Seasonal habitat use and resource partitioning between two sympatric crocodilian populations (*Gavialis gangeticus* & *Crocodylus palustris*) in Katerniaghat Wildlife Sanctuary, India

Dissertation submitted to the Saurashtra University, Rajkot in partial fulfilment of Masters Degree in Wildlife Science (June 2011)

By

Shikha Choudhary

Supervisors

Prof. B.C. Choudhury

&

Mr. G.V. Gopi

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Certificate

This is to certify that **Ms. Shikha Choudhary** has carried out an original piece of research in partial fulfilment of Master's Degree in Wildlife Science of the Saurashtra University, Rajkot. The topic of her dissertation is **"Seasonal habitat use & resource partitioning between two sympatric crocodilian populations (*Gavialis gangeticus* & *Crocodylus palustris*) in Katerniaghat Wildlife Sanctuary, India**. The study was carried out under our supervision from December 2010 to June 2011. We hereby certify that this work has not been submitted for any degree to any university.

Shri. B.C.Choudhury
Scientist-G
Supervisor

Mr. G.V. Gopi
Scientist- C
Co-supervisor

Date:

Place: Dehradun

पत्रपेटी सं0 18, चन्द्रबनी, देहरादून – 248 001, भारत
Post Box No. 18, Chandrabani, Dehra Dun - 248001. INDIA
ई.पी.ए.बी.एक्स : + 91-135-2640111 से 2640115 फैक्स : 0135-2640117, तार : WILDLIFE
EPABX : + 91-135-2640111 to 2640115: **Fax :** 0135-2640117; **GRAM :** WILDLIFE
ई–मेल / **E-mail :** wii@wii.gov.in

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

First of all I would like to thank my supervisors **Prof. B.C Choudhury** and **Mr. G.V. Gopi** for the unconditional guidance, care and support I have got from them throughout the whole process of my study and also during my stay in WII.

I would like to acknowledge **The Director WII, Dean WII** for supporting the M.Sc programme and making this study possible. Whole-hearted thanks to our Course Director, **Dr. V.P Uniyal** and Asst. Course Director, **Mr. R Suresh Kumar** for being so nice to us and helping out with even small and silly issues. The **entire faculty** who taught and prepared us to work on our own in field deserve credit. Especially to **Mr. Qamar Qureshi** and **Dr. Y.V. Jhala** for statistics (though I learned most of it in one month before submission); **Dr. Karthikeyan Vasudevan** for helping and guiding us during thesis writing. I would personally like to thank **B.C sir and Nalini ma'am** for being my guardians. Personal thanks to **Gopi sir**, with whom I never felt odd and could confide in.

In Katerniaghat I am grateful to the Chief Wildlife Warden, U.P **Mr. B.K. Patnaik** for granting me permission to work in Katerniaghat Wildlife Sanctuary; to D.F.O Katerniaghat **Mr. R.K. Singh** for his short but warm conversations; and especially to R.F.O Katerniaghat **Mr. M.K. Shukla** for cooperating with me and for providing me with all sorts of resources I needed in field, for all those dinner invitations and for long and fruitful conversations regarding wildlife management. I appreciate his keen interest and knowledge of wildlife. Thanks to **Raja Chandramani Kant Singh** for royal meals and royal treatments. He, being a great *shikari* in his youth is now a keen conservationist, very active and enthusiastic and eager to help serious researches. Thanks to engineer **Sharmaji** (Girgapuri barrage) for sharing rainfall data.

Big thanks to **Prakashji** and **Mullaji** for being excellent field assistants and helping me in data collection. It was not an easy task to row a country boat from 6am to 6pm and then cook food after that. Without them this study was next to impossible. Both being extremely laborious and cooperative, with them I never felt insecure in a place like Katerniaghat (though I had few terribly bad experiences) but both were there for me always and thanks to my cycle too for taking me everywhere without a single puncture. **Ramroopji** and **Subhaiji** for helping me out in finding Gharial and Mugger nest.

Back at base, **Meraj** for giving me wonderful company in field and making field life more lively, for taking me to the other parts of the sanctuary and teaching me how to deploy and remove cameras (Hey u haven't given me that day's wage), for everything you did for me and yes in data entry (which was really great of you). **Ajay** for his movie and song collection, which helped a lot during off days and I also enjoyed the company of **Lalit**. And yes, **Chotu** for making tea at odd times and managing the food supply whenever I went there without invitation.

Thanks to **Nick**, from MCBT, for helping me out with ideas during the initial phase of designing my study and for allowing me to use the library. **Tarun Nair** for good suggestions and sending me a whole lot of papers.

Back in WII, again a truck load of thanks to **tirtho** for being my 3rd supervisor and helping me to come out from a deep pool of stats (I was sure without his help I would have drowned, as I don't know how to swim also), for every single minute correction (I was not scared or depressed), for giving me time and I appreciate his patience. **Sabuj** for long discussion on how to separate winter from summer (it is not simple, as it sounds). **Ved** and **Indro** for helping in making Maps. **Megha, Upma, Manjari** for their support and presence; **Shazia, Madura** and **Daya** for a very wonderful time; **Monica** for going with me to Katerniaghat; **Prakash** for the list of papers; **Salvan, Ninad, Sajan, Pruthvi** and **Gajju Bhai** for their concern and giving me the mental support (they had this thing in mind, that I can finish it before the deadline???). Among seniors **Murli** for small but extremely fruitful conversations on gtalk during the proposal writing, **Abhi** for giving me time whenever I asked for.

Rusty for being with me always and helping me to come out of depression and tension with her playful attitude and sweet little meow.

And finally among my classmates, **Blow-pipe** for analysis and great suggestions, for being extremely caring and sweet, and patiently listening to all my small-small silly doubts and solving them with no irritation. **"Reha"- the tailor bird**, for fun time especially 2am walks of institute & practising karate in front of auditorium, for listening to my problems and secrets, giving me company in all illicit activities (Can't mention here). **Zoooli** for her working pace that made me pull up my socks little higher (both have same co-supervisor) and for teaching me Bihu (I hope I managed it). **Satan** for being a very good friend, with whom I tried all nonsense stuffs, for helping me out in most terrible phase of my life, for being there always whenever needed. **Amit** for the fights (not serious ones), chai during exams and for turning his room in a movie hall. **Bista** for being so concerned and caring, for calling almost daily during field work, and off course for being a great dance partner. **Samuel** for being so nice and supportive, for sharing similar views regarding few issues (still remember Delhi work-shop & conservation tour), for practising Rajasthani dance steps whole heartedly (little more practise & you'll be perfect); **Dramesh** for being a great room-mate and neighbour; **Kambale** for teaching how to use different modes and setting in camera (for me auto was best); **Nadia** for rescuing us from evening starvations.

My friends from the old days of graduation and school who took interest in my field stories and patiently listened to my non-ending rambles of work and crocodiles without any clue of what I was talking about. Last and most important, my family members whose support and blessings made a strong foundation that enabled me to achieve my target. **Papa** and **am'mi** for having faith in me and allowing me to do what I wanted to. **Shipra** and **Aayush** for appreciating my work and narrating it proudly among friends (Chotu use me in interview also).

A Big thanks to Microsoft **EXCEL** and **SPSS** for making analysis just a matter of selection and click.

Last but not the least I would like to thank **Gharials** and **Muggers ("all three size classes")** for allowing me to work on them. Thanks for letting me sleep for longer, unlike my other class-mates who worked on birds. For being extremely calm and not attacking (I think somehow they came to know that I like them).

SUMMARY

Gharial (*Gavialis gangeticus*) and Mugger (*Crocodylus palustris*) are sympatric in their distribution range in some of the Northern River system of Indian sub-continent. Katerniaghat Wildlife sanctuary along Indo-Nepal border in Uttar Pradesh harbours the second largest breeding population of critically endangered Gharial, after National Chambal Sanctuary. Several studies have been carried out on the ecological aspects of Gharial and Mugger separately but very few studies exist on the sympatric populations and the mechanisms favouring the coexistence of the species. This study has tried to fill this gap by investigating how the resources are shared (Basking sites and Nesting sites) and what are the key requirements that lead to the selection of a particular basking and nesting site. Temporal separation across species and size classes and preference for nearest neighbour has been established. Relative abundance in terms of encounter rate across season, river segments and a gradient of disturbances were studied. Other aspects that have been looked into detail in this study are the impact of tourism and illegal fishing on the flight distance of Gharial and Mugger.

Data were collected from December 2010 to May 2011, covering two seasons (late winter and early summer). Entire study was carried out using a non-mechanised boat. Habitat parameters for every sighted basking crocodile were recorded for habitat use and for determining the habitat availability variables at every 100 meters on both banks and on islands were recorded. Nests were located by following the spoor marks of crocodiles. Gharial and Mugger were divided into three size classes (SC1 - <1.5m, SC2 – 1.5m to 3m, SC3 - > 3m). Once in a month day survey was carried out to estimate the relative abundance and on every alternate Monday temperature and number of basking individual were recorded at every hour from 0600 to 1800 hrs from a watch tower. Flight distance of crocodiles was recorded from a non-mechanised boat and a mechanised boat by accompanying the tourists.

Relative abundance as mean encounter rate (#/20km) was maximum for Gharial juveniles followed by Gharial adult. Mugger juvenile had lowest mean encounter rate (#/20km). Encounter rate was not uniform for the river and it varies across season also. Maximum sightings took place in river segments with sand bars irrespective of moderate to high disturbance. With increase in mean ambient temperature encounter rate declined.

Basking sites were selected during summer by Gharial based on depth gradient, current land usage, island, distance to water, slope, platform height and soil moisture while selection of basking site by mugger was based on current land usage, distance to water and depth gradient. In winter, Gharial selected sites based on slope, platform height, soil moisture, current land usage, distance to water and place while Mugger looked for current land usage, distance to water, islands and banks.

In winter, there was no temporal segregation between different size classes of Gharial and Mugger while in summer there was a temporal segregation between and within size classes of Gharial and Mugger. Choice of slope, height, soil moisture, places and substrata for basking sites were different for Gharial and Mugger. Gharial preferred very gentle slope while Mugger preferred a slight slope. Gharials do not prefer elevated basking platforms whereas Mugger was found basking on elevated platform. Gharial preferred moist areas for basking and Mugger basked even on little dry substrate. Gharial was seen mostly on Islands and Muggers on banks. Among basking substrate Gharial preferred sand & sand+silt, whereas Mugger was found on a variety of substrata. Mugger moved to side streams (Nalla) in summer while Gharial kept on preferring island for basking. For nest sites there is a significant difference in the use of slope, height, distance to water, places and substrate by Gharial and Mugger.

Flight distance for crocodiles was more when there was a disturbance from non-mechanised boat than from a mechanised boat. Mechanised boat is mainly used for tourism purpose while non-mechanised boat for illegal fishing by local people. Between species Mugger was more tolerant to human presence than Gharial. Among hatchlings and adults of Gharial, hatchling showed a late response to disturbance while adults used to be the first one to slide in to water.

Girwa river of Katerniaghat Wildlife Sanctuary is one of the very few rivers of India where Gharials are breeding in wild. Though the river stretch is about 20 – 21 km only a small stretch of 5-8 km harbours the maximum number of Gharial and Mugger. This small section is used for both basking and nesting and it is very crucial to protect this small stretch in order to save a critically endangered species from the brink of extinction.

1. INTRODUCTION

1.1 The Riverine Ecosystem

Riverine ecosystem, also called lotic ecosystem like any spring, stream, or river are viewed as an ecosystem. The waters are flowing (lotic) and exhibit a longitudinal gradation in temperatures, concentration of dissolved material, turbidity, and atmospheric gases, from the source to the mouth. There are two major zones: rapids, shallow water where currents are strong enough to keep the bottom clear and firm; and pools, deeper waters where currents are reduced and silt and other debris collect on the bottom. Each zone has its specially adapted life forms. Riverine ecosystems are transitional semi-terrestrial areas regularly influenced by fresh water and extending from the edges of water bodies to the edges of upland communities. They integrate interactions between the aquatic and terrestrial components of the landscape and are very dynamic environments (strong energy regimes, habitat heterogeneity, diversity of ecological processes, etc.). Its importance can be analysed in many prospective like contribution to biodiversity, provision of ecological goods and services, regulation of water and enrichment of water table.

1.2 Riverine Ecosystem and crocodiles

Riverine ecosystem has suffered most among ecosystems due to anthropogenic activities (Naiman et al. 2000). Major causes of degradation are pollution, change in hydrology, destructive fishing, sand mining and other development activities (Richter et al. 2003) which profoundly change the processes that drive ecosystem structure and functioning (Roland et al. 2000). Every ecosystem has an inbuilt capacity to heal but when damage is huge, restoration becomes important. After restoration of ecosystem, monitoring is a key part of adaptive management (Lovett et al. 2007). Not everything within an ecosystem can be monitored so it is important to select indicators that are representative of the system, integrate system responses, show clear responses to system change, can be effectively and efficiently monitored, and are easily communicated. Crocodilians (alligators and crocodiles) serve as one of the major indicators (Mazzotti et al. 2008). These being top predators keep food chain in shape. Distribution and abundance of crocodilians in a Riverine ecosystem is directly dependent on timing, quality, quantity and location of freshwater flow (Dunson et al. 1989)

1.3 Resource Partitioning

Resource partitioning among sympatric species is an evolutionary strategy to avoid competition through habitat selection and prey choice (Schoener 1974) and to coexist in the same ecological community without one pushing the others to extinction through competition. Habitat, food and time are the three traditional categories of resource dimensions (Pianka 1975). Resource-partitioning patterns result from three categories of causes, of which competition is just one; the other two are predation and factors that operate independently of interspecific interactions, such as physiological constraints (Toft 1985). Similar species commonly use limiting resources in different ways and the ways in which sympatric species differ in their utilization of resources have long been of interest in ecology and this differential resource selection is one of the principal relationships which permit species to coexist (Rosenzweig 1981). Resources are different for different species, according to their habits and requirements. Due to similarity in morphology and habits of sympatric species, one expects similar strategies for the exploitation of frequently limited resources. These resources, which include nutrients and habitat, are the raw materials needed by organisms to grow, live, and reproduce. Species can divide up a limiting resource by using its different parts or even using the same part but in different time or place. Elucidating these species-habitat relationships and resource use patterns is important to understand their ecological segregation and may also help us to predict how ongoing species declines will impact the functioning of ecosystems.

1.4 Habitat selection and Partitioning in Crocodiles

Crocodilians show habitat partitioning within their aquatic environments and this preference may be particularly evident when multiple species are sympatric (Magnusson 1985, Rao and Choudhury 1990) in order to avoid competition (Hutton 1989) or predators (Cott 1961). Differential habitat preference by crocodilians has also been attributed to territoriality during the breeding season (Rootes and Chabreck 1933) and to divergent foraging modes (Magnusson et al. 1987). Segregation is between species and also within species based on sizes. Within a species individuals with different sizes have different foraging behaviours and levels of threats. Size-related habitat segregation is known in *Alligator mississippiensis* (Goodwin and Marion 1978), *Caiman crocodilus* (Herron 1994), *Melanosuchus niger* (Herron 1994), *C. niloticus* (Hutton 1989, Kofron 1992) and *C. johnstoni* (Tucker et al. 1997)

In Indian contest only Gharial and Mugger are sympatric (Rao and Choudhury 1990) as both require fresh water unlikely to salt water crocodile (*Crocodylus porosus)*, which prefers brackish water.

Table.11. Previous studies on habitat selection and resource partitioning by sympatric crocodilian species.

SPECIES	REGION	STUDY	AUTHORS
Caiman crocodilus, Melanosuchus niger, Paleosuchus trigonatus & Paleosuchus palpebrosus	Jaú National Park, Amazonas, Brazil	Distribution and abundance, species associations, habitat partitioning	Rebêlo and Lugli 2001
Melanosuchus niger & Caiman yacare	Oxbow lakes of the Ichilo river floodplain, Bolivia	Population estimation, the effect of environmental and anthropogenic variables on distribution patterns	Aguilera et al. 2008
Crocodylus niloticus, Crocodylus cataphractus & Osteolaemus tetraspis	Liberia, Africa	Partitioning of habitats & population estimation	Kofron 1992
Caiman crocodilus & Melanosuchus niger	Anavilhanas Archipelago, Central Amazonia, Brazil	Distribution, abundance & Breeding areas	Silveira et al. 1997
Crocodylus johnstoni	Fossil brook Creek, Queensland.	Habitat selection	Tucker et al. 1997
Gavialis gangeticus	Chambal, India	Habitat features given preference	Taigor and Rao 2010
Gavialis gangeticus	Narayani River, Nepal	Habitat use	Maskey et al. 1995

Melanosuchus niger & Caiman crocodilus	Peruvian Lake, Peru	Spatial Distribution, and Microhabitat Use	Herron 1994
Crocodylus novaeguineae & Crocodylus mindorensis	Papua New Guinea	Variation in Geographic Isolates	Hall 1989
Crocodylus acutus	Everglades, Florida	Nest site selection	Lutz and Dunbar-Cooper 1984
Gavialis gangeticus	National Chambal Sanctuary, India	Basking site selection	Hussain 2009
Melanosuchus niger and Caiman crocodilus	Central Amazonia, Brazil	Nest site selection	Villamarín et al. 2011

1.4.1 Basking Site selection

Thermoregulation involves behavioural and physiological adjustments in order to maintain body temperature within a range. Reptiles bask in sun (heliothermy) or absorb heat from a warm surface (thigmothermy) to raise their body temperature (Huey 1982). Basking being a crucial behaviour involves reptiles for maximum time (Huey 1982) and since they spend a large proportion of their time basking there may be some selection for basking site which gives proper substrata from which heat can be absorbed, provides escape cover, and less effort to reach there.

Gharial prefers sandy banks and islands near to water body (Hussain 2009, Taigor and Rao 2010). Since their limbs are not strong as that of Mugger, it is very difficult for them to reach places that are high, far away from water or requires a high walk. Whereas Mugger has the advantage of high walk, it can bask on a number of substrata. Gharials are intolerant to human presence while Mugger are more generalist, so Gharial require a place that is free from disturbance and they bask on substrate other then sand only when undisturbed sandy sites are not available. Also Gharials prefer those sites that are close to easily accessible escape cover. (Hussain 2009, Taigor and Rao 2010).

Information on basking site selection by Gharial and Mugger is lacking and mostly based on ocular observations and natural history. Full prove scientific information is lacking.

1.4.2 Nest Site Selection

Nest-site selection behaviour is a maternal effect that contributes to offspring survival and variation in offspring that are subject to natural selection (Kolbe and Janzen 2002). Site selection often results in non-random patterns of organism distribution, which are assumed to be the result of natural selection (Martin 1998). Evaluating the nest-site selection offers a tangible way to track habitat selection during an important life-history event with implications for offspring and maternal fitness. Proper nest site selection is an effort towards survival of the hatchlings. Every crocodilian species select specific sites for making nest as few are hole nesters and few make mounds of dead vegetation.

The Gharial is a hole nesting species which selects mid-river sandbars and sandbanks as nesting sites (Whitaker and Basu 1983, Groombridge 1987) and such areas free from predators are given more preference. Mugger too is a hole nesting species and prefers sloping banks of much harder substrate to make nest. Distance to water varies in condition when there is a fluctuation in water level. What makes Gharial and Mugger to select a particular site for nesting is not known properly and there have been no studies on different preferences for nesting sites in same habitat.

1.5 Effect of disturbances on Crocodiles

Major disturbing agents for crocodiles in their aquatic habitat are tourism, sand mining, illegal fishing, pollution, land-use changes, reduction in water flow due to dams, modification of river morphology, loss of nesting sites, egg-collection for consumption and poaching (Whitaker and Basu 1983, Venugopal and Prasad 2003, Hussain 2009). Due to these disturbances crocodile population in India had gone down in 1970s. In 1975 steps were taken towards the conservation of crocodilians in India. By 1995 population of crocodiles was made secure in wild through reintroduction programmes (Hussain 1999). From 1999 to 2007 there has been a decline of 58% in the population of Gharial while Mugger and saltwater crocodiles are doing relatively well (IUCN 2007)

Tourism also creates pressure on crocodiles. Areas with heavy tourism activities are generally avoided by crocodiles (Venugopal and Prasad 2003) but due to continuous trips of mechanised boats in crocodile areas, crocodiles exhibit a behavioural change by becoming habitual to human presence (Venugopal and Prasad 2003). However, such habitual adaptation also infringes on their natural behavioural patterns whose impact on their life history parameters has not been studied.

1.6 Study Species

Crocodiles are large aquatic reptiles and are one of the most primitive animals on the earth. Found throughout the tropics in Asia, Africa, America and Australia. Of the twenty three species of crocodilians India is home to three: Gharial (*Gavialis gangeticus*), Mugger (*Crocodylus palustris*) and saltwater crocodile (*Crocodylus porosus*). All the three species have been accorded highest protection by the Indian Wildlife (protection) Act, 1972 and have been placed under Schedule I. Of the three species, the Gharial has been listed as critically endangered by the World Conservation Union (IUCN) (Whitaker and Basu 1983, Stevenson and Whitaker 2010). Two of the three species occurring in India i.e. Gharial and Mugger were studies in this dissertation work in Katerniaghat Wildlife Sanctuary. Both are sympatric in north Indian rivers (Ganges, Chambal, Son, Ramganga, and Girwa) and in Mahanadi in east (Rao and Choudhury 1990) (Fig 1.1).

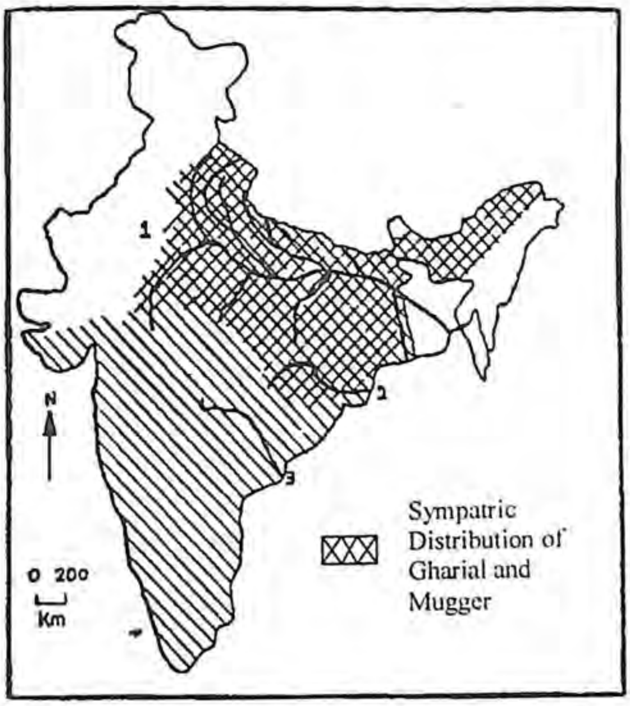


Figure 1.1 Sympatric distributions map of Gharial and Mugger (Rao and Choudhury 1990)

1.6.1 Gharial (*Gavialis gangeticus)*

The Gharial (*Gavialis gangeticus*) is a sole member of the family Gavialidae, a long-established group of crocodile-like reptiles with long, narrow jaws. *Gavialis* is a miss-spelling of the Hindi word *Gharial* which is a name for "crocodile". *gangeticus* means "of the Ganges (River)", where *-icus* means "belonging to" (Latin) Word *Gharial* refers to the *ghara* (Hindi for "pot") - a swelling around the nostrils of mature males used for communication (sound). *Ghara* has several functions attributed to it: a vocal resonator with which the Gharial can produce a loud buzzing noise during social behaviour, a visual stimulus for females during courtship, and an aid to producing bubbles also during courtship (Martin and Bellairs 1977). Gharial is endemic to the Indian sub-continent. It was once common in the river systems of Pakistan, northern India, Bangladesh, Myanmar, Bhutan and Nepal (Whitaker and Basu 1983, Whitaker 2007, Hussain 1999, Hussain 2009). But now it is found only in the Gangetic and Mahanadi river system in India and in the Narayani-Rapti and Karnali-Babai river system in Nepal (Bustard & Choudhary 1981, Whitaker 2007) (Fig 1.2).

Gharials are adapted to an aquatic lifestyle in the calmer areas of deep, fast-moving rivers (Whitaker and Basu 1983). Sandbanks on such rivers are exposed seasonally, sometimes in different areas as the banks are moulded by the river flow over time. Gharials concentrate around these sandbanks during the dry season making them more vulnerable to disturbance. The Gharial is poorly equipped for locomotion on land, and adults cannot lift their bodies clear off the ground. It usually leaves the water to bask and nest, both of which usually occur on sandbanks.

The diet changes from juveniles to adults - the juveniles are well suited to deal with a variety of invertebrate prey such as insects and smaller vertebrates such as frogs. Adults, however, are almost exclusively fish-eaters (Whitaker and Basu 1983). There have been accounts of larger gharials being more opportunistic and taking larger prey, including mammals, but this seems extremely rare (Whitaker 2007). Gharials are not considered a threat to humans. They have occasionally been blamed for human fatalities, but there is no evidence to back this up. Human remains and jewellery have been found in their stomachs and were thought to validate this fear, but these are most likely to have been scavenged from the dead - the Hindi funeral ritual ends with the remains of the cremated body being sent down the river. Jewellery is possibly ingested in the same way that stones would be in order to be used as gastroliths - hard objects which aid in digestion.

Females reach sexual maturity around 3 m in length (usually over 10 years old). Males guard a harem of several females. The mating period occurs for two months during November, December and into January. Nesting occurs in March, April and May (the dry season) where hole nests are dug into seasonally-available riverine sand banks. Between 30 and 50 eggs (average of 37) are deposited into the hole before it is covered over carefully (Whitaker and Basu 1983). The size of the eggs in Gharials is the largest for any crocodilian species, weighing on average 160 grams. After 83 to 94 days, the juveniles emerge, although the female has not been observed assisting the hatchlings to the water as in many other crocodilian species. This is perhaps because of the unsuitability of their jaws for carrying hatchlings, and also because of their needle-sharp teeth (Singh and Bustard 1977). However, protection of the young by the mother crocodile does occur around the nesting area for some time after hatching.

The Gharial is one of the most endangered of all crocodilians, and the most endangered large aquatic animal on the Indian subcontinent (IUCN Red List). The Gharial, in spite of its high fecundity and a massive egg collection/head-starting/release programme (12,000+ eggs collected, 5,000+ young Gharial released) is faring much worse than the tiger, another critically endangered animal in India. Breeding populations of Gharial survive in only 3 reserves in India, namely, Katerniaghat, Chambal and the Son, and one in Nepal at Chitwan (Gharial Recovery Action Plan, 2006). There are an estimated <200 breeding adult Gharial left in 3 places in India where 88 nests were recorded and one location in Nepal where 6 nests were recorded in 2006 (Gharial Recovery Action Plan, 2006). This represents a decline in the population of over 80% since the 1940s (a time-span equating to roughly 3 generations), and qualified it for Critically Endangered (CR) listing on the IUCN Red List (Choudhury et al. 2007). The drastic reduction in Gharial numbers over a 60-year period is attributed to a number of factors such as habitat alteration/ destruction, hunting/poaching for skins, killing by fishermen, killing for medicinal uses, egg collection, and accidental drowning in fishing nets. Human influences on riverine habitat are a major threat to the Gharial, with sand-mining, agriculture, irrigation channels, dams, barrages, modifications to river course all combining to create an irreversible loss of Gharial habitat (IUCN 2009).

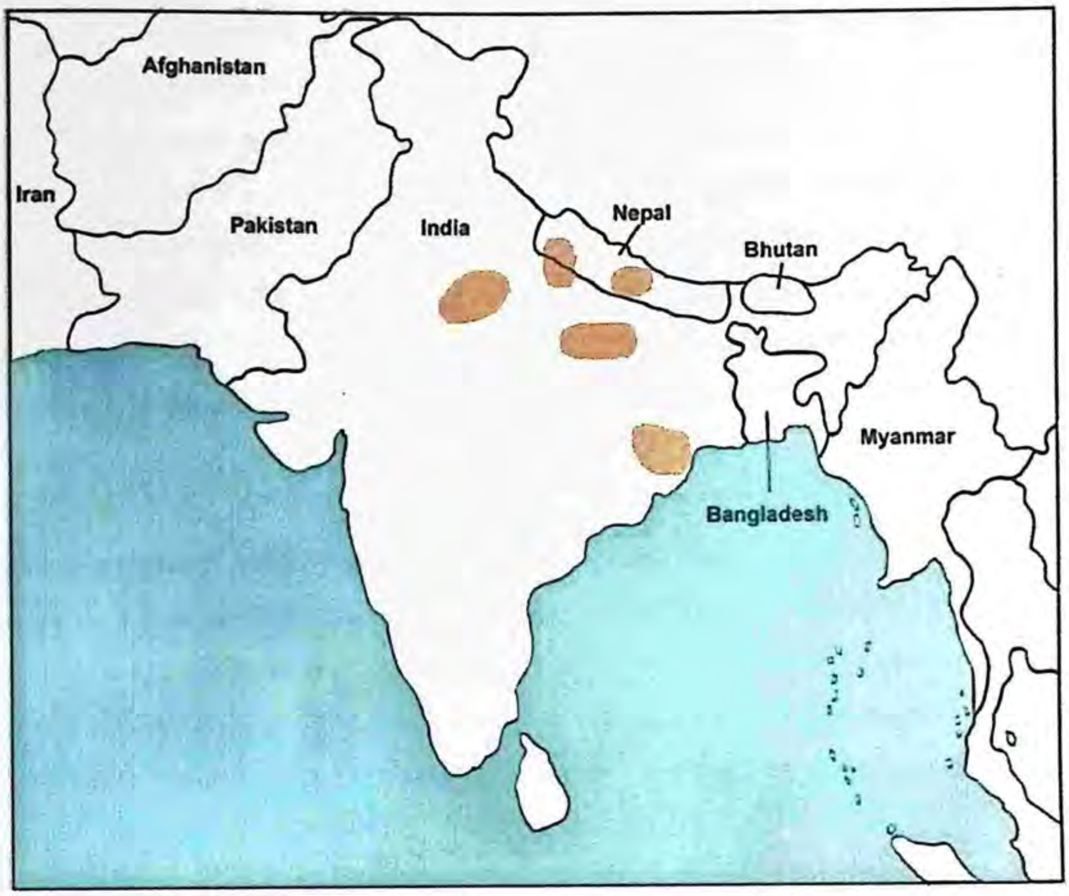


Figure 1.2 Distribution map of Gharial (Stevenson and Whitaker 2010).

1.6.2 Mugger (*Crocodylus palustris*)

The Mugger (*Crocodylus palustris)* a medium to large crocodile belongs to family Crocodylidae also called marsh crocodile is found throughout the Indian subcontinent and the surrounding countries. *Crocodylus* is derived from the Greek *krokodeilos* which means "pebble worm" (*kroko* = pebble; *deilos* = worm, or man) referring to the appearance of a crocodile. *palustris* means "marshy" or "swampy" (Latin), referring to extensive habitat where it is found, and hence one of its common names "Marsh crocodile". "Mugger" is a corruption of the Hindi word *magar* which means "water monster". Colour is generally light tan in juveniles, with black cross-banding on body and tail. Adults are generally grey to brown, with little banding remaining. This is a medium to large species (4 to 5 m). The snout is the broadest of any member of the *Crocodylus* genus, giving the Mugger a more alligatorine appearance.

Mugger prefers freshwater lakes and marshes, slow-moving, shallow rivers. In India, Pakistan, Sri Lanka and Iran (Fig 1.3), *C. palustris* has adapted well to reservoirs, irrigation canals and man-made ponds and occasionally reported from saltwater lagoons (Whitaker 1987; Whitaker and Whitaker 1984; Whitaker and Andrews 2003). Sympatric with *Gavialis gangeticus* in some areas of India (Rao et al. 1990), but usually separated by habitat. When found together with Gharial, Mugger will bask on midstream rocks or muddy banks (Groombridge 1982). They have been reported to migrate considerable distances over land (several km) in search of more suitable habitat (Whitaker 1977, Whitaker and Whitaker 1979).

Females reach sexual maturity at around 1.7 to 2.0 m in length (usually around 6 years old), while males mature at about 2.6 m (10 years old) (Whitaker and Whitaker 1984). Nests are holes excavated during the dry season (from December to February). Location of the nest varies considerably (even within burrows on rare occasions, which is unusual as they are not normally associated with breeding activities), but they are most commonly found on sloping banks. The female usually lays 25 to 30 eggs (although this may range from 10 to 48 eggs). However, captive specimens have sometimes been observed laying two clutches per year (Whitaker et al. 1984) but this has yet to be observed under natural conditions. Eggs hatch after a relatively short period, usually 55 to 75 days, and the juveniles are around 30cm long at hatching (Whitaker 1987). Research into the effects of temperature upon sex of the embryo (Temperature-dependant Sex Determination - TSD) has revealed male-only embryos at 32.5°C, with a greater percentage of females produced below and above this (Lang 1987). Female-only embryos are produced between 28°C and 31°C. While the female usually guards the nest, opens it and transports hatchlings to the water in her mouth, the male has been observed undertaking this task in captivity.

By the late 1960s, their populations were exterminated to extremely low numbers (Whitaker and Daniel 1978), mainly due unregulated hunting for skins, but now the threats come from habitat destruction (considerable agricultural and industrial development), mortality in fishing nets (as they attempt to capture ensnared fish), egg collecting and illegal hunting (including the use of parts for medicinal purposes). Habitat degradation through damming and channeling of river systems for irrigation, have caused severe fragmentation of habitats and populations throughout the species' distribution range. South India's largest wild breeding population at Amravati reservoir in Tamil Nadu had a mere 14 breeding females & of north at

Hiran lake in Gir National Park, with 20 breeding females (Whitaker et al. 1991. Although a number of populations exist throughout its range, they are isolated and their numbers are low. Several populations are feared to be extinct (e.g. Bangladesh, Myanmar). The largest populations are present in Sri Lanka, and are estimated to be around 2000 animals. In India, estimates of between 3000 and 5000 animals have been made, but these are split up into over 50 small populations.

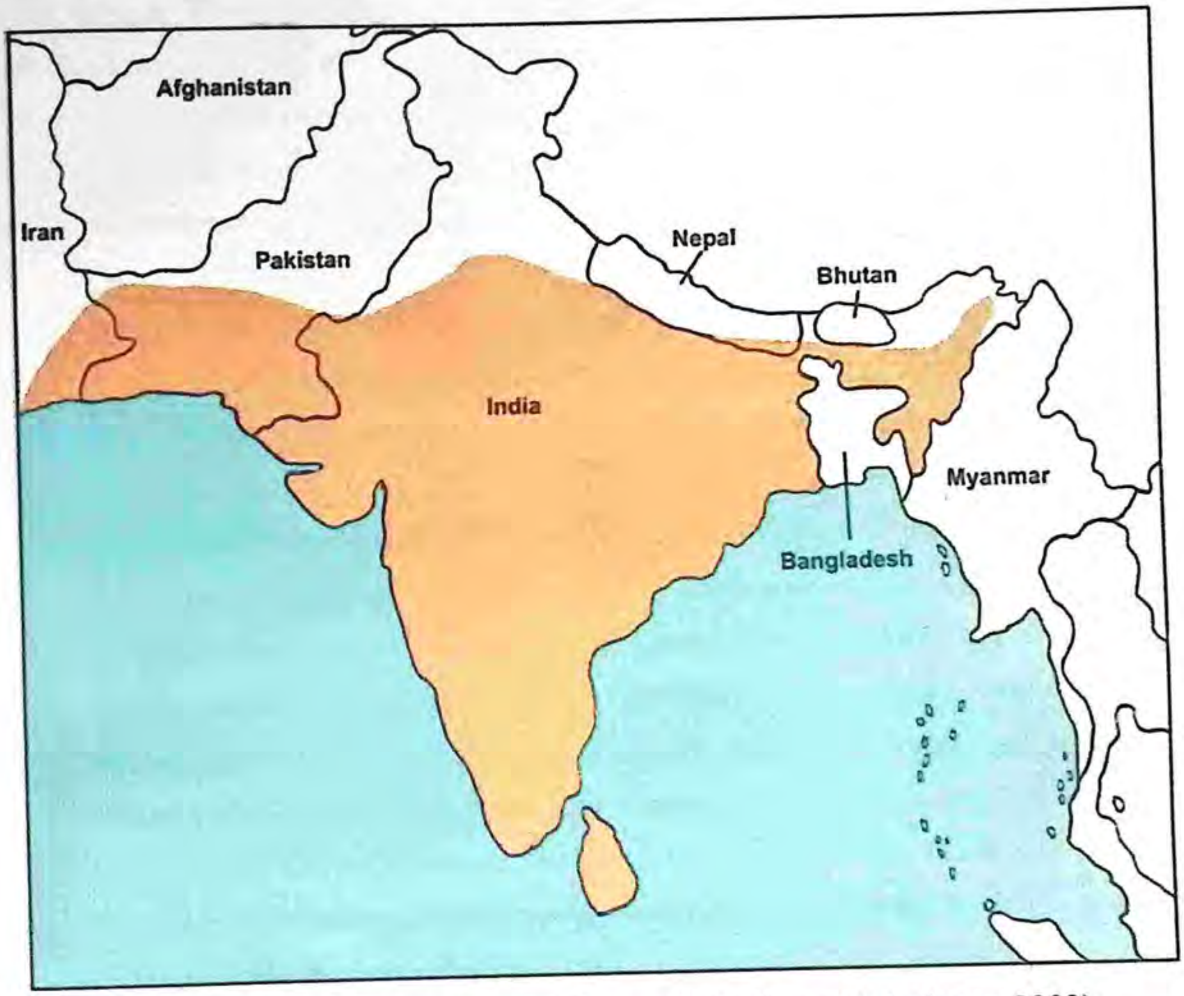


Figure 1.3 Distribution map on Mugger (Whitaker and Andrews 2003).

1.7 Project justification

Among the fresh water species of India Gharial appeared first during evolution and got adapted to a life of perennial rivers while Mugger came much later. The disappearance of Gharial from peninsular India may have been due to, in the past, competition with 'evolutionary young' and 'versatile' Mugger (Singh 1991). Today all Gharial habitats in the country contain Mugger as well (Gharial recovery plan 2006). Till 1970s-1980s Mugger numbers in all Gharial habitats was comparatively less, which lead to suspect that after invading peninsular India Mugger radiated in North (Singh 1991). Number increased due to conservation mistakes committed by releasing large number of Mugger in Gharial habitat and due to increased pressure on marshland because of its need for conversion into agricultural fields or for other developmental use. This study will throw some light on whether Gharials will have same fate in north India or successfully partition resources with Mugger will help their survival. The proposed study attempts to examine resource partitioning and pattern in site selection for basking and nesting sites between Gharial and Mugger, effect of disturbance which being very important aspect of their behavioural ecology and for conservation implications. The study further examines the feasibility of restraint on reintroduction of mugger in predominant Gharial habitat.

- Study of the inter relationship between Gharial and Mugger has been recommended by the Gharial Multi-Task force, 2006 to determine whether an impact of human induced increase in Mugger numbers in Gharial habitat is detrimental to Gharial survival.
- Crocodiles spend time on land and in water in the same area. As both are obligate carnivores, there may also be a dietary overlap. How much overlap and how resources are partitioned to ensure co-existence is unknown. Very few studies has been carried out on habitat selection and preference (Whitaker & Basu 1981, Singh 1978 & Hussain 2009) but not on resource partitioning among these sympatric species, as earlier studies focused mainly on their status and conservation implications with foremost objective of increasing the population. Therefore information on habitat selection and utilization patterns among these sympatric crocodile species is lacking (Rao & Choudhury 1990).
- This study will help in identification and dynamics of communal Gharial nesting and basking sites, which is very important to know, to provide protection to those sites
- This study will examine the current method of population estimation being practiced (census figures from 2005 onwards are available), for developing a population trend and to develop a simplified robust technique.

1.8 Objective & research questions

The main objectives of the proposed study are:

1. To estimate the relative abundance and population structure of Gharial and Mugger populations in Katerniaghat wildlife sanctuary and investigate their variation due to Riverine habitat structure, seasonality and disturbance based on data of basking individuals.
2. To compare and describe habitat utilisation against habitat availability between Gharial and Mugger in terrestrial environment.
3. To examine the means of available resource partitioning resorted to in time, space and season by various size-classes.
4. To see the effect of tourism & fishing on the crocodile population.

The pertinent questions with respect to these objectives are:

1) **Relative abundance and population structure**
   a) What are the relative abundance and which size class dominates for both species in the population structure?
   b) Is there any effect of season and temperature on the encounter rate?
   c) To identify the critical habitat hot spots or places preferred by Gharial and Mugger
   d) To investigate the response of Gharial and Mugger encounter rate to varying intensities of anthropogenic pressure.

2) **Habitat utilization**
   a) How basking habitat use of Gharial and Mugger differ from habitat availability?

3) **Resource partitioning**
   a) Is there any difference in basking site selection & requirements between Gharial and Mugger?
   b) Is there any difference in nest site selection & requirements between Gharial and Mugger?
   c) Is there temporal separation for basking between these two species with respect to size class?

d) What is the inter & intra specific nearest neighbour distance in basking individuals?

4) **Response to tourism & fishing**

   a) Is there is a difference in flight distances of Gharial and Mugger from mechanised and non- mechanised boat in terms of anthropogenic disturbances?

2. STUDY AREA

2.1 General

Katerniaghat Wildlife Sanctuary along with Kishanpur wildlife sanctuary and Dudhwa National Park forms Dudhwa Tiger Reserve. Katerniaghat Wildlife Sanctuary was founded in 1975 and is an integral part of the Terai Eco-system. The geographic coordinates of the sanctuary are 81° 11' East 28° 15' north. Katerniaghat Wildlife sanctuary lies towards the eastern side of Dudhwa National Park (Fig 2.1). The Indo Nepal border constitutes the northern boundary of the wildlife Sanctuary. It has an area of 400.09 sq km. The Sanctuary, together with the adjoining 150.03 km² of Reserve Forests, which serves as buffer, constitutes one ecological unit. It is one of the few remnants of the rich and diverse Terai ecosystems, and a trans-boundary protected area having connectivity with Bardia National Park in Nepal which lies to the north of Katerniaghat WLS through Khata corridor.

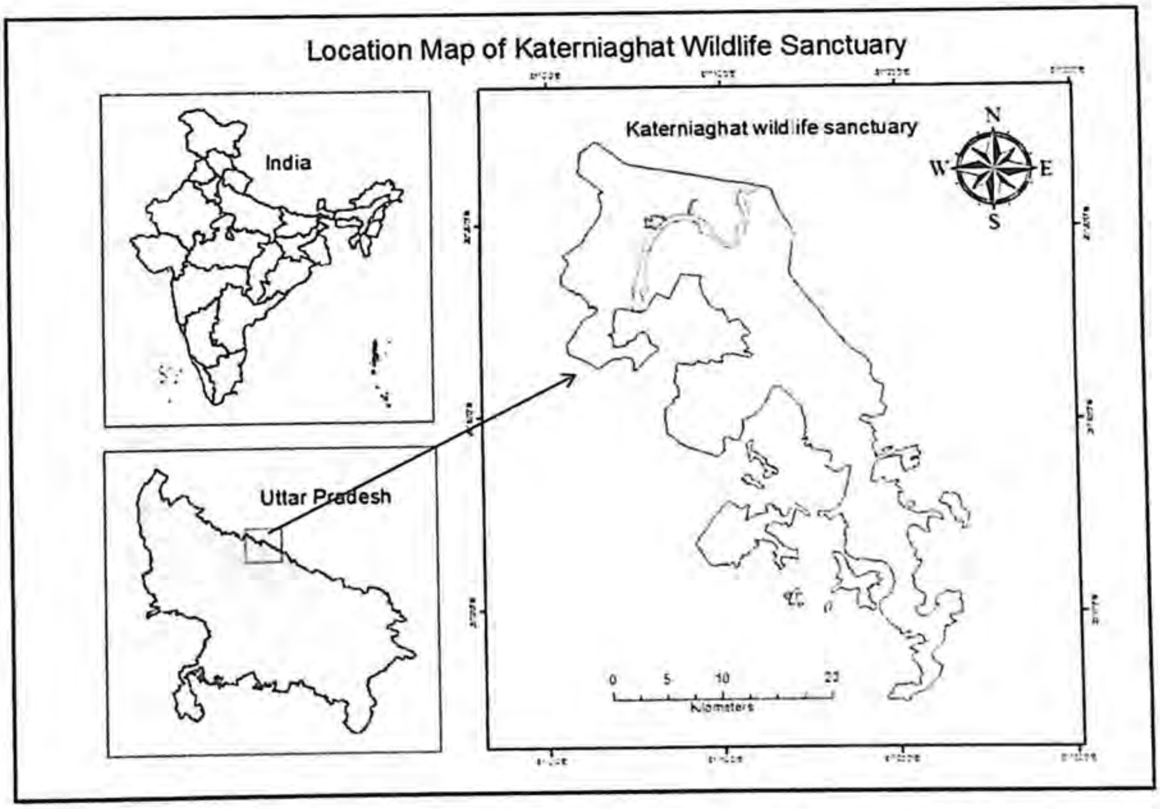


Figure 2.1 Location Map of Katerniaghat Wildlife Sanctuary, India

2.2 Geology, Rock and Soil

Katerniaghat Sanctuary lies on the alluvium of the Gangetic plain, in which three main types of soil are found:

(a)The low alluvium consisting of large areas in the north and along the eastern boundary of the WLS.

In the low alluvial tracts of the Kauriala and Saryu rivers, the soil is almost pure river sand, enriched in many places by a deposit of fine silt, and in these localities, Sissoo (*Dalbergia sissoo*), Khair (*Acacia catechu*), Semal (*Bombax ceiba*) and various other miscellaneous species of a similar habit of growth are found in varying quantities . Tree growth rapidly becomes established on the courses of the rivers wherever the soil conditions are suitable. Practically, throughout the northern portions of the Kauriala basin, a stratum of shingle and water worn boulders occur at variable depths

(b) The middle alluvium in the south of the WLS.

In the middle alluvium, which is of earlier origin than the low alluvium, the soil is sandy but has a certain admixture of vegetable matter.

(c) The high alluvium consisting of the rest of the WLS.

In the high alluvium, the following types of soil are found:

- A light sandy loam, rich, moist, and containing vegetable moulds to a depth of two feet or more. This type supports the best tree growth and on it occurs the best quality Sal forests.
- A heavier loam with varying proportions of clay and a fair amount of vegetable mould. This type of clayey loam is fairly fertile, but is inferior to the light loamy soils, and where there is a large proportion of clay, Asna (*Terminalia alata*) is the predominant species.
- A Stiff infertile clay containing manganese dioxide and with reefs of kankar from place to place, many of which have become exposed as a result of erosion.

2.3 Hydrology and Water Sources

The Katerniaghat WLS is very rich in terms of water sources. The main rivers flowing through the Sanctuary are:

(i) Girwa

(ii) Kauriala

(iii) Ghagra

(iv) Saryu

The rivers Kauriala and Girwa that are actually two halves of the river Karnali branching out well before entering India from Nepal recombine at Girijapuri barrage. Not far from the meeting point of the duo, a perennial stream (Nalla) called Patalchuli also drains off and after the confluence the system forms the river Ghagra. The confluence presents not only a rare scenic beauty, but also attracts a large number of birds including the migratory ones. The system incorporates dozens of islands, the exact number and their sizes varying according to seasons, which constitute excellent habitats for chital, sambar, hog deer, Tigers, elephants & occasional Rhinos. The WLS has very good network of streams ending up eventually into one of the above rivers, the important ones being.

The WLS has very good network of streams (Nallas), tals & swamps ending up eventually into one of the above rivers.

2.4 Climate

There are three distinct seasons approximately as follows:

Cold weather - mid October to mid March

Hot weather - mid March to mid June

Rainy season - mid June to mid October

Winter : In winter the days and nights are generally cold and foggy. The month of January is the coldest with mean maximum temperature of 23.7°C and mean daily minimum temperature of 6.6°C. In winter the dewfall is quite severe with the vegetation remaining damp until about the middle of the day. Frost is common in the grasslands (phantas). In the months of December to middle of February it is usually quite severe. The months of February to early part of April are very pleasant.

Summer : The months of May and June are the hottest with the maximum temperature ranging between 40°- 44°C. The high temperatures during the daytime are associated with hot westerly winds (loo). The nights are moderately cool until the beginning of May.

Monsoon : The rainy season generally begins in the middle of June and lasts up to September. The day and night temperatures during the months of July/August are between 37.2°C and 19.8°C respectively. This period accounts for about 90% of total annual rainfall. The total annual rainfall is about 223cm.

Wind : The prevalent winds are westerly, gathering in strength with the onset of summer. Hot winds (loo) blow very strongly from the middle of April up to the end of May. These are then replaced by easterly winds, which are prevalent during the rainy season. Northern winds also occur during the month of June. Storms are rare.

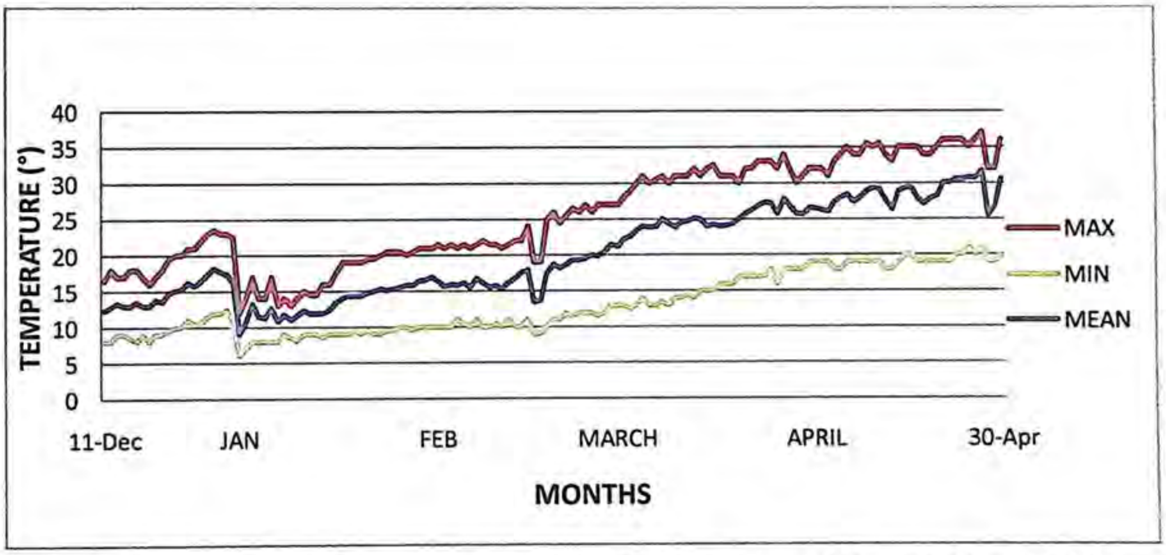


Figure 2.2 Maximum, minimum and mean daily temperature of Katerniaghat Wildlife Sanctuary from 11 Dec 2010 to 30 April 2011

2.5 Flora

The rich soils of Terai coupled with an annual precipitation of over 1300 mm result in great diversity of vegetation in the WLS. The vegetation varies from dense moist tarai Sal forests to large open grasslands. The vegetation close to Girwa River and its tributaries is characterized by the presence of dense canebrakes. Some artificial regeneration of exotic and indigenous species has also been done in past. The Katerniaghat WLS represents the tarai-bhabhar bio-geographic sub-division of Upper Gangetic Plains.

As per Champion and Seth's classification the following forest types are recognized.

(i) The Sal forests

3C/C2b Moist Bhabhar Sal

3C/C2b Moist Bhabhar Sal/5B/C1b Dry Plains Sal

5B/C1b Dry Plains Sal

(ii) The Miscellaneous Forests

3/E1 *Terminalia alata forests*

1/E1 Cane brake

4D/SSI EasternSeasonal Swamp Forest/4D/SS2

Barringtonia Swamp Forests

3/1SI Low Alluvial Sawannah Woodland *Bombox-Albizzia*

5B/C2 Northern Mixed Deciduous Forest

5/E6 Aegle Forest

5/Is2 Khair-sissoo Forest

(iii) Grasslands

3/ISI Low Alluvial Savannah Woodland *Bombax- Albizzia*

2.6 Fauna

Katerniaghat wildlife Sanctuary has a vast and varied heritage of fauna. The innumerable large and small taals, rivers and streams, vast grasslands, densely forested areas, open woodlands and mixed forests provide a unique admixture of shelter, food and habitat conditions for wild life. Major terrestrial mammals comprises of Tiger, Leopard, Asiatic Elephant, Great Indian one-horn Rhinoceros, Barking deer, Hog Deer, Chital, Sambar, Fishing cat, Leopard cat, Wild Boar, Palm civet and small Indian civet. Major aquatic and semi aquatic fauna that can be seen in the sanctuary are Gharial, Mugger, Gangetic Dolphin, Fresh water turtles, Otters, resident & migratory waterfowls. Among reptiles cobra, python, banded krait, rat snake monitor lizard are commonly seen.

2.7 Girwa River

The Girwa River originates in Nepal and runs through the Katerniaghat block of Katerniaghat Wildlife Sanctuary. Though the Sanctuary is spread across 400 sq. km. the prime Gharial habitat in this river of 21 km is only 3-5 km (Singh, 1978). Although it does not suffers the same pressures as in the Chambal. The environment of Katerniaghat Wildlife Sanctuary is dynamic, with the course and water levels of the river changing drastically seasonally, in turn drastically altering the sand bars and banks upon which Gharials depend. The river has many nalahs, taals and swamps running into and out of it.

Table 2.1 List of major nallas, taals and swamps of Girwa River in Katerniaghat Wildlife Sanctuary

NAME	SEASONALITY/ AREA
Maili Nalla	Seasonal
Maila Nalla	Perennial
Mahadeva taal	Perennial
Damdama taal	Perennial
Choti Belli swamp	200 ha area
Badi Belli swamp	300 ha area

Figure 2.3 Google image of study area with ten segments (2km each) in Girwa River of Katerniaghat wildlife Sanctuary

3. METHODS

3.1 Reconnaissance and Selection of study area & methods

The entire river stretch was surveyed several times in the beginning of the study period, to get familiarised with the area and to identify areas that harboured both Gharial and Mugger population. Out of the 18 km of the main river only 14 km was taken as Intensive Study Area (ISA). Four outermost segments (upstream & downstream) were excluded from the sampling area since the river was shallow upstream and was difficult to cover even with non-mechanised boat. Areas of downstream were auctioned for fishing even though they were part of the sanctuary & disturbance factors were high. Length of tributaries to be included was also fixed according to the feasibility. A day was divided into 4 time blocks i.e. 6am – 9am, 9am- 12pm, 12pm-3pm & 3pm – 6pm, based on observation of activity patterns during survey. Segment length was decided based on how many kilometres could be surveyed in 3 hrs allowing sufficient time for data collection. Identifying Gharial and Mugger from a distance and visually estimating their size was also practiced during this period.

3.2 Sampling Methods

3.2.1 Habitat Availability

The 14 km main river stretch chosen as Intensive Study Area was divided into 7 segments & 6 km of tributaries into 3 segments, each 2 km in length. Segments were marked on trees along the river bank by pasting a number cut out of radium paper along with GPS locations. A buffer of 50m terrestrial area along both banks was taken. Available habitat was quantified by systematic sampling. In each segments Data Recording Points (DRP) were laid at every 100 m on both banks and on sand bars if present (Fig 3.1). DRP were marked by round radium stickers along with GPS locations. Habitat variables such as temperature (ambient, water and soil), slope, height, soil type, soil moisture, distance from vegetation, depth profile, and land use were collected from every DRPs.

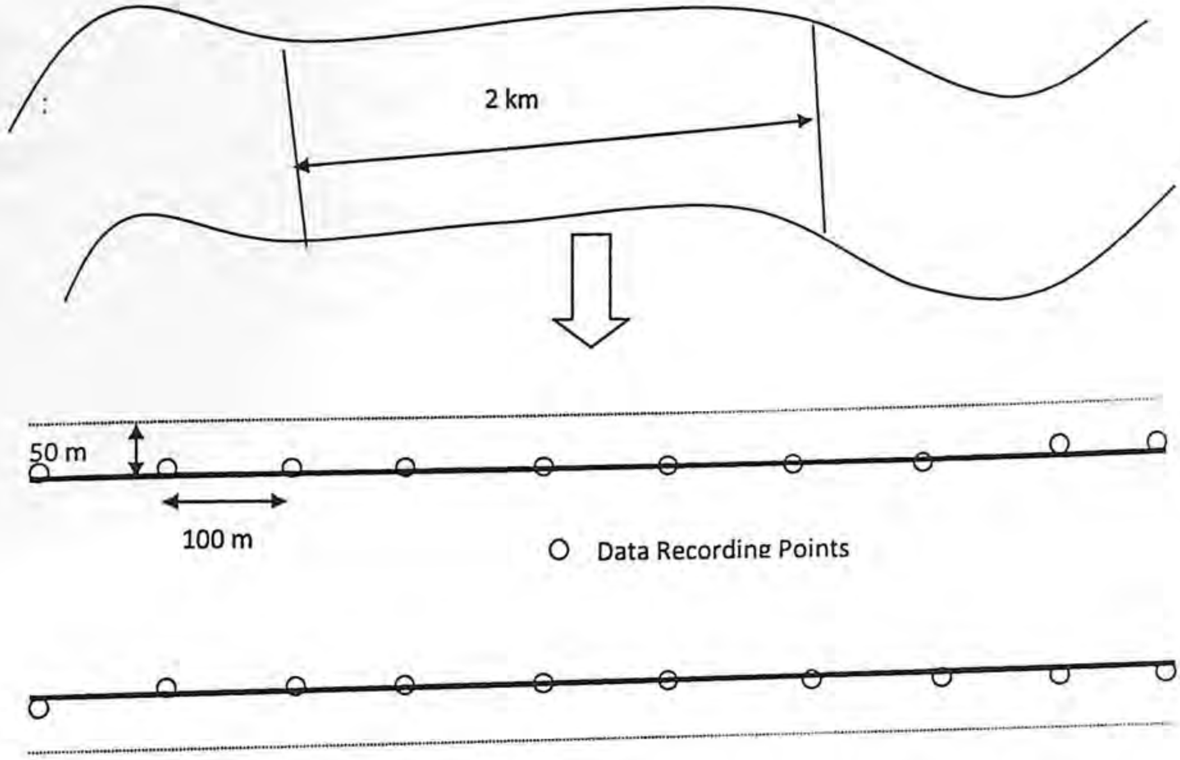


Figure 3.1 Rough layouts of segments and Data Recording Points on Girwa River in Katerniaghat wildlife Sanctuary (Dec 2010 – April 2011).

3.2.2 Basking habitat use

Each segment was sampled once a month in all 4 time blocks. A country boat was used for this purpose. Only direct sightings were taken into consideration. For basking habitat selection, location of all basking Gharial and Mugger was recorded using a handheld Garmin 72 Global Positioning Unit and individuals were categorised into 3 size-classes i.e. hatchlings and juveniles (<1.5 m) sub-adults (1.5-2.5 m) and adults (>2.5m) (Personal communication, Choudhury). Habitat parameters such as ambient, soil and water temperature, soil type and moisture, distance from water and vegetation, nearest neighbour and nearest neighbour distance, slope, height, depth of river, current land use, were measured for every occupied site.

3.2.3 Nesting habitat use

Nests were located with the help of the Katerniaghat Wildlife Sanctuary staff by quickly surveying the whole river stretch and searching spoor marks of crocodiles every morning from 20th March onwards. Nests were located by following Gharial and Mugger spoor marks (Singh, http://www.wildlifeorissa.in/croctracking.html# Tracks of 'high-walk' to distinguish Gharial and Mugger) along the river banks, and probing suspected nest locations with a metal probe (Blake, 1974). Damaged eggs were removed from the nest immediately. Nests were identified based on the size of the egg and spoor marks of the individual. If it is a drag mark then it is of Gharial and if spoor mark is a raised walk then nest is of Mugger. GPS location and habitat parameters such as slope, soil type, height, distance from water and vegetation were recorded for all nests.

3.2.4 Temporal separation

For temporal separation of activities of Gharial and Mugger, two species of crocodiles from a watch tower were observed every alternate Monday (when tourism pressure was less) during 0600 – 1800 hrs from 20.12.2010 to 25.4.2011. 6am to 6pm. A stretch of 5 km (4km to 9km) was visible from the watch. Time, ambient temperature and location of individuals (in water, half-submerged and on land) were recorded for both species along with size class at an interval of one hour. Temperature profile of the study period was maintained by recording hourly ambient temperature on a daily basis during the observation duration.

3.2.5 Association

Nearest neighbour and nearest neighbour distance for different size classes of Gharial and Mugger was measured. Basking individuals were approached as near as possible. Aided with photographic capture and binoculars sequences of size class of individuals was noted before they rushed into water. Further confirmation was done using spoor marks and distance between spoor marks measured with a measuring tape. Presence of other species was also recorded.

3.2.6 Effect of disturbance

To investigate effects of disturbance on habitat use, an inventory of disturbances was made. Land usages was classified as: grazing (G), human habitation (H), fishing (IF), tourist boat (T), transport boat (S), SSB boat (SB), SSB camp (SC), wood collection (WC), path (P) etc. Current land usage for every segment was recorded at every 100 metre. No of sightings, were also recorded segments wise to compare disturbed and undisturbed areas. For the effect of tourism on basking behaviour of both Gharial and Mugger, wariness of both the target species with size class was recorded from mechanised and non-mechanised boats. The distance to which an animal can be approached before it escapes is an indicator of response to disturbance caused by man, often referred to as wariness or flight distance or approach distance (Pacheco 1995; Venugopal 2003).

3.2.7 Relative abundance & Population Structure

Relative abundance and population structure of the two crocodile species was obtained from systematic search based on direct observation. Active searches were conducted during the mid day between 0900 to 1700 hrs in sunny days on the last date of every month from December to April. The best season for crocodile survey is post winter and pre summer month, i.e. January-March. During this period the temperature conditions are such that crocodiles bask for longer periods and visibility is good for sighting. This is also the courtship season and breeding groups tend to bask in groups (Choudhary and Rao 1982, Rodgers 1991). Number of Gharial and Mugger were recorded with size class and segment wise. Night survey was not possible firstly because of initial lack of permission for night survey secondly due to logistic problem and finally river was very wide and it was difficult to identify crocodilians at the species level from a distance eye-shine.

3.3 Habitat Parameters

Ambient, soil and water temperature

Ambient temperature was recorded with a mercury thermometer at an interval of 1 hr. For basking sites, surface temperature was measures.

Soil moisture

Soil moisture was measured with a moisture meter at the surface for occupied basking sites.

Soil type

Soil texture was determined by jar test .Collected soil sample (with the help of soil auger of 15 cm) in a jar with 2/3rd filled with clean water was shaken until all the soil particles were broken and suspended in water. By allowing soil to settle got different layers of sand, silt and clay. Plus I used standard soil texture figure tests (http://www.cmg.colostate.edu/).

Slope

Slope of basking & nest site was measured by using Sunnto MC-2 Compass/Clinometer.

Height

Height of the basking platform and nest was measured by a measuring tape. A long bamboo pole was kept perpendicular to the nest site or basking site and its height from water was measured.

Water depth

Water depth was recorded for the basking site at 5 m intervals from the site, up to a distance of 50 m (Nair, 2010) by using stone tied to a measuring tape.

Distance from water and vegetation

These distances were measured by a measuring tape. Occupied basking site or nest was taken as one end.

4. RELATIVE ABUNDANCE & POPULATION STRUCTURE

4.1 Main objective

Katerniaghat Wildlife Sanctuary, in spite of harbouring the second largest breeding Gharial population within its distribution-range, lacks reliable information on abundance of Gharial and Mugger populations. Hence it was important to assess the population status of Gharial and Mugger in the study area. Also abundance being the central parameter in ecological science was a prerequisite of inferring about how the two crocodilian species partitioned their resources. The relative abundance of Gharial and Mugger based on basking individuals was estimated to address the following objectives:

1) Population structure determines the health of a population. First objective was to compare the population structure of the two crocodilian species, and to test the null hypothesis that population performance (consequence of breeding vs., mortality) was similar between them.

2) Basking activity of crocodiles depends largely on temperature. Expectedly they would bask more in winter than summer. However the changes in basking rate with seasonal factors (temperature) are rarely quantified, although such information is important for various reasons, say for choosing the time window to census population based on basking individuals. Second objective was to assess whether encounter rate of basking individuals changed across the study period (December to April), and hypothesis that basking rate would decrease from winter to summer was tested.

3) Selection of space by animals can arise from simple to complex interplay of environmental factors and ecological history. Third objective was to identify spaces preferred by the two crocodile species (in my case river segments) or their critical habitat hotspots. Identifying Gharial critical habitats hotspots was extremely important to offer more protection to those river stretches in order to manage the critically endangered species.

4) Considering the Critically Endangered status of Gharial, fourth objective was to investigate their response to varying intensities of anthropogenic pressure, and hypothesis of no influence of disturbance on population was tested.

4.3 Methods of data analysis

4.3.1 Relative abundance and population structure

Crocodile sightings from five repeats of day surveys in a month from December 2010 to April 2011 were segregated into size classes for each species. From this data, mean encounter rates per 20 km (number of total sightings/total distance covered) were estimated. Population pyramid was computed from population structure of size classes for both Gharial and Mugger. Microsoft Excel 2007 was used for graphically representing the results.

4.3.2 Effect of seasonality on encounter rate

Mean encounter rate per 20 km of different size classes of Gharial and Mugger was separately estimated for each month and their correlation with mean, maximum and minimum monthly temperatures was computed by Pearson's Correlation analysis to investigate the effect of ambient temperature on the relative abundance of basking individuals.

4.3.3 Encounter rate and habitat

Encounter rate for each 2km segment of all three size classes of Gharial and Mugger was calculated to understand to preferred critical habitat hotspots for basking.

4.3.4 Encounter rate and disturbance

Each disturbance factor was recorded as '1' if present and '0' otherwise on 40 data recording points at 100 metres interval in each river segment, and summed to generate a synthetic disturbance index for segments. Encounter rate of all size classes of Gharial and Mugger was calculated for each segment. Presence or absence of sand bars (islands) in the segment was also recorded. Generalised linear regression (identity link and Gaussian error distribution) was used to model encounter rate with disturbance index and presence/absence of sandbar across segments. Four alternative ecological models were constructed from combinations and interactions of these two variables in Program SPSS version 16.

Models were as follows:

1) ER = a + b disturbance [Ho: b_1=0, Ha= b_1>0]

2) ER = a + b sand bar [Ho: b_1=0, Ha= b_1>0]

3) ER = a+ b sand bar * disturbance [Ho: b_1=0, Ha= b_1>0]

4) ER = a + b_1 sand bar + b_2 disturbance

First model depicts encounter rate as a function of disturbance only. Second model depicts encounter rate as a function of presence of sand bars only. Third and fourth model depicts encounter rate as a function of interaction and combination of disturbance and presence of sand bars. The smallest AIC model was selected as the best model and influence of these variables on segment encounter rate was interpreted using this model.

4.4 Results

4.4.1 Relative abundance and population structure

Out of 928 sightings of crocodiles during the study period (Dec 2010 to April 2011), 718 were of Gharial and 210 were of Mugger. Relative abundance of Gharial juvenile was highest with mean encounter rate of 57±10.3 followed by Gharial adult with mean encounter rate of 49.2±8.5. Mugger juvenile had the lowest encounter rate of 1.8±0.7 (Fig 4.1).

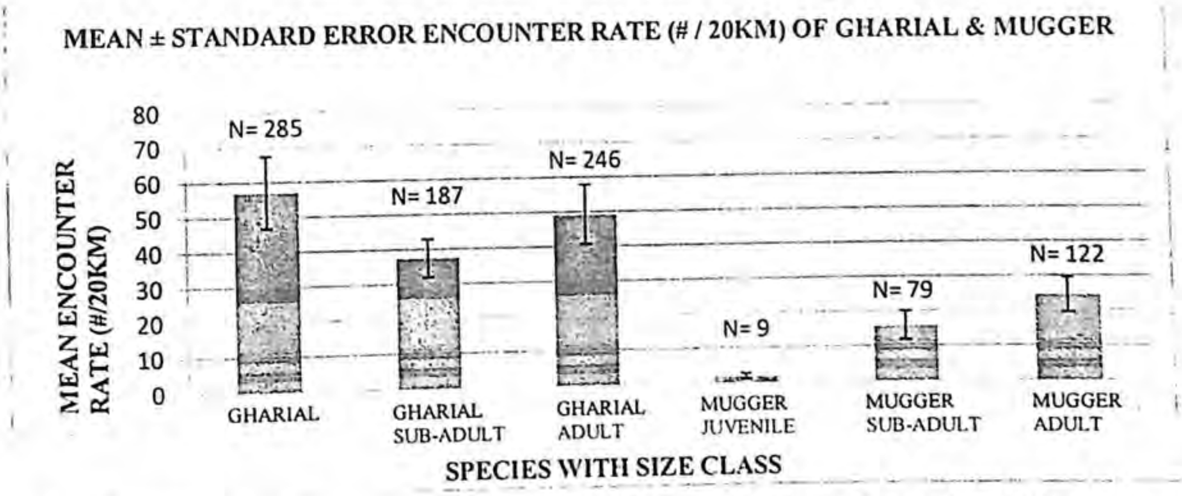


Figure 4.1 Mean± std error encounter rate for three size class of Gharial and Mugger in Katerniaghat Wildlife Sanctuary (Dec 2010 to April 2011).

The size-pyramids revealed that in Gharial, juveniles > adults > sub-adults whilst in Mugger, adults > sub-adults > juveniles (Fig 4.2).

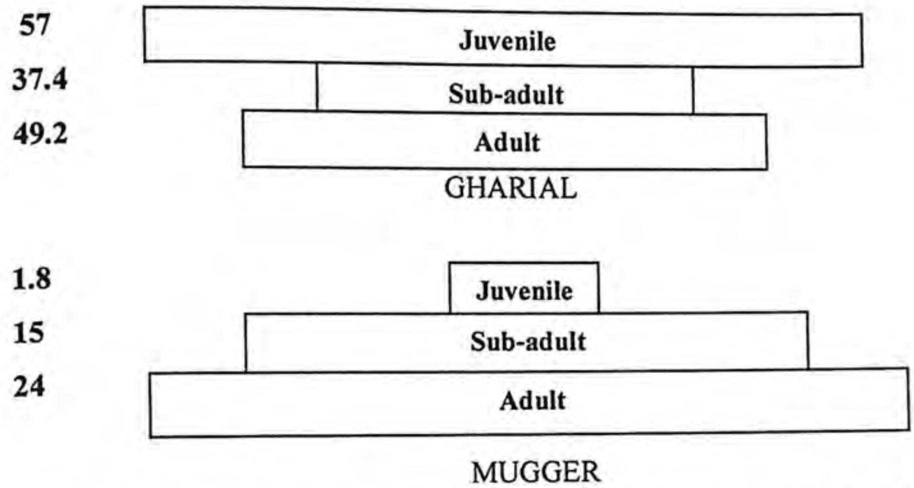


Figure 4.2 Population pyramids of Gharial and Mugger in Katerniaghat wildlife Sanctuary (Dec 2010 to April 2011)

5.4.2 Seasonal and temporal effect on encounter rate

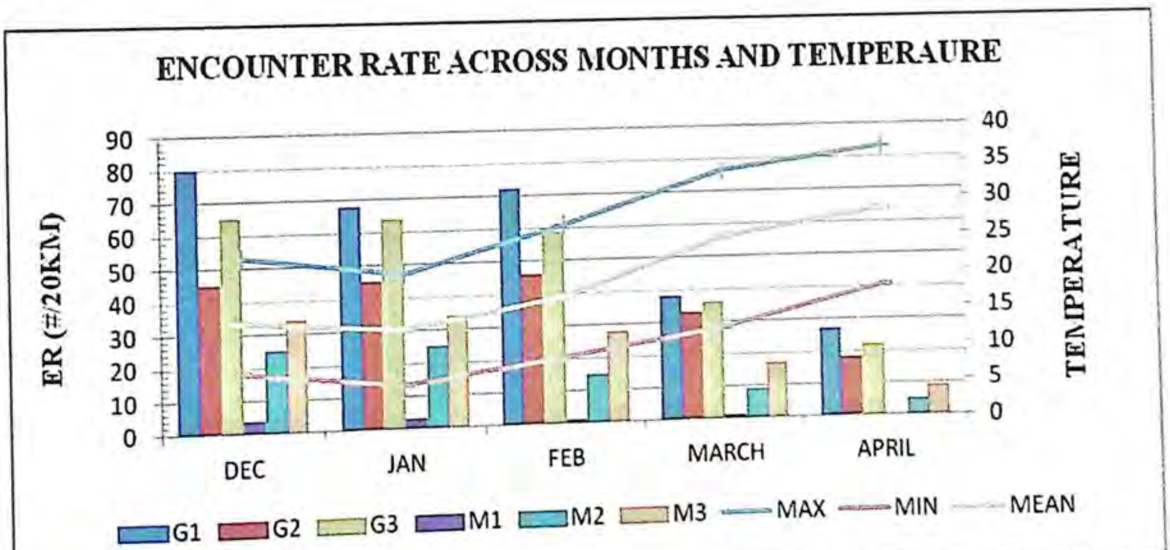


Figure 4.3 Encounter (#/20 km) for three size classes of Gharial and Mugger across months with maximum, minimum and mean temperature of Katerniaghat Wildlife Sanctuary (Dec 2010 to April 2011) where G1 is Gharial Juvenile, G2 is Gharial Sub-adult, G3 is Gharial adult, M1 is Mugger Juvenile, M2 is Mugger sub-adult and M3 is Mugger Adult

Encounter rate was highest for all size classes of Gharial and Mugger in December, when mean temperature was low (~15°C). Increase in mean temperature in March and April reduced the encounter rate of all size classes of Gharial and Mugger (fig 4.3).

Table 4.1 Correlation matrix of encounter rate (#/ 20km) of Garial and Mugger with max, min & mean temperature of Katerniaghat wildlife Sanctuary from Dec 2010 to April 2011

Species	Maximum Temperature (°C)	Minimum Temperature (°C)	Mean Temperature (°C)
Gharial juvenile	-0.92	-0.90	-0.96
Gharial sub-adult	-0.90	-0.97	-0.94
Gharial adult	-0.97	-0.97	-0.99
Mugger juvenile	-0.86	-0.80	-0.84
Mugger sub-adult	-0.98	-0.92	-0.96
Mugger adult	-0.98	-0.97	-0.99

Encounter rate of Gharial and Mugger was highly correlated with temperature (max, min, & mean) (Table 4.1)

4.3.3 Encounter rate and segments

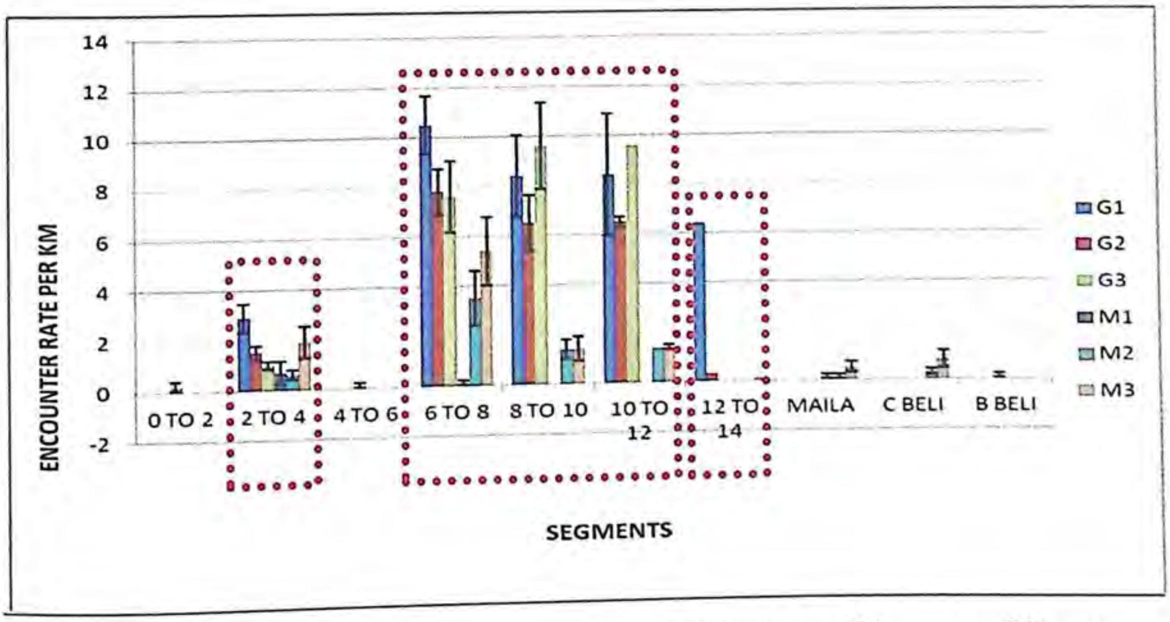
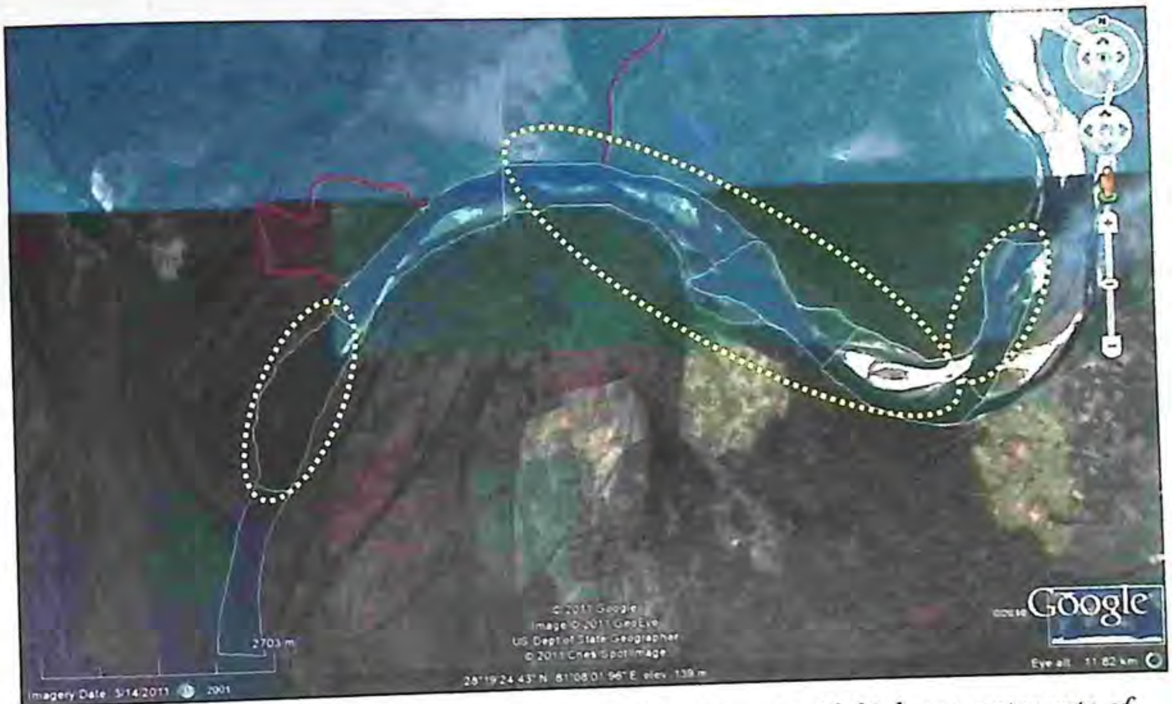


Figure 4.4 Encounters rates of three size classes of Gharial and Mugger in different segments of Girwa River of Katerniaghat wildlife Sanctuary (Dec 2010 to April 2011)

Based on encounter rates, segments 6-8 km, 8-10 km and 10-12 km (N28°20'0.72" E81°6'51.9" to N28°19'0.66" E81°10'56.52") were identified as the critical habitat hotspots for all size classes of Gharial (Fig 4.4 & Fig 4.5), followed by segment 2-4 km. Encounter rates of Muggers was more evenly distributed over the river stretch but maximum in segment 6-8 km (N28°20'0.72" E81°6'51.9" to N28°19'55.32" E81°8'45.66"). Nallas like Maila, Choti Beli and Badi Beli harboured only Mugger and encounter rate was very low. Segment 0-2 km and 4-6 km had the least encounter rate for both Gharials and Muggers (Fig 4.4 & Fig 4.5).



<u>Figure 4.5</u> Google earth image of segments (yellow ellipses) with high encounter rate of Gharial and Mugger in Girwa River of Katerniaghat Wildlife Sanctuary (Dec 2010 – April 2011).

4.3.4 Encounter rate and disturbance

The river segments (2-4km, 4-6km, 6-8km, 8-10km, 10-12km & 12-14km) had moderate to high disturbance regimes. Sand bars occurred in segments (2-4km, 4-6km, 6-8km, 8-10km, 10-12km & 12-14km). The crocodile encounter rate was higher in segments (2-4km, 6-8km, 8-10km & 10-12km.) (Fig 4.6).

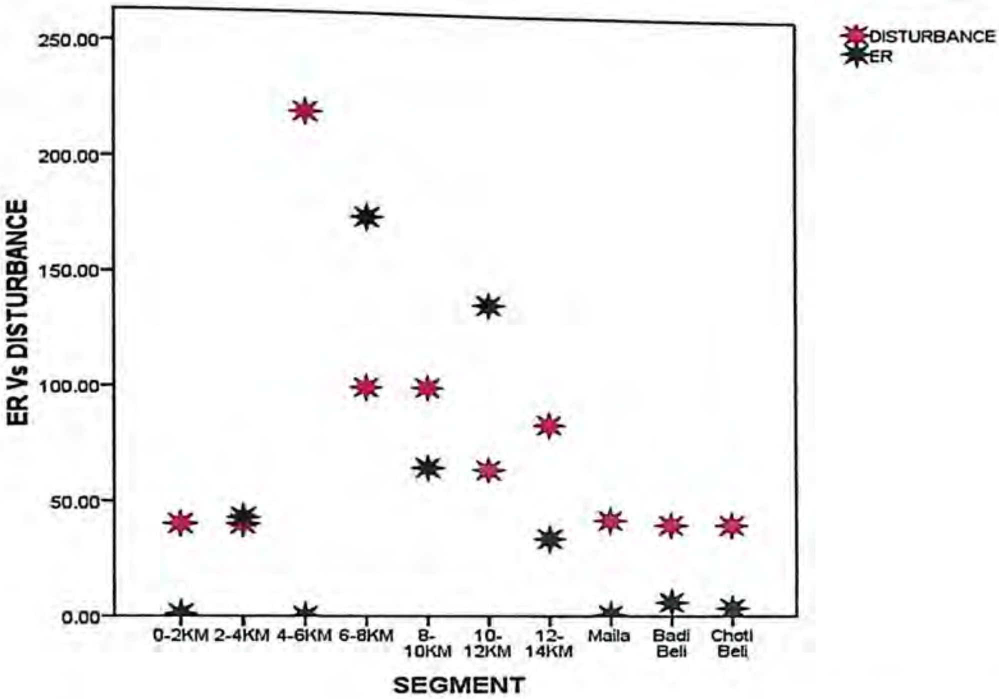


Figure 4.6 Disturbance index and encounter rate per 2 km of crocodilians in different segments of Girwa River of Katerniaghat wildlife Sanctuary (Dec 2010 – April 2011)

Table 4.2 Models explaining crocodile (Mugger+Gharial) encounter rate as a function of disturbance index and/or sand bar in Katerniaghat WLS during Dec (2010) to April (2011)

Model	Log Likelihood	Model df	AIC	*P*
ER = a + b_1 sand bar	-18.99	3	47.98	0.05
ER = a + b_1 disturbance	-20.78	3	51.56	0.61
ER = a + b_1 sand bar + b_2 disturbance	-18.77	4	53.45	0.12
ER = a+ b_1 sand bar * disturbance	-18.73	3	53.46	0.11

The best (smallest AIC) regression model explained crocodile encounter rate as a function of presence of sand bar only. Segments with sand bar had 74 units higher encounter rate on an average than segments without sand bar. This might result from higher detection of crocodiles as they would aggregate to bask on sand bars, and not necessarily higher absolute abundance. Disturbance seemed to be less important within the Sanctuary river stretch.

5. HABITAT UTILISATION

5.1 Main Objective

Whole of the available habitat is never utilised by an animal. It may use some portion of it based on time, season or physiological condition or may not uses it at all. Availability of habitat is a relative measure that is decided by the observer but whether it is actually availably is very difficult to find. Through this research question, what are the key habitat variables that drive a site to be chosen by Gharial and Mugger for basking were investigated.

5.2 Hypothesis

5.2.1 Habitat variables that lead to its selection for basking sites are same for Gharial and Mugger across seasons.

5.3 Methods of data analysis

Habitat data from available and used sites was arranged separately for Gharial and Mugger for winter and summer. Pearson and Spearman correlation matrices were computed to check for multicollinearity among habitat variables (see appendices 1 to 4). In case of group of cross-correlated continuous variables, Principle Component Analysis was conducted to explain the information in reduced dimensions. Principle component scores were used for subsequent analyses. Logistic regressions (generalised linear models with logixt link and binomial error distribution) using backward elimination procedure were used to quantify how habitat features influenced the basking site selection of crocodiles across seasons. Model with least AIC value was chosen as best (see appendix 5 to 12). Analyses were conducted in Program SPSS version 16.

5.4 Results

5.4.1 Gharial (winter)

<u>Table 5.1</u> Results of linear logistic regression for winter basking sites of Gharial in Katerniaghat Wildlife Sanctuary (Jan 2011- Feb 2011)

RI[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	Upper Bound
1	Intercept	29.135	1.855	246.82	1	.000			
	PCA (SLOPE, HEIGH & SOIL MOISTURE)	-4.307	1.453	8.791	1	.003	.013	.001	.232
	USE	-1.316	.248	28.080	1	.000	.268	.165	.436
	DIST TO WATER	.084	.015	32.656	1	.000	1.087	1.056	1.119
	[SAND+SILT ISLAND=.00]	-21.446	.578	1.376E3	1	.000	4.854E-10	1.563E-10	1.507E-9
	[SAND+SILT ISLAND=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND BAR=.00]	-19.863	.489	1.649E3	1	.000	2.364E-9	9.065E-10	6.165E-9
	[SAND BAR=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND+SILT BANK=.00]	-17.106	.000	.	1	.	3.724E-8	3.724E-8	3.724E-8
	[SAND+SILT BANK=1.00]	0[b]	.	.	0	.	.	.	.

According to the minimal adequate model (ΔAIC=952, χ^2=963.4, df=6,, p-value<0.001 compared to the null model), basking site selection of Gharial in winter was a function of slope, height, soil moisture, current land usage, distance to water, sand bars and sand+silt island (Table 5.1). Regression coefficients revealed that basking site selection was positively influenced by distance to water, presence of sand+silt island, presence of sand bar and presence of sand+silt bank, and negatively influenced by principle component (scores of slope, height & soil moisture) and intensity of usage (Table 5.1) for Gharial during winter.

5.4.2 Mugger (winter)

Table 5.2 Results of the linear logistic regression for Mugger basking sites in winter in Katerniaghat Wildlife sanctuary (Jan 2011 to Feb2011)

Parameter Estimates

R1[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	Upper Bound
1	Intercept	4.770	513.378	.000	1	.993			
	USE	-1.009	.264	14.586	1	.000	.365	.217	.612
	DIST TO WATER	.034	.006	36.122	1	.000	1.034	1.023	1.046
	[SAND+SILT BANK=.00]	-2.214	.394	31.593	1	.000	.109	.051	.236
	[SAND+SILT BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND BAR=.00]	-1.930	.414	21.742	1	.000	.145	.065	.327
	[SAND BAR=1.00]	0[b]	.	.	0	.	.	.	.
	[SILT BANK=.00]	13.329	513.377	.001	1	.979	6.151E5	.000	.[c]
	[SILT BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[LOG ON BANK=.00]	-20.067	.000	.	1	.	1.927E-9	1.927E-9	1.927E-9
	[LOG ON BANK=1.00]	0[b]	.	.	0	.	.	.	.

According to the minimal adequate model (ΔAIC=348, χ^2=359.64, df=6,, p-value<0.001 compared to the null model), basking site selection of Mugger in winter was a function of current land usage, distance to water, sand bars (Table 5.2). Regression coefficients revealed that basking site selection was positively influenced by distance to water, presence of sand+silt bank and presence of sand bar, and negatively influenced by the intensity of usage (Table 5.2) for Mugger during winter.

5.4.3 Gharial (summer)

Table 5.3 Results of the linear logistic regression for the selection of summer basking site by Gharial in Katerniaghat Wildlife Sanctuary(March 2011 to April 2011)

Parameter Estimates

R1[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
1	Intercept	8.806	2.215	15.812	1	.000			
	PCA (SLOPE, HEIGHT & SOIL MOISTURE	-12.152	2.991	16.508	1	.000	5.278E-6	1.502E-8	.002
	DEPTH GRADIENT	-.276	.120	5.273	1	.022	.759	.600	.960
	DIST TO WATER	-.113	.015	55.561	1	.000	.893	.867	.920
	[SAND+SILT ISLAND=.00]	-3.502	.870	16.204	1	.000	.030	.005	.166
	[SAND+SILT ISLAND=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND BAR=.00]	-4.423	.753	34.500	1	.000	.012	.003	.052
	[SAND BAR=1.00]	0[b]	.	.	0	.	.	.	.
	USE	-.539	.233	5.368	1	.021	.583	.370	.920

According to the minimal adequate model (ΔAIC=935, χ^2=946.7, df=6,, p-value<0.001 compared to the null model), basking site selection of Gharial in summer was a function of slope. Height, soil moisture, depth gradient, distance to water, sand+silt island, sand bars and current land usage (Table 5.3). Regression coefficients revealed that basking site selection was positively influenced by, presence of sand+silt bank and presence of sand bar, and negatively influenced by the principle component (scores of slope, height & soil moisture), depth gradient, distance to water and intensity of usage (Table 5.3) for Gharial during summer.

5.4.4 Mugger (summer)

Table 5.4 Results of the linear logistic regression for the selection if summer basking Site by Mugger in Katerniaghat Wildlife Sanctuary (March 2011 to April 2011)

Parameter Estimates

R1[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
1	Intercept	-12.165	1.147	112.472	1	.000			
	USE	-.712	.358	3.965	1	.046	.490	.243	.989
	DIST TO WATER	-.075	.012	39.572	1	.000	.927	.906	.949
	DEPTH GRADIENT	-.218	.071	9.540	1	.002	.804	.700	.923
	[SILT BANK=.00]	16.639	.000	.	1	.	1.683E7	1.683E7	1.683E7
	[SILT BANK=1.00]	0[b]	.	.	0	.	.	.	.

According to the minimal adequate model (ΔAIC=95, χ^2=103.37, df=6,, p-value<0.001 compared to the null model), basking site selection of Mugger in summer was a function of current land usage, distance to water and depth gradient (Table 5.4). Regression coefficients revealed that basking site selection was negatively influenced by the intensity of usage, distance to water and depth gradient (Table 5.4) for Mugger during summer.

6. RESOURCE PARTITIONING

6.1 TEMPORAL SEPARATION

6.1.1 Main Objective

Reptiles being ectotherms utilize external heat for metabolic growth. The more active the animal the greater the rate of heat production but in cold environment, however the heat produced as a by product of normal metabolism and activity may not be sufficient. So they bask in sun to adjust their metabolic reactions. Gharial and Mugger have difference in body sizes and size also varies within species, also there will be a difference in the amount of heat requirement. To check if there is any effect of size on the amount of basking following hypothesis was tested.

6.1.2 Hypothesis

6.1.2.1 There is no temporal separation among all classes of Gharial and Mugger across season.

6.1.3 Methods of data analysis

6.1.3.1 Seasonal separation

Ambient temperature was collected at an interval of one hour over the entire study period. Basking observations were taken every alternate Monday (on Monday pressure of tourism was least) from a watch tower (watch tower facilitated observations without disturbance). Data from ten Mondays of the study duration was collected to investigate temporal separation between size class of Gharial and Mugger across seasons. Size classes were defined as (sc1- <1.5m, sc2- 1.5m to 3m, sc3- >3m) for both the species. Basking rate of all three size classes was calculated for every Monday separately, as:

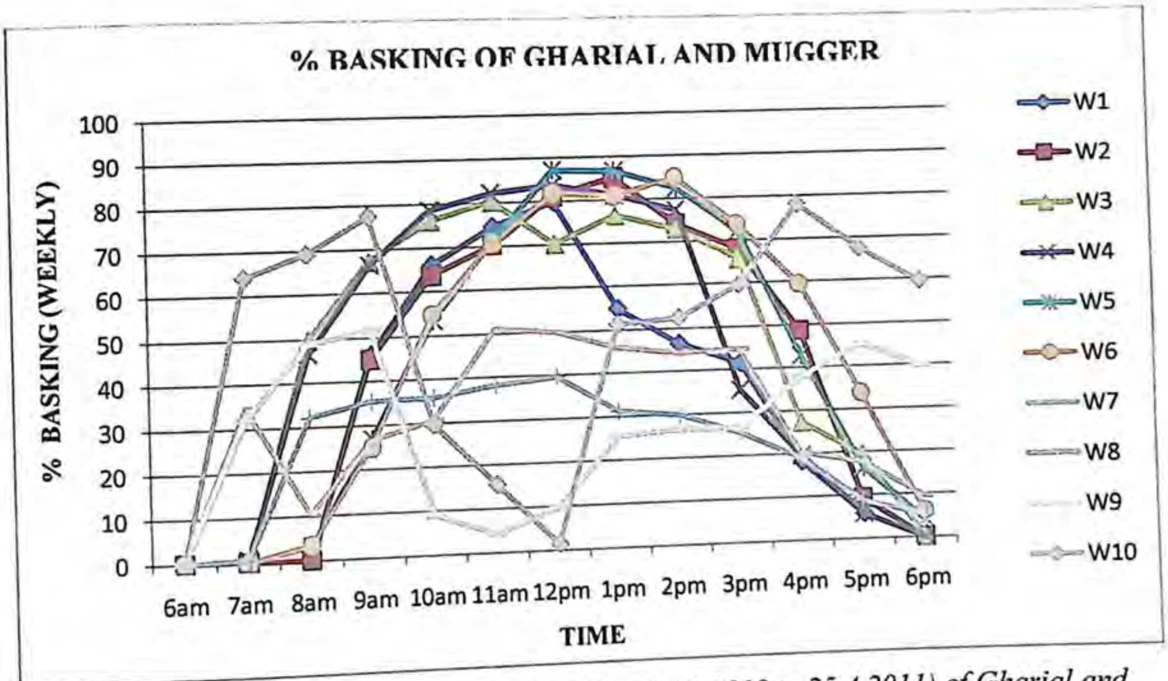
$$BASKING\ RATE = \frac{NO.\ OF\ BASKING\ INDIVIDUALS\ AT\ A\ PARTICULAR\ TIME}{MAX\ NO.\ OF\ SIGHTINGS\ FOR\ THAT\ MONDAY} * 100$$

6.1.3.2 Temporal separation

Average basking rate was calculated from this data for all size classes of both the species. Days of overall ambient temperature were pooled into ten groups by taking watch tower Mondays in centre i.e. seven days before and six days after was considered as one group. Average hourly ambient temperature was calculated for all ten weeks. Average basking rate for all three size class of Gharial and Mugger were graphically represented in Microsoft Excel 2007. To test for any temporal separation in basking, Kruskal-Wallis test was used.

6.1.4 Results

6.1.4.1 Seasonal separation



<u>Figure 6.1</u> % basking (alternate Monday from 20.12.2010 to 25.4.2011) of Gharial and Mugger in Girwa River of Katerniaghat wildlife Sanctuary (Dec 2010 to April 2011). Where W1 means Monday of first week, W2 is Monday of second week till W10 that is Monday of tenth week

Basking rate in crocodiles (Gharial + Mugger) showed a unimodal pattern till the 6th week and bimodal pattern from 8th week onwards (Fig 6.1). Summer (till 6th week) and winter (8th week) seasons as relevant to crocodiles (ecological seasons) was decided from the shift in basking pattern. This result coincides with month also i.e. Dec to Feb is winter and March-April it is summer.

6.1.3.2 Temporal separation

In winter there was no temporal separation between and within different size classes of Gharial and Mugger [$\chi^2 = 1.6$, df=5, $p= .899$, $\alpha=.05$]. During winter, for all three size classes of Gharial, basking rate peaked at temperature ~20°C. Similarly, for all three size classes of Mugger, basking rate peaked ~20°C and reduction in temperature from 20°C led to reduction in % basking.

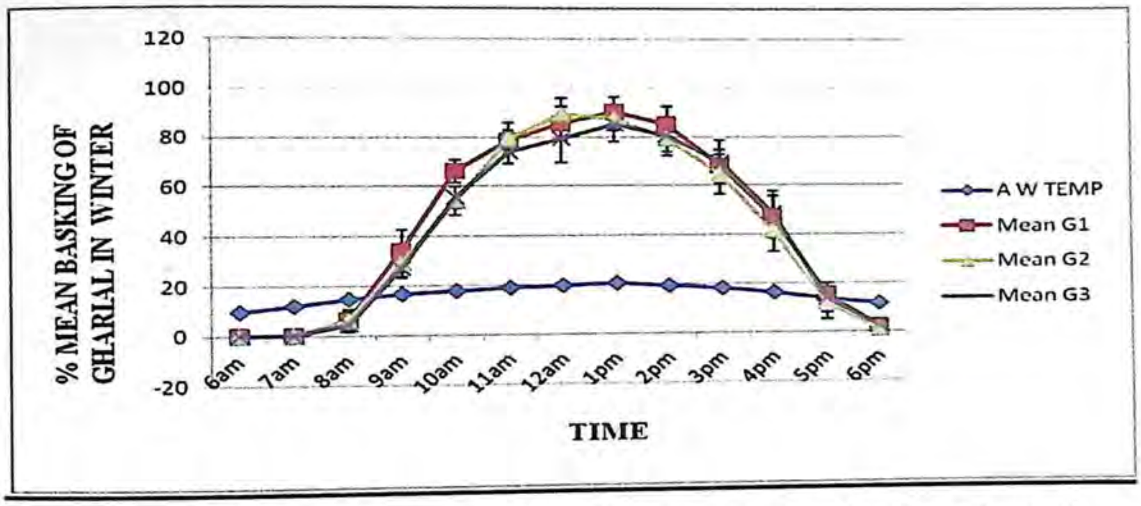


Figure 6.2 % basking in winter for three size classes in Gharial in Girwa River of Katerniaghat Wildlife Sanctuary (Dec 2010 to Feb 2011).

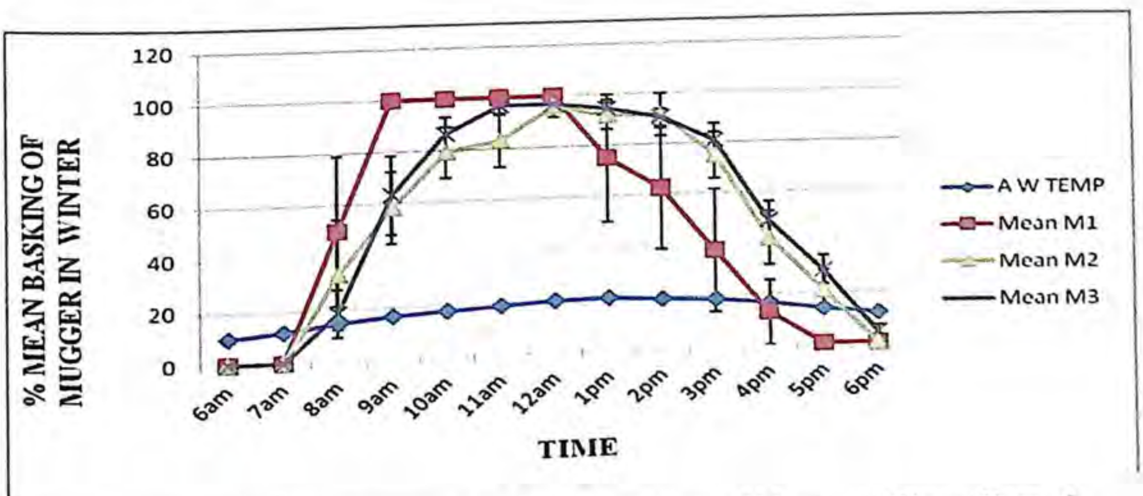


Figure 6.3 % basking in winter for three size classes of Mugger in Girwa River of Katerniaghat wildlife Sanctuary (Dec 2010 to Feb 2011).

In summer there was temporal separation between and within size classes of Gharial and Mugger [χ^2=11.9, df=5, p= .036, α=.05].

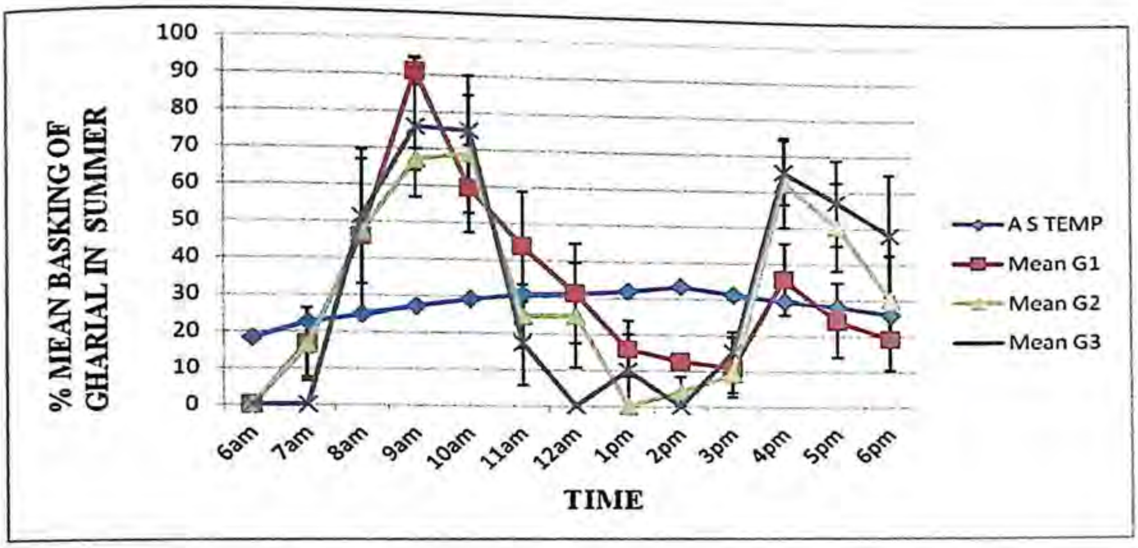


Figure 6.4 Summer % Basking for three size classes of Gharial in Girwa River of Katerniaghat Wildlife Sanctuary (March 2011 to April 2011)

During this season, basking rate of Gharial juveniles and adults peaked around 27°C and 29°C respectively. But basking rate in juveniles declined before that of sub adults and adults. For juvenile decline temperature was 27°C but for sub adults and adults it was 29°C for the first basking phase. For the second basking phase, basking rate peaked at 29°C declining thereafter. Least basking rate was different for all three size classes. Also the temperatures at which basking rate increased was different for all size classes. This indicated that in summer there was a partitioning for temperature in different size classes of Gharial (Fig 6.4).

In Mugger, during the first basking phase, basking rate of juveniles and sub adults peaked at 22°C while that of adults peaked at 29°C. At this temperature, the basking rate of juveniles and sub adults however dipped to the minimum. Decline point was different for all three size classes. Ambient temperature at which the basking rate of juveniles and sub adults was rising, basking rate for adults was declining. For second basking phase, maximum basking rate and decline temperature were similar between all size classes (Fig 6.5).

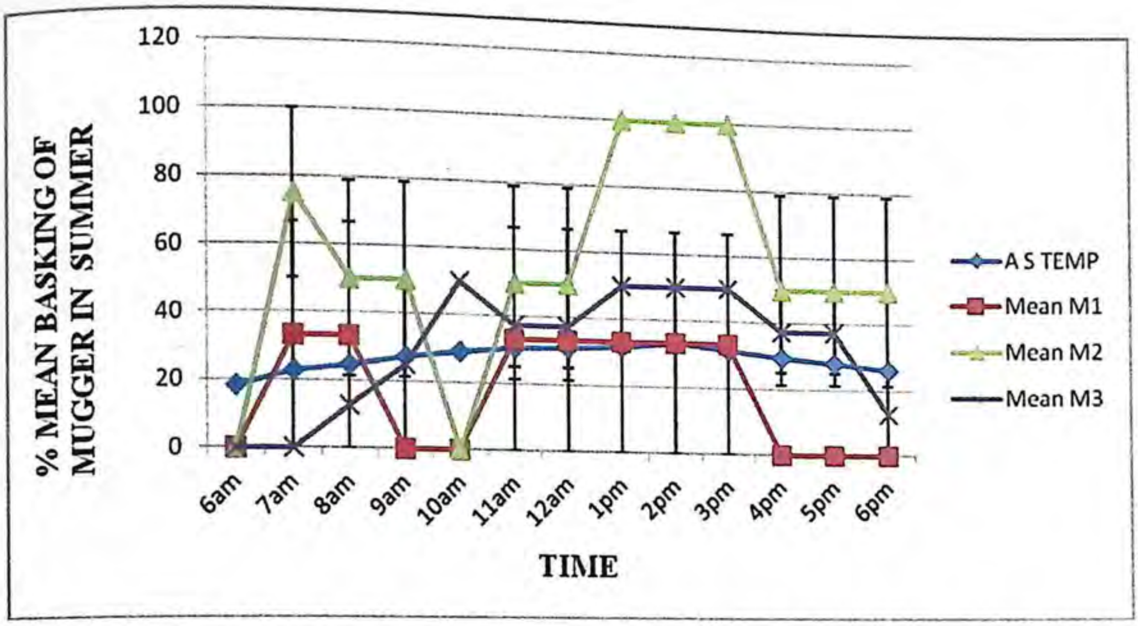


Figure 6.5 Summer % Basking for three size classes of Mugger in Girwa River of Katerniaghat wildlife Sanctuary (March 2011 to April 2011).

6.2 BASKING SITE REQUIREMENTS

6.2.1 Main Objective

In Katerniaghat wildlife Sanctuary Gharial and Mugger are two sympatric crocodilian species with very small differences in physiology and habits. It is essential for both to bask in sun and utilize heat energy as efficiently as possible. Here main objective was to investigate whether key requirements for basking site selection are same for both species or they have partitioned resource by separating their basking sites.

6.2.2 Hypothesis

7.2.2.1 Basking site requirement for Gharial and Mugger are same in both seasons.

6.2.3 Methods for data analysis

Basking data (continuous variables) of all occupied basking sites was arranged according to species and season. To test the hypothesis both summer and winter basking data of Gharial and Mugger were used. Mann-Whitney U test was used to compare differences or similarities in pairs. For categorical data Fisher's exact test was used as data had many zeros. SPSS version 16 was used for running the test and plotting the graphs.

6.2.4 Results

6.2.4.1 Winter basking sites of Gharial and Mugger

Table 6.1 Results of Mann Whitney U test for winter basking site of Gharial and Mugger in Girwa River of Katerniaghat Wildlife Sanctuary (Jan 2011 to March 2011)

	SLOPE(°)	HEIGHT (cm)	SOIL MOISTURE (%)	DISTANCE TO WATER (cm)
Mann- Whitney U	1.376E4	8.880E3	11255.5	25950
Z	-13.75	-12.15	-13.115	-1.761
P	0.000	0.000	0.000	0.078

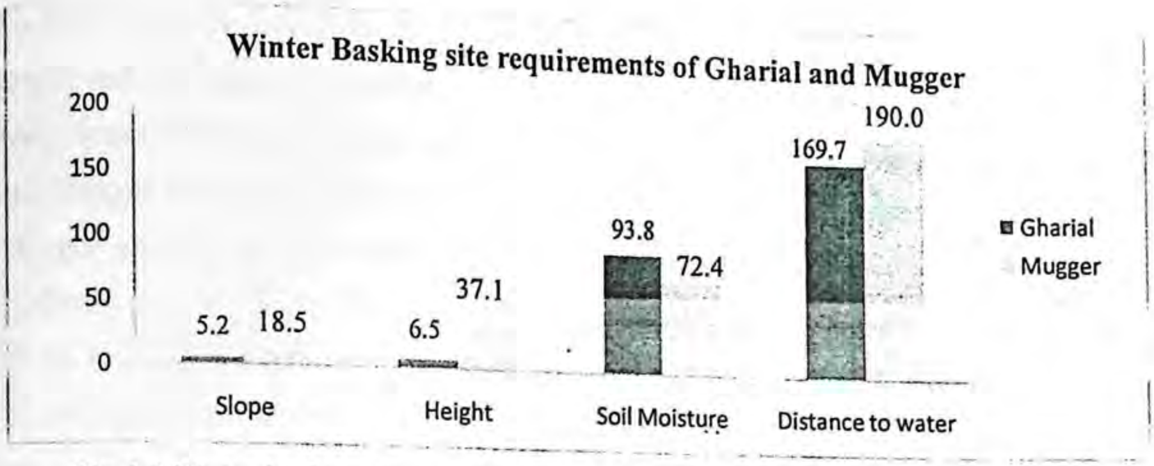


Fig 6.6 Winter basking site requirements by Gharial and Mugger in Girwa River of Katerniaghat wildlife sanctuary (Jan 2010 to Feb 2011).

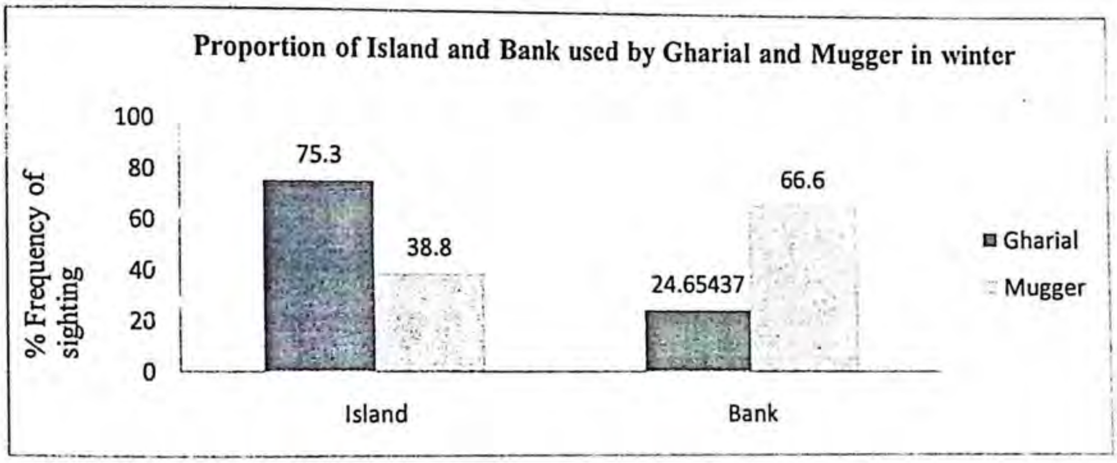


Fig 6.7 Proportion of Island and Bank used as winter basking sites by Gharial and Mugger in Girwa River of Katerniaghat wildlife sanctuary (Jan 2011 to Feb 2011)

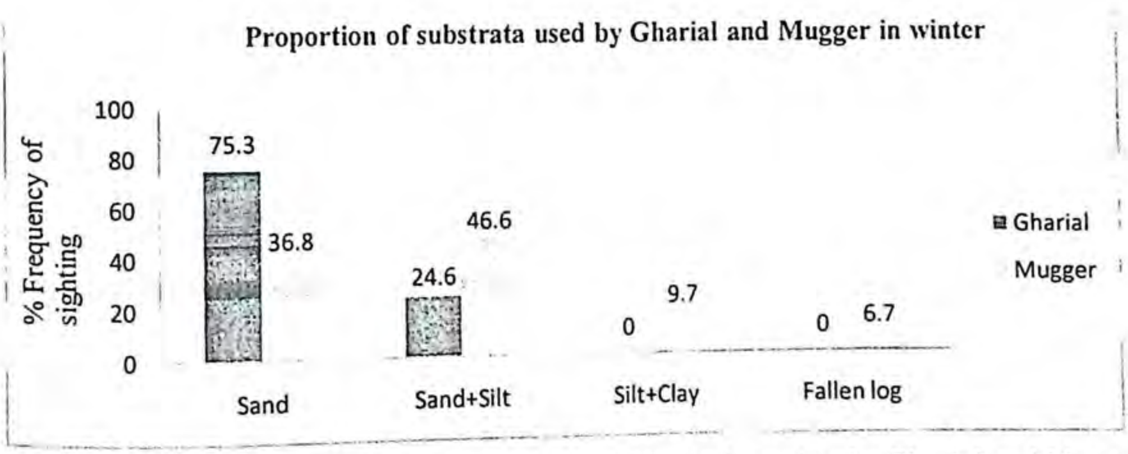


Fig 6.8 Proportion of different substrata used as winter basking sites by Gharial and Mugger in Girwa River of Katerniaghat wildlife sanctuary (Jan 2011 to Feb 2011)

Table 6.1 gives the result that shows that there is a significant difference in the use of slope, height and soil moisture by Gharial and Mugger for winter basking sites while distance to water is not different for Gharial and Mugger. Fig 6.6 shows different preferences of Gharial and Mugger for winter basking site. Gharial prefers very gentle slope (M= 5.2° ±0.05) while Mugger goes for a slight slope (M=18.5° ± 1.9). Gharial don't prefer elevated basking platforms (M = 6.5cm ± .15) whereas Mugger was found basking on elevated platform (M= 37.16cm ± 3.8). Gharial prefers moist areas for basking (M= 93.8% ± .13) and Mugger basks on little dry substrata (M= 72.4% ± 2.7). Distance to water from basking site was less for Gharial (M= 169cm ± 3.8) than Mugger (M= 190cm ±8.2). The fisher's exact test reveals that there is a significant difference in the use of places (P= 0.000) and substrata (P =0.000) for basking by Gharial and Mugger during winter. Fig 6.7 and Fig 6.8 shows the most preferred places and substrata by Gharial and Mugger for winter basking sites. Gharial was seen mostly on islands (N= 327, 75%) and Muggers on banks (N=84, 66%). Among different substrata Gharial preferred only sand and sand+silt while Mugger was spotted on a variety of substrata.

6.2.4.2 Summer basking sites of Gharial and Mugger

Table 6.2 Results of Mann Whitney U test for summer basking site of Gharial and Mugger in Girwa River of Katerniaghat Wildlife Sanctuary (March 2011 to April 2011)

	SLOPE	HEIGHT	SOIL MOISTURE	DISTANCE TO WATER
Mann- Whitney U	1.376E4	8.880E3	11255.5	25950
Z	-6.9	-5.03	-8.74	-2.9
P	0.000	0.000	0.000	0.003

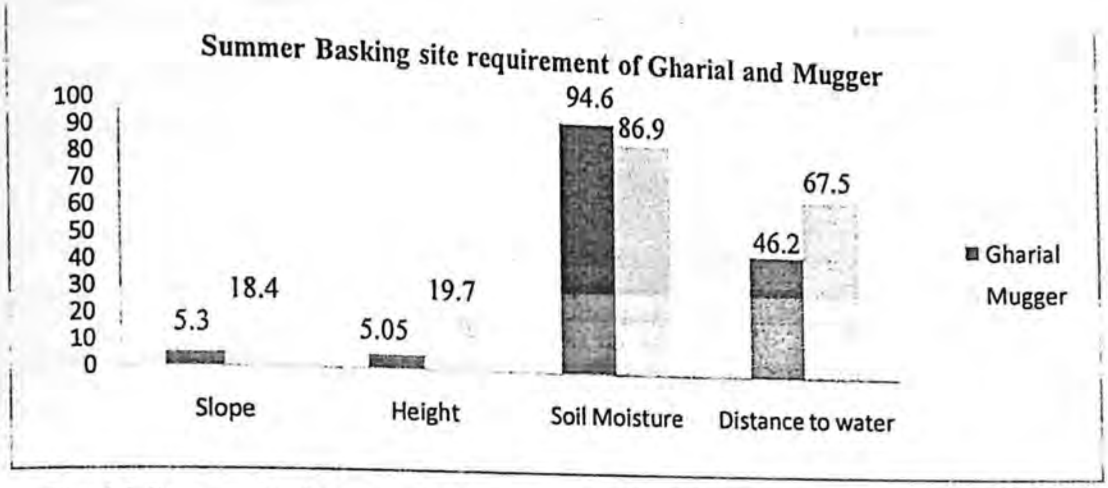


Fig 6.9 Summer basking site requirements by Gharial and Mugger in Girwa River of Katerniaghat wildlife sanctuary (March 2011 to April 2011).

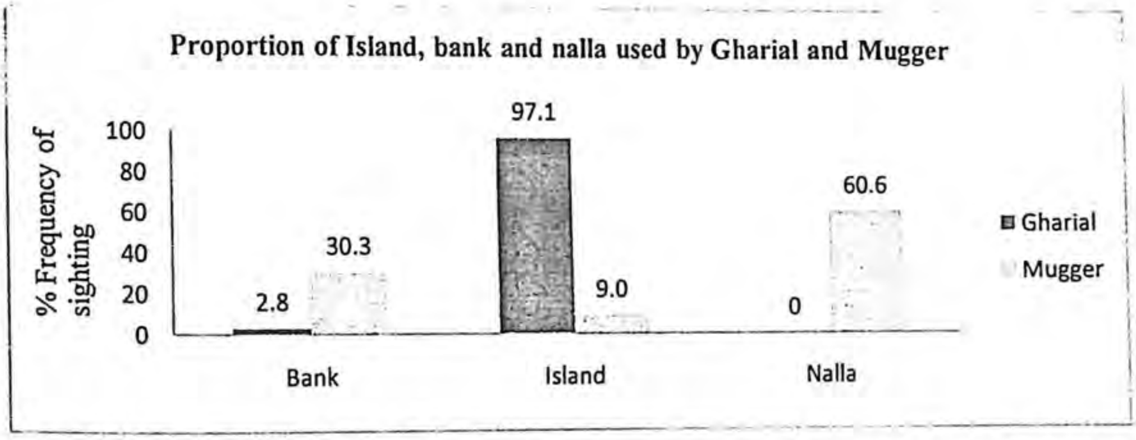


Fig 6 .10 Proportion of Island, Bank and Nalla used as summer basking sites by Gharial and Mugger in Girwa River of Katerniaghat wildlife sanctuary (March 2011 to April 2011)

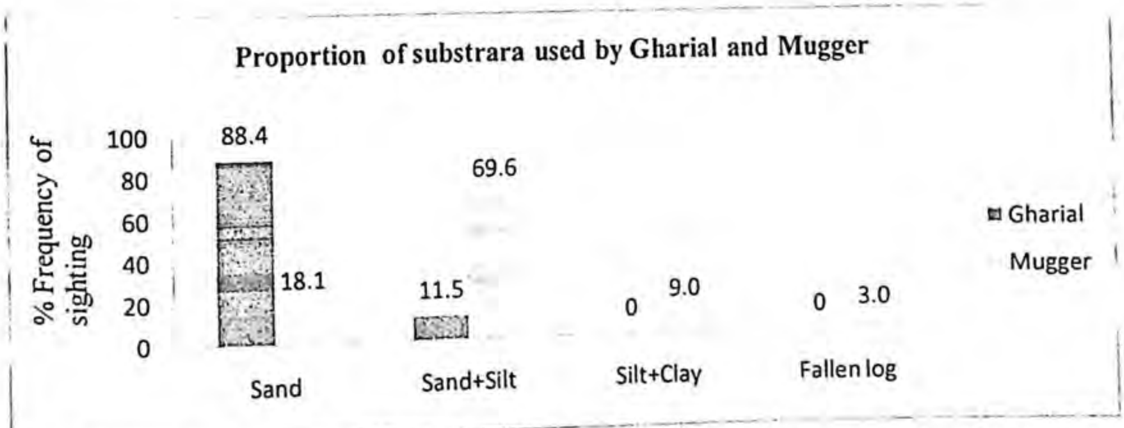


Fig 6.11 Proportion of different substrata used as summer basking sites by Gharial and Mugger in Girwa River of Katerniaghat wildlife sanctuary (Jan 2011 to March 2011)

Table 6.2 gives the result of Mann Whitney U Test that shows that there is a significant difference in the use of slope, height, soil moisture and distance to water by Gharial and Muggers in summer.

Fig 6.9 shows the preferred habitat variables for summer basking sites by Gharial and Mugger. In summer again Gharial preferred very gentle slope (M= 5.3° ± 0.12) compared to Mugger (M= 18.4° ± 4.3). Basking platform height for Gharial was less (M= 5.0cm ± 0.16) than that of Mugger (M= 19.7cm ± 3.2). Preferred soil moisture by Gharial was again more (M= 94.6% ± 0.09) compared to Mugger (M= 86.9% ± 2.9). Distance to water reduced drastically for both species in summers, for Gharial it was less (M= 46.2cm ± 1.59) than that of Mugger (M= 67.5± 8.3).

Fisher's exact test reveals that there is a significant difference in the use of places (P= 0.000) and substrates (P= 0.000) as summer basking sites by Gharial and Mugger. Fig 6.10 shows that Mugger moved to Nalla in summers. Gharial kept on preferring island for basking. Among substrata sand was preferred most by Gharial and Mugger preferred sand+silt the most (Fig 6.11).

6.3 NEST SITE REQUIREMENTS

6.3.1 Main Objective

In Katerniaghat Wildlife Sanctuary both the crocodilian species have a good breeding population and every year a large number of hatchlings can be seen in the river. How many of them survive to breed is a different question. Selecting a site for making nest or laying eggs is very crucial and plays an important role in the survival of the nest: Both crocodilian species are hole nesters i.e. they dug up the soil and lay eggs in it. Aim of this hypothesis was to check whether both the crocodilian species prefer same habitat parameters or their criteria are different.

6.3.2 Hypothesis

6.3.2.1 Nest site selection is same for Gharial and Mugger

6.3.3 Methods for data analysis

Continuous habitat variables were compared using a Mann Whitney U Test while categorical variables were compared using Fisher's exact test. Fisher's exact test was used because there were many zeros in the data. SPSS was used to run Mann Whitney U test and for plotting graphs.

6.3.4 Results

Table 6.3 *Results of Mann Whitney U test for slope, height, distance to water and distance to vegetation of nesting sites of Gharial and Mugger in Katerniaghat Wildlife Sanctuary(March 2011 to April 2011)*

	Slope	Height	Distance to water	Distance to vegetation
Mann-Whitney U	28	28	253	87
Z	-4.12	-3.9	-2.8	-0.89
P	0.000	0.000	0.005	0.369

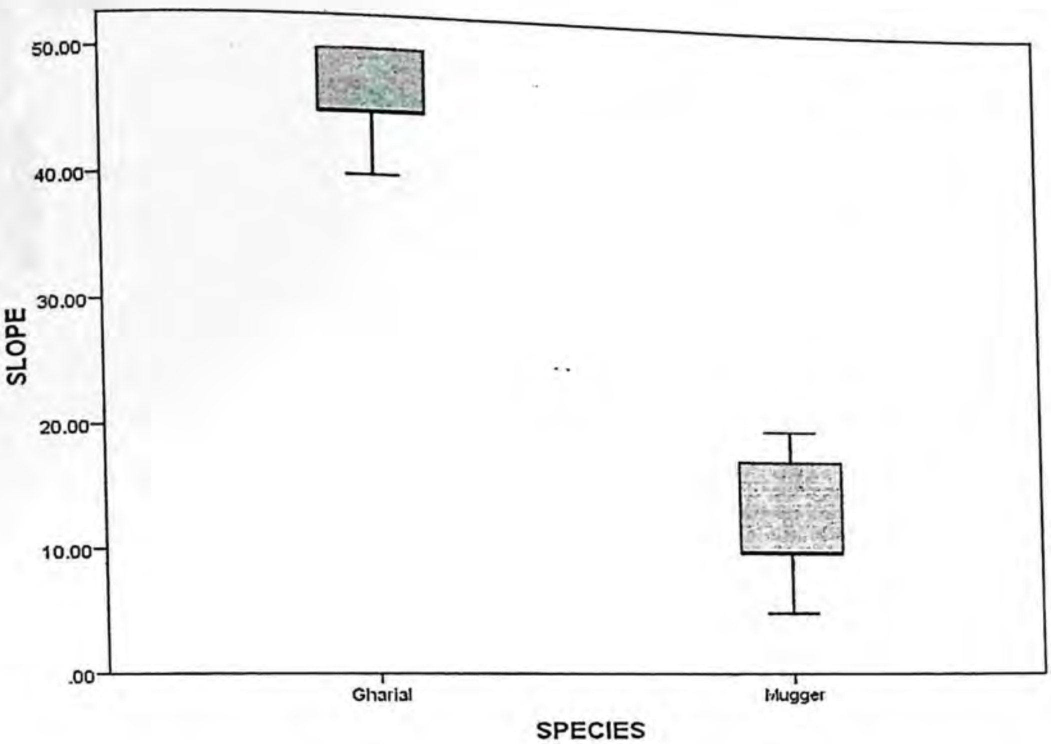


Figure 6.13 Box-plot showing the slope preference by Gharial and Mugger for nest site in Katerniaghat Wildlife Sanctuary (March 2011 to April 2011)

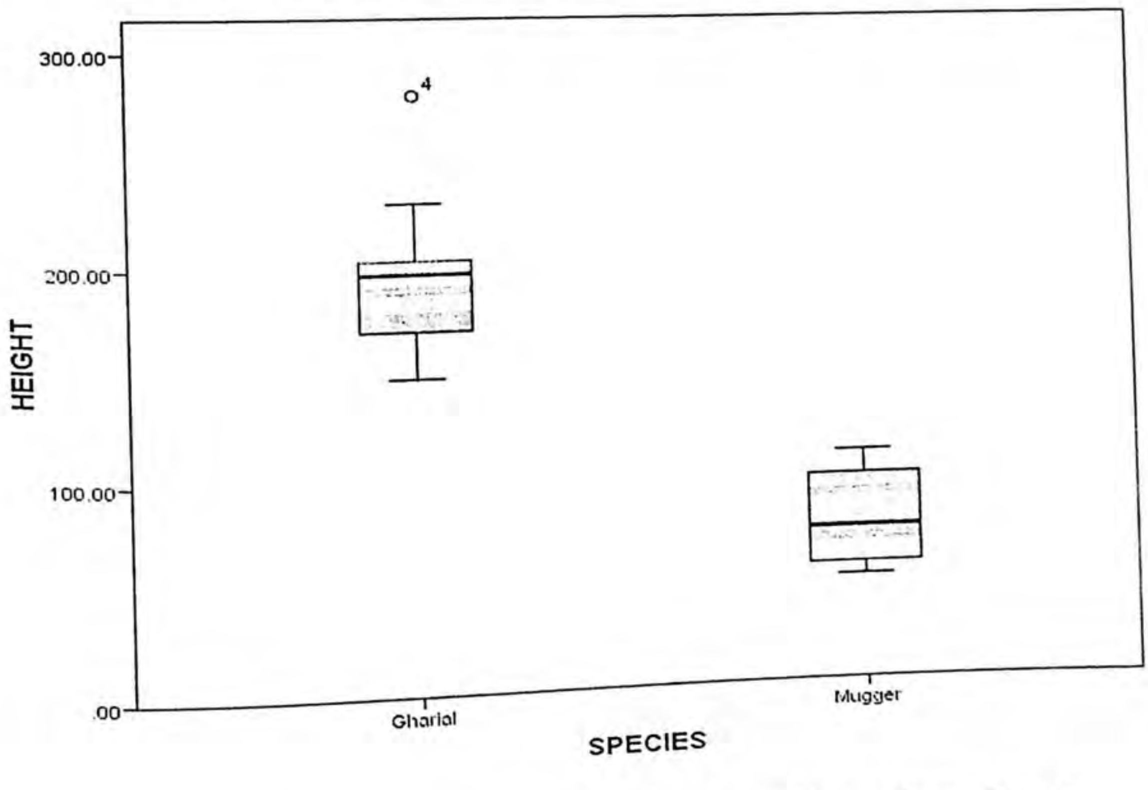


Figure 6.14 Box-plot showing preferred height by Gharial and Mugger for nest sites in Katerniaghat Wildlife Sanctuary (March 2011 to April 2011)

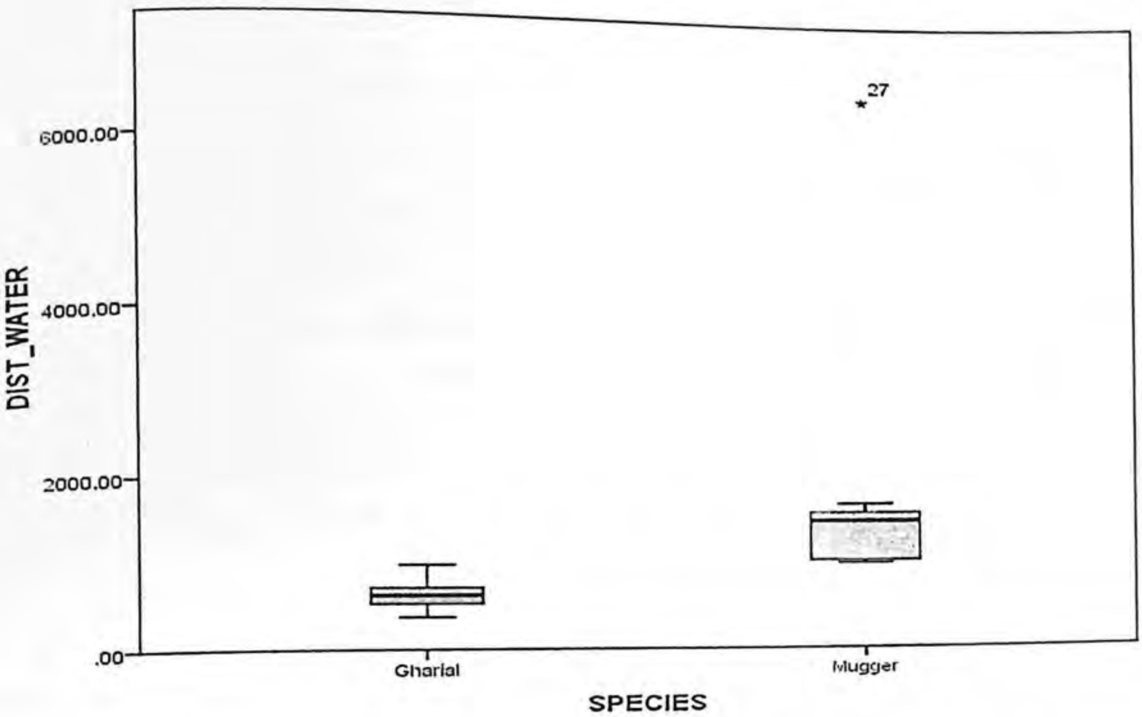


Figure 6.15 *Box-plot showing distance to water for Gharial and Mugger nest in Katerniaghat Wildlife Sanctuary (March 2011 to April 2011)*

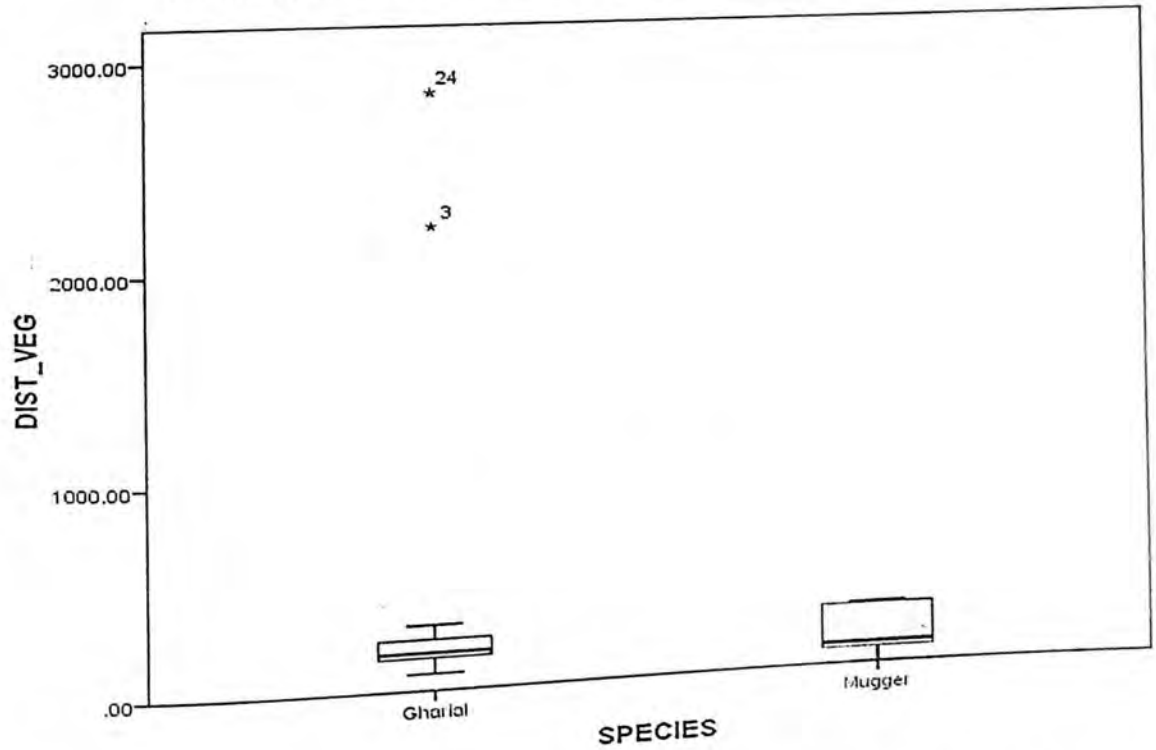


Figure 6.16 *Box-plot showing distance to vegetation for Gharial and Mugger nest in Katerniaghat Wildlife sanctuary (March 2011 to April 2011).*

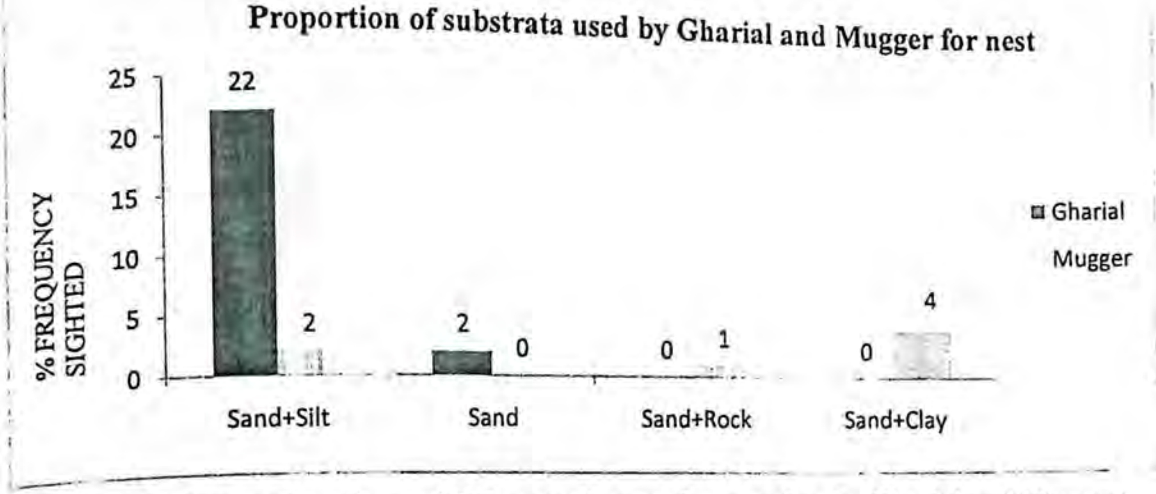


Figure 6.17 Proportion of use of different substrata for nest sites by Gharial and Mugger in Katerniaghat Wildlife Sanctuary (March 2011 to April 2011)

Table 6.3 gives the results of Mann Whitney U test run for different habitat variables for nest sites of Gharial and Mugger. Slope, height and distance to water are significantly different for Gharial and Mugger while not distance to vegetation.

Figure 6.13 gives a graphical view of the separation in the slope preference by Gharial (M= 45.4° ±0.7) and Mugger (M=12.8° ± 0.2). Fig 6.14 gives difference in height preference by Gharial (M= 190.96cm ±5.8) and Mugger (M= 76cm ± 9.2). Fig 6.15 shows that distance to water for Gharial nest is less (M= 639.21cm ± 30.5) than Mugger nest (M= 2037cm ± 7.5). Fig 7.16 tells that distance to vegetation for the nest of Gharial (M= 384.5cm ± 136) and Mugger (M= 160.8cm ± 48).

Fisher's exact test reveals that there is a significant difference in the selection of substrata for the nest by Gharial and Mugger (*P*= 0.000). Gharial preferred sand and silt only whereas Mugger preferred sand and clay the most.

6.4.1 Main Objective

After testing partitioning for temperature and habitat this objective investigated whether there is any preference to nearest neighbour and does nearest neighbour distances varies if neighbour is different species as well as size class.

6.4.2 Hypothesis

6.4.2.1 There is no preference to nearest neighbour by species and size class.

6.4.2.2 Nearest neighbour distance remains same irrespective of the neighbour.

6.4.3 Methods for data analysis

% Frequency of sightings was taken as a measure of nearest neighbour preference. Mean ± SE of nearest neighbour distance was calculated for each pair to check if it varies with species and size class.

6.4.4 Results

6.4.4.1 Preference to nearest neighbour

Table 6.4 *% frequency of sightings for different size classes for Gharial and Mugger in Katerniaghat Wildlife Sanctuary (Dec 2010 to April 2011)*

	G1	G2	G3	M1	M2	M3
G1	65.15					
G2	16.24	16.66				
G3	15.51	33.33	39.22			
M1	0	0	0	0		
M2	0.91	9.84	5.38	0	5.19	
M3	2.19	6.44	3.59	100	31.17	13.41

Out of total number of sightings for Gharial juveniles (G1) it was seen maximum with Gharial juveniles (G1) followed by Gharial adult (G3) and Gharial sub-adult (G2). Never seen with Mugger juvenile (M1) and maintained a distance from Mugger sub-adult (M2) and

Mugger adult (M3). Gharial sub-adult (G2) was seen mainly with Gharial adult (G3) and maintained distance from Mugger. Gharial adult (G3) preferred Gharial adult (G3) and seen very less with Mugger. Mugger juvenile (M1) was seen only with Mugger adult (M3).

6.4.4.2 Nearest neighbour distance

<u>Table 6.5</u> *Mean ± Standard error of nearest neighbour distance of different pairs of size classes for Gharial and Mugger in Katerniaghat wildlife Sanctuary (Dec 2010 to April 2011)*

	G1	G2	G3	M1	M2	M3
G1	223.4±8.6					
G2	343.1±22.1	339.7±35.1				
G3	220.2±14.4	301.4±18.4	276.04±13.1			
M1	0	0	0	0		
M2	654.7±110.2	461.7±30.7	411.8±62.2	0	398.6±45.1	
M3	579±70.8	483.2±35.9	448.25±52.1	359.2±144	441.8±31.5	454.3±44

Mugger juvenile (M1) was observed only with Mugger adult (M3) so with other size classes its mean is 0. For Gharial juvenile (G1) mean nearest neighbour distance is least between Gharial adult (G3) and Gharial juveniles (G1). Maximum distance was with Gharial sub-adult (G2) and Mugger adult (M3). G1 also maintains distance from G2. G2 was always close to G3 rather than other size classes of both species. G3 prefers to be close to G3 and maintained distance from M3.

7. TOURISM & FISHING AS A POTENTIAL DISTURBANCE FOR CROCODILES

7.1 Main Objective

In Katerniaghat Wildlife Sanctuary a large range of disturbance factors were acting of which tourism and illegal fishing were causing direct impact on crocodilian population. To check how crocodilians are responding to these two disturbance factors flight distance was taken as an indicator. Mechanised boat is used for tourism purpose and non-mechanised boat for illegal fishing. In first hypothesis, difference in disturbance caused by these two modes on flight distances for crocodiles based on flight distance was tested.

Gharial and Mugger have different potentials to respond with levels of disturbances. Mugger being more aggressive is habitual of human presence while Gharial is more timid and prefers human free areas. In second hypotheses difference between Gharial and Mugger flight distances form mechanised and non-mechanised boats was explored.

With age crocodiles acquire knowledge and experience and generally tend to avoid human beings. In third hypothesis, whether it applies for Gharial and Mugger also was tested. Flight distance of hatchlings and adults from mechanised and non-mechanised boats was used.

7.2 Hypothesis

7.2.1 There is no difference in the flight distance from mechanised and non-mechanised boats.

7.2.2 The flight distances from mechanised and non-mechanised boat are same for Gharial and Mugger.

7.2.3 Size class has no effect on flight distance from mechanised and non mechanised boat.

7.3 Methods of data analysis

Data was arranged in three different forms. For first hypothesis all sightings were clubbed together just to check if there is any difference in flight distance from mechanised and non-mechanised boats. Species identity was kept for second hypothesis. Data of size class of both species was used to check third hypothesis. Mann-Whitney U test was used to compare between pairs. Non-parametric test was opted because data was not normally distributed. SPSS 16 was used to run Mann- Whitney U test.

7.4 Results

7.4.1 Between Mechanised and non-mechanised boat

The Mann- Whitney U test reveals a significant difference in the flight distances from mechanised and non-mechanised boats ($z = -31.0$, $p = .000$, $\alpha = .05$) where mean rank for non-mechanised boat was 964.8 and of mechanised boat was 252.6. From Figure 7.1 it is clear that mean flight distance from a non-mechanised boat is 245.2 metres while from that of a mechanised boat it is only 58.9 metres.

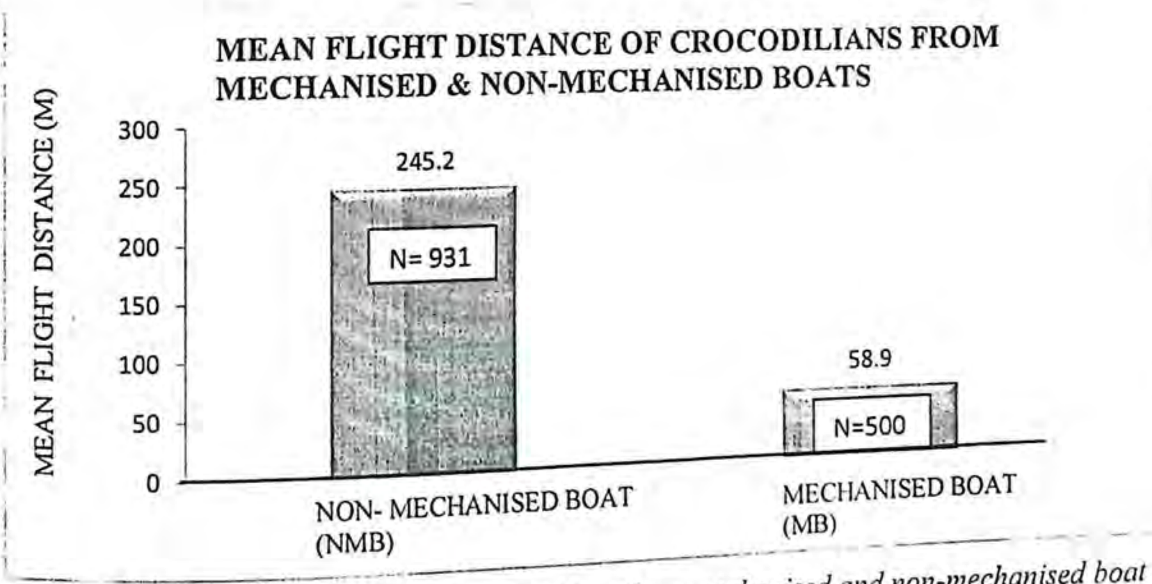


Figure 7.1 Mean flight distance of crocodilians from mechanised and non-mechanised boat in Katerniaghat Wildlife Sanctuary (Dec 2010 to April 2011)

7.4.2 Comparisons between Gharial and Mugger

There is no statistically significant difference in flight distances of Gharial and Mugger from non-mechanised boats (z = -1.4, p= .15, α=.05) with mean rank for Gharial of 470 and for Mugger of 502. From mechanised boat there is a statistically significant difference in flight distances of Gharial and Mugger (z = -14.5, p= .000, α=.05) with mean rank for Gharial of 319.2 and for Mugger of 121.7.

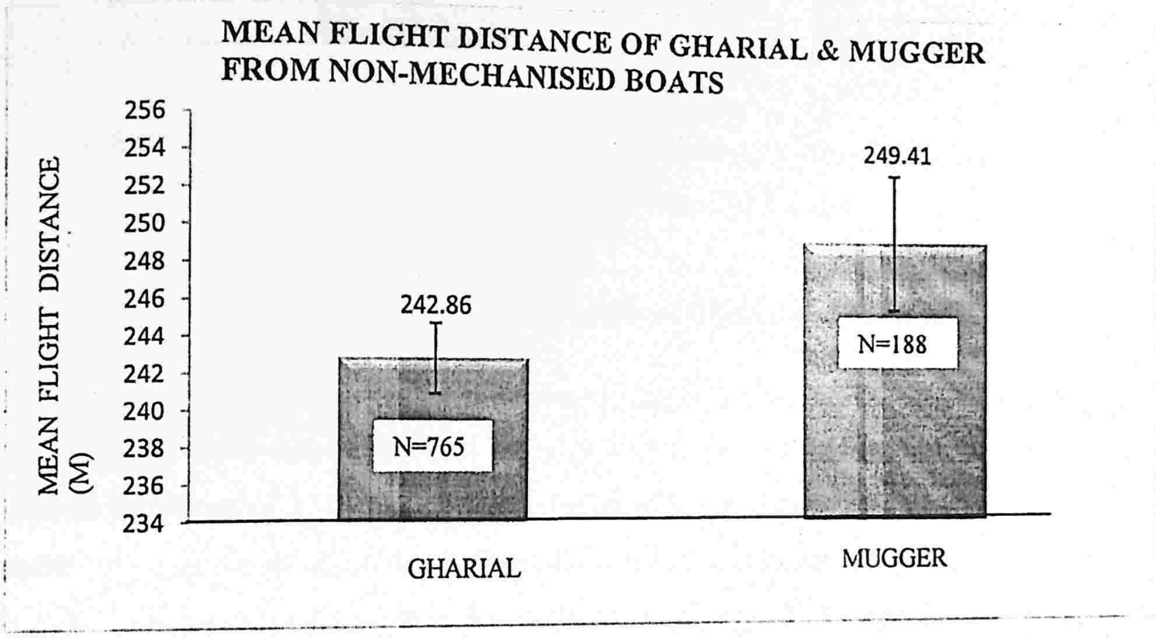


Figure 7.2 Mean flight distance for Gharial and Mugger from non-mechanised boat in Katerniaghat wildlife sanctuary (Dec 2010 to April 2011)

The mean flight distance of Gharial from non-mechanised boat was observed as 242.8metres while for Mugger it was 249.4 metres (Fig 7.2). From a mechanised boat flight distance of Gharial was 71.4 meters while of Mugger was only 35.35 meters (Fig 7.3).

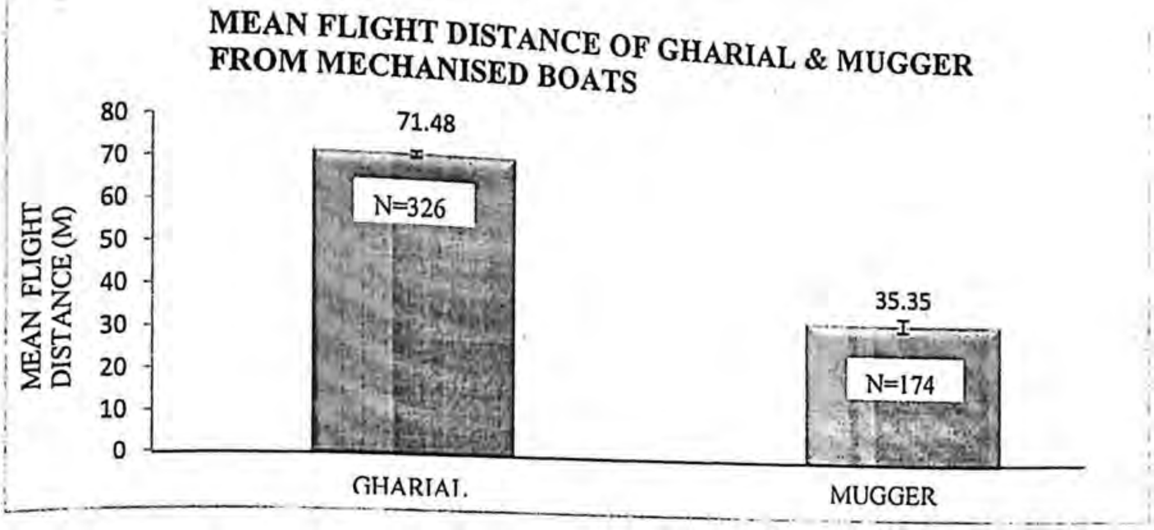


Figure 7.3 Mean flight distance for Gharial and Mugger from mechanised boat in Katerniaghat Wildlife Sanctuary (Dec 2010 to April 2011)

7.4.3 Comparisons between juveniles and adults of Gharial and Mugger

There is a statistically significant difference in flight distances of Gharial hatchlings and Gharial adult from non-mechanised boats (z = -5.2, p= .000, α=.05) with mean rank for Gharial hatchlings of 274.6 and for Gharial adult of 350.8. From mechanised boat there is no statistically significant difference in flight distances of Gharial hatchlings and adult from (z = -0.9, p= .351, α=.05) with mean rank for Gharial hatchlings of 135.2and for Gharial adult of 126.3.

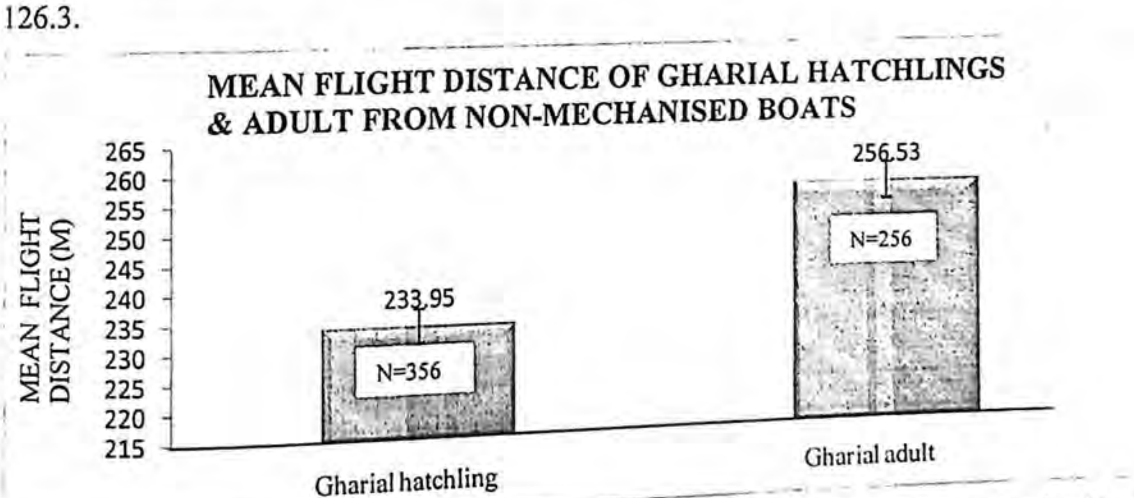


Figure 7.4 Mean flight distance for Gharial hatchlings and adult from non-mechanised boat in Katerniaghat Wildlife sanctuary (Dec 2010 to April 2011)

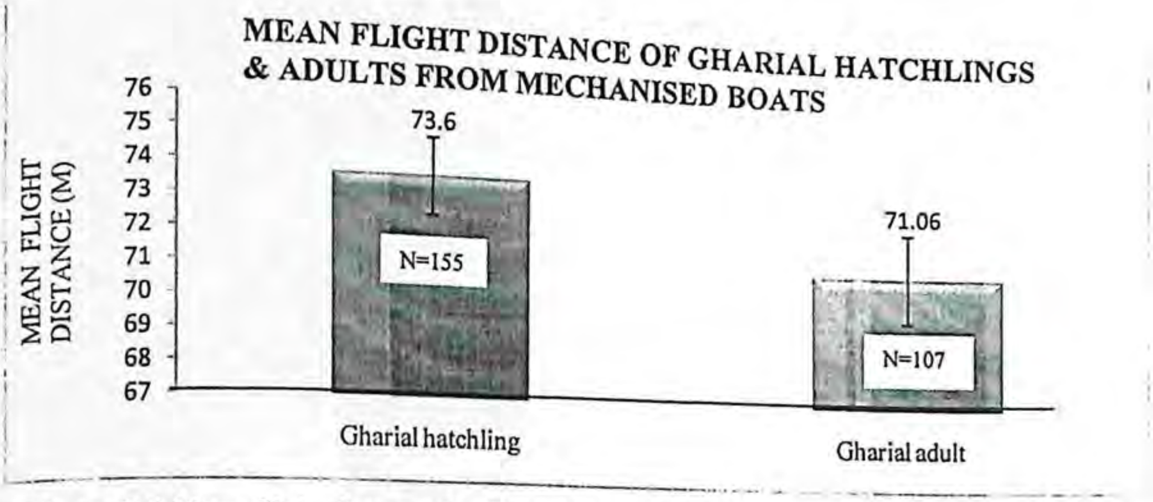


Figure 7.5 Mean flight distance for Gharial hatchlings and adult from mechanised boat in Katerniaghat Wildlife Sanctuary (Dec 2010 to April 2011)

There is no statistically significant difference in flight distances of Mugger hatchlings and Mugger adult from non-mechanised boats (z = -0.72, p= .47, α=.05) with mean rank for Mugger hatchlings of 55.2and for Mugger adult of 60.7. From mechanised boat there is a statistically significant difference in flight distances of Mugger hatchlings and adult from (z = -6.7, p= .000, α=.05) with mean rank for Mugger hatchlings of 92.2 and for Mugger adult of 45.1.

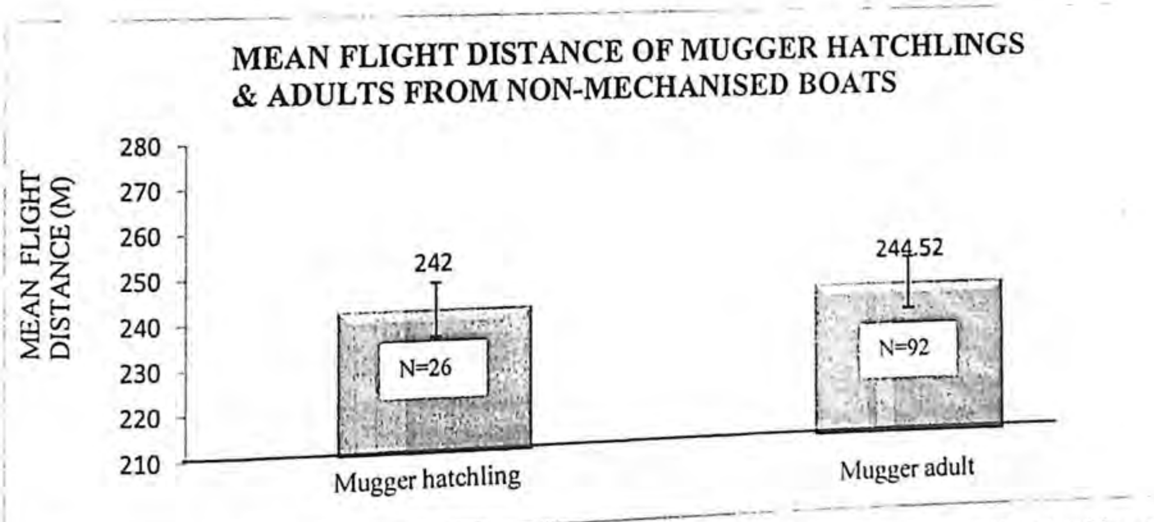


Figure 7.6 Mean flight distance for Mugger hatchlings and adult from non-mechanised boat in Katerniaghat Wildlife Sanctuary (Dec 2010 to April 2011)

From Fig 7.6 it is clear that between Mugger juveniles and adults there is no difference in flight distance from non-mechanised boat but from mechanised boat there is a huge differences in flight distances (Fig 7.7).

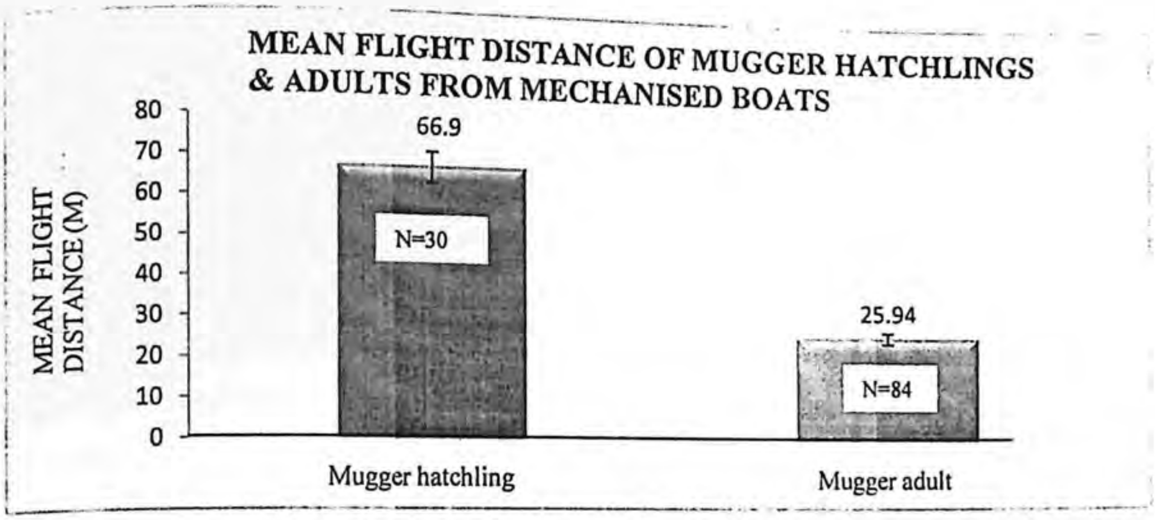


Figure 7.7 Mean flight distance for Mugger hatchlings and adults from mechanised boat in Katerniaghat Wildlife Sanctuary (Dec.2010 to April 2011)

8.1 Relative abundance & age structure

8.1.1 Relative abundance

For Gharial, adults and juveniles are more in number in the sanctuary compared to sub adults. Number of juveniles were more because Gharial hatchlings from kukrail , lucknow are released in Girwa river every year and there is natural increment from the wild population as well. This release programme started in 2005 (R.F.O. per.comm) and prior to this release, population increase was from the wild. Adults were more in number, as they were the survived individuals that were released during head-start programme in 1995 (Maskey 1999). After this the population was left to grow. Since survival rate of Gharial is <1% population increment was very low, that may be the reason for the sub-adult abundance were less compared to juveniles and adults.

For Mugger, juveniles are way less compared to sub adults and adults. One reason can be since Mugger prefers shallow, stagnant water and make nest near those pools (Whitaker 2007). These pools connect with the main river during monsoon only. Few juveniles that were sighted may have come in to the river during flood. Large number of adults and sub adults in river were seen may be because during winter and summer the water of nearby pools become insufficient for large bodied individuals so they migrate in to the main river. Long distance migrations are reported in Muggers during scarcity of water (Whitaker 1977, Whitaker and Whitaker 1979).

8.1.2 Seasonal and temporal effect on sightings

Crocodiles being cold blooded rely on ambient temperature for metabolic functions, growth and to meet their other physiological requirements. Heat is produced as a by-product of metabolic activity but during winters this heat is not sufficient. To get ample amount to heat they bask in sun (Huey 1982). Fluctuating environmental conditions that differ from thermal preferences of reptiles increase the time required to thermoregulate. Hence basking is more in winters compared to summers as the water temperature gets colder than the air temperature and hence they spend more time basking and simultaneously sightings in winter were more (Venugopal 2003). During summers mid-day temperature reaches about 36°c that becomes unbearable for crocodiles so they bask only when temperature is low i.e. morning and evening. Also in summers water temperature become close to preferred body temperature (Seebacher and Grigg 1997). That's why sightings reduce as temperature increases in summers.

8.1.3 Encounter rate and segments

Gharial encounter rate was high in segment 6-8km, 8-10km & 10-12km (Fig 4.5). These areas contained >50% of the total individuals sighted. All these segments had sand bars which was the most preferred place by Gharial (Hussain 2009, Taigor and Rao 2010). Mugger encounter rate was highest in segment 6-8km. Majority of mugger sightings were on the banks and also on sand bars. Mugger preferred all types of substrata for basking and most preferred is rocks (Venugopal and Prasad 2003) but in Katerniaghat wildlife Sanctuary not a single sighting of mugger on rocky areas were found because very small stretch of the river had rocky substratum.

8.1.4 Encounter rate across a gradient of disturbance

Encounter rate was high for segments with high to moderate disturbance while for segment with highest disturbance encounter rate was minimum. This can be because all the segments with moderate to high disturbances had sand bars. Though segment with minimum encounter rate also had sand bars but the level of disturbance was extremely high which would have deterred crocodiles to use those sand bars. Segments with low disturbance and low encounter rate had no sand bars in them. So I conclude that moderate disturbance is bearable if suitable habitats like sand bar are present. In Chambal Gharial are known to bask on rocky surface when suitable habitats like undisturbed sandy area are unavailable (Hussain 2009). Though the study area, there was various degree of disturbances and it was noted that Gharial have become tolerant to moderate levels of disturbances.

8.2 Habitat utilization

Habitat utilization against availability was also observed to be different for Gharial and Mugger and it also varies with season. Habitat variables that make a site that lead to its selection for basking in winter for Gharial are slope, height, soil moisture, presence of island, distance to water and current land use pattern where as for Mugger it was slope, height and soil moisture did not appeared to be important. Gharial has weak legs so it cannot negotiate to places that are steep and elevated. Current land usage effect the selection of site as basking site for both species as continuous disturbance will increase shunting between land and water and instead of continuous thermoregulation, they will lose it in this process. Mugger in Katerniaghat Wildlife Sanctuary appears to be tolerant to human presence than Gharial but both preferred to avoid human beings.

During summer habitat use, depth gradient and distance to water for Mugger and slope, height, soil moisture, presence of island, depth gradient and distance to water for Gharial were important variables that lead to the site selection. Water depth gradient came into picture in summer since body heating takes place quick and to avoid overheating they descend into water more often.

A large extent of Riverine habitat may seem to be available but are not in use by crocodiles as maximum encounter rate were confined only to a few segments.

8.3 Resource partitioning

8.3.1 Temporal separation

In winters there is no temporal segregation among different size classes of Gharial and Mugger. Both the species exhibited unimodal pattern of basking. This was because in winters suitable ambient temperature (9.8°C to 20.5°C) is during mid-day and that too only for a short duration. So every individual wanted to utilise the heat as efficiently as possible. While in summers they had plenty of time for basking, so they basked according to their requirement of heat based on their body sizes and dominance. Large bodied individuals tend to bask for longer duration to meet their heat requirements compared to smaller individuals. Social interactions interfere with thermoregulation (Huey 1982) and the basking sites are physically competed for (Magnuson et al. 1979). The early arrival of juveniles and sub-adults to bask could be to avoid interactions with the dominant larger individuals, which were observed to arrive later for basking (Fig 6.4 & Fig 6.5). The bimodal basking pattern is also observed in *Crocodylus palustris* (Tibbo 1991, Venugopal and Prasad 2003), *Alligator mississippiensis* (Lang 1987), *C. Niloticus* (Modha 1968, Loveridge 1984) and *Gavialis gangeticus* (Kumar 1988). Basking pattern of *Crocodylus palustris* (Gupta and Hari 1989) and *Gavialis gangeticus* (Kumar 1988, Hussain 2009) changes with season.

8.3.2 Basking site selection

Choice of basking site was different for Gharial and Mugger. Gharial preferred gentle slopes and less platform height compared to Mugger because Gharial doesn't have strong legs as that of Mugger. Gharial can only crawl on land unlike Mugger which resort to high walk. So Gharials select such sites which are not difficult to reach and get down to water. Gharials being lighter in colour need more heat to warm their body compared to Mugger with darker coloration, that's why Gharials like to bask on sand or sand+silt which has far more moisture than other surfaces and hence provide a hot (sun) and cool (moisture in sand) environment, thus reducing the chance of desiccation while basking in the sun and can spend more time basking or tolerate high ambient temperature (Hussain 2009). In Chambal 67% of the total sighted Gharial were basking on Sand (Hussain 2009). Mugger can go for a variety of basking substrata ranging from sand to silt and rock to fallen logs. In the present study area sand was only available on sand bars (Islands) and hence Gharials were mainly sighted on islands. Muggers were found almost in all Riverine habitat including river banks.

8.3.3 Nesting site selection

Selection of best nest site is the most important decision that an animal takes that would help in establishing successful progenies. If nest site is not free from predators or not far enough form water, not in proper substrata then nest survival also reduces. Gharial and Mugger had totally different preference to habitat variables for nest site selection. Gharial laid eggs near to water than Mugger. One explanation can be that due to physiological and morphological reasons they can't excavate their nest and carry young ones to water unlike Mugger. It is necessary to select a site that is near to water but elevated so that fluctuation in water level doesn't damages the nest.

8.3.4 Nearest neighbour distance during basking

Gharial juveniles prefer Gharial juveniles and Gharial adults, as they were observed mostly with Gharial juveniles and in very close proximity. Hatchlings tend to remain in group and every group is guarded by an adult female (Bustard 1978). If hatchlings were seen with Gharial sub-adult, they maintained a distance. Sub adults may cause some threat to hatchlings. It has been reported in *Crocodylus moreleti* (Hunt 1977) and *Alligator mississippiensis* (Hunt and Watanabe 1982). Gharial juveniles were seen only on very few occasions with Mugger sub-adult or Mugger adult only when accompanied by an adult Gharial. There are reports of Mugger predating on Gharial hatchlings (RFO Katerniaghat per. Comm.). Gharial sub-adult maintained a distance from Gharial sub-adult and was seen on few occasions only. This can be because this stage is the dispersing stage Gharial adult remained in a close proximity with Gharial juveniles and Gharial adults. It generally avoided Muggers, to reduce competition. Mugger juveniles were seen only with Mugger adult or alone. Muggers preferred to be alone most of the time during the study period.

8.4 Tourism & fishing as potential disturbance factors

In the above results flight distance from a mechanised boat was observed to be less compared to non-mechanised boat. It implies that crocodiles are not affected by tourism or with time they have learned that mechanised boats except for making noise are harmless. One explanation for more flight distance from non-mechanised fishing boats can be that they have correlated non-mechanised boats with fishing or hunting and non-mechanised boats are not common unlike mechanised boats. Though most of the Girwa River is protected, there are few areas of the river that are auctioned or given to villages for fishing (R.F.O, Katerniaghat per. Comm.). In Spectacled Caiman (*Caiman crocodilus*) wariness was more with engine as compared to switched off engine (Paquier et al.).

Comparison for flight distances among the two species reveals that Muggers are more tolerant to disturbance than Gharial. Muggers have been living in close vicinity of human beings and with a slight danger do not hesitate to resort to retaliatory attack (Whitaker 2007). Whereas Gharial preferred areas free from anthropogenic pressure (Hussain 2009). Gharials can also attack humans but only under certain physiological conditions (Bustard and Choudhury 1981).

When flight distance among size classes of Gharial was compared hatchlings had less flight distance from non-mechanised boat than that of Gharial adults. The relationship between size and flight was also observed in *Crocodylus porosus* (Webb and Messel 1979) *Caiman yacare and Melanosuchus niger* (Pacheco 1996) *Crocodylus porosus* and *Crocodilus novaeguineae* (Montaguje 1983). Hatchlings were found to show little or no avoidance behaviour. Increased size appears to be inherently associated with increased flight distance *(Webb and Messel 1979).*and they postulated that flight distance is not totally explicable on the basis of learned behaviour. However, larger crocodilians become wary on the basis of experience, which increases with age. Differences in the types of experience (i.e., hunting, capturing) to which a population is subjected will determine differences in wariness.

9. CONCLUSION & CONSERVATION IMPLICATIONS

This study focused on the population structure, relative density as a function of habitat, behavioural aspects and disturbance. This section also focuses on the conservation implications for Gharial based on the outcome of the study.

1) Due to assisted anthropogenic alteration in the population structure and sex ratio of Gharial in the study area there is bias towards a particular size class. According to head start programme individuals more than 1.5cm of length were released but in the study area hatchlings <1.5cm of length were released or eggs from kukrail, Lucknow were artificially laid. Out of 20 km river stretch only 5 to 8 kms are used extensively for basking and nesting by Gharials. Habitat resources being critically limited, a review of further reintroduction of either Gharial or Mugger or both the species requires a critical examination. It would perhaps be not out of place to suggest a moratorium on any further reintroduction of crocodilians in sanctuary for the time being.
2) Segments/ areas with maximum encounter rate have to be protected from natural and anthropogenic disturbances in order to save a critically endangered species i.e. Gharial from the brink of extinction. Sand bars play the major role in the selection of basking sites by Gharial; hence it is important to protect them from erosion due to water.
3) Study area is subjected to various intensities of anthropogenic pressures like tourism, illegal fishing, human habitation etc. which may create hindrance in the long term survival of Gharial in the study area. It is crucial for the forest Department to reduce pressure by increasing patrolling.
4) Sympatric crocodilian species based on the study seems to have an efficient resource partitioning mechanism given the fact that habitat resources both in time and space are limiting. Given the fact that Katerniaghat Wildlife Sanctuary supports a relatively small stretch of habitat for crocodiles, it will be prudent to work at the absolute carrying capacity of the Sanctuary in terms of the two species of crocodilian population.

REFERENCE

Aguilera, X., J. S. Coronel, T. Oberdorff, and P. A. V. Damme. 2008. Distribution patterns, population status and conservation of *Melanosuchus niger* and *Caiman yacare* (Crocodylia, Alligatoridae) in oxbow lakes of the Ichilo river floodplain, Bolivia. Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) 56.

Bustard, H. R. 1978. Maternal care in Gharial (*Gavialis gangeticus).* British Journal of Herpetology 6:63-64.

Bustard, H. R., and B. C. Choudhury. 1981. The distribution of Gharial. Journal of Bombay Natural History Society 79:427-428.

Choudhury, B. C., and R. K. Rao. 1982. Status survey of crocodile populations. A field guide. Central Crocodile Breeding and Management Training Institute, Hyderabad, Andhra Pradesh, India.

Cott, H. B. 1961. Scientific results of an inquiry into the ecology and economic status of the Nile crocodile (*Crocodylus niloticis*) in Uganda and Northern Rhodesia. Trans. Zool. Soc. London 29:211-356.

Dunson, W. A., F. J. Mazzotti, and 1989. Salinity as a limiting factor in the distribution of reptiles in Florida Bay: a theory for the estuarine origin of marine snakes and turtles. Bulletin of Marine Science 44:229-244.

Goodwin, T. M., and W. R. Marion. 1978. Aspects of the Nesting Ecology of American Alligators (*Alligator mississippiensis*) in North-Central Florida. Herpetologica 34:43-47.

Groombridge, B., editor. 1987. The distribution and status of world crocodilians. Surrey Beatty R. Sons. Pvt. Ltd. in association with the Conservation Commission of the Northern Territory: Australia.

Gupta, R. C., and P. S. Hari. 1989. On the basking behaviour of the mugger *Crocodylus palustris* at Bhorsainda Crocodile Sanctuary, Haryana, India. J. Bombay Nat. Hist. Soc. 86.

Hall, P. M. 1989. Variation in Geographic Isolates of the New Guinea Crocodile (*Crocodylus novaeguineae* Schmidt) Compared with the Similar, Allopatric, Philippine Crocodile (*C. mindorensis* Schmidt). Copeia 1989:71-80.

Herron, J. C. 1994. Body Size, Spatial Distribution, and Microhabitat Use in the Caimans, *Melanosuchus niger* and *Caiman crocodilus*, in a Peruvian Lake Journal of Herpetology 4:508-513.

Huey, R. B., editor. 1982. Temperature, physiology, and the ecology of reptiles. Volume 12.Academic Press. New York.

Hunt, R. H. 1977. Aggressive Behavior by Adult Morelet's Crocodiles *Crocodylus moreleti* toward Young. Herpetologica 33:195-201.

Hunt, R. H., and M. E. Watanabe. 1982. Observations on Maternal Behavior of the American Alligator, *Alligator mississippiensis* Journal of Herpetology 16:235-239.

Hussain, S. A. 1999. Reproductive success, hatchling survival and rate of increase of gharial *Gavialis gangeticus* in National Chambal Sanctuary, India. Biological Conservation 87:261-268.

Hussain, S. A. 2009. Basking site and water depth selection by gharial *Gavialis gangeticus* Gmelin 1789 (Crocodylia, Reptilia) in NationalChambal Sanctuary, India and its implication for river conservation. Aquatic Conserv: Mar. Freshw. Ecosyst. 19:127–133.

Hutton, J. 1989. Movements, Home Range, Dispersal and the Separation of Size Classes in Nile Crocodiles. American Zoologist 29:1033-1049.

Kofron, C. P. 1992. Status and Habitats of the Three African Crocodiles in Liberia. Journal of Tropical Ecology 8.

Kolbe, J. J., and F. J. Janzen. 2002. Impact of Nest-Site Selection on Nest Success and Nest Temperature in Natural and Disturbed Habitats. Ecology. 83: 269-281.

Kumar, R. 1988. Basking behaviour of gharials.Unpublished masters dissertation thesis, Bharathidasan University, Tiruchirapalli.

Lang, J. 1987. Crocodilian thermal selection. *In*: Wildlife management: crocodiles and alligators. pp: 301-317. G. J. W. Webb, S. C. Manolis & P. J. Whitehead (Eds). Surrey Beatty and Sons Pty Limited/Conservation Commission of the Northern Territory, Chipping Norton. Loveridge, J. P., editor. 1984. Thermoregulation in Nile crocodiles. Academic Press, London.

Lovett, G. M., D. A. Burns, C. T. Driscoll, J. C. Jenkins, J. M. Myron, L. Rustad, J. B. Shanley, G. E. Likens, and R. Haeuber. 2007. Who Needs Environmental Monitoring? Frontiers in Ecology and the Environment 5:253-260.

Lutz, P. L., and A. Dunbar-Cooper. 1984. The Nest Environment of the American Crocodile (*Crocodylus acutus*). Copeia 1984:153-161.

Magnusson, J. J., L. B. Crowder, and P.A. Medvick. 1979. Temperature as an ecological resource. American Zool. 19: 331-343.

Magnusson, W. E. 1985. Habitat selection, parasites, and injuries in Amazonian crocodiles. Amazonia 9:193-204.

Magnusson, W. E., E. V. d. Silva, and A. P. Lima. 1987. Diets of Amazonian Crocodilians. Journal of Herpetology 21:85-95.

Martin, B. G. H., and A. D. A. Bellairs. 1977. The narial excresence and pterygoid bulla of the gharial, *Gavialis gangeticus* (Crocodilia). J. Zool. Lond 182:541-558.

Martin, T. E. 1998. Are microhabitat preferences of coexisting species under selection and adaptive Ecology 79: 656-670.

Maskey, T. M., H. F. Percival, and C. L. Abercrombie. 1995. Gharial Habitat Use in Nepal. Journal of Herpetology 29:463-464.

Maskey TM. 1999. Status and conservation of gharial in Nepal. In ENVIS Bulletin on Wildlife and Protected Areas. Wildlife Institute of India: Dehra Dun, Vol. 2; 95-99.

Mazzotti, F. J., R. G. Harvey, K. G. Rice, M. S. Cherkiss, and B. M. Jeffery. 2008. The Crocodilian Indicator in the Greater Everglades: 2006 Assessment Report. University of Florida, Fort Lauderdale Research and Education Center, Davie, FL.

Modha, M. L. 1968. Basking behaviour of the Nile crocodile on Central Island, Lake Rudolf. E. African Wildl. J 8:81-89.

Montaguje, J. 1983. Influence of water level, hunting pressure, and habitat type on crocodile abundance in the Fly River drainage, Papua New Guinea. Biol. Conser. 26:309-339.

Pacheco, L. F. 1996. Wariness of Caiman Populations and Its Effect on Abundance Estimates. Journal of Herpetology 30:123-126.

Paquier, F., P.-Y. Henry, and G. Dubois. Impacts of tourism motorized boating and recreational capture on caimans.

Pianka, E. R., editor. 1975. Ecology and evolution of communities. Harvard Univ. Press.

Rao, R. J., and B. C. Choudhury. 1990. Sympatric distribution of Gharial and Mugger in India. Journal of Bombay Natural History Society 89:312-315.

Rebêlo, G. H., and L. Lugli. 2001. Distribution and abundance of four caiman species (Crocodylia: Alligatoridae) in Jaú National Park, Amazonas, Brazil. Rev. Biol. Trop 49.

Richter, B. D., R. Mathews, D. L. Harrison, and R. Wigington. 2003. Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity. Ecological Applications 13:206-224.

Rodgers, W. A. 1991. Techniques for wildlife census in India. A field Manual TM- 2, Wildlife Institute of India, Dehradun, India.

Roland, J., C. Nilsson, M. Dynesius, and E. Andersson. 2000. Effects of River Regulation on River-Margin Vegetation: A Comparison of Eight Boreal Rivers. Ecological Applications 10:203-224.

Rootes, W. L., and R. H. Chabreck. 1933. Reproductive status and movement of adult female alligators. J. Herpetol 27:121-126.

Rosenzweig, M. L. 1981. A Theory of Habitat Selection. Ecology 62:327-335.

Schoener, T. W. 1974. Resource partitioning in ecological communities. Science. New series 185:27-39.

Seebacher , F., and G. C. Grigg. 1997. Patterns of body temperatures in wild freshwater crocodiles *Crocodylus johnstoni*: thermoregulation versus thermoconformity, seasonal acclimatization and the effect of social interactions. Copeia 1997(3): 549-557.

Silveira, R. D., W. E. Magnusson, and Z. Campos. 1997. Monitoring the Distribution, Abundance and Breeding Areas of Caiman *Crocodilus crocodilus* and *Melanosuchus niger* in the Anavilhanas Archipelago, Central Amazonia, Brazil. . Journal of Herpetology 31:514-520.

Singh, L. A. K. 1991. Non-survival of gharial *Gavialis gangeticus* in mahanadi, Orissa. Wildlife Wing Forest and Enveronment Dept. Govt. of Orissa.

Stevenson, C., and R. Whitaker, editors. 2010. Gharial *Gavialis gangeticus* Third Edition.Crocodile Specialist Group: Darwin.

Taigor, S. R., and R. J. Rao. 2010. Habitat Features of Aquatic Animals In The National Chambal Sanctuary, Madhya Pradesh, India. Asian J. exp. biol. scl 1:409-414.

Tibbo, K. 1991. Thermoregulatory and social behaviour in muggers in captivity. Madras Crocodile Bank Trust.

Toft, C. A. 1985. Resource Partitioning in Amphibians and Reptiles. Copeia 1985:1-21.

Tucker, A. D., H. I. McCallum, and C. J. Limpus. 1997. Habitat Use by *Crocodylus johnstoni* in the Lynd River, Queensland. Journal of Herpetology 31:114-121.

Venugopal, P. D., and K. V. D. Prasad. 2003. Basking behaviour and survey of marsh crocodiles *Crocodylus palustris* in Ranganthittu Bird sanctuary, Karnataka, India. Hamadryad 27.

Villamarín, F., B. Marioni, J. B. Thorbjarnarson, B. W. Nelson, R. Botero-Arias, and W. E. Magnusson. 2011. Conservation and management implications of nest-site selection of the sympatric crocodilians *Melanosuchus niger* and *Caiman crocodilus* in Central Amazonia, Brazil Biological Conservation 144:913–919.

Webb, G. J. W., and H. Messel. 1979. Wariness in *Crocodilus porosus* (Reptilia: Crocodilidae). Aust. Wildl. Res 6:227-234.

Whitaker, R. 1977. Note on the status of Gir crocodiles. J. Bombay Nat. Hist. Soc. 75:224-227.

Whitaker, R. 2007. The Gharial: Going extinct again. Iguana 14:24-33.

Whitaker, R., and D. Basu. 1983. The gharial (Gavialis gangeticus): a review. Journal of Bombay Natural History Society 79:531–548.

Whitaker, R., and J. C. Daniel. 1978. The status of Asiatic crocodiles. Tiger paper (FAO, Asia) 5:12-17.

Whitaker, R., and Z. Whitaker. 1979. Preliminary crocodile survey - Sri Lanka. . J. Bombay Nat. Hist. Soc. 76:66-85.

Whitaker, R., and Z. Whitaker. 1984. Reproductive biology of Mugger. J. Bombay Nat. Hist. Soc. 81:119-127.

Whitaker, R., and H. Andrews. 2003. Crocodile conservation, Western Asia Region: an update. J. Bombay Nat. Hist. Soc. 100(2&3): 432-445.

Whitaker, R., B. Barr, A. de Silva, and P. Ratnasiri. 2007. Observations on burrows dug by mugger crocodiles (*Crocodylus palustris*) in Bundala National Park, Sri Lanka. J. Bombay Nat. Hist. Soc. 104(2): 19-24.

Gharial Recovery Action Plan 2006

http://www.flmnh.ufl.edu/cnhc/csl.html

http://www.wildlifeorissa.in/croctracking.html# Tracks of 'high-walk' to distinguish Gharial and Mugger

http://www.cmg.colostate.edu/

APPENDIX 1

CORRELATION MATRIX OF HABITAT VARIABLES OF WINTER GHARIAL BASKING HABITAT

	SAND_ BAR	SAND_ SILT_ ISLAND	SAND_ CLAY_ BANK	SILT_ BANK	SAND_ BANK	SAND_ SILT_ BANK	ROCKY _BANK	SLOPE	HEIGHT	MOISTURE	DIST_ WATER	USE	D_G
SAND_BAR	1	-0.3	-0.5	-0.219	-0.143	-0.341	-0.103	-0.419	-0.317	0.319	0.409	-0.259	0.187
SAND_SILT_ ISLAND	-0.3	1	-0.182	-0.079	-0.052	-0.124	-0.037	-0.161	-0.134	0.155	-0.163	0.067	-0.125
SAND_CLAY_ BANK	-0.5	-0.182	1	-0.133	-0.087	-0.207	-0.062	0.597	0.448	-0.44	-0.273	0.149	-0.089
SILT_BANK	-0.219	-0.079	-0.133	1	-0.038	-0.09	-0.027	0.144	0.1	-0.129	-0.119	0.151	-0.159
SAND_BANK	-0.143	-0.052	-0.087	-0.038	1	-0.059	-0.017	-0.071	-0.043	0.063	-0.078	-0.027	-0.037
SAND_SILT_ BANK	-0.341	-0.124	-0.207	-0.09	-0.059	1	-0.042	-0.033	-0.012	-0.009	0.0203	0.012	0.058
ROCKY_BANK	-0.103	-0.037	-0.062	-0.027	-0.017	-0.042	1	-0.057	-0.035	0.032	-0.056	0.097	0.045
SLOPE	-0.419	-0.161	0.597	0.144	-0.071	-0.033	-0.057	1	0.562	-0.628	-0.253	0.242	0.07
HEIGHT	-0.317	-0.134	0.448	0.1	-0.043	-0.012	-0.035	0.562	1	-0.759	-0.194	0.054	-0.034
MOISTURE	0.319	0.155	-0.44	-0.129	0.063	-0.009	0.032	-0.628	-0.759	1	0.1963	-0.2	0.0009
DIST_WATER	0.409	-0.163	-0.273	-0.119	-0.078	0.02	-0.056	-0.253	-0.194	0.196	1	-0.328	0.15
USE	-0.259	0.067	0.149	0.151	-0.027	0.012	0.097	0.242	0.054	-0.2	-0.328	1	-0.05
D_G	0.187	-0.125	-0.089	-0.159	-0.037	0.058	0.045	0.07	-0.034	0.0009	0.15	-0.05	1

APPENDIX 2

CORRELATION MATRIX OF HABITAT VARIABLES OF WINTER MUGGER BASKING HABITAT

	SAND _BAR	SAND_ SILT_ ISLAND	SAND_ CLAY_ BANK	SAND_ BANK	SAND_ SILT_ BANK	SILT_ BANK	ROCKY_ BANK	LOG_ BANK	SLOPE	HEIGHT	MOISTUR E	DIST_ WATER	USE
SAND_BAR	1	-0.083	-0.392	-0.148	-0.275	-0.087	0.0489	-0.054	-0.201	-0.159	0.1126	0.1067	-0.04
SAND_SILT_ ISLAND	-0.083	1	-0.119	-0.045	-0.084	-0.05	-0.027	-0.016	-0.113	-0.08	0.1059	-0.049	-0.05
SAND_CLAY_ BANK	-0.392	-0.119	1	-0.2	-0.394	-0.227	-0.127	-0.078	0.3865	0.2442	-0.12	-0.221	0.048
SAND_BANK	-0.148	-0.045	-0.2	1	-0.149	-0.069	-0.048	-0.029	-0.047	-0.071	0.0476	0.0656	0.100
SAND_SILT_ BANK	-0.275	-0.084	-0.394	-0.149	1	-0.167	-0.089	-0.055	-0.153	-0.031	-0.021	0.1471	-0.14
SILT_BANK	-0.087	-0.05	-0.227	-0.069	-0.167	1	0.1419	-0.033	0.0073	-0.041	0.0421	-0.104	0.116
ROCKY_BANK	0.0489	-0.027	-0.127	-0.048	-0.089	0.1419	1	-0.017	-0.107	-0.035	0.0224	0.0766	0.038
LOG_BANK	-0.054	-0.016	-0.078	-0.029	-0.055	-0.033	-0.017	1	-0.017	0.0075	-0.104	0.0258	-0.05
SLOPE	-0.201	-0.113	0.3865	-0.047	-0.153	0.0073	-0.107	-0.017	1	0.4745	-0.454	-0.122	0.136
HEIGHT	-0.159	-0.08	0.2442	-0.071	-0.031	-0.041	-0.035	0.0075	0.4745	1	-0.679	0.1	-0.09
MOISTURE	0.1126	0.1059	-0.12	0.0476	-0.021	0.0421	0.0224	-0.104	-0.454	-0.679	1	-0.11	0.006
DIST_WATER	0.1067	-0.049	-0.221	0.0656	0.1471	-0.104	0.0766	0.0258	-0.122	0.1	-0.11	1	-0.24
USE	-0.043	-0.059	0.048	0.1003	-0.14	0.1161	0.0384	-0.057	0.1368	-0.096	0.0068	-0.247	1
D_G	-0.011	0.0419	0.0042	0.0193	0.0834	-0.169	-0.008	0.0477	0.1326	0.0087	-0.044	0.0476	0.044

APPENDIX 3

CORRELATION MATRIX OF HABITAT VARIABLES OF SUMMER GHARIAL BASKING HABITAT

	SAND_ BAR	SAND_ SILT_ ISLAND	SAND_ BANK	SAND_ SILT_ BANK	SILT_ CLAY_ BANK	SILT_ BANK	ROCKY_ BANK	SLOPE	HEIGHT	MOISTUR E	DIST TO WATER	USE	DEPTH
SAND_BAR	1	-0.223	-0.207	-0.313	-0.545	-0.235	-0.110	-0.482	-0.370	0.3877	-0.558	-0.309	0.3309
SAND_SILT_ ISLAND	-0.223	1	-0.054	-0.081	-0.142	-0.061	-0.028	-0.130	-0.101	0.1068	-0.106	-0.086	0.0522
SAND_BANK	-0.207	-0.054	1	-0.076	-0.132	-0.057	-0.026	-0.041	-0.028	0.0438	0.1334	0.1660	-0.048
SAND_SILT_ BANK	-0.313	-0.081	-0.076	1	-0.199	-0.086	-0.040	-0.002	0.0102	-0.034	0.1690	0.0864	0.0036
SILT_CLAY_ BANK	-0.545	-0.142	-0.132	-0.199	1	-0.149	-0.070	0.5840	0.4417	-0.436	0.3948	0.1478	-0.288
SILT_BANK	-0.235	-0.061	-0.057	-0.086	-0.149	1	-0.030	0.1336	0.0944	-0.124	0.1706	0.1512	-0.211
ROCKY_BANK	-0.110	-0.028	-0.026	-0.040	-0.070	-0.030	1	-0.064	-0.039	0.0355	0.0800	0.0969	0.0778
SLOPE	-0.482	-0.130	-0.041	-0.002	0.5840	0.1336	-0.064	1	0.5573	-0.627	0.3704	0.2395	-0.165
HEIGHT	-0.370	-0.101	-0.028	0.0102	0.4417	0.0944	-0.039	0.5573	1	-0.761	0.3036	0.0610	-0.196
MOISTURE	0.3877	0.1068	0.0438	-0.034	-0.436	-0.124	0.0355	-0.627	-0.761	1	-0.310	-0.206	0.1772
DIST_WATER	-0.558	-0.106	0.1334	0.1690	0.3948	0.1706	0.0800	0.3704	0.3036	-0.310	1	0.4298	-0.364
USE	-0.309	-0.086	0.1660	0.0864	0.1478	0.1512	0.0969	0.2395	0.0610	-0.206	0.4298	1	-0.066
D_G	0.3309	0.0522	-0.048	0.0036	-0.288	-0.211	0.0778	-0.165	-0.196	0.1772	-0.364	-0.066	1

APPENDIX 4

CORRELATION MATRIX OF HABITAT VARIABLES OF SUMMER MUGGER BASKING HABITAT

	SAND_ BAR	SAND_ SILT_ ISLAND	SAND_ BANK	SAND_ SILT_ BANK	SILT_ BANK	SILT_ CLAY_ BANK	ROCKY_ BANK	LOG_ BANK	SLOPE	HEIGHT	MOISTURE	DIST_ WATER	USE
SAND_BAR	1	-0.075	-0.162	-0.167	-0.146	-0.403	-0.067	-0.019	-0.292	-0.203	0.2183	0.0445	-0.025
SAND_SILT_ ISLAND	-0.075	1	-0.061	-0.062	-0.054	-0.151	-0.025	-0.007	-0.122	-0.088	0.1094	0.0239	-0.015
SAND_BANK	-0.162	-0.061	1	-0.135	-0.118	-0.325	-0.054	-0.015	-0.159	-0.093	0.0964	-0.006	0.0777
SAND_SILT_ BANK	-0.167	-0.062	-0.135	1	-0.121	-0.334	-0.056	-0.016	-0.085	-0.074	0.0593	-0.049	0.0020
SILT_BANK	-0.146	-0.054	-0.118	-0.121	1	-0.292	-0.049	-0.014	0.0520	0.0261	-0.055	0.0461	0.0809
SILT_CLAY_ BANK	-0.403	-0.151	-0.325	-0.334	-0.292	1	-0.135	-0.038	0.4262	0.3002	-0.277	-0.022	-0.091
ROCKY_BANK	-0.067	-0.025	-0.054	-0.056	-0.049	-0.135	1	-0.006	-0.116	-0.077	0.0747	0.0213	0.0668
LOG_BANK	-0.019	-0.007	-0.015	-0.016	-0.014	-0.038	-0.006	1	-0.033	-0.014	-0.157	-0.184	-0.038
SLOPE	-0.292	-0.122	-0.159	-0.085	0.0520	0.4262	-0.116	-0.033	1	0.4789	-0.542	0.1017	0.0771
HEIGHT	-0.203	-0.088	-0.093	-0.074	0.0261	0.3002	-0.077	-0.014	0.4789	1	-0.717	0.0878	-0.103
MOISTURE	0.2183	0.1094	0.0964	0.0593	-0.055	-0.277	0.0747	-0.157	-0.542	-0.717	1	-0.052	-0.057
DIST_WATER	0.0445	0.0239	-0.006	-0.049	0.0461	-0.022	0.0213	-0.184	0.1017	0.0878	-0.052	1	0.0557
USE	-0.025	-0.015	0.0777	0.0020	0.0809	-0.091	0.0668	-0.038	0.0771	-0.103	-0.057	0.0557	1
D_G	0.1757	0.0219	-0.049	0.1786	-0.136	-0.175	0.1333	-0.091	0.0183	-0.059	0.0454	0.0630	0.1747

APPENDIX 5

Model with all the variables in forced entry (Gharial winter basking site) AIC – 357.790

R1[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
1	Intercept	17.661	1691.50	.000	1	.992			
	SL_HT_PC_MO_NC	-3.941	1.454	7.347	1	.007	.019	.001	.336
	USE	-1.172	.250	22.006	1	.000	.310	.190	.505
	[ROCKY_BANK=.00]	1.249	.000	.	1	.	3.486	3.486	3.486
	[ROCKY_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_BANK=.00]	2.161	1136.00	.000	1	.998	8.677	.000	.[c]
	[SAND_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_SILT_ISLAND=.00]	-17.116	284.216	.004	1	.952	3.68E-8	4.383E-250	3.1E234
	[SAND_SILT_ISLAND=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_BAR=.00]	-15.419	284.216	.003	1	.957	2.01E-7	2.392E-249	1.6E235
	[SAND_BAR=1.00]	0[b]	.	.	0	.	.	.	.
	[SILT_BANK=.00]	-.797	663.152	.000	1	.999	.451	.000	.[c]
	[SILT_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_SILT_BANK=.00]	-12.645	284.216	.002	1	.965	3.22E-6	3.832E-248	2.7E236
	[SAND_SILT_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	DIST_WATER	.082	.015	31.481	1	.000	1.086	1.055	1.117
	D_G	.151	.104	2.114	1	.146	1.164	.949	1.427

APPENDIX 6

Model with only significant variables in forced entry, rest in backward elimination (Gharial winter basking site) **AIC – 359.33**

R1[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
1	Intercept	-4.526	1.826	6.145	1	.013			
	SL_HT_PC_MO_NC	-4.530	1.412	10.287	1	.001	.011	.001	.172
	USE	-1.356	.250	29.315	1	.000	.258	.158	.421
	DIST_WATER	.086	.014	35.477	1	.000	1.089	1.059	1.121
	[SAND_SILT_ISLAND =.00]	-5.199	.551	89.104	1	.000	.006	.002	.016
	[SAND_SILT_ISLAND =1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_BAR=.00]	-3.590	.460	60.847	1	.000	.028	.011	.068
	[SAND_BAR=1.00]	0[b]	.	.	0	.	.	.	.

APPENDIX 7

Model with all the variables in forced entry (Mugger winter basking site) **AIC – 317.4**

							95% Confidence Interval for Exp(B)	
R1[a]	B	Std. Error	Wald	df	Sig.	Exp(B)	Lower Bound	Upper Bound
1 Intercept	-.972	4477.75	.000	1	1.000			
SL_HT_PC_MO_NC	.239	.168	2.018	1	.155	1.270	.913	1.765
USE	-1.032	.268	14.854	1	.000	.356	.211	.602
[ROCKY_BANK=.00]	.908	769.048	.000	1	.999	2.480	.000	.[b]
[ROCKY_BANK=1.00]	0[c]	.	.	0	.	.	.	.
[SAND_SILT_BANK=.00]	-1.433	769.047	.000	1	.999	.239	.000	.[b]
[SAND_SILT_BANK=1.00]	0[c]	.	.	0	.	.	.	.
[SAND_CLAY_BANK=.00]	.977	769.048	.000	1	.999	2.657	.000	.[b]
[SAND_CLAY_BANK=1.00]	0[c]	.	.	0	.	.	.	.
[SAND_BAR=.00]	-1.188	769.047	.000	1	.999	.305	.000	.[b]
[SAND_BAR=1.00]	0[c]	.	.	0	.	.	.	.
[SAND_SILT_ISLAND=.00]	.317	769.048	.000	1	1.000	1.373	.000	.[b]
[SAND_SILT_ISLAND=1.00]	0[c]	.	.	0	.	.	.	.
[SAND_BANK=.00]	1.215	769.048	.000	1	.999	3.371	.000	.[b]
[SAND_BANK=1.00]	0[c]	.	.	0	.	.	.	.
[SILT_BANK=.00]	13.764	798.398	.000	1	.986	9.49E5	.000	.[b]
[SILT_BANK=1.00]	0[c]	.	.	0	.	.	.	.
[LOG_BANK=.00]	-19.007	.000	.	1	.	5.56E-9	5.565E-9	5.565E-9
[LOG_BANK=1.00]	0[c]	.	.	0	.	.	.	.
DIST_WATER	.035	.006	31.696	1	.000	1.036	1.023	1.049

APPENDIX 8

Model with only significant variables in forced entry, rest in backward elimination (Mugger winter basking site) **AIC – 339.9**

R1[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	Upper Bound
1	Intercept	-3.722	1.092	11.618	1	.001			
	USE	-1.104	.258	18.262	1	.000	.332	.200	.550
	DIST_WATER	.034	.006	33.205	1	.000	1.035	1.023	1.047
	SL_HT_PC_MO_NC	.323	.156	4.302	1	.038	1.381	1.018	1.873
	[SAND_SILT_BANK=.00]	-1.438	.468	9.429	1	.002	.237	.095	.594
	[SAND_SILT_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_CLAY_BANK=.00]	1.063	.562	3.581	1	.058	2.896	.963	8.712
	[SAND_CLAY_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_BAR=.00]	-1.188	.478	6.168	1	.013	.305	.119	.778
	[SAND_BAR=1.00]	0[b]	.	.	0	.	.	.	.

APPENDIX 9

Model with all the variables in forced entry (Gharial summer basking site) **AIC – 225.3**

R1[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
1	Intercept	43.822	1819.775	.001	1	.981			
	SL_HT_PC_MO_NC	-12.032	3.003	16.048	1	.000	5.952E-6	1.652E-8	.002
	D_G	-.308	.126	5.948	1	.015	.735	.574	.941
	[ROCKY_BANK=.00]	.206	.000	.	1	.	1.229	1.229	1.229
	[ROCKY_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_SILT_BANK=.00]	-12.069	393.878	.001	1	.976	5.735E-6	.000	.[c]
	[SAND_SILT_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_SILT_ISLAND=.00]	-15.145	393.878	.001	1	.969	2.645E-7	.000	.[c]
	[SAND_SILT_ISLAND=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_BAR=.00]	-16.078	393.877	.002	1	.967	1.041E-7	.000	.[c]
	[SAND_BAR=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_BANK=.00]	-12.200	393.879	.001	1	.975	5.033E-6	.000	.[c]
	[SAND_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SILT_BANK=.00]	.543	992.213	.000	1	1.000	1.721	.000	.[c]
	[SILT_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	USE	-.551	.235	5.474	1	.019	.576	.363	.914
	DIST_WATER	-.111	.015	55.147	1	.000	.895	.870	.922

APPENDIX 10

Model with only significant variables in forced entry, rest in backward elimination (Gharial summer basking site) **AIC – 225.3**

R1[a]	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
							Lower Bound	Upper Bound
1 Intercept	43.822	1819.77	.001	1	.981			
SL_HT_PC_MO_NC	-12.03	3.003	16.048	1	.000	5.95E-6	1.652E-8	.002
D_G	-.308	.126	5.948	1	.015	.735	.574	.941
DIST_WATER	-.111	.015	55.147	1	.000	.895	.870	.922
[ROCKY_BANK=.00]	.206	.000	.	1	.	1.229	1.229	1.229
[ROCKY_BANK=1.00]	0[b]	.	.	0	.	.	.	.
[SAND_SILT_BANK=.00]	-12.069	393.878	.001	1	.976	5.73E-6	.000	.[c]
[SAND_SILT_BANK=1.00]	0[b]	.	.	0	.	.	.	.
[SAND_SILT_ISLAND=.00]	-15.14	393.878	.001	1	.969	2.64E-7	.000	.[c]
[SAND_SILT_ISLAND=1.00]	0[b]	.	.	0	.	.	.	.
[SAND_BAR=.00]	-16.07	393.877	.002	1	.967	1.04E-7	.000	.[c]
[SAND_BAR=1.00]	0[b]	.	.	0	.	.	.	.
[SAND_BANK=.00]	-12.20	393.879	.001	1	.975	5.03E-6	.000	.[c]
[SAND_BANK=1.00]	0[b]	.	.	0	.	.	.	.
[SILT_BANK=.00]	.543	992.213	.000	1	1.000	1.721	.000	.[c]
[SILT_BANK=1.00]	0[b]	.	.	0	.	.	.	.
USE	-.551	.235	5.474	1	.019	.576	.363	.914

APPENDIX 11

Model with all the variables in forced entry (Mugger summer basking site) **AIC – 164.9**

R1[a]	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	Upper Bound
1 Intercept	22.994	30.178	.581	1	.446			
SL_HT_PC_HT_NC	-.501	.334	2.246	1	.134	.606	.315	1.167
USE	-.635	.352	3.258	1	.071	.530	.266	1.056
[LOG_BANK=.00]	-15.66	.000	.	1	.	1.5E-7	1.567E-7	1.567E-7
[LOG_BANK=1.00]	0[b]	.	.	0	.	.	.	.
[SILT_CLAY_BANK=.00]	-2.127	5.938	.128	1	.720	.119	1.051E-6	13511.411
[SILT_CLAY_BANK=1.00]	0[b]	.	.	0	.	.	.	.
[SAND_SILT_BANK=.00]	-1.233	5.973	.043	1	.836	.291	2.400E-6	35390.090
[SAND_SILT_BANK=1.00]	0[b]	.	.	0	.	.	.	.
[SAND_SILT_ISLAND=.00	.847	7.981	.011	1	.915	2.333	3.753E-7	1.450E7
[SAND_SILT_ISLAND=1.0	0[b]	.	.	0	.	.	.	.
[SAND_BAR=.00]	-1.840	5.935	.096	1	.756	.159	1.409E-6	17880.941
[SAND_BAR=1.00]	0[b]	.	.	0	.	.	.	.
[SAND_BANK=.00]	-1.588	5.953	.071	1	.790	.204	1.750E-6	23845.423
[SAND_BANK=1.00]	0[b]	.	.	0	.	.	.	.
[SILT_BANK=.00]	.732	6.457	.013	1	.910	2.079	6.637E-6	651345.836
[SILT_BANK=1.00]	0[b]	.	.	0	.	.	.	.
[ROCKY_BANK=.00]	0[b]	.	.	0	.	.	.	.
[ROCKY_BANK=1.00]	0[b]	.	.	0	.	.	.	.
DIST_WATER	-.071	.013	30.852	1	.000	.932	.909	.955
D_G	-.191	.080	5.748	1	.017	.826	.706	.966

APPENDIX 12

Model with only significant variables in forced entry, rest in backward elimination (Mugger summer basking site) **AIC – 164.9**

R1[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
1	Intercept	22.994	30.178	.581	1	.446			
	USE	-.635	.352	3.258	1	.071	.530	.266	1.056
	DIST_WATER	-.071	.013	30.852	1	.000	.932	.909	.955
	D_G	-.191	.080	5.748	1	.017	.826	.706	.966
	SL_HT_PC_HT_NC	-.501	.334	2.246	1	.134	.606	.315	1.167
	[LOG_BANK=.00]	-15.669	.000	.	1	.	1.567E-7	1.567E-7	1.567E-7
	[LOG_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SILT_CLAY_BANK=.00]	-2.127	5.938	.128	1	.720	.119	1.051E-6	13511.411
	[SILT_CLAY_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_SILT_BANK=.00]	-1.233	5.973	.043	1	.836	.291	2.400E-6	35390.090
	[SAND_SILT_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_SILT_ISLAND=.00]	.847	7.981	.011	1	.915	2.333	3.753E-7	1.450E7
	[SAND_SILT_ISLAND=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_BAR=.00]	-1.840	5.935	.096	1	.756	.159	1.409E-6	17880.941
	[SAND_BAR=1.00]	0[b]	.	.	0	.	.	.	.
	[SAND_BANK=.00]	-1.588	5.953	.071	1	.790	.204	1.750E-6	23845.423
	[SAND_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[SILT_BANK=.00]	.732	6.457	.013	1	.910	2.079	6.637E-6	651345.836
	[SILT_BANK=1.00]	0[b]	.	.	0	.	.	.	.
	[ROCKY_BANK=.00]	0[b]	.	.	0	.	.	.	.
	[ROCKY_BANK=1.00]	0[b]	.	.	0	.	.	.	.