



Chapter 19

Riverbed mining as a threat to in-stream agricultural floodplain and biodiversity of Ganges River, India

Nitin Kamboj and Vishal Kamboj*

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Abstract

Growth of urbanization, infrastructural and economic development activities in the last few decades all over the world have increased the demand of riverbed material for construction purposes. This high demand of materials has resulted in unsystematic and unscientific mining in in-stream and floodplain and agricultural area of the river basin and has caused severe damage in

✉ Vishal Kamboj, Email: visikamboj94@gmail.com

Department of Zoology and Environmental Science, Gurukula Kangri Vishwavidyalaya, Haridwar-249404 (Uttarakhand), INDIA.

the form of changes in channel morphology, degradation of water quality, loss of biodiversity (aquatic and terrestrial), soil erosion and loss of agricultural fields. The present study makes an attempt to know the effect of riverbed mining in in-stream and floodplain area of River Ganga. Also, suggestions have been made thereafter for the improvement of the overall River Ganga basin.

Keywords: Environmental impacts, Floodplain mining, Haridwar, In-stream mining, River Ganga, Riverbed mining

Introduction

Rivers are the main source of riverbed materials (boulder, stone and sand) and also provide habitat for many aquatic and terrestrial animals and plants (Lu *et al.*, 2007; Padmalal and Maya, 2014). Riverbed mining is an extraction activity, unrelated to the process of navigating degrading (Kondolf, 1997; Padmalal and Maya, 2014, Kamboj *et al.*, 2017). The mining process involves the displacement of bottom sediments and underlying materials and is adopted by using some mechanical or physical dredge style operation (Erskine, 2008; Erskine *et al.*, 1985). The riverbed materials like sand, gravel and boulder are mechanically removed from river channels for a variety of reasons i.e. to improve navigation, flood control, agricultural drainage, and stability of river channel and production of construction aggregate (Kondolf, 2000; Erskine, 2008). The extraction of riverbed materials: sand, gravel and boulders for construction purpose is the largest mining industry all over the world. Nowadays, the population increase has increased the demands on the riverbed materials increase to develop the urban and industrial sector (Sreebha and Padmalal, 2011). The excess amount of riverbed mining causes many problems like channel erosion, degrading of water quality, groundwater depletion, loss of aquatic habitat, loss of riparian vegetation and flood-like conditions (Kamboj *et al.*, 2012, Kamboj *et al.*, 2017). The aquatic habitat like stone and boulder, are the habitat of many fishes and other aquatic animals. Fishes are spawning into the stone and boulders where the fish eggs are protected from the predators and other factors. But due to mining these stones and boulders are removed from the riverbed which affects the population of the fishes (Kondolf, 1994; Erskine, 2008). Due to these developments, the removal of riverbed materials in in-stream and floodplain area of the rivers shows the up hazard and unscientific mining activity (Sreebha and Padmalal, 2011). The up hazard and unscientific mining create severe environmental impact in that area where an excess amount of mining occur i.e. in-stream and floodplain area. In-stream mining involves the mechanical removal of riverbed materials (sand, stone and gravel) directly from the active channel of rivers and streams. Active channel deposits are desirable as construction aggregates because they are typically strong, well-sorted, and frequently located near markets or on transportation routes. In-stream mining commonly causes morphology of the river and channel erosion, which can spread the river in upstream and downstream for kilometers (Kondolf, 1994). Floodplain mining involves the

mechanical removal of riverbed materials (sand, stone and gravel) directly from the non-active channel of rivers, river bank and agriculture field. These types of mining mainly occur in nearby areas of rivers. Floodplain mining, commonly causes nearby vegetation, agriculture area and land use of the area. Because of the high demand for raw materials, this type of mining increase in an illegal way (Langer, 2003).

River Ganga also faces these types of problems in the Haridwar district of Uttarakhand state. So the present study is carried out to know the effect of riverbed mining activity in in-stream and floodplain area of River Ganga. The altered water quality due to incorporation of different kinds of soil contaminants from the river-bed mining practices has been discussed as well.

Materials and methods

Study area

The present study was carried out from June 2017 to May 2018 in the River Ganga, near Bhogpur village in district Haridwar (Figure 19.1). Haridwar district covers an area about 2360 sq. Km in of the western part of the Uttarakhand state of India. The geo-coordinates of the district Haridwar are as follows: Latitude: 29° 56' 52.48" N Longitude: 78° 09' 36.90" E. In Haridwar district, Bhogpur

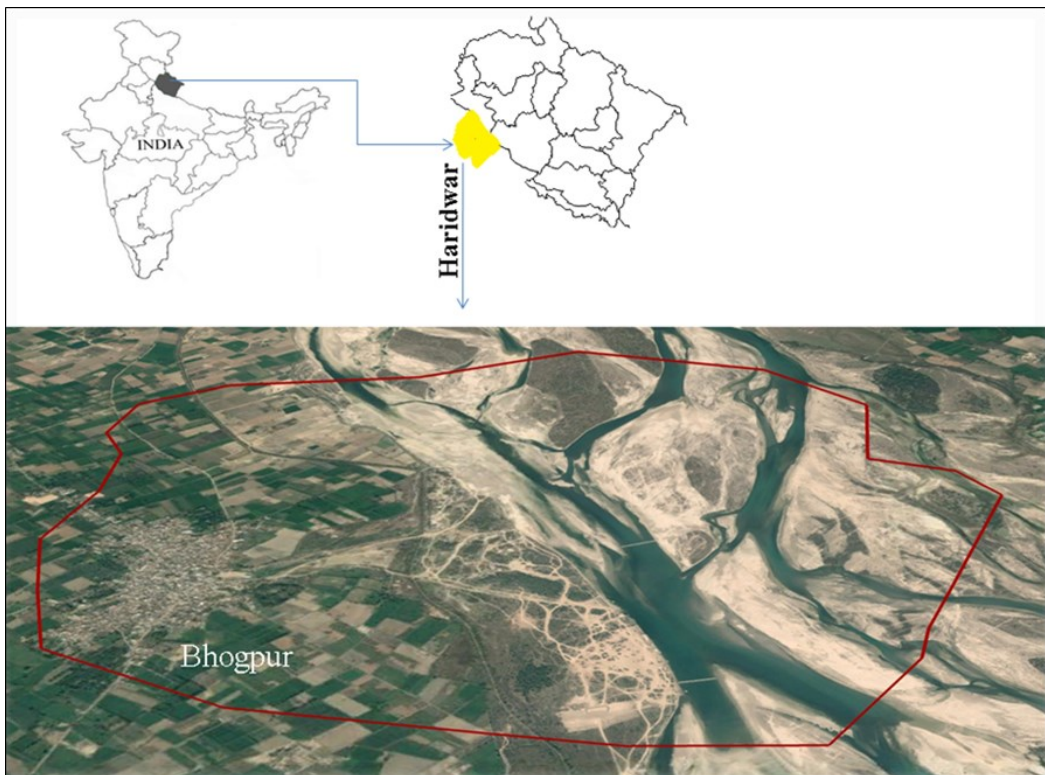


Figure 19.1. Satellite map of study area of River Ganga (Source: Google Earth).

village is famous for providing the raw material (sand, gravel and boulders) for construction purpose. The Geo-coordinates of the Bhogpur village are as follows: Latitude: 29° 51' 43.79" N and Longitude: 78° 08' 34.17" E. In Bhogpur village (Haridwar) the mining activity takes place in two ways: 1. In-stream mining 2. Floodplain mining.

Methodology for in-stream mining area

Channel morphology: The changing in channel morphology of River Ganga in two decades was analysed through satellite image (Google earth pro) and drainage map made by using QGIS (free trial version). The data was collected from the official site of USGS (Landsat 4-5 TM C1, Landsat 7 ETM+C1) to find out the changes in land use/land cover and ground survey was conducted.

Physico-chemical analysis of surface water

The Sampling of Physiographical parameters, water quality parameters (physico-chemical) and Fish fauna were performed from June 2017 to May 2018. The physiographical parameters were analysed through visualization and studied as per standard methods (Wentworth, 1922). Water samples were collected from 2 different stream orders of River Ganga in Bhogpur village by grab sampling. The water samples were collected from 8 a.m. to 10 a.m. when mining is active. A total of 15 physico-chemical parameters, water velocity, river depth, water temperature, Conductivity, pH, TDS, Analytical parameters like alkalinity, total Hardness, calcium, magnesium, dissolve oxygen (DO), BOD, sodium and potassium were analysed in the laboratory, following the standard methods (APHA *et al.*, 2012; Trivedy and Goal, 1998). Experimental fishing was carried out in the River Ganga with the help of locally hired professional fisherman. Fish species were collected with gill nets (mesh size 2.5 × 2.5 cm; 3 × 3 cm; 7 × 7 cm; length × breadth = 75 × 1.3 m; 50 × 1 m), cast nets (mesh size 0.6 × 0.6 cm), drag nets or locally called Mahajal (mesh 0.7 × 0.7 mm, L×B = 80 × 2.5 m with varying mesh size) and fry collecting nets (indigenous nets using nylon mosquito nets tied with the bamboo in both ends. All the gears except cast nets were used at least ten times during sampling. The cast nets (5.5 m²) were operated 20 times in sampling area covering about 100² meter of river segment allowing 3-5 minutes settled times in each cast. Fish species identified by Day (1875); Badola and Pant (1973).

Methodology for floodplain mining area

The Sampling of Riparian Vegetation was performed from June 2017 to May 2018. Riparian vegetation sampling was done by Quadrature method. For vegetation samples, a total of 5 sampling plots were selected on 2-3 Km stretch of River Ganga. The size of quadrates was decided by number of species-area curve and mostly 5 m × 5m for shrubs, and 1 m × 1 m for herbaceous species. Identification of the Phyto-diversity was done with the help of standard identification (Gangwar and Gangwar, 2011; Gangwar and Joshi, 2006). Data was collected by ground survey and secondary data was collected from the forest department. The data of mining activity in the agricultural field of Bhogpur village was taken with the help of photographs.

Statistical analysis of the data

The data presented in this study is mean followed by standard deviation of three replicates.

Results and discussion

Channel morphology

The change in flow energy of water and sediments has evolved the river channel in different bed forms. The flow of the river built up and maintains the river channel by deposition of sediments and erosion of nearby area (Whiting, 1998; Heede, 1986; Padmalal and Maya, 2014). Riverbed mining is one of the most devastating anthropogenic activities which affects and obstructs the natural riverbed forms. Extraction of riverbed materials targets the morphology of river and disturbs the balance of river channels by interception of the material load. The changes in channel pattern are due to the reduced supply of bed load sediments. Due to the riverbed mining activity, the main channel got divided into the various small stream orders which led to the different riverbed forms. The changes in the channel morphology of River Ganga near Bhogpur village are shown in Figure 19.2 through satellite images of 1991, 2001, 2011, and 2017. Figure 19.3 shows the drainage map of River Ganga during 1991, 2001, 2011, 2017 and demonstrates the large measurable changes in channel pattern of River Ganga over two decades.



Figure 19.2. Changing pattern of channel morphology of River Ganga in Bhogpur Village during 1991, 2001, 2011 and 2017.

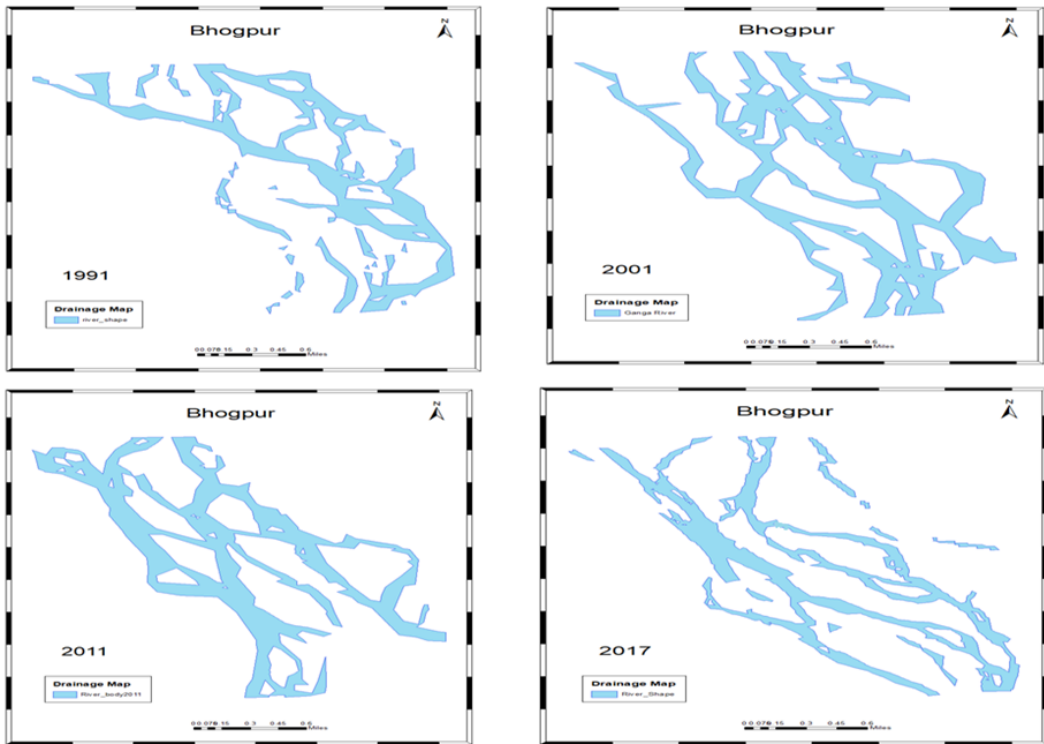


Figure 19.3. Drainage map of River Ganga shows changes in channel morphology in Bhogpur Village during 1991, 2001, 2011 and 2017.

In the past two decades, both manual and mechanical mining has changed the channel pattern in way of channel instability, changes in channel width, division of the main channel in various small stream orders and bank erosion. In the upstream mining, the head cutting of channel increase the slope of the river. Gravel bar skimming found out during the study period and it creates the instability of channel and changes the width of the river. Kondolf (1997); Kondolf and Swanson (1993) show the change in channel pattern due to the dams and gravel mining. Rinaldi (2005); Padmalal and Maya (2014); Kamboj *et al.* (2017) also described the effect of sand mining on channel morphology like changes in width, an increase of slope due to the upstream mining, instability of channel due to the downstream mining, changes in cross-sectional area of the river.

Physiographical parameters

The physiographical parameters are an important part of the river bed; it is the mixture of boulder, stone, gravel, cobbles, sand, silt and clay. The physiographical parameters of River Ganga are shown in Table 19.1. During the study period, the bottom substrate covered with 2% boulders, 16% cobbles, 22% pebbles, 15% gravel and 45% sand. The physiographical parameters important for the aquatic organisms for their reproduction process, and habitat of many aquatic organisms like benthos, fishes (Figure 19.4).

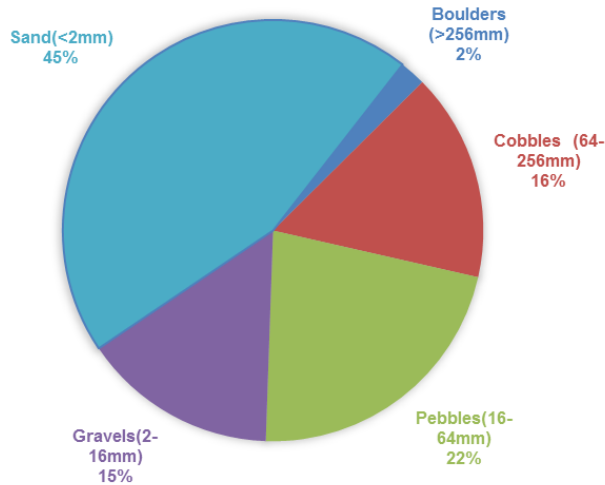


Figure 19.4. Physiographical parameters of river Ganga at Bhogpur village.

Water quality parameters

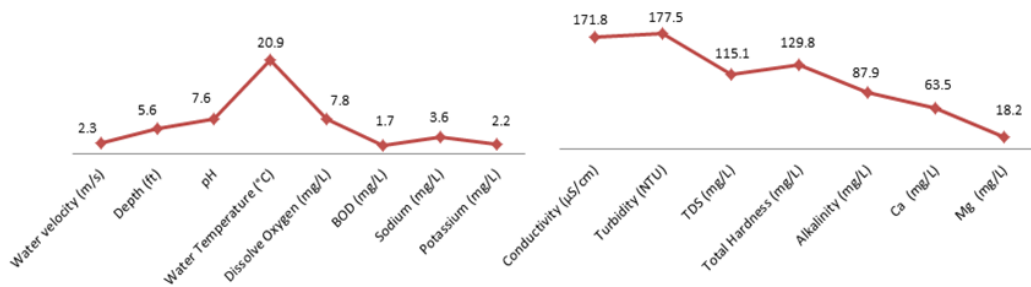
The physico-chemical parameters provide a fair idea of water quality of a water body. A total of 15 water quality parameters were selected to know the quality of River Ganga in a stretch of Bhogpur village shown in Table 19.2. Mean of water velocity 2.3 ± 1.9 m/s, average depth of river 5.6 ± 1.4 ft, average water temperature of river water $20.9 \pm 4.6^\circ\text{C}$, mean pH value of river water 7.6 ± 0.6 ; conductivity value 171.8 ± 44.7 $\mu\text{S/cm}$; TDS value of river water 115.1 ± 29.9 mg/L; turbidity value of river water 177.5 ± 204.1 NTU; dissolved oxygen of river water 7.8 ± 0.5 mg/L; biochemical oxygen demand (BOD) of river water 1.7 ± 0.6 mg/L; alkalinity of river water 87.9 ± 11.6 mg/L as CaCO_3 ; total hardness of river water 129.8 ± 16.6 mg/L, average value of calcium and magnesium 63.5 ± 9.1 mg/L and 18.2 ± 2.15 mg/L respectively, average value of sodium and potassium 3.6 ± 0.7 mg/L and 2.2 ± 0.4 mg/L respectively were recorded during the study period. All the parameters were within the permissible limit given by BIS standards 2012, except turbidity. During the study period, turbidity was higher because of the mining activity but the turbidity of water persists temporarily because of the high velocity of water (Figure 19.5).

Table 19.1. Physiographical parameters of River Ganga at Bhogpur village (Haridwar).

Physiographical variables	%
Boulders (>256mm)	2
Cobbles (64-256mm)	16
Pebbles(16-64mm)	22
Gravels(2-16mm)	15
Sand(<2mm)	45

Table 19.2. Average value of water quality of River Ganga at Bhogpur village (Haridwar).

Parameters	Mean \pm S.D.	BIS Standards (2012)
Water velocity (m/s)	2.3 \pm 1.9	----
Depth (ft)	5.6 \pm 1.4	---
pH	7.6 \pm 0.6	6.5-8.5
Conductivity (μ S/cm)	171.8 \pm 44.7	300
Water temperature ($^{\circ}$ C)	20.9 \pm 4.6	--
Turbidity (NTU)	177.5 \pm 204.1	5-10
TDS (mg/L)	115.1 \pm 29.9	500
Dissolve oxygen (mg/L)	7.8 \pm 0.5	5
BOD (mg/L)	1.7 \pm 0.6	5
Sodium (mg/L)	3.6 \pm 0.7	---
Potassium (mg/L)	2.2 \pm 0.4	---
Total hardness (mg/L)	129.8 \pm 16.6	300
Alkalinity (mg/L)	87.9 \pm 11.6	120
Ca (mg/L)	63.5 \pm 9.1	75
Mg (mg/L)	18.2 \pm 2.15	30

**Figure 19.5.** Water quality of River Ganga at Bhogpur Village.

Fish fauna

In Haridwar region, a total of 20 fish species belonging to 5 families were found in River Ganga (Table 19.3 and Figure 19.6), in which Cyprinidae family were the dominant (>60 % of total fish catch) in the riverine segment of the river Ganga, while the fish diversity diminished in Bhogpur village because of the mining activities (mining impacted area). The reason for the decline in the fish diversity in this region was found to be unscientific mining. Due to the mining activity, River Ganga got divided into the small stream orders. In the summer and winter season these stream orders are dry and all the aquatic animal's phytoplankton, zooplankton, benthos and fish were disturbed during these seasons. Stream orders are shown in Figure 19.2 and Figure 19.3. In Past decades, some researchers like Khanna *et al.* (2013); Vass *et al.* (2010); Sarkar *et al.* (2012) studied the diversity of fish in the Ganga River in lower Shivalik Himalaya and show the present status of fish in River Ganga. In the Bhogpur Patch of Ganga river, some fish species were showing the abundance, and some fish species rarely found due to the anthropogenic activities like river bed mining.

Table 19.3. Status of fish diversity in the Bhogpur village stretch of river Ganga.

Scientific Name	Common Name	Present status	Past decades fish fauna status of Ganga River	References
Family- Cyprinidae				
<i>Tor tor</i>	Mahseer	-	P	Khanna <i>et al.</i> (2013) Nautiyal <i>et al.</i> (2013) Vass <i>et al.</i> (2010) Sarkar <i>et al.</i> (2012)
<i>Cyprinus carpio</i>	China carp	+	P	Sarkar <i>et al.</i> (2012) Nautiyal <i>et al.</i> (2013)
<i>Raimas bola</i>	Indian trout	*	P	Khanna <i>et al.</i> (2013) Sarkar <i>et al.</i> (2012)
<i>Barilius bendelisis</i>	Fulra	+	P	Khanna <i>et al.</i> (2013) Sarkar <i>et al.</i> (2012)
<i>Barilius barna</i>	Gunthala	*	P	Khanna <i>et al.</i> (2013) Sarkar <i>et al.</i> (2012)
<i>Garra gotyla gotyla</i>	Gunthala	-	P	Khanna <i>et al.</i> (2013) Nautiyal <i>et al.</i> (2013)
<i>Puntius ticto</i>	Ticto barb	*	P	Khanna <i>et al.</i> (2013) Sarkar <i>et al.</i> (2012)
<i>Puntius sophore</i>	Dark mahseer	*	P	Khanna <i>et al.</i> (2013)
<i>Labeo rohita</i>	Rohu	+	P	Khanna <i>et al.</i> (2013) Sarkar <i>et al.</i> (2012)
<i>Crossocheilus latius latius</i>	Gangatic latia	*	P	Sarkar <i>et al.</i> (2012)
Family - Cobitidae				
<i>Noemachelius rupicola</i>	Gadiyal	+	P	Khanna <i>et al.</i> (2013) Nautiyal <i>et al.</i> (2013)
<i>Noemachelius beavani</i>	Gadiyal	+	P	Khanna <i>et al.</i> (2013)
<i>Noemachelius montanus</i>	Gadiyal	-	P	Khanna <i>et al.</i> (2013)
<i>Noemachelius Savone</i>	Gadiyal	-	P	Khanna <i>et al.</i> (2013) Nautiyal <i>et al.</i> (2013)
<i>Noemachelius multifasciatus</i>	Gadiyal	-	P	Khanna <i>et al.</i> (2013)
<i>Botia dario</i>	Bengal loach	*	P	Khanna <i>et al.</i> (2013) Nautiyal <i>et al.</i> (2013)
Family- Belonidae				
<i>Xenentodon cancila</i>	Needal Fish	+	P	Khanna <i>et al.</i> (2013) Sarkar <i>et al.</i> (2012) Kamboj and Kamboj (2019)
Family- Siluridae				
<i>Wallago attu</i>	Singhara	+	P	Vass <i>et al.</i> , (2010) Sarkar <i>et al.</i> (2012)
Family - Sisrodidae				
<i>Bagarius bagarius</i>	Goonch	*	P	Vass <i>et al.</i> , (2010) Sarkar <i>et al.</i> (2012)
<i>Glyptothorax cavia</i>	Nayid	*	P	Khanna <i>et al.</i> (2013) Nautiyal <i>et al.</i> (2013)

+ = Abundance/ Common, * = Rare, - = Nil, P= present, A= absent

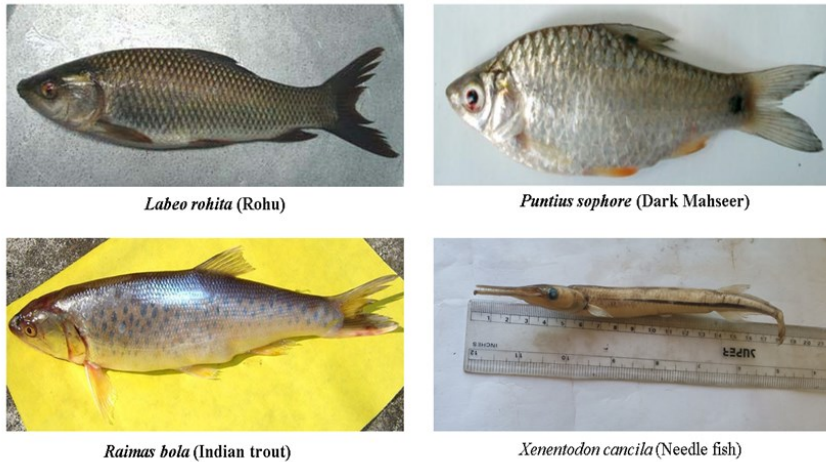


Figure 19.6. Fish species found in Ganga River near Bhogpur village.

Table 19.4. Status of floral diversity in the Bhogpur village stretch of river Ganga.

Name of Species	Common/ Local name	Present Status	Past decade status	References
Shrubs				
<i>Cannabis sativa</i>	Bhang	*	P	UFDC (2015)
<i>Cassia opaca</i>	Karonda	*	P	UFDC (2015)
<i>Cassia tora</i>	Panwar	-	P	UFDC (2015)
<i>Lantana camara</i>	Kurrii	+	P	Gangwar and Gangwar (2011); UFDC (2015)
<i>Murraya koeingli</i>	Karipatta	*	P	Gangwar and Gangwar (2011); UFDC (2015)
<i>Rubus elliptica</i>	Hisalu	*	P	UFDC (2015)
<i>Rouwolfia Serpentina</i>	Dhaura	+	P	UFDC (2015); Krishnamurti (1991)
Herbs				
<i>Cynodon dactylon</i>	Doovghas	+	P	UFDC (2015)
<i>Sida cordifolia</i>		*	P	UFDC (2015); Gangwar and Gangwar (2011); Krishnamurti (1991)
<i>Sida rhombiolia</i>	Sahadeva	*	P	UFDC (2015); Gangwar and Gangwar (2011); Krishnamurti (1991)
<i>Sida acuta</i>	Wire weed	+	P	UFDC (2015); Gangwar and Gangwar (2011); Krishnamurti (1991)
<i>Ischaemum rugosum</i>	Ribbed	*	P	Gangwar and Gangwar (2011)
<i>Parthenium hysterophorus</i>	Congress grass	+	P	UFDC (2015); Gangwar and Gangwar (2011); Krishnamurti (1991)
<i>Saccharum spontaneum</i>	Muni	-	*	Gangwar and Gangwar (2011)
<i>Tinospora cordifora</i>	Amrita	-	P	Gangwar and Gangwar (2011); Krishnamurti (1991)

+ = Abundance/ Common, * = Rare, - = Nil, P= present, A= absent

Riparian vegetation

The riparian vegetation is a link between aquatic and terrestrial ecosystem of a river. The riparian vegetation pertains to the vegetation which is found on the banks of any river. A good riparian zone was recorded on both the banks of river Ganga. The vegetation was recorded in the form of many types of shrubs and herbs shown in Table 19.4. The main factors for degradation of the riparian vegetation were the transport process of the raw material and illegal mining near the bank of the river shown in Figure 19.7.

Agriculture

Bhogpur village has a good agriculture field. The common agricultural crops are wheat, rice, popular, sugar cane. But due to the high demand of the raw materials, the agriculture area was destroyed by the illegal mining. They removed the upper layer of the agricultural field by using mechanical sources like JCB, after the removal of the fertile soil layer; they extract the stone, boulder from the lowest layer of the agricultural field shown in Figure 19.8.

Conclusion and recommendations

Unscientific and up hazard mining of riverbed materials over the years has forced irreparable damages to River Ganga ecosystem in Haridwar region. Lack of sufficient information regarding the extent of environmental impacts caused by riverbed mining is a noteworthy lacuna challenging regulatory efforts and minimizing the adverse effects of riverbed mining. The present study discloses the facts that unscientific and up hazard riverbed mining has degraded the Ganga basin in Haridwar region over the past few decades. The main degradation of riverbed mining in in-stream mining area is the changing pattern of channel morphology in last two decades and it divides the River Ganga in the various small stream orders. The changing pattern of channels has caused the degradation of water quality and aquatic biodiversity of the River Ganga. In Flood-plain mining area, the riparian vegetation has also degraded due to the transportation of the riverbed materials and due to the illegal mining, the nearby agricultural field was destroyed.

For the present study, a set of recommendations are drawn for recovering and improving the overall environmental quality of River Ganga basin in the study area.

- The Riverbed mining activity should be done in a scientific way and according to the guidelines of the Ministry of Environment Forest and Climate Change (MoEFCC) for Sand mining.
- Construction of Roads for transportation of raw materials from the river.
- River bed mining should be done manually without the use of any machinery like JCB.
- Awareness programmes to be conducted among people of that area about the various impacts of riverbed mining and immediate need for control measures.
- Training cum awareness programme should be mandatory for the people who are engaged in mining activity.



Figure 19.7. Riparian vegetation disturbed due to the transportation of Riverbed material.



Figure 19.8. Unscientific mining in the agricultural fields at Bhogpur village.

- Ban the illegal mining in agricultural fields and reclaim that area by landfilling.
- Extraction of riverbed material should be in right proportion of replenishment rate of riverbed material.

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