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Impact of Sand Mining on Zooplankton of River Ganga in and Around Patna, Bihar, India

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ABSTRACT

The River Ganga and its tributaries, mainly southern tributaries, are the main source of coarse sand in Bihar. Demand of coarse sand is soaring with rapid increase in building and other activities of infrastructural development. This led to increase in sand mining activities in rivers throughout India especially in the last 3-4 decades. The present seasonal study was carried out to assess the impacts on zooplankton in the main stem of the Ganga in and around Patna at three sand mining sites, Lodhi Ghat downstream River Son-Ganga confluence near Maner, Digha Ghat near Jai Prakash Bridge and Gai Ghat upstream Gandak-Ganga confluence and close to Mahatma Gandhi Bridge at Patna between March 2016 and December 2017. Sand mining increases the concentration of suspended materials which ultimately increases the turbidity of the water. Student's t-test results show that mean turbidity and transparency level at reference and impact sites at Lodhi Ghat (p=0.001, p=0.0006) and Digha Ghat (p=0.016, 0.001) differed significantly. The statistical analyses including t-test also showed the number of species and average Shannon diversity index of zooplankton at reference and impact sites of Lodhi Ghat (p=0.004, p= 0.016) and Digha Ghat (p=0.001, p=0.0005) differed significantly, except at Gai Ghat. The most important effects of sand mining on zooplankton were reduction in species diversity and abundance, in the River Ganga.

Keywords River Ganga, Sand mining, Shannon-Weiner diversity index, Transparency, Turbidity.

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INTRODUCTION

Sand mining is a common practice in many rivers and flood plains across India. The demand for these resources continues to increase in response to population growth, economic development and infrastructure development, urbanization and plan to construct 60 million new low-income houses by 2024 (Balachandran 2017). Steinberger et al. (2010) estimated that indiscriminate sand mining globally extracted 32-50 billion tons aggregate (Sand and Gravel) sand each year which threatens the very existence of the riverine habitats (Freedman et al. 2013). A lack of proper scientific sand mining methodology for the river has also led to indiscriminate aggregate mining (John 2009).

The basin of River Ganga drains about 1,060,000 km^2 and is the fifth largest basin in the world and bears very high cultural, heritage and religious values (Welcomme 1985). This River basin is also home to a variety of life forms ranging from phytoplankton to the Ganga River dolphin, thus signifying its biological and ecological importance. Mainly southern tributaries of the River Ganga originating from Central India are the main source of coarse sand in the main stem of the Ganga. The main source of the coarse sand in Ganga near Patna is the River Son originating from Amarkantak Hills in Madhya Pradesh and discharging into the Ganga about 35 km upstream Patna near Maner. The coarse sand is preferred for building and road construction as it requires less processing, easily accessible and may be mined without using expensive equipment (Mingist and Gebremedhin 2016). Manual sand mining, using country boats, has been in practice in Ganga and its tributaries since time immemorial. But with increasing demand for coarse sand in the last three to four decades, thousands of mechanized country boats are being used for sand mining at various sites in Ganga and all its tributaries in and around Patna and there is no information available on its impacts on over all ecology of the River Ganga.

The physical impact of sand mining increases the concentration of suspended materials which ultimately increases the turbidity of the water (CEDA 2000). Dankers (2002) revealed that the reduction of light penetration and changes in light spectra caused by high turbidity levels can affect primary production. According to Phua et al. (2004), an increase in suspended matter concentrations may affect foraging efficiency of zooplankton as the amount of food particles captured par time period will be reduced as a result of increased concentrations of non-digestible material and clogging of feeding appendages. Another consequence is the possibility that zooplankton will ingest inorganic particles associated with phytoplankton, reducing the nutritional value of the algal food (Burford and O'Donohue 2006), affecting their weight, body size and feeding behavior. Mingist and Gebremedhin (2016) found that aggregate mining had a number of negative impacts on local fish populations. Fish are directly threatened by suction dredging during their embryonic stages (Harvey and Lisle 1998).

Literature review reveals that indiscriminate mining of river sand and gravel causes the destruction of aquatic habitats by bed degradation, lower water levels and channel degradation (Padmalal and Maya 2014). Although several researchers have conducted studies on rivers of South India (John 2009, Saviour 2012, Swer and Singh 2004) and in foreign countries (Freedman et al. 2013, Kondolf 1994, Smith and Meyer 2010), literature review reveals that no such work has been done on the impact of sand mining on ecology of the River Ganga.

Zhou et al. (2008) stated that the biota is the best indicator of ecological changes as it provides the data concerning the actual biological impact. The zooplankton assemblage is a sensitive indicator of the ecological status of an aquatic ecosystem since it can respond to environmental changes with rapid modifications in the species composition and structure (Jeppesen et al. 2005, Sousa et al. 2008).

The present study was conducted in the main stem of the River Ganga in and around Patna at three sites namely, Lodhi Ghat, Digha Ghat and Gai Ghat at Patna. They were selected based on intensive and extensive sand mining. The main objective of this study was to assess the impact of sand mining on abundance and diversity of zooplankton in the stretch of the River Ganga.

MATERIALS AND METHODS

Study area

The study was conducted between Doriganj and Fatuha in a stretch of about 60 km of the River Ganga in and around Patna. The study sites were located Upstream and Downstream Lodhi Ghat ($84^0$57´35´´E, $25^0$39´57´´N and $84^0$58´26´´E, $25^0$40´12´´ respectively), downstream River Son-Ganga confluence near Maner, Upstream and Downstream Digha Ghat ($85^0$06´03´´ E, $25^0$39´48´´ N and $85^0$06´13´´E, $25^0$38´24´´N respectively) near Jai Prakash Bridge and Upstream and Downstream Gai Ghat ($85^0$18´´17´´E, $25^0$34´28´´N and $85^0$18´26´´E, $25^0$34´35´´N respectively) just upstream Gandak-Ganga confluence and

Fig. 1. Map of the River Ganga showing three different sand mining sites in and around Patna.

close to Mahatma Gandhi Bridge at Patna (Fig. 1). Sampling was done at about 50-60 meter upstream and downstream each sand mining site. Upstream (Us) of sand mining site is referred to as reference site and downstream (Ds) of sand mining location site is referred to as impact site in this study.

Sample collection and processing

The zooplankton in freshwater comprises mainly of rotifers, cladocerans and copepods. Qualitative and quantitative analysis of the zooplankton is important not only to assess the species diversity but for monitoring of the river water quality. The plankton samples were collected for quantitative and qualitative studies. For quantitative examination, plankton sample was collected by filtering 50 l of water through plankton net (made up of bolting silk number 21 with 77 mesh/cm^2) and for qualitative examination, the plankton net was dragged at 45^0 angle for few minutes in a limnetic zone of the lake. The plankton were preserved in 5% formalin solution at the site and then brought to the laboratory for qualitative and quantitative analysis. Identification was done using Sedgwick-Rafter cell and Trinocular Research Microscope, Microlux-11 of Kyowa, Tokyo with the help of standard texts like, Alfred et al. (1973), Michael and Sharma (1988), Sharma (1983, 1986, 1987, 1988), Tonapi (1980), Vasisht and Sharma (1976), Ward and Whipple (1992).

The densities of Rotifers,Cladocerans and Copepods and densities of individual zooplankton species were done by Alekseev (2002) Korinek (2002), Kutikova (2002) by the following equation :

$$\text{Zooplankton density} = \frac{\text{(No. of individuals in 1ml)} \times \text{(Sample volume in ml)}}{\text{Volume of water filtered (liters)}}$$

Some physical parameters like water temperature, pH, transparency and turbidity were also analyzed following standard method (APHA 1998, Trivedy and Goel 1986) physical parameters of river water were correlated with biotic components under this study.

Statistical analysis

After identification and enumeration of zooplankton, the abundance and Shannon-Weiner diversity index were calculated using Biodiversity Pro software to

Table 1. Average number of mining boats and sand extracted (ft^3/day).

Sites	Range of mining boat	Average number of mining boats	Range of sand extracted (fr^3/day)	Sand extracted (ft^3/day)
Lodhi Ghat	40-112	82 ± 23.51	48000-134400	98800 ± 28210.64
Digha Ghat	35-94	69 ± 21.46	42000-112800	82400 ±25755.78
Gai Ghat	2-6	4 ±1.47	2400-7200	5000 ± 1766.352

Table 2. Detail of Student's s t-test to compared turbidity (NTU) at reference and impact sites.

Sites	Reference sites		Impact sites		t-test (df=5)	
	Range	Mean ± SD	Range	Mean ± SD	t-value	p-value
Lodhi Ghat	12-30	21.50 ± 6.32	18-42	33 ± 9.12	6.658	0.001
Digha Ghat	6-30	15.67 ± 9.52	8-38	21 ±10.95	3.559	0.016
Gai Ghat	22-33	28.67±4.32	22-37	29.67 ± 5.16	1.369	0.229

evalute the species diversity, Margalef (1958) index to evaluate species richness. Statistical analyses of data were carried out using Student's t-test to compared the differences in density, number of species and diversity between reference site and the impact sites.

RESULTS AND DISCUSSION

The maximum number of the average sand boats were 82 ± 23.51 and sand extraction 98800 ± 28210.64 fr^3/day was observed at Lodhi Ghat whereas the lowest number of sand boats 4 ±1.47 and sand extraction 5000 ± 1766.352 ft^3/day at Gai Ghat, Patna (Table 1). The removal of sand from sand bars, known as bar skimming or scalping can lead to bar erosion, local channel widening and downstream erosion. The removal of gravel or coarse sand from bars causes a loss of the bar and increases the flow capacity of the channel by exposing the underlying finergrained sediment to erosion by high flows (Padmalal and Maya 2014). The major effect of mining activity on the surface water of any river is shown by altered turbidity (Kamboj et al. 2018).

Annual mean of turbidity varied from 15.67 ± 9.52 to 28.67 ± 4.32 NTU at reference sites of Digha Ghat, Lodhi Ghat and Gai Ghat during March 2016 to December 2017, respectively (Table 2). Annual mean of turbidity at impact sites varied from 21 ±10.95 to 29.67 ±5.16 NTU at Digha Ghat, Lodhi Ghat and Gai Ghat during March 2016 to December 2017, respectively. Student's t-test results show that mean turbidity level at reference and impact sites at Lodhi Ghat (p=0.001) and Digha Ghat (p=0.016) differed significantly but at Gai Ghat did not differ significantly due to lesser amounts of sand mining at this location (Table 2). The turbidity of water increased which may be attributed to increase in suspended particulate matters caused by the process of dredging (Dankers 2002). The annual mean of transparency at all study sites on the Ganga mainstream ranged between 0.75 m and 1.2 m at reference sites whereas 0.63 m and 1.15 m at impact sites from March 2016 to December 2017 (Table 3). The annual mean transparency at all study sites ranged between 0.74 ± 0.07 m at Lodhi Ghat D/S and 0.99 ± 0.0.16 m at Digha Ghat U/S. Student's *t*-test results (Table 3) show that

Table 3. Detail of Student's t-test to compared transparency (m) at reference and impact sites.

Sites	Reference sites		Impact sites		t-test (df=5)	
	Range	Mean ± SD	Range	Mean ± SD	t-value	p-value
Lodhi Ghat	0.78 - 0.98	0.87 ± 0.05	0.63 - 0.92	0.74 ± 0.07	7.65	0.0006
Digha Ghat	0.79 - 1.2	0.99 ± 0.16	0.71 - 1.15	0.92 ± 0.16	6.74	0.0010
Gai Ghat	0.75 - 0.88	0.81 ± 0.05	0.73 - 0.86	0.79 ± 0.05	11	0.0001

Table 4. Zooplankton in River Ganga at in and around Patna during (March 2016–December 2017).

Order S↓	Taxa↓	Reference sites species ↓	Impact sites species↓
Rotifera	*Anuraeopsis coelata* (De Beauchamp 1992)	-	+
	Anuraeopsis fissa (Gosse 1851)	+	+
	Anuraeopsis sp.	+	+
	Ascomorpha ecaudis	+	+
	Ascomorpha sp.	+	+
	Asplanchna brightwelli (Gosse 1850)	+	+
	Asplanchna priodonta (Gosse 1850)	+	+
	Brachionus angularis (Gosse 1851)	+	+
	Brachionus bidentata (Anderson 1889)	+	+
	Brachionus budapestinensis (Daday 1885)	+	+
	Brachionus calyciflorus f. amphiceros (Ehrenbergh 1838)	+	+
	Brachionus calyciflorus f. anuraeiformis (Brehm 1909)	+	-
	Brachionus caudatus f. acculeatus (Hauer 1937)	+	+
	Brachionus caudatus f. majusculus	+	+
	(Ahlstrom 1968)	+	+
	Brachionus caudatus f. personatus (Ahlstrom 1940)	+	+
	Brachionus falcatus (Zacharias 1898)	+	+
	Brachionus forficula (Wierzejski 1891)	+	+
	Brachionus quadridentatus (Hermann 1783)	+	-
	Brachionus rubens (Ehrenberg 1838)	+	-
	Cephalodella gracilis (Ehrenberg 1832)	+	+
	Cephalodella sp.	+	-
	Colurella uncinata	+	+
	Conochilus	+	+
	Elosa worellri	+	+
	Filinia longiseta (Ehrenberg 1834)	+	+
	Keratella cochlearis	+	+
	Keratella lenzi (Hauer 1938)	+	+
	Keratella procurva	+	-
	Keratella tropica (Apstein 1907)	+	+
	Lecane internis	+	-
	Lecane pyriformis	+	-
	Lecane ungulata (Gosse 1887)	+	+
	Platyias leloupi	-	+
	Polyarthra vulgaris (Garlin 1943)	+	-
	Polyathra sp.	+	+
	Pompholyx sulcata (Gosse 1851)	+	+
	Testudinella elliptica	+	+
	Testudinella patina (Herman 1783)	-	+
	Trichocera verfalis	-	+
	Trichocerca similis (Wierzejski 1893)	+	+
	Trichocerca sp.	+	+
Cladocera			
	Bosmina sp.	+	+
	Bosmina longirostris (Muller OF 1776)	+	+
	Bosminopsis deitersi (Richard 1895)	+	-
	Macrochaetus collinri	+	-
Copepoda			
	Cletocamptus albuguerquensis (Herrick 1895)	+	+
	Cyclops sp.	+	+
	Heliodiaptomus chelospinus	+	-
	Nauplius sp.	+	+
	Spicodiaptomus sp.	+	-
	Total (50)	46	38

Table 4. Continued.

mean transparency level at reference and impact site at Lodhi Ghat (p=0.0006), Digha Ghat (0.0010) and Gai Ghat (p=0.0001) differed significantly.

The transparency of water decreased may be due to the increasing concentration of suspended particle and resuspension of sediment particle caused by the process of dredging (Dankers 2002). High turbidity decreases the ability of water to transmit light. According to Owens et al. (2005), sand mining impacts the physical condition of the river including the sediment-laden plumes which reduce the depth of light penetration in water. Krishnamoorthi et al. (2011) reported primary productivity in the river may be reduced because of high turbidity.

A total of 50 species of zooplankton belonging to three taxonomic groups were recorded during the two years of the study (Table 4). The taxa of Rotifera, Cladocera and Copepoda were represented by forty-one, four and five species respectively (Table 4). The maximum number of zooplankton sp. twenty nine was found at Lodhi Ghat (reference site) whereas the lowest number of species fifteen was found at Digha Ghat and Gai Ghat (impact site). There was reduction in number of rotifer, cladoceran and copepod to the tune of 10.81% , 50% and 40% species at impact sites compared to the reference sites during the study, due to the water quality deterioration cspecially the transparency and turbidity at the respective area. *Anmaeopsis coclata. Platyias leloupi, Testudinella patina* and *Trichocera verfalis* were present only at the impact site for unknown reasons.

Table 5. Range, Mean, SD and t-test of individual, total no. species and diversity at Lodhi Ghat.

	Lodhi Ghat					
	Reference sites		Impact sites		t-test (df=5)	
	Range	Mean and SD	Range	Mean and SD	t-stat	p-value
Individual/l	11.4 - 18.9	15.25 ±2.87	3.9 - 14.1	6.95 ±4.48	4.017	0.010
Total no. of species	10 - 20	15 ±3.58	7 - 17	10 ± 3.74	5.000	0.004
Shannon H´ Log Base 2.718	1.79 - 2.82	2.38 ±0.35	1.82 - 2.55	2.07 ± 0.29	3.596	0.016

The density of zooplankton at the upstream site of Lodhi Ghat ranged from 11.4 to 18.9 individual/l (annual mean 15.25 ±2.87) while at downstream site it ranged from 3.9 to 14.1 individual/l (annual mean 6.95 ± 4.48) respectively. The pooled Shannon's diversity index of zooplankton ranged between 2.38 ± 0.35 and 2.07 ± 0.29 while mean total number species of zooplankton ranged between 15 ± 3.58 and 10 ± 3.74 at reference site and impact sites of Lodhi Ghat respectively (Table 5). Student's t-test results (Table 5) show that average of density (p=0.010), no. of species (p=0.004) and Shannon diversity index (p=0.016) of zooplankton at reference and impact sites of Lodhi Ghat differed significantly.

The density of zooplankton at upstream site of Digha Ghat ranged from 6.90 - 13.50 individual/l (annual mean 10.70 ± 2.45) while at downstream site it ranged from 2.10 - 4.50 individual/l (annual mean 3.15 ± 0.80) respectively. The pooled Shannon's diversity index of zooplankton ranged between 2.09 ± 0.16 and 1.53 ±0.16 while mean total number species of zooplankton ranged between 10.50 ±1.38 and 5.83 ±1.17 at reference site and impact sites of Digha Ghat respectively (Table 6). Student's t-test results (Table 6) show that mean of density (p = 0.001), no . of species (p=0.001) and diversity (p=0.0005) of zooplankton at reference and impact sites of Digha Ghat differed significantly. In this study, the average density, total no. of species and diversity of zooplankton at reference and impact sites of Lodhi Ghat and Digha Ghat differed significantly in the River Ganga, which may be related to the disturbances due to sand mining, as the maximum sand extraction was found at Lodhi Ghat (98800 ft^3/day), followed by Digha Ghat (82400 $feet^3$/day).

Sand mining increases levels of suspended solids, in the overlying water column, which in turn leads to higher turbidity levels. This can directly affect the aquatic system by decreasing the water transparency. Supriharyono (2004) revealed that the reduction of light penetration affect the primary production of the ecosystem and ultimately affect zooplankton because zooplankton nibble on phytoplankton (Castro and Huber 2005). This may be one of the factors affecting zooplankton population (Castro and Huber 2005). Yen and Rohasliney (2013) told that increase in suspended contents may affect the zooplankton by reducing the food particles that are captured and by clogging the feeding system. Ekwu and Sikoki (2013) reveals that creation of sediments laden plumes during sand mining, results in clogging and killing of micro aquatic biota, mostly the plankton. McCabe and O' Brien (1983) also found that suspended sediments may affect the abundance of cladocerans by decreasing their survival and fecundity. Several studies indicate that sand mining may affect the zooplankton diversity

Table 6. Range , Mean, SD and t-test of individual, total no. species and diversity at Digha Ghat.

	Digha Ghat					
	Reference sites		Impact sites		t-test (df=5)	
	Range	Mean and SD	Range	Mean and SD	t-stat	p-value
Individual/l	6.90 - 13.50	10.70 ±2.45	2.10 - 4.50	3.15 ± 0.80	7.947	0.001
Total no. of species	9.00 - 12.00	10.50 ±1.38	5.00 - 8.00	5.83 ±1.17	7.593	0.001
Shannon H´ Log Base 2.718	1.93 -2.28	2.09 ± 0.16	1.30 - 1.77	1.53 ± 0.16	8.114	0.0005

Table 7. Range, Mean, SD and t-test of individual, total no. species and diversity at Gai Ghat.

	Gai Ghat					
	Reference sites		Impact sites		t-test (df=5)	
	Range	Mean and SD	Range	Mean and SD	t-stat	p-value
Individual/l	6.00 - 17.10	11.60 ± 4.82	4.20 - 11.10	8.05 ± 2.73	3.840	0.012
Total no. of species	9.00 - 12.00	10.50 ± 1.38	8.00 - 10.00	9.17 ± 0.98	2.169	0.082
Shannon H' Log Base 2.718	1.99 - 2.31	2.10 ± 4.22	1.85 - 2.11	1.97 ± 0.10	1.913	0.114

(Garrido et al. 2003, Vandysh 2004).

The density of zooplankton at upstream Gai Ghat ranged from 6.00 - 17.10 individual/l (annual mean 11.60 ± 4.82) while at downstream site it ranged from 4.20 - 11.10 individual/l (annual mean 8.05 ± 2.73) respectively. The pooled Shannon's diversity index of zooplankton ranged between 2.10 ± 4.22 and 1.97 ± 0.10 while mean total number of species of zooplankton ranged between 10.50 ± 1.38 and 9.17 ± 0.98 at reference site and impact sites of Gai Ghat respectively (Table 7). Student's t-test results (Table 7) show that mean density (p=0.012), of zooplankton at reference and impact sites of Gai Ghat is differed significantly due to impact of sand mining. Student's t-test results (Table 7) show that Mean of no. of species (p=0.082) and diversity (p=0.114) of zooplankton at reference and impact site of Gai Ghat did not differ significantly because the relatively low number of mining boats (4) and less sand extraction (5000 feet^3/day), at this site. The present findings also corroborate with Castro and Huber (2005), Ekwu and Sikoki (2013), Yen and Rohasliney (2013).

CONCLUSION

Indiscriminate mining of river sand and gravel is one of the potential threats to many of the aquatic habitats by bed degradation, lower water levels and channel degradation. Mining of sand to the tune of 2400 to 134400 ft^3/day from three sand mining sites can impose marked changes in the abundance and diversity of zooplankton of the River Ganga. Increase in turbidity and decrease in transparency of the physico-chemical attributes responsible for the observed changes in the abundance and diversity of zooplankton.

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