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Abundance and Prey Availability Assessment of Ganges River Dolphin (*Platanista gangetica gangetica*) in a Stretch of Upper Ganges River, India

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Abstract

The present study was conducted between January and June 2007 to assess the abundance and density of Ganges River dolphin (*Platanista gangetica gangetica*) and their prey in a 28-km stretch of the River Ganges between Narora Barrage and Anupshahar. Two different sampling methods were used to estimate dolphin densities. Estimated density was 2.58 ± 0.40 individuals/km^2 (mean ± 1 SE) using the direct count method and 4.97 ± 0.60 individuals/km^2 using the boat-based, line-transect distance methods, with an encounter rate of 0.52 ± 0.068 individuals/km and detection probability of 0.647. No significant differences between the upstream and downstream counts (t = 1.29, df = 9, $p > 0.05$) were detected. The adult male to adult female ratio was 0.66: 1.00, whereas the calf to adult female ratio was 0.42: 1.00. We collected 16 fish species of length class varying from 3.5 to 20 cm (range of preferred size of dolphin prey) with a total density of 176.42 fish/km^2 and a total average biomass of 5.36 kg/km^2. Dolphin density showed a significant positive relationship (R^2 = 0.587) with density of Reba fish (*Cirrhinus reba*) ($\beta = 0.31$, $p = 0.00$) and Baam fish (*Mastacembelus armatus*) ($\beta = 0.50$, $p = 0.04$) and also with water depth ($\beta = 0.17$, $p = 0.03$). Presence of dolphins varied across different water depth categories (χ^2 = 106.38, df = 3, $p < 0.01$) and different parts of the river (χ^2 = 21.68, df = 2, $p = 0.00$) with more than 50% of dolphin sightings occurring in confluences, indicating their preference for deep water pools.

Key Words: Ganges River dolphin, *Platanista gangetica gangetica*, *Cirrhinus reba*, *Mastacembelus armatus*, confluence, deep water pool, line-transect

Introduction

River dolphins throughout the world are represented by five species (Walker, 1968; Mohan, 1989). Two species—Ganges River dolphin (*Platanista gangetica gangetica*) and Indus River dolphin (*P. minor*) (Roberts, 1997)—are found in the Indian subcontinent. The Ganges River dolphin, locally known as Susu, is restricted to the Ganges, Brahamputra, Karnaphuli-Sangu, and Meghna river systems and their tributaries, from the foot hills of the Himalaya to the limits of the tidal zone in India, Bangladesh, Nepal, and Bhutan (Anderson, 1879; Jones, 1982; Reeves & Brownell, 1989; Sinha, 1997, 2000). It is the only mammalian predator in the Ganges which is exclusively aquatic, and it plays a vital role in maintaining the essential balance of the ecosystem, occupying the apex of the food chain (Behera, 1995). In spite of being a "flagship" species, representing an ecosystem in need of conservation (Behera, 1995; Anonymous, 2006; Choudhary et al., 2006; Behera et al., 2008; Bashir, 2010), its status has become a matter of grave concern over the past few decades (Behera, 2002). As the tiger is to the forest, the dolphin is to the Ganges River because both are important indicator species and have significant roles to play in their respective ecosystems (Singh, 2001). The condition of Ganges River dolphin is probably worse than that of the tiger as less attention has been paid to its conservation and management.

Once believed to be in the tens of thousands (Anderson, 1879), their number has gradually reduced to four to five thousand (Jones, 1982), with a further decline to a mere 1,800 individuals in all the tributaries of its distribution (Behera et al., 2008). The species is facing a series of threats for its survival due to poaching, construction of dams and barrages (Smith & Reeves, 2000a; Smith et al., 2000), pollution, mining of sand and stones, and incidental catches in gillnets (Nair, 2009). Consequently, it has been placed in Schedule-I of Wildlife (Protection) Act of India (1972) and is in Appendix-1 of the Convention on International Trade in Endangered Species (CITES) (International Union for Conservation of Nature [IUCN], 1991). The species has also been listed as Endangered by the IUCN (2004).

Only a few dolphin surveys of the entire Ganges River mainstream (Behera et al., 2008) and ecological studies (Behera, 1995; Bashir et al., 2007; Kelkar, 2008) have been conducted in the past two decades. Some inventories of its behavior (Singh & Sharma, 1985; Smith, 1993; Behera & Rao, 1999; Sinha, 2000; Bashir et al., 2007; Sinha et al., 2010) have been conducted as well. However, its status and distribution has been well-studied. It was therefore necessary to review the status of Ganges River dolphin in the present study area as the species was known to be declining at a rate of 10% annually (Behera, unpub. data). Because the conservation and management of a species requires sound understanding of its ecology, a study of the abundance and prey base of the Ganges River dolphin was conducted to collect baseline information.

Study Area

The present study was conducted in the Upper Ganges River between Narora Barrage (N 28° 11' 28.4", E 78° 23' 48.1") and Anupshahar Bridge (N 28° 21' 52.0", E 78° 16' 24.8") in Western Uttar Pradesh (Figure 1). A stretch of about 28-km length with an average width of 200 m and covering an area of about 5.6 km^2 was selected for the study. This stretch was reported as one of the most suitable habitats for Ganges River dolphin (Behera & Rao, 1999). The entire study area is shallow in depth with only intermittent small stretches of deep-water pools. The banks of the entire river stretch are either sandy or muddy. However, during the dry season when the availability of water is reduced significantly in the upstream, it is fed through the Kalagarh feeder canal, which originates from the Kalagarh barrage built on the Ramganga River (Behera, 1995). In addition to the Simbhaoli Sugar Mills (near Garmukteswar), a number of drainage outlets from adjoining villages discharge sewage directly into the river. The natural flow of the river has been altered due to the construction of barrages, either for generation of electricity or irrigation purposes.

Forest shrub and grasses characterize the banks of the study area. The floral communities have developed on coarse, textured alluvial soil adjacent to the river bank with tree species such as Sissoo (*Dalbergia sisoo*), False ashok (*Polyalthia longifolia*), Eucalypts (*Eucalyptus* sp.), Indian fig (*Ficus bengalensis*), and Neem (*Azadyrachta indica*). Some aquatic flora such as Water hyacinth (*Eichhorina* sp.), Tape grass (*Vallisneria spiralis*), Esthwaite waterweed (*Hydrilla verticillata*), and Bullrush (*Typha*) are dominant species of vegetation along the river bank. Important wildlife species other than *P. gangetica* include Marsh crocodile (*Crocodylus palustris*), Checkered keelback (*Xenochropis piscstor*), Indian roofed turtle (*Kachuga tecta*), and Brown-roofed turtle (*Kachuga smithii*) (Behera, 2002), in addition to a number of fish and water bird species.

Materials and Methods

Status and Abundance

We laid 28 collinear transects of 1 km each to cover the river stretch and sampled this area during January to June 2007 by using a motor boat powered by a 15-hp engine at a constant speed of 6 km/h. Transects were sampled between 0600 to 1200 h and 1500 to 1900 h. One complete survey that included samplings of all 28 transect lines took 2 d, and at least three to four such surveys

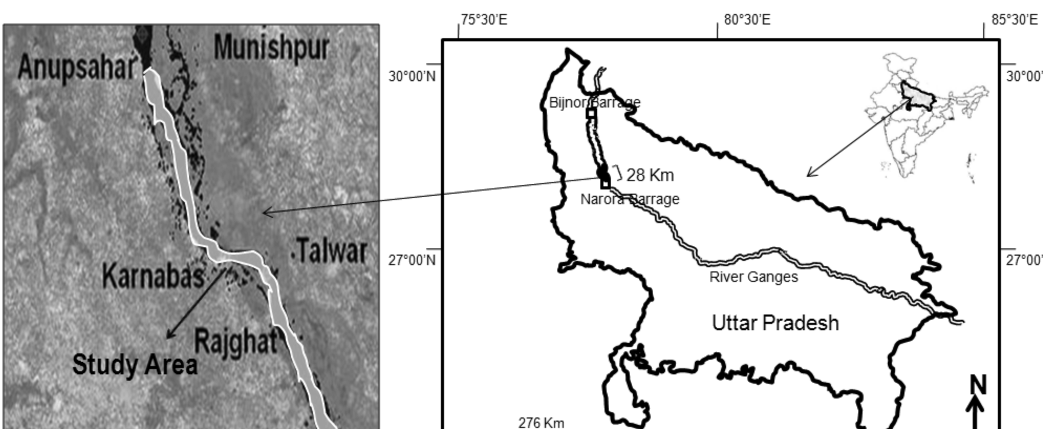

Figure 1. Map showing the location of the study area in Uttar Pradesh, India. *Source:* WWF-India

were carried out every month (totaling 48 d). We used two conventional dolphin sampling methods. The direct count method (Perrin & Brownell, 1989; Rao et al., 1989; Mohan et al., 1993; Sinha & Sharma, 2003) was adopted in which density was estimated from dolphins counted during a survey, assuming complete detection of all individuals and following simple calculations of numbers per sampled area (5.6 km^2). A boat-based line-transect method (Hammond, 1986; Geise et al., 1999; Smith & Reeves, 2000b; Kreb & Budiono, 2005) was also adopted in which transects were sampled by three dependent observers stationed in different directions (right, left, and front) with each observer searching an angle of 120° at an observer eye height of *ca*. 4.5 m. Corresponding to each sighting, sighting angle using a Suunto compass, GPS location, time, and age/sex category of the individual was recorded. Sex of the adult individual was determined on the basis of shape and size of its beak, which is longer and up-curved in female dolphin (Behera & Rao, 1999) and clearly visible since beak exposure is in accordance to each surfacing mode (Behera, 1995). However, in subadults, juveniles, and calves, sexual dimorphism is not apparent. Moreover, it was difficult to differentiate between juveniles and 1- to 2-y-old calves; hence, they were placed in a single class (calf). Subadults were differentiated from the adults on the basis of their smaller size (100 to 150 cm) compared to the adults (> 150 cm), while the juvenile and calf size ranged from 50 to 100 cm. Thus, we had four age/sex categories: (1) adult female, (2) adult male, (3) subadult, and (4) calf. The observers took extreme care to eliminate repeated dolphin counts considering their spatio-temporal array and beak morphology (Mohan et al., 1997). In addition, some habitat parameters like pH, water depth, and water temperature at each sighting location were also recorded using a Hanna pocket pH-meter and GARMIN depth finder. A total of 20 sampling repeats of all 28 transects were conducted, resulting in an overall sampling effort of 560 km.

Prey Availability Assessment

Our focus was to assess the availability of dolphin-prey fish species (3.5- to 20-cm length range; Sinha et al., 1993). A large silken gillnet (American Public Health Association [APHA] et al., 1985; Mohan et al., 1998; Sarkar et al., 2007) of 40-m length, 5-m width/height, and 20-mm mesh size was used to sample the 28 transect lines of the study area. Netting in each transect was done by releasing both ends of the stretched net in the river with its line of axis perpendicular to the line of transect, allowing it to flow with the water current until a distance of 1 km (i.e., transect length) was covered. The net was then retrieved, and the individuals of each species were immediately put in a bucket of water, counted, weighed using a spring balance, and released back into the river to ensure their survival. In total, five sampling/netting replicas along each transect line with an overall sampling effort of 140 km (in 20 d) were made during the entire study period.

Data Analysis

We estimated dolphin density from the line-transect method using the software program *DISTANCE*, Version 5.0 (Thomas et al., 2002) and selected the appropriate model on the basis of minimum Akaike information criterion (AIC) value. The difference between upstream and downstream dolphin counts was tested for significance using *t*-test. Fish diversity, richness, and evenness were calculated using the software program *EstimateS Win*, Version 7.5.0 (Colwell, 2005) based on the following equations:

Shannon-Weiner Diversity Index:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i - [(S-1)/2N]$$

$$\text{Species Evenness } E = H'/H_{max} = H'/\ln S$$

Where, N = total number of individuals, S = species richness (total # of species present), and p_i = proportion of total sample belonging to the ith species

The chi-square test (Box et al., 1978) was used to analyze the difference between dolphins sighted in different depth categories and also in different parts of the river (confluence, middle, and side channel). A multiple regression analysis using *SPSS 16.0* (Norusis, 1990) was performed to investigate the relationship among dolphin density, density of catfish species (*preferred in literature*), and hydrological parameters (pH, temperature, and water depth).

Results

Status and Abundance

In total, we had 289 dolphin sightings in the study period. Of these, 37 sightings were of dolphins of unidentified age/sex. The dolphin density derived from the direct count method was calculated as 2.58 ± 0.40 individuals/km^2 (mean ± 1 SE), with an overall maximum count of 23 individuals in a single survey. Boat-transect-generated dolphin density using the line-transect-based *DISTANCE* sampling method was 4.97 ± 0.60 individuals/km^2. Encounter rate of dolphins was estimated at 0.52 ± 0.07 individuals/km. The estimated effective strip width and detection probability were 51.9

± 5.06 m and 0.647, respectively. However, the individual detection probabilities of adult female, adult male, subadult, and calf were 0.373, 0.386, 0.253, and 0.376, and their densities were 2.12 ± 0.27, 1.005 ± 0.16, 0.97 ± 0.17, and 0.86 ± 0.17 individuals/km^2, respectively (Table 1). The difference in the upstream and downstream dolphin counts was not found to be significant (t = 1.288, df = 9, p = 0.230).

Out of the total sightings (N = 289), 33.22% were adult females; 22.14% adult males; 18% subadults; 13.84% calves; and the rest, 12.8%, were in the unidentified category. The adult male to adult female ratio was 0.66: 1.00, and the ratio of calves to adult females was 0.42: 1.00. Dolphin abundance in the study area generated through density estimates of direct count method was 14, whereas the count based on *DISTANCE* sampling was found to be 28 individuals.

Prey Availability Assessment

A total of 16 fish species were identified with length ranging from 3.5 to 20 cm at a total density of 176.42 individuals/km^2. Maximum density (118.57 individuals/km^2) was observed for *Clupisoma garua*, while minimum density (0.178 individuals/km^2) was observed for *Labeo rohita* and *Mystus bimaculatus*. Moreover, maximum biomass (2.701 kg/km^2) was observed for *Clupisoma garua* and minimum biomass (0.001 kg/km^2) was observed for *Bagarius bagarius*, respectively (Table 2). Total mean fish biomass was 5.36 kg/km^2 with a mean fish weight of 30.4 g. Within the above-mentioned specified size range, the Shannon-Weiner Index for fish species diversity was 1.23 (SE = 0.05), species richness was 16.84 (SD = 0.61), and evenness was 0.47 (SD = 0.1). Among seven habitat variables (density of four prey species and three hydrological parameters), dolphin density showed significant positive association (Table 3) with the density of *Cirrhinus reba* (β = 0.31, p = 0.00), *Mastacembelus armatus* (β = 0.50, p = 0.04), and with the water depth (β = 0.17, p = 0.03). The analysis derived the regression equation as

$$DD = -15.65\ (SE = 9.63) + 0.31(SE = 0.08) \times RD + 0.50(SE = 0.22) \times BD + 0.17(SE = 0.07) \times WD$$

$$[R^2 = 0.587,\ p = 0.006]$$

Where, DD = Dolphin density, RD = Reba density, BD = Baam density, and WD = Water depth

Water depth along the river showed varied degrees of fluctuations during the study period ranging from 0.86 to 14.12 m. The chi-square test showed significant difference in the number of

Table 1. Estimated densities (D), detection probability (DP), encounter rate (n/L), and effective strip widths (ESW) of dolphin with standard error (SE) and 95% confidence interval (CI) at minimum Akaike information criterion (AIC).

Dolphin	Model	AIC	χ^2	p	df	DP	D	SE	95% CI		n/L	SE	95% CI		ESW	SE	95% CI	
									U.lt	L.lt			U.lt	L.lt			U.lt	L.lt
Overall	Half normal	640.30	0.0113	0.99436	2	0.647	4.9724	0.6028	6.30	3.92	0.52	0.068	0.59433	0.44812	51.894	5.0614	62.85	42.85
Adult female	Half normal	198.47	0.0002	0.99992	2	0.373	2.1242	0.2686	2.72	1.66	0.173	0.030	0.21077	0.14235	40.771	7.72	47.51	34.99
Adult male	Half normal	166.39	0.1145	0.99004	3	0.386	1.0050	0.1617	1.37	0.73	0.10	0.032	0.14617	0.89354	56.861	5.6653	69.35	46.62
Subadult	Uniform	105.27	0.0030	0.99848	2	0.253	0.97022	0.1662	1.35	0.70	0.093	0.023	0.12400	0.069534	47.854	4.1229	56.87	40.27
Calf	Half normal	86.756	0.1121	0.99035	3	0.376	0.86470	0.1690	1.27	0.59	0.073	0.019	0.9897	0.05416	42.335	5.0761	53.90	33.25

Table 2. Density and biomass of different fish species in the Narora-Anupshahar stretch of the Ganges

Serial no.	Species	Family	Common names	Density (# fish/km^2)	Biomass (kg/km^2)
1	*Pangasius pangasius*	Pangasiidae	Pariasi	18.571	1.254
2	*Clupisoma garua*	Schilbeidae	Baikeri	118.571	2.701
3	*Mystus seenghala*	Bagridae	Singara	15.357	0.749
4	*Labeo rohita*	Cyprinidae	Rohu	0.178	0.223
5	*Labeo bata*	Cyprinidae	Bata	0.893	0.047
6	*Parambassis ranga*	Ambassidae	Chanari	2.857	0.020
7	*Wallago attu*	Siluridae	Barari	10.893	0.185
8	*Labeo boga*	Cyprinidae	Bhangan	1.071	0.028
9	*Mystus bimaculatus*	Bagridae	Ketra	0.178	0.002
10	*Salmostoma bacaila*	Cyprinidae	Chelwa	4.821	0.079
11	*Mastacembelus armatus*	Mastecembelidae	Baam	0.357	0.034
12	*Mystus bleekeri*	Bagridae	Kitua	0.536	0.003
13	*Cirrhinus reba*	Cyprinidae	Reya	0.714	0.021
14	*Sisor rhabdophorus*	Sisoridae	Chennuah	0.357	0.002
15	*Bagarius bagarius*	Sisoridae	Gounch	0.357	0.001
16	*Botia dario*	Cobitidae	Bakatia	0.714	0.013

Table 3. Coefficients of multiple regression between dolphin density and different habitat variables

Variables	Unstandardized coefficients	SE	Beta	*t*	Sig.
(Constant)	-15.65	9.63		-1.62	0.12
Mastacembelus armatus	0.50	0.22	0.33	2.25	0.04
Wallago attu	0.01	0.02	0.09	0.61	0.55
Bagarius bagarius	0.41	0.25	0.27	1.63	0.12
Cirrhinus reba	0.31	0.08	0.59	4.09	0.00
Water depth (m)	0.17	0.07	0.38	2.32	0.03
Temperature (°C)	-0.39	0.27	-0.36	-1.45	0.16
pH	2.29	1.23	0.46	1.85	0.08

Note: Dependent variable: Dolphin density

dolphins sighted within different water depth categories ($\chi^2 = 106.38$, df = 3, $p < 0.01$) as well as in different parts of the river ($\chi^2 = 21.68$, df = 2, $p = 0.00$) The rates of dolphin sightings were 7.5/d and 0.27/km in confluences, 4.9/d and 0.18/km in the middle of the river, and 2.05/d and 0.07/km in side channels. This accounted for 52% of sightings in confluences, 34% in the middle stretch, and 14% in the side channels. The pH-value and temperature ranged from 9.1 to 11.9° C and 20.8 and 30.6º C (February to May), respectively, but showed no significant relation with dolphin density.

Discussion

Status and Abundance

The encounter rate of Ganges River dolphin in the present study (0.52 individuals/km) was found to be similar to the encounter rate for this species in the Brahmaputra River, Assam (0.44 individuals/km) (Mohan et al., 1997). However, estimates in Vikramshila Gangetic Dolphin Sanctuary (1.8 individuals/km) were found to be higher (Choudhary et al., 2006), while the encounter rate in the Lohit River, Eastern Assam (0.23 individuals/km), were lower (Wakid, 2005) than those of the present study and, hence, represent a corresponding index of dolphin abundance in the study area. The overall detection probability of dolphin in the study area was high, but the subadult class had an unexpectedly low detection probability as compared to other age/sex classes. This study predicts an effective strip width of 40 to 60 m (on both sides of the transect line), adequate for the detection of dolphin presence in the stretch. Also, more effective strip width for the detection of adult males compared to that of all other age/sex classes indicates that either adult males remain separate (except in mating season) or tend to keep a greater distance from the area due to disturbance caused by the motor boat during sampling. An ecologically viable population structure, female biased sex ratio, and a healthy proportion of calves in the study area are indicators of an increasing population trend (Smith, 1993), provided conservation importance of the species is felt at the local levels.

This study delivers an interesting comparison between two different conventional dolphin sampling methods and throws light on their sampling adequacy. The high detection probability deduced through *DISTANCE* sampling complemented by a maximum count of 23 individuals suggests that the direct count method gives underestimates and supports the line-transect method as being more appropriate for the population estimation of Ganges River dolphin. Insignificant differences in the upstream and downstream counts were contrary to the findings of Choudhary et al. (2006) in Vikramshila Gangetic Dolphin Sanctuary, which may be due to high dolphin density in the present study area.

Prey Availability Assessment

Fluctuations in the population are mainly influenced by habitat conditions. The most obvious and immediate threat to Ganges River dolphin is loss of habitat (Anderson, 1879) and depletion of fish stock (Mohan et al., 1997). The Ganges River dolphin's diet consists exclusively of fish (Blandford, 1891), and this study site is the known habitat for about 50 to 80 fish species (Hamilton-Buchanan, 1822). Our fish size and catch composition (comprising 16 species) with size ranging from 3.5 to 20 cm and average weight 30.4 g is in keeping with the findings in stomach contents of Ganges River dolphins (Shrestha, 1989; Sinha et al., 1993; Choudhary et al., 2006); hence, the total catch in this study can be considered as the preferred size range for the dolphin.

The positive relationship of dolphin density with *Cirrhinus reba* and *Mastacembelus armatus* in light of a healthy R^2 value is in keeping with the findings of Shrestha (1989) and Mohan et al. (1998) from studies of stomach contents of Ganges River dolphins. Also, the positive relationship between dolphin densities and water depth is in accordance with the findings of Biswas et al. (1997) in the Brahmaputra River, which illustrates its preference for deep water pools (Kreb & Budiono, 2005) for safe surfacing and breeding (Sinha, 1997). This study predicts a possibility of an increase in dolphin density in the areas with increasing density of Reya and Balm and increasing water depth. During sampling, dolphins were observed to prefer deeper portions of the river except while chasing and moving between deep pool areas (Reeves et al., 1993; Reeves & Leatherwood, 1997), which is also confirmed by the fact that we had maximum sightings in the confluences with fewer sightings in side channels (McGuire & Winemiller, 1998). Water temperature range is also in keeping with the suitable habitat model of Ganges River dolphin (Behera, 1995), though the pH regime reflects a high level of pollution (Kannan et al., 1993), which may discourage the planktonic growth (Gremion et al., 2004), thereby depleting the fish fauna (Junk et al., 1989) and ultimately affecting the dolphin population.

Conclusion

This study certifies the study area as a viable habitat for the Ganges River dolphin and suggests its inclusion in the Protected Area network of India. An estimated abundance of 28 individuals in this small stretch is indeed a good sign, but increasing pollution and decreasing deep water pools remain a matter of concern (Behera & Rao, 1999; Behera et al., 2008). We recommend that there is a need for frequent monitoring of dolphin numbers in this stretch and that species importance awareness be encouraged within the local community in order to ensure its continued survival in the Ganges River lest it shares its fate with the now functionally extinct Chinese River dolphin (*Lipotes vexillifer*).

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