Population Assessment & Habitat Ecology Study of Saltwater Crocodiles in Sundarbans

Sundarban Biosphere Reserve
Department of Forests
Government of West Bengal

2024

বিরবাহা হাঁসদা
রাষ্ট্রমন্ত্রী (স্বাধীন দায়িত্বপ্রাপ্ত)
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Foreword

The Sundarbans, a UNESCO World Heritage Site, is a captivating mosaic of mangrove forests, rivers, and tidal flats. This unique ecosystem serves as a vital sanctuary for a multitude of species, including the apex predator, the saltwater crocodile. The Sundarbans has been rightly designated as the Ramsar Wetland of International Importance.

The climate change has brought into focus changes in crocodile population and the health of their habitat and concerns have grown in recent years. In response to these concerns, this report presents the findings of a comprehensive study on the saltwater crocodile population in the Sundarbans. The dedicated teams employed robust population estimation techniques to assess crocodile numbers. Additionally, a thorough investigation into the habitat ecology provided insights into the factors influencing crocodile distribution and survival.

The knowledge gained from this exercise is very important. The report brings a detailed picture of the current state of the saltwater crocodile population and the intricate relationship between these magnificent creatures and their environment. This information will help in planning and developing effective conservation strategies for continued well-being of both the crocodiles and the Sundarbans ecosystem.

I commend the officers and staff for their efforts and dedication in conducting this crucial study. The findings presented within the report are a significant contribution to the field of crocodile conservation and will undoubtedly guide future research and management practices.

01st August'2024;
Aranya Bhavan, Salt Lake - 700106

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However, concerns regarding the status of the crocodile population and the health of their habitat have grown in recent years due to the effects of Climate Change and human disturbances. In response to these concerns, this report presents the findings of a comprehensive study on the saltwater crocodile population in the Sundarbans. The dedicated teams employed robust population estimation techniques to assess crocodile numbers. Additionally, a thorough investigation into the habitat ecology provided insights into the factors influencing crocodile distribution and survival.

The knowledge gleaned from this study is of paramount importance. It paints a detailed picture of the current state of the saltwater crocodile population and the intricate relationship between these magnificent creatures and their environment. This information will serve as a cornerstone for developing effective conservation strategies to ensure the continued well-being of both the crocodiles and the Sundarbans ecosystem.

I commend the officers and staff for their tireless efforts and dedication in conducting this crucial study. The findings presented within this report are a significant contribution to the field of crocodile conservation and will undoubtedly guide future research and management practices.

Principal Chief Conservator of Forests
(Wildlife) & Chief Wildlife Warden,
West Bengal

Acknowledgement

The Sundarbans, a vast mangrove forest stretching across the delta of the Ganges, Brahmaputra, and Meghna rivers, is a unique and fragile ecosystem. Within its tangled roots and brackish waters, a formidable predator thrives— the Saltwater Crocodile (Crocodylus porosus). These ancient reptiles, with their armored hides and powerful jaws, have fascinated scientists, conservationists, and adventurers alike.

An attempt to record their presence in Sundarban Biosphere Reserve was made for the first time in the year 2012. The exercise brought the status of population of the species and habitat occupancy to the fore. The long gap since the last exercise necessitated a more comprehensive and detailed study on the current status of the species.

The estimation and study exercise was carried out in 3 days involving 23 teams. The enumeration teams covered 1115 kms of creek length covering more than 60% of the navigable creeks. The teams noted data on direct sighting, indirect signages, salinity, temperature, creekwidth, distance, slopes etc. The data gathered during the 3 days was thoroughly analysed, discussed and brainstormed. The report analyse the habitat ecology of saltwater crocodiles and presents meaningful insights on the preferences exercised by this magnificent animal. The insights will be useful for planning the measures for conservation for this species.

I extend my gratitude to the dedicated officers, staff, field researchers and NGOs who collaborated on this study. Their tireless efforts deserve appreciation. I hope this report will go long in conservation of saltwater crocodiles and its habitat.

My heartfelt gratitude to the PCCF Wildlife & Chief Wildlife Warden for providing overall guidance and support for the successful completion of the exercise.

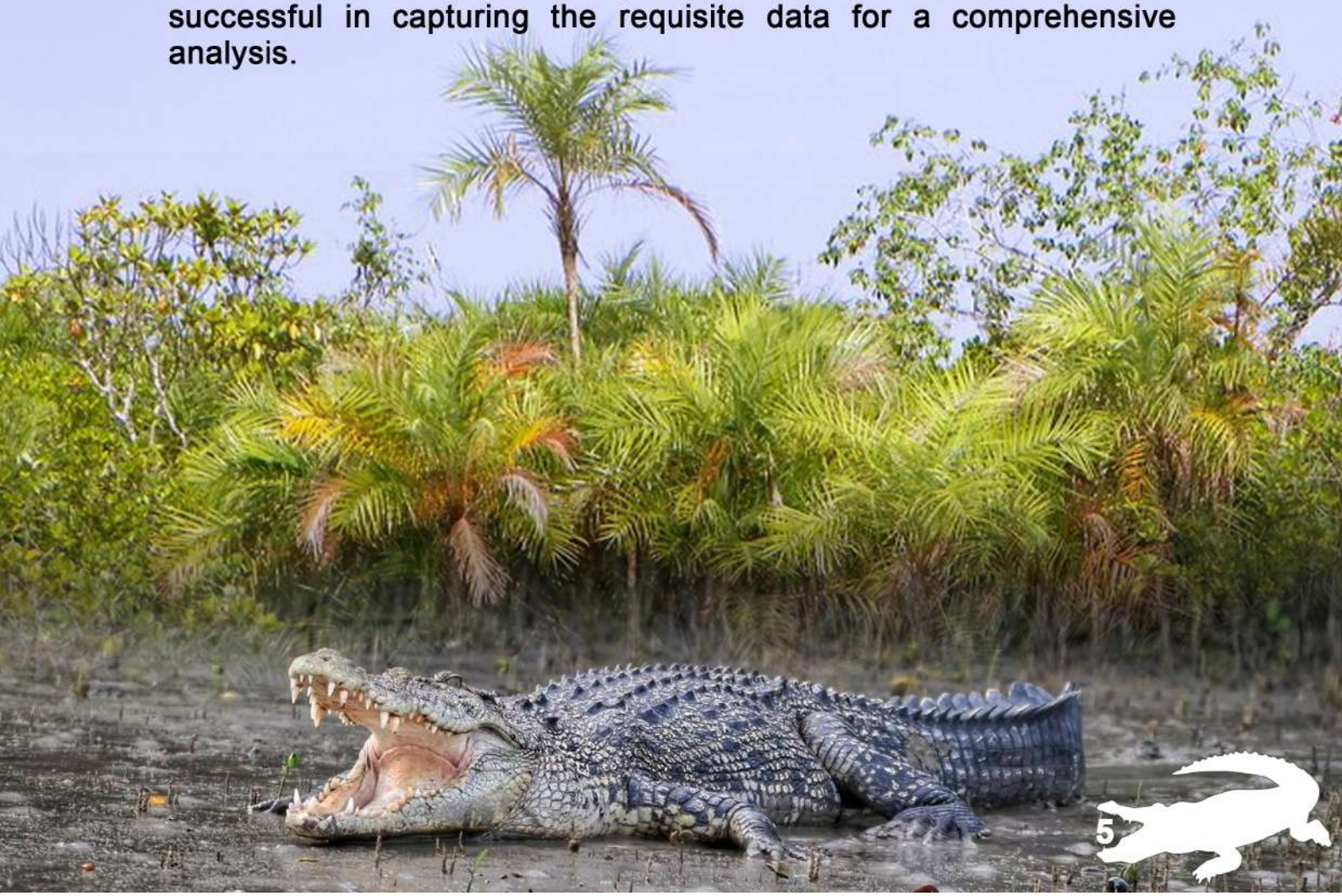
Chief Conservator of Forests &
Field Director
Sundarban Tiger Reserve

Contents

Summary

Saltwater crocodiles are one of the apex predators in the Sundarban landscape and they play an important role in maintaining the health of the aquatic ecosystem. Saltwater crocodiles are an important indicator species of the health of the aquatic ecosystem. The conservation of aquatic ecosystems is important to conserve the overall biodiversity of the region apart from supporting the fringe population which depends on fishing and crab collection for their livelihood.

A detailed population assessment exercise was planned and conducted during the month of January 2024 to assess the population status of the saltwater crocodiles in Indian Sundarbans and to increase the understanding of the habitat ecology of the species. The exercise captured the direct and indirect sighting data of saltwater crocodiles, salinity, surface water and ambient temperature for basking, creek widths and other parameters like slope of the banks and vegetation. The days of the exercise were finalised on the basis of the phases of the moon and forecasted temperature range, but the weather didn't behave in the predicted way. The untimely rains and cloudy sky during the exercise led to a reduced number of direct sightings. However, the exercise was successful in capturing the requisite data for a comprehensive analysis.



The number of saltwater crocodiles in Sundarbans has increased in comparison to the previous exercise that was held in 2012. Total direct and indirect sighting along the transect length of 1115 kilometers was 168 for the whole of Sundarban Biosphere Reserve. **The estimated number of saltwater crocodiles in Indian Sundarbans is between a minimum of 204 up to 234.**

The encounter rate of saltwater crocodiles in Sundarbans is around 0.15 per kilometer i.e around one saltwater crocodile per 6.6 kilometers of transect. It was found that the saltwater crocodiles in Sundarbans preferred high tide creek width between 10-170 metres with a median around 90 metres. Saltwater crocodiles in Sundarbans prefer a salinity range between 14-26 PPT. Preferred ambient temperature for basking is between 20-28°C in the winter months.

It is recommended that the assessment exercise may be continued for the next 3 years to understand the population trends, population dynamics and to further the knowledge of habitat ecology. The study should also include a survey of the nesting sites.

This report delves into the details of the exercise, the methodology used, analysis and results.

Saltwater Crocodiles

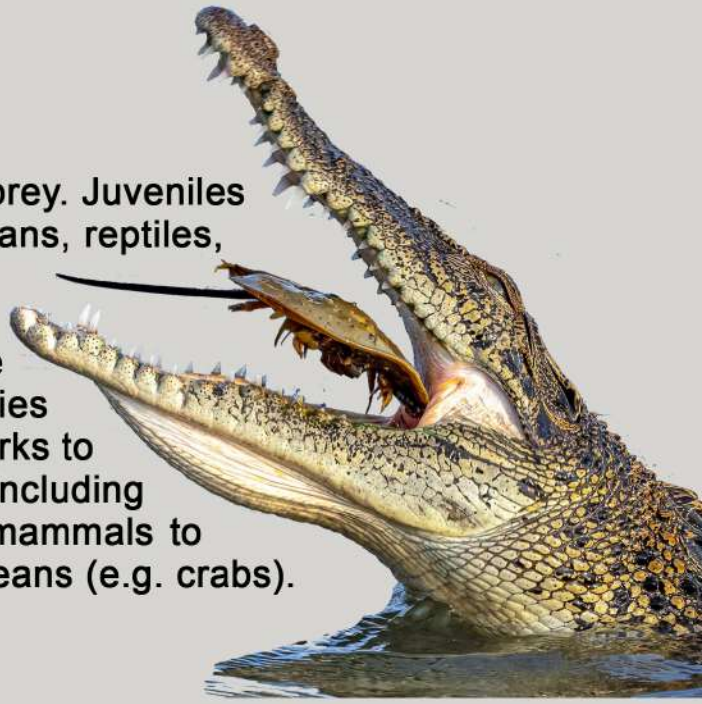
Saltwater Crocodile (*Crocodylus porosus*), also known as estuarine crocodile, lives in saline and brackish mangrove swamps, deltas, lagoons, and lower stretches of rivers. The saltwater crocodile is a formidable and opportunistic hyper- carnivorous apex predator. Most prey are ambushed and then drowned or swallowed whole. It is important to note that this apex predator plays a vital role in keeping the lotic ecosystem clean by eating the carcasses and other wild remains in the water.

The saltwater crocodile is the largest of all crocodilians, and the largest reptile in the world. The species has a relatively large head, with a pair of ridges that run from the eye along the centre of the snout. Adults are generally dark in colour, with lighter tan or grey areas, and dark bands and stripes on the lower flanks. The underside is creamy yellow to white, becoming greyer along the tail.

The juvenile is usually pale tan, with black stripes and spots on the body and tail, which gradually fade with age, although never disappear entirely. Female saltwater crocodiles are smaller in size than their male counterparts, normally reaching a maximum length of 2.5 to 3 m. With its long, powerful tail, webbed hind feet, and long, powerful jaws, the saltwater crocodile is a superbly adapted aquatic predator.

As in all crocodilians, the eyes, ears and nostrils are located on top of the head, allowing the crocodile to remain almost totally submerged when lying in water, helping to conceal it from potential prey, while a special valve at the back of the throat allows the mouth to be opened underwater without water entering the throat.

The saltwater crocodile is considered to be more aquatic than most crocodilians, and is less heavily armored along the back and neck.



(●) Prey base:

Saltwater crocodiles have a variety of prey. Juveniles are restricted to small insects, amphibians, reptiles, crustaceans, and small fish. Adults feed on crabs, turtles, snakes, birds, buffalo, wild boar, and monkeys.The broad-spectrum food habits of the species range from apex predators such as sharks to diverse freshwater and marine fishes including pelagic species to reptiles, birds and mammals to even invertebrates such as the crustaceans (e.g. crabs).

(●) Nesting Season in India:

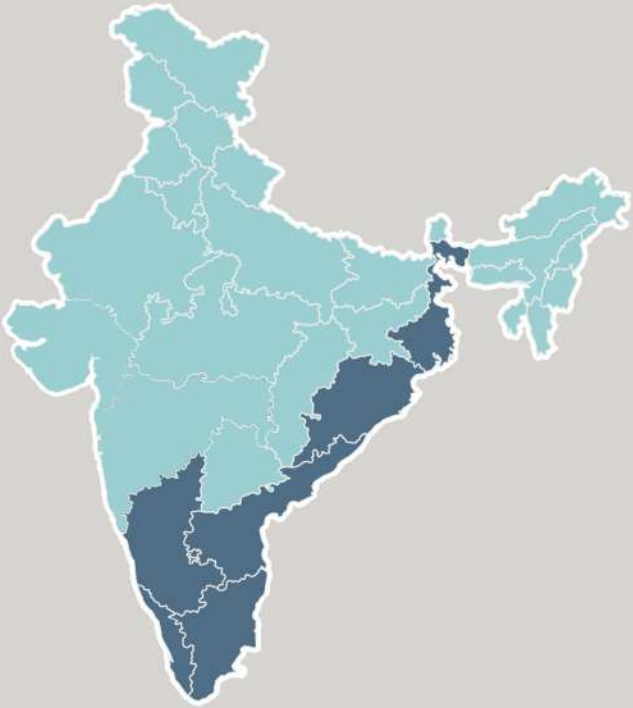
May to August

(●) Distribution in the World:

From India's east coast across Southeast Asia and the Sundaic region to northern Australia and Micronesia.

(●) Distribution in India:

Mangroves of Bhitarkanika and Sunderbans, Mahanadi Delta, and in the swamplands in Odisha and West Bengal (including rivers), other coastal areas of the Andaman and Nicobar Islands in India.



Conservation efforts for Saltwater Crocodiles in Sundarbans

Sundarban is the one of the largest deltaic regions of the world and encompasses over hundreds of islands (approx. 105) criss-crossed by a maze of innumerable rivers, rivulets, and creeks. The name 'Sundarban' means "beautiful forest" and it is believed to be derived from a mangrove tree species 'Sundari' (*Heritiera fomes*). The Indian Sundarban is the southernmost part of the estuarine delta formed by the River Ganges and Brahmaputra, bordering the Bay of Bengal. The Dampier-Hodges line separates the Sundarbans from the rest of West Bengal.

Sundarban Biosphere Reserve is the second largest Biosphere Reserve in India. For its unique and fragile ecosystem, it is declared as UNESCO World Heritage Site and its a Ramsar site of International importance.

To revive the wild population of Saltwater crocodile in Sundarbans and to maintain the aquatic ecological balance of Sundarban Ecosystem, the Bhagabatpur Crocodile Project under 24 Parganas (South) Division was started in 1976. This conservation breeding facility helped in nesting, incubation and raising the hatchlings and juveniles. In order to restore the number of Crocodiles in the territorial waters of Sundarbans, the hatchlings after reaching a certain size class were released in the wild.

The conservation efforts had resulted in an increasing number of saltwater crocodiles in the wild and it was recorded in the Saltwater crocodile estimation exercise that was taken up in the year 2012 (Results attached as Annexure VI). In order to ensure the sustainable increase in the population of the saltwater crocodiles in Sundarbans, the project continued till 2022 during which 577 individuals were released in the wild.

To assess the population trend of saltwater crocodiles in Sundarbans and to study the habitat ecology of the species a special exercise was planned and executed in 2024. The details of the exercise are explained in the upcoming pages.

Threats for Conservation of the species

(●) Habitat related threats:

Globally the habitat degradation is the biggest threat to the saltwater crocodiles as many rivers have seen reduced water inflow due to building of dams, altering the course of rivers etc resulting in shrinkage of the area of the habitat and degrading the quality of the remaining habitat. Apart from this, noxious water pollutants and sewage released into the water ecosystems and coastal waters also threaten the survival of the species. Excessive fishing and the resulting interaction with humans results in conflicts which also threaten the species.

In Sundarbans, apart from the reduced freshwater flow, increase in salinity, erosion of nesting sites and progressive siltation resulting in choking of smaller streams is leading to degradation of habitat.

(●) Poaching and Wildlife Trade:

Globally saltwater crocodiles are being illegally poached and trafficked for their lucrative skin, meats, eggs, snouts, and bones in medicinal and cosmetic industries.The other major threat is saltwater crocodiles becoming bycatch in the fishing gears. However these threats are not found to occur in Sundarbans. No incident of poaching of saltwater crocodiles has been reported in the past two decades.

(●) Climate Change and the resultant threats:

The aquatic ecosystem in Sundarbans is subjected to a lot of challenges in the form of increasing salinity, increasing temperatures on a global level and change in the pH level due to erratic rainfall. Increasing sea levels reduce the nesting habitats available for the saltwater crocodiles which prefer nesting sites which are not influenced by tides. Apart from this, the increasing temperatures and erratic rainfall patterns may also have an impact on the incubation of the eggs of the species in the longer run as sex of the reptile individuals depends on the incubation temperature.

(●) IUCN Red list:

Least Concerned (LC) species

(●) WPA :

Schedule I of Indian Wildlife (Protection) Act, 1972.

(●) CITES :

Appendix I

Objectives of the Exercise

1. To assess and estimate the population of saltwater crocodiles.
2. To study and understand the basic habitat ecology of the species.
3. To propose future courses of action and interventions as required for conservation of saltwater crocodiles.

Methodology

Population estimation and habitat ecology study of the saltwater crocodile in the Sundarban Biosphere Reserve (SBR) was done by collection of data through individual count by direct daytime sighting using boat-transect method and the required abiotic ecological data in the said transects covering 60% of total creek length of Sundarbans.

(●) Transects:

Boat transects (average length- 20 kms) maps were prepared by using Google Earth Pro (Image Landsat/Copernicus) covering all the primary, secondary and tertiary creeks and rivulets that are easily accessible and are potential crocodile basking sites in the Sundarban Biosphere Reserve. The transects maps are attached in Annexure I.

(●) Dates and timing of the exercise:

Dates of the exercise were chosen by thorough study of the advance tide charts. Middle of the neap tide phase of the lunar cycle and favourable tide conditions (low tide) between 9am to 3pm during the day are considered ideal for direct sighting. The 18th & 19th January, 2024 were chosen for the field exercise as it met all the criteria as mentioned. Tourism was closed in both the divisions on the said dates.

Data Collection:

The following data was collected along the transects in 2 sheets for data collection (Form A & Form B) as provided in the Annexure II.

Species related data:

Direct sighting

- Age class - Adult, Juvenile, Hatchling
- Length of the individual
- Time of sighting
- GPS location
- Creek width
- Salinity at the location of sighting
- Temperature - Ambient and Surface water
- Slope of the bank
- Vegetation profile of the site

Indirect Sighting

- Along with the above details - Pawmark (except for
- Length of the individual)

Abiotic Parameters data (for every 1 km in the transect):

- Temperature - Ambient and Surface water
- Salinity

Team Composition:

Each team was composed of
1 team leader (Range Officer/ Beat Officer);
2 field staff;
1 NGO participant.

The team composition was relaxed as per availability of the staff. Division wise team composition and NGO participants are attached as Annexure III.

Each team was provided with an estimation kit (i.e. transect maps, GPS, thermometer, refractometer, range finder, notebook, pen/pencil, survey datasheets and sample falcons for water collection). Each team was provided with prior training to use the equipment (Annexure IV).

(●) Training:

On 16th January, 2024, resource person Dr. BC Chowdhury (former scientist WII-Dehradun) gave a lecture on the saltwater crocodiles followed by hands-on training by Shri S.Jones Justin IFS Deputy Field Director, STR to the staff in the data collection protocol that would be followed in the exercise. Data collection protocol was extensive and included salinity, temperature (ambient and surface water), distance, type of habitat and length of sighted crocodiles among others. The training was comprehensive including both theoretical and practical usage of the equipment for the collection of data during the exercise.

(●) Weather related changes during the Exercise:

Due to rain and cloudy weather predictions on the selected dates, the exercise was done on different dates by different teams which are listed below. Care was taken so that there is no bias or double counting in the data due to such change of dates and the whole exercise was synchronized and accommodated within the closest possible dates. Since the tourism could not be closed on such short notice, the exercise continued alongside the tourism being open. Due to the unfavourable weather conditions and the tourism disturbance the sighting numbers were affected which needs to be considered when interpreting the absolute numbers in terms of the estimation of the population. The days on which the exercise was carried out is depicted in the table below.

Range	Survey Day 1 (17.01.2024)	Survey Day 2 (20.01.2024)	Survey Day 3 (21.01.2024)
BHT	✓	✓	
SWLS	✓	✓	
NPE		✓	✓
NPW		✓	✓
Matla		✓	✓
Bhagabatpur		✓	✓
Namkhana		✓	✓
Raidighi		✓	✓
Ramganga		✓	✓

Result and Analysis

The data that has been recorded during the exercise has been subjected to a lot of analysis to derive the preferred habitat for saltwater crocodiles in Sundarbans along with the estimation of the population in Indian Sundarbans.

(●) Habitat Ecology - Creek width Analysis:

The analysis of the data regarding the direct sighting and corresponding creek width provides us with important information about the usage of the habitat by the saltwater crocodiles.

The following graph depicts the sighting frequency vs creekwidth, wherein creek widths have been taken in 100 metres interval.

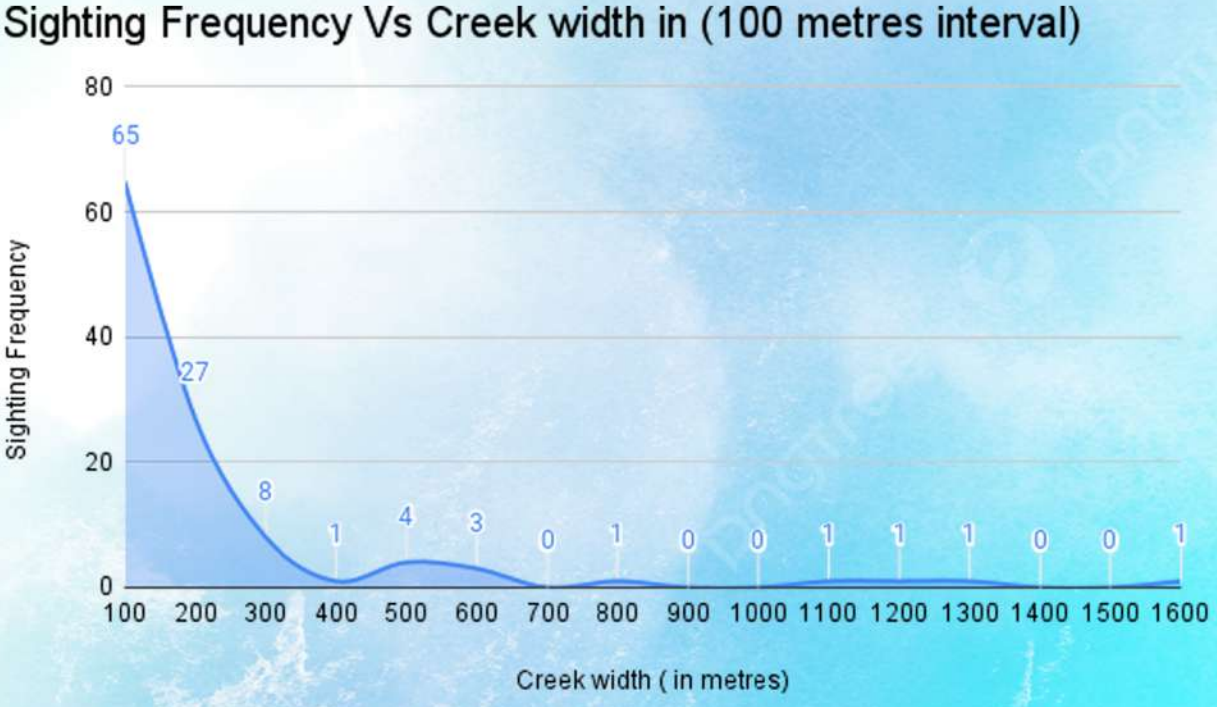


Figure : Graph showing the Direct Sighting frequency with respect to the Creek width (100 metre interval)

It is apparent that the frequency of direct sighting reduces drastically in the creeks and rivers having a width larger than 200 metres.

When the frequency of direct sighting is plotted with respect to creek-width in the interval of 10 metres, the following graph is obtained.

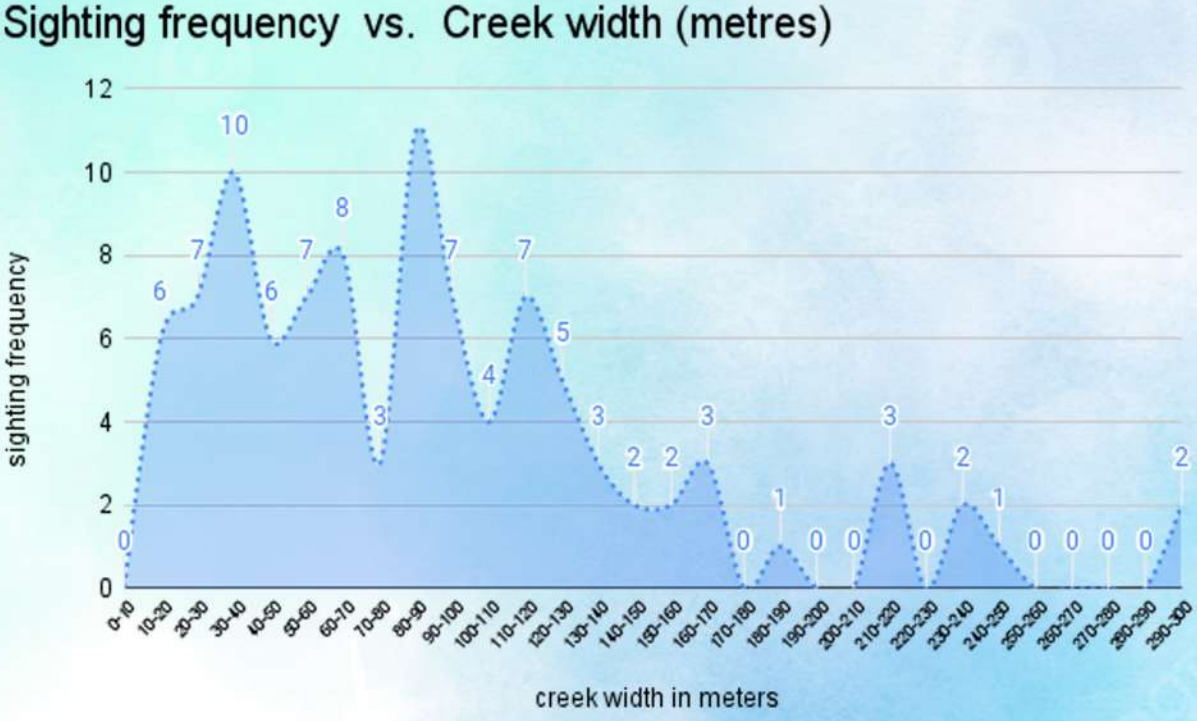


Figure : Graph showing the Direct Sighting frequency with respect to the Creek width (in 10 metres interval)

Mode: 90 metres Median: 85 metres

Mode: 90 metres

Regression analysis of the data gives the following equation:

Sighting(S) = 9.85 + (-0.0440) (W)

Coefficient of Determination Standard Error= 2.08
R Square = 59.89%

The regression analysis shows that the number of sightings becomes almost negligible in creeks and rivers having width beyond 250 metres. While the median creek width class is 80-90 metres, the data shows that saltwater crocodiles prefer creeks that are wide from 10 metres to 170 metres during the high tide. It can be inferred that the preferred habitat for saltwater crocodiles in the Sundarbans are creeks and rivers having width less than 170 metres.

(●) Habitat Ecology - Salinity Analysis:

Analysis of the sighting frequency data alongside the corresponding salinity profile of the surface water reveals a lot about the salinity regime preference of saltwater crocodiles in Sundarbans.

Saltwater crocodiles in Sundarbans are tolerant to a wide range of salinity extending from 10 PPT (Parts Per Thousand) to 28 PPT. Mode of the values is around 20 PPT, while median is at 19 PPT. However, closer analysis shows that the preferred salinity range is between 14-26 PPT.

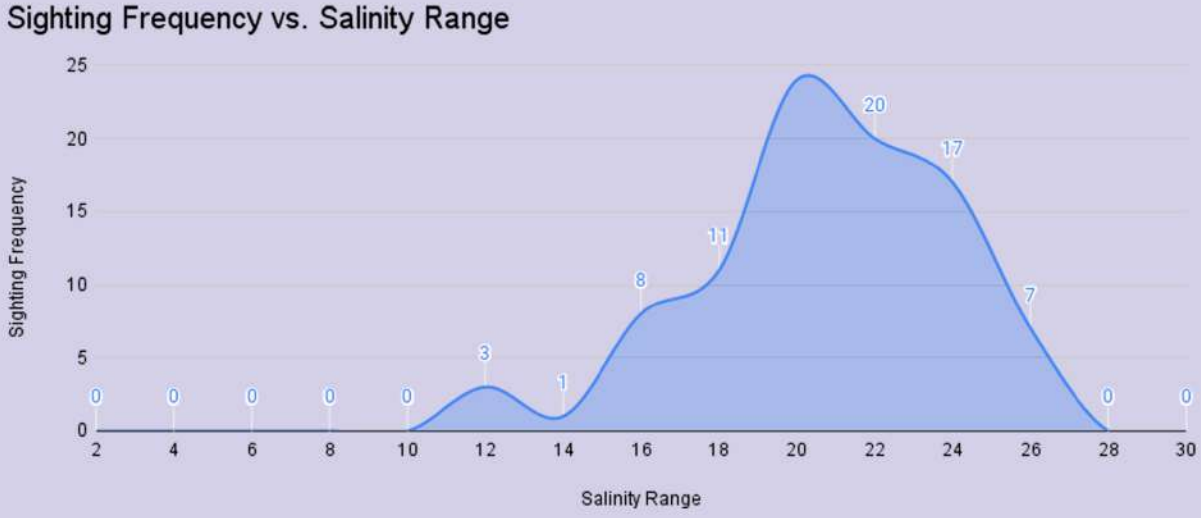
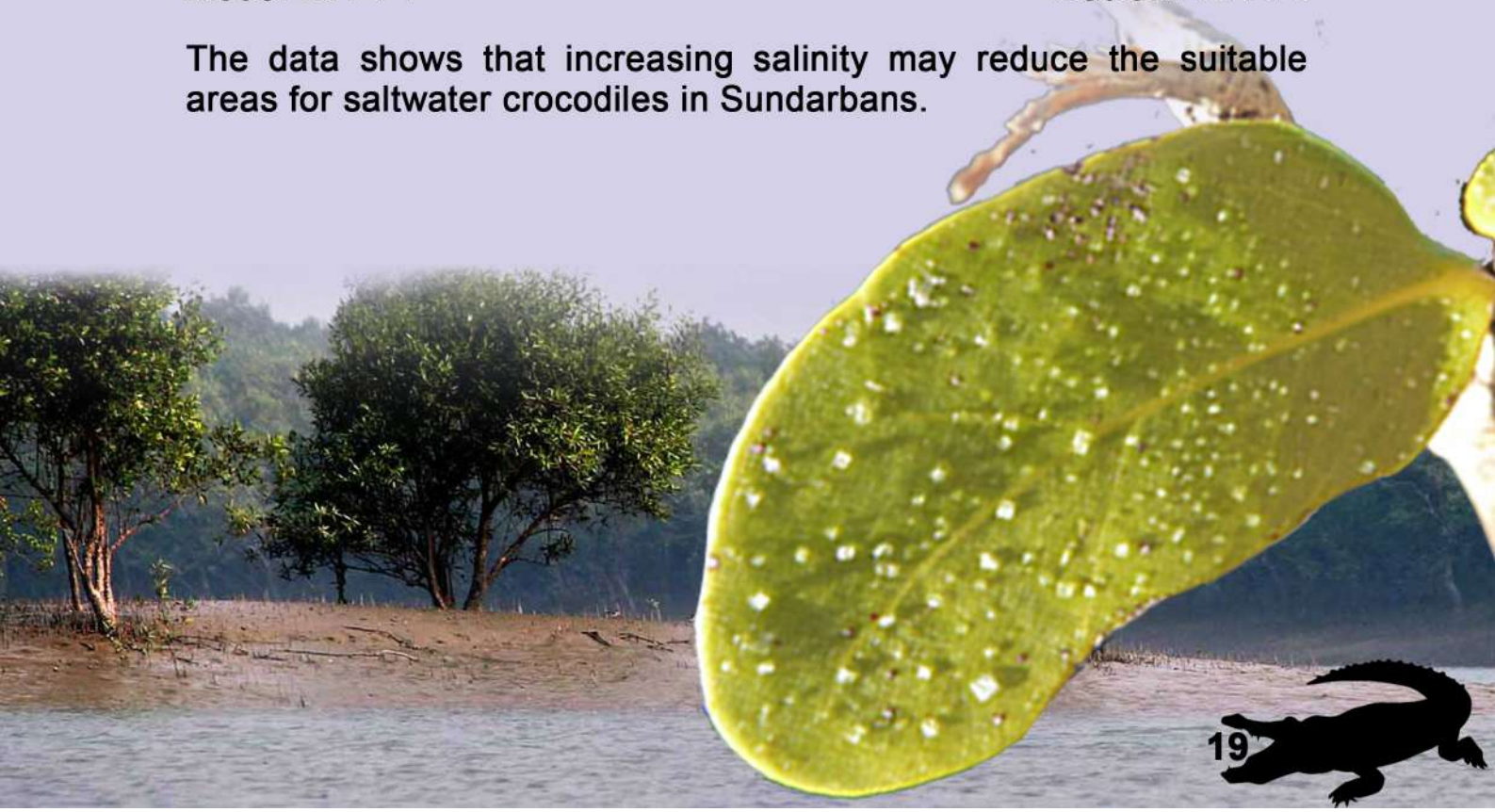


Figure : Graph showing the Direct Sighting frequency with respect to corresponding salinity

Mode: 20 PPT

Median: 19 PPT

The data shows that increasing salinity may reduce the suitable areas for saltwater crocodiles in Sundarbans.



(●) Habitat Ecology - Ambient Temperature Analysis:

The data related to Water Surface Temperature (WST) and Ambient Temperature was collected during the exercise. It was found that Water Surface Temperature (WST) didn't vary beyond 2° celsius throughout the exercise and the WST remained between 20-22°C. This may be due to high specific heat capacity of water and relatively less movement of the water during the neap tide phase of the moon. As the WST variation was negligible no correlation with frequency of sighting could be established.

However, analysis of the data with respect to ambient temperature and the frequency data of direct sighting reveals a range of temperature that is preferred for basking by the species during the winter season. The following graph depicts the relation between sighting frequency and ambient temperature.

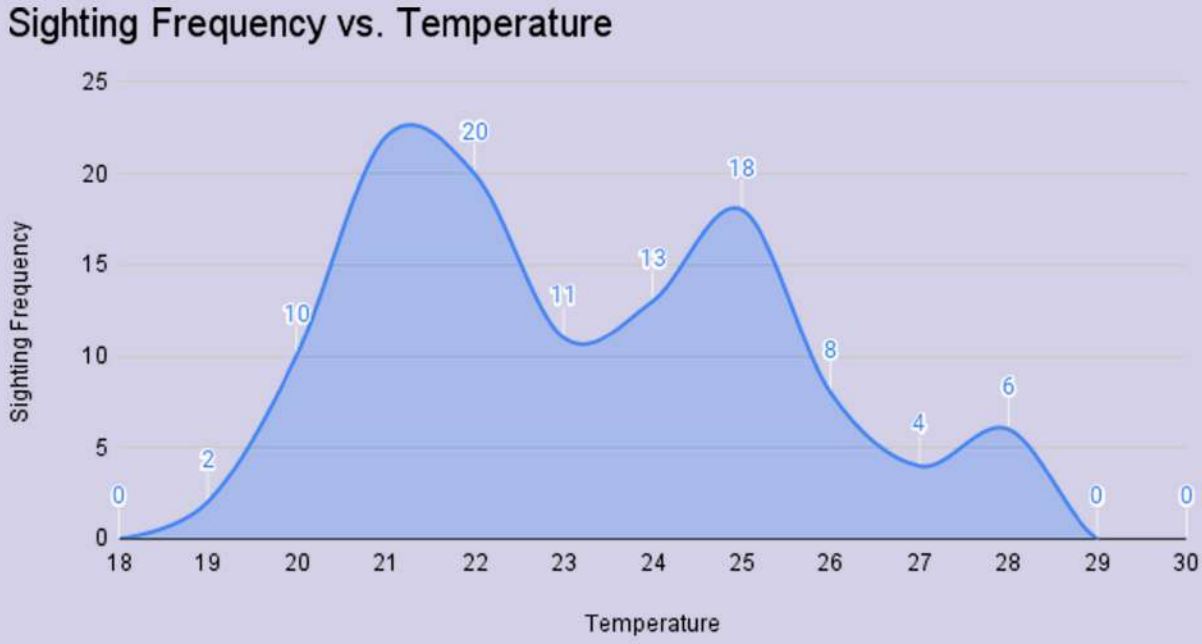


Figure : Graph showing the Direct Sighting frequency with respect to corresponding Ambient Temperature of the location

Median: 23.5°C *Mode: 21°C*

It is apparent that the preferred ambient temperature range for basking in Sundarbans is between 20 °- 28 °celsius. The median temperature is 23.5°C.

The regression analysis of the data shows that the maximum sightings would happen when the ambient temperature is around 22.7°C. As the WST was around 20-22°C, the crocodiles preferred to come out in maximum numbers when the ambient temperature was 1-3°C above the WST. However the duration and timing of basking is also affected by the tide levels and the body temperature of the animal at the time of sighting.

(●) Direct and Indirect Sighting Analysis:

The data from the direct and indirect sighting during the exercise is depicted range wise in the following table. It is found that certain ranges have recorded substantially low numbers of sighting which is probably due to the unfavourable weather conditions during the days of the estimation exercise.

Ranges	Basirhat	SWLS	NPE	NPW	Bhagabatpur	Matla	Namkhana	Raidighi	Ramganga	Total
Direct Sighting	8	14	18	18	0	11	0	19	26	114
Indirect Sighting	3	7	17	10	0	4	0	7	6	54
Total	11	21	35	28	0	15	0	26	32	168
Division wise Total sighting details										
Sundarban Tiger Reserve (Total)				95	South 24 Parganas (Total)				73	

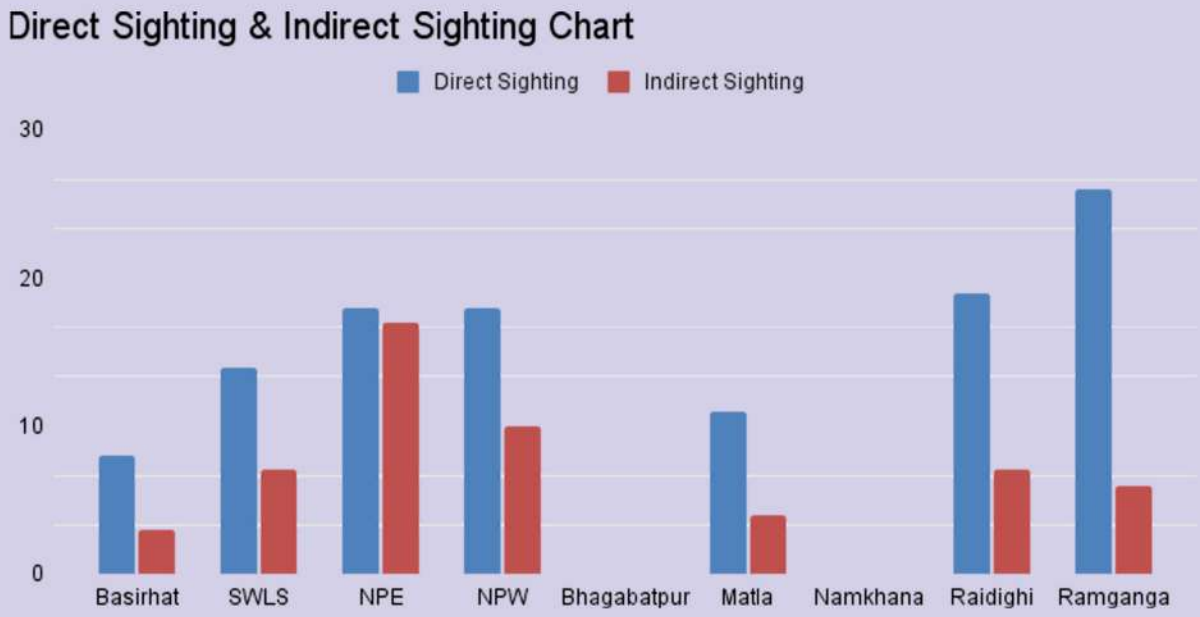


Figure 1. Direct and Indirect Sighting Graphical representation

Figure 2. Map showing the Locations where direct sighting of Saltwater crocodiles were recorded - Spatial distribution of the salt-water crocodiles in Sundarbans.

(●) Population Estimation:

Out of the 1800+ kilometers length of creeks in Sundarban Biosphere Reserve, the exercise only covered around 955 kilometers which is little more than 50% of the total creek length of significance (till 200 metres) in the forested reserve areas. The creek width analysis with respect to the frequency of direct sighting which is discussed in detail in the previous pages reveals that there is a clear preference for a certain band of creek width by the saltwater crocodiles.

A regression analysis (Till the data of significance) of the Direct sighting frequency data with respect to the creekwidth and the kilometer surveyed in that particular creek width gives the following regression equation.

$$\text{Sighting}(S) = 9.44 + (-0.0429)\,(W) + 0.0025(Km)$$

Coefficient of Determination
R Square = 60.00%

Standard Error= 2.14

Applying this regression equation for the remaining unsurveyed creek lengths within the preferred creek width range, the estimated population of crocodiles in Sundarban Biosphere Reserve is as follows.

Sightings in SBR	Estimated Population of Saltwater Crocodiles in SBR Maximum | Minimum	
168	234	204

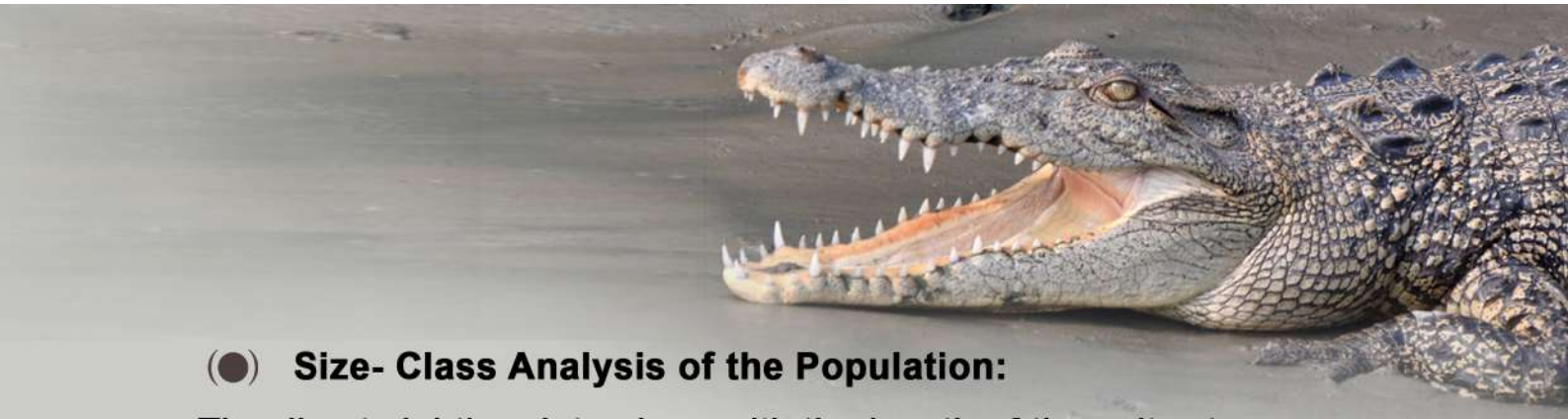
The estimated population of saltwater crocodiles in Sundarban Biosphere Reserve is thus a minimum of 204 crocodiles and a maximum of 234 crocodiles. The estimated number could be projected with a higher degree of confidence as the number of sightings were less due to unfavourable weather conditions (Data attached as Annexure V). The lower base has resulted in higher confidence level.

(●) Encounter Rate:

Encounter rate gives the number of sightings per kilometer transect. It is calculated by dividing the number of sightings recorded by the total kilometers surveyed in the exercise. It is important to note that since the crocodiles are highly territorial animals, the indirect sightings are also used for the calculation of the encounter rate. All the indirect sightings that are closer than 500 meters to a nearby direct sighting were eliminated as crocodiles generally are recorded to move not more than 300-400 metres in a day during winter.

Encounter Rate =(Number of Sightings)/(Total kms surveyed)

	Sundarban Tiger Reserve (95/725)	South 24 Parganas (74/390)	Sundarban Biosphere Reserve (168/1115)
Encounter Rate per Kilometer	**0.13** i.e 1 Saltwater Crocodile per 7.6 kms	**0.189** 1 Saltwater Crocodile per 5.2 kms	**0.15** 1 Saltwater Crocodile per 6.6 kms



(●) Size- Class Analysis of the Population:

The direct sighting data along with the length of the saltwater crocodiles (Size- Class Analysis) that was recorded has given various insights into the demography and age structure of the population that was sighted. Though the hatchlings and juveniles are hard to sight as they are very shy and go underwater even at the slightest disturbance in the water or on land, the number of sightings of hatchlings are relatively low compared to the corresponding numbers in 2012 population estimation exercise.

Based on Direct Sighting			
Range	Adult (> 240 cm)	Juvenile (50<x<240cm)	Hatchling (<50 cm)
Basirhat	5	3	0
SWLS	10	4	0
NPE	10	8	0
NPW	12	6	0
Bhagabatpur	0	0	0
Matla	2	7	2
Namkhana	0	0	0
Raidighi	13	6	0
Ramganga	19	7	0
Total	71	41	2

Recommendations and Conclusions:

The data gathered through the exercise points that the population dynamics is different from the expected trajectory. This may be due to several factors including climate change induced factors like increasing sea level in sundarbans, warming of estuarine water, increasing salinity and anthropogenic factors like disturbance due to movement of vessels or the natural factors like erosion and accretion in different islands.

It is imperative that further studies are undertaken to understand the impact of each of these factors on the phenology of the species. The various concerns regarding the conservation of the species would be better understood and better conservation measures can be planned on the basis of the outcome of such studies.

It is recommended that a three (3) year study covering estimation of the population (on yearly basis), habitat status, threats due to climate change (increasing temperature, salinity, impact on nesting sites, dissolved oxygen, pH etc) and impact of anthropogenic pressures be conducted to make informed decisions regarding the efforts and interventions that are required for the conservation of the species in the long run.

The brief of such study may be outlined as follows-

Survey of nesting sites

The size class analysis of the data also shows that the population demography is skewed towards the adults. This needs to be studied further.

Nesting surveys are important to ensure that the population is breeding and the population is stable in the ecosystem. Saltwater crocodiles usually start nesting in the early May and continue till late august. Their average incubation time period is 80 - 90 Days.

It is evident that patches of the *Nypa fruticans, Phoenix paludosa* are a potential place for roosting and nesting sites of the saltwater crocodiles. From the camera trap photographs, in some moderate sloped banks adult crocodiles are also found with Garan (*Ceriops sp.*) vegetation. Field surveys can identify such locations with potential nesting sites for the saltwater crocodiles.

In order to locate the existing nesting sites and to map the potential nesting sites in Sundarbans region a survey for the proposed three years (2024-25 to 2026-27) shall be conducted in the following timeline-

Dates	Transects & Data to be collected	Remarks
15th May 15th June 15th July 15th August	Patrolling along the high banks (inside forest areas), foot patrolling along the high banks and embankments (along the inhabited islands) Data to be collected: GPS, Vegetation, clutch size, Land level	Data Collection shall be done for all the 4 months, Collated and analysed to prepare a map for the nesting sites in Sundarbans and their threat levels with respect to human disturbances, sea level change and other climate related events, erosion and accretion etc

Comprehensive 3 year Population estimation exercise:

A 3 year population estimation exercise (2024-25 to 2026-27) shall be conducted every year during the 3 winter months of December, January and February. This can be continued every year from then on as required to keep track of the trends in population.

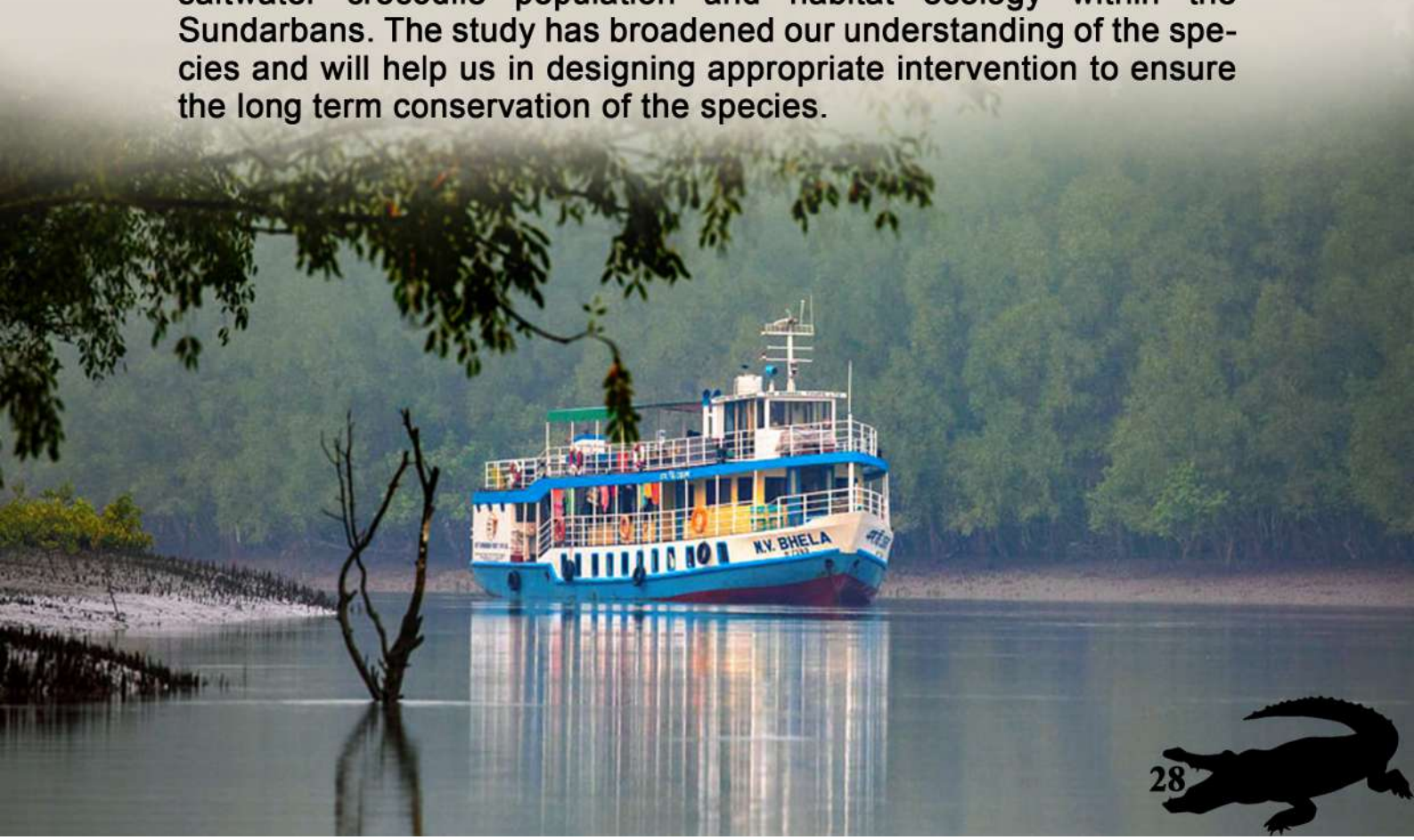
Sighting recording for every year shall be done following the table below:

Month	Dates	Transects	Remarks
Early December	2 Dates may be selected as per tide conditions - Banks are exposed (low tide) during most part of the day from 9am to 3pm	Normal Patrolling duty may be done along the Transect lines during the dates by staff.	Data Collection will be done for all the 3 months, Collated and analysed to arrive at a average sighting rate per transect and subsequently creek width
Early January			
Early February			

The exercise is recommended to be conducted every year for 3 months in each year in place of a 2 day annual exercise for the following reasons-

- To decrease the chances of vagaries of weather affecting the exercise and data collection.
- To increase the statistical significance of the data for every transect.
- To reduce the bias on data due to human disturbances and other external disturbances.

To conclude the current study has provided valuable insights into the saltwater crocodile population and habitat ecology within the Sundarbans. The study has broadened our understanding of the species and will help us in designing appropriate intervention to ensure the long term conservation of the species.



Annexure I: Transect Maps

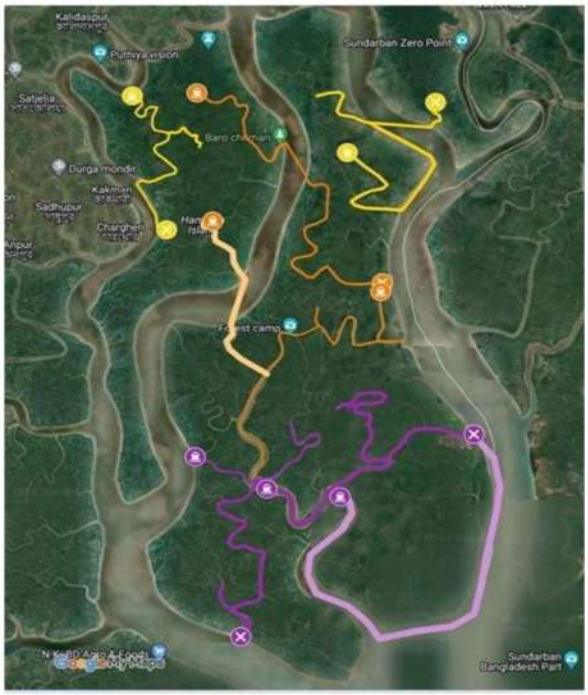


Fig i:Basirhat Range transects

Fig ii: Sajnekhali WLS transects

Fig iii: National Park East Range transects

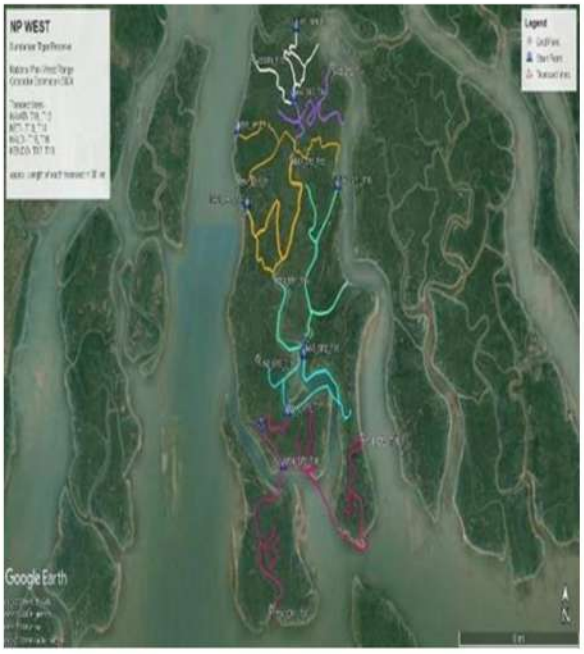


Fig iv: National Park West Range transects

Fig v: Matla Range transects

Fig vi: Raidighi Range transects

Fig vii: Ramganga Range transect

Fig viii: Bhagabatpur & Namkhana Range transects

Annexure II: Datasheet

FORM-A Team No:----------

PRIMARY DATA REGARDING CROCODILE ESTIMATION 2024

DIRECT SIGHTING RECORDS

Circle/Division. :..... Transect No.: ..... Start Point (GPS) & Time: .....

Range: ..... Date : ..... End Point (GPS) & Time: .....

Beat : .....

Sl. No	Direct Sighting			Time	G.P.S Location (D-M-S)		Length (Feet)	Water Surface Temperature	Ambient Air Temperature	Water Salinity	Slope of River/Creek Bank & Blank/With Vegetation(Please √ any one)						Direct Sighting of any other wildlife & No
											Gentle (G)		Moderate (M)		Steep (S)		
	Adult	Juvenile	Hatchling		LAT (N)	LONG (E)					Blank	Veg.	Blank	Veg.	Blank	Veg.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12	(13)	(14)	(15)	(16)	(17)	(18)

Name of the Team Leader & Signature

Name of the Team Members:

Form-B: INDIRECT SIGHTING

S. No.	Sighting Side (L/R)	River Bank Slope Type		Time	GPS Location (D-M-S)		Pugmark/ Slide fresh	Pugmark/ Slide old	Condition of tide	Disturbance observed in creek (Y/N)	Remarks
		Gentle	Steep		LAT (N)	LONG (E)					
1											
2											
3											
4											
5											
6											
7											
8											

K.M	Temp	Salinity
0.5		
1.0		
1.5		
2.0		
2.5		
3.0		
3.5		
4.0		
4.5		
5.0		
5.5		
6.0		
6.5		
7.0		
7.5		
8.0		
8.5		
9.0		
10.0		
10.5		

SL No	Temp	Salinity
11.0		
11.5		
12.0		
12.5		
13.0		
13.5		
14.0		
14.5		
15.0		
15.5		
16.0		
16.5		
17.0		
17.5		
18.0		
18.5		
19.0		
19.5		
20.0		
20.5		

Annexure III: Team Composition

Team Composition of Sundarban Tiger Reserve Division

Sl. No.	Range	Team No.	Name of the team members	Remarks
1	SWLS	Team- I	1. Ranjit Halder DR/Fr.	Team Leader
			2. Susanta Das F.G.	
			3. Koushik Biswas BS.	
		Team-II	1. Sourav Biswas DR/Fr.	Team Leader
			2. Chiranjit Biswas F.G.	
			3. Saibesh Sarkar BS	
			4. Parimal Mandal As	
		Team- III	1. Mrityunjoy Biswas DR/Fr.	Team Leader
			2. Mithun Das F.G.	
			3. Gour Chandra Nath F.G.	
			4. Motin Molla BS	
2	Basirhat	Team -I	1. Anupam Das,DR/Fr	Team Leader
			2. Santosh Kumar Sardar,DR/Fr	
			3. Debajyoti Das,FG	
		Team-II	1.Swapan Bera,FG	Team Leader
			2.Swapan Bakshi,Majhi	
			3.Mahibur Rahaman, BS	
			4.Sunil Mondal, BS	
		Team-III	1.Sk Maniruddin FR(T)	Team Leader
			2.Narayan Chandra Mandal,FG	
			3.Brahma Sarkar,Aranya Sathi	
			4.Bablu Ghosh, Banasahayak	
3	NP(E)	Team-I	1. Nabakumar Sahoo FR(T)	Team Leader
			2. Debnath Mandal F.G.	
			3. Subrata kumar sahoo BS	
			4. Sushanta Halder DL	
		Team-II	1. Samir Das F.G.	Team Leader
			2. Subrata Nath AS	
			3. Surajit Saha Banasahayak	
		Team-III	1. Madan Mohan Das DR/Fr	Team Leader
			2. Gunadhar Gayen BS	
			3. Pinaki Mandal DL	
		Team-IV	1. Avik Das FR	Team Leader
			2. Ashoke Kumar Baur FG	

Sl.No.	Range	Team	3. Sachindranath Mondal BM	Remark
4	NP(W)	Team-I	1. Masum Ali DR/Fr	Team Leader
			2. Krishna Bhadra FG	
			3. Amalendu Halder FG	
		Team-II	1. Goutam Dhali DR/Fr	Team Leader
			2. Baidyanath Hansda FG	
			3. Ranjit Sarkar BM	
	NP(W)	Team-III	1. Arka Raut FR	Team Leader
			2. Niranjan Giri FG	
			3. Surajit Roy FG.	
		Team-IV	1. Sabir Ansari FR(T)	Team Leader
			2. Samarendranath Ghosh FG	
			3. Santu Pramanik BS	

(●) Team Composition of South 24 Parganas Division

Sl.No.	Range	Team	Name of the Team Member	Remark
1.	Ramganga	Team-I	Shiladitya Acharyya, FR	Team Leader
			Sanjay Bala, FG	
			Debraj Jana, BSK	
			Mehesus Rahaman, BSK	
		Team-II	Debabrata Pramanik, DR/Fr.	Team Leader
			Kartick Naskar, FG	
			Sadananda Rauth, BSK	
			Ajit Kumar Bera, BSK	
		Team-III	Tapas Kumar Maity, DR/Fr.	Team Leader
			Sujit Nayek, AS	
			Rupam Shee, BSK	
			Anup Kumar Kayal, BSK	
2.	Raidighi	Team-I	Sanat Kumar Deb, DR/Fr.	Team Leader
			Lalit Mridha, FG	
			Avijit Maity, AS	
		Team-II	Amirchand Mondal, FG	Team Leader
			Pijush Kanti Das, DL	
			Dayal Khan, AS	
		Team-III	Khokon Sardar BS	Team Leader
			Prabir Mondal AS	
			Amalesh Das AS	
3.	Matla	Team-I	Krishnapada Mondal, DR/Fr.	Team Leader
			Soham Mitra, RA	
			Sourav Biswas, FG	
			Anupam Kayal, BNS	

Sl.No.	Range	Team	Name of the Team Member	Remark
4.	Bhagabatpur	Team-I	Suvankar Mondal, DR/Fr.	Team Leader
			Debasis Jana, BSK	
			Utpal Sarkar, AS	
			Gurupada Mondal, AS	
5.	Namkhana	Team-I	Soumita Bose, DR/Fr.	Team Leader
			Pranay Raha, FG	
			Mahadeb Bera, BSK	
			Arpan Kumar Das, BSK	

(●) NGO Participants

Sl.	Participants	Range Allotted
1	Paromit Chatterjee, WWF-India	Bashirhat
2	Ratul Ghosh Society for Heritage & Ecological Researches (SHER)	Bashirhat
3	Somik Ghosh, Naturemates -Nature Club	Bashirhat
4	Swati Das, Nature Environment & Wildlife Society (NEWS)	Sajnekhali WLS
5	Animesh Mistry, Bali Nature & Wildlife Conservation Society	Sajnekhali WLS
6	Chakresh Kumar, IISER-Kolkata	NP East
7	Niranjan Sardar, Juktibadi Sankritik Sanstha, Canning	NP West
8	Anirban Chaudhury, WCS	Kalas, Ramganga
9	Prabir Biswas, SEED	Dhanchi, Ramganga
10	Samrat Chakraborty, WTI	Kultali, Raidighi
11	Ardhendu Banik, HEAL	Herobhanga, Matla
12	Sourav Sahoo, Jadavpur University	Bhagabatpur
13	Saswata Chakraborty, KSCH	Namkhana

Annexure IV: Equipments

GPS

RANGE FINDER

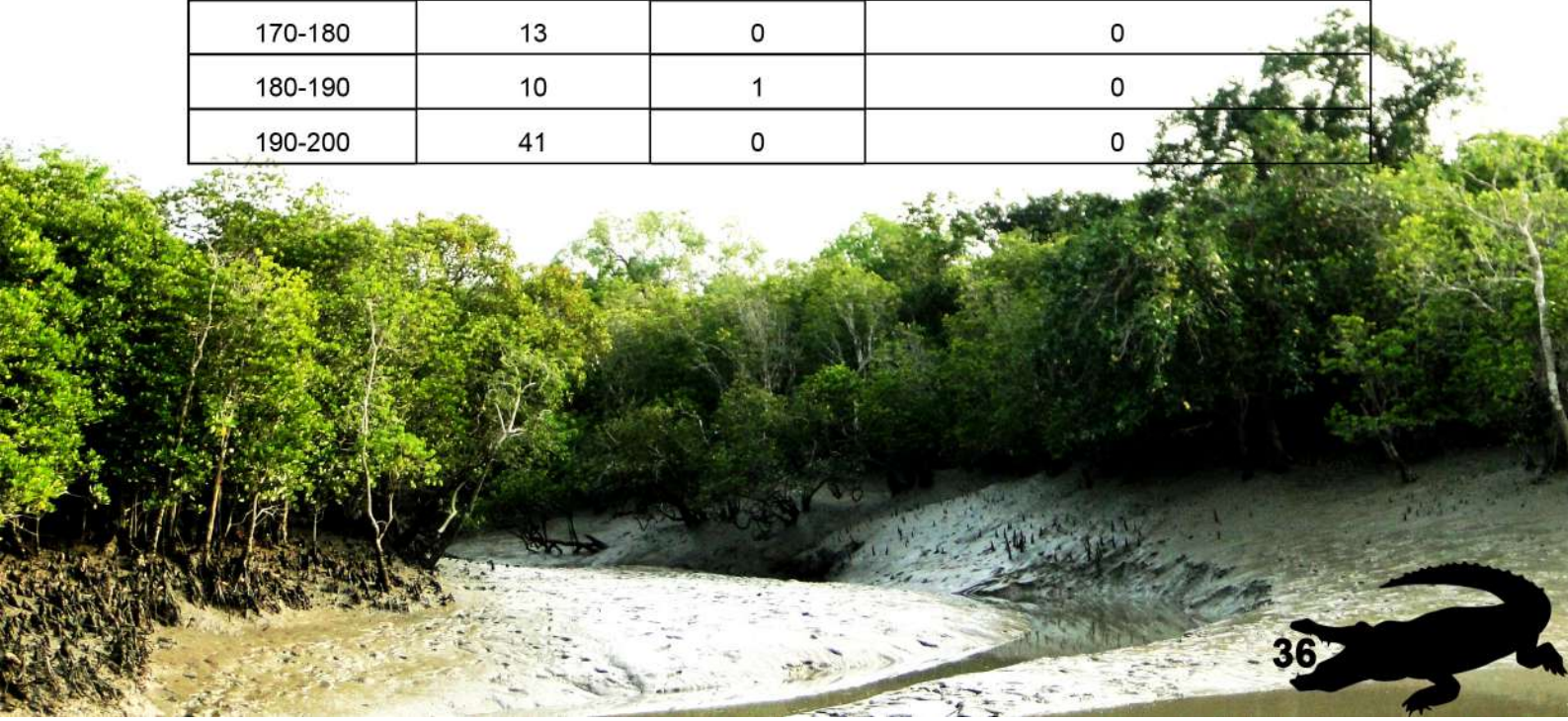
REFRACTOMETER

WATER SAMPLE VIALS

DIGITAL THERMOMETER

Annexure V : Creek width, Kilometers Surveyed and Frequency of Direct Sighting

Creek width in meters	Kilometers Surveyed	Sighting frequency	Uncovered distance in corresponding Creek width
0-10	0	0	
10-20	183	6	274.428
20-30	54	7	80.4876
30-40	65	10	97.875
40-50	85	6	84.827
50-60	17	7	11.58
60-70	65	8	27.801
70-80	5	3	0
80-90	98	11	0
90-100	25	7	0
100-110	51	4	0
110-120	66	7	7.386
120-130	30	5	0
130-140	136	3	0
140-150	3	2	0
150-160	8	2	0
160-170	0	3	0
170-180	13	0	0
180-190	10	1	0
190-200	41	0	0



Annexure VI: Results of the 2012 Population estimation exercise

Results:

Based on the data provided from the Estuarine Crocodile (Crocodylus porosus) survey conducted in the Indian portion of the Sundarbans from 16 - 18 January 2012 , the following results were obtained -

1) A total of **240 detections** were made during the Sundarbans survey effort. Of these, 141 detections (69 adults, 61 juvenile, 10 hatchlings and 1 indeterminate) were made on the basis of direct sightings, and 99 detections were on the basis of indirect evidences (see Figure 3).

The total survey effort, in terms of distance covered, was **1163.20 km,** and in terms of time spent was **612.48 hrs**.

2) The distribution of directly-sighted individuals in the different ranges is provided in Figure 4.

69.5 % (N=98) of the direct-sightings were reported from the 3 ranges of NP East (N=40), Sajnekhali WLS (N=30) and NP West (N=28), indicating these to be themost important ranges for C. porosus in the Sundarbans.

The distribution on indirect detections in the different ranges is provided in Figure 5.

51.5 % (N=51) of the indirect detections were reported from NP East alone, which again the underlines the importance of this range for

C. porosus in the Sundarbans.

3) The size-class distribution (in 24 inch class intervals) of *C. porosus* from the present dataset is provided in Figure 6.

It must be noted that this distribution only provides inference from observations during this survey, and need not reflect actual size-class distributions since crocodilian population surveys are affected by biases against smaller size classes, size-related wariness to approaching observers, and from observer and concealment biases which have not been quantified in this survey. In crocodilians, depleted populations generally have population structures heavily biased towards juveniles, with few adults, and as they recover, this structure shifts to populations heavily biased towards adults and sub-adults, and low numbers of juveniles (Webb et al. 2000, Fukuda et al. 2011). Changes in population size-structures often indicate density-dependent adjustments involving complex interactions between cannibalism, social exclusion, and increased rates of both emigration and mortality (Fukuda et al. 2011).Similarly, 'restocked' populations exhibit a population structure biased towards juveniles, and overtime juveniles and sub-adults.

4) Figure 7 illustrates direct-sighting detections of adult and juvenile C. porosus across 8 ranges in the Sundarbans, and the corresponding effort (distance covered) in each of these ranges. Although NP East seems to be the most favoured range with 38 direct detections, the encounter rates at NP East, NP West and Sajnekhali WLS are comparably similar (see table below). Figure 8 suggests that the number of detections is more a function of effort (distance covered) rather than a function of density, and hence more detections with increased survey effort.

RANGE	NP East	NP West	Sajnekhali WLS	Basirhat	Ramganga	Matla	Raidighi	Namkhana	TOTAL
Detection (ADULT + JUVENILES)	38	27	23	20	15	1	4	2	130
Effort (km)	220	171	151	164.2	125	64	140	44	1079.2
ENCOUNTER RATE / km	0.17	0.16	0.15	0.12	0.12	0.02	0.03	0.05	0.12

5) Based on the direct-sighting detections of all size classes (N=141) and the survey effort in terms of distance (1163.20 km) and time (612.48 hrs), we can make coarse estimates of encounter rates at 0.12 individuals/km OR 0.23 individuals/hour.

Note: The encounter rate only indicates the number of individuals detected per unit effort (distance or time). It does not necessarily translate into population densities. It can however be used as an index of density, provided that survey design and techniques are standardised. The population density in the region is estimated by dividing the encounter rate by the estimated detection probability, i.e. density = (encounter rate / detection probability).

By accounting for the effects of survey effort (distance covered) on the number of detections, Figure 9 provides a better index of relative density in the Sundarbans. Here, we see that the ranges of NP East, followed by NP West and Sajnekhali have the highest relative densities with 0.17, 0.16 and 0.15 encounter/ km respectively.

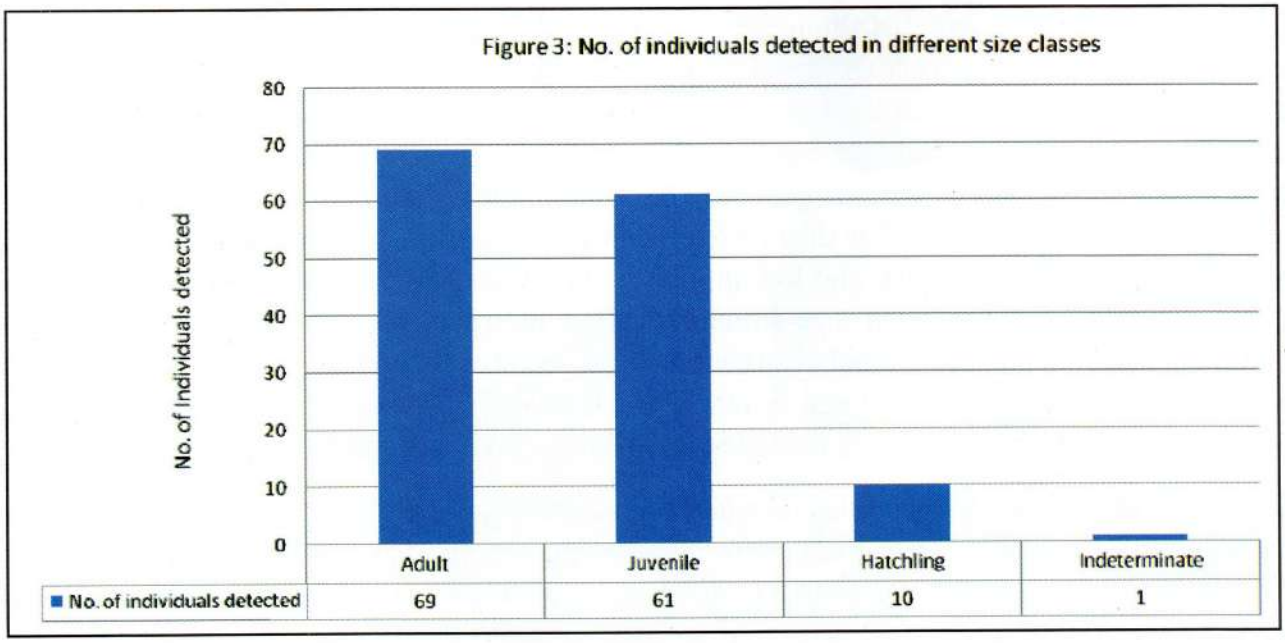
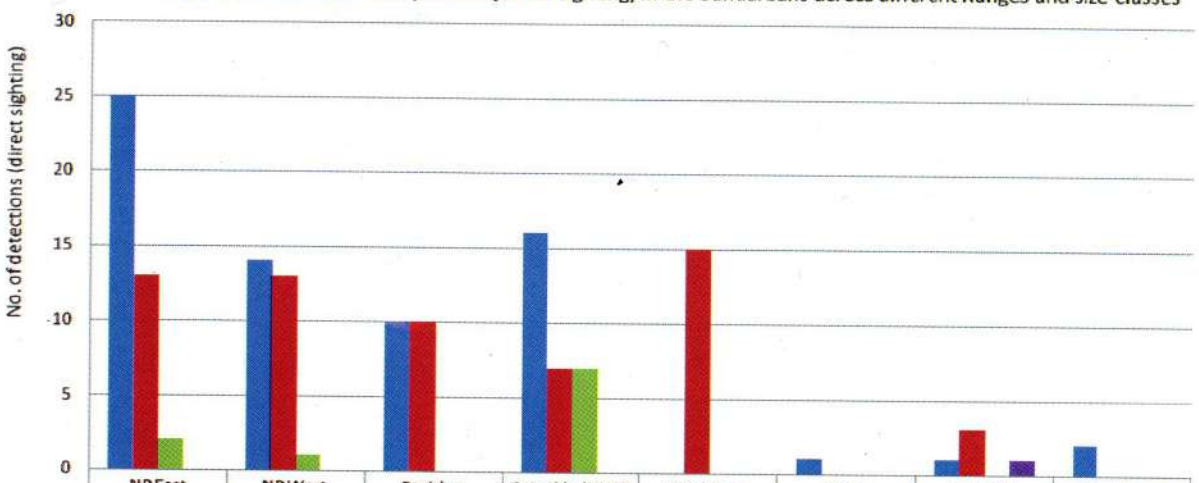
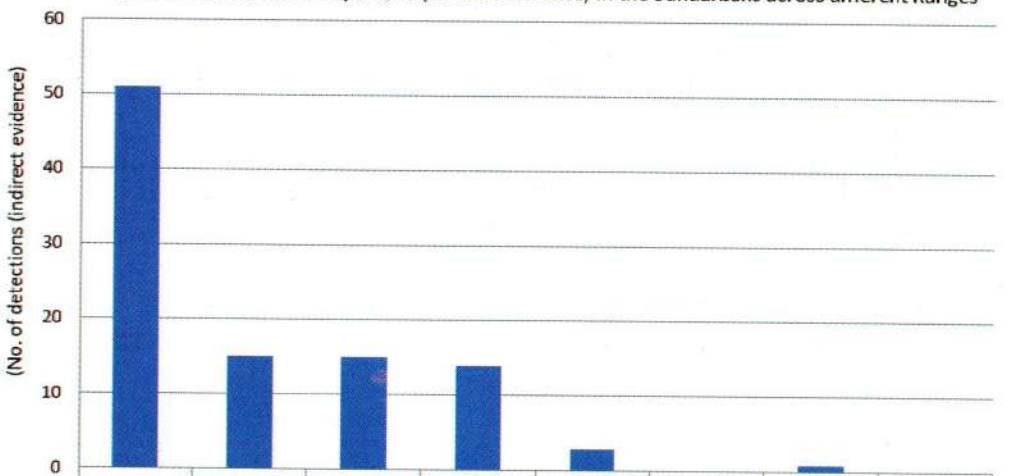


Figure 4: Distribution of *C. porosus* (direct sighting) in the Sundarbans across different Ranges and size-classes



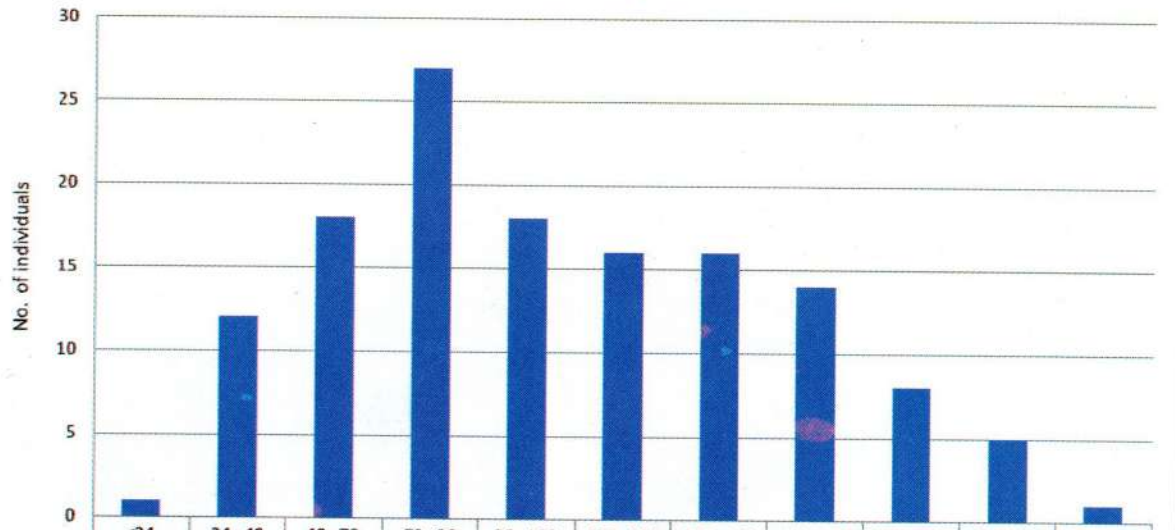
	NP East	NP West	Basirhat	Sajnekhali WLS	Ramganga	Matla	Raidighi	Namkhana
Adult	25	14	10	16	0	1	1	2
Juvenile	13	13	10	7	15	0	3	0
Hatchling	2	1	0	7	0	0	0	0
Indeterminate	0	0	0	0	0	0	1	0

Figure 5: Distribution of *C. porosus* (indirect evidence) in the Sundarbans across different Ranges



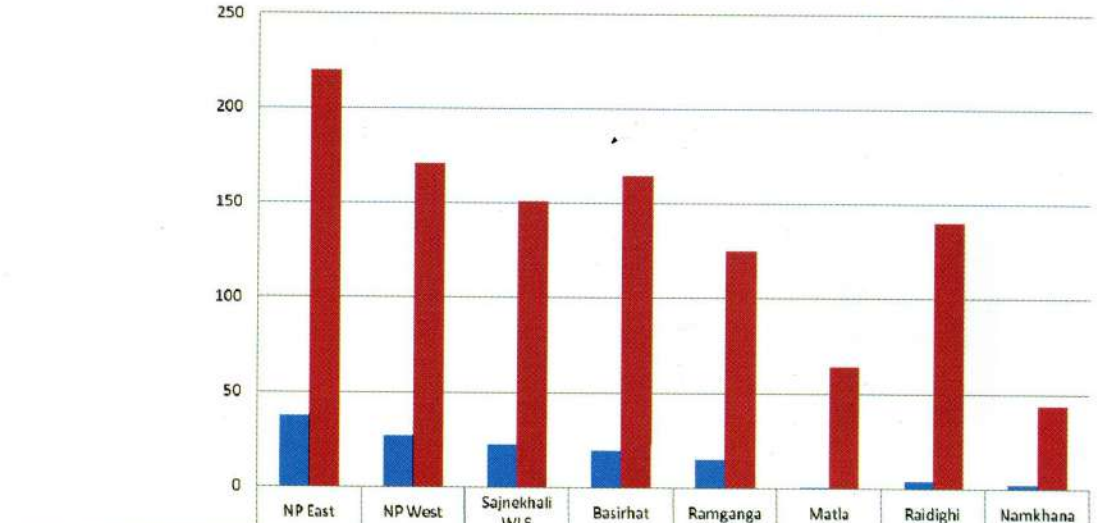
	NP East	NP West	Basirhat	Sajnekhali WLS	Ramganga	Matla	Raidighi	Namkhana
No. of detections (indirect evidence)	51	15	15	14	3	0	1	0

Figure 6: Size-class distribution of *C. porosus* (at class intervals of 24 inches)



	<24	24 - 48	48 - 72	72 - 96	96 - 120	120 - 144	144 - 168	168 - 192	192 - 216	216 - 240	240 - 264
No. of individuals	1	12	18	27	18	16	16	14	8	5	1

Figure 7: Survey effort (distance) and detection (direct sightings) of *C. porosus*



	NP East	NP West	Sajnekhali WLS	Basirhat	Ramganga	Matla	Raidighi	Namkhana
Detection (ADULT + JUVENILES)	38	27	23	20	15	1	4	2
Effort (km)	220	171	151	164.2	125	64	140	44

Figure 8: Scatter plot showing correlation between survey effort (distance) and detection (direct sightings) in different ranges

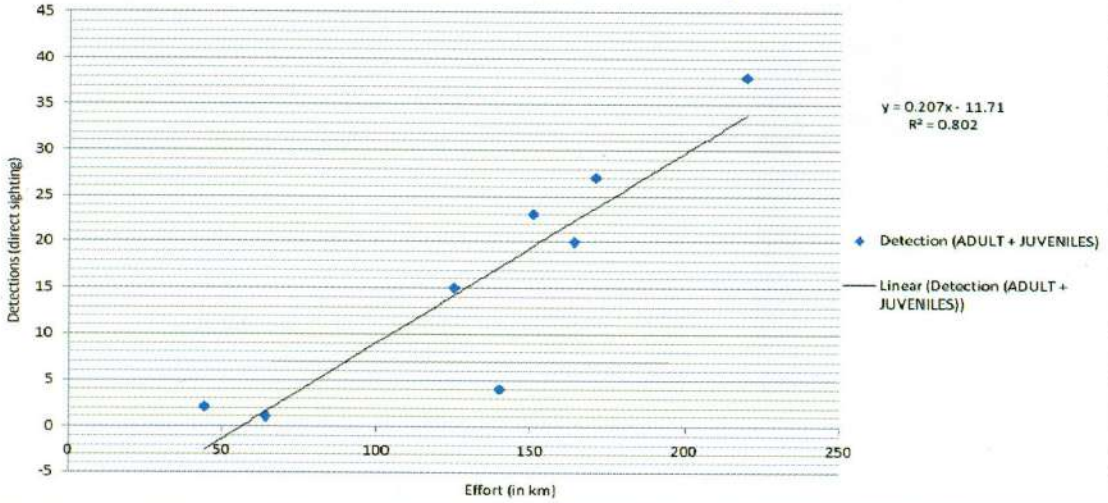
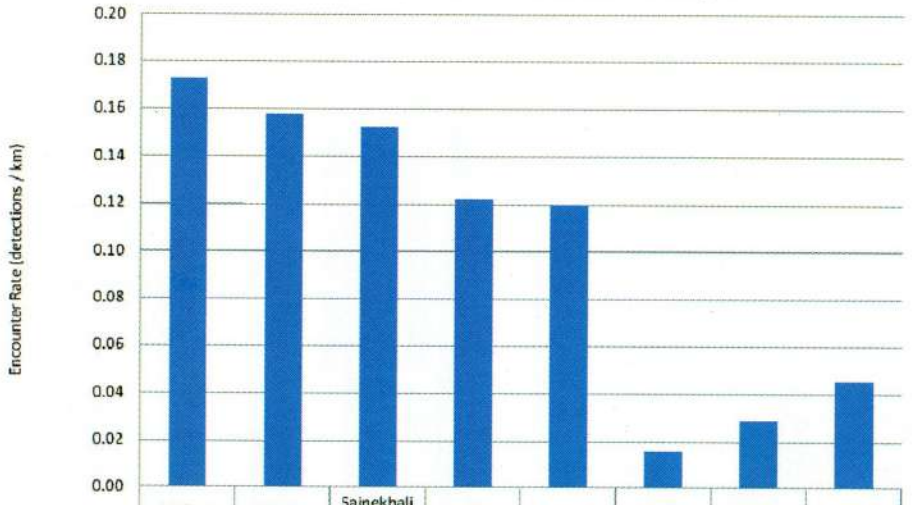


Figure 9: Encounter Rate / hour of Adult + Juvenile *C. porosus* in the Sundarbans in January 2012



	NP East	NP West	Sajnekhali WLS	Basirhat	Ramganga	Matla	Raidighi	Namkhana
ENCOUNTER RATE / km (Adult + Juveniles)	0.17	0.16	0.15	0.12	0.12	0.02	0.03	0.05

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