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Status and Threats to Mugger Crocodile *Crocodylus palustris* Lesson, 1831 at Rani Tal, Shuklaphanta Wildlife Reserve, Nepal

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Abstract

A study was carried out for preparing baseline information on water quality, population status and threats to Mugger crocodile, *Crocodylus palustris* Lesson at Rani Tal, Shuklaphanta Wildlife Reserve. Water quality analysis was conducted for three seasons (summer, autumn and winter) in the year 2008 - 2009. The study has found the physico-chemical contamination in the lake. The water quality parameters (dissolved oxygen, total hardness, free carbon dioxide, biological oxygen demand and ammonia) exceeded the normal range to support the Muggers. A survey around the lake recorded four adult Mugger crocodiles (>180 cm body length) basking in sandy and muddy bank during the investigation period. The lake is under pressure from diverse anthropogenic factors. The principal threats to the Mugger crocodile include water pollution, habitat destruction, sedimentation, food shortage, egg collection and seasonal fluctuation of water level. The total area and depth of the lake is diminishing due to encroachment by *Phragmites karka* and flash flood during monsoon. Conservation and proper management of the lake are urgently required.

Key words: Mugger crocodile, population status, threats, water quality

Introduction

Among the 23 species of crocodilian within its 4 families, only two species, Mugger crocodile (*Crocodylus palustris* Lesson) and Gharial (*Gavialis gangeticus*) occur in Nepal. At smaller sizes they often eat aquatic insects, small fish and crustaceans, and as they grow larger they tend to eat more vertebrates, including fish, turtles, birds and mammals (Wagle 2010). Mugger crocodile is a semi aquatic, keystone and top carnivore of slow flowing freshwater ecosystem and performs a vital service in the aquatic ecosystem by distributing the nutrients throughout the water body resulting an increment in the primary production and fish population (Mulozoki 2000).

Mugger crocodiles have several features that differentiate them from other crocodiles. They have the broadest snout of any member of their genus. They generally reach maturity between 1.7 and 2.6 meters between the ages of six to ten years. The Mugger is a hole-nesting species, with egg-laying taking place during the annual dry season. Females become sexually mature at approximately 1.8 - 2 m body length and lay 25-30 eggs (Whitaker & Whitaker 1989).

Mugger crocodile is principally restricted to the Indian subcontinent where it may be found in various freshwater habitat types including rivers, lakes, and marshes (Whitaker 1987, Whitaker & Whitaker 1989). It is listed as a vulnerable species in the IUCN Red Data Book and is protected by law in all the countries of its occurrence (Whitaker 1987).

Historically, Mugger crocodile was relatively common throughout the Terai of Nepal in marshy lakes, ponds and small rivers (Groombridge 1982). The results of a 1993 survey indicated that the Muggers were restricted to isolated populations, primarily in protected habitats

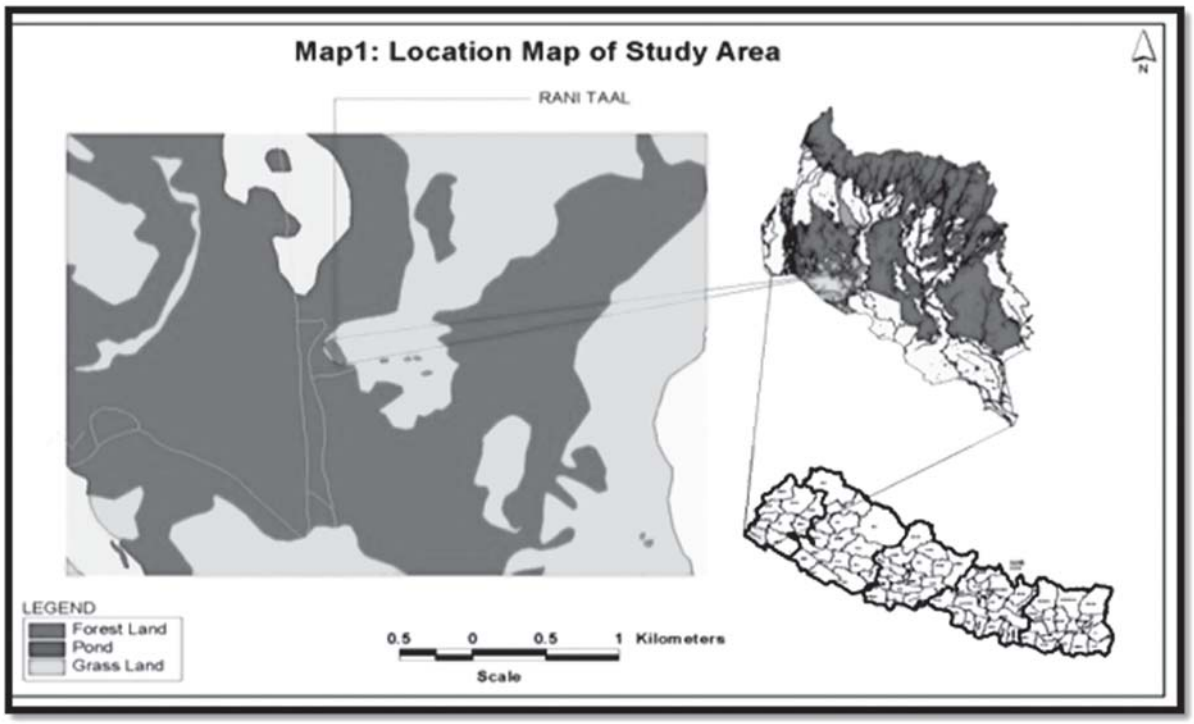
of Shuklaphanta Wildlife Reserves, Bardiya and Chitwan National Park. Small number of individuals were known or suspected from the Mahakali, Bahuni Nala, Chaudhara, Karnali, Babai, Rapti, Narayani and Koshi River systems. Modification of the habitats by river disruption and damming and mortality in fisheries operations were major problems (McEachern 1994). Andrews and McEachern (1994) estimated 200 wild *C. palustris* in 1993 in Nepal. Reduction of wetland areas, deposition of silt and sediments, eutrophication, deterioration of water quality, construction of dams and other anthropogenic factors are responsible for its population decline in Nepal (Shrestha 2001).

To restore the rapidly dwindling population of crocodile in Nepal, since 1978, crocodile conservation efforts in Nepal began by establishing Gharial Breeding Center at Kasara inside the Chitwan National Park. Over the interim years, the Gharial and Mugger crocodiles have been bred in captivity and released in different rivers like Narayani river (Wagle 2010).

Information on the status and threats to *C. palustris* in Nepal is scanty. The physico-chemical parameters of water are very important for the composition, abundance and distribution of living organisms in the aquatic ecosystem. Abundance, diversity and distribution of animals are related to various physico-chemical biotic factors (Dutta & Malhotra 1986). Understanding the population status and identifying the threats to determine the vulnerability is foremost step to start conservation measures for a species. The outcomes of this research may be used in formulating an integrated conservation strategy for the Mugger crocodile.

Study Area

Rani Tal is a natural lake nestled in Sal forest located in eastern side of Shuklaphanta Wildlife Reserve, Kanchanpur, 18 km from the Majhgaun (headquarter of Shuklaphanta Wildlife Reserve) at 28^0 50.2' N and 80^0 13.2' E above 140 m asl (Bhandari 2009). This is a 350 years old oxbow lake formed by shifting of Chaudhara river (DNPWC/PCP 2004).



Lohani (2000) mentioned reduction in the lake's area by 3 ha to that of 11ha (Bhandari 2009) due to encroachment by *Phragmites karka*. *P. karka* having high colonization in Rani Tal may reduce the number of bird species. High evaporation rate of *P. karka* cover helps in drying Lakes (Wetzel 2001).

The climate of the area is sub-tropical. The average temperature during winter ranges from 10 - 20 °C & rises to 22 - 25 °C and reaches up to 40 °C in summer (DNPWC 2004). Monsoon season (June to September) comprises over 90% of the annual precipitation. The geology of the area is very similar to the gangetic alluvium. The soils vary to loamy sand, sandy loam, loam, silty loam and clay loam (Pradhan *et al*. 1967). The bottom soil contains high organic matter whereas surrounding soil contains low organic matter with highly acidic nature (Pokharel & Jun 2008).

Methedology

Baseline information on water quality, population status and threats to Mugger crocodile was collected between June 2008 and February 2009. A total of five sampling sites including inlet, outlet and main water bodies were selected. Physico-chemical analysis of water was conducted for three seasons (summer, autumn and winter) to determine the water quality of the lake. Similarly, to facilitate counting of Mugger, five sampling sites were selected based on the composition of soil and vegetation (Bogati 2003).

Site 1 : The bank of the lake covered by mud

Site 2 : The bank of the lake which contained sand mixed with black soil

Site 3 : The bank of the lake which contained sparse grass on the sandy soil area (sandy bank)

Site 4 : The bank of the lake dominated by dense grass bank

Site 5 : The bank of the lake which contained water erosion prone area

Utilization of the resources, population status and threats to Mugger crocodile were studied by visual aid and questionnaire method. Different open ended questions were asked to 50 respondents including local residents (i.e., Beldandi, Rauteli Bichuwa & Raikbar Bichuwa), leaders, government officers, shopkeepers, teachers, students and visitors.

Water sampling and analysis

Boats were used to reach the sampling sites and water samples (surface water) were collected from the sites with the help of sterilized sampling bottles. The sampling date and time were selected in such a manner that the impacts of rainfall was minimum (samplings during rainfall or immediately after the flooding were avoided). The parameters like pH, temperature, transparency, conductivity, total alkalinity, hardness, dissolved oxygen, free carbon dioxide and chloride were measured immediately on the site at the time of sampling. The other parameters were determined in the laboratory where the samples were kept and preserved in a refrigerator (Kelvinator, Model KCF 0310 OS). All the physico-chemical parameters were determined according to the methods described in APHA, AWWA and WEF (1998) and by Trivedi and Goel (1986).

Survey for the mugger crocodile

A continuous survey was conducted for 15 days in February 2009. Direct observation was made to count the population of Mugger crocodile using binocular (8×40 magnification) from the viewing towers and nearby tall trees.

Muggers are amphibious in nature and can be counted both in water and on the land. It is easier to count the number and estimate the size of crocodiles basking on land during day time particularly in post - winter and pre - summer seasons (Rodgers 1991). Winter months, therefore are good times for counting crocodiles as in day time, they tend to bask in groups (Choudhary & Roy 1982, Rodgers 1991). Possible basking places were frequently visited to explore the population status of the Mugger. To avoid double counting, different natural features like tall trees and Machans (viewing towers) were used with the help of local staff and nature guides. The age class of Mugger was estimated visually as suggested by Rodgers (1991) as hatchling (< 50 cm), yearling/juvenile (50 - 120 cm), sub adult (120 - 180 cm), Adult (>180 cm), eyes only (for very far or difficult to estimate).

Results and Discussion

Population status

Sporadic sightings of basking crocodiles were made during the investigation period. During whole survey period (10th to 24th February 2009), the highest number of Mugger crocodiles recorded was four individual basking in the sandy bank and mud bank of Rani Tal (Table 1). Number of Mugger crocodiles were sighted during cloudy days (10th - 16th February & 20th - 22nd February).

Table 1. Mugger crocodile population sighting

Date of sighting	No. of observed individuals	Size and Age class	Observation site
17th Feb. 2009	4	Adult (>180 cm)	Site 3 (Sandy bank)
18th Feb. 2009	4	Adult (>180 cm)	Site 3 (Sandy bank)
19th Feb. 2009	4	Adult (>180 cm)	Site 1 (Mud bank)
23rd Feb. 2009	4	Adult (>180 cm)	Site 3 (Sandy bank)
24th Feb. 2009	4	Adult (>180 cm)	Site 3 (Sandy bank)

Water quality analysis

Water temperature was maximum (28.90 ± 1.14 ^{0}C) in summer and minimum (17.08 ± 0.39 ^{0}C) in winter. High water temperature in summer might be due to high air temperature and greater light penetration. Natural bodies of water may exhibit seasonal and diurnal variations, as well as vertical stratification in temperature, which is related with the change in atmospheric temperature (Kundangar *et al*. 1996). Temperature is a factor of great importance for aquatic ecosystems as it affects the organisms as well as physical and chemical characteristics of water (Delince 1992).

The hydrogen ion concentration (pH) was maximum (7.70 ± 0.35) in winter and minimum (7.14 ± 0.40) in summer. Low pH during summer might be due to the dilution of alkaline substances and high turbidity. High pH during winter can be attributed to phytoplankton maximum causing excessive production of carbon dioxide (Roy 1955, Sisodia & Moundiotiya 2006). A pH range of 6.5 to 9 is best for majority of aquatic organisms (Wurts & Durborow 1992).

The maximum value of conductivity in water was (358 ± 14.83 µS) in summer and minimum (174 ± 26.08 µS) in autumn. Freshwater bodies should have 10 - 1000 micro siemens according to WHO (1970).

The dissolved oxygen (DO) was maximum (7.52 ± 0.66 mg/l) in winter and minimum (3.72 ± 0.54 mg/l) in summer. According to United States Environmental Protection Agency (USEPA 2000), DO (> 5 mg/l) is considered favorable for growth and activity of most aquatic organisms. Low value of DO in summer is due to higher rate of decomposition of organic matter and limited flow of water in low oxygen holding environment due to high temperature (Rani *et al*. 2004). High Oxygen content water is required for the survival of crocodiles. Low level of DO causes stress to the crocodile population reducing the aquatic diversity of organism (Shrestha 1983).

The maximum value of free carbon dioxide was (39.44 ± 1.89 mg/l) in summer and minimum (9.40 ± 2.23 mg/l) in winter. Maximum concentration of Carbon dioxide during summer could probably be associated with influx of carbonic acid through rain water and active decomposition of organic matter (Mishra *et al*. 1999). APHA (1998) recommends < 6 mg/l of free carbon dioxide is suitable for aquatic and sub aquatic species.

The maximum total alkalinity was 143.20 ± 14.18 mg/l in winter and minimum 119.60 ± 6.39 mg/l in summer. The high value of alkalinity during winter may be due to increase in free Carbon dioxide as decomposition process. The low alkalinity during summer may be due to dilution of water (Chakraborty *et al*. 1959). A total alkalinity of 20 mg/l or more is necessary for good community production (Wurts & Durborow 1992).

Total hardness was maximum (117.44 ± 13.00 mg/l) in winter and minimum (94.80 ± 14.04 mg/l) in summer. Maximum total hardness in winter might be due to low volume and slow current of water. Similar results were obtained by Misra *et al*. (1999) on limnological investigation of a freshwater tributary in Assam, India. Minimum quantity in summer may be due to more dilution of water (Patralekh 1994). Hardness of 15 mg/l or above may be considered suitable for the animals and plants (Swingle 1967).

Chloride contents were found maximum in summer (32.04 ± 2.93 mg/l) while minimum in winter (29.20 ± 3.03 mg/l). The maximum quantity of chloride content recorded in summer may be due to high temperature and high rate of decomposition of organic matters. The chronic standard of chloride for aquatic life is 230 mg/l (MPCA 2010). UN (1995) recommended > 350 mg/l is harmful for aquatic animals.

Total dissolved solids (TDS) was maximum (776 ± 69.86 mg/l) in summer and minimum (440 ± 27.39 mg/l) in autumn. High concentration of TDS during summer may be due to addition of solids from runoff water. Government of Nepal (2009) recommended <2000 mg/

l of TDS is desirable for freshwater organisms. Total suspended solids (TSS) was maximum (770 ± 70.00 mg/l) in summer and minimum (241.40 ± 33.60 mg/l) in autumn. Government of Nepal (2009) recommended <20,000 mg/l of TSS desirable for aquatic organisms.

The maximum concentration of NO_3^- (1.74 ± 0.16 mg/l) in water was observed in autumn whereas the minimum value (0.51 ± 0.09 mg/l) in winter. UN (1995) recommended < 10 mg/l of NO_3^- is desirable for freshwater aquatic and semi aquatic species.

The maximum concentration of PO_4^- (1.10 ± 0.24 mg/l) in water was observed in winter whereas the minimum value (0.31 ± 0.03 mg/l) in autumn. The seasonal variation of orthophosphate of the lake might be due to the fluctuation on surface runoff, weathering of rocks, soil decay and mineralization of plants and animals remains (Kennan & Job 1980). UN (1995) recommended a maximum orthophosphate of 0.4 mg/l suitable for aquatic organisms.

The maximum concentration of ammonia (0.08 ± 0.01 mg/l) in water was observed in summer whereas the minimum value (0.05 ± 0.01 mg/l) in winter. The chronic un-ionized ammonia standard for aquatic life is 0.04 mg/l. Ammonia at elevated levels in the un-ionized form (NH_3) is toxic to aquatic life (MPCA 2010).

The maximum biological oxygen demand (BOD) was 34.32 ± 2.30 mg/l in summer and minimum 14.60 ± 1.57 mg/l in autumn. High BOD in summer might be due to high rate of organic decomposition and agricultural runoff. The agricultural lands of Beldandi, Raikbaar Bichuwa and Rauteli Bichuwa of Kanchanpur district lie near the lake. There was a sharp decline in BOD in autumn and continued to be low through winter. This may be due to low temperature, which slows down the microbial activity as reported by Bhatt *et al.* (1999). According to UN (1995), 5 day BOD shouldn't exceed 7 mg/l for common aquatic use by aquatic/semi aquatic animals. High content of BOD causes oxygen depletion, which leads to the suffocation of the aquatic life (Verma *et al.* 1984).

Arsenic content was found to be nil during the study period. Government of Nepal (2009) has recommended that < 0.05 mg/l of arsenic is desirable for aquatic/semi aquatic use.

Threats to the Mugger Crocodile

The water quality parameters (dissolved oxygen, total hardness, free carbon dioxide, orthophosphate, biological oxygen demand and ammonia) of Rani Tal exceeded the normal range to support the Mugger crocodile. Poor water quality in monsoon season causes significant death of hatchlings of crocodile. Six-hundred and five Gharial crocodile died of myotic infections particularly in monsoon season in captive reared Gharials (*G. gangeticus*) in Kasara, Chitawan, Nepal due to poor water quality and extreme humidity (Maskey 1989). Lal (1982) reported the snout bones rotting and falling of teeth in Gharial hatchlings due to myotic infections. Singh *et al*. (2001) noted rubbery of snout and hunch back condition occurrence in the captive Muggers is due to high level of calcium presence in the water.

The lake is facing threats from various anthropogenic activities in recent days. The seasonal fluctuation of water level of the lake is a threat to the Muggers. Low water level without replacement for long time causes the infection by bacteria to the hatchling of crocodiles (Mishra *et al*. 1993). Flash flood during rainy season from the surrounding agricultural land entering the lake with huge amount of silt (sedimentation) is another threat to Mugger. Excessive overloading in the lake may cause the outbreak of the fungi, bacteria, which are the main agents to cause many physiological disorders in the crocodile such as kidney, spleen and liver diseases (Gaire 2007). The environmental change, change in water quality parameters cause abnormalities in crocodiles (Wataru 1976).

Other anthropogenic threats to Mugger crocodile in Rani Tal area include egg collection of Mugger crocodiles, illegal fishing in Rani lake by poisoning, illegal hunting of small mammals, fish and birds by local Tharus which may result in dearth of food to the Mugger crocodile.

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