DAMODAR RIVER

Ecological status and trends

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

ASSESSMENT OF THE ECOLOGICAL STATUS OF DAMODAR RIVER FOR CONSERVATION PLANNING

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Preface

India being a megadiverse country, hosts a wide number of landscapes and ecosystems. A vital component of these are their riverine networks, which are in themselves a complete ecosystem. The nation's Ganga River is an internationally revered and recognised river that has been and continues to be a haven for a variety of animals and birds, making it an extremely important area with regard to biodiversity conservation. A number of tributaries make up the mighty Ganga River, of which the Damodar River is also a part. They also provide essential provisioning and regulating ecosystem services. The Wildlife Institute of India through the Biodiversity Conservation and Ganga Rejuvenation Project and National Mission for Clean Ganga funded by the Ministry of Water Resources, River Development and Ganga Rejuvenation has been working towards the conservation of Damodar River, along with all the other tributaries of Ganga River, so as to strengthen concerted efforts for restoration of its biodiversity value. For a complete scientific assessment of Damodar River, robust information on the diversity, abundance and distribution of aquatic vertebrate fauna of Damodar River, their major threats and the various drivers of these threats causing decline in their populations and habitat is collated in the present report.

As a part of the National Mission for Clean Ganga (NMCG), in the first phase, detailed biodiversity profiling of the Ganga River was carried out and subsequently the importance of its tributaries like the Damodar River in supporting biodiversity was realized. With this in mind, in phase II the project "Planning and Management for Aquatic Species Conservation and Maintenance of Ecosystem Services in the Ganga River Basin for a Clean Ganga" was envisaged to prepare a holistic restoration plan for the Damodar River through the support and involvement of stakeholders of all the Damodar states. The Wildlife Institute of India through the Biodiversity Conservation and Ganga Rejuvenation Project and this report attempts to compile biodiversity of Damodar River through literature review and Rapid Biodiversity Assessment. This report aims to develop a thorough knowledge base for the priority species of Damodar River, aid in biological restoration, and assist policy planners and managers to judiciously use water from the Damodar River, in view of the needs of the aquatic species therein.

Ruchi Badola
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EXECUTIVE SUMMARY

Damodar River is known for its destructive nature due to floods as 31 major floods occurred in the river between the years 1823 and 1943. This resulted in the formation of the Damodar Valley Corporation (DVC) in 1947 that has so far constructed 6 major reservoirs on the Damodar River and its major tributaries. Damodar River Basin (DRB) lies argely in the Deccan Peninsula (6B)biogeographic zone, with a small portion extending into the Gangetic Plain (7B). It spans a catchment area of 23,370.98 km² and experiences a humid, subtropical monsoon climate with erratic and uneven rainfall distribution across the basin. DRB comprises of tropical moist deciduous forest type with an admixture of tropical dry deciduous vegetation with over 850 plant species. The faunal diversity of the region consists of approximately 55 species of mammals, 17 species of reptiles, and 222 species of birds. However, this rich biodiversity is under constant pressure due to anthropogenic influences as open cast mining and sand mining in the upper and middle stretches of the river cause severe degradation. The water quality in this stretch is deteriorating due to the direct influx of untreated industrial effluents. This ecosystem has a unique mosaic of habitats that supports distinct biodiversity and provides essential ecosystem services which support a strong reason for its conservation and restoration.

A vehicle cum boat-based biodiversity survey approach was followed in December 2020, to identify biodiversity-rich habitats for systematic planning and conservation of the DRB. The survey was conducted from Panchet, Jharkhand to Basudevpur (Damodar-Hooghly confluence), West Bengal. In the present study, we recorded 44 species of waterbirds among which one species each is classified as Vulnerable and Near Threatened by the IUCN red list of Threatened Species. We also recorded 90 species of riparian vegetation on both the banks of the surveyed stretch of Damodar River. The anthropogenic influence scores were higher in the lower zone than the middle zone of the River as the intensity of ferry and fishing intensity along with riverbed agriculture, water extraction and livestock grazing were higher in the lower zone.

1. INTRODUCTION

Damodar River, also known as Damuda or Deonad (Mondal et al., 2018), is a rain-fed, shallow, wide, flashy river that originates in the Khamarpat Hills of Chotanagpur Plateau in Palamau district, Jharkhand at an elevation of 610 m asl (Chandra, 2003; Bhattacharyya, 2011). The total length of the Damodar River is 565 km of which 265 km flows in Jharkhand and the rest 300 km flows in West Bengal (Chandra, 2003). Geographically, DRB extends from 22°15' N to 24°30' N latitude and 84°30' E to 88°15' E longitude. The entire bain encompasses an area of 23370.98 km^2 of which 73.7% lies in Jharkhand and 26.3% lies in West Bengal (Majumder et al., 2010; Ghosh et al., 2014; DVC, 1992). The upper catchment area of DRB lying in Jharkhand, is rich in mineral and coal deposits whereas the lower catchments of DRB is a fertile stretch of recently deposited alluvium in West Bengal (Singh and Hasnain, 1999; Bhattacharyya, 2011; Ghosh and Guchhait, 2014; Ghosh and Mistri, 2015). Damodar River meets Barakar River in Dishergarh and bifurcates into Mundeshwari and Lower Damodar River near Bardhhman. The Lower Damodar River conjoins with Hooghly River at Falta, approximately 50 km downstream of Kolkata (Chandra, 2003; Bhattacharyya 2011).

Although small in size, Damodar River is notorious for its destructive capacity due to floods. Historically, from 1823 to 1943, 31 major floods occurred in the Damodar River (Chatterjee, 1967; Sen, 1991; Mukhopadhya and Dasgupta, 2010). Recurrent floods have resulted in a shift of 128 km in the course of the river (Acharrya and Shah, 2007; Rudra, 2010).

To mitigate flood damage and development of water resources, Damodar Valley Project was approved in 1947, under which 6 major reservoirs viz. Tenughat Dam (1978), Panchet Dam (1959), and Durgapur Barrage (1955) were built on Damodar mainstream; Tilaiya Dam (1953) and Maithon Dam (1957) on Barakar River; and Konar Dam (1955) on Konar River were constructed (Chandra, 2003; Ghosh et al., 2014).

1.1 Course of the Damodar River

Damodar River originates in the Kharampat hills of Palamau Hill Range of Chota Nagpur Plateau in the eastern part of Jharkhand (Krik, 1950). After traversing nearly 550 km, the river joins Hooghly River 55 km downstream of Kolkata at Chandipur (Sen, 1991; Singh et al., 2005). Of the total 550 km, 250 km of the river stretch lies in the state of Jharkhand, and the rest 300 km lies in West Bengal (Chandra, 2003).

From its origin, Damodar River follows a steady course until Mahuamilan after which it flows through a steep gradient till Tenughat Dam in Bokaro District of Jharkhand. Past Tenughat the river flows in an eastward direction till it reaches Panchet Dam at the border of Jharkhand and West Bengal. Downstream of Panchet Dam, the river enters into West Bengal and flows in an eastward manner with a relatively high gradient till Dishergarh. From Dishergarh, the river enters into the narrow flatlands and follows an easterly course till Bardhhaman where it takes a steep turn towards the south near the village Chachai, 24 km southeast of Bardhhaman (Bhattacharyya, 2011). After further southward flow, the Damodar River splits into two important channels, the Mundeshwari and the Damodar. After splitting at Bardhhaman, the Damodar river flows over the Arambagh subdivision of Hooghly district and Uluberia subdivision of Howrah district to meet the Hooghly opposite Falta (Mondal et al., 2018). Damodar River along with its major tributary Barakar constitutes the core area of the Damodar River basin. Barakar, Konar, Bokaro, Haharo, Jamnia, Ghari, Guaia, Khudia, and Bhera are the major tributaries and sub-tributaries of Damodar River (DVC 1992; CMRI 2001).

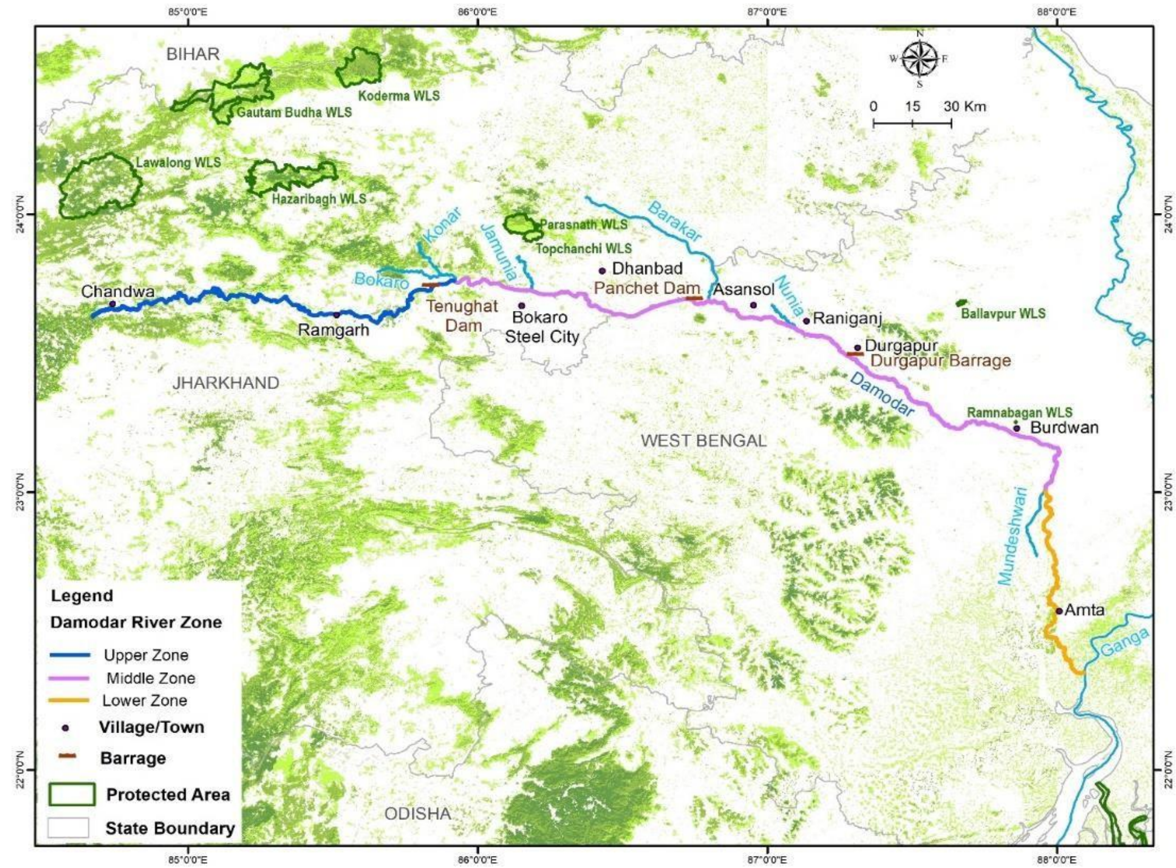

Figure 1: Zonation of the Damodar River

1.2 Geology and Geomorphology

DRB is located in the transition zone between Bengal Basin Tectonic Plate and Chota Nagpur Plateau. Normal tectonic faults oriented in the North-South direction act as a separating barrier between Bengal Basin Tectonic Plate and Chota Nagpur Plateau (Sengupta, 1972).

Based on geographical features, the entire DRB is divided into 3 segments: Upper, Middle, and Lower. The Upper and Middle catchment of DRB constitutes over $4/5^{th}$ of the total catchment area. The Upper and Middle segments are predominantly hilly with a steep slope, gullied, isolated low rounded hills, and monadnocks over the plateau (Mahadevan, 2002). The Lower segment is a narrow valley with flat terrain and deposition of new fertile alluvial soil is a prominent characteristic of the segment.

Geomorphological characters classify the entire DRB into 3 segments: Upper, Middle, and Lower. The Upper segment is formed by granites and granitic gneisses of the Archean age. The lithology of the upper catchment is quartzites, quartz-mica schists, biotite gneiss, biotite-schist, garnetiferous-gneiss and schist, acid granulites with hornblende and amphibolites of Archean age (Ghose, 1983).

Middle segment consists of sandstones and shales of Gondwana rocks with a prominent distribution of fire clay, bauxite, mica, and limestone (Singh et al., 2005) forming the catchment areas of Tenughat, Panchet, and Durgapur Barrage (Ghose, 1983).

Lower segment of DRB is characterized by tertiary rock depositions and fertile alluvium depositions due to recurrent floods (Singh et al., 1998). The substrata of the alluvium were formed during Late Jurassic to Late Cretaceous Period due to the outpouring of lava (Sengupta, 1972; Alam et al., 2003).

Upper and Middle segments of DRB are characterized by the presence of forest and mineral resources in the North and West region of the DRB. Mineral sources in the DRB region consist mainly of coal reserves, approximately 46% of total coal reserves in India. The lower segment of DRB is characterized by recent fertile alluvium frequently deposited by the recurrent floods within the region during South-East Monsoon (Ghosh, 2014).

1.3 Soil types

The soil in uplands of DRB depends upon the bedrock and may be either Red Loam, Lateritic, or Dark Gray-colored Calcareous Soil. All these soils lack organic matter and nitrogen content due to decomposition of organic matter and leaching because of high temperature and humidity (Davidson and Janssens, 2006). Red loam soil develops on granite, gneiss or, schist and obtains its red color due to oxidation of Fe^{+2} and Fe^{+3} ions. Red loam contains abundant potash but lacks phosphorous and calcium. Lateritic soil develops due to prolonged weathering of sandstones, fireclays, and limestones and contains abundant Iron and Aluminium, and has a rich water retention capacity (Fatondji et al., 2013). Dark gray colored Calcareous Soil is developed on Hornblende schist and rich in clay content and calcium carbonate. This type of soil is found in patches in the Upper catchment of DRB. The lower catchments of DRB have rich deposits of riverine alluvium (Old and New). Riverine alluvium is red-colored due to its high iron content and rich in clay, silt, and lime. The older alluvium is deposited on the flood banks of the river whereas newer alluvium gets deposited seasonally in the floodplains and riverbed (Mondal et al., 2018).

Marsh/swamp Soil is found at the confluence of Damodar-Hooghly. This type of soil is clayey in nature and rich in Nitrogen, Phosphorous, and Organic Matter (Mandal et al., 2009).

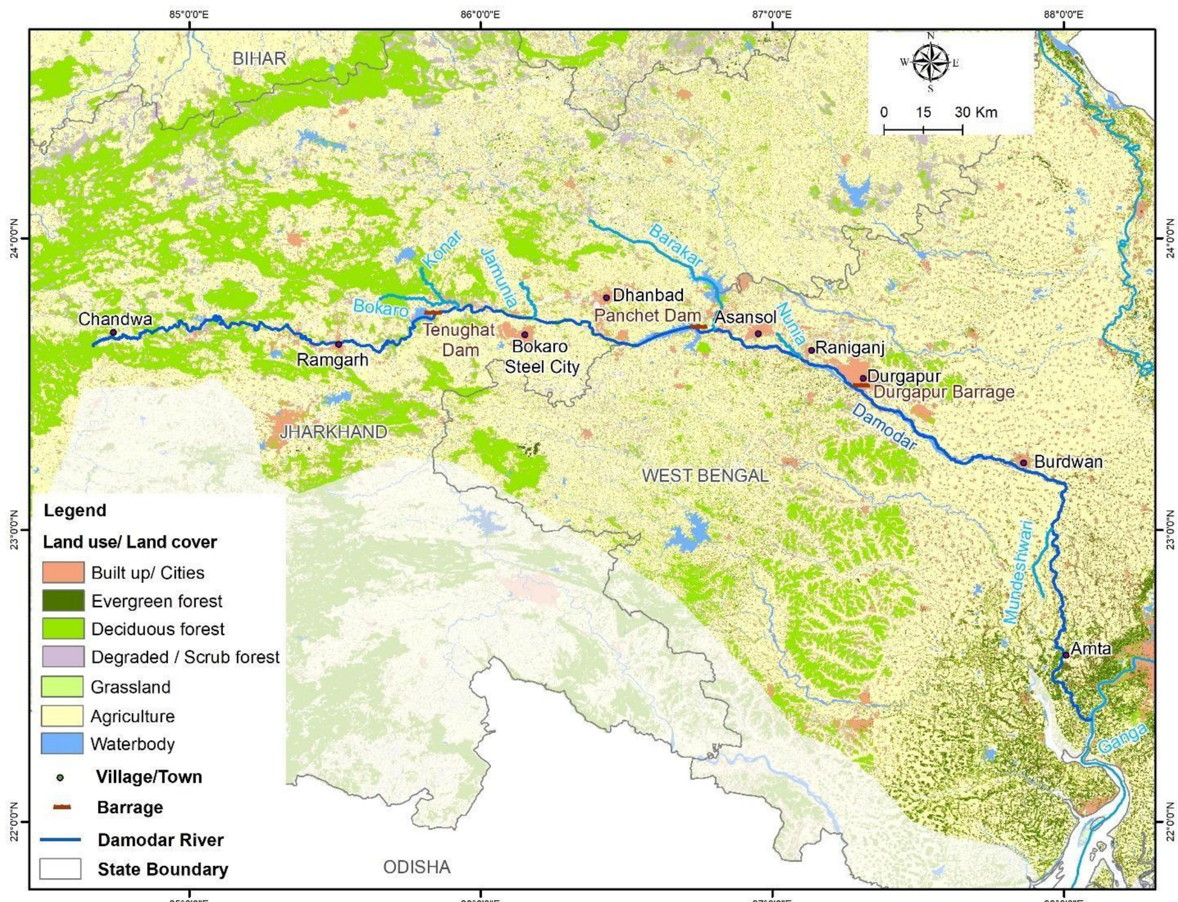

Figure 2: Land use Land cover of the Damodar River basin

1.4 Climate

The river basin is divided into 3 zones based on geological and hydrological features. The climate in the basin is characterized by humid and sub-tropical monsoon with erratic and uneven distribution of rainfall within the basin. DRB is considered one of the major rainstorm and flood zones of India (Kale, 2003; 2005). Average monsoon rainfall in DRB ranges from 23.33mm/hr to 26.66mm/hr (Siddartha, 2007; Pramanik and Rao, 1953). Upper and Lower Catchment of DRB receives 1209 mm and 1329 mm rainfall annually (Chandra, 2003). The course of Damodar River is parallel but opposite to the South-West monsoon visiting annually to the Indian Subcontinent in June. In extreme events, DRB has previously experienced approximately 100 mm of rainfall in 3 hours (Ghosh and Mistri, 2015). The basin also experiences an average of 20-25 intense short spells of rainstorms (Roy et al., 1995; Kale, 2003). Temperature ranges from a minimum mean of 4.8°C in December and January to a maximum mean of 44.2°C in May and June.

1.5 Drainage & Hydrology of the Damodar River

DRB has a catchment area of 23,370.98 km^2 of which approximately 74% area lies within Jharkhand and the rest 26% lies in West Bengal. However, in terms of the length of the river, only 240 km of Damodar River lies in Jharkhand whereas 300 km of the river flows in West Bengal (Majumder et al., 2010; Ghosh et al., 2014). The slope of the river for the initial 241 km is 1.86 m/km, 57m/km for the next 167 km of the stretch, and in the last stretch, the slope of the river is 16m/km (Chandra, 2003; Mahata & Maiti, 2019).

Barakar, Konar, Bokaro, Haharo, Jamnia, Ghari, Guaia, Khudia, and Bhera are the major tributaries and sub-tributaries of Damodar River (DVC, 1992; CMRI, 2001). There are only two distributaries of the Damodar River, i.e. Amta Channel (Lower Damodar) and Mundeshwari (Sen, 1991; Bandyopadhyay, 2007). Previous studies have indicated the presence of extinct tributary and distributary channels that further connected to other rivers flowing parallel to the Damodar River (Rudra, 2010; Chakraborty and Nag, 2015).

Before the commencement of DVC in 1953, a total of 31 major flood events were documented from 1823 to 1943 in Damodar Lower Basin with a peak discharge of 18,500 cumecs in 1915 and 1935 (Saha, 1979). In the last 3 decades, 16 major and moderate flood events have been recorded in Damodar Lower Basin (Bhattacharyya, 2011). The shape of DRB is funnel-shaped with a wide catchment in the Upper and Middle segments and a narrow catchment in the Lower segments of the Damodar river. The high volume of runoff collected in the upper and middle catchment areas proves to be excess for the narrow lower catchment to absorb resulting in spillage of the surplus volume of streamflow (Saha, 1979; Majumder et al, 2010). Prominent reasons for the low capacity of the lower basin are the bottleneck, elbow-shaped location near Burdhhman, heavy siltation, embankments on the lower stretch of the

Damodar River, drainage congestion, and burdens of roads, railways, canals, and tidal behavior of lower reach (Sengupta, 2001).

Geomorphic signs of the DRB fan correspondingly clarifies the reason for recurrent flooding within the region. The form of the Damodar fan delta is deviated due to excess erosion from the Dwarkeshwar and Ajay rivers giving concave shape to the northern and southern boundary of the fan. The convex shape of the distal part is heavily trimmed due to the Hooghly River. Also, the existence of spill channels and paleochannels in the elbow near Burdhhman shows signs of embankment breaching and shifting course during major floods (Ghosh and Mistry, 2013).

1.6 Biogeography, Flora & Fauna

Damodar River basin is situated in two biogeographic zones viz., Deccan peninsula (6B) and Gangetic plain (7B). The basin has a rich tropical forest in the upper catchment area which receives around 1,209 mm of rainfall annually (Chakrabarti, 2011) and has an undulating topography, therefore it has various types of terrestrial ecosystems with a diverse vegetation. The documented flora has 853 species of flowering plants belonging to 137 families and 535 genera (Chakrabarti, 2011). The vegetation type is dominated by moist deciduous forests and interspersed with tropical dry deciduous elements.

Figure 3: Forest cover of the Damodar River basin

Faunal diversity is represented by 56 species of mammals belonging to 10 orders, 26 families and 45 genera. Seventeen species of reptiles and about 222 species of birds belonging to 17 orders, 51 families and 149 genera, have been documented by (Chakrabarti, 2011). Of special interest are reports of Smooth coated otter (*Lutragale perspicillata*) from Ghagra nallah ((23° 55' 48" N, 85° 07' 47" E)) in Haziribagh district (Chakrabarti, 2011). The only known record of Gangetic rdolphin is of a rescued individual which was likely to have strayed from the Hooghly River in the year 2000 (Mallick, 2010).

1.7 Demography

Damodar River basin supports an average density of 708 individuals/km^2 (Table 1). The upper zone of the river consists of an average density of 511 individuals/ km^2, which is lower than the density of the middle stretch (762 individuals/ km^2), the highest population density (1554 individuals/km^2) is found in the lower stretch. .

Table 1: Human density along the Damodar River (Source: GOI, 2011; FSI, 2019)

River	Zone	Districts	Geographical Area (km^2)	Persons	Density (Persons/km^2)
Damodar	Upper	Palamau	4393	1939869	442
		Bokaro	2883	2062330	715
		Hazaribagh	3555	1734495	488
		Ramgarh	1341	949443	708
		Kodarma	2540	716259	282
		Girdih	4962	2445474	493
		Ranchi	5097	2914253	572
		Lohardaga	1502	461790	307
		Dumka	3761	1321442	351
		Chatra	3718	1042886	280
		Dhanbad	2040	2684487	1316
	Middle	Dhanbad	2040	2684487	1316
		Purulia	6259	2930115	468
		Bankura	6882	3596674	523
		Bardhaman	7024	7717563	1099
	Lower	Bardhaman	7024	7717563	1099
		Howrah	1467	4850029	3306
		Hooghli	3149	5519145	1753
Total			**60573**	**42886254**	**708**

(Source: https://www.census2011.co.in/census/district)

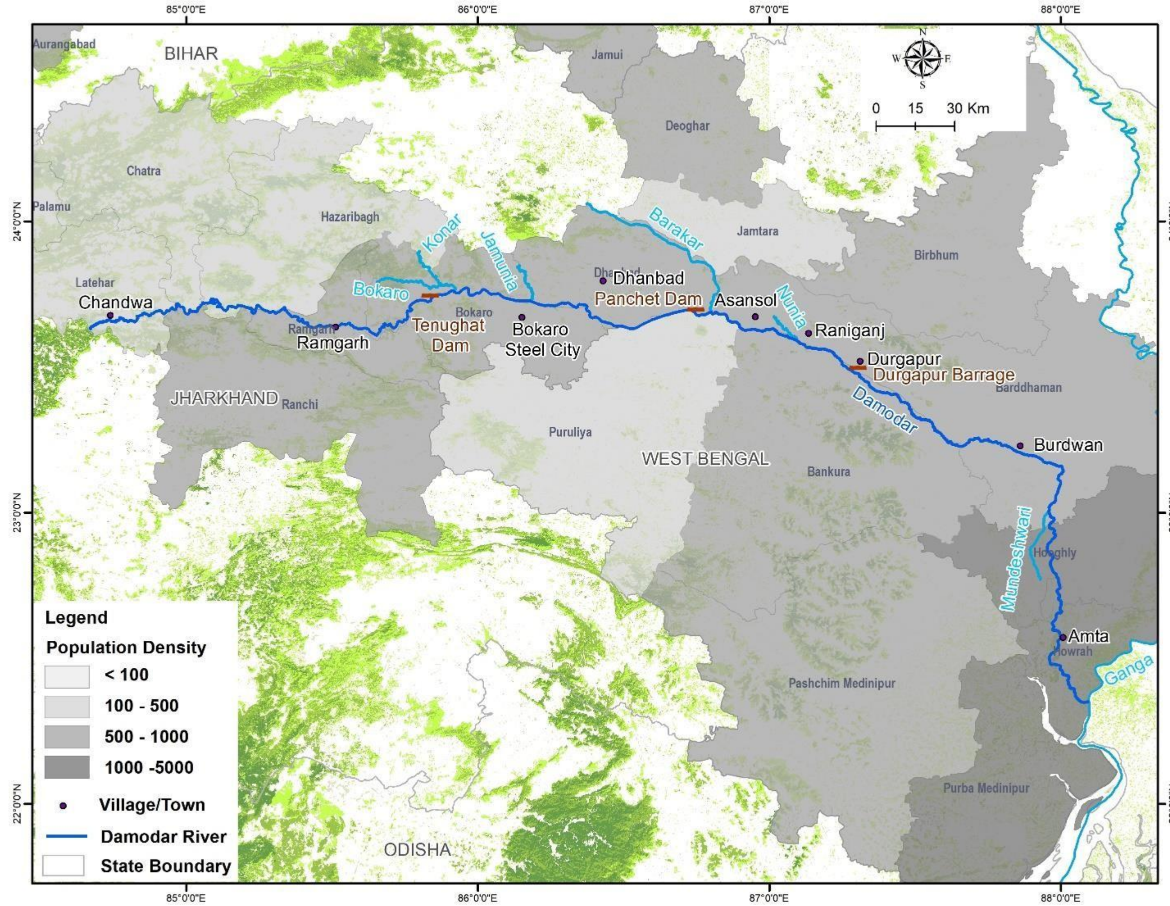

Figure 4: Demographic map of Damodar River basin

2. STATUS OF AQUALIFE IN THE DAMODAR RIVER

2.1 Methodological Framework

To prepare the status report of the Damodar River, a survey framework was developed by consulting available published literature and evaluating the species distribution and occurrence patterns, habitat profile of major settlements along the Damodar River. The Rapid biodiversity assessment was conducted in the Middle and Lower Zones of the Damodar covering a stretch of 290 km of the river from Panchet Dam, Jharkhand (N 23° 41′ 24.37″, E 86 ° 39 ′ 27.10) to Basudevpur (N 22° 21′ 2.96″, E 88 ° 05 ′ 16.82″), in Howrah district. A vehicle cum boat-based direct observation method was employed in December, 2020 to assess relative abundance and occurrence of aquatic biota of the Damodar River. Surveys were carried out during daylight hours between 8:00 hrs to 12:00 hrs in the morning and 16:00 hrs to 18:00 hrs in the afternoon looking for sightings of Gangetic dolphin, otters, waterbirds, gharial, mugger and turtles (Perrin and Brownell, 1989; Smith and Reeves, 2000; Behera *et al*., 2013; Sinha; Gopi and Hussain; Grimmett *et al*., 2016; 2014Singh, 1985; Hussain, 2009). We also recorded diversity of aquatic vegetation, habitat features and water quality indices, at each 5 km interval. Major vegetation type of the wetland area was classified based on habitat characteristics, viz. riparian, marshy, and aquatic. Free-floating, rooted hydrophytes were considered as aquatic plants. In marshy areas mainly reeds and sedges were considered, whereas water-loving trees and shrubs were considered in riparian habitats. For identification and documentation of the flowering plants of the wetland area different floras viz., Babu (1977), Duthie (1903-29), Naskar (1990), Adhikari (2008) were consulted and a checklist was prepared.

Habitat parameters such as water current (slow, medium, fast), channel depth and channel width (m), Bank characteristics (right & left), shoreline vegetation (right & left), GPS coordinates, areas of confluences, meandering, downstream of sandbars, physicochemical parameters as well as anthropogenic factors were also recorded. Channel depth (m) and Channel width (m) were recorded with a help of a GARMIN Striker Plus fish finder and a YUKON laser range finder respectively. YSI Pro DSS multi-parameter water quality meter was used to measure physicochemical parameters such as dissolved oxygen, pH, conductivity, salinity, TDS, water temperature. These parameters were monitored through in situ measurement techniques following standard procedures of APHA (1998). Bank characteristics were broadly classified into five categories viz., 1. pebbles and boulders; 2. sandy; 3. loamy; 4. clayey, and 5. rocky embankment based on geomorphic features and substrate types of the river. Shoreline vegetation was grouped into three major classes i.e., fully covered (> 90% bank surface covered with riparian vegetation); partially covered (< 50% green cover), and exposed (< 10% green cover). As a measure of indices of the quality of riverbank a series of river bank scenarios were assessed, based on bank slopes ranging from vertical (90° from horizontal) to an angle of < 30° from horizontal. Slopes of the bank were then classified into three categories viz. low slope (< 30°), medium slope (30-60°), and high slope (> 60°) (Doble et al., 2012).

Mammals

During the pilot survey we didn't find the presence of any mammalian fauna such as Gangetic dolphin and otters in the Damodar River.

2.2 Avifauna

A total of 44 species of birds belonging to 14 families and 9 orders were recorded from Panchet dam to Basudevpur (confluence of Damodar and Hooghly River) (Annexure I). Distribution of waterbirds were restricted to certain pockets along the river and major congregations were observed downstream of the Rondhia weir in the middle zone and lower zone of the Damodar River (Figure 5).

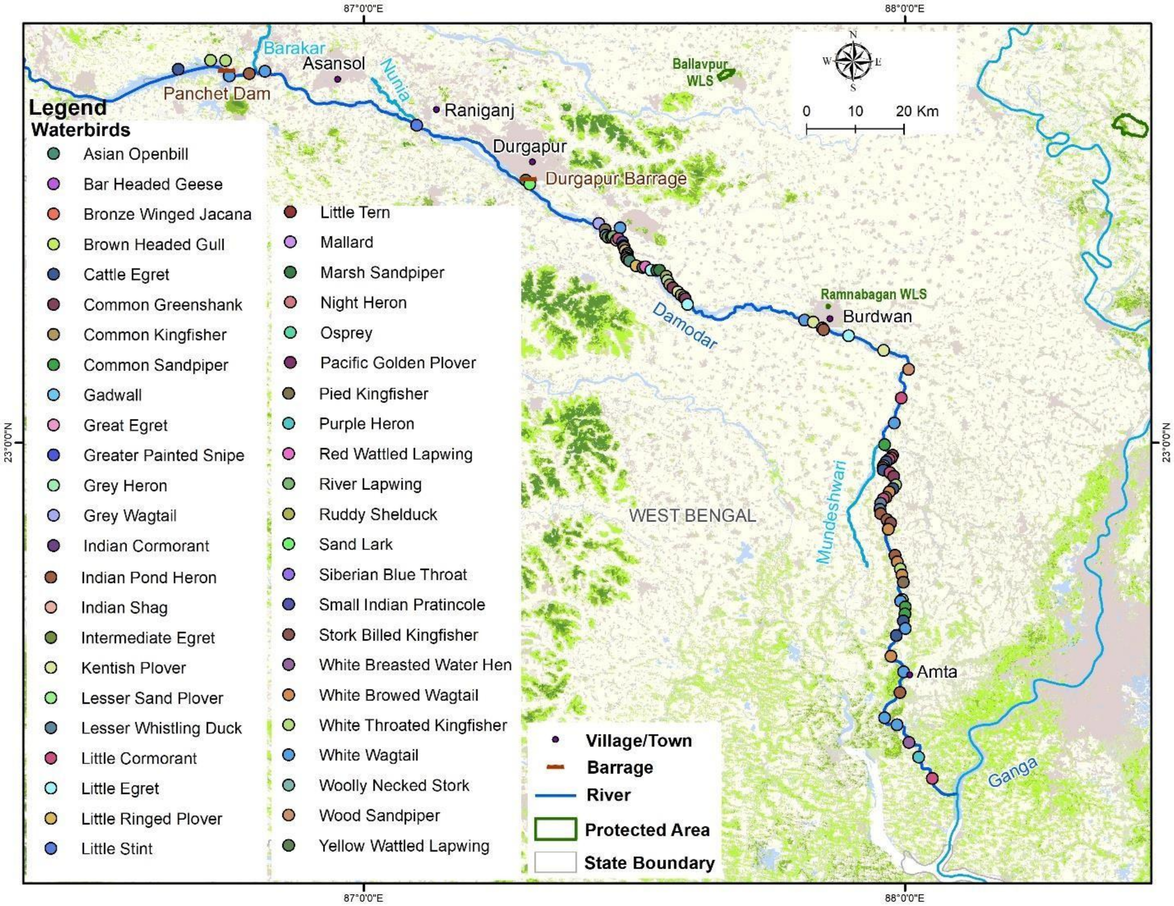

Figure 5: Waterbird species recorded during post monsoon survey of the Damodar River

Amongst these 8 species belonged to the Ardeidae family, followed by 7 species in the Charadriidae family, 5 species in Anatidae and Scolopacidae. Alaudadae, Glareolidae, Jacanidae, Pandionidae, and Rallidae were represented by one species each (Figure 6).

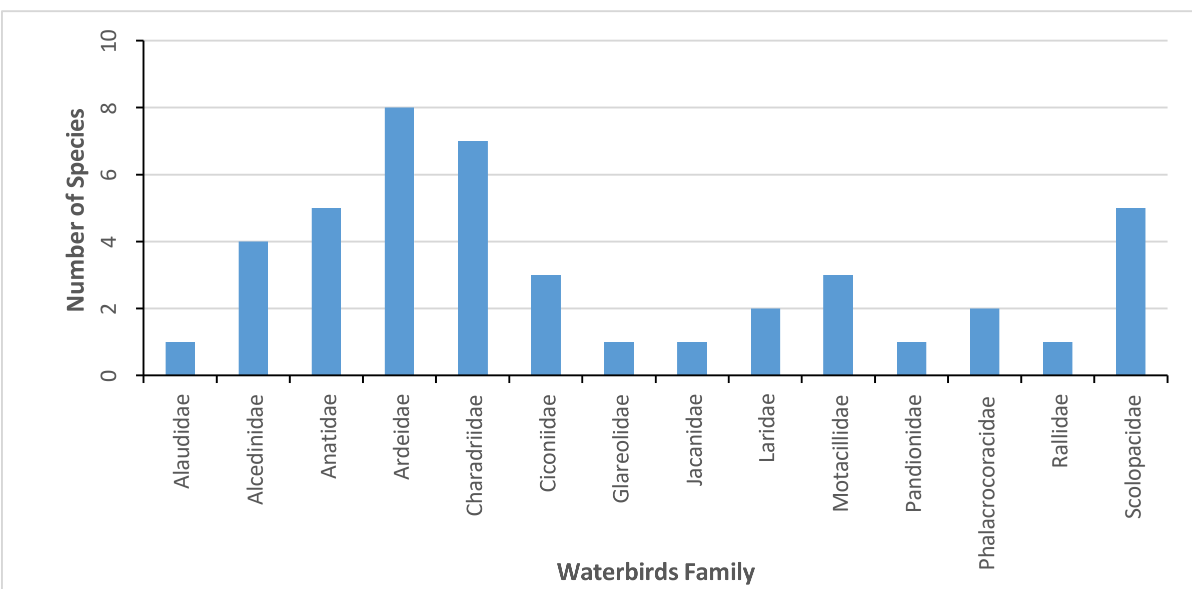

Figure 6 : Familywise composition of waterbirds communities along the Damodar River observed during the post monsoon Survey

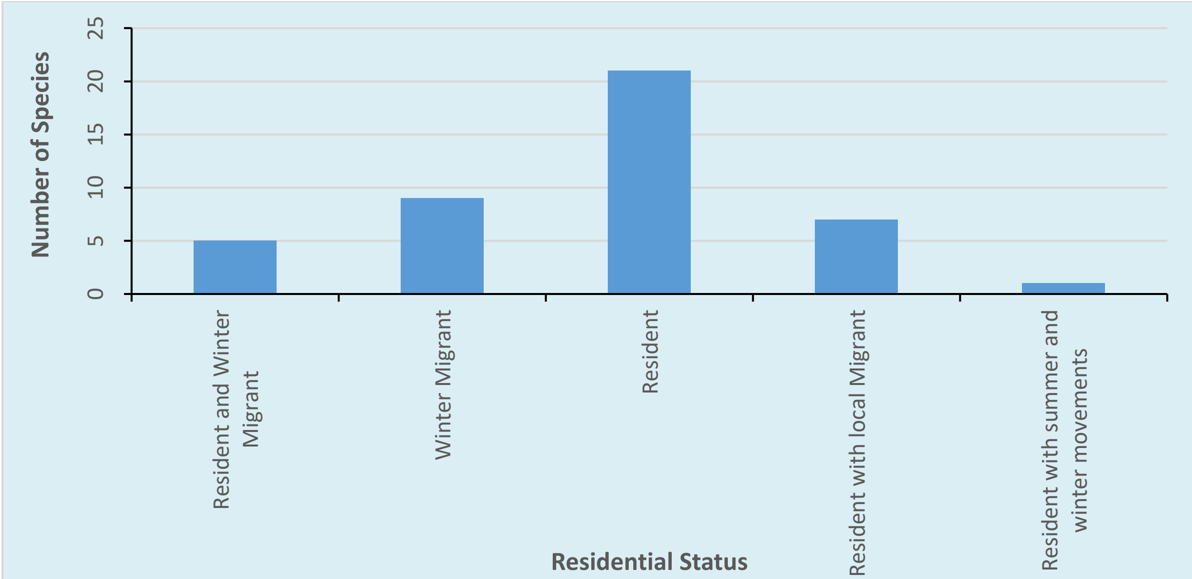

Figure 2.3 Residential status of waterbirds along the Damodar River observed during the post monsoon survey

White Wagtail roaming on the bank of Damodar River

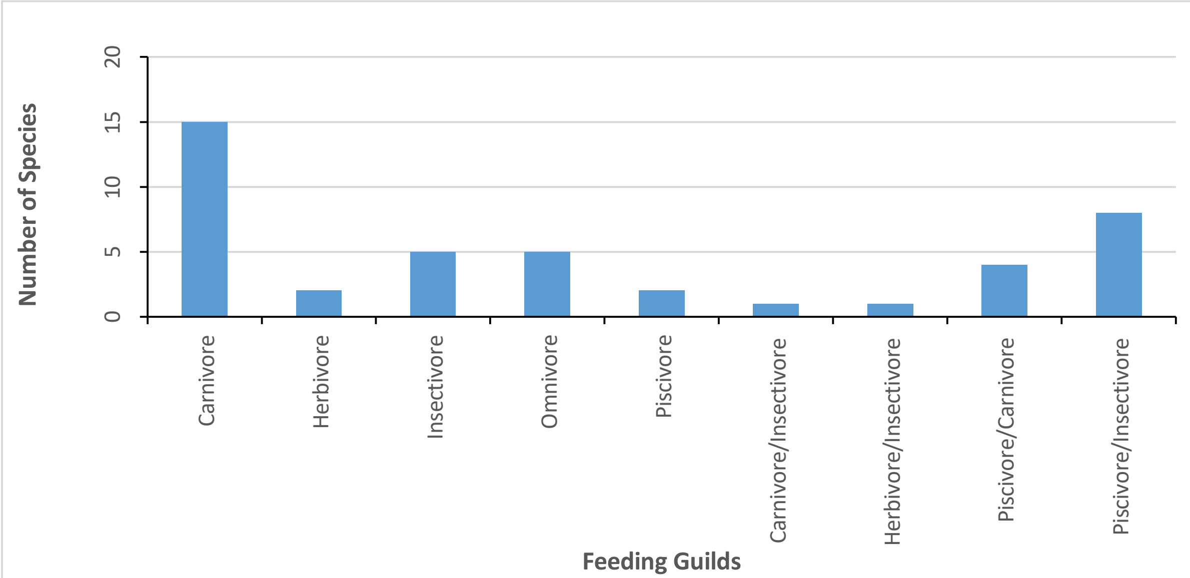

Figure 8: Feeding guilds composition of waterbirds along the Damodar River observed during the post monsoon survey.

Out of all recorded species, 21 species were resident, 9 species were winter migrants, followed by resident with local migrants (7 species), resident with winter migrant (5 species) and one species was resident with summer and winter movements (Kumar et. al. 2003) (Figure-7). Species were grouped into nine feeding guilds: carnivorous (15 species), piscivorous/insectivorous (8 species), 5 species each in insectivorous and omnivorous, followed by piscivorous/carnivorous (4 species), 2 species each in the herbivorous and piscivorous group, carnivorous/insectivorous and herbivorous/insectivorous consists of one species each (Figure- 8).

2.3 Vegetation

During the survey, 90 species of plants belonging to 80 genera and 43 families were recorded (Annexure II; Fig 9). Dominant plant families were Poaceae with 9 species followed by Asteraceae with 8 species, Amaranthaceae and Polygonaceae with 5 species each. Araceae, Lamiaceae, Scrophulariaceae, Solanaceae with 4 species each, Pontaderiaceae, Potamogetonaceae with 3 species each and Acanthaceae, Apiaceae, Convolvulaceae, Cyperaceae, Hydrocharitaceae, Lythraceae, Onagraceae, Verbenaceae were represented with 2 species. Twenty five families were represented with a single species (Fig 10). Of the total recorded species, 66 species were herbaceous, followed by 9 species of grass, 7 shrubs, 4 sedges and reeds, 3 climbers, and 1 fern (Fig 11). Among 90 species 48 species were found Least Concern (LC) category in the IUCN Red List of Threatened species.

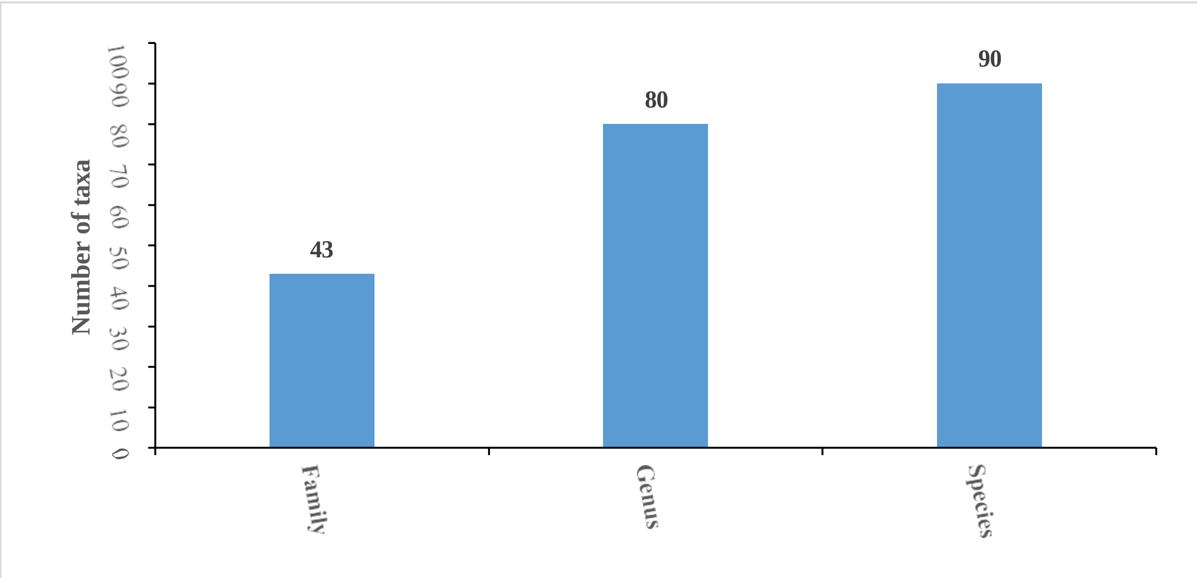

Figure 9: Floristic diversity of Damodar River

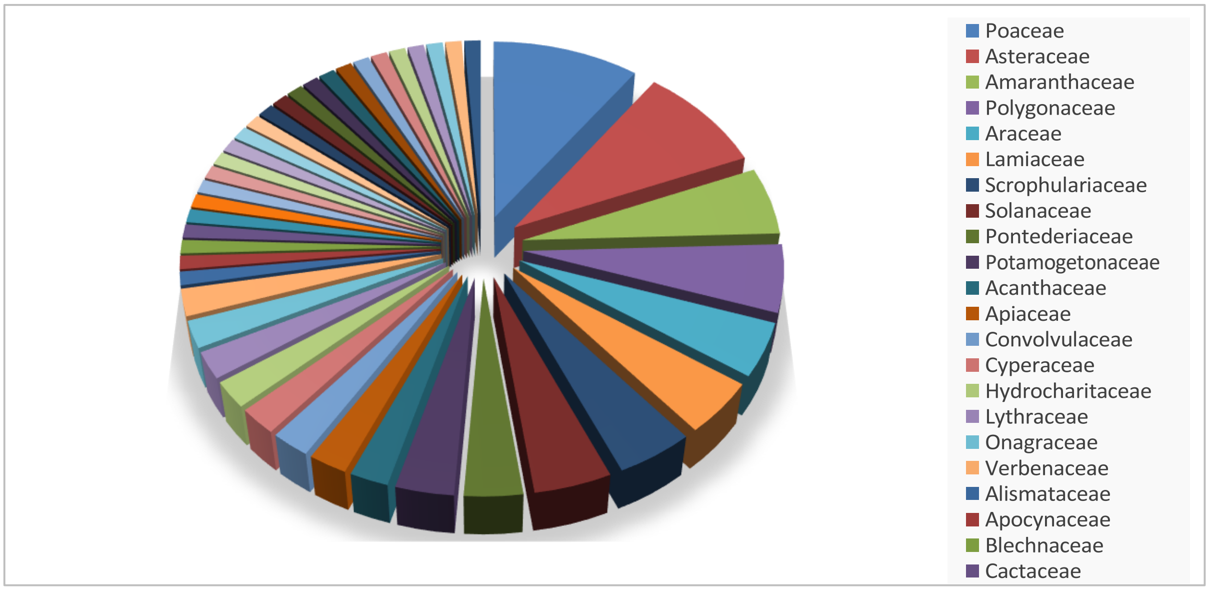

Figure 10: Total Number of plant families recorded from Damodar River

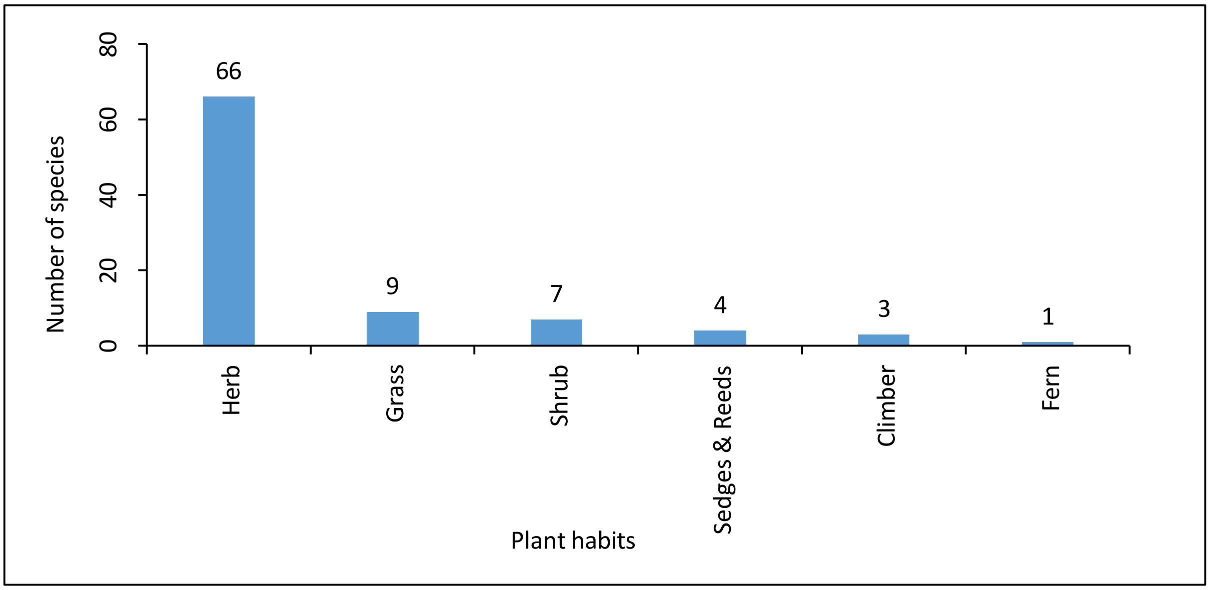

Figure 11: Different habit wise plant classification

Habitat Specificity

The plant species common in all habitats were *Ipomoea carnea* Jacq., *Polygonum barbatum* L., *Cyperus rotundus*, *Kyllinga brevifolia* Rottb., *Paspalum distichum* L. *Saccharum spontaneum*, *Saccharum ravennae*, *Phragmites karka*, *Cyperus rotundus*, *Vallisneria natans*, *Hydrilla verticillata*, *Potamogeton crispus*, *Potamogeton nodosus*, *Stuckenia pectinata*, *Nymphoides hydrophylla*, *Eichhornia crassipes*, *Alternanthera philoxeroides*, *Solanum sisymbriifolium*, *Lippia alba*, *Ipomoea aquatica*, *Typha domingensis*. Among 90 species, 48% were found in marshy habitat followed by 33% in the riparian area and 19% were recorded completely in aquatic habitat (Fig 12).

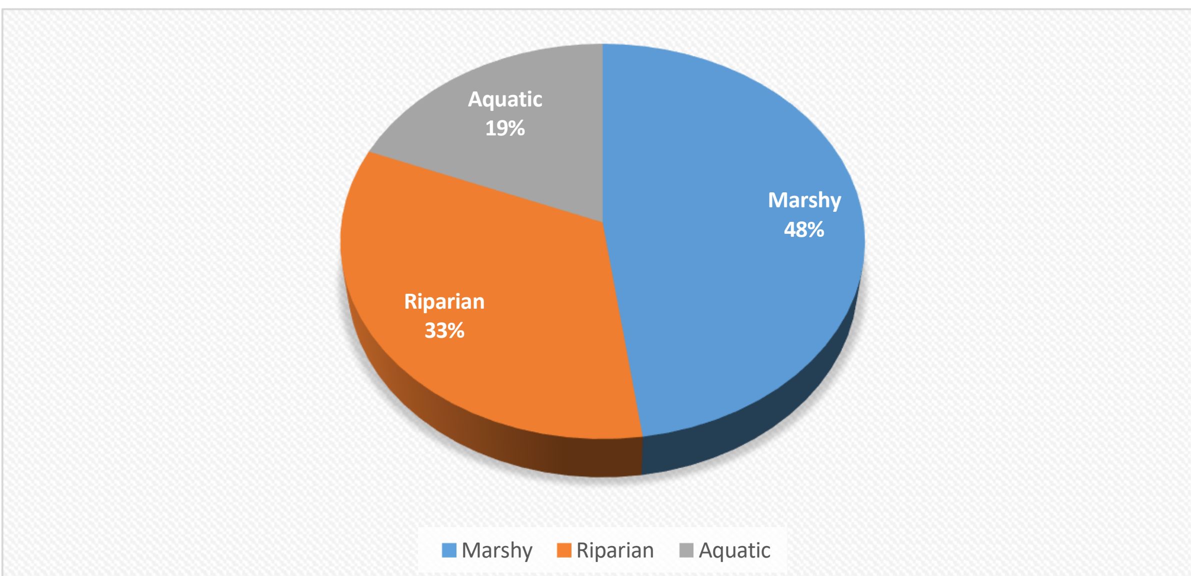

Figure 12: Habitat wise classification of recorded plants

Marshy vegetation: types and extent

The marshy vegetation of the area was primarily dominated by *Typha angustata* Bory. & Choub., *Phragmites karka* (Retz.) Trin. ex Steud., *Tamarix indica* Willd., *Ipomoea carnea* Jacq., *Saccharum spontaneum* L., *Saccharum ravennae* (L.) L. species. This marshy area provides a good habitat to many wild animals and birds (resident as well as migratory).

Riparian vegetation: types and extent

The riparian vegetation of the river Damodar was mainly dominated by trees and shrubs. The most dominant species were *Vachellia nilotica* (L.) P.J.H. Hurter & Mabb., *Albizia lebbeck* (L.) Benth., *Albizia procera* (Roxb.) *Azadirachta indica* A. Juss., *Eucalyptus tereticornis* Sm., *Ficus benghalensis* L., *Ficus racemosa* L., *Lippia alba* (Mill.) N.E.Br. ex Britton & P.Wilson, *Calotropis procera* (Aiton) etc. and were distributed throughout the river stretch.

Aquatic vegetation: types and extent

The aquatic vegetation of the area supports several free-floating and rooted hydrophytes. The common free-floating hydrophytes like *Ceratophyllum demersum* L., *Hydrilla verticillata* (L. f.), and *Stuckenia pectinata* (L.) as well as rooted hydrophytes like *Ipomoea aquatica* Forssk. *Monochoria hastata* (L.), *Vallisneria natans* (Lour.) H., and *Sagittaria sagittifolia* L. were recorded from wetlands.

Status of riparian and aquatic vegetation

Most of the river stretches are disturbed due to sand mining, low flow of water, temporary bridges, fishing, dumping of religious and domestic wastes. Vegetation diversity was very poor from Panchet Dam to Durgapur Barrage. After Durgapur Barrage, a little abundance of hydrophytic vegetation like *Potamogeton crispus*, *Potamogeton nodosus*, *Stuckenia pectinata*, *Monochoria hastata*, *Monochoria vaginalis*, *Nymphoides hydrophylla*, *Vallisneria natans*, *Hydrilla verticillata* were observed in patches although minimal water flow was found throughout all stretches, water level increases after Burdwan, West Bengal During the field survey it was observed that various types of invasive weeds, e.g. riparian (*Parthenium, Ageratum, Argemone*), floating (*Eichhornia*, *Pistia*, *Spirodela*), and submerged (*Hydrilla*, *Potamogeton*, and *Ceratophyllum*), have impacted the river health by reducing water storage; obstruction of water flow, fish production, and aesthetic value. Another challenge in habitat conservation is unregulated sand mining, overgrazing in and around the wetland area, permanent ghats and human habitation near the river bank.

2.4 Habitat Parameters

The channel width of the Damodar River ranged from 65 m to 2300 m (average = 395.86 ± 491.50) and the channel depth ranged from 0.4 m to 5.4 m (average = 1.75 ± 1.04).

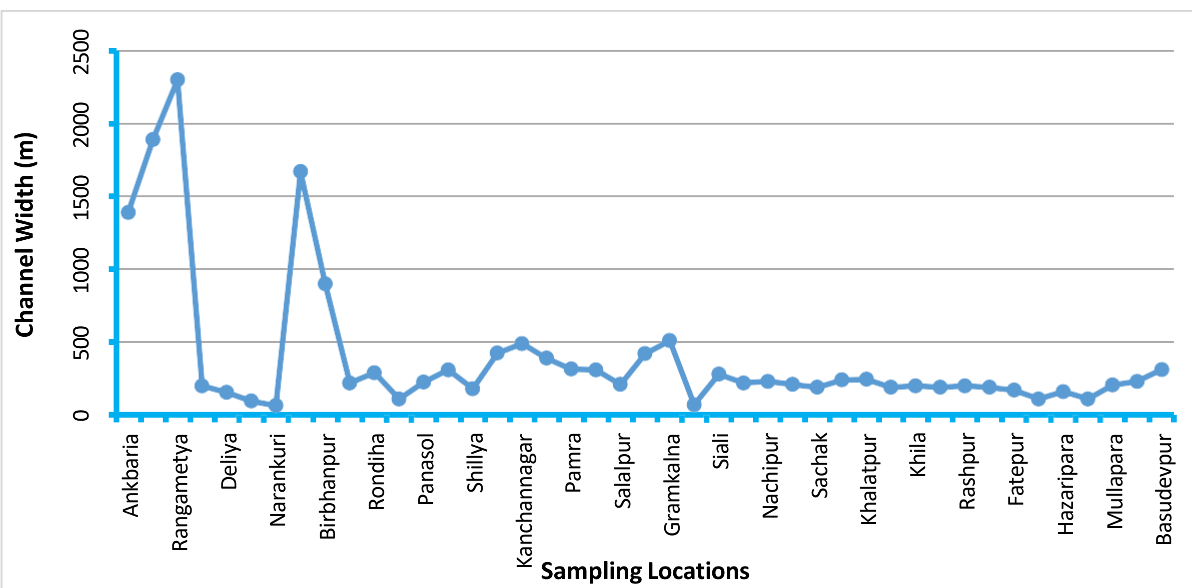

Figure 13: Channel width profile of each river segment of the Damodar River during post monsoon survey

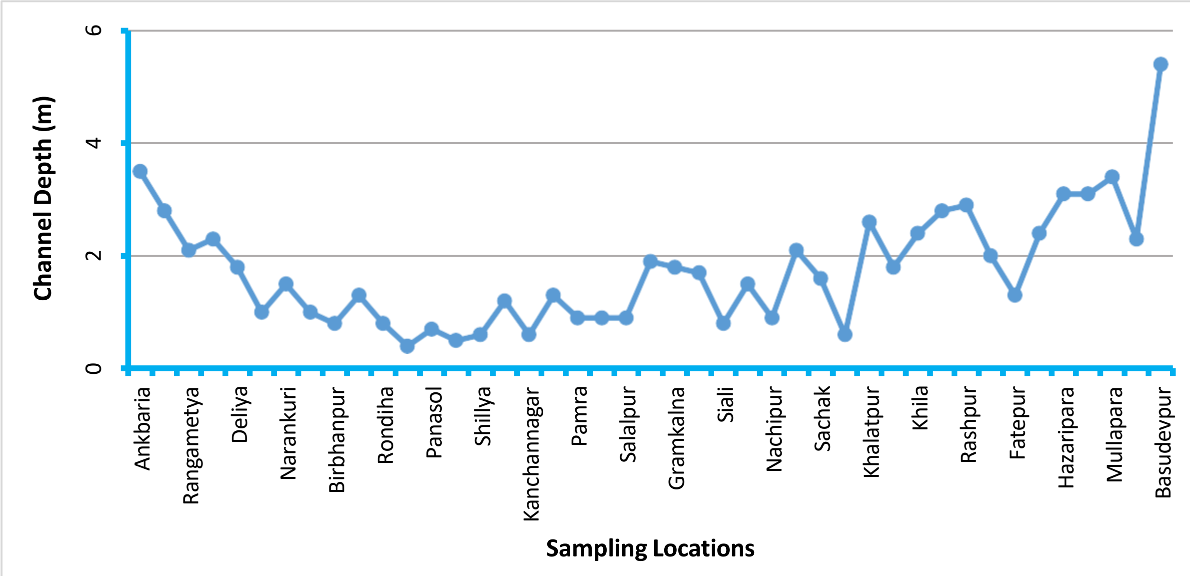

Figure 14: Channel Depth profile of each river segment of the Damodar River during post monsoon survey

Our surveyed data revealed that loamy substratum was the most dominant riverbank feature throughout the river. Almost 65% on the left bank and 60% on the right bank of the river was loamy substrate, followed by rocky (16% at left bank, 10% at right bank), clayey (12% at left bank, 15% at right bank) and sandy (7% at left bank, 15% at right bank). On the left bank the riverbank slope was high (12%), medium (46%), and low (42%). Similarly, on the right side of the river, the medium slope was higher (54%) than the low (37%) and high (9%) slope. 90% of both the banks of surveyed river stretch were found partially covered by vegetation and 10% of both river banks were fully covered by vegetation.

2.5 River Stretches with High Biodiversity Value

Rondiha to Gopdal

The length of the Damodar River flowing through this stretch is approximately 20 km. A total of 479 individuals of waterbird species belonging to 25 different species were documented. Five winter migrant waterbird species (Gadwall, Mallard, Ruddy Shelduck, Marsh sandpiper, Common greenshank) were also recorded in this stretch. The number of little cormorant was highest (140 individuals) along this stretch with a encounter rate of 7 sightings km^{-1} (Figure 15).

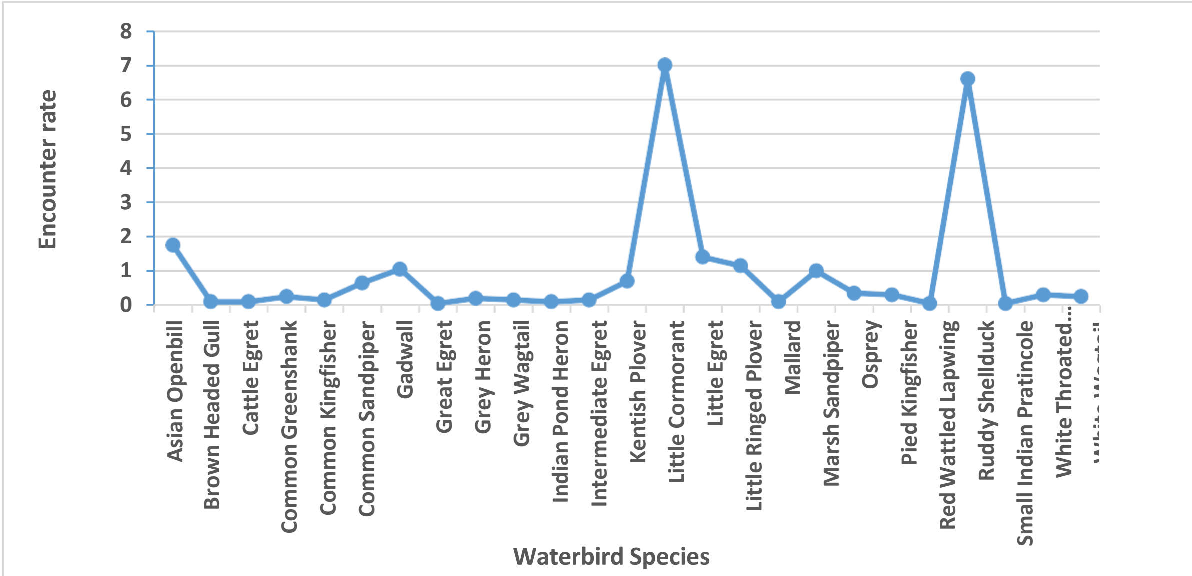

Figure 15: Encounter rate of recorded waterbirds from Rondiha to Gopdal

3. THREATS TO THE BIODIVERSITY OF THE DAMODAR RIVER

3.1 The upper zone

This zone lies in the mineral-rich Gondwana coal seam basin. The upper stretch of the Damodar River has experienced serious anthropogenic pressure due to the development of industrial belt and townships based around coal mines. Major industrial units in DRB are coal mines, coal washeries, coke oven plants, thermal power plants, steel plants, cement plants, explosive plants (Bhattacharyya et al. 2013; Sundararajan and Mohan 2011; Ghosh and Banerjee 2012; Singh et al. 2014; Chatterjee et al. 2010; George et al. 2010; Mukherjee et al. 2012).

Deterioration of water quality of Damodar River in the upper catchment area is primarily attributed to the direct influx of industrial effluents discharged into the river without any subsequent treatment. These effluents include heavy metal ions, oils, greases, acids, dissolved inorganic, pesticides, polychlorinated biphenyls (PCBs), dioxins, polyaromatic hydrocarbons (PAHs), petrochemicals, phenolic compounds, and microorganisms (De et al., 1980; Tiwary and Abhishek, 2005; George et al., 2010; Chatterjee et al., 2010; Mukherjee et al., 2012; Banerjee and Gupta, 2013). Furthermore, very high concentrations of TDS, TH, BOD, Fe, and NO_3^- result from untreated sewage water (Pal and Maiti, 2018; Savichev et al., 2020; Chakraborty et al., 2021; Bhattacharyya et al., 2013; Sundararajan, 2011; Ghosh and Banerjee, 2012; Singh et al., 2014; Tiwary and Dhar, 1994).

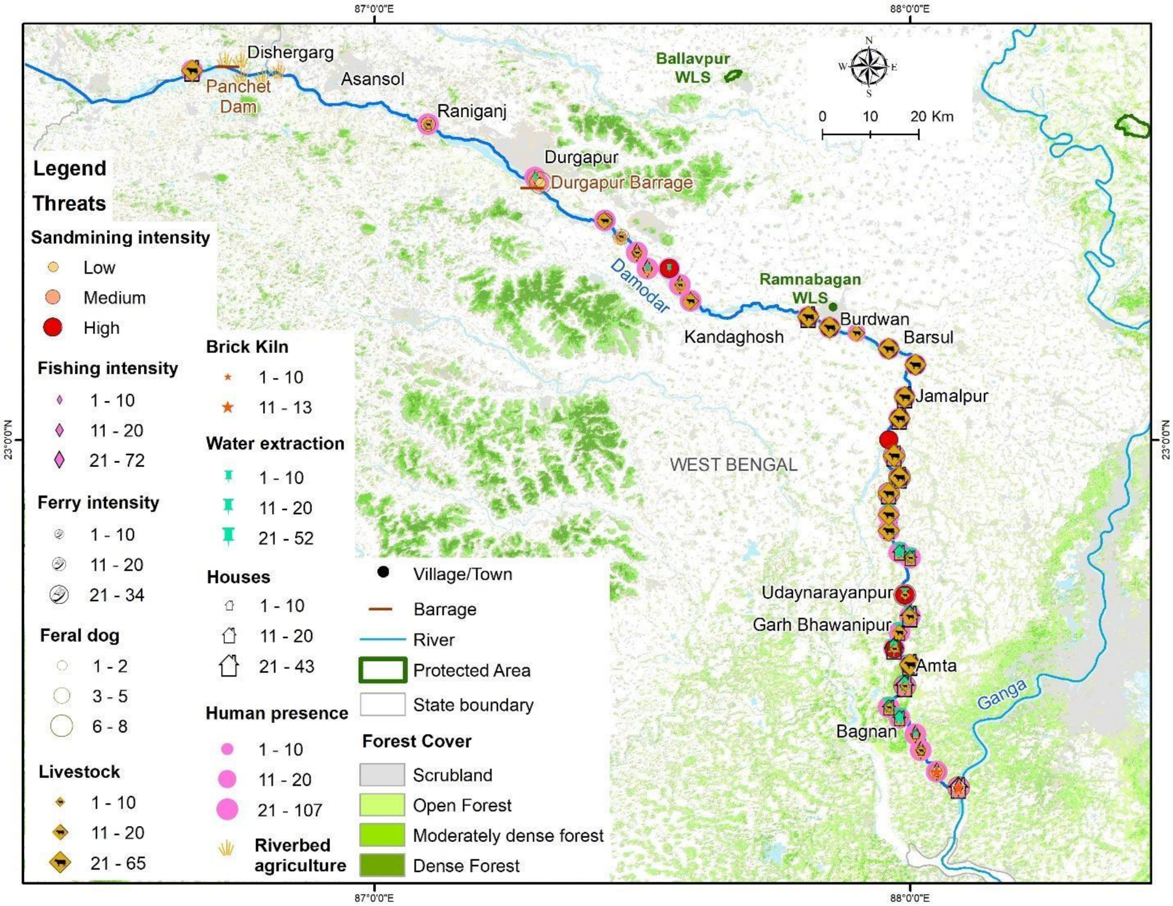

Figure 16 : Threats observed during post monsoon survey in the Damodar River

3.2 The middle zone

About 60% of coal production in Damodar Valley is through Open-Cast Mining. Opencast mining and associated activities cause land degradation, dust generation, and overall deterioration of ambient air quality index (Choubey, 1991; CMRI, 2001; Tiwary, 2001; Singh et al., 2008). Disposal of fly ash and oil in river basins decreases the percolation of rainwater and reduces the recharging of the groundwater table. Jharia coalfields are infamous for the largest coal mine fire complex in the world with more than 70 mine fires covering 17.32 km^2 (BCCL, 2003; Gupta and Prakash, 1998). These mine fires uncontrollably emit greenhouse and poisonous gases such as CO_2, NO_x, SO_2, CO, CH_4, C_2H_6, C_3H_6 which reduces the overall AQI. Water quality of the middle stretch from our obtained data revealed that the pH ranged from 8.94 to 11.6 (Figure 17) and dissolved oxygen (DO) ranged from 1.12 mg/L to 4.61 mg/L (Figure 18). According to the Central Pollution Control Board of India, the standard pH limit for sustaining aquatic organisms in the river is range between 6.5 to 8.5, and dissolved oxygen is 4 mg/L or more. In this stretch, pH is much higher due to the higher anthropogenic activities. Dissolved oxygen is within the standard range (CPCB, 2012).

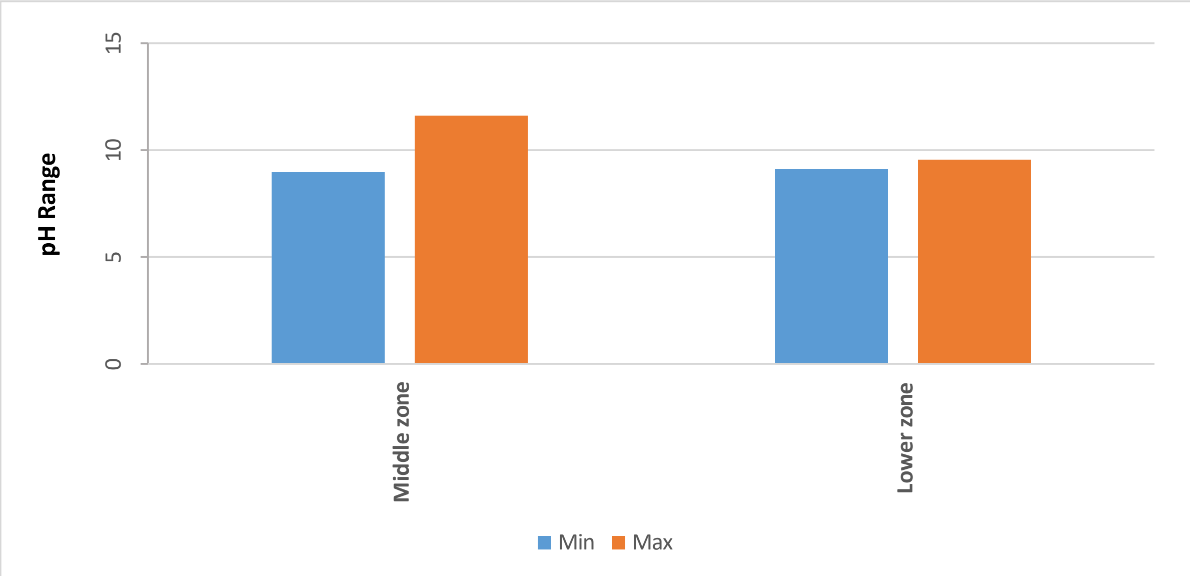

Figure 17: pH Range along the middle and lower zone of Damodar River.

3.3 The lower zone

Despite the active role of DVC in flood mitigation, the frequency of floods in the Lower Damodar Basin has been rising. The inability of the DVC Project to moderate the seasonal flow of Damodar River is attributed to factors such as high runoff from the deforested upper catchment of DRB and high sedimentation from upper catchment areas (Rudra, 2010), siltation of reservoirs and river beds due to low flow and obstruction, downstream drainage obstruction (Bhattacharya, 1959; Ghosh, 2014) and congestion, degradation and delinking of paleochannels, rainfall in abrupt and short spell bursts of 3-4 days, cloud bursts in upper catchment areas, tidal activity at the lower end of Damodar-Hooghly confluence (Dutt, 2006), etc (Saha, 1979; Sen, 1993; Roy et al., 1995; Majumder et al., 2010; Chakrabarty et al., 2011). Funnel-shaped DRB with wide upper catchment and narrow lower catchment further accentuates the destructive capacity of floods within the lower DRB. Flood moderation capacity of DVC has reduced from 78% in 1959 to 32% in 2007 due to a high overload of siltation (Rudra, 2010; Ghosh, 2014). DVC dams can temporarily hold the incoming runoff and stream flow till the critical reservoir storage limit, after which the reservoirs are compelled to release water in later stages of the monsoon. Till this time, soils of lower DRB have already gained full moisture and excess runoff is added in the reservoir released waters (Chandra, 2003). In the lower stretch, unrestricted sand mining is the major cause of the degradation of habitat. We observed that high-power jet pumps, JCBs were used for the extraction of sand from the river bed. The water quality of this stretch as assessed by us revealed that the pH ranged from 9.1 to 9.54 (Figure 17) and dissolved oxygen (DO) ranged from 1.61 mg/L to 2.65 mg/L (Figure 18).

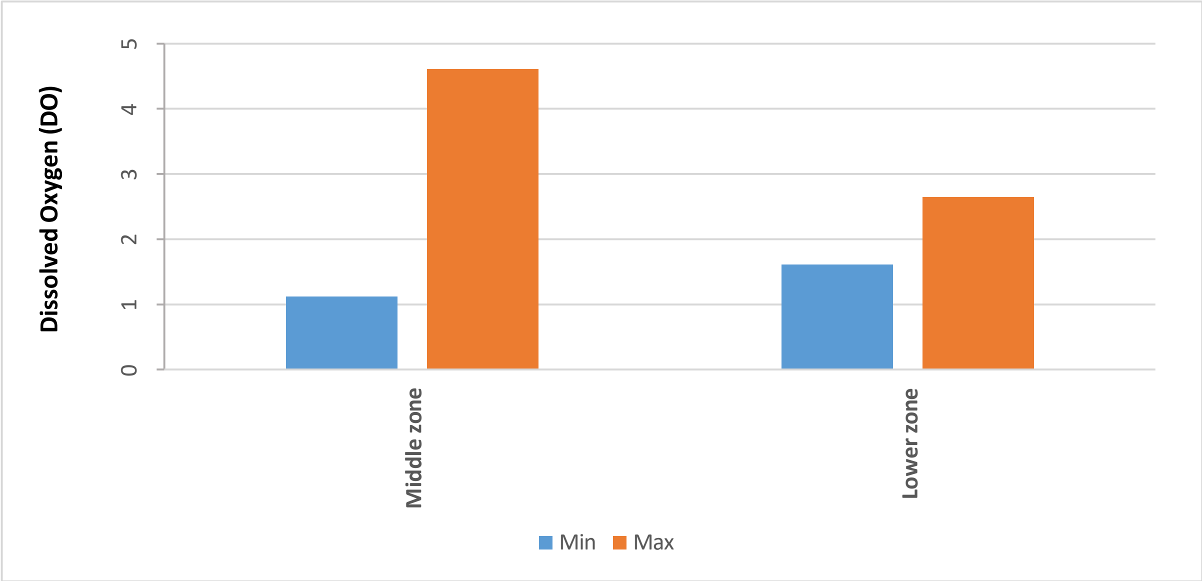

Figure 18: Dissolved Oxygen (DO) recorded along the middle and lower zone of Damodar River.

4. CONSERVATION IMPLICATIONS

An effective ecological restoration plan that considers the biotic and abiotic factors such as species composition and abundance, habitat characteristics, and its use by species, assessment of threats, etc. (McDonald et al., 2016) is required. The diversity of species or life forms are essential for reducing the risk of ecological collapse and maintain the ecosystem services of the area. As evident from the post-monsoon survey and published literature, river ecosystem restoration activities are needed to restore its lost structure and function. The Damodar River ecosystem faces an imminent threat due to unsustainable sand mining activities in the middle and lower stretches and a scientifically controlled method must be adopted for regulating the sand mining in the region.

The capacity building of the frontline staff i.e. the forest department, local communities, and various stakeholder groups is needed for reducing the mortality of endangered species caused due to anthropogenic activities.

The socio-economic profile of the region is needed to identify the dependency on the river so as to mitigate activities which contribute to habitat degradation and threaten the survival of aquatic species.

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ANNEXURE I

Feeding habits, conservation and residential status of waterbirds

Order	Family	Species Name	Scientific Name	IUCN Status	IWPA Status	Residential status	Feeding Guilds
Accipitriformes	Pandionidae	Osprey	*Pandion haliaetus*	LC	I	R/WM	P
Anseriformes	Anatidae	Bar-headed Goose	*Anser indicus*	LC	IV	R/WM	H
		Gadwall	*Mareca strepera*	LC	IV	WM	H
		Lesser Whistling Ducks	*Dendrocygna javanica*	LC	IV	WM	O
		Mallard	*Anas platyrhynchos*	LC	IV	WM	O
		Ruddy Shelduck	*Tadorna ferruginea*	LC	IV	WM	O
Charadriifomes	Charadriidae	Kentish Plover	*Charadrius alexzandrinus*	LC	IV	R/LM	C
		Lesser Sand Plover	*Charadrius mongolus*	LC	IV	R/WM	C
		Little Ringed Plover	*Charadrius dubius*	LC	IV	R	C
		Pacific Golden Plover	*Pluvialis fulva*	LC	IV	WM	C
		Red-wattled Lapwing	*Vanellus indicus*	LC	IV	R	C
		River Lapwing	*Vanellus duvaucelli*	NT	IV	R	C
		Yellow-wattled Lapwing	*Vanellus malabaricus*	LC	IV	R	C
	Glareolidae	Small Pratincole	*Glareola lactea*	LC	IV	R	I
	Jacanidae	Bronze-winged Jacana	*Metopidius indicus*	LC	IV	R	H/I

	Laridae	Brown-headed Gull	*Larus brunnicephalus*	LC	IV	R/WM	C
		Little Tern	*Sternula albifrons*	LC	IV	R	P/C
	Scolopacidae	Common Greenshank	*Tringa nebularia*	LC	IV	WM	C
		Common Sandpiper	*Actitis hypoleucos*	LC	IV	R/WM	I
		Greater Painted Snipe	*Rostratula benghalensis*	LC	IV	R	O
		Little Stint	*Calidris minuta*	LC	IV	WM	C
		Marsh Sandpiper	*Tringa stagnatilis*	LC	IV	WM	C
Ciconiiformes	Ciconiidae	Asian Openbill	*Anastomus oscitans*	LC	IV	R	C
		Woolly-necked Stork	*Ciconia episcopus*	Vu	IV	R	C
		Wood Sandpiper	*Tringa glareola*	LC	IV	WM	C
Coraciiformes	Alcedinidae	Common Kingfisher	*Alcedo atthis*	LC	IV	R/SM/WM	P/I
		Pied Kingfisher	*Ceryle rudis*	LC	IV	R	P/I
		Stork Billed Kingfisher	*Pelargopsis capensis*	LC	IV	R	P/C
		White-throated Kingfisher	*Halcyon gularis*	LC	IV	R	P/C
Gruiformes	Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*	LC	IV	R	O
Passeriformes	Alaudidae	Indian Sand Lark	*Alaudala raytal*	LC	IV		
	Motacillidae	Grey Wagtail	*Motacilla cinerea*	LC	IV	R	I
		White-browed Wagtail	*Motacilla maderaspatensis*	LC	IV	R	I

		White Wagtail	*Motacilla alba*	LC	IV	R	I
Pelecaniformes	Ardeidae	Black crowned Night Heron	*Nycticorax nycticorax*	LC	IV	R/LM	C
		Cattle Egret	*Bubulcus ibis*	LC	IV	R	C/I
		Great Egret	*Ardea alba*	LC	IV	R/LM	P/I
		Grey Heron	*Ardea cinerea*	LC	IV	R	P/I
		Indian Pond Heron	*Ardeola grayii*	LC	IV	R/LM	P/I
		Intermediate Egret	*Ardea intermedia*	LC	IV	R/LM	P/I
		Little Egret	*Egretta garzetta*	LC	IV	R/LM	P/I
		Purple Heron	*Ardea purpurea*	LC	IV	R/LM	P/I
Suliformes	Phalacrocoracidae	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	IV	R	P
		Little Cormorant	*Microcarbo niger*	LC	IV	R	P/C

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Abbreviation LC-Least Concerned,

R- Resident, WM-Winter migratory, R/WM-Resident and winter migrant, R/LM-Resident with local migrant, R/SM/WM-Resident with summer and winter movements, R/LM/SM- Resident local as well as summer movements

C-Carnivore, H-herbivore, O-Omnivore, P-Piscivore, I-Insectivore, H/C-Herbivore/Carnivore, H/I-Herbivore/Insectivore, P/I-Piscivore/Insectivore, C/I- Carnivore/Insectivore, P/C-Piscivore/Carnivore

ANNEXURE II

Checklist of plant species recorded from the Damodar River

Family	Species name	Habit	Habitat	IUCN Status
Acanthaceae	*Justicia adhatoda* L.	Shrub	Riparian	–
	Hygrophila polysperma (Roxb.) T. Anders.	Herb	Marshy	LC
Alismataceae	*Sagittaria sagittifolia* L.	Herb	Marshy	LC
Amaranthaceae	*Alternanthera paronychioides* A.St.-Hil.	Herb	Marshy	–
	Alternanthera philoxeroides (Mart.) Griseb.	Herb	Aquatic	–
	Alternanthera sessilis (L.) R. Br. ex DC.	Herb	Marshy	LC
	Achyranthes aspera L.	Herb	Riparian	–
	Cyathula tomentosa (Roth) Moq.	Herb	Riparian	–
Apiaceae	*Centella asiatica* (L.) Urb.	Herb	Marshy	LC
	Hydrocotyle sibthorpioides Lamk.	Herb	Marshy	LC
Apocynaceae	*Calotropis procera* (Aiton) Dryand.	Shrub	Riparian	–
Araceae	*Colocasia esculenta* (L.) Schott	Herb	Riparian	LC
	Lemna perpusilla Torr.	Herb	Aquatic	LC
	Pistia stratiotes L.	Herb	Aquatic	LC
	Spirodela polyrrhiza (L.) Schleid.	Herb	Aquatic	LC
Asteraceae	*Ageratum conyzoides* L.	Herb	Riparian	–
	Eclipta alba (L.) Hassk.	Herb	Marshy	LC
	Chromolaena odorata (L.) R.M.King & H.Rob.	Herb	Riparian	–
	Gnaphalium pensylvanicum Willd.	Herb	Marshy	–
	Mikania scandens (L.) Willd.	Climber	Riparian	–
	Parthenium hysterophorus L.	Herb	Riparian	–
	Tridax procumbens L.	Herb	Marshy	–
	Xanthium strumarium L.	Herb	Riparian	–
Blechnaceae	*Parablechnum ambiguum* (Kaulf.) C. Presl	Fern	Marshy	–
Cactaceae	*Opuntia stricta* (Haw.) Haw.	Shrub	Riparian	LC
Ceratophyllaceae	*Ceratophyllum demersum* L.	Herb	Aquatic	LC
Convolvulaceae	*Ipomoea aquatica* Forssk.	Herb	Aquatic	LC
	Ipomoea carnea Jacq.	Shrub	Marshy	–
Cucurbitaceae	*Coccinia grandis* (L.) Voigt	Climber	Marshy	–
Cyperaceae	*Kyllinga brevifolia* Rottb.	Sedges & Reeds	Marshy	LC
	Cyperus rotundus L.	Sedges & Reeds	Marshy	LC
Euphorbiaceae	*Croton bonplandianus* Baill.	Herb	Riparian	–
Hydrocharitaceae	*Hydrilla verticillata* (L. f.)	Herb	Aquatic	LC
	Vallisneria natans (Lour.) H. Hara	Herb	Aquatic	LC
Lamiaceae	*Anisomeles indica* (L.) Kuntze	Herb	Riparian	–
	Clerodendrum infortunatum L.	Shrub	Riparian	–
	Leucas aspera (Willd.) Link	Herb	Marshy	–

	Ocimum gratissimum L.	Herb	Riparian	–
Leguminosae	*Senna tora* (L.) Roxb.	Herb	Riparian	–
Lentibulariaceae	*Utricularia australis* R. Br.	Herb	Aquatic	LC
Linderniaceae	*Lindernia antipoda* (L.) Alston	Herb	Marshy	LC
Lythraceae	*Ammannia baccifera* L.	Herb	Marshy	LC
	Rotala ramosior (L.) Koehne	Herb	Marshy	LC
Menyanthaceae	*Nymphoides hydrophylla* (Lour.) Kuntze	Herb	Aquatic	LC
Molluginaceae	*Glinus oppositifolius* (L.) Aug.DC.	Herb	Marshy	LC
Nymphaeaceae	*Nymphaea rubra* Roxb. ex Andrews	Herb	Aquatic	LC
Onagraceae	*Ludwigia adscendens* (L.) H.Hara	Herb	Marshy	–
	Ludwigia octovalvis (Jacq.) P.H.Raven	Herb	Aquatic	LC
Papaveraceae	*Argemone mexicana* L.	Herb	Riparian	–
Phyllanthaceae	*Phyllanthus reticulatus* Poir.	Herb	Riparian	LC
Phyrmaceae	*Mazus pumilus* (Burm.f.) Steenis	Herb	Marshy	–
Plantaginaceae	*Bacopa monnieri* (L.) Wettst.	Herb	Marshy	–
Poaceae	*Coix lacryma-jobi* L.	Grass	Marshy	–
	Cynodon dactylon (L.) Pers.	Grass	Riparian	–
	Dactyloctenium aegyptium (L.) Willd.	Grass	Marshy	–
	Brachiaria ramosa (L.) Stapf.	Grass	Marshy	LC
	Pennisetum polystachion (L.) Schult.	Grass	Riparian	LC
	Phragmites karka (Retz.) Trin. ex Steud.	Sedges & Reeds	Riparian	LC
	Saccharum ravennae (L.) L.	Grass	Riparian	LC
	Saccharum spontaneum L.	Grass	Riparian	LC
	Eleusine indica (L.) Gaertn.	Grass	Marshy	LC
	Setaria verticillata (L.) P. Beauv.	Grass	Riparian	
	Paspalum distichum L.	Grass	Marshy	LC
Polygonaceae	*Polygonum barbatum* L.	Herb	Marshy	LC
	Polygonum hydropiper L.	Herb	Marshy	LC
	Persicaria lapathifolia (L.) Delarbre	Herb	Marshy	LC
	Polygonum plebeium R.Br.	Herb	Marshy	–
	Rumex dentatus L.	Herb	Marshy	–
Pontederiaceae	*Eichhornia crassipes* (Mart.) Solms	Herb	Aquatic	–
	Monochoria hastata (L.)	Herb	Aquatic	LC
	Monochoria vaginalis (Burm.f.) C.Presl	Herb	Marshy	LC
Portulacaceae	*Portulaca oleracea* L.	Herb	Marshy	LC
Potamogetonaceae	*Potamogeton crispus* L.	Herb	Aquatic	LC
	Potamogeton nodosus Poir.	Herb	Aquatic	LC
	Stuckenia pectinata (L.)	Herb	Aquatic	LC
Primulaceae	*Anagallis arvensis* L.	Herb	Marshy	–
Ranunculaceae	*Ranunculus sceleratus* L.	Herb	Marshy	LC
Rubiaceae	*Oldenlandia corymbosa* L.	Herb	Marshy	–
Sapindaceae	*Cardiospermum halicacabum* L.	Climber	Riparian	LC

Scrophulariaceae	*Veronica anagallis-aquatica* L.	Herb	Marshy	LC
	Mazus pumilus (Burm. f.) Steen.	Herb	Marshy	–
	Lindernia ciliata (Colsm.) Penn.	Herb	Marshy	LC
Solanaceae	*Datura stramonium* L.	Herb	Riparian	–
	Physalis minima L.	Herb	Riparian	–
	Solanum sisymbriifolium Lam.	Shrub	Riparian	–
	Nicotiana plumbaginifolia Willd.	Herb	Marshy	–
Tamaricaceae	*Tamarix indica* Willd.	Herb	Riparian	–
Typhaceae	*Typha angustata* Bory. & Choub. = *Typha domingensis* Pers.	Sedges & Reeds	Marshy	LC
Verbenaceae	*Lippia alba* (Mill.) N.E.Br. ex Britton & P.Wilson	Shrub	Riparian	–
	Phyla nodiflora (L.) Greene	Herb	Marshy	LC

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