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Conservation and Management of Salt Water Crocodile (*Crocodylus porosus*) in Relation to Some Physico-Chemical Parameters from Bhitarkanika Sanctuary, Orissa

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ABSTRACT

Bhitarkanika is the second largest mangrove forest of India, situated in the East Coast of Orissa. It stretches over an area of 672 sq. km inhabiting several flora and fauna. The rare and endangered species like saltwater crocodile (*Crocodylus porosus*) is found in Bhitarkanika Wildlife Sanctuary. The salt water crocodile breeding centre started from 1975 with 24 number of crocodiles. Within 36 years of its existence, the salt water crocodiles have reached up to 1610 during 2009-10. The water temperature of the sanctuary varied from 27.6°C to 36.10°C, and air temperature from 27.3°C to 35°C. The pH value ranged from 6.7 to 9.2. Salinity fluctuated from 8.1 to 31.2 ppt. The dissolved oxygen concentration ranged from 5.1 to 9.9 mL/L. The highest percentage of population of saltwater crocodile result was +26.58 % in the year 1999-2000 and the lowest percentage was -6.70 % in the year 2004-05. Though, there is an increase in the crocodile population over the years, it is not quite satisfactory. Therefore, it is our obligatory duty to conserve the rare and endangered species of salt water crocodile and to make proper management plan for increase in its population in Bhitarkanika sanctuary.

INTRODUCTION

Bhitarkanika is endowed with a very complex and dynamic ecosystem and is highly fragile in nature. The ecosystem is complex in a sense that all the sub ecosystems namely freshwater, marine and terrestrial are intricately mixed with each other. The essential factor for maintenance of such ecosystem is regular influx of freshwater from adjoining land and tidal inflow from the sea. Any change in the regime of either factor is likely to affect a corresponding change in the mangrove ecosystem. The Bhitarkanika mangrove forest is the second largest mangrove forest in India. The mangrove forests all along the Orissa coast are threatened due to high density of population in these areas and demand for land for agriculture and shrimp farming. The mangrove belt in Kendrapada district is called the Bhitarkanika mangrove forest, comprising areas between Dhamara mouth and Barunei coast. It has been notified as Bhitarkanika Wildlife Sanctuary in April 1975 covering an area of 672 sq. km. The core area of sanctuary has been declared as Bhitarkanika National Park in September 1998 covering an area of 145 sq. km. The Bhitarkanika area has been designated as the second Ramsar site (i.e., Wetland of International Importance) of the State in August 2002. It is a unique area with rich biodiversity as it covers different ecosystems such as landmass, tidal water bodies of the deltaic region, estuaries and territorial waters of the Bay of Bengal along with their associated flora and fauna. The proposed Bhitarkanika Biosphere Reserve covers erstwhile Kanika and Kujang Zamindary area. It includes at present three protected areas namely: Bhitarkanika Wildlife Sanctuary, Bhitarkanika National Park and the Gahirmatha Wildlife Sanctuary. The area supports rich biodiversity including mangroves and mangroves associated largest population of estuarine crocodiles and the rare white crocodiles etc. The mangrove ecosystem plays a vital role in contributing to the food web, in general, and detritus food chain in particular, supporting rich estuarine and adjacent marine fisheries (Chadha & Kar 1999). The mangroves play a significant role in protecting the internal against cyclones and the ingress of seawater during tidal surge. Mangroves stabilize coastal landmass against sea erosion. Mangrove forests act as a buffer against any natural disasters (Nayak et al. 2009).

Several works have been done on distribution of mangroves in India (Sidhu 1963, Nayak 2006). Some work has been done on the floral characteristics of Bhitarkanika by Banerjee & Das (1972), Mishra & Panigrahy (1978), Pattanaik & Choudhury (1989) and Banarjee & Rao (1990). Few works have been carried out on the hydrological features of Mahanadi estuary by Upadhyay (1998) and Raju et al. (2000). No work has been done on saltwater crocodiles in relation to physico-chemical characteristics from Bhitarkanika Sanctuary. Therefore the present study is an attempt to study the conservation and management of salt water crocodile (*Crocodylus porosus*) in relation to some important physico chemical parameters

of Bhitarkanika Sanctuary, Orissa.

MATERIALS AND METHODS

The saltwater crocodiles are endangered species belonging to the Order Crocodylia and Family Crocodylidae. The common English name for this crocodile is salt water crocodile or estuarine crocodile and the scientific name is *Crocodylus porosus*. The study was carried out during January 2008 to December 2008. Bhitarkanika is situated between 20° 04' and 20° 08' N latitude and 86°45' and 87°05' E longitude. The monthly water samples were collected from three different stations i.e., 1st is Nalitapatia, 2nd is Dangmal located between Nalitapatia and Bhitarkanika estuary, and the 3rd station is chosen at Bhitarkanika estuary, which is towards the sea where the physico-chemical parameters are highly fluctuative. The hydrological parameters like temperature, pH, salinity and dissolved oxygen were studied at monthly interval of time. The air and water temperatures were measured using a centigrade thermometer of ± 0.1°C accuracy. The water samples were brought to the laboratory. The pH was measured using a digital pH meter. The samples were analysed for salinity and dissolved oxygen following the standard methods (APHA 2005). The standard deviation for each sample was calculated. The secondary data on salt water crocodile population were collected and the percentage of increasing and decreasing of salt water crocodile population was calculated for the years 1995-96 to 2009-10.

RESULTS

The hydrological data collected from the three stations of Bhitarkanika are represented in Tables 1, 2 and 3. The population of the crocodile (*Crocodylus porosus*) in Bhitarkanika during the year 1995-96 to 2008-09 is given in Table 4. In the Station 1, the air temperature was highest being 33.1±1.150°C during May, and lowest being 27.3±1.044°C during January (Table 1). The water temperature was highest being 33.0±1.148°C during May, and lowest being 27.6 ±1.148°C during December. The pH value was highest (8.8±0.593) in the month of December, and the lowest (6.8±0.521) in the month of October. The salinity was highest of 20.9±0.914 ppt in the month of April, and the lowest of 8.1±0.569 ppt in August. The dissolved oxygen was highest at 8.5±0.583 mL/L during April, and the lowest at 5.4±0.464 mL/L during November at Station 1.

At Station 2, the air and water temperatures were highest (34.5±1.174°C, 36.1±1.201°C) during May, and lowest (27.5±1.048°C, 28.2±1.1.062°C) during January respectively. The pH value was highest being 8.4±0.579, and the lowest being 7.0±0.529 in December and August respectively. The salinity was highest with a values of 27.1±1.041 ppt in April, and lowest of 13.0±0.721 ppt in July. The dissolved oxygen concentration was highest being 9.9±0.629 mL/L, and lowest being 5.1±0.451 mL/L during July and February respectively.

Similarly at Station 3, the highest air temperature was 35.0±1.183°C, and lowest 28.7±5.357°C during the months of May and January respectively. The water temperature was highest being 35.1±1.184°C in May, and the lowest being 28.2±1.062°C during January. The pH value was highest at 9.2±0.606 in December, and lowest at 6.7±0.517 in May. The salinity was highest (31.2±1.117 ppt) in May, and lowest (12.8±0.715 ppt) August. The dissolved oxygen was highest with 9.9±0.629 mL/L in July, and the lowest with 5.2±0.456 mL/L in January. The saltwater crocodile is perhaps the largest living reptile in the World. During 1975, H. R. Bustard has coordinated a Project by Government of India/FAO/UNDP on crocodile breeding and management. Bustard captive breeding of saltwater crocodiles was initiated by the Forest Department of Government of Orissa in 1975 at Dangamal, the Bhitarkanika Wildlife Sanctuary (BWLS). The estimated population of crocodiles during 1976 at Bhitarkanika was 96 (Gopi & Pandav 2009). The saltwater crocodile (*Crocodylus porosus*) population of 14 years is represented in Table 4. The highest population of saltwater crocodile was observed to be 1610 during the year 2009-10, and the lowest of 511 during the year 1995-96. The highest increased percentage of saltwater crocodile population was observed to be +26.58 % during the year 1999-2000, and the lowest decreased population of -01.68 % during the year 2002-03.

Salt water crocodile population varied from station to station in Bhitarakanika (Table 5). The highest population was observed to be 580 at Station 3, and lowest of 398 at Station 1. Crocodile population showed a perfect positive correlation with air temperature, salinity and dissolved oxygen (r = 0.999, 0.997, 0.946) respectively. Likewise crocodile population showed a positive correlation with water temperature and pH, being r = 0.795 and 0.323 respectively (Table 6).

DISCUSSION

The air temperature varied from 27.3 to 35°C during the study period. There has been a gradual decrease in temperature from Station 1 to Station 3 towards the downstream along the river. The findings are in agreement with the results of Upadhyay (1988) and Raju et al. (2000). The water temperature varied from 27.6 to 36.1°C during the study period. The temperature is slightly higher than the results of Nayak et al. (2009) from the same environment. This may be due to collection of samples in different times of the day and other environ-

Table 1: Monthly average values of physico-chemical parameters of Bhitarkanika during January 2008 to December 2008 at Station 1.

Months/Parameter	Air Temperature (°C)	Water Temperature (°C)	pH	Salinity (ppt)	Dissolved Oxygen (mL/L)
January 2008	27.3± 1.044	29.1±1.078	8.2±0.572	18.8±0.867	6.6±0513
February 2008	28.0±1.058	29.8±1.091	8.7±0.589	18.9±0.869	8.1±0.569
March 2008	30.3±1.100	29.1±1.078	8.6±0.586	19.1±0.874	7.0±0.529
April 2008	31.3±1.118	31.9±1.129	8.2±0.572	20.9±0.914	8.5±0.583
May 2008	33.3±1.150	33.0±1.148	7.8±0.558	17.8±4.219	7.8±0.558
June 2008	29.1±1.078	32.5±1.140	7.7±0.554	9.0±0.6	8.4±0.579
July 2008	28.1±1.060	31.9±1.129	7.2±0.536	8.3±0.576	7.0±0.529
August 2008	29.7±1.089	29.1±1.078	7.9±0.562	8.1±0.569	6.1±0.493
September 2008	28.3±1.063	30.9±1.111	7.4±0.544	9.2±0.606	6.2±0.497
October 2008	30.0±1.095	32.1±1.133	6.8±0.521	11.0±0.663	5.5±0.469
November 2008	29.8±1.091	31.3±1.118	8.3±0.576	11.9±0.689	5.4±0.464
December 2008	30.5±1.104	27.6±1.048	8.8±0.593	12.0±0.692	6.8±0.521

Table 2: Monthly average values of physico-chemical parameters of Bhitarkanika during January 2008 to December 2008 at Station 2.

Months/Parameter	Air Temperature (°C)	Water Temperature (°C)	pH	Salinity (ppt)	Dissolved Oxygen (mL/L)
January 2008	27.5±1.048	28.2±1.062	8.1±0.569	24.2±0.983	6.0±0.489
February 2008	30.2±1.099	29.7±1.089	8.2±0.572	23.8±0.975	5.1±0.451
March 2008	31.0±1.113	31.7±1.126	7.3±0.540	22.4±0.946	7.3±0.540
April 2008	34.4±1.173	34.1±1.167	8.0±0.565	27.1±1.041	6.9±0.525
May 2008	34.5±1.174	36.1±1.201	8.2±0.572	16.3±0.807	8.0±0.565
June 2008	33.9±1.164	34.8±1.179	7.5±0.547	14.2±0.753	7.2±0.536
July 2008	33.6±1.159	34.1±1.167	7.6±0.551	13.0±0.721	9.9±0.629
August 2008	33.1±1.150	33.1±1.150	7.0±0.529	16.0.±0.800	9.6±0.619
September 2008	32.1±1.133	31.9±1.129	7.2±0.536	17.1±0.827	8.8±0.593
October2008	32.0±1.130	30.8±1.113	7.9±0.562	20.2±0.898	8.4±0.579
November 2008	31.4±1.120	32.0±1.131	8.1±0.569	20.1±0.896	8.3±0.576
December 2008	28.1±1.060	29.3±1.082	8.4±0.579	19.1±0.874	7.1±0.532

mental conditions. The water temperature was slightly higher as compared to the air temperature during winter season, which is due to absorption of heat by the surface layer (Nayak 1991). The value of pH was quite low during June because of the organic matter carried out by the flood water into the riverine system (Raju et al. 2000). The Salinity values ranged from 8.1 to 31.3 ppt during the study period. Nayak et al. (2009) have studied the salinity from Bhitarkanika which ranged from 9.0 to 33.8 ppt coinciding with the present result. The salinity values increased both in post-monsoon and pre-monsoon months. The high salinity values may be due to high evaporation and low intensity of river runoff into the estuarine system during this period. The dissolved oxygen value showed wide range of variation throughout the year. The value varied from 5.1 to 9.9 mL/L. The value ranged from 2.325 to 7.250 mL/L as studied by Nayak et al. (2009), which is coinciding with the present result. The low value of dissolved oxygen may be due to biodegradation of organic matter in water (Raju et al. 2000).

Environment in relation to crocodiles: The saltwater crocodile (*Crocodiles porosus*) is a carnivorous and scavenger species. It plays a vital ecological role as master predator in the aquatic habitat where it lives. It feeds on weak and diseased fish and animals. It maintains genetic quality, by its habit of selective feeding, which controls predatory fish population. Thus, presence of crocodile actually helps to increase yield of edible fish for man. Crocodiles are commercially and economically important because their skin has a high demand in the national and international market for making shoes and bags which are long lasting and beautiful. Crocodiles are long lived and a female crocodile produces about 30 eggs per year. Fifty percent of its eggs can reach up to culling size within 3-4 years in captivity. These 15 crocodiles will have a gross value of Rs. 1,56,000. A female crocodile can remain productive for about 30 years, which will worth about Rs. 4,68,000. The crocodiles, in general, keep the environment clean and maintain the population of unwanted fishes in the environment. Therefore, it is our obligatory duty to protect and conserve the rare and endangered species like saltwater crocodile in Bhitarkanika sanctuary.

Table 3: Monthly average values of physico-chemical parameters of Bhitarkanika during January 2008 to December 2008 at Station 3.

Months/Parameter	Air Temperature (°C)	Water Temperature (°C)	pH	Salinity (ppt)	Dissolved Oxygen (mL/L)
January 2008	28.7±5.357	28.2±1.062	7.9±0.562	24.7±0.993	5.2±0.456
February 2008	30.6±1.106	30.8±1.109	7.6±0.551	24.2±0.983	7.1±0.532
March 2008	32.9±1.147	32.3±1.136	7.8±0.558	21.3±0.923	7.0±0.440
April 2008	34.5±1.174	34.1±1.167	7.1±0.532	31.1±1.115	6.3±0.501
May 2008	35.0±1.183	35.1±1.184	6.7±0.517	31.2±1.117	6.9±0.525
June 2008	34.4±1.173	34.0±1.166	7.4±0.544	15.8±0.794	7.9±0.562
July 2008	34.0±1.166	33.3±1.154	7.3±0.540	13.8±0.742	9.9±0.629
August 2008	32.3±1.136	32.0±1.131	7.2±0.536	12.8±0.715	9.4±0.613
September 2008	32.1±1.133	31.3±1.118	7.1±0.532	18.7±0.864	8.2±0.572
October 2008	31.9±1.129	32.2±1.117	7.0±0.529	21.0±0.916	5.6±0.473
November 2008	31.1±1.115	30.3±1.100	7.2±0.536	20.1±0.896	6.0±0.489
December 2008	29.8±1.091	30.0±1.095	9.2±0.606	22.8±0.954	7.3±0.540

Table 4: The number of saltwater crocodile (*Crocodylus porosus*) in Bhitarkanika from the year 1995-96 to 2009-10.

Year	Hatchling	Yearling	Juveniles	Sub-Adult	Adult	Total	% of Increase or Decrease
1995-96	304	71	34	92	10	511	-
1996-97	136	232	161	63	68	660	+22.57
1997-98	252	106	121	113	76	668	+1.19
1998-99	149	146	160	144	72	671	+0.44
1999-00	319	181	123	145	146	914	+26.58
2000-01	341	277	237	136	107	1098	+16.75
2001-02	441	340	187	145	217	1330	+17.44
2002-03	438	333	184	140	213	1308	-01.68
2003-04	525	303	210	100	220	1358	+3.68
2004-05	402	279	458	106	204	1449	+6.28
2005-06	657	283	196	121	197	1454	+0.34
2006-07	503	466	257	132	224	1482	+1.88
2007-08	538	342	227	139	252	1498	+1.06
2008-09	529	374	256	144	267	1572	+4.70
2009-10	519	373	298	150	270	1610	+2.36

Source: Forest Department, Government of Orissa, Dharitri, 15th January, 2010.

Table 5: Availability of saltwater crocodile (*Crocodylus porosus*) in relation to physico-chemical parameters from different stations.

Stations	Crocodile Population	Air Temperature (°C)	Water Temperature (°C)	pH	Salinity (ppt)	Dissolved Oxygen(mL/L)
1. Nalitapatia	398	33.3	33	8.8	20.9	8.5
2. Dangmala	520	34.5	36.1	8.4	27.1	9.9
3. Bhitarakanika Estuary	580	35	35.1	9.2	31.2	9.9

Table 6: Correlation of saltwater Crocodile (*Crocodylus porosus*) population with different physico-chemical parameters.

	Crocodile Population	Air Temperature (°C)	Water Temperature (°C)	pH	Salinity (ppt)	Dissolved Oxygen(mL/L)
Crocodile population	1					
Air temperature	0.999232	1				
Water temperature	0.795523	0.818657	1			
pH	0.323473	0.286143	-0.31602	1		
Salinity	0.997035	0.993253	0.746537	0.395329	1	
Dissolved oxygen	0.946237	0.958187	0.948753	-1.3E-15	0.91854	1

MANAGEMENT STRATEGIES

The broad strategy adopted for rehabilitation of crocodiles was to protect them in their natural habitat to enhance the population quickly through captive breeding (rear and release) and to build up trained personnel for the job. The broad objectives and activities under the crocodile project are the following:

1. To protect the remaining population of crocodilians in their natural habitat by creating sanctuaries.
2. To rebuild natural population quickly through grow and release or rear and release technique involving the following phases of operation:

- Collection of eggs from natural nests as soon as these are laid.
- Incubation of these eggs under ideal temperature and humidity maintained in artificial hatcheries.
- Hatchlings are reared up to the young crocodiles in ideal captive-husbandry conditions.
- Marking and releasing young crocodiles in protected area and assessing the result of release along with protection of the released crocodiles.

3. To promote captive breeding.
4. To take up research work on behavioural biology including reproduction, thermo-regulation, feeding, water orientation, locomotion, etc. in order to improve the management plan.
5. To build up a level of trained personnel for better continuity of the project through training imparted at the project sites and through the Central Crocodile Breeding and Management Training Institute, Hyderabad.
6. To involve the local people intimately in the crocodile breeding project. They should be engaged in collection of eggs and rearing of the crocodiles. The other local fishermen population should be provided with alternative source of income during no fishing season i.e., during the breeding and nesting periods of the crocodiles, so that they will not harm to the crocodile.

Conservation of crocodiles: Crocodilians were threatened in India due to indiscriminate killing for commercial purposes and severe habitat loss until enforcement of the Wildlife (Protection) Act, 1972.

All three species of crocodiles (Gharial, Mugger and Saltwater crocodile) in the river systems of Orissa were on the verge of extinction during 1970s. So the conservation of crocodiles was felt most urgent. The following measures should be taken for conservation of crocodiles.

- Crocodiles were very few because of ever-increasing human activity in the rivers and their other traditional habitats, and consequent reduction in the extent of habitable stretches. So crocodile habitat protection areas should be identified.
- The survival rate of the crocodile hatchings in the nature is low because of predation. Therefore, captive breeding is required for better survival rate of the crocodiles.
- The Gharial and Saltwater Crocodile Conservation Programme was first implemented in Orissa in early 1975 and subsequently the Mugger Conservation Programme was initiated, since Orissa is having distinction of existence of all the three species of Indian crocodilians. The funds and technical support for the project came from UNDP/ FAO through the Government of India should be exerted to other areas and for longer period.
- Public-relation should be among the local people to make aware of the importance of the crocodiles in ecosystems.
- Habitat development inside the sanctuary should be done with funds received from MoEF, Govt. of India for plantations, digging and renovation of creeks and digging of ponds.
- To wean the poachers away from poaching, a massive awareness programme should be undertaken for anti-poaching strategies.
- Encroachment on the mangrove habitat for rehabilitation, agriculture and prawn culture, etc. should be banned.
- Use of gill nets in the rivers, creeks and estuaries throughout the sanctuary should be strictly prohibited.
- Degraded mangrove forest should be taken up for restoration, plantation and rigid protection. Moreover, at least 100 meter wide strip of mangrove forest should be created all along the rivers/creeks adjacent to cultivated land inside the sanctuary.
- Measures should be taken to eliminate man-crocodile conflict.
- Studies on the ecology of estuary/saltwater crocodiles should be continued considering the existing gap in the knowledge regarding various aspects of ecology of the species in Bhitarkanika and other distributional range in Orissa as well as in the entire country.
- Education and awareness should be created among the local inhabitants to change their hostile attitude towards conservation of saltwater crocodiles and other wildlife species along with the threatened mangrove ecosystem.

CONCLUSION

The endangered species crocodiles are threatened in India due to indiscriminate killing for commercial purposes and severe habitat loss. The saltwater crocodile (*Crocodylus porosus*) in the river systems of Orissa was on the verge of extinction during 1970s and still now its population is very low. Crocodiles were very few because of ever-increasing human activity in the rivers and their other traditional

habitats and consequent reduction in the extent of habitable stretches. Despite best efforts of rearing and rehabilitant, for this species, the future can not be bright unless the sanctuary and the crocodiles are adequately protected and large number of juvenile saltwater crocodiles attain breeding size and commence breeding in the wild. A long term research programme on crocodile habitat is highly essential at Central Institutes, Universities and NGOs in order to protect and conserve the saltwater crocodiles.

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