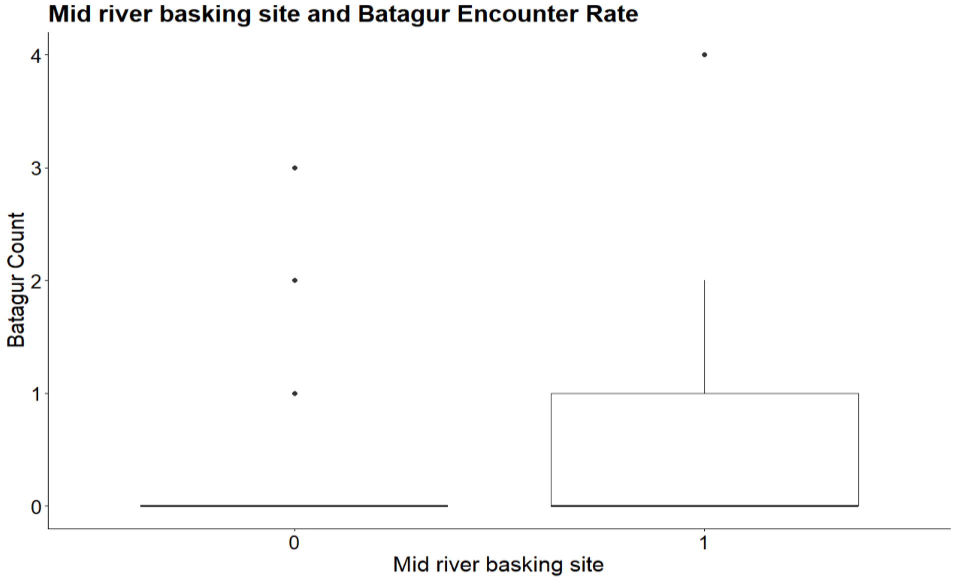

Figure 12: Plot of Batagur kachuga Encounter Rate with Mid River Basking Site

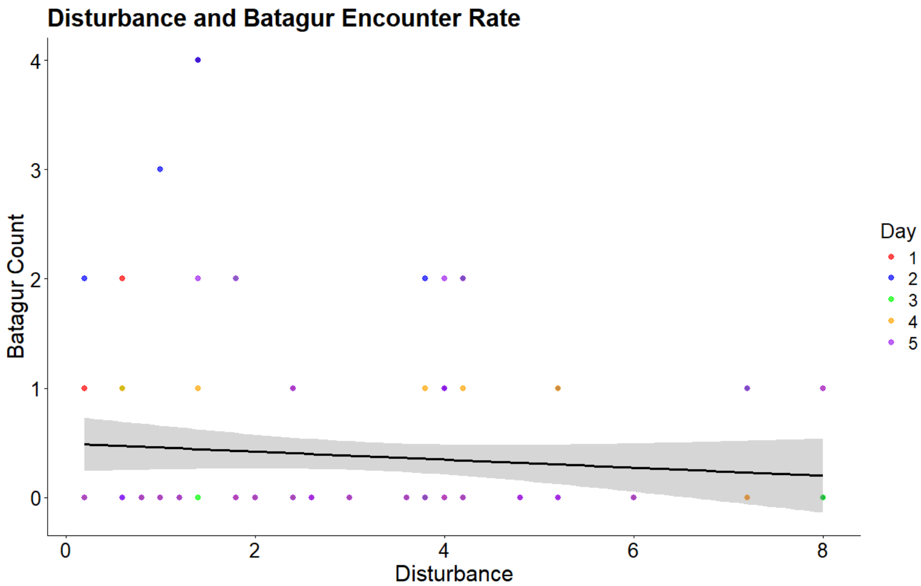

Figure 13: Plot of Batagur kachuga Encounter Rate with Disturbance

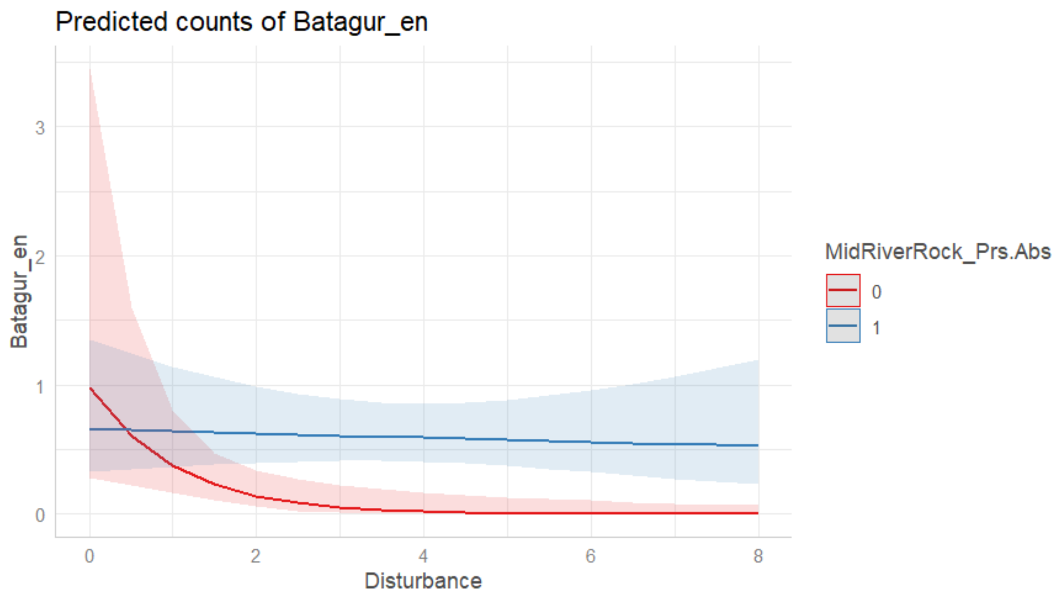

Figure 14: Predicted count of Batagur kachuga with interaction effect of Disturbance and Mid-River Basking Site

The Interactive model between Disturbance and presence of mid river basking site for *Batagur* encounter rates show that the *Batagur* encounter rate is significantly positively associated (p value=0.043) with the interaction effect and significantly negatively associated (p value= 0.031) with Disturbance. The *Batagur* count vs Mid River basking site plot shows that while due to a smaller number of observations, the mean *Batagur* count is close to 0 despite of presence or absence of Mid river basking sites. But in the presence of mid river basking sites, the interquartile range is between 0 and 1 while in the absence of such sites, the *Batagur* counts are absolutely 0, with a few outliers. The *Batagur* count vs Disturbance plot show *Batagur* count decreasing with increasing disturbance while the plot for the interaction term clearly shows that *Batagur* counts are higher under low disturbance irrespective of presence or absence of mid river basking sites, but as the disturbance increases, in the absence of mid river basking sites. *Batagur* encounter rates fall sharply, practically reaching 0 when disturbance value is >3 while in the presence of mid river basking sites, the encounter rate remains almost stable or show slight decline. The model summary also shows despite interaction effect having a positive estimate (1.1288), the estimate is still lower than the magnitude of negative effect (1.1646) due to Disturbance.

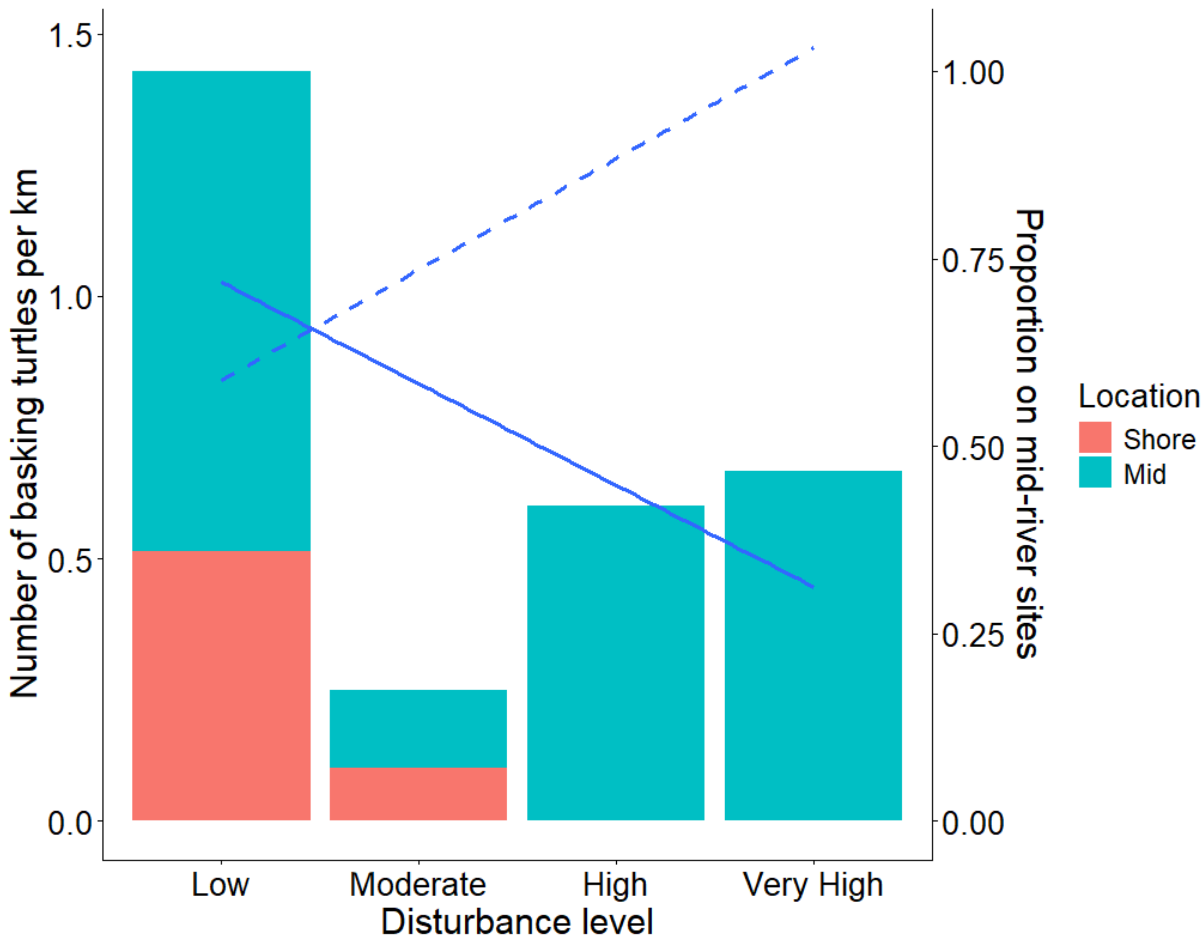

Figure 15: Plot of Number of Turtles and Proportion on Mid-River Sites Under Varying Disturbance Levels

The above plot shows that with increasing Disturbance level, total number of turtles basking per km goes down (solid line) while proportion of turtles basking on mid river islands increase (dashed line).

<u>Effect of Disturbance and Mid-River Basking Site on *Pangshura tentoria* Macrohabitat Usage</u>

*Table 11: Disturbance*Mid-River Basking Site Model for Pangshura tentoria Encounter Rate*

Predictor	**Estimate**	**Std. Error**	**Z value**	***P* value**
Intercept	-5.1062	1.6459	-3.102	0.00192
Disturbance	0.3165	0.9234	0.343	0.73180
Mid-river rock present	2.0211	1.9410	1.041	0.29773
Disturbance × Mid-river rock	0.9896	1.2553	0.788	0.43050

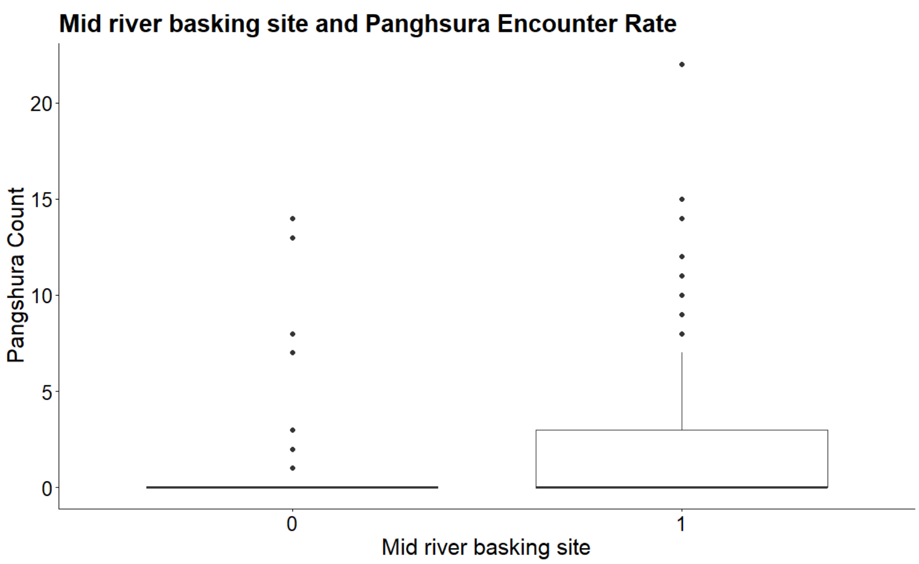

Figure 16: Plot of Panghsura tentoria Encounter Rate with Mid-River Basking Site

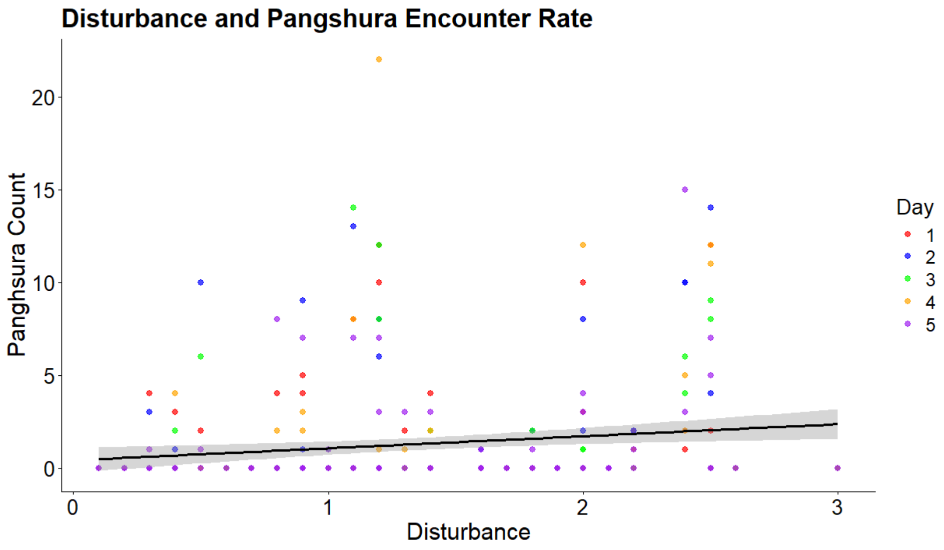

Figure 17: Plot of Pangshura tentoria Encounter Rate with Disturbance

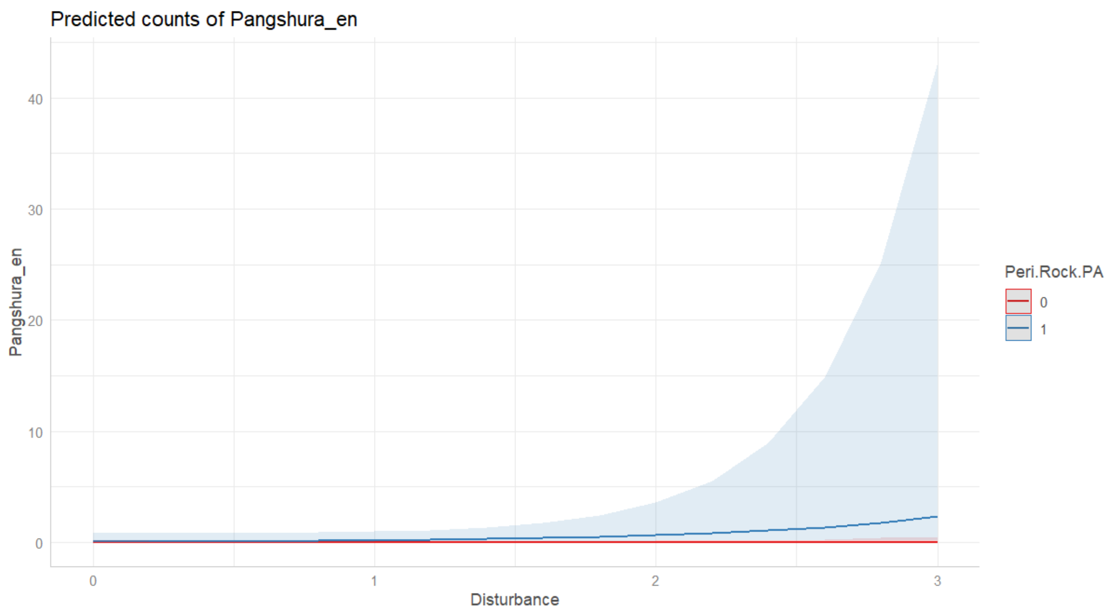

Figure 18: Predicted Count of Pangshura tentoria Encounter Rate with Interaction Effect of Disturbance and Mid-River Basking Site

The Interactive model between Disturbance and presence of mid river basking site for *Pangshura* encounter rates, show that there is no significant relationship between Disturbance (p value= 0.732), presence of mid river basking sites (p value= 0.298) and their interactive effect on *Pangshura* encounter rates (p value= 0.43). The *Pangshura* count vs Mid River basking site plot shows that the mean *Pangshura* count is close to 0 with the inter quartile range ranging between 0-5 in the presence of mid river basking sites, while in the absence of such site, most of the observations are 0 with a few outliers. But the presence of mid river basking site is not significantly associated with *Pangshura* count as seen from the model summary. The *Pangshura* count vs Disturbance plot show *Pangshura* count increasing with increasing disturbance though the effect is insignificant while the plot for the interaction term is inconclusive because of extremely high standard errors. As per the model summary as well, the interaction term has no significant effect on *Pangshura* encounter rate.

<u>Effect of Disturbance and Mid-River Basking Site on *Nilssonia gangetica* Macrohabitat Usage</u>

*Table 12: Disturbance*Mid-River Basking Site Model for Nilssonia gangetica Encounter Rate*

Predictor	Estimate	Std. Error	Z value	*P* value
Intercept	1.4199	0.7551	1.880	0.0601
Disturbance	-0.9524	0.2941	-3.238	0.0012
Mid river basking site present	-1.1902	1.0697	-1.113	0.2658
Disturbance × Mid river basking site	0.8029	0.3446	2.330	0.0198

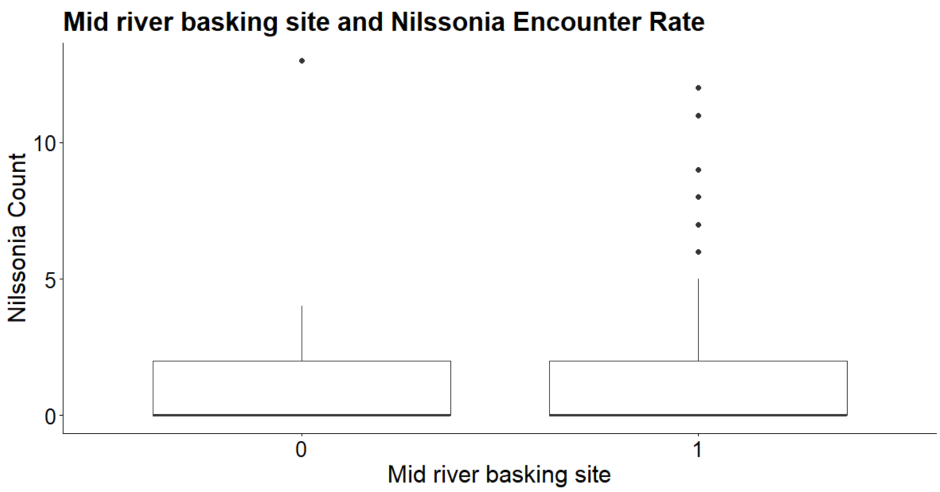

Figure 19: Plot of Nilssonia gangetica Encounter Rate with Mid-River Basking Site

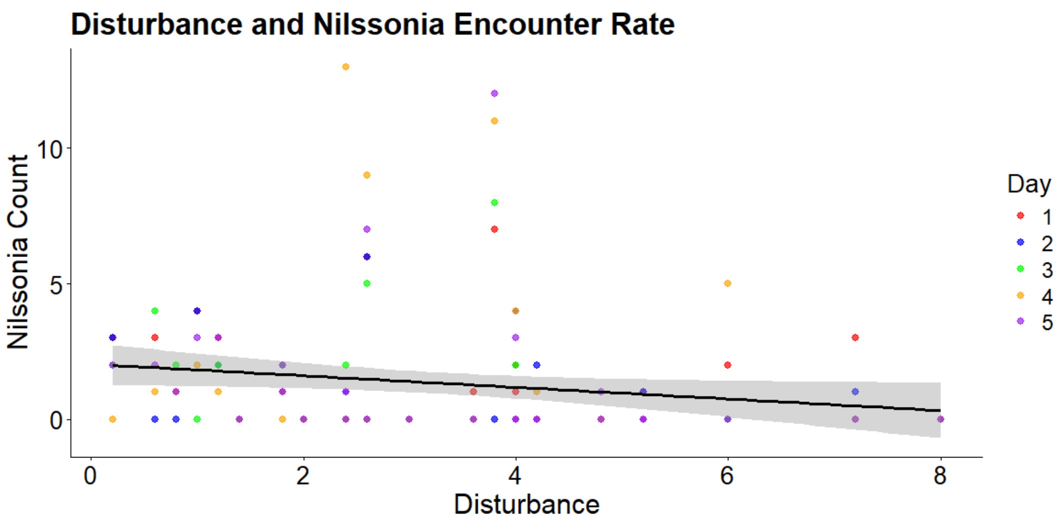

Figure 20: Plot of Nilssonia gangetica Encounter Rate with Disturbance

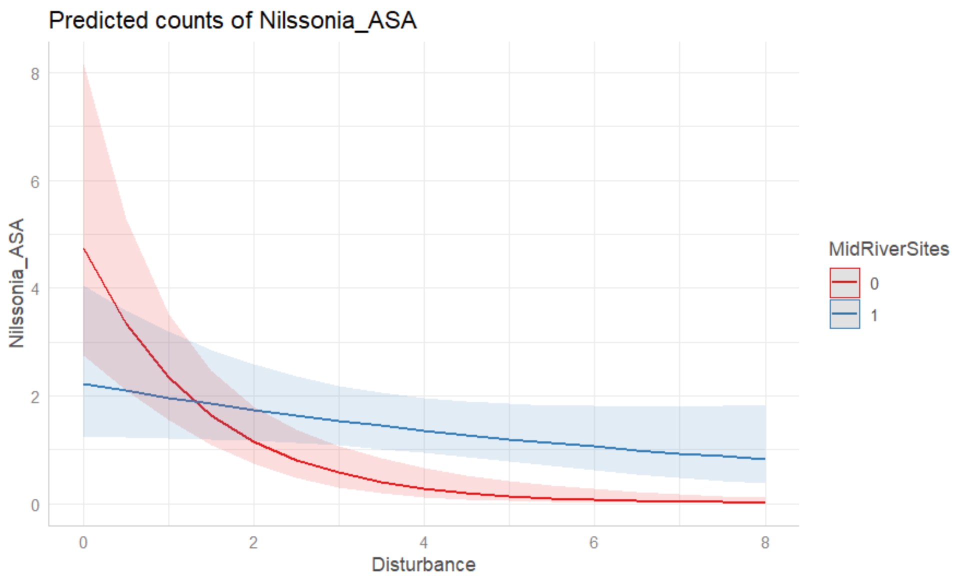

*Figure 21: Predicted Count of Nilssonia gangetica with Interaction Term of Disturbance*Mid-River Basking Site*

The Interactive model between Disturbance and presence of mid river basking site for *Nilssonia* encounter rates, show that there is a significant negative effect of Disturbance (p value= 0.0012) and significant positive effect of interaction factor (p value=0.0198). The *Nilssonia* count vs Mid River basking site plot shows the mean *Nilssonia* count and inter quartile range I similar between segments with mid river basking sites and without such sites. But the presence of mid river basking site is not significantly associated with *Nilssonia* count as seen from the model summary. The *Nilssonia* count vs Disturbance plot shows negative trend while the plot for the interaction term shows that *Nilssonia* numbers are high under low disturbance irrespective of the presence of mid river basking sites. As the disturbance increases, *Nilssonia* numbers are seen to go down in both cases (presence and absence of mid river basking sites). But the dip in Turtle numbers is steeper during the absence of mid river basking sites while if such sites are present, the decline is much gentler. The model summary also shows despite interaction effect having a positive estimate, the estimate (0.8029) is still lower than the magnitude of negative effect (0.9524) due to Disturbance.

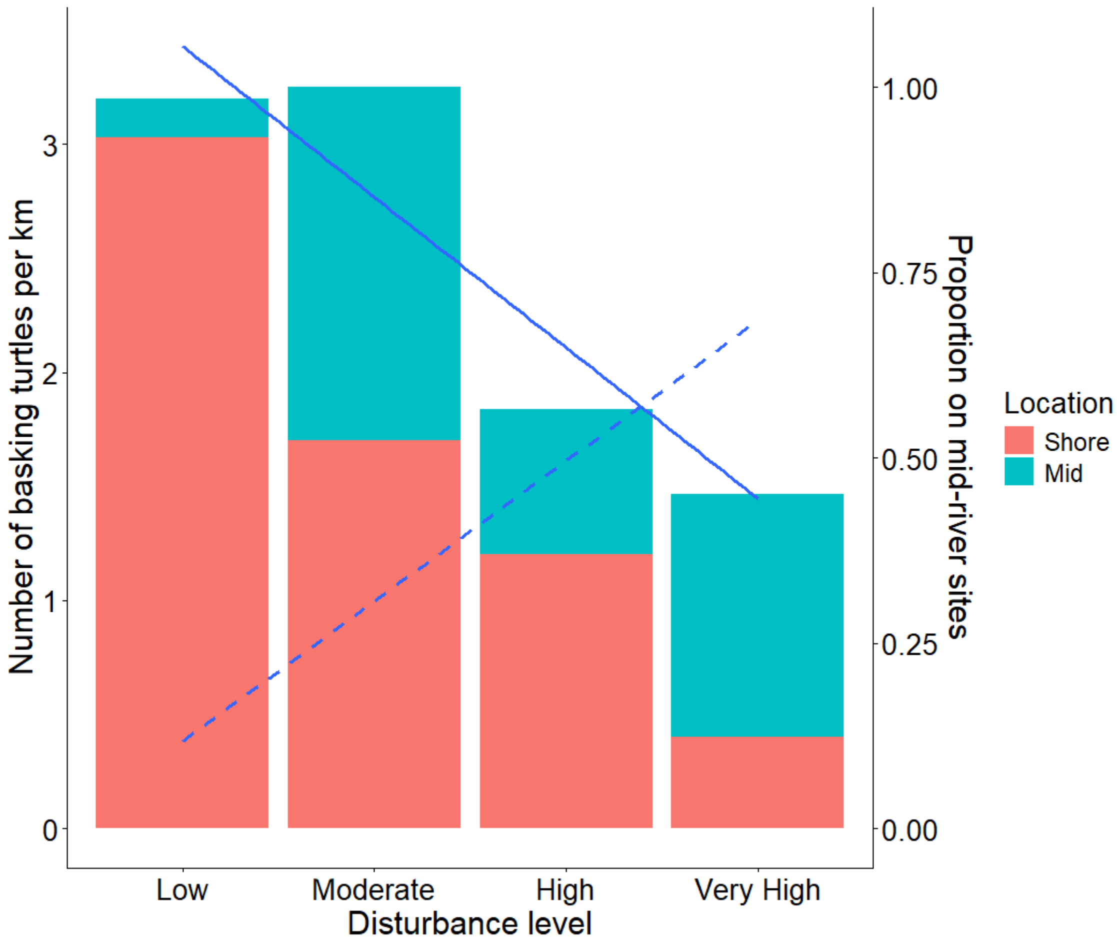

Figure 22: Number and Proportion of Turtles Basking on Mid-River Sites Under Varying Levels of Disturbance

The above plotted graph shows that with increasing Disturbance, the number of basking turtles per km decrease (solid line) while proportion of turtles basking on mid river sites increase (dashed line)

DISCUSSION

The result of the site selection component of the study show that basking habitat usage is governed by Macrohabitat factors, microhabitat factors and Disturbance. But the effect and magnitude are not constant from species to species. It has been seen that response to disturbance might vary between the taxa (Irwin et al., 2010) and a similar trend is observed in turtles of Chambal, based on these results. For *Batagur kachuga*, the best supported model to explain Encounter rate at macrohabitat scale consisted of Water Depth and Interaction term for Disturbance and Mid river basking site. Even though our knowledge of depth preferences for Indian turtle species is almost non-existent, *Batagur kachuga* is known to prefer depths of 3-5 metres (WII, 2025). Furthermore Hussain, 2009 states that Gavialis gangeticus at Chambal River might prefer deeper water sections, as it serves as a refugia to which the animal can easily retreat to in the presence of a disturbance. *Batagur affinis* have been seen to prefer water depth of 3metres (Yusofa et al., 2018), thus water depth is known to be an important predictor in the habitat suitability index for the *Batagur* genus. The maximum number of *Batagur* observations were made in 2 segments with river depth varying between (12-15 metres) with the presence of mid river basking sites. *Batagur* encounter rates were negatively correlated with disturbance and positively correlated with interaction effect of Disturbance and mid river basking sites. Both Hussain, 2009 and Chowdhury et al., 2017 found the model to best explain Gharial encounter rates to be presence of sandbars/mid channel basking/nesting sites, this might be an artifact of higher detections due to crowding on sandbars (Chowdhury et al., 2017) or because animals particularly choose to utilize segments where resources such as mid channel basking sites are available (Hussain, 2009). The same pattern has been observed for *Batagur kachuga* as well.

Pangshura tentoria encounter rate was determined by % Rock on shoreline and presence of mid river rocks, with encounter rates increasing with both the predictors, thus for *Pangshura*, availability of rocky basking substrates explained *Pangshura* encounter rates. Out of 441 sightings, *Pangshura* was observed to bask on rock 435 times.

The model for *Nilssonia* encounter rate mirrored the model for *Batagur* encounter rate, whereby the best fit model to explain *Nilssonia* encounter rate was found to be interactive effect of Disturbance and mid river basking site. The model was negatively correlated with Disturbance (Subba et al., 2026) but positively correlated with interaction effect. In the micro scale, *Nilssonia* occurrence was explained by Site type, Substrate and Distance from waterline. In the micro-scale, *Nilssonia* seemed to select mid river basking sites more than shoreline sites. This strengthens the *Nilssonia* encounter rate model, for it is not only that *Nilssonia* numbers are higher in the presence of mid river basking sites, the micro scale model also implies that *Nilssonia* use mid river basking sites more for basking. This might be due to thermal properties of the site (Meek & Luiselli, 2023) or due to disturbed shoreline (Gill et al., 2001). *Nilssonia* was observed to use gravel and sand more than mud, probably due to substrate driven thermoregulatory efficiency as coarser, better draining substrates heat more predictably (Meek and Luiselli, 2022) while *Nilssonia* occurrence was negatively influenced with distance from waterline. Hussain, 2009 hypothesized that gharials prefer to bask close to the waterline to ensure quick retreat in case of any disturbance. For *Nilssonia*, quick retreat could be considered a reason for selecting to bask close to the waterline, though it might also be due to physiological limitations to the movement of a softshell on land.

For Hypothesis 1a and 1b, *Nilssonia* and *Batagur* showed avoidance to disturbance at segment level/macro scale, though the presence of mid river basking sites seemed to buffer the impact. The plots for the model for both the species followed a similar pattern, whereby encounter rates are high under low disturbance and keeps on decreasing as disturbance increases. This decrease was found to be much steeper in the absence of mid river basking sites, while if such sites were present, the decrease was much gentler, for both the species. Since no studies exist on turtles and impact of mid river basking sites on turtle basking, the closest comparative that can be drawn is to Chowdhury et al., 2017 where they found that Gharials can tolerate moderate amount of disturbance if sandbars are present. But this is to be mentioned, even though the presence of mid river basking sites seems to buffer the effect of disturbance, it cannot completely remove the negative effect due to disturbance (estimate size of Disturbance $_{Batagur}$= -1.16, Interaction $_{Batagur}$= 1.13, Disturbance $_{Nilssonia}$= -0.95, Interaction $_{Nilssonia}$ = 0.80). Thus, both *Nilssonia* and *Batagur* responded to disturbance by avoidance of disturbed segments while mid river basking sites buffered the effect. Even though this particular aspect has been hypothesized in a few studies, particularly for crocodilians, no such literature exists for hardshell or softshell turtles.

Pangshura encounter rate was found to be not significantly affected by disturbance or interaction effect of disturbance and mid-river basking sites. Thus, *Pangshura* do not respond to disturbance by avoiding disturbed segments. This is in line with Jani et al., 2008 that suggests *Pangshura tentoria tentoria*'s habitat usage for basking was least affected by disturbance. This does not necessarily mean that they are tolerant to disturbance, rather they might respond to disturbance in some different ways. Amo et al., 2006 found the body condition of lizards in highly disturbed areas to be worse than lower disturbed areas as they were not responding to disturbance by increasing FID, resulting in frequent retreats and lower basking duration. Thus, animals need to employ different strategies to avoid negative effect of disturbance. The reason *Pangshura* is not avoiding disturbed stretches may also be due to substrate selection. As already mentioned, *Pangshura* in the landscape were almost exclusively seen basking on rocks, which constitute only 93 of the 546 availability points quantified. Since the best fit encounter rate model had the predictors – percentage rock and mid river rocks, there is a possibility that substrate selection (Peterman & Ryan, T.J., 2009) is overpowering the avoidance towards disturbance response in case of *Pangshura*.

OBJECTIVE 2

STUDY AREA

3 sites were selected within the study area, for behavioural observations.

Site 1 – Dominated by Rocky basking structures. This site is just adjacent to the tourism area of Chambal, and thus disturbance is very high on the weekends. The major disturbances present in the area are Human presence and cattle presence. While on the weekends, both these disturbances are present almost throughout the day, during the weekdays, disturbance due to livestock is the major disturbance while disturbance due to humans is largely reduced. Thus, the degree of disturbance during weekends is very high compared to the weekdays. The site harbours rocky basking substrates both along the shore and away from the shore (mid river basking sites) and has a very high density of *Pangshura*, *Nilssonia* and *Lissemys* basking.

Site 2- Sandbank as well as sandbar present. Very high disturbance on the shoreline due to intense sand mining throughout the day. On the 5^{th} of April, due to a court ruling by the Hon'ble Supreme Court of India, sand mining came to a standstill, thus the shoreline remained undisturbed for the most part, except of occasional human or livestock disturbance. Large number of Adult *Nilssonia gangetica*s are known to bask here.

Site 3- Similar structure and disturbance level as Site 2, but without the presence of any sandbar or other alternate basking structures in the vicinity. A large number of *Nilssonia gangetica*s were seen to regularly bask here and like site 2, disturbance at the shoreline became almost non-existent after the ruling of Hon'ble Supreme Court of India.

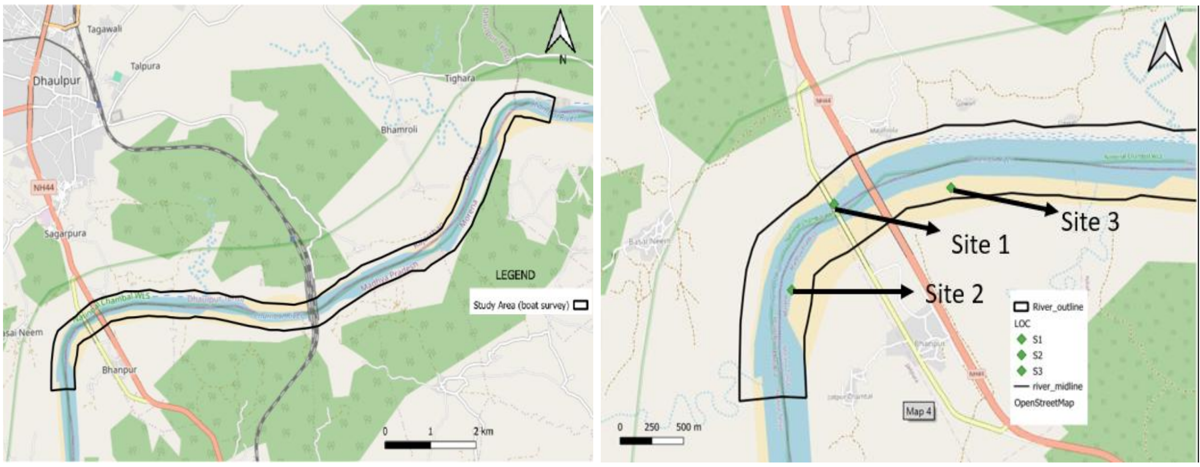

Figure 23: Sites for Behavioural Observations within my Study Area

Image 14: Site 1

Image 15: Site 2

Image 16: Site 3

<u>**FIELD METHODS**</u>

Focal observations were done from 6AM in the morning till 6PM in the evening under clear weather days. Observations on Site 1 were made by standing on a bridge about 50feet high over the basking patch, to ensure that disturbance due to observer is absent. During the reconnaissance, it was seen that *Nilssonia* individuals could be individually identified based on head markings which were possible to photograph when observed from the bridge. Observations were made on 6 weekdays (low disturbance) and 6 weekends (high disturbance). Whenever a *Nilssonia* emerged to bask and retreated from basking, it was recorded along with photo of the individual for individual identification. To ensure emergence and retreat events were not missed, scans were also conducted at every 5-minute intervals. In case an unrecorded emergence or retreat event was recognized, that was attributed to the starting time of the scan. If the turtle was basking on the shore or away from the shore was also recorded. 7 individuals of *Nilssonia* were identified out of which 2 were juveniles. N6 and N7 were the largest turtles to bask in Site 1 regularly. Basking attempts (if made) were also recorded along with individual ID and category of basking site (Shore or mid river). Aggressive interactions were also recorded with ID of aggressor (in case of *Nilssonia*, while in case of *Pangshura*, only species was recorded) and recipient and the outcome of aggressive interaction.

Image 17: N1 (Juvenile)

Image 18: N2 Juvenile

Image 19: N3

Image 20: N4

Image 21: N5

Image 22: N6

Image 23: N7

In Site 2 and Site 3, continuous behavioural observations were made from 6AM in the morning to 6PM in the evening for 10 days on each site- 5 days during high disturbance (before the court ruling) and 5 days during low disturbance (after the court ruling to stop all illegal mining activities). Observations were made from the opposite bank (~250m from the basking site) to prevent any disturbance due to the observer. Individuals could not be identified from this distance, thus basking bouts were calculated (Moore & Seigel, 2006). Emergence and retreat time of each basking event was recorded and a notebook was used to keep track of individuals if they were seen to change positions while basking, to ensure emergence and retreat times of each basking incidence were accurate. For Site 2, if a basking incidence is taking place on bank or mid channel basking site was also recorded. Site 3 lacked any mid channel basking sites. Number of aggressive interactions every hour was recorded on site 2 along with number of turtles basking on sandbar (Since no aggressive interactions were observed on shoreline of site 2 and 3).

ANALYTICAL METHODS

Sub-objective 2.1: Based on emergence and retreat timing, the basking duration of a bout was calculated. If individual identification was possible (Site 1), based on the photographs taken, these basking bouts were attributed to different individuals. After checking the normality of the data, Paired t test/Wilcoxon signed rank test was performed in R software to see if there is any significant difference in total basking duration between highly disturbed and lesser disturbed days. Time spent basking on shoreline and Time spent on basking on mid channel basking sites were separated for each individual. Based on normality of the data, Paired t test/Wilcoxon signed rank test was performed to check for any significant difference in proportion of mid river basking site usage between highly disturbed and lesser disturbed days. If individual ID was not possible (Site 2 and 3) Basking bouts were calculated under high disturbance and low disturbance and based on normality of the data, unpaired t test/ Wilcoxon rank sum test was performed to see if there is any significant difference between basking bouts under high disturbance and low disturbance. Basking bouts were calculated on bank and mid river basking site under high disturbance and low disturbance and based on normality of the data, unpaired t test/ Wilcoxon rank sum test was performed to see if there is any significant difference between basking bouts on mid river basking sites and shore under high disturbance and low disturbance.

Sub-objective 2.2: Data of total duration of basking of each *Nilssonia* individual in Site 1, and proportion of basking duration on mid river sites to shoreline for each individual were separated for weekdays and weekends. Wilcoxon rank-sum test was performed for each individual to check for any significant changes between weekday and weekend.

Sub-objective 2.3: Visual representation of aggressive interactions at Site 1

Spearman correlation test performed to check for correlation between number of aggressive interactions in an hour and number of turtles basking on sandbar at site 2.

RESULTS (sub-objective 1)

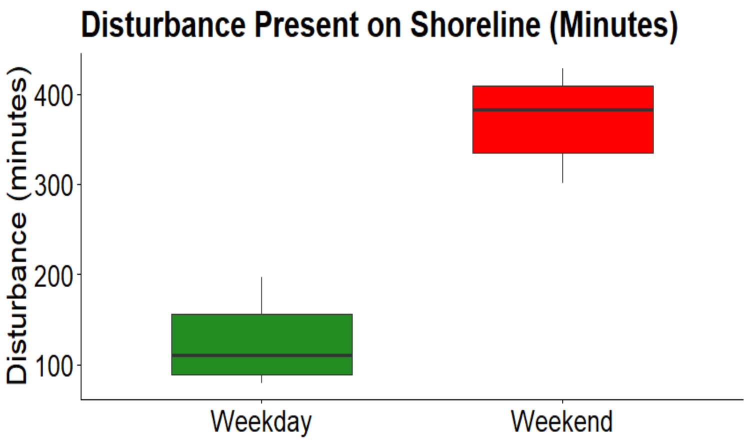

Figure 24: Duration of Disturbance at Shore

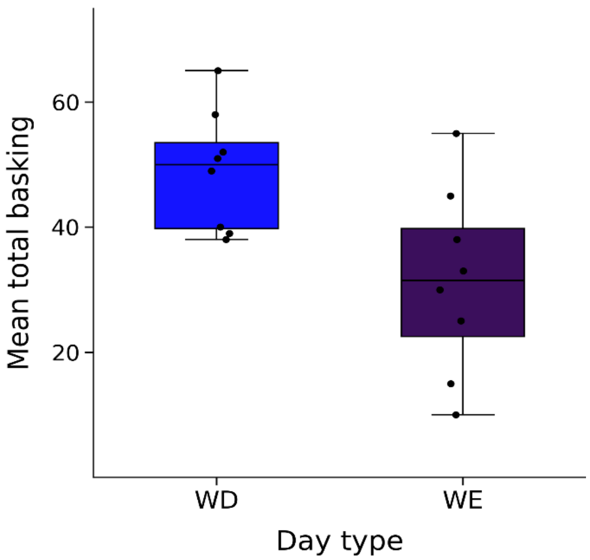

Figure 25: Plot of Mean Total Basking on Weekday vs Weekend

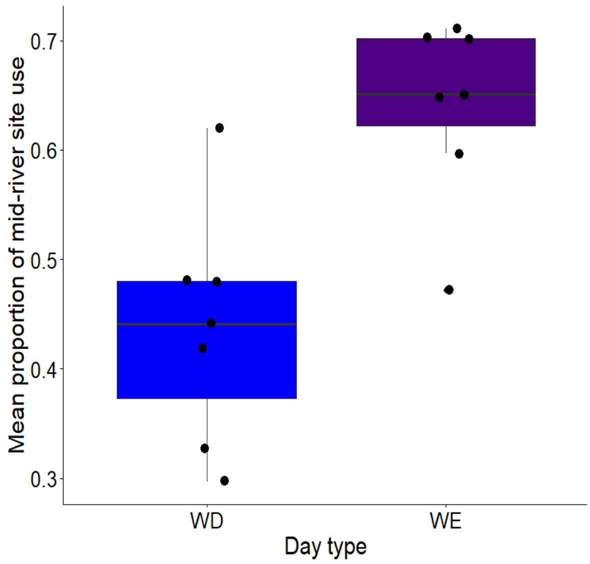

Figure 26: Proportion of basking on mid river sites on Weekday vs Weekend

Disturbance is around thrice on the weekends as compared to the weekdays.

There is a significant decrease in the amount of time spent in basking on weekends compared to the weekdays for the individually identified turtles (t= -3.9185, p value=0.008) in site 1. The mean difference between time spent in basking during weekend vs weekdays was -17.93 minutes (95% CI= -29.12mins to -6.73mins).

There was a significant increase in the proportion of time spent basking on Mid river basking sites by the *Nilssonia* individuals (t=3.3841, p value=0.0148) in site 1 on weekends compared to the weekdays. The mean difference between proportion of time spent basking on mid river sites were 0.203 or +20.3% (95% CI= 5.61% - 34.91%).

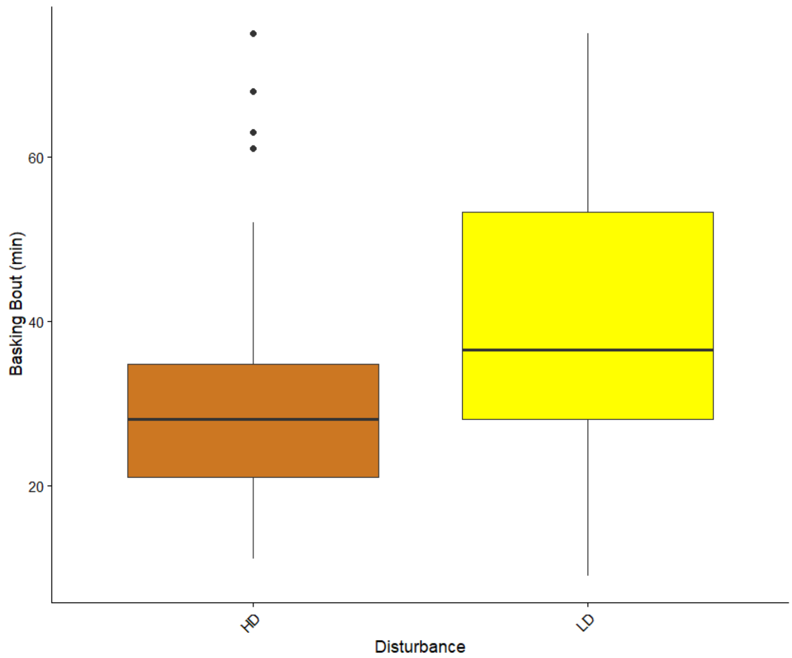

Figure 27: Basking Bout at Site 3 (without sandbar) Before and After Stopping of Sand Mining

There is a significant decrease in the amount of time spent in each basking bout during HD or high disturbance (before the crackdown on sand mining) compared to the LD or Low disturbance days (after the crackdown on sand mafias) for the basking turtles (W= 6424, p value=1.465e-08) in site 3. The estimated basking duration during sand mining was approximately 9 minutes lower than after removal of the disturbance (95% CI= -13 mins to -6 mins).

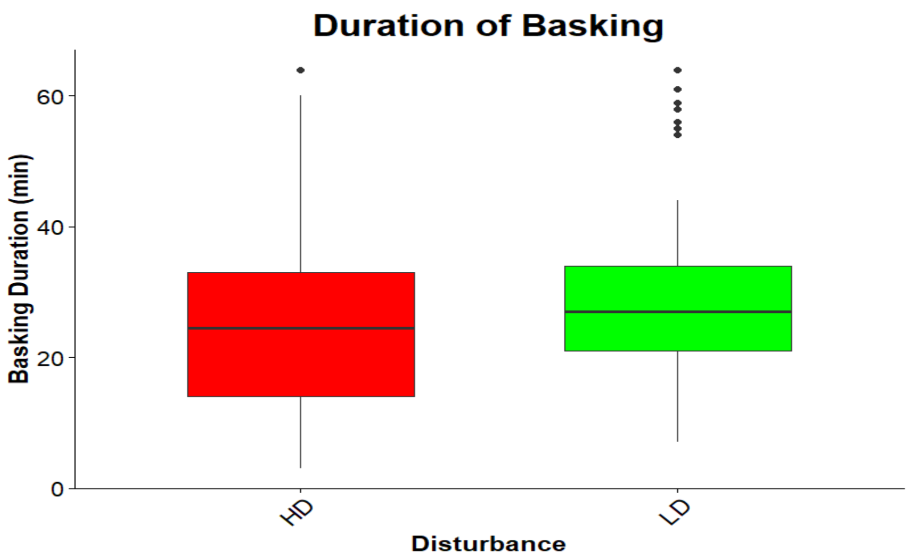

Figure 28: Basking Bout at Site 2 (with sandbar) Before and After Stopping of Sand Mining

There is a significant difference in the basking bouts at Site 2 under High disturbance and Low disturbance (W=8290.5, P value= 0.005). The estimated basking bout during low disturbance was 4 mins higher than high disturbance (95% CI= -7mins to -1min).

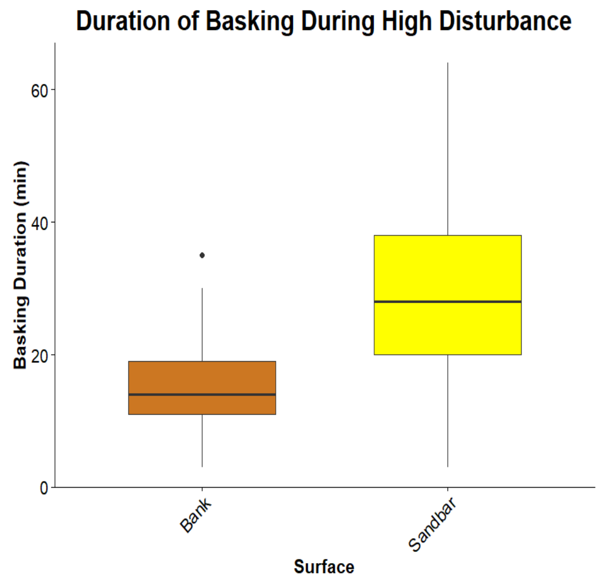

Figure 29: Duration of Basking During High Disturbance on Bank vs Sandbar

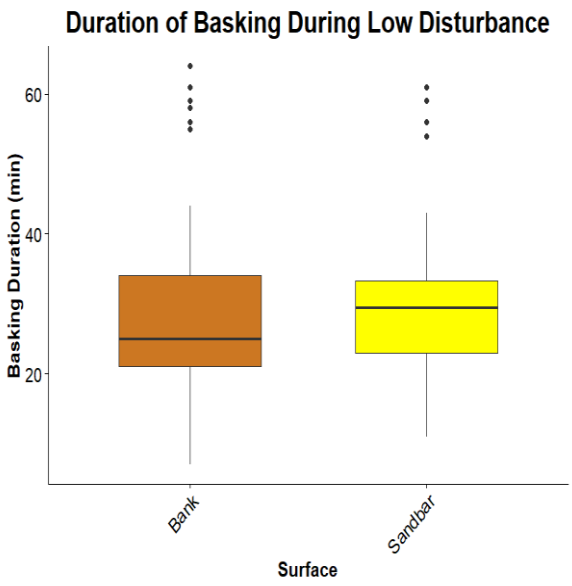

Figure 30: Duration of Basking During Low Disturbance on Bank vs Sandbar

The duration of basking bouts is significantly higher (W=928, p value=1.754e-10) on sandbars as compared to sandbank on Site 2 under High disturbance (before crackdown on sand miners). The basking duration on sandbar was estimated to be 14mins higher (95% CI= (+18mins to +10mins). While during low disturbance (after the crackdown on sand mafias) there was no significant difference between the basking bouts on sandbars and sandbanks (W=1868, p value=0.1457).

R E S U L T S (Sub-Objective 2.2)

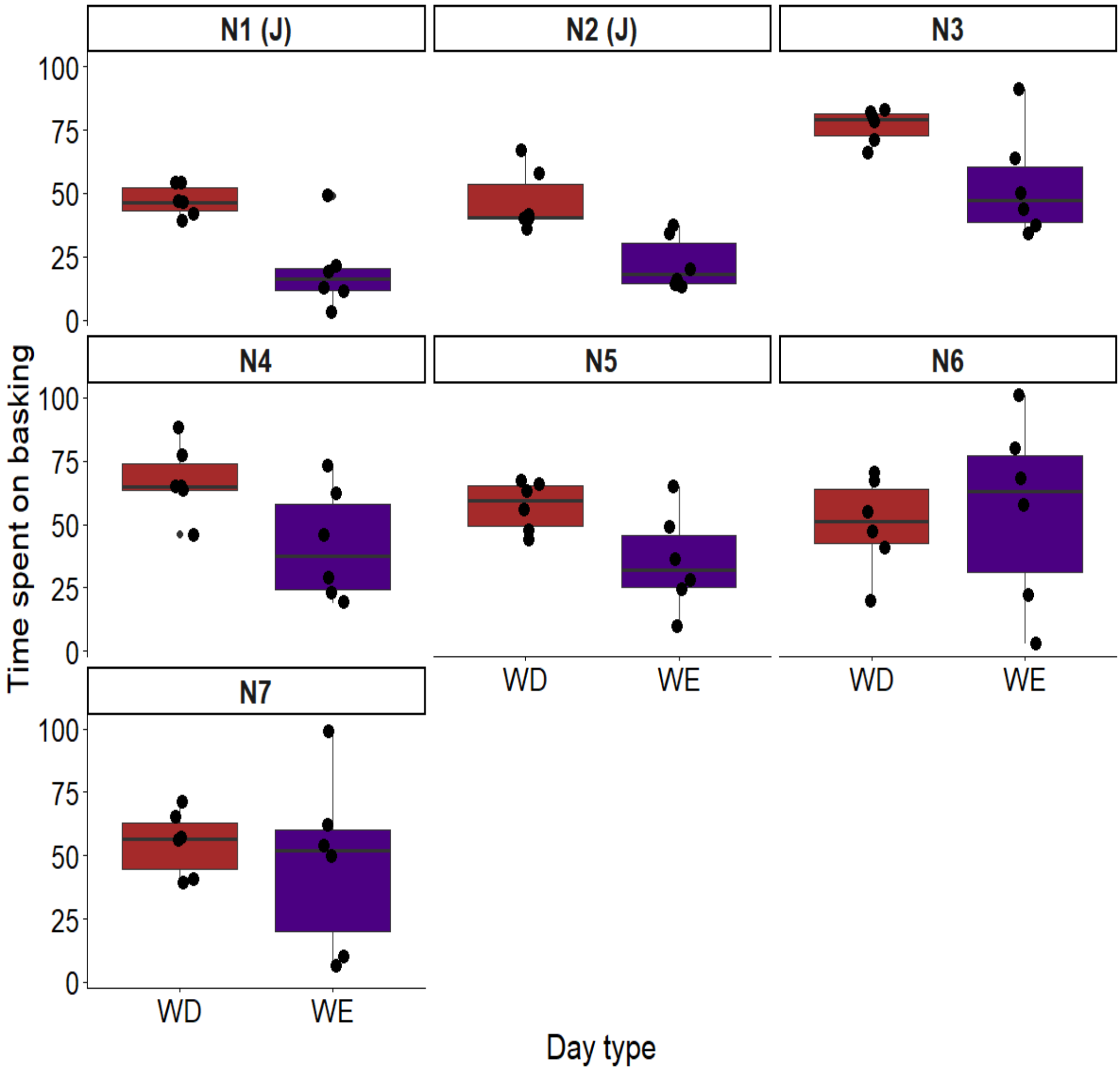

Figure 31: Time Spent on Basking at Individual Level Weekday vs Weekend

For N1 there is a significant decrease ($p=0.006$) in basking duration on weekends compared to weekdays. The mean basking duration is 27.7minutes lower on weekend.

For N2 there is a significant decrease ($p=0.004$) in basking duration on weekends compared to weekdays. The mean basking duration is 24.7minutes lower on weekend.

For N3 there is a significant decrease ($p=0.043$) in basking duration on weekends compared to weekdays. The mean basking duration is 23.3minutes lower on weekend.

For N4 there is a significant decrease ($p=0.044$) in basking duration on weekends compared to weekdays. The mean basking duration is 25.3minutes lower on weekend.

For N5 there is a significant decrease ($p=0.042$) in basking duration on weekends compared to weekdays. The mean basking duration is 21.8minutes lower on weekend.

For N6 (p value=0.76) and N7 (p value=0.62) there is no significant change in the basking duration on weekend and weekdays.

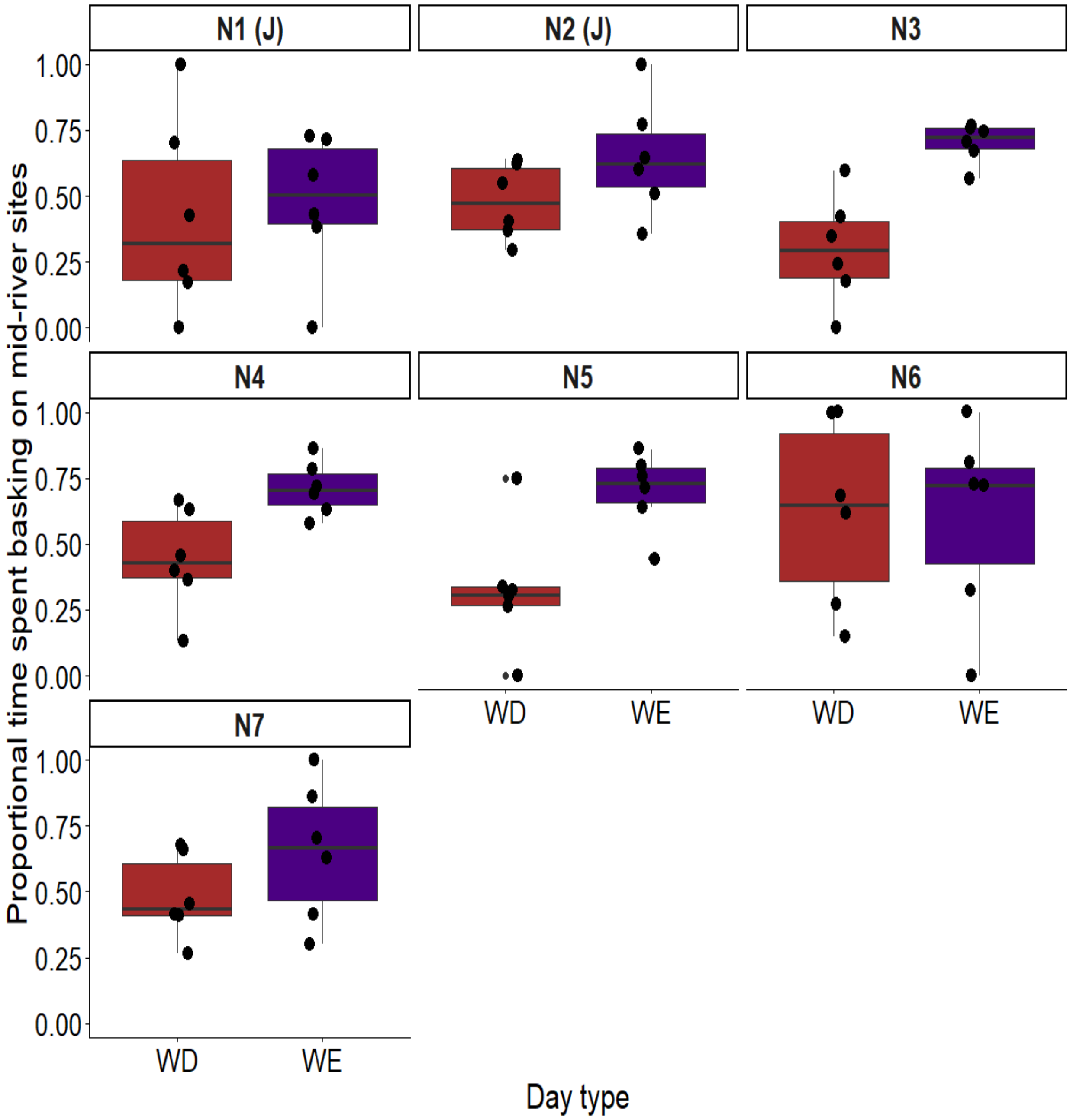

Figure 32: Proportion of Time Spent in Basking on Mid-River Sites at Individual Level Weekday vs Weekend

For N1 (p value= 0.63), N2 (p value=0.23), N6 (P value=0.94) and N7 (P value=0.3) there is no significant change in proportion of basking duration on mid channel basking sites to shoreline on weekends compared to weekdays.

For N3 there is a significant increase (p=0.008) in proportion of basking duration on mid channel basking sites to shoreline on weekends compared to weekdays. The mean proportional basking duration on mid channel basking sites is increased by 40.5% on weekend.

For N4 there is a significant increase (p=0.031) in proportion of basking duration on mid channel basking sites to shoreline on weekends compared to weekdays. The mean proportional basking duration on mid channel basking sites is increased by 27% on weekend.

For N5 there is a significant increase (p=0.025) in proportion of basking duration on mid channel basking sites to shoreline on weekends compared to weekdays. The mean proportional basking duration on mid channel basking sites is increased by 37.4% on weekend.

R E S U L T S (Sub-objective 2.3)

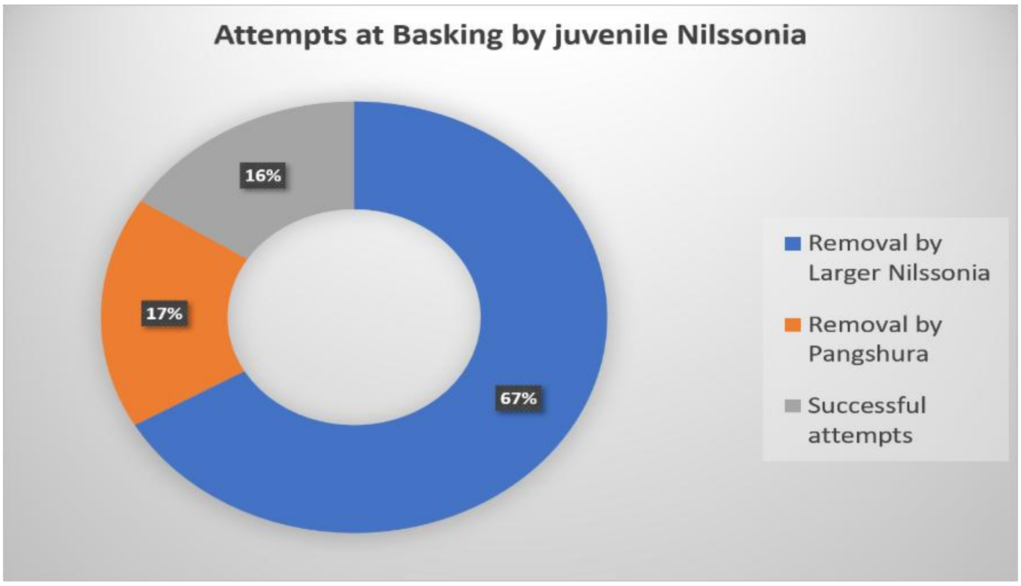

Figure 33: Visual Representation of Basking Attempts and Outcomes of Juvenile Nilssonia gangetica on Mid-River Sites

Out of 70 observations of Juvenile *Panghsura* attempting to bask on mid channel basking sites, on 47 occasions Larger *Nilssonia* individuals got into direct conflict with them and removed the juvenile ones, on 12 occasions they were removed by *Pangshura* while only on 11 occasions they were able to successfully bask on mid channel basking sites.

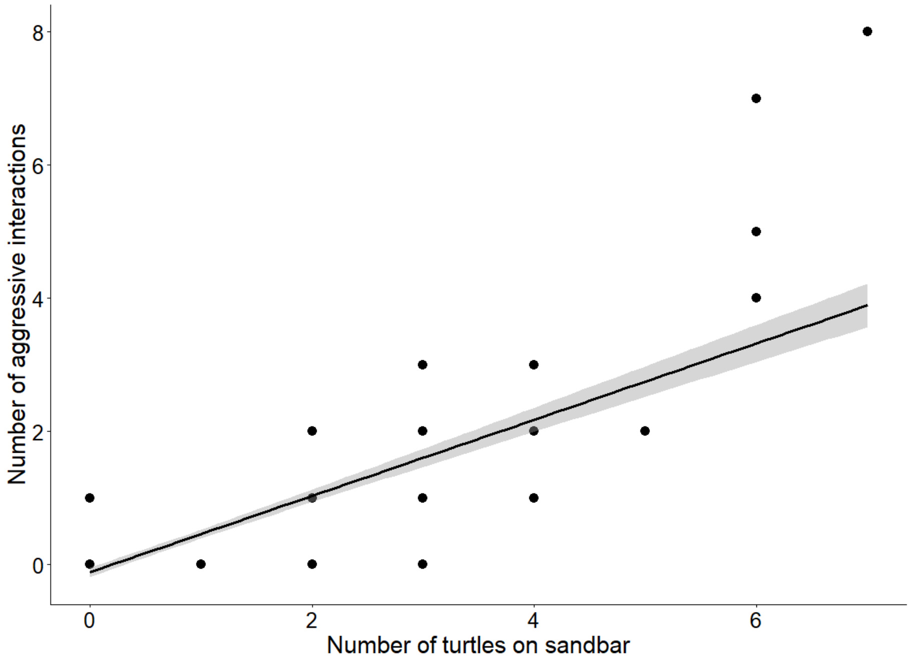

Figure 34: Plot of Number of Aggressive Interactions with Crowding on Sandbar

On site 2, it was seen that number of aggressive interactions were positively correlated (rho=0.645) with crowding (number of basking turtles) on sandbars with a significant effect (p value= 2.2e-16).

DISCUSSION

The behavioural part of the thesis, combined together with the site selection part aims to show in what all ways turtles respond to disturbance and how disturbance affects particular aspects of a basking turtle, even if not avoiding disturbed stretches. Across all the 3 sites, High disturbance resulted in lower basking duration, both at basking bouts level as well as individual level- proving my hypothesis 2a. While basking bouts has been used as a metric when individual identification is not possible (Moore & Seigel, 2006), it shows that under high disturbance one continuous basking event is shorter. Though, the conclusions that can be drawn are limited, as turtles can emerge to bask throughout the day, in which case, even if basking bouts were shorter the total time spent in basking may turn out to be equal. Thus, to account for that, one site was chosen where individuals could be identified (Site 1). A mean decrease of 18 minutes of total basking duration was observed under high disturbance as compared to low disturbance at site 1 for 7 identified *Nilssonia* individuals. Since the mean total basking duration during low disturbance was around 55 minutes, there is a reduction of one-third of the total basking duration during high disturbance. At Site 2 (with sandbar) and Site 3 (without sandbar) the estimated basking bout after disturbance removal is 4 minutes and 9 minutes higher than estimated basking bout before removal of disturbance, respectively. Thus, as already discussed in site 1, that disturbance results in a decrease of total basking duration, the decrease in basking bouts at site 2 and 3 may also be assumed to be reflected as reduced individual basking duration. This proves Hypothesis 2a that under high disturbance the total basking duration/basking bouts will be lowered. This is in line with how

Indian pythons have been known to bask half the time in disturbed areas as compared to undisturbed areas (Mukherjee et al., 2018). Thus, even if turtles are basking at disturbed locations, they are affected within the behavioural aspect of it, in this case, the effect being lowered basking duration. Heppard and Buchholz, 2019 showed that due to high tourism pressure, turtles are unable to bask properly resulting in a lowering of body temperature. It was modelled that for 0.34ºC lowering of body temperature, the metabolic rate went down by 8%. It could not be quantified what are the physiological effects of this reduced basking duration on turtles, as permissions for intrusive studies were not there, it is an important aspect that needs to be looked into, for 33% reduction in basking duration may very well result in reduced body temperature (Chessman, 2024). The importance of studying how disturbance affects different aspects of an organism can be seen through this finding, where site selection would conclude turtles are basking close to disturbance, thus site selection is not affected by disturbance, while adding focal behavioural observations to it, it can be seen that under high disturbance, there is a huge reduction in basking duration within the disturbed sites- this is also an effect of disturbance but would not be included if the aim was only to look at site selection and the inference would be wrong.

Hypothesis 2b: Individually identified *Nilssonia* at site 1, significantly increased the proportion of basking duration on mid channel sites compared to the shoreline by 20% during high disturbance as compared to low disturbance. Similar pattern was also seen in basking bouts at site 2, whereby basking bouts on sandbar were significantly longer by 14 minutes as compared to sandbank during high disturbance, whereas there was no significant difference in basking bouts on sandbank and sandbar during low disturbance phase. During the site selection component, it was inferred that presence of mid river basking sites buffers the negative effect of disturbance, thus encounter rates were higher under high disturbance when alternate basking sites were available, as compared to when they are not. Thus, it shows that the mid river basking sites may also serve as a buffer, not only for site selection but also for basking behaviour, as basking bouts and proportion of basking on mid river sites were higher under high disturbance. Thus, individual turtles were seen to modulate their space use in direct response to disturbance regime, similar to a site-shifting response (Gill et al., 2001). If the before after disturbance removal comparison could not be done, it would not be possible to conclude that the higher basking bout on sandbar was due to disturbance or because of certain fixed thermal property of the habitat. The fact that after removal of disturbance, the basking bouts became similar on sandbank and sandbar and proportion of time spent on basking on mid river sites differed between high disturbance and low disturbance days suggest that the mid river basking sites were highly used, at least partially, due to high disturbance on shoreline.

Sub-Objective 2.2: The basking behaviour was looked at through individual level, as a lot of studies exist on population level of basking dynamics, which usually revolves around emergence rate, retreat rate, basking bout, etc. While that in itself provides a lot of information, since it was made possible to identify each individual at site 1 and track their entire basking behaviour, it could be possible to look at individual level variation in basking behaviour, which is something that has not been looked into as such. It was seen that 5 of the 7 individuals had significantly reduced basking under high disturbance. The other 2 *Nilssonia* (N6 and N7) showed no significant change, while the effect on N1 and N2 was the most striking as compared to N3, N4 and N5. While N3, N4 and N5 significantly increased their proportion of time on mid river basking sites during high disturbance, the same pattern was not seen for N1, N2, N6 and N7. Based on field observations, N6 and N7 were the largest softshell in the basking patch and only few basking rocks were large enough to support them.

Thus, N6 and N7 would be basking on large mid river and shoreline rocks and were observed to get into direct conflict several times with other individuals if they approach their basking sites. Lack of alternate options, ability to defend the basking spot and lower wariness among larger individuals (Lefevre & Brooks, 1995) may be attributed to the observations that there was no significant change in basking duration and proportion of time spent in basking on mid river basking sites between high disturbance and low disturbance days. N1 and N2 that is the juveniles were seen to significantly reduce basking duration on high disturbance days but did not significantly change the proportion of time basking on mid channel sites. This may be attributed to the field observation of the many times that juvenile *Nilssonia* would attempt to bask on mid river basking sites but were almost always removed as the site was already occupied by larger *Nilssonia* or even *Pangshura*.

Hypothesis 2c: Thus, it has been seen that mid river basking sites serve as buffer, both by reducing the effect of disturbance on site selection and on behaviour (basking duration) as well. But mid river basking sites, for the most part can be considered a point habitat if compared to the extensive stretch of shoreline that is available for basking. Thus, during disturbance, if all turtles move to mid river basking sites, it will result in crowding and social interactions, particularly aggression might take place. At Site 2, the number of aggressive interactions in an hour was significantly positively correlated with number of turtles basking on the sandbar. Thus, crowding results in higher degree of aggressive interactions, which is similar to the phenomenon of disturbance induced habitat compression (Gilbert et al., 2022) resulting in increased social interactions, in this case aggressive behaviour. Thus, even though the mid river basking sites provide a buffer to negative effects of disturbance, it substitutes the risk of exposure to disturbance to exposure to aggressive interactions. At Site 1, of 70 recorded attempts of Juvenile *Nilssonia* attempting to bask on mid river basking sites, 47 resulted in removal by a larger *Nilssonia*, 12 resulted in removal by *Pangshura* while only on 11 attempts successful basking was performed. Thus, social interactions were altered due to high disturbance resulting in crowding on mid river basking sites.

CONCLUSION

The thesis demonstrates that anthropogenic disturbance influences basking site selection and basking behaviour of turtles in the Chambal river system, not through a single mechanism but through a set of responses operating at different spatial and ecological scales. At the macro-scale, *Nilssonia* and *Batagur* were seen to avoid disturbed segments, the negative effect of which was buffered by the presence of mid river basking sites, while *Panghsura* was not seen to avoid disturbed segments. In the micro-scale, the best fit model for *Nilssonia* did not include disturbance in it but they selected Mid river sites significantly more than shoreline sites. The behaviour data added the response of basking behaviour to disturbance as well. 3 disturbed but used sites were chosen- without the documentation of behaviour, the presence of basking turtles would result in the conclusion that they tolerate disturbance. But upon testing the patterns of basking behaviour before and after disturbance clearly shows basking duration is lowered under high disturbance and turtles prefer to utilize mid river sites more during high disturbance, which might result in increase in aggressive interactions. The study emphasizes the need of incorporating responses at various scales and for both site selection and behaviour aspects, to get a better picture of how anthropogenic disturbance is affecting freshwater turtles from various aspects.

The study identifies mid river rocks, sandbars and gravel bars being functionally distinct from the overall basking substrates available on the shoreline, by virtue of these kinds of structures providing an alternate site to bask upon away from the shore under high disturbance on shoreline. Thus, mid river basking sites came out to be an important factor in determining turtle encounter rates, as well as for buffering the negative effect of disturbance, both in site selection and basking behaviour aspects. Though it is to be remembered that even though they buffer the negative effects of disturbance, the macrohabitat usage was still seen to be decreasing in the presence of mid river basking sites but at a lower rate, while for basking behaviour, mid river sites provide safer refugia under disturbance but the area available is often too small to accommodate a large population, resulting in increased aggressive interactions, with smaller individuals suffering the most as a result. Even when alternate sites are available, the basking bouts and total basking duration were found to be significantly lower under high disturbance. This might result in decreased body temperature, which ultimately affects metabolic activities, locomotion, body condition and finally survival. Thus, removal or regulation of disturbance still has to be the first priority followed by protection of mid river basking sites (especially protection of sandbars from sand miners). Sand mining emerged as THE one kind of disturbance that affects basking behaviour the most (as well as nesting), not only due to higher escape distance of turtles as a response to sand mining, but also due to the very disturbance being responsible for removal of crucial basking and nesting habitats for freshwater turtles. Furthermore, it was seen that after the removal of sand mining from the study sites, turtles returned to bask on the shoreline, drastically reducing the frequency of aggressive interactions and basking bouts becoming longer.

Going forward, multi-scale and multi-species approach should be employed to know the impact of disturbance at various scales and on various aspects. Individual identification for *Nilssonia gangetica* can be used to study individual level responses and dominance hierarchy in utilization of a basking spot, which can provide more detailed ecological and management implications.

Limitations:

1) Thermal data could not be incorporated into the analysis.

2) Seasonal variation could not be captured due to the field session lasting from February to April.

3) Even though based on previous literature it has been assumed that lowering of basking duration may result in lowering of body temperature, the same could not be verified due to lack of permissions for conducting such studies.

4) While FID is one of the most widely studied metrics to understand response to disturbance, it could not be incorporated into the study as a main objective because of lack of permissions.

R E F E R E N C E S

- Amo, L., López, P., & Martı, J. (2006). Nature-based tourism as a form of predation risk affects body condition and health state of Podarcis muralis lizards. Biological Conservation, 131(3), 402-409.
- Batabyal, A., Balakrishna, S., & Thaker, M. (2017). A multivariate approach to understanding shifts in escape strategies of urban lizards. Behavioral Ecology and Sociobiology, 71(5), 83.
- Beale, C. M., & Monaghan, P. (2004). Human disturbance: people as predation-free predators? Journal of applied ecology, 41(2), 335-343.
- Benitez-Lopez, A., Alkemade, R., Schipper, A. M., Ingram, D. J., Verweij, P. A., Eikelboom, J. A. J., & Huijbregts, M. A. J. (2017). The impact of hunting on tropical mammal and bird populations. Science, 356(6334), 180-183.
- Brinky Desai, Tathagata Bhowmik, Rohith Srinivasan, Nikhil Whitaker, Ratna Ghosal, Monitoring the stress physiology of free-ranging mugger crocodiles (Crocodylus palustris) across diverse habitats within Central Gujarat, India, Conservation Physiology, Volume 12, Issue 1, 2024, coae035, https://doi.org/10.1093/conphys/coae035
- Capula, M., Luiselli, L. U. C. A., Rugiero, L. O. R. E. N. Z. O., & Filippi, E. (1994). A field experiment on the selection of basking sites by Emys orbicularis (Linnaeus, 1758). Herpetozoa, 7(3/4), 91-94.
- Carrascal, L. M., López, P., Martín, J., & Salvador, A. (1992). Basking and antipredator behaviour in a high-altitude lizard: implications of heat-exchange rate. Ethology, 92(2), 143-154.
- Chessman, B.C. (2024), The conundrum of turtle and tortoise basking: A critical review. J Zool, 323: 263-283. https://doi.org/10.1111/jzo.13175
- Choudhary S, Choudhury BC, Gopi GV. Spatio-temporal partitioning between two sympatric crocodilians (Gavialis gangeticus & Crocodylus palustris) in Katarniaghat Wildlife Sanctuary, India. Aquatic Conserv: Mar Freshw Ecosyst. 2018; 28:1067–1076. https://doi.org/10.1002/aqc.2911
- Choudhary, S., Choudhury, B. C., & Gopi, G. V. (2017). Differential response to disturbance factors for the population of sympatric crocodilians (Gavialis gangeticus and Crocodylus palustris) in Katarniaghat Wildlife Sanctuary, India. Aquatic Conservation: Marine and Freshwater Ecosystems, 27(5), 946-952.
- Ciuti, S., Northrup, J. M., Muhly, T. B., Simi, S., Musiani, M., Pitt, J. A., & Boyce, M. S. (2012). Effects of humans on behaviour of wildlife exceed those of natural predators in a landscape of fear. PloS one, 7(11), e50611.
- Cooper Jr, W. E. (2009). Optimal escape theory predicts escape behaviors beyond flight initiation distance: risk assessment and escape by striped plateau lizards Sceloporus virgatus. Current Zoology, 55(2), 123-131.
- Cooper Jr, W. E. (2011). Influence of some potential predation risk factors and interaction between predation risk and cost of fleeing on escape by the lizard Sceloporus virgatus. Ethology, 117(7), 620-629.
- Das, J., Sreenivasan, N., Mahesh, N., & Dharwadkar, S. (2025). First photographic evidence of nesting behaviour of Leith's Softshell Turtle (Nilssonia leithii, Gray 1872) in the Cauvery Wildlife Sanctuary, Karnataka. Hamadryad, 42(1 and 2).
- Dave, U., & Bhatt, N. (2021). Basking behavior of marsh crocodiles (Crocodylus palustris) in pond Deva, Anand district, Gujarat, India. Reptiles & Amphibians, 28(1), 26-29.
- Debata, S., Kar, T., Palei, H. S., & Swain, K. K. (2019). Breeding ecology and causes of nest failure in the Indian Skimmer Rynchops albicollis. Bird Study, 66(2), 243-250.
- Dieter, C. D., Dixon, L. A., Ronningen, S. L., & Ronningen, T. (2014). Survey of turtles nesting on the Missouri River on the South Dakota-Nebraska border. Great Plains Research, 111-118.
- Dixon, L. A. (2009). False map, spiny softshell and smooth softshell turtle nest and nest-site habitat characteristics along the lower stretch of the Missouri National Recreation River in South Dakota. South Dakota State University.

- Doherty, T. S., Hays, G. C., & Driscoll, D. A. (2021). Human disturbance causes widespread disruption of animal movement. Nature Ecology & Evolution, 5(4), 513-519.
- Downs, C. T., Greaver, C., & Taylor, R. (2008). Body temperature and basking behaviour of Nile crocodiles (Crocodylus niloticus) during winter. Journal of Thermal Biology, 33(3), 185-192.
- Erdélyi, G., Szabó, B., & Kiss, I. (2021). BASKING SITE SELECTION AND USAGE STRATEGIES OF THE EUROPEAN POND TURTLE, Emys orbicularis (LINNAEUS, 1758) IN BABAT VALLEY (GÖDÖLLÕ, HUNGARY). Russian Journal of Herpetology, 28(4).
- Frid, A., & Dill, L. (2002). Human-caused disturbance stimuli as a form of predation risk. Conservation ecology, 6(1).
- Gaynor, K. M., Hojnowski, C. E., Carter, N. H., & Brashares, J. S. (2018). The influence of human disturbance on wildlife nocturnality. Science, 360(6394), 1232-1235.
- Gilbert, N. A., Stenglein, J. L., Pauli, J. N., & Zuckerberg, B. (2022). Human disturbance compresses the spatiotemporal niche. Proceedings of the National Academy of Sciences, 119(52), e2206339119.
- Gill, J. A., Norris, K., & Sutherland, W. J. (2001). Why behavioural responses may not reflect the population consequences of human disturbance. Biological conservation, 97(2), 265-268.
- Heppard, J. M., & Buchholz, R. (2019). Impact of human disturbance on the thermoregulatory behaviour of the endangered ringed sawback turtle (Graptemys oculifera). Aquatic Conservation: Marine and Freshwater Ecosystems, 29(6), 990-1001.
- Hill, S. K., & Vodopich, D. S. (2013). Habitat use and basking behavior of a freshwater turtle community along an urban gradient. Chelonian Conservation and Biology: Celebrating 25 Years as the World's Turtle and Tortoise Journal, 12(2), 275-282.
- Hussain, 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, 19(2), 127.
- Irwin, M. T., Wright, P. C., Birkinshaw, C., Fisher, B. L., Gardner, C. J., Glos, J., ... & Ganzhorn, J. U. (2010). Patterns of species change in anthropogenically disturbed forests of Madagascar. Biological Conservation, 143(10), 2351-2362.
- Jani, C., Choudhury, B. C., & Sivakumar, K. (2009). Species assemblage and differential basking habitat use of freshwater turtles in a gradient of Mahanadi Riverine ecosystem, Orissa (Master's dissertation). Wildlife Institute of India. https://digitalrepository.wii.gov.in/items/71603350-4ddb-4133-abd5-f46835f5e7e4
- Kaur, J., Nair, A., & Choudhury, B. C. (2008). Conservation of the Vulnerable sarus crane Grus antigone antigone in Kota, Rajasthan, India: a case study of community involvement. Oryx, 42(3), 452–455. doi:10.1017/S0030605308000215
- Kaur, P. (2015). Study of effect of temperature and anthropogenic activities on the basking behaviour of marsh crocodile (Crocodylus palustris) of Vishwamitri River, Vadodara, Gujarat. Unpubl. Gujarat. MSc. The Maharaja Sayajirao University of Baroda.
- Kofron, C.P., 1993. Behavior of Nile crocodiles in a seasonal river in Zimbabwe. Copeia 2, 463–469.
- Krishnaswamy, J. (2015). Saving India's rivers and riverine ecosystems. Fundamatics.
- Lambert, M.R., Nielsen, S.N., Wright, A.N., Thomson, R.C. & Shaffer, H.B. (2013) Habitat features determine the basking distribution of introduced red-eared sliders and native Western Pond turtles. Chelonian Conservation Biology, 12, 192–199. Available from: https://bioone.org/journals/chelonian-conservation-and-biology/volume-12/issue-1/CCB-1010.1/Habitat-Features-Determine-the-Basking-Distribution-of-Introduced-Red-Eared/10.2744/CCB-1010.1.full
- Larson, C. L., Reed, S. E., Merenlender, A. M., & Crooks, K. R. (2016). Effects of recreation on animals revealed as widespread through a global systematic review. PloS one, 11(12), e0167259.
- Lefevre, K., & Brooks, R. J. (1995). Effects of sex and body size on basking behavior in a northern population of the painted turtle, Chrysemys picta. Herpetologica, 217-224.
- Meek, R., & Luiselli, L. (2022). Living in patchy habitats: substrate selection by basking sympatric lizards in contrasted anthropogenic habitats in western France. Russian Journal of Herpetology, 29(4).
- MODHA, M. L. 1967. The ecology of the Nile crocodile (Crocodylus niloticus Laurenti) on Central Island, Lake Rudolf. East Afr. Wildl. J.
- MODHA, M. L. 1968. Basking behaviour of the Nile croc- odile on Central Island, Lake Rudolf. Ibid. 6:81- 88
- Moore, M. J., & Seigel, R. A. (2006). No place to nest or bask: effects of human disturbance on the nesting and basking habits of yellow-blotched map turtles (Graptemys flavimaculata). Biological Conservation, 130(3), 386-393.

- Mukherjee, A., Kumara, H. N., & Bhupathy, S. (2018). Sun-basking, a necessity not a leisure: Anthropogenic driven disturbance, changing the basking pattern of the vulnerable Indian rock python in Keoladeo National Park, India. Global Ecology and Conservation, 13, e00368.
- Nordberg, E. J., & McKnight, D. T. (2020). Nocturnal basking behavior in a freshwater turtle. Ecology, 101(7), 1-3.
- Nordberg, E. J., & McKnight, D. T. (2023). Seasonal, environmental and anthropogenic influences on nocturnal basking in turtles and crocodiles from North-Eastern Australia. Austral Ecology, 48(8), 1516-1531.
- O'Bryan, C., Hamed, M. K., Laughlin, T. F., & Coffey, J. W. (2022). Body-size and aerial basking dynamics of the Spiny Softshell (Apalone spinifera) in a human-modified landscape in Tennessee, USA. Journal of North American Herpetology, 2022(1).
- Palmer, M. S., Gaynor, K. M., Becker, J. A., Abraham, J. O., Mumma, M. A., & Pringle, R. M. (2022). Dynamic landscapes of fear: understanding spatiotemporal risk. Trends in Ecology & Evolution, 37(10), 911-925.
- Panek, J. M. (2006). The Relationship Between Basking Behavior, Parasite Load, And Growth Rates In Midland Painted Turtles (Chrysemys Picta Marginata).
- Pareek, P. S., Khalid, M. A., Michaels, C. J., & Singh, S. (2026). Nesting habitat characterisation of red-crowned roofed turtle Batagur kachuga along lower Chambal, India. Herpetological Journal, 36(1), 27-37.
- Pareek, P. S., Singh, S., & Dutta, S. (2024). Nesting crawls and associated behaviors of turtles in the genus Batagur along the Chambal River, India. Reptiles & Amphibians, 31(1), e21297-e21297.
- Patel, J. (2020, June 17). Nest guardians to keep the Indian skimmer's eggs safe. Mongabay-India. https://india.mongabay.com/2020/06/nest-guardians-to-keep-the-indian-skimmers-eggs-safe/
- Peterman, W. E., & Ryan, T. J. (2009). Basking behavior of emydid turtles (Chysemys picta, Graptemys geographica, and Trachemys scripta) in an urban landscape. Northeastern Naturalist, 16(4), 629-636.
- Pickerell, G. (2015). Braided-river islands as refuges from introduced mammalian predators: characteristics influencing predator presence, and consequences of reduced flow (Doctoral dissertation, University of Otago).
- Pittfield, T., Burger, J. Basking habitat use and response of freshwater turtles to human presence in an urban canal of Central New Jersey. Urban Ecosyst 20, 449–461 (2017). https://doi.org/10.1007/s11252-016-0606-5
- Riddington, R., Hassall, M., Lane, S. J., Turner, P. A., & Walters, R. (1996). The impact of disturbance on the behaviour and energy budgets of Brent Geese Branta b. bernicla. Bird study, 43(3), 269-279.
- Ross, J., Bluett, R., & Dreslik, M. J. (2014). INHS Reports August 2014: Spatial ecology of the smooth softshell Turtle (Apalone mutica) in the Kaskaskia River of Illinois. INHS Reports no. 412 (2).
- Seebacher, F. (1999). Behavioural postures and the rate of body temperature change in wild freshwater crocodiles, Crocodylus johnstoni. Physiological and Biochemical Zoology, 72(1), 57-63.
- Selman, W., Qualls, C. and Owen, J.C. (2013), Effects of human disturbance on the behavior and physiology of an imperiled freshwater turtle. Jour. Wild. Mgmt., 77: 877-885. https://doi.org/10.1002/jwmg.538
- Steven, R., Pickering, C., & Castley, J. G. (2011). A review of the impacts of nature-based recreation on birds. Journal of environmental management, 92(10), 2287-2294.
- Stillman, R. A., West, A. D., Caldow, R. W., & DURELL, S. E. L. V. D. (2007). Predicting the effect of disturbance on coastal birds. Ibis, 149, 73-81.
- Subba, A., Limbu, K., Lama, P., Limbu, N., Rai, D., Lama, S., & Khanal, L. (2026). Water depth and human disturbance drive occupancy of endangered softshell turtles (Nilssonia spp.) in eastern Nepal. *Wildlife Biology*, e01531.
- Tracy-Smith, E., Galat, D. L., & Jacobson, R. B. (2012). Effects of flow dynamics on the aquatic-terrestrial transition zone (ATTZ) of Lower Missouri River sandbars with implications for selected biota. River research and applications, 28(7), 793-813.
- Tucker, M. A., Böhning-Gaese, K., Fagan, W. F., Fryxell, J. M., Van Moorter, B., Alberts, S. C., ... & Mueller, T. (2018). Moving in the Anthropocene: Global reductions in terrestrial mammalian movements. Science, 359(6374), 466-469.
- Tyagi A, Kumar V, Kittur S, Reddy M, Naidenko S, Ganswindt A, Umapathy G. Physiological stress responses of tigers due to anthropogenic disturbance especially tourism in two central Indian tiger reserves. Conserv Physiol. 2019 Jul 12;7(1): coz045. doi: 10.1093/conphys/coz045. PMID: 31321036; PMCID: PMC6626984.
-

- Venugopal, P. D., & Deviprasad, K. V. (2003). Basking behaviour and survey of marsh crocodiles, Crocodylus palustris (Lesson, 1831) in Ranganthittu Bird Sanctuary, Karnataka, India. HAMADRYAD-MADRAS-, 27, 241-247.
- Vignoli, L., Bologna, M. A., Manzini, S., Rugiero, L., & Luiselli, L. (2015). Attributes of basking sites of the European pond turtle (Emys orbicularis) in central Italy. Amphibia-Reptilia, 36(2), 125-131.
- Weston, M. A., Ehmke, G. C., & Maguire, G. S. (2011). Nest return times in response to static versus mobile human disturbance. The Journal of Wildlife Management, 75(1), 252-255.
- Wildlife Institute of India. (2025). Ecological assessment of the Chambal River: Status of major aquatic fauna and flow requirements (Final report). Wildlife Institute of India.
- Ydenberg, R. C., & Dill, L. M. (1986). The economics of fleeing from predators. In Advances in the Study of Behavior (Vol. 16, pp. 229-249). Academic Press.
- Yusof, F. M. (2018). Habitat Predictive Modelling and Geospatial Database of Batagur Affinis (Contor, 1847) in Kemaman River, Malaysia. *Master of Science Thesis, Universiti Putra Malaysia, 112p*.