Human-Crocodile (*Crocodylus porosus*) conflict around Bhitarkanika: Causes and Consequences

Pattnaik M[1], Mohanty S[1], Sen S K[2]

Environmental Science Research Laboratory, CEMC, Pahala, Bhubaneswar, 752101
Ex-Demonstrator in Botany, Panchayat College, Bargarh, 768028

Abstract

The estuarine crocodile (*Crocodylus porosus*) is a keystone species in mangrove wetlands and also a dangerous predator that affects the safety and livelihood of the people if not properly dealt with. Human-Crocodile conflict occurs when human requirements encroach upon the crocodile habitat that causes loss to both humans and crocodiles. The trend of casualty of human beings is increasing every year around the protected area of Bhitarkanika, that might be due to the increasing density of estuarine crocodiles in a limited area of natural habitat. Monsoon is considered as the critical season when maximum casualty took place which might be due to the over flooding of water and nesting season during which the crocodile remains aggressive. Minimizing the contact between people and crocodilians by generating awareness about crocodile behaviour is an important aspect to reduce human-crocodile conflict. Government bodies and local NGOs should deal with the issues proactively to protect the life of both crocodile and people. A management strategy integrating the ecological knowledge of local people in the development of a Comprehensive Management Plan is essential for effective co-existence of human and salt water crocodiles which will reduce the dependency on mangrove forest resources, ensure the conservation of estuarine ecosystem, minimise the risk of crocodile attack for harmonious co-existence of humans and crocodiles in and around Bhitarkanika landscape.

Key words: Estuarine crocodile, Keystone Species, Bhitarkanika, Mangrove, Wetland, Casualty, Conflict.

Introduction

Salt water crocodiles or estuarine crocodiles (*Crocodylus porosus*) are considered to be the largest of living crocodilians inhabited on the earth (Webb and Monolis, 1989, 2009; Whitaker and Whitaker, 2008). It is most widely distributed among all the crocodilians, due to its ability to traverse long distances in the open sea (Gopi and Pandav, 2009). Distribution of *Crocodylus porosus* ranges from Southern India and Sri Lanka, throughout Southeast Asia, east through the Philippines to Micronesia and down through Indonesia, Papua New Guinea and the Salomon Islands to northern Australia (Webb *et al*., 2010). But they are extinct from Seychelles and Mauritius (Gopi and Pandav, 2009). In India currently they are inhabited in the Bhitarkanika of Odisha, the Sundarbans in West Bengal and the Andaman and Nicobar Islands. Information in the Guinness Book of World Records (2006), suggests that the largest living crocodile in the world is present in Bhitarkanika (Das and Chatterjee, 2015; Senapati, 2023). They are considered as Keystone species in mangrove wetlands and a dangerous predator that affects the safety and livelihood of the people (Than, 2020). It preys on people when given as opportunity (Webb *et al*., 2010) and known as a man eater. It is one of the important reasons for its hunting and a threat to its existence. They are ambush predators and mostly lie low. Often, they lurk on the edge of the rivers/creeks with only nose and eyes, located atop the skull above the surface. When an unsuspecting prey steps by, crocodile explodes out of the water, grabs and snaps its neck, drags and drowns it before eating. It lacks the ability to chew the prey well, though it possesses strong jaws, but violently rotates its body in the water with the prey firmly in its mouth dismembering it. Saltwater crocodile is a skilled aquatic predator, whose eyes are adapted to see under water, and it has excellent night

vision, for which the nocturnal reptile can hunt at night. It is capable of prevailing over almost any animal that enters its territory and ambushes most of its prey and then drowns or shallow it as a whole. The depleted populations of crocodilians have been managed by supplementation since 1975-76 under "Project Crocodile" a Government of India initiative (Mukherjee and Mallapur, 2022). Although such effort is supported by most of the crocodile enthusiasts, aimed to recover endangered crocodilian populations, most of the large crocodilians are potential predators of humans and / or livestock and thus these recoveries have quickly turned into conflicts (IUCN CSG, 2021).

Human-wildlife conflict is a growing issue all over the world (Woodroffe *et al.,* 2005) and crocodilians are one of the major groups involved in such conflict (Lamrque *et al.,* 2009). Population growth is in an increasing trend in the villages at the periphery of Bhitarkanika and they depend mostly on mangrove forest resources to meet their daily livelihood requirements that results the loss of habitat (Banerjee, 2016). As the human population increases near protected areas, the possibilities of conflict is exacerbated when there is competition for limited resources between people and wildlife (Newmark *et al.,* 1993; Madden, 2004; Wallace *et al.,* 2011).

Habitat loss is a major factor for human-crocodile conflict (Santiapillai and de Silva, 2001; Sivaperuman, 2015). Negative attitudes towards Salt water crocodiles are common in areas where livelihoods of the people are affected by crocodiles (Than *et al*., 2020). Addressing such attitudes and any potential conflict are essential component of effective conservation strategies for salt water crocodiles (Kaltenborn *et al*., 2006; Thmos, 2006; Wallace *et al*., 2011). The term human-crocodile conflict refers to any interaction which results in negative effects on human social, economic or cultural life, or on the conservation of crocodilians species and / or their habitats (IUCN CSG, 2021). Though some studies have been conducted on human-crocodile conflict in Bhitarkanika, these are inadequate to meet the present need. Thus, the present work is an attempt to study the incidences of mortality due to human-crocodile conflict from management point of view and to trace out the causes to safe guard the life of estuarine crocodiles and local inhabitants by prescribing some feasible mitigative measures.

Under Indian legislation *Crocodylus porosus* is listed under Schedule-I of Wildlife (Protection) Act, 1972 and also in Amendment, 2022; that covers endangered species which need rigorous protection. This species is protected globally being enlisted in the Appendix-I of CITES and in Least Concern (LC) category of IUCN Red List.

Study area

Bhitarkanika in the district of Kendrapara, Odisha, along the east coast of India harbours the second largest mangrove forest in the country next to Sundarbans of west Bengal. It has been notified as Bhitarkanika Wildlife Sanctuary covering an area of 672 km^2 in April 1975 and 673 km^2 in February 2020 in the amended notification. The core area of the Sanctuary spreading over an area of 145 km^2 has also been declared as Bhitarkanika National Park in September 1998. This wetland has gained its status as Ramsar site, an wetland of international importance in August, 2002. The proposed Bhitarkanika Biosphere Reserve covers erstwhile zamindary area of Kanika and Kajang, that includes three protected areas like Bhitarkanika Wildlife Sanctuary, Bhitarkanika National Park and the Gahirmatha (marine) Wildlife Sanctuary. It is a unique region with rich biodiversity as it covers varied ecosystems like landmass, tidal water bodies of the deltaic region, estuaries and tidal waters of Bay of Bengal along with their associated flora and fauna. Bhitarkanika houses 62 mangrove species out of the 72 species found world over. The faunal diversity of this area is represented by 42 species of reptiles, 5 species of amphibians, 280 species of birds and 28 species of mammals (Das and Chatterjee, 2015). The mangrove ecosystem, supporting rich estuarine and adjacent marine fisheries, plays a vital role in contributing to the food web in general and detritus food chain in particular (Chadha and Kar, 1999).

Methods of study

A survey to assess the human-crocodile conflict was carried out between May to August, 2023 in and around Bhitarkanika at 20 villages covering Kanika, Rajnagar, Gahirmatha and Mahakalpada Wildlife Ranges located inside and outside the protected area. Information was collected from the villagers and school teachers with structured questionaries and semi- structured interviews regarding salt water crocodile and their habitats, threats to crocodiles, awareness level of human-crocodile conflicts, benefits from crocodile conservation, attitude of public towards salt water crocodiles and main source of livelihood of the local inhabitants. Information also gathered about topography, vegetation, nearness of villages to water sources, activities for which inhabitants depend on water sources and condition of mangrove forest from the local people as well as through reconnaissance survey. Census report of crocodiles and information relating to casualty from 2013-14 to 2023 August were also collected from the office of the Divisional Forest Officer, Mangrove Forest Division, Rajnagar.

Observations

The unique ecosystem of Bhitarkanika is inundated by the waters from ramifications of creeks and canals of rivers Baitarani, Brahmani, Dhamra, Patasala, Hansua and Hansina. The bottom of canals, creeks and rivers were shallow (3-5m) towards the bank and 7-8m or more at the center. The distance between houses of inhabitants from the banks were within 20-30m and such proximity from water bodies to the houses in almost all villages were seemed more or less to be uniform. The villagers were dependent on the flowing creeks and rivers for bathing, fishing, washing cloths and sometimes collecting drinking water for themselves and for their domestic cattle.

There were 29 incidences of casualty in human-crocodile conflict during 2013-14 to 2023 August, out of which 4 (13.8%) incidences were within National Park. Most of the casualties (48.27%) were recorded from the river Brahmani that includes 4 creeks connected to the river. Baitarani and Kharasrota rivers each account for 10.34% of casualty. Lowest incidences of casualty 3.45% were recorded from each of the rivers namely Patasala, Hansua and Kharinasi (Table-1, Fig.-3). The percentage distribution of casualty across rivers indicated that Brahmani, Baitarani and Kharasrota rivers account for 68.95% of casualty. Most of the victims of crocodile attack are males (75.9%) in comparison to females (24.1%) (Fig.-4).

Table-1: Rivers where casualties due to crocodile attacks occurred.

Name of the River	No . of casualty	Percentage(%)
Baitarani	03	10.34
Bramhani	14	48.27
Kharasrota	03	10.34
Gobari	02	6.90
National Park	04	13.80
Patsala	01	3.45
Hansua	01	3.45
Kharinasi	01	3.45
Grand total	**29**	**100**

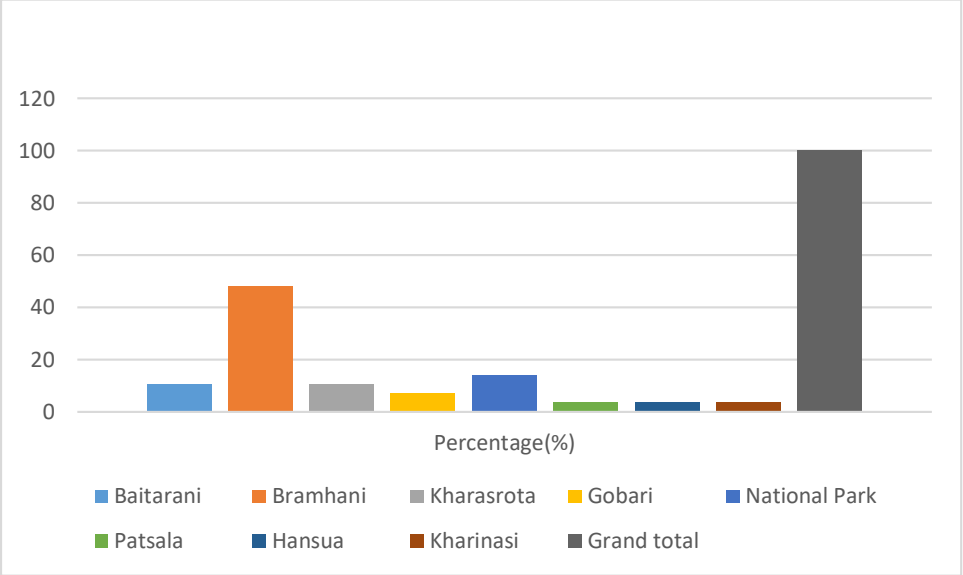

Fig-3: Human Casualties in different rivers

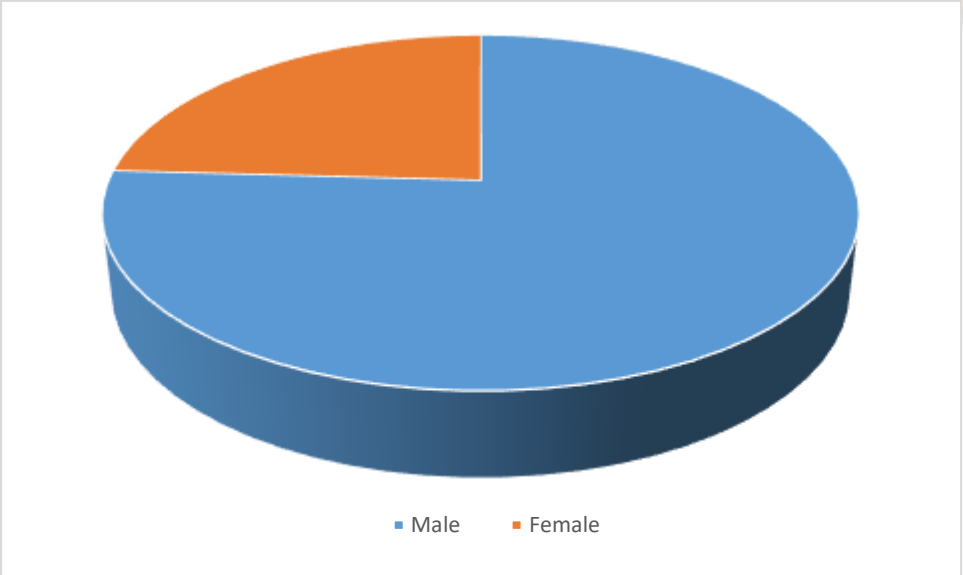

Fig-4: Mortality Percentage of male & female

More incidences of casualties (17.24%) were recorded during 2019-20, 2022-23 and 2023-24. There were 13.79% of casualties during 2020-21 followed by 10.34% during 2021-22. Least incidences of casualties (3.45%) were recorded during 2014-15, 2015-16 and 2017-18 (Table-2, Fig.-5). From the available data an average 2.9% of casualties per year were recorded during 10 years from 2014-15 to 2023 (August). With a view to study the pattern of attack leading to casualty the data were segregated into 3 years (2014-15 to 2016-17, 2017-18 to 2019-20, 2020-21 to 2022-23) and 5 years (2014-15 to 2018-19, 2019-20 to 2023 August) interval. It was observed that there were only 4 (13.8%) causalities reported from 2014-15 to 2016-17, which increased sharply to 8 (27.6%) from 2017-18 to 2019-20 and was maximum 12 (41.4%) from 2020-21 to 2022-23 (Fig.-6a). on the contrary during first 5 years from 2014-15 to 2018-19 there were 7 (24.1%) incidences of causalities that increased more than 3 fold to 22 (75.9%) in the second 5 year interval from 2019-20 to 2023 August (Fig.-6b).

Table-2: Percentage of human casualties due to crocodile attack (2014-15 to 2023 August)

Year	No . of casualties	Percentage (%)
2014-2015	1	3.45
2015-2016	1	3.45
2016-2017	2	6.90
2017-2018	1	3.45
2018-2019	2	6.90
2019-2020	5	17.24
2020-2021	4	13.79
2021-2022	3	10.34
2022-2023	5	17.24
2023 August	5	17.24
Grand total	**29**	**100**

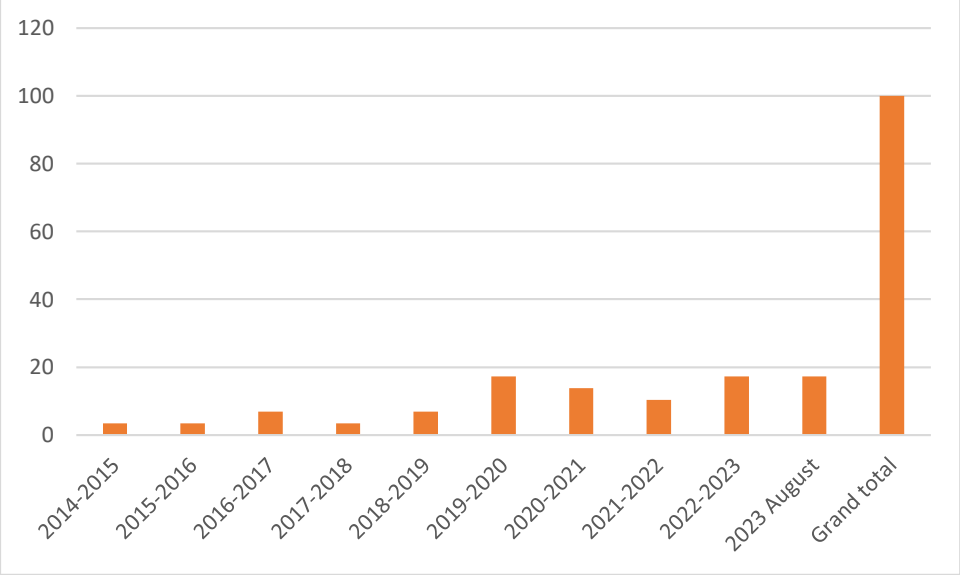

Fig-5: Human casualties due to crocodile attack (2014-15 to 2023 August)

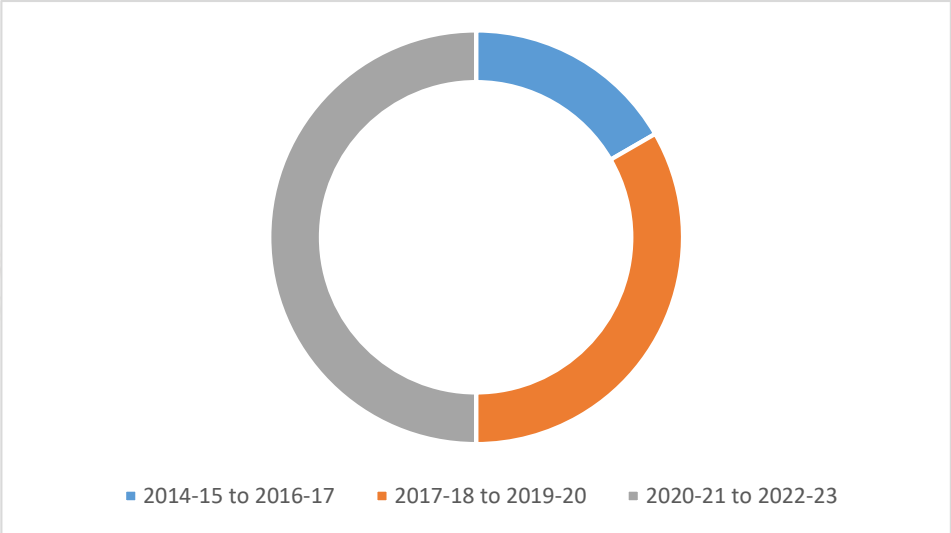

Fig-6 (a): Mortality trend in three years interval

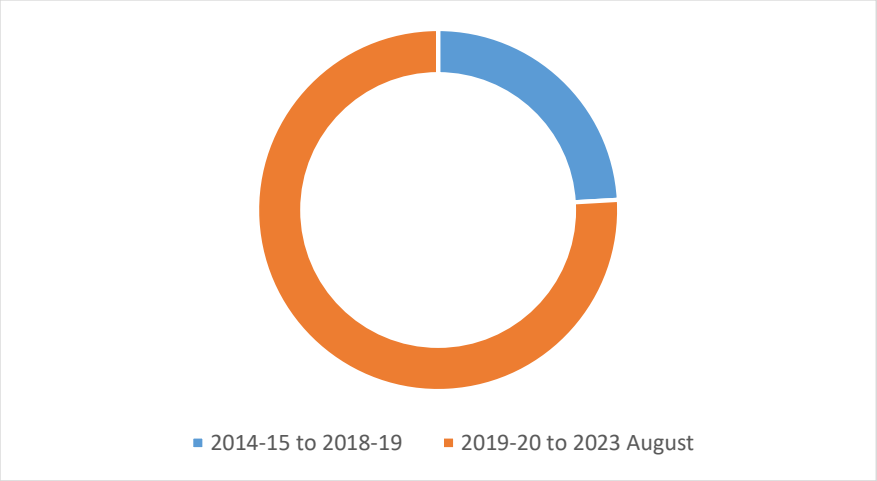

Fig-6 (b): Mortality trend in five years interval

Highest number of incidences of casualties (27.58%) were recorded from Rajnagar Police Station followed by Pattamundei Police Station (24.1%) and Rajkanika Police Station (17.24%). There were least case of casualties 3.45% each in Nikirai Police Station, Jamboo Marine Police Station, Pattamundei (Rural) Police Station and Mahakalapara Police Station (Table-3, Fig.-7). The casualty rate was highest (58.62%) in Rajnagar Range whereas Kanika Range and Mahakalapara Range accounted for 24.14% and 17.24% of casualties respectively (Table-4, Fig.-8).

Table-3: Percentage of casualties in different Police Stations

Name of the Police Station	No. of casualties	Percentage (%)
Rajnagar	8	27.58
Rajkanika	5	17.24
Pattamundei	7	24.14
Nikirai	1	3.45
Talachua Marine	2	6.90
Jamboo Marine	1	3.45
Aul	3	10.34
Pattamundei (Rural)	1	3.45
Mahakalapada	1	3.45
Grand total	**29**	**100**

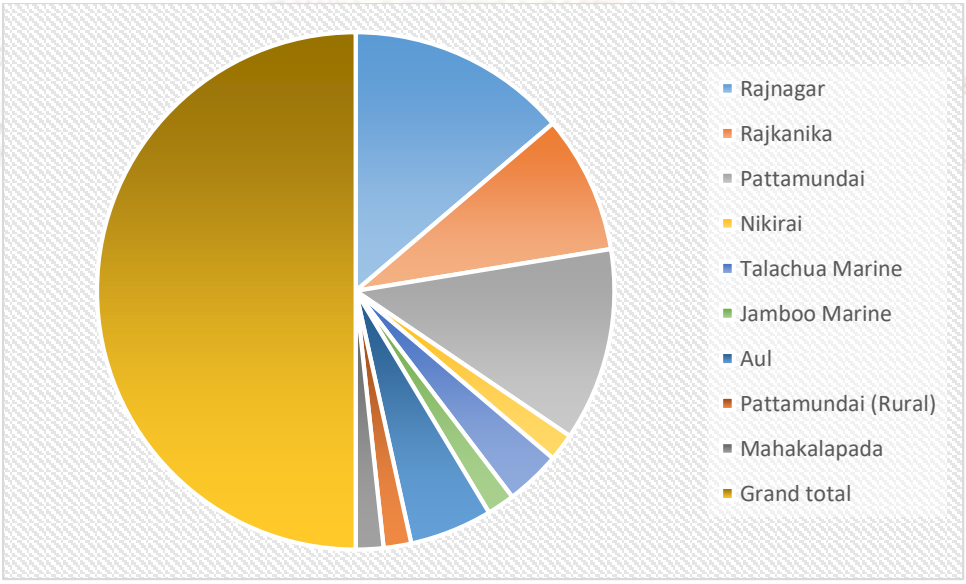

Fig-7: Casualties in different police stations

Table-4: Percentage of casualty in different Forest Ranges.

Name of the Range	No. of casualties	Percentage (%)
Rajnagar	17	58.62
Kanika	07	24.14
Mahakalapara	05	17.24
Grand total	**29**	**100**

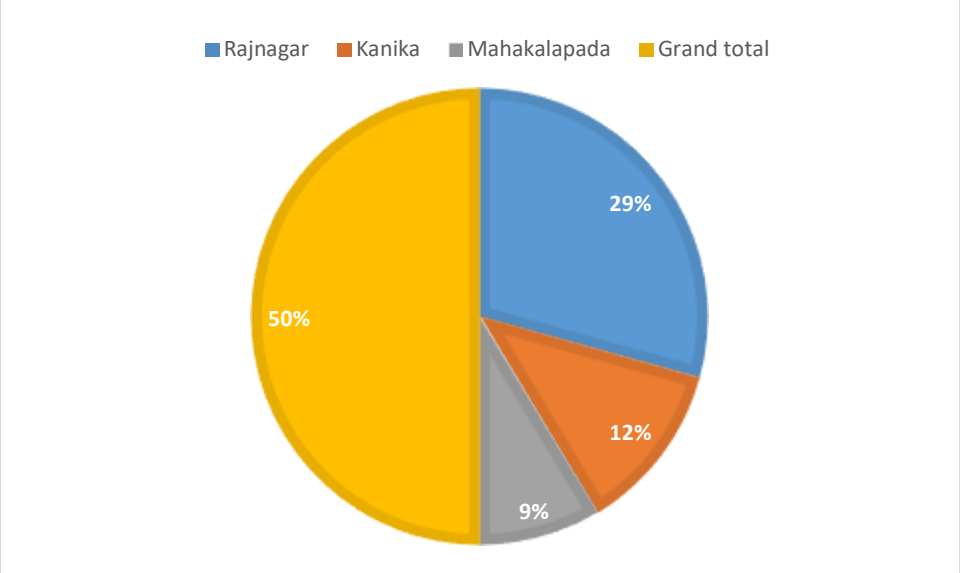

Fig-8: Casualties in different Forest Ranges

The data were arranged month wise to have an insight into the seasonal pattern of casualty of human beings (Table-5, Fig.-9). The peak month for casualty was June, during which 28.58% of casualty took place followed by July (20.73%) and the lowest number of casualty (3.44%) occurred during February and March. Most incidences occurred during monsoon season and June to August were identified as the critical period when most of the incidences took place. No case of casualty due to crocodile attack was reported during September, November, December and January.

Table-5: Month wise distribution of casualties due to crocodile attacks

Month	No.of casualties	Percentage (%)
February	1	3.44
March	1	3.44
April	3	10.34
May	3	10.34
June	8	27.58
July	6	20.73
August	4	13.79
October	3	10.34

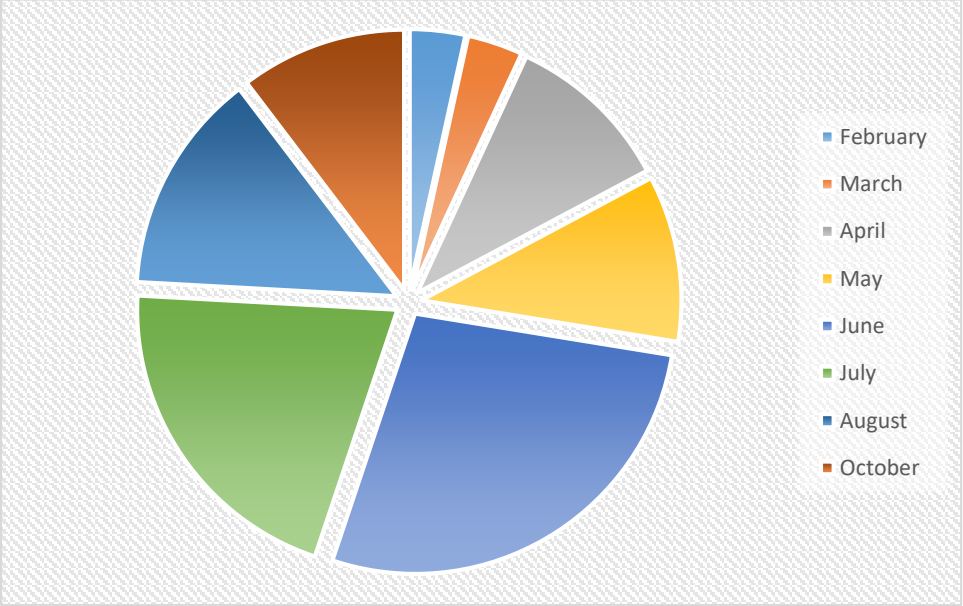

Fig-9: Month wise distribution of casualties

Most of the incidences of causality (84%) occurred when the victims were bathing in shallow waters close to the banks, although mortality while engaged in fishing, livestock grazing, washing clothes and household utensils were reported (Fig.-8). Information also revealed that crocodile attacks were likely to occur during the day when most of the human activities took place.

(https://roundglassustain.com/species/saltwater-crocodile-sunderbans-swamps)

Discussion

Kendrapara district has 209 km^2 of mangrove forest cover which is 81% of the mangrove cover of Odisha (258.98km^2) as of 2021. According to 1991 census, there were 309 villages with 118,939 people, but in 2011 census there were 310 villages with 145,301 people in Bhitarkanika Sanctuary, covering 673km^2 indicating that the population density was 216 persons/km^2 as against 382 persons/km^2 in India and 269 persons/km^2 in Odisha. This high-density population is dependent mostly on biodiversity rich mangrove forest to meet their bonafide requirements to earn their livelihood. Also, due to gradual increase of human population in the villages, more and more people moved closer to crocodile habitats for living space, better access to water and forest resources to meet their daily needs.

Available information provided by Wildlife Wing of State Forest Department indicates the increase in number of salt water crocodiles in Bhitarkanika (Table-6, Fig.-11).

Table-6: Saltwater Crocodile Census Report (2013-14 to 2022-23)

Year	Total no of Crocodiles
2022-2023	1793
2021-2022	1819
2020-2021	1830
2019-2020	1809
2018-2019	1763
2017-2018	1713
2016-2017	1694
2015-2016	1671
2014-2015	1665
2013-2014	1644

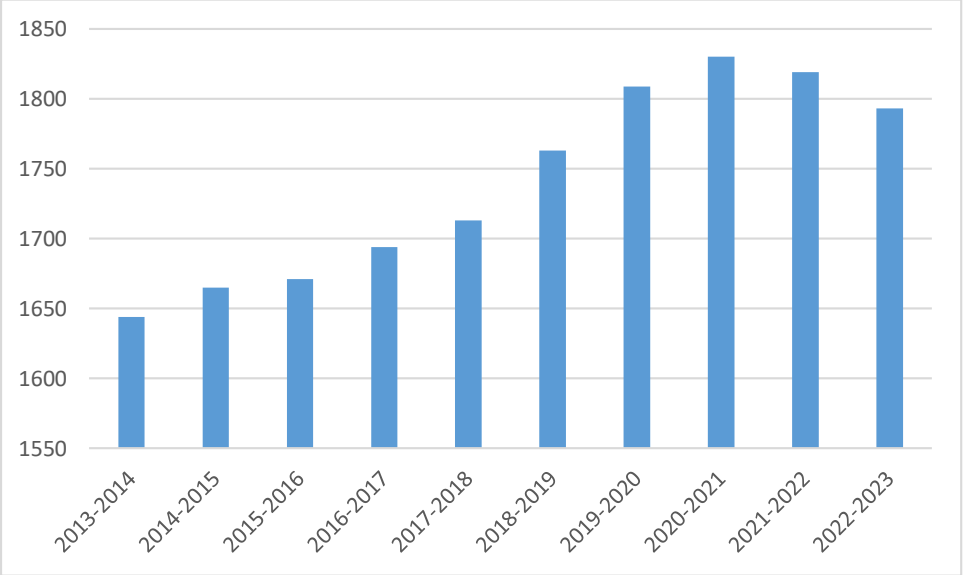

Fig-11: Saltwater crocodile population (2013-14 to 2022-23)

Saltwater crocodiles and Muggers both attack humans (Caldicott *et al.*, 2005) and are responsible for numerous fatalities each year (Samaweera and de Silva, 2013). Human and wildlife conflict, as well as human-crocodile conflict are complex, which requires simple, mutual inclusive approaches for the continued existence of both human (and their livelihood) and the so-called problem animal (FAO, 2010). Conflict is likely to occur in any crocodile occupied habitat associated with human activity (Das and Jena, 2017). Crocodilians are among the few species that cause reflexive fear in humans, perhaps because the fear of being eaten is greater than the fear of being bitten (Graham, 1990). Many species will bite, but only a few attack people as they would other prey items (Coldicott *et al.*, 2005). Successful recovery of crocodile populations in wild often reinstates human- crocodilian conflict, leading to negative public attitudes about those same crocodilian populations for which there was support previously. Now the challenge is how to maintain those populations in the face of increasing human-crocodile conflict (IUCN CSG, 2023).

Present study reveals that highest number of casualties occurs in Brahmani River followed by Baitarani and Kharasrota. Communities residing in fringing villages of the protected areas largely depend on the flowing waters of rivers and creeks for their daily activities and also, they depend on water bodies those are connected to Brahmani, Baitarani and Kharasrota rivers. These findings indicate higher population density of crocodiles in Brahmani river, moderate in Baitarani and Kharasrota rivers and lowest in Patasala, Hansua and Kharinasi rivers. Highest casualty might be due to the fact that thickly populated villages like Chandanpur, Sahupara, Nilakanthapur, Jagannathpur, Srirampur, Nalapahi, Jharpara, Hatiagadi, Ghagardia, Kulasahi and Rajpur besides the river Brahmani are more frequently using the river waters for their daily activities. The increasing casualty of human beings might also be due to the overcrowding of crocodiles in the limited area of natural habitat which is corroborated by the findings of Mukherjee and Mallapur (2022). The lowest rate of casualty is probably due to the lower rate of dispersion of crocodiles away from the Sanctuary limits as the species is a territorial reptile.

Mortality due to the attack of saltwater crocodile is in an increasing trend. Segregation of casualty data into three years interval depicts that during second three years the casualty is double of the first three years and half of the casualty of third three years. Also, the segregation of casualty data into five years interval suggests that casualties in second five years is more than three times the casualty of first five years. This indicates the increasing rate of casualties every year and the average of casualties during second five years (2019-20 to 2023 August) is 4.4 humans per year whereas it is 1.4 persons per year in first five years. This information clearly indicates that incidences of casualties due to attack of salt water crocodiles on human beings is increasing every year.

There are more number of casualties in Rajnagar Police Station followed by Pattamundei Police Station and Rajnagar Wildlife Range followed by Kanika Wildlife Range. Nikirai Police Station, Jamboo Marine Police Station and Pattamundei Police Station away from protected areas witnesses least casualties. So also, in Mahakalapara Wildlife Range far from protected area, there are lowest number of human casualties. These information depicts that the distance from Bhitarkanika Wildlife Sanctuary and Bhitarkanika National Park is a function of the rate of casualty that reflects upon population density of crocodiles which decreases gradually with distance. Also, higher biotic interferences inform of fishing movement of mechanised boats for transportation and tourism activities might contribute to some extent towards lower density of crocodiles in the areas of lower casualty. Proximity of Bhitarkanika Wildlife Sanctuary and Bhitarkanika National Park might account for the more number of causalities in Rajnagar Police Station and Rajnagar Range followed by Kanika Range.

There is occurrence of most of the incidences of casualties during monsoon from June to August which are probably due to the high tidal up surge when there were human intrusion into the crocodile habitat. April to August is the nesting season of crocodiles in Bhitarkanika region and during this period the species remains very aggressive for the protection of their eggs (Gopi *et al.*, 2007). For this reason, the Park remains close every year from May to July to prevent the tourists to enter the Park that may cause disturbance in the habitat. Moreover, the maximum casualties during monsoon (June-August) are probably due to the aggressive instinct of salt water crocodiles during their nesting period which is a part of their egg lying and nest guarding behaviour to protect the eggs. Salt water crocodiles have 80-90 days of incubation period after which the young ones hatched out of eggs (Webb *et al.*,2010). They also show intense parental care and remain aggressive during the period for the protection of their young ones (Patro and Padhi, 2019). Higher number of casualties during monsoon as revealed from the present study might be due to the aggressive instinct of the species to protect their eggs and youngs which is corroborated by Patro and Padhi (2019). No casualty during winter months November, December and January suggests that the harvesting season of paddy probably drives the people not to enter to the crocodile infested waters for their daily activities. Fewer casualties during post-monsoon season (August- October) are probably due to the high water level in the rivers and creeks associated with higher frequencies of cyclonic disturbances, that discourage people to use the river waters. Das and Jena (2017) reported that in Indian Sundarbans though the attacks are distributed throughout the year, peak occurs during monsoon (June-August) which is in agreement with the present finding. But several authors have reported that crocodile attacks increase in warm summer months (Fergusson, 2004; Caldicott *et al;* 2005).

Among other activities highest incidences of casualties took place at the time of bathing. Present study shows that there are 21 (72.45 %) casualties out of 29 at the time of bathing maximum of which occurs during June (28.56 %) followed by July (19.04 %). Minimum one (4.76 %) casualty has been recorded during February. Higher rate of casualties of males in comparison to females perhaps due to the more exposure of males to arduous nature of activities to maintain the livelihood of their families.

From questionnaire survey it was revealed that majority of attacks on humans occur when they enter the crocodile habitats for illegal fishing, bathing, washing clothes and household wares, cattle grazing, agricultural activity, collection of Nalia grasses (*Myriostachia wightiana*), poaching, collection of wood and honey. Most of the attacks takes place during high tide and rainy season when river banks are inundated with flood waters due to high tidal upsurge. Information also indicates that human-crocodile conflict occurs in sites where people live close to salt water crocodiles' habitats outside the protected areas and also when crocodiles stray into the village ponds outside the Sanctuary limits. Some attacks were also reported due to the intrusion of people and cattle into the crocodile habitat which is corroborated with the findings of Kar and Bustard (1989).

From the information available with the Wildlife Wing of state Forest Department it is revealed that there are 29 casualties during the period from 2014-15 to 2023 August, on account of Human-crocodile Conflict leaving aside the fatal and minor attacks. Senapati (2022) has also reported that as many as 50 people have been killed by crocodiles since 2012 in and around the park, while 25 crocodiles died during the same time after entering human settlements or getting caught in fishing nets. Basing on the statement of Dr.

Sudhakar Kar, Herpetologist and former Research Officer, in the office of the Principal Chief Conservator of Forests (Wildlife), Odisha. Senapati (2023) has reported that during 2023 saltwater crocodile census 569 hatchling (≤2ft), 388 yearlings (2-3ft), 325 juveniles (3-6 ft), 166 sub-adults (6-8ft) and 345 adult (>8ft) crocodiles were sighted including 20 whitish crocodiles whereas 564 hatchlings, 378 yearlings, 338 juveniles, 158 sub-adults and 346 adults were sighted during 2022 census. From these data it is revealed that the number of crocodiles at each stage of recruitment are more or less equal and surprisingly the number of adult crocodiles are nearly same, which is probably due to the territorial nature of crocodiles. These adult and sub-adult crocodiles confined within a limited area might be responsible for human-crocodile conflict though the carrying capacity of the Sanctuary and their dispersal mechanisms have not been studied. On the basis of opinion of B.C Choudhury, a former Wildlife Scientist from Wildlife Institute of India, Dehradun; Senapati (2022) has reported that the crocodile is a territorial aquatic reptile. If too many of them are packed into a small space, there will be increased competition for food, mating partners, basking sites and for all other things that are important for crocodiles to survive. The crocodile population has reached a saturation point in Bhitarkanika since long time. The then Union Ministry of Forest and Environment in 1991 had directed the state Forest Department to stop crocodile rearing programme in Bhitarkanika. A high population density means higher incidents of conflict with human and many crocodiles venture to come out from the water, particularly during rains (Senapati, 2022). Patro and Padhi (2019) have also reported that overcrowding of salt water crocodiles in a limited natural habitat is perhaps the reason for frequent incidents of humans getting attacked. It has also been opined by Gopi and Pandav (2009) that human-crocodile conflicts have risen over the years with increase in the population of both. As envisaged from the present study, increase in both human population and salt water crocodile population in a limited natural habitat probably be the key factors for increasing number of human-crocodile conflicts which is in agreement with the aforesaid findings (Gopi and Pandav, 2009; Patra and Padhi, 2019) and report (Senapati, 2023).

The saltwater crocodiles have the ill repute of attacking humans throughout their distribution range (Neil, 1971) and male crocodiles are generally more aggressive than the female (Gopi and Pandav, 2009). Analysing the available information Gopi and Pandav (2009) have reported that there are 72 instances of attack on humans from 1975-76 to 2006-07 over a period of 32 years, out of which 30 human causalities and 36 injuries have been reported between 1994-95 and 2006-07, but there are only 6 conflicts prior to 1994. Also, within the period from 1975 (August) to 2005 (March), the reported number of attacks by saltwater crocodiles on livestock is 62, that includes cows, buffaloes, calves, goats and bullocks. All reported attacks are by large male crocodiles. This might be due to the larger territory of male crocodile and their ferociousness. Saltwater crocodiles are not picky eaters and feed on anything they can get their jaws on like fish, crabs, snakes, birds, deer, wild pig, rhesus macaques, cows, buffaloes, sheeps, goats and monitor lizards. It can overpower a swimming tiger in water. An instance of a tiger killed by an estuarine crocodile has been reported at Dobanki camp of Sundarban Tiger Reserve. Some forest Officers, who have witnessed that fight claim that to be the most ferocious battle in the history of the park.

Gopi and Pandav (2009) have reported that, though Bhitarkanika Wildlife Sanctuary encompasses 673km^2 area, the habitat of salt water crocodiles is largely confined to 30km^2 of aquatic area. During 1976 the estimated population of salt water crocodiles was 96 in Bhitarkanika. To conserve them along with two other species of crocodilians like Gharial (*Gavialis gangeticus*) and Mugger (*Crocodylus palustris*) the Government of India enforced a protective legislation by enforcing Indian Wildlife Protection Act, 1972 and to manage the depleted population by supplementation under 'Project Crocodile'. Thus, captive breeding of salt water crocodiles was initiated by the Odisha Forest Department in 1975 at Dangmal under Bhitarkanika Wildlife Sanctuary under the Government of India/FAO/UNDP Crocodile Breeding and Management Project, coordinated by FAO experts Dr. H.R. Bustard. Following the captive breeding (rear and release) programme, eggs of salt water crocodiles were collected from the wild and hatchlings were reared in the captivity. These hatchlings when they attained a length of 1.2 m were released in the wild. As such from 1977 to 1993, a total of 1400 captive-bred hatchlings were released and surveys in 1994 revealed the presence of at least 580 salt water crocodiles in Bhitarkanika Wildlife Sanctuary indicating a recovery of the species (Gopi and Pandav, 2009). Considering the aquatic area of confinement to be 30 km^2 the population density of salt water crocodiles is 59.8 individuals/km^2 whereas it is 2.7 individuals/km^2 taking the notified area of 673 km^2 into consideration in 2022-2023 census. However, the average encounter rate of salt water crocodiles, barring the

hatchlings was 0.87 individuals/km prior to release during 1976-77 census (Kar and Bustard. 1989); but the encounter rate was 5.0 individuals/km in 2007 census (Gopi and Pandav,2009).

Outside the limits of protected area fishing is the primary as well as secondary occupation of the people and there is record of two incidences of causality in fishing during the present study. Amarasinghe *et al*. (2015) have reported that as saltwater crocodiles consume fish (e.g. *Oreochromis mossambicus*, *O. niloticus*, *Etroplus*, *Suratensis*, *Channa striata*, *Latus sp.*) there is perceived competition for the same food source. Thus, sometimes human-crocodile conflict attributes to overfishing of one of the crocodile's main food sources, leading crocodiles to hunt other prey, including humans (Uragoda, 1994; Rao, 1996. Anderson and Pariela, 2005).

Though the breeding and rearing programme for three species of crocodilians had been started during 1975 in West Bengal , Madhya Pradesh , Uttar Pradesh , Bihar and other states in India and Nepal in 34 places; Saltwater crocodile conservation programme in Bhitarkanika is the most successful one as in 1975 , Bhitarkanika was the home of only 96 crocodiles which has increased to 1793 in 2023 including 20 whitish individuals (Senapati, 2023) basing on the opinion of Dr. Sudhakar Kar, former Research Officer. Gopi and Pandav (2009) have also opined that rear and release programme has been a great success in Bhitarkanika in terms of boosting crocodile population. All these reports are in agreement with the present findings. The present scenario of overcrowding of salt water crocodiles in a limited crocodile occupied natural habitat where there is increasing rate of human activity, contribute substantially to human-crocodile conflict. The probable causes of human-crocodile conflict as perceived during the present study are-

- Overcrowding of salt water crocodiles population in a limited area of 30km^2
- Large scale release of head start stock enhancing the density and increasing territorial dispersal of crocodiles into sub-optimal habitats.
- Restocking of sub-optimal crocodile habitats.
- Livelihood based subsistence fisheries operations in crocodile habitats.
- Illegal fishing, bathing and other activities in crocodile infested waters and agricultural activities, near the creek and river banks.
- Warding in the crocodile habitat for fishing, crab collection, fire wood collection and for other activities.
- Grazing of livestock and movement of stray dogs along the bank of rivers and creeks.
- Recreational use of water sources stocked with crocodile.
- Straying of crocodiles in to agricultural fields and village ponds.
- Movement of people (to reach rivers and creeks for various activities) and grazing of cattle in the crocodile habitat where the mangrove cover has been degraded and green grasses grows.
- Shifting of human dietary habits (i.e. increased intake of fish, meat, chicken, and disposal of food wastes into near the water bodies) and intoxication.
- Lack of understanding of territoriality of saltwater crocodiles.

The Salt water crocodiles seem to have low public esteem because of human-crocodile conflicts. This species is mostly killed by the people out of fear of attacks (Senanayake, 1995), that has contributed towards the prevailing ill repute that crocodiles have (Santiapillai *et al.*, 2004). In the present scenario, the public attitude towards crocodile is negative and they are regarded as man- eaters, monsters and killers (Thasun Amarasinghe, *et al*., 2015). Thus, conservation of the species as well as protection of life and livelihood of the people by reducing human-crocodile conflicts is a national and international issue. Some of the mitigative measures may be incorporated with management interventions in and around Bhitarkanika to reassess the conservation approach.

1. **Research initiatives**
   - To determine the carrying capacity of Bhitarkanika Wildlife Sanctuary through robust scientific research.
   - To assess the dispersal range of juvenile, sub-adult and adult crocodiles and to map the territory of adult crocodiles employing suitable GIS techniques.
   - To undertake behavioral study of breeding crocodiles, in relation to their feeding, egg lying and nest guiding habit and to evaluate their nesting habitat.
   - To identify the additional release sites for translocation of excess crocodiles beyond carrying capacity in the region of Mahanadi delta and Devi river mouth for which assessment of habit suitability needs to be taken up on priority. But it should be kept in mind that salt water crocodiles have strong homing instinct and may return to the original capture site (Webb and Monolis, 1989; Walsh and Whitehead, 1993; Read *et al*., 2007).
   - To identify the problematic crocodiles along with their home range that very often attack human beings and livestocks so as to capture and kept them in captivity.
   - To identify the stretches of rivers and creeks, highly prone to human-crocodile conflicts and should be fenced by using double layer Chain link mess providing strong fencing posts to bring down the conflict level.

2. **Habitat restoration**

Maintenance of healthy wild populations of salt water crocodiles ultimately depend on the availability of suitable habitats and loss/destruction of habitat is the key factor that aggravates human-crocodile conflict. Habitat restoration includes the following activities.

   - To reintroduce mangroves by planting suitable mangrove species along the bank of rivers and creeks in the Sanctuary where mangrove cover has been degraded as cattle prefer to graze in the river and creek bank for the presence of green flush of grasses.
   - To remove human encroachments and relocate the people from the areas having status of forest land and to restock these areas with mangroves. Steps should be initiated to resettle the relocated people outside the buffer zone of the Sanctuary.
   - To prohibit the dumping of garbage and farm refuge near the water bodies or inside the mangrove forest.
   - To remove the invasive aquatic weeds from streams and small creeks leading into the rivers with a strategy to improve and maintain the habitat quality in short-and long-term basis to prevent the camouflaging of crocodiles, that leads to human-crocodile conflict.
   - To regulate the tourist boats to enter at least to some parts of the Sanctuary as the vibration and sound produced may disperse the crocodiles out of their potential habitat. It has been reported from a study in Sri Lanka that movements of tourist boats have triggered the migration of saltwater crocodiles to the adjacent healthier habitat (Amarasinghe *et al*., 2015).

3. **Creation of Safety barriers**

Safety barriers are physical barriers known as Crocodile Exclusion Enclosures (CEE), that facilitate the prople to take up their daily activities without any interaction with crocodiles in rivers and creeks and should be effectively designed to cater for normal, low and high water levels. These barriers include erection of fences at the sites preferably at a common point in the villages for bathing, washing clothes and household utensils. Its gate should always be kept closed whether in or out of use (IUCN CSG, 2011) and danger warning signs, indicating safe places, should be shown at entry points and also how the CEE works (PWSNT, 2012). Though forest department has erected some safety barriers which have not been maintained property and are inadequate to meet the requirements. Thus, the local inhabitants should be sensitised to erect more number of barriers placing the poles very closely to prevent the intrusion of crocodiles and in this case the choice of fencing materials are important. A proper design of safety barrier should be designed by the Forest Department. People need to be encouraged to use the protective barriers and to maintain those voluntarily.

4. **Creation of wells besides the river**

The villagers should be sensitised to dig wells close to the rivers and creeks, especially in locations having high water table such that water can be collected safely from the wells instead of direct collection of water from rivers and creeks. This measure is required to reduce human-crocodile conflict. Women and children who regularly take bath and fetch water are easily preyed by salt water crocodiles as crocodiles spend long time monitoring all most all movements at the water sources as a hunting strategy (August, 2009).

5. **Establishment of public bathing facilities**

Forest Department, NGOs, Mangrove Mitras should insist and assist local villagers living closer to rivers and creeks to construct ablution blocks for bathing installing water tanks with solar powered motor for males and females separately away from rivers and creeks. This reduces the risk of attacks by crocodiles as public will not come very close to the crocodile infested waters.

6. **Regulation on fishing activities**

Forest Department and NGOs need to take adequate measures to ban illegal fishing activities if any from the protected areas and minimise fishing at peripheral regions outside the buffer area as it can decline the food resources required for the survival of salt water crocodiles to address human-crocodile conflict.

7. **Provision of alternative livelihood**

The lives of locals in and around Bhitarkanika are mostly dependent on mangrove forest resources for different livelihood opportunities. Their regular interaction with the mangroves often leads them towards fatal encounters with salt water crocodiles, besides over-exploitation of forest resources. To overcome this problem Forest Department with local EDCs (Eco-Development Committees) should initiate alternative livelihood programmes like rearing of cows, sheeps and goats; rearing of poultry, agarbati making, brown rice production, development of handicrafts through the local SHGs (Self Help Groups) and to impart them training for better utilisation of indigenous skills in that aspect. That will reduce the forest dependency and minimise human-crocodile conflict.

8. **Awareness generation**

Local rural inhabitants should be sensitised through creation of awareness regarding the importance of salt water crocodiles conservation, risk associated with it and how to safeguard their lives when living in a crocodile dominated landscape. Several studies have focused on public awareness about crocodilians and support for crocodile conservation. Skupien *et al*. (2016) have opined that conservation education programmes can improve wildlife acceptance capacity for American alligators. Smithem and Mazzotti (2008) have established the significant relationship between the attitude to American crocodiles in Florida to risk perceptions and acceptance of the species, and better knowledge about the species corresponding to positive attitudes towards them. Strong bias towards negative human-crocodilian interactions in reports by media, scientific and Government agencies in Columbia has been reported by Balaguera-Reina and Fartan-ardila (2018), which is undermining the community support for crocodilian conservation in the Caribbean region and they have recommended for better publicising conservation projects to the general public. Whetaker and Whitaker (1979) have emphasized on public education and awareness 43 years ago, when the frequency of human-crocodile conflict was at its minimum. But, at present human-crocodile conflict has increased many folds and to address this challenging issue, not only at regional level public awareness should increases at State, National and International level.

- To involve diverse range of stakeholders, including Government agencies, NGOs, business and tourism sectors, rural and urban public, school and college students and teachers who need to be trained for providing training and to dedicate themselves to spread the message of conservation.
- To sensitise the employees from various Government departments like agriculture, housing, tourism, health, animal husbandry, fishery, water supply, transport, police, military about human-crocodile conflict and to make them aware about the legislations that pertains to crocodiles and other wildlife.

- All Government departments and NGOs should arrange seminars and symposiums inviting resource persons taking other departments, local people, SHGs as target group in collaboration with Research Institutions and Universities.
- To spread the message of real dangers and realities of *living with crocodiles* and to convey the reasons for crocodile conservation through brochures, pamphlets, glow warning signages, t-shirts, calendars, posters, media coverage, school and college curriculum, public and media presentation, tourist guides, museum exhibits and the alike.

9. **Providing High Mast Solar Light**

Most of the villages besides rivers and creeks are inaccessible and remaining in darkness during night and majority of people do not have a torch light even. Thus, to have a better communication with their surroundings High mast Solar Lighting System needs to be provided by the Government departments and NGOs importing proper training to the village youths for maintenance of the lighting system.

10. **Increasing the numbers of *Wetland Mitras***

Village youths should be sensitized to volunteer themselves to serve the estuarine wet land as *Wetland Mitra* (friend of the wetland). They should be properly trained through workshops, seminars and guided tours to other mangrove sites about the importance of wetland conservation, conservation of mangroves and how to live in harmony with the crocodiles.

11. **Involving the Community**

Community involvement in conservation is an important field that should include approaches like training in monitoring and handling crocodiles as well as participating in educational talks, drama, road shows and also interactive activities. It is always valuable to educate community with positive cultural beliefs and practices about crocodilians and outsiders (eco-tourists) can learn from indigenous knowledge about co-existence with crocodilians too (Van der Ploeg *et al.*, 2011; Pooley and Marchini, 2020).

Conclusion

Salt water crocodiles are prominent and important component of estuarine ecosystem in and around Bhitarkanika. Crocodiles are opportunistic predators that are most dangerous in water and also at the land-water interface (Webb and Monolis, 1998). Both primary and secondary preventive measures should be taken into consideration while addressing human-crocodile conflict. Primary measures involve to avoid the attack altogether whereas the secondary measures deals with how to minimize the harm after an attack has occurred (Caldicott *et al.*, 2005). Minimising the contact between people and crocodilians, generating awareness about crocodile behaviour, banning fish and crab collection from crocodile prone areas, introducing rural alternative livelihood schemes like tourism, poultry farming, rainwater harvesting for multi cropping, providing education and training, microcredit and access to feasible markets are, however the measures to reduce human-crocodile conflict. Government bodies and local NGOs should deal with the issues proactively to protect the life of both crocodile and people. Thus, a comprehensive management strategy is to be formulated to reduce the dependency on mangrove forest resources, to ensure the conservation of estuarine ecosystem, to minimise the risk of salt water crocodiles attack for harmonious co-existence of humans and crocodiles in and around Bhitarkanika landscape.

References

- Anderson, J. and Pariela, F. (eds.) (2005). Strategies to Mitigate Human-Wildlife Conflict in Mozambique. Report for the National Directorate of Forests and Wildlife, Mozambique. Food and Agriculture Organization of the United Nations, Rome, Italy.

- Amarasinghe, A.A.T., Karunarathna, D.M.S.S., Hallermann, J., Fujinuma, J., Grillitsch, H. and Campbell, P.D. (2014). A new species of the genus Calotes (Squamata: Agamidae) from high elevations of the Knuckles Massif of Sri Lanka. *Zootaxa* 3785: 59-78.

- Amarasinghe, A.A.T., Madawala, M.B., Karunarathna, D.M.S.S., Manolis, S.C., de Siliva, A. and Sommerlad, R. (2015). Human crocodile conflict and conservation implications of Saltwater Crocodiles *Crocodylus Porosus* (Reptilia: Crocodylia: Crocodylidae) in Sri Lanka. *Journal of Threatened Taxa*7 (5): 7111-7130; http://dx.doi.org/10.11609/JoTT.o4159.7111-30.

- Aust (2009). The ecology, conservation and management of Nile crocodiles *Crocodylus niloticus* in a human dominated landscape. Imperial College London Division of Biology. UK (http://spiral.imperial.ac.uk/handle/10044/1/5297)
- Balaguera-Reina, S.A. and Farfan-Ardila, N. (2018). Are we ready for successful apex predator conservation in Colombia? Human- Crocodilian interactions as a study case. *Herpetological Review* 49(1): 5-12.

- Banerjee, S. (2016). Ecological History of an Ecosystem Under Pressure: A case of Bhitarkanika in Odisha, Institute of Social and Economic Change, Bangalore, India, pp.1-20.

- Chadha, S. and Kar, C.S. (1999). Bhitarkanika: Myth and Reality, Natraj Publisher, Dehradun, pp. 55-170.
- Caldicott, D.G.E., Croser, D., Manolis, C., Webb, G. and Britton, A. (2005). Crocodile attacks in Australia. An analysis of its incidence, and review of the pathology and management of crocodilian attacks in general. *Wilderness and Environmental Medicine* 16(3): 143-159.

- Das, C.S. and Jana, R. (2017). Human –Crocodile conflict in the Indian Sundarban: an analysis of spatio-temporal incidences in relation to people's livelihood., *Oryx*, Cambridge University Press 52(4):1-24.

- Das, M. and Chatterjee, B. (2015). Ecotourism: A panacea or a predicament? *Tourism Management Perspectives*, 14, 3-16.
- FAO (2010). Food and Agricultural Organization of the United Nations, Managing the conflicts between people and lion. Rome: The Organization.
- Fergusson, R.A. (2004). Preliminary analysis of data in the African human-crocodile conflict database. *Crocodile Specialist Group Newsletter*, 23:21-22.
- Gopi, G.V., Pandav, B. and Angom, S. (2007). Aspects of nesting biology of *Crocodylus porosus* at Bhitarkanika, Orissa, eastern India, *J. Bombay Nat. Hist Soc*. 104 (3), 328-333.
- Gopi, G.V. and Pandav, B. (2009). Humans sharing space with *Crocodylus porosus* in Bhitarkanika Wildlife Sanctuary: conflicts and options. Current Science, 96, 459-460.
- Graham, A. (1990). Eyelids of Morning: The Mingled Destinies of Crocodiles and Men. Chronicle Books, San Francisco, USA.
- IUCN CSG (2021). Human-Crocodile Conflict (http://www.iucncsg. org/pages/Human%252dCrocodile-Conflict.html).

- IUCN CSG (2023). Human-Crocodile Conflict.www.iucncsg.org/ pages/ Human%252dCrocodile-Conflict.html.
- IUCN CSG (2011) - Crocodile Specialist Group, January 2011- March 2011 Newsletter, Volume 30(1).
- Kaltenborn, B.P., Bjerke, T., Nyahongo, J.W. and Williams, D.R. (2006). Animal preferences and acceptability of wildlife management actions around Serengeti National Park, Tanzania. *Biodiversity and Conservation*, 15, 4633-4649.

- Kar, S. K. and Bustard, H. R. (1989). Status of the Saltwater Crocodile (*Crocodylus porosus* Schneider) in the Bhitarkanika Wildlife Sanctuary, Orissa, India. J. Bombay Nat. Hist. Soc.,86: 141-150.
- Lamarque, F., Anderson, J., Fergusson, R., Lagrange, M., Osei-Owusu, Y. and Bakker, L. (2009). Human-Wildlife Conflict in Africa: Causes, Consequences and Management Strategies. Food and Agriculture Organization of the United Nations, Rome, Italy.
- Madden, F. (2004). Creating coexistence between humans and wildlife: global perspectives on local efforts to address human- wildlife conflict. Human Dimensions of Wildlife, 9, 247-257.
- Pooley, S. And Marchini, S. (2020). What living alongside crocodiles can teach us about coexisting with wildlife. The Conversation, May 26, available at: https://theconversation.com/what-wing-alongside-crocodiles-can-teach-us-about-coexisting-with-wildlife-139144.
- Mukherjee, S. and Mallapur, G. (2022). Survey of Human –Crocodile Conflict in non-protected areas of Kendrapada district, Odisha, India. https://www.researchgate.net/publication/362657638.
- Neill, W. T., (1971). The Last of the Ruling Reptiles: Alligators, Crocodiles, and their Kin, Columbia University Press, New York.
- Newmark, W.D., Leonard, N.L., Sariko, H.I. and Gamassa, D.G.M. (1993). Conservation attitudes of local people living adjacent to five protected areas in Tanzania. *Biological Conservation*, 63, 177 – 183
- Patro, S. and Padhi, S.K. (2019). Saltwater crocodile and human conflict around Bhitarkanika National Park, India: A raising concern for determining conservation limits. Ocean and Costal Management, ELSEVIER, https://doi.org/10.1016/j.ocecoaman.2019.104923.
- PWSNT (2012). Parks and Wildlife Service of the Northern Territory, Management programme for the saltwater crocodile in the Northern Territory of Australia 2012-2014. Palmerston, NT: NT Department of Natural Resources, Environment and the Arts.
- Rao, M.V.S. (1996). Nesting behavior of the Indian crocodiles, *Gavialis gangeticus*, *Crocodylus palustris* and *Crocodylus porosus*, pp. 212-216. In: Ramamurthi, R. & Geetabali (eds.). *Readings in Behaviour*. Newage International Ltd, New Delhi, India.
- Santiapillai, C. and de Silva, M. (2001). Status, distribution and conservation of crocodiles in Sri Lanka. Biological Conservation 97: 305-318.
- Santiapillai, C., Wijeyamohan, S., Vandercone, R. and Somaweera, R. (2004). Crocodiles of Sri Lanka. Mannar District Rehabilitation and Reconstruction through Community Approach Project (www.manrecap.com).
- Senanayake, N. (1995). Human and reptile conflicts: impact on reptiles in Sri Lanka. *Lyriocephalus* 2: 86.
- Sivaperuman, C. (2015). Crocodiles in Andaman and Nicobar Islands, with special reference to human-crocodile conflict. In *Marine Faunal Diversity in India* (eds K. Venkataraman & C. Sivaperuman). pp. 453-460. Elsevier, Amsterdam, The Netherlands.
- Somaweera, R. and de Silva, A. (2013). Using traditional knowledge to minimize human-crocodile conflict in Sri Lanka, pp. 257. In: Crocodiles. Proceedings of the 22nd Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN, Gland, Switzerland.
- Skupien, G.M., Andrews, K.M. and Larson, L.R. (2016). Teaching tolerance? Effects of conservation education programs on wildlife acceptance capacity for the American alligator Human Dimensions of Wildlife: An International Journal 21(3): 264-279.
- Smithem, J.L. and Mazzotti, F.J. (2008). Risk perception and acceptance of the American crocodile (*Crocodylus acutus*) in South Florida *Flonida Scenist* 71(1): 9-22

- Thomas, G.D. (2006). Human-crocodile conflict (Nile Crocodile: *Crocodylus niloticus*) in the Okavango Delta, Botswana. MSc Thesis, Stellenbosch University, Stellenbosch, South Africa.
- Uragoda, C.G. (1994). Wildlife Conservation Sri Lanka. Wildlife and Nature Protection Society, Colombo, Sri Lanka, 162pp.
- Van Der Ploeg, J., Araño, R.R. and Van Weerd, M. (2011). what local people think about crocodiles: challenging environmental policy narratives in the Philippines. *The Journal of Environment & Development*, 20, 303-328.
- Wallace, K.M., Leslie, A.J. and Coulson, T. (2011). Living with predators: a focus on the issues of human-crocodile conflict within the lower Zambezi valley. *Wildlife Research*, 38, 747-755.
- Webb, G. and Manolis, C. (1989). Crocodiles of Australia. Reed Books, Frenchs Forest, Australia,
- Webb, G.LW., Manolis, S.C., Brien, M.L., (2010). Saltwater crocodile *Crocodylus porosus*. in Manolis, S.C., Stevenson, C. (Eds.), Crocodiles: Status Survey and Conservation Action Plan. Third Edition. Australia, pp. 99-113.
- Whitaker, R. and Whitaker, N. (1979). Preliminary crocodile survey- Sri Lanka, J.Born.Nat.Hist.Soc., 76:66-85.
- Whitaker, R. and Whitaker, N. (2008). Who's got the biggest? *Crocodile Specialist Group Newsletter* 27: 26-30.
- Woodroffe, R., Thirgood, S. and Rabinowitz, A. (2005). People and Wildlife: Conflict or Coexistence. Cambridge University Press, UK, pp. 516.

.\