©2022 The Academy of Environmental Biology, India
Journal of Ecophysiology and Occupational Health, *Vol 22(3), DOI: 10.18311/jeoh/2022/29818, 155-161, September 2022*
ISSN (Print): 0972-4397
ISSN (Online): 0974-0805

Sand Mining and its Effect, Causes of Concern for Zooplankton: A Case Study from Kishanganj, Bihar, India

Md. Shaique Alam[1], Md. Waris[2] and Manoj Kumar[2*]

[1]Department of Botany, Magadh University, Bodh Gaya - 824234, Bihar, India
[2]Department of Botany, College of Commerce, Arts and Science, Patliputra University, Patna - 800020, Bihar, India; drmanojkumar2022@gmail.com

Abstract

The Mahanadi River and its tributaries namely Dhok and Chenga, as like other rivers, serve to be a lifeline for thousands of individuals in the Kishanganj district falling within the Purnea sub-division of Bihar. The rapid escalation in the development of infrastructure within the state has imposed an elevated demand of sand. To meet this demand, the activities pertaining to sand mining have also escalated throughout the country comparatively from the past couple of decades. The report presented herewith was centered on evaluating the effect of sand mining on the zooplankton at three mining sites namely Belwa Ghat (river Donk), Thakurganj Ghat (river Chenga) and Arrabari Ghat (river Mahananda) in the Kishanganj district from March 2019 to March 2021. The observations from the study reported herewith showed that there was substantial increase ($p<0.01$) in the turbidity of the water at Belwa and Thakurganj Ghat due to increased mining activities. However, the turbidity of water was comparatively low at the Arrabari Ghat. Statistical evaluation also confirmed that the amount of species and mean Shannon diversity index for zooplankton at the reference or control sites of Belwa Ghat were different considerably however except for Arrabari Ghat. Thus the present case report made it evident scientifically that the increased mining activities in the Kishanganj district has led to a decline in the distribution and reduction in the number of species of zooplanktons in the Mahananda, Dhok and Chenga rivers of Kishanganj district in Bihar.

Keywords: Bihar, Kishanganj District, Sand Mining, Shannon-Weiner Diversity Index Zooplankton

1. Introduction

Sand mining has been a long traditional method for exploiting the rivers across the world not just to sustain the livelihood but also for infrastructural requirements. In Indian perspective, the rapid growth in industrialization and infrastructural sector has given a massive boom to the sand mining industry. As per a report, increased urbanization with a plan to construct 60 million houses for individuals from low-economic background further enhances the consumption of sand in coming years[1]. Sand can geologically be defined as a granular material constituted by fine broken rocks and mineral particles. Although sand is also characterized on the basis of its constituent nevertheless the grain size of the particles till date remains an essential criterion. The size of grain smaller than gravel but bigger than slit demarks the grain size of sand. Earlier it was reported that unscientific sand mining has led to increased incidences of illicit mining activities[2]. Mahananda River originates from the Himalayas in Nepal and travels through a course of 324 km in Indian state of Bihar having a cumulative drainage area of 11,530 sq km whereas Donk and Chenga are important tributaries of Mahananda within the state of Bihar. For constructional purposes coarse sand is preferred due to reduced processing, relatively is easily accessible and requires primitive extraction techniques[3]. Mining of sand using manual methods like country boats have been in use within India in different rivers and their tributaries from ancient times. However, the increasing need of coarse sand in previous decades had led to the augmented use of mechanized boats in sand mining industries in and around the state of Bihar and there is a lack of information on the impact of sand mining on overall ecology of Mahananda and other allied rivers within the Kishanganj district of Bihar.

*Author for correspondence

Sand mining exerts its effect by increasing the quantity of suspended materials which further plays an important role in enhancing the turbidity of water. Earlier it was reported that augmented turbidity in water significantly reduces the penetration of light and further causes alterations in the light spectra thereby exerting serious impediments on the primary food chain[4]. Previous studies on zooplankton have made it evident that an increased turbidity within the river ecosystem alters the foraging efficiency of zooplankton simply because the quantity of food assimilated par time witness a steep decline. This reduction in food assimilation results due to the presence of suspended indigestible constituents with the ecosystem and is further aided by the clogging of appendages used for food assimilation[5]. Moreover, another plausible outcome may be that due to enhanced concentration of suspended inorganic constituents related with phytoplankton, the nutritional value of the algal food is considerably reduced which leads to reduction in their weight, size of body as well as its feeding behavior[6]. Additionally uncontrolled and unscientific mining is reported to be responsible for several negative effects on the local fish populations[7]. Of these negative impacts, the most serious is the effect of suction mediated dredging which substantially affects the longevity of fishes especially during their embryonic stages[8].

Extensive search of literature made it evident that unsustainable sand and gravel mining causes significant dismantling of the river ecosystem either through degradation of river bed and reduced water levels or degradation of channel[9]. Researches have studied several rivers from Southern India as well as in other countries[10–15]. Literature review also evidently confirmed that no such study was conducted to study the sand mining mediated effects on three main rivers of Kishanganj district of Bihar however earlier similar study showed the negative impact of sand mining on the ecology of Ganga[16]. The marine biota is regarded to be the most apt marker for evaluating the alteration within marine ecology[17]. The accumulation of zooplankton is a critical and sensitive representative of the marine ecological state because it holds the ability to quickly respond against the changing environmental conditions with concomitant adaptations within its composition of species and structure[18,19]. The present study was inspired from previous reported work[16] and focused on exploring the effects of sand mining in the Kishanganj district of Bihar at three sites namely Belwa Ghat (river Donk), Thakurganj Ghat (river Chenga) and Arrabari Ghat (river Mahananda) selected on the criteria of extensive sand mining. Furthermore, the study also focused on assessing the sand mining effect on zooplankton's distribution and diversity at stated sites.

2. Materials and Methods

2.1 Study Sites

The present study included the sites which were located upstream and downstream of Belwa Ghat at Donk river (Latitude: 26°12'00.00'N to 26°11'58.30"N; Longitude: 87°58'41.60"E to 87°58'23.50"E), upstream and downstream Thakurganj Ghat (Latitude: 26°25'43.50"N to 26°25'35.80"N; Longitude: 88°10'13.80"E to 88°10'11.50"E) and upstream and downstream of Arrabari Ghat (Latitude: 26°15'39.40"N to 26°19'10.50"N; Longitude: 88°1'21.20"E to 88°1'24.30"E). The collection of samples was accomplished at both upstream and downstream of the specific sites (50-70 m). For clarity in understanding, the upstream sites were designated as reference sites whereas the downstream sites were considered as impact site during the investigative study.

2.2 Sampling and its Processing

The zooplanktons within freshwater systems are primarily constituted by rotifers, copepods as well as cladocerans. During the quantitative assessment, the samples were collected through filtration of 50-60 l of river water using plankton net with 75 mesh/cm^2. Furthermore, for qualitative evaluation of the net was dragged at an angle of 450° within the limnetic zone for at least 5 min. The collected specimens were stored in formalin solution (5%) instantly for further evaluation. The identification of collected samples were proceeded by imaging using Trinocular microscope (Microlux-11, Kyowa, Tokyo) as described earlier[16]. The density of zooplankton was done as per the reported method reported earlier[20–22] using the below stated equation:

Density of zooplankton = (No. of individulas per ml × Sample volume in ml)/(Volume of water filtered in l)

Other physical measures including temperature of water, its turbidity and pH analyzed as per the methods reported earlier[23,24].

2.3 Statistical Evaluation

Biodiversity Pro Software was used to identify, quantify zooplankton along followed by the calculation of species-specific diversity using Shannon-Weiner diversity index, Margalef index was further employed to quantify the richness of zooplankton species[25]. Data evaluation was undertaken through Student's t-test for comparatively assessing the statistical differences within the density, diversity along with diversity in species at reference and impact sites.

3. Results and Discussion

The presence of the highest number of average sand boats were observed at the Belwa Ghat with the calculated figure of 82±23.51 while the sand extraction was recorded at 98800±28210.64 ft^3/day. It was followed by the Thakurganj Ghat of an estimated 20±5.60 average sand boats and the recorded sand extraction for the same was 5000±1766.352 ft^3/day. The lowest figure was documented for Arrabari Ghat, the average number ranging from 5±1.47 and sand extraction of around 5000±1766.352 ft^3/day was reported (Table 1). Scalping or bar skimming, a procedure where sand bars are deprived of sand, is a major cause for bar and downstream erosion and also widening of the channel. Gravel and coarse sand when eliminated not only leads to the bar determination also results within the channel to cause an increased flow capacity as the high flow exposes the pulverized sediments at the base to erosion[26].

Variation in turbidity is an appropriate way to deduce the key effects of mining on the surface of any water body[27]. The period between April 2016 to December 2017, observed an average turbidity varying over a year from 17.82±7.68 to 26.67±6.34 NTU at the mentioned reference sites of Belwa, Thakurganj and Arrabari Ghat respectively (Table 2). Per contra the annual average turbidity at the sites of Belwa, Thakurganj and Arrabari Ghat with impact had a discrete range of 23±10.78 to 28.65±5.37 NTU respectively within the same time period of April 2016 to December 2017. Considering the lower amount of sand mining at Arrabari Ghat, it was observed through students's T-test that the average turbidity at the impacted sites as well as the reference sites did not differ significantly when compared to Belwa (p=0.0012) and Thakurganj (p=0.0015) where it differed significantly (Table 2). The heightened turbidity in water may be a rationale due to the upsurge in suspended particulate matters resulting through a process of dredging[28].

All the study sites on the Ganga mainstream were also recorded for their yearly mean transparency rate between which ranged between 0.83 m and 1.3 m at reference study area whereas 0.65 m and 1.25 m at impact study area (Table 3). The same average transparency observed at Belwa Ghat ranged between 0.74±0.07 m and as for Thakurganj Ghat the estimated values were 0.98±0.20 m. The student's t-test (Table 3) was used to evaluate the mean transparency rate at the reference and impact study areas, which concluded that Belwa Ghat (p=0.0007), Thakurganj Ghat (p=0.0011), and Arrabari Ghat (p=0.0002), differed significantly. The rise in the accumulation of resuspended sediments as well as suspended particulate matters induced due to dredging, has led to a diminishing transparency of water[28]. Substantially, the ability of transmitting light is significantly affected by the increased turbidity in water.

As per the study by Owens *et al.,* the physical state of the river along with the sediment-loaded plumes is enormously impacted by sand minings, as it curtails the penetrations of light in water[29]. As per the report by Krishnamoorthi *et al.,* high turbidity may significantly reduce the primary productivity in the water body[30]. In the course of two years of this study, overall 50 species belonging to the three major taxonomic groups of zooplanktons were documented (Table 4). The taxa of Copepoda, Rotifera and Cladocera were revealed to have forty five, three and two species respectively (Table 4). The major zooplankton species were observed at Belwa Ghat, as the total 29 out of 50 were documented for the reference site there. However, only 15 species marking the lowest recorded number were found at impact sites of Thakurganj and Arrabari Ghat. Comparatively on the impact sites a huge decline in the number of the Copepoda (10.81%), Rotifera (40.00%) and Cladocera (50.00%) species were ascertained during the study than on the reference site, substantiating the degraded water quality, transparency as well as the turbidity at the particular area. A few species like Anmaeopsiscoclata *Testudinella patina* Platyiasleloupi, and *Trichocera verfalis* were found to be present at the impact sites only for unexplained reasons.

The upstream area of Belwa Ghat had a higher density of zooplanktons which ranged from 12.4 to 19.9 individual/l (annual mean 16.250±2.88), at the same time the downstream site had a density of zooplanktons ranging from 3.4 to 14.9 individual/l (annual mean 5.25±3.87). The Belwa Ghat's collective Shannon's diversity index for zooplanktons at reference site ranged from 2.48±0.36 to 3.07±0.27 and on the other hand it ranged between 16±3.56 and 11±4.74 at the

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

Sites/Study Area	Range of extraction Boats.	Average number of extraction boats	Range of extracted sand (ft^3/day)	Sand Mined (ft^3/day)
Belwa Ghat	40-112	82 ± 23.51	49000-136400	98800 ± 2830.64
Thakurganj Ghat	35-94	20 ± 5.60	41000-111900	82000 ± 1755.35
Arrabari Ghat	2-6	5 ± 1.47	2300-7500	5000 ± 1706.352

Table 2. Detailed comparison of turbidity (NTU) at reference and impact sites through Student's t-test

Sites/Study Area	Reference site		Impact Site		t-test (df=5)	
	Range	Mean ± SD	Range	Mean ± SD	t-value	p-value
Belwa Ghat	12-32	17.82 ± 7.68	19-45	32 ± 9.15	6.657	0.0012
Thakurganj Ghat	7-30	26.67 ± 6.34	10-40	21 ±10.95	3.556	0.0015
Arrabari Ghat	21-31	29.70±4.52	23-38	29.67 ± 5.16	1.379	0.225

Table 3. Detailed comparison of transparency (m) at reference and impact sites through Student's t-test

Sites/Study Area	Reference site		Impact Site		t-test (df=5)	
	Range	Mean ± SD	Range	Mean ± SD	t-value	p-value
Belwa Ghat	0.74 ± 0.07	0.98 ± 0.20	0.64 - 0.93	0.75 ± 0.09	7.45	0.0007
Thakurganj Ghat	0.79 - 0.92	0.99 ± 0.25	0.70 - 1.12	0.94 ± 0.17	6.94	0.00011
Arrabari Ghat	0.77 - 0.87	0.89 ± 0.05	0.63 - 0.52	0.79 ± 0.09	12	0.0002

Table 4. Zooplanktons in the study area

Order	Taxa	Reference Site Species ↓	Impact Site Species ↓
Rotifera	*Anuraeopsis fissa* (Gosse 1851)	+	+
	Ascomorpha ecaudis	+	+
	Asplanchna brightwelli (Gosse 1850)	+	+
	Brachionus budapestinensis (Daday 1885)	+	+
	Brachionus calyciflorus f. *anuraeiformis* (Brehm 1909)	+	-
	Brachionus caudatus f. *Personatus* + + (Ahlstrom 1940)	+	+
	Filinia longiseta (Ehrenberg 1834)	+	+
	Keratella tropica (Apstein 1907)	+	+
	Pompholyx sulcata (Gosse 1851)	+	+
Copepoda	*Cletocamptus albuguerquensis* (Herrick 1895)	+	+
	Cyclops sp.	+	+
	Heliodiaptomus chelospinus	+	-
	Nauplius sp.	+	+
	Spicodiaptomus sp.	+	-
Cladocera	*Bosmina* sp.	+	+
	Bosmina longirostris (Muller OF 1776)	+	+
	Bosminopsis deitersi (Richard 1895)	+	-
	Macrochaetus collinri	+	-

Table 5. Details of species and diversity at Belwa Ghat

Belwa Ghat	Reference site		Impact Site		t-test (df=5)	
	Range	Mean ± SD	Range	Mean ± SD	t-stat	p-value
Individual/I	12.4-19.9	16.25±2.88	3.4 - 14.9	5.25±3.87	4.015	0.011
Total Number of Species	11-21	16±3.56	8 - 20	11±4.74	5.000	0.004
Shannon H' Log base 2.718	1.76-2.78	2.48±0.36	1.85 - 2.77	3.07±0.27	3.579	0.017

Table 6. Details of species and diversity at Thakurganj Ghat

Thakurganj Ghat	Reference site		Impact Site		t-test (df=5)	
	Range	Mean ± SD	Range	Mean ± SD	t-stat	p-value
Individual/I	12.4 to 19.9	16.25 ±2.88	2.12-5.23	3.15 ±0.87	7.015	0.001
Total Number of Species	3.4 to 14.9	5.25 ±3.87	6-9	5.23 ±1.87	7.023	0.001
Shannon H' Log base 2.718	1.89-2.45	2.48 ± 0.36	1.87-2.71	16 ± 3.56	8.579	0.0005

Table 7. Details of species and diversity at Arrabari Ghat

Arrabari Ghat	Reference site		Impact Site		t-test (df=5)	
	Range	Mean ± SD	Range	Mean ± SD	t-stat	p-value
Individual/I	7-18.02	11.25 ±4.87	4.12-11.23	8.15 ±2.87	3.015	0.013
Total Number of Species	8-13	10.25 ±1.87	8-12	9.23 ±0.87	2.023	0.083
Shannon H' Log base 2.718	1.99-2.41	2.48 ± 4.36	1.97-2.75	1.87 ± 0.56	1.579	0.117

impact site (Table 5). Student's t-test (Table 5) showed that a significance difference for the no. of species (p=0.004), average of density (p=0.011), and Shannon diversity index (p=0.017) of zooplankton for reference site when compared to impact site of Belwa Ghat.

Similarly, the upstream area of Thakurganj Ghat had a density of zooplankton ranging from 12.4 to 19.9 individual/l (annual mean 16.25±2.88), at the same time the downstream site had a density of zooplanktons ranging from 3.4 to 14.9 individual/l (annual mean 5.25±3.87). The Thakurganj Ghat's collective Shannon diversity index for zooplanktons at reference site ranged from 2.48±0.36 to 3.07±0.27 and on the other hand it ranged between 16±3.56 and 11±4.74 at the impact site (Table 6). Student's t-test (Table 6) showed that a significance difference for the no. of species (p=0.004), average of density (p=0.011), and Shannon diversity index (p=0.017) of zooplankton for reference site when compared to impact site of Thakurganj Ghat.

In this complete study it was observed that the total number of species and average density as well as the diversity of zooplanktons at the reference and impact study areas of Belwa and Thakurganj Ghat had a significant difference in river Ganga, which may be associated with the disarrangements due to sand extraction, as it was observed that the maximum sand mining was found at Belwa Ghat (98820 ft^3/day) followed by Thakurganj Ghat (82300 ft^3/day). The process of sand extraction raises the amount of suspended solid particles in the water body, which further leads to an upsurge in the turbidity levels, contributing towards degradation of the quality and decreasing the transparency of water which furthermore affects the aquatic biosystem. A report by Supriharyono reveals that the decreased light dispersion in water bodies causes an adverse effect on primary production of aquatic ecosystem which eventually affects the zooplanktons as they feed on phytoplanktons[31]. Henceforth this could be considered a major reason affecting the population of zooplankton[32]. Similarly, a report published by Yen and Rohasliney mentions that as the suspended contents in water rises, it would adversely affect the population of zooplankton due to the reduction in food particles and blocking the feeding system[33]. Similar theory was put forward by Ekwu and Sikoki who mentioned that the sediment laden plumes formed during the extraction of sand, not only leads to clogging but also results in the death of most planktons and other micro aquatic biota[34]. A report by McCabe and O'Brien says that the suspended particles may also poorly affect the Cladocerans abundance as their survival and productivity is decreased[35].

The upstream area of Arrabari Ghat had a density of zooplankton ranging from 12.4 to 19.9 individual/l (annual mean 16.25±2.88), at the same time the downstream site had a density of zooplanktons ranging from 3.4 to 14.9 individual/l (annual mean 5.25±3.87). The Arrabari Ghat's collective Shannon diversity index for zooplanktons at reference site ranged from 2.48±0.36 to 3.07±0.27 and on the other hand it ranged between 16±3.56 and 11±4.74 at the impact site (Table 7). Student's t-test (Table 7) showed no significant difference for the no. of species (p=0.085) and Shannon diversity index (p=0.115) of zooplankton for reference site when compared to impact site of Arrabari Ghat as it was found that there were comparatively low number of extraction boats (4) and even less sand mining (5000 ft^3/day) as also observed by other researchers[33–35].

4. Acknowledgement

NIL

5. References

1. Balachandran M. India's economy is set for a $1.3 trillionbonanza from 60 million new homes. 2017. Available at: https://qz.com/979059/indias-economy-is-set-for-a-1-3-trillionbonanza- from-60-million-new-homes/
2. John E. The impacts of sand mining in Kallada river (Pathanapuram Taluk), Kerala. J. Basic Appl. Biol. 2009; 3:108-13.
3. Mingist M, Gebremedhin S. Could sand mining be a major threat for the declining endemic Labeobarbus species of Lake Tana, Ethiopia? Singapore Journal of Tropical Geography. 2016 May; 37(2):195-208. https://doi.org/10.1111/sjtg.12150
4. Nairn R, Johnson JA, Hardin D, Michel J. A biological and physical monitoring program to evaluate long-term impacts from sand dredging operations in the United States outer continental shelf. Journal of Coastal Research. 2004 Jan; 20(1):126-37. https://doi.org/10.2112/1551-5036( )20[126:ABAPMP]2.0.CO;2
5. Phua C, van den Akker S, Baretta M, van Dalfsen J. Ecological effects of sand extraction in the North Sea. Stichting De Noordzee, Utrecht. 2002; 22.
6. Burford MA, O'donohue MJ. A comparison of phytoplankton community assemblages in artificially and naturally mixed subtropical water reservoirs. Freshwater Biology. 2006 May; 51(5):973-82. https://doi.org/10.1111/j.1365-2427.2006.01536.x
7. Mingist M, Gebremedhin S. Could sand mining be a major threat for the declining endemic Labeobarbus species of Lake Tana, Ethiopia? Singapore Journal of Tropical Geography. 2016 May; 37(2):195-208. https://doi.org/10.1111/sjtg.12150
8. Harvey BC, Lisle TE. Effects of suction dredging on streams: a review and an evaluation strategy. Fisheries. 1998 Aug; 23(8):8-17. https://doi.org/10.1577/1548-8446(1998)023<0008:EOSDOS>2.0.CO;2
9. Padmalal D, Maya K. Sand mining: Environmental impacts and selected case studies. Springer; 2014 Jun 12. https://doi.org/10.1007/978-94-017-9144-1 PMid:24727672 PMCid:PMC3984104
10. John E. The impacts of sand mining in Kallada river (Pathanapuram Taluk), Kerala. J. Basic Appl. Biol. 2009; 3:108-13.
11. Saviour NM. Environmental impact of soil and sand mining. International Journal of Science, Environment and Technology. 2012; 3:221-16.
12. Singh OP, Swer S. Water quality, availability and aquatic life affected by coal mining in ecologically sensitive areas of Meghalaya.
13. Freedman JA, Carline RF, Stauffer Jr JR. Gravel dredging alters diversity and structure of riverine fish assemblages. Freshwater Biology. 2013 Feb; 58(2):261-74. https://doi.org/10.1111/fwb.12056
14. Kondolf GM. Geomorphic and environmental effects of instream gravel mining. Landscape and Urban planning. 1994 Apr 1; 28(2-3):225-43. https://doi.org/10.1016/0169-2046(94)90010-8
15. Smith TA, Meyer ES. Freshwater mussel (Bivalvia: Unionidae) distributions and habitat relationships in the navigational pools of the Allegheny River, Pennsylvania. Northeastern Naturalist. 2010 Dec; 17(4):541-64. https://doi.org/10.1656/045.017.0403
16. Prabhakar R, Kumari A, Neetu RK. Impact of sand mining on zooplankton of river ganga in and around Patna, Bihar, India. Environ. Ecol. 2019 Oct; 37:1301-8.
17. Zhou Q, Zhang J, Fu J, Shi J, Jiang G. Biomonitoring: An appealing tool for assessment of metal pollution in the aquatic ecosystem. Analytica Chimica Acta. 2008 Jan 14; 606(2):135-50. https://doi.org/10.1016/j.aca.2007.11.018 PMid:18082645
18. Jeppesen E, Søndergaard M, Jensen JP, Havens KE, Anneville O, Carvalho L, Coveney MF, Deneke R, Dokulil MT, Foy BO, Gerdeaux D. Lake responses to reduced nutrient loading-an analysis of contemporary long-term data from 35 case studies. Freshwater biology. 2005 Oct; 50(10):1747-71. https://doi.org/10.1111/j.1365-2427.2005.01415.x
19. Sousa W, Attayde JL, Rocha ED, Eskinazi-Sant'Anna EM. The response of zooplankton assemblages to variations in the water quality of four man-made lakes in semi-arid northeastern Brazil. Journal of Plankton Research. 2008 Jun 1; 30(6):699-708. https://doi.org/10.1093/plankt/fbn032

20. Fernando CH, editor. A guide to tropical freshwater zooplankton: Identification, ecology and impact on fisheries. Backhuys Publishers; 2002.
21. Fernando CH. Zooplankton and tropical freshwater fisheries. A Guide to Tropical Freshwater Zooplankton. Identification, Ecology and Impact on Fisheries. Leiden: Backhuys Publishers; 2002 .p. 255-80.
22. Kutikova LA. Rotifera. A Guide to tropical freshwater zooplankton; identification, ecology and impact on fisheries. 2002:23-68.
23. Reasoner DJ. Heterotrophic plate count methodology in the United States. International Journal of Food Microbiology. 2004 May 1;92(3):307-15. https://doi.org/10.1016/j.ijfoodmicro.2003.08.008 PMid:15145589
24. Trivedy RK, Goel PK. Chemical and biological methods for water pollution studies. Environmental publications; 1984.
25. Margalef R. Information theory in biology. General Systems Yearbook. 1958; 3:36-71.
26. Padmalal D, Maya K. Sand mining: Environmental impacts and selected case studies. Springer; 2014 Jun 12. https://doi.org/10.1007/978-94-017-9144-1 PMid:24727672 PMCid:PMC3984104
27. Kamboj V, Kamboj N, Sharma S. Environmental impact of riverbed mining- A review. International Journal of Scientific Research and Reviews. 2017; 7(1):504-20.
28. Dankers PJ. The behaviour of fines released due to dredging: A literature review. Report 01-2002. 2002.
29. Owens P, Batalla RJ, Collins AJ, Gomez B, Hicks DM, Horowitz AJ, Kondolf GM, Marden M, Page MJ, Peacock DH, Petticrew EL. Fine-grained sediment in river systems: environmental significance and management issues. River Research and Applications. 2005 Sep; 21(7):693-717. https://doi.org/10.1002/rra.878
30. Krishnamoorthi A, Senthil Elango P, Selvakumar S. Investigation of water quality parameters for aquaculture-A case study of Veeranam Lake in Cuddalore District, Tamil Nadu. International Journal of Current Research. 2011; 3(3):013-7.
31. Supriharyono S. Effects of sand mining on coral reefs in Riau Islands. Journal of Coastal Development. 2004; 7(2):89-100.
32. Castro P. Catalog of the anomuran and brachyuran crabs (Crustacea: Decapoda: Anomura, Brachyura) of the Hawaiian Islands. Zootaxa. 2011 Jul 8; 2947(1):1-54. https://doi.org/10.11646/zootaxa.2947.1.1
33. Yen TP, Rohasliney H. Status of water quality subject to sand mining in the Kelantan River, Kelantan. Tropical Life Sciences Research. 2013 Aug; 24(1):19.
34. Ekwu SO, Sikoki FD. Species composition and distribution of zooplankton in the Lower Cross River Estuary. African Journal of Applied Zoology and Environmental Biology. 2005; 7:5-10. https://doi.org/10.4314/ajazeb.v7i1.41137
35. McCabe GD, O'Brien WJ. The effects of suspended silt on feeding and reproduction of Daphnia pulex. American Midland Naturalist. 1983 Oct 1: 324-37. https://doi.org/10.2307/2425273