

# Ecological Impact Assessment for Drawl of Water for Industrial Use: A Case Study of River Wainganga

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## Abstract

The study has attempted to assess ecological impact for drawl of water for industrial usage from river Wainganga comprising of producers (viz., Planktons, Periphytons, Macrophytes) and consumers like benthic organisms and fishes, reptiles, amphibians and birds. For the purpose, the study analysed the diversity and load of phytoplankton and zooplankton of river Wainganga. Furthermore, Species Diversity, which measures the bio-diversity and heterogeneity of aquatic ecosystem, was calculated based on the Shanon Weiner's function. Now, species diversity of a community has 2 components: (i) species richness, and (ii) species evenness. To calculate species evenness, Pielou's Index of equitability was used. The study further explored the presence of periphytons, macrobenthos, aquatic/semiaquatic macrophytes, fishes, reptiles, amphibians, water birds, etc. in Wainganga river. Finally, based on the threat assessment, the study has envisaged essential actions to restore the ecological balance of the river Wainganga. Considering the scenario of likely impacts for drawl of water for industrial usage from the river, it was explored that there will be no major negative impacts on the ecology, as only 70 MCM water annually have been allocated for industrial usage. Furthermore, as ecological cycle has a self-regulating mechanism, therefore it is hoped that possibility of having minor impacts on the ecological environment of the River Wainganga shall be naturally mitigated with time.

**Keywords:** Impact Assessment Study, Ecology, Drawl of Water, Species Diversity, Ecological Balance, Aquatic Biodiversity

## Introduction

With reference to the Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India (GoI), and Environmental Clearance (EC) for any industry, an ecological impact assessment study, as a part of the water source sustainability study, for drawl of water from the nearby river(s) for various operational activities of the industry shall be carried out periodically and details submitted to MoEF&CC.

In 2002, approximately 33,000 salmon putrefied in the Klamath River when farmers were allowed to withdraw increased volumes of water for irrigation. Similarly, over-pumping and upstream removal of water have reduced biodiversity in the Colorado River and the Rio Grande (Pimentel et al., 2004). The major alteration of the natural water flow in the lower US portion of the Colorado River has been responsible for 45 species of plants and animals being listed as federally endangered or threatened (Glenn et al., 2001).

Mubako et al. (2013) explored the relationship between water withdrawal and its impact on freshwater ecosystem, where the concept of an adverse resource impact threshold, as established by the Michigan Water Withdrawal Assessment Process, was applied in conjunction with a water use database of in-stream freshwater ecosystem. Shank and Stauffer (2014)

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conducted an empirical study to explore fish and macro invertebrate assemblages in lotic habitats of the Susquehanna River basin, USA, due to surface water withdrawal for burgeoning shale gas extraction activities. The studies by Bogra et al. (2016) in the Indian context of evolving water-withdrawal input-output model estimated direct and indirect water withdrawal of all economic sectors.

The objective of this study was to assess how far the aquatic ecosystem of river Wainganga, comprising producers (viz., Planktons, Periphytons, Macrophytes) and consumers, like benthic organisms and fishes, reptiles, amphibians, and birds, may be affected due to drawl of water for industrial usage. For the purpose, the study analysed the diversity and load of phytoplankton and zooplankton of river Wainganga. Furthermore, species diversity, which measures the bio-diversity and heterogeneity of an aquatic ecosystem, was calculated based on the Shannon-Weiner function. Now, species diversity of a community has 2 components: (i) species richness and (ii) species evenness. To calculate species evenness, Pielou's index of equitability was used. The study further explored the presence of periphytons, macrobenthos, aquatic/semiaquatic macrophytes, fishes, reptiles, amphibians, water birds, and so on, in river Wainganga. Finally, based on the threat assessment, the study envisaged essential actions to restore the ecological balance of the river Wainganga.

## Material and Methods

Wainganga River originates in the Mahadeo Hills in Mundara, Madhya Pradesh, India. Wainganga is a key tributary of the Godavari. The river flows over about 579km towards the south through the states of Madhya Pradesh and Maharashtra. Then it joins the Wardha River and ends in the Godavari River at Kaleshwaram, Telangana.

However, over the last few decades, dams and barrages have significantly fragmented the network of the river Wainganga. Due to these obstructions, the rivers have been carved into numerous segments, and as a result, it has caused interruption in the flow of water, nutrients, sediments, and aquatic biota of the river. It was observed that the river water is used mostly for religious occasions, bathing, washing, agriculture purposes, and immersion

of idols. The water requirement from Wainganga River for the nearby industry is estimated at approximately 70 MCM per annum. For the industry, the daily water drawl schedule from river Wainganga is 1,91,780m<sup>3</sup>/d, with an average pumping capacity of 2.0-2.5m<sup>3</sup>/s (including silt flushing) for 18-20 hours per day.

The field survey was carried out in the winter, i.e., January-February 2019. Water intake is located approx. 5km from the plant site. For plankton study, 5 sampling locations were selected that include the water intake site of the industry – (1) industrial water intake point, near barrage (S<sub>1</sub>); (2) 2-3km upstream of barrage (S<sub>2</sub>); (3) 10km upstream of barrage (S<sub>3</sub>); (4) 14-15km upstream of barrage (S<sub>4</sub>); and (5) 5km downstream of barrage (S<sub>5</sub>). Water sample of mid-river streams was collected at a depth of 0.5-1.0m and filtered through a plankton net (mesh 40nm). Periphytons were collected at random from the banks of the river; Zoobenthos and other macro flora/fauna were examined; the aquatic macrophytes and riparian vegetation composition were recorded; and other aquatic biota were collected/observed. Plankton samples were preserved after collection on-site using FAA preservatives and then brought to the laboratory for further qualitative and quantitative analysis.

To assess the ecological impact of drawl of water from river Wainganga, the study analysed the diversity and load of phytoplankton and zooplankton in river Wainganga. Furthermore, species diversity, which measures the bio-diversity and heterogeneity of an aquatic ecosystem, was calculated based on the Shannon-Weiner function. Species diversity of a community has 2 components: (i) species richness and (ii) species evenness. To calculate species evenness, Pielou's index of equitability was used.

*Species Diversity Index:* Species diversity was calculated based on the Shannon-Weiner function, as follows.

$$H = - \sum_{i=1}^n \left( \frac{n_i}{n} \right) \log_2 \left( \frac{n_i}{n} \right)$$

Where,

H = species diversity

n<sub>i</sub> = number of individuals of each species in sample

n = total number of individuals of all species in the sample

To calculate species evenness, Pielou’s index was used.

Pielou’s index of equitability (E):  $E = \frac{H}{H_{max}}$

Where,

E = equitability index (Range 0-1)

H = observed species diversity

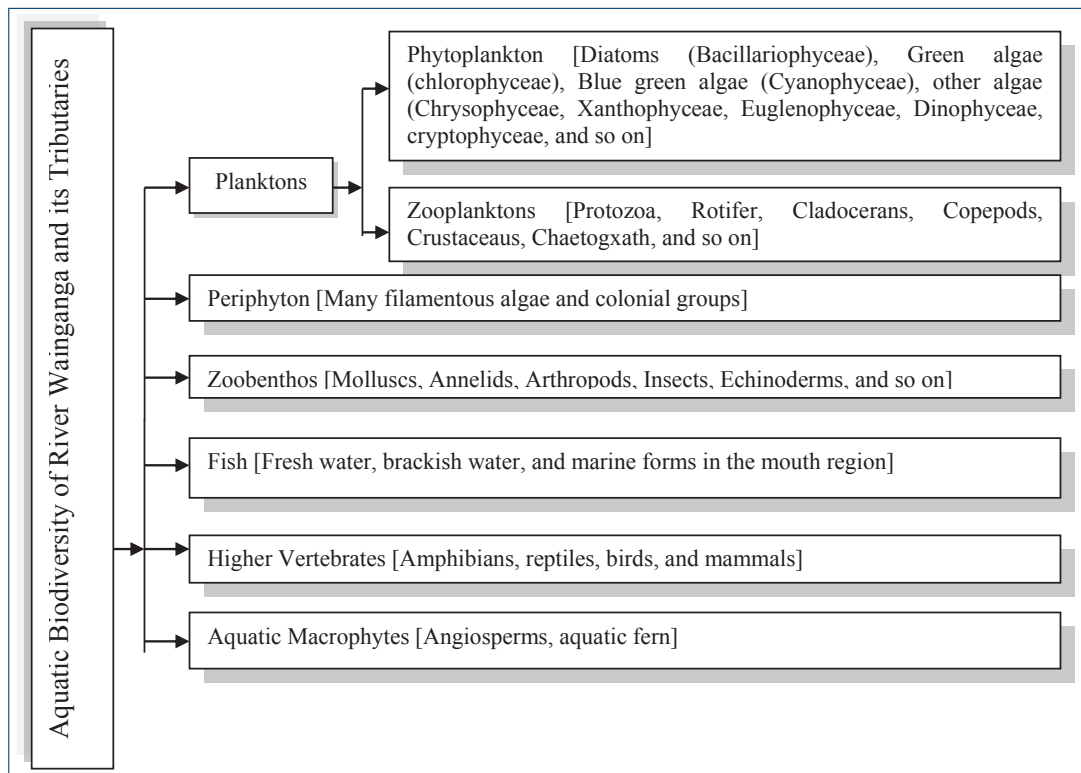
$H_{max}$  = maximum species diversity =  $\text{Log}_2 S$

S = total number of species in the community

The study further explored the presence of periphytons, macrobenthos, aquatic/semiaquatic macrophytes, fishes, amphibians, reptiles, water birds, and so on, in Wainganga River.

## Results and Discussion

A wide variety of aquatic biota, starting from microscopic flora and fauna to higher invertebrates, vertebrates, and plants are found in and around the river Wainganga and its tributaries (Fig. 1).



**Fig. 1: Aquatic Biodiversity of River Wainganga and its Tributaries**

The aquatic ecosystem of river Wainganga comprises producers (viz., planktons, periphytons, macrophytes) and consumers (viz., benthic organisms and fishes, reptiles, amphibians, and birds).

The aquatic biodiversity of river Wainganga is categorised into 3 major regions, namely upper reach, middle reach and lower reach. Being limited in middle reach, the present study covers 10-15km upstream and 10 km downstream of the water intake site at the barrage.

### Aquatic Flora and Fauna

The aquatic ecosystem of Wainganga River includes river networks, adjoining swamps, and a couple of reservoirs or artificial lakes (viz., Khairbanda, Bodalkasa and Chorkhamara). The biotic components include producers (planktons, macrophytic plants, periphytons) and consumers (benthic invertebrates, fishes, reptiles, amphibians, and water birds).

*Plankton Diversity:* Upstream of the intake represents both phyto and zooplankton. The most dominant phytoplanktons and zooplanktons are presented in Tables 1 and 2.

**Table 1: Diversity and Load of Phytoplankton in Wainganga River**

Phytoplanktons		Sampling Locations with Load (no/100ml)				
		$S_1$ (Intake)	$S_2$ (U/s)	$S_3$ (U/s)	$S_4$ (U/s)	$S_5$ (D/s)
Chlorophyceae:						
1.	Scenedesmus sp.	40	50	60	40	10
2.	Spirogyra sp.	60	70	40	50	20
3.	Zygnema sp.	50	60	40	40	10
4.	Oedogonium sp.	40	50	40	40	10
5.	Gonatozygon sp.	30	30	30	20	-
Bacillariophyceae:						
6.	Cymbella sp.	40	60	740	40	10
7.	Navicula sp.	50	40	40	45	10
8.	Nitzzia sp.	40	30	30	30	-
Cyanophyceae:						
9.	Microcystis sp.	60	70	60	50	20
10.	Nostoc sp.	40	40	40	30	10
11.	Anabaena sp.	50	50	40	30	-
12.	Merismopedia sp.	60	50	40	30	20
13.	Oscillatoria sp.	30	40	40	40	20

**Table 2: Diversity and Load of Zooplankton in Wainganga River**

Zooplanktons		Sampling Locations with Load (no/100ml)				
		$S_1$ (Intake)	$S_2$ (U/s)	$S_3$ (U/s)	$S_4$ (U/s)	$S_5$ (D/s)
Rotifer:						
1.	Brachionus sp.	30	40	30	30	10
2.	Keratella sp.	40	30	40	40	-
Cladocera:						
3.	Bosmina sp.	20	30	30	30	10
4.	Cypris sp.	20	30	20	20	-
Copepoda:						
5.	Cyclops sp.	30	30	40	30	10
6.	Naupilussp.	40	20	20	20	20

The phytoplankton diversity ranges from 3.239-3.665, whereas the equitability index ranges from 0.875 to 0.991 (Table 3). The zooplankton diversity ranges from 1.922 to 2.556, whereas the equitability index ranges from 0.744 to 0.989. This indicates moderate water pollution.

**Table 3: Shannon-Weiner Species Diversity Index and Pielou's Index of Equitability for Phytoplanktons and Zooplanktons**

Location	Date of Sampling	North Coordinates	East Coordinates	Diversity Index	Equitability Index	Diversity Index	Equitability Index
				Phytoplankton		Zooplankton	
$S_1$ : Water Intake Point	01.02.19	21°26'31"	79°53'01"	3.660	0.989	2.530	0.979
$S_2$ : Bhandara Village	01.02.19	21°27'51.5"	79°53'44"	3.650	0.986	2.556	0.989
$S_3$ : Bupera Village	01.02.19	21°30'47.7"	79°55'30"	3.656	0.988	2.530	0.979
$S_4$ : Sawriya Village	01.02.19	21°32'52.6"	79°55'29.5"	3.665	0.991	2.544	0.984
$S_5$ : Mandvi Village	02.02.19	23°68'83"	82°74'70"	3.239	0.875	1.922	0.744

- *Periphytons*: A good number of periphytonic algal samples were collected. They are mostly filamentous green and blue-green algae from floating and semi-merged macrophytes in the area. The dominant species were Oedogonium, Spirogyra, Zygnema, Oscillatoria and Phormidium.
- *Macrobenthos*: After collecting benthic macro invertebrates from the water, they were analysed for taxonomic certainty. Mostly, they belong to Annelida, Arthropoda and Mollusca groups. The predominant annelida belong to Oligochaeta viz., Tubifex and Limnodrilus species. Identically predominant arthropoda and the most abundant molluscs are presented in Table 4.

**Table 4: Benthic Macro Invertebrates of Wainganga River**

Groups	Class/Order/Family	Scientific Name
Mollusca	Gastropoda	1. <i>Bellamya dissimilis</i>
	• Mesogastropoda	2. <i>Pila globosa</i>
	• Basumatophora	3. <i>Lymnaea sp.</i>
	Bivalvia-Unionoida	4. <i>Lamellidens sp.</i>
Annelida	Oligochaeta	5. <i>Tubifex</i>
	• Tubificidae	6. <i>Limnodrilus sp.</i>
	• Naididae	7. <i>Pristina sp.</i>
Arthropoda	Crustacea	8. <i>Macrobrachium sp.</i>
	• Decapoda	9. <i>Laccophilus sp.</i>
	Insecta	10. <i>Gerris sp.</i>
	• Copepoda	11. <i>Gomphus sp. (Nymph)</i>
	• Hemiptera	12. <i>Culex larvae</i>
	• Diptera	13. <i>Limnophora sp.</i>
	• Odonata	14. <i>Chironomus sp.</i>

- *Aquatic/Semiaquatic Macrophytes*: Among the macrophytes, the species submerged in shallow water bodies and species in floating forms in stagnant water are presented in Table 5.

Family	Scientific Name
Group – Waterfern	
Azollaceae	1. <i>Azolla pinnata</i>
Salviniaceae	2. <i>Salvinia molesta</i>
Group – Aquatic angiosperms	
Alismataceae	3. <i>Sagittaria trifolia</i>
Amaryllidaceae	4. <i>Crinum viviparum</i>
Araceae	5. <i>Pistia stradiotes</i>
Hydrocharitaceae	6. <i>Hydrilla verticillata</i>
	7. <i>Vallisneria spiralis</i>
Lemnaceae	8. <i>Lemna minor</i>
	9. <i>Spirodela polyrrhiza</i>
Najadaceae	10. <i>Najas indica</i>
	11. <i>Najas marina</i>
Pontederiaceae	12. <i>Eichhornia crassipes</i>
Potamogetonaceae	13. <i>Potamogeton crispus</i>
Typhaceae	14. <i>Typha angustifolia</i>
Acanthaceae	15. <i>Hygrophila spinosa</i>
Amranthaceae	16. <i>Alternanthera sessilis</i>
	17. <i>Aerva lanata</i>
	18. <i>Celosia argentea</i>
Asteraceae	19. <i>Eclipta alba</i>
	20. <i>Sphaeranthus indicus</i>
	21. <i>Spilanthus pariculata</i>

Family	Scientific Name
Cyperaceae	22. <i>Cyperus sp.</i>
	23. <i>Scirpus articulatus</i>
Gentianaceae	24. <i>Limanthemum speltatum</i>

*Fishes*: The most dominant fish species of Wainganga River are presented in Table 6. Except 2 or 3 species, most of them were quite common. There are also some fishes, which fall under the vulnerable category as per IUCN status, like olive barb (darai), cotio (bhongi) and butter catfish (Gougavarti).

**Table 6: Freshwater Fishes of Wainganga River**

Sr. No.	Scientific Name	Common Name (Local Name)	IUCN Status
Order – Cyprixiformes, Family: Cyprinidae			
1	<i>Rasbora daniconius</i>	Stenderbarts (Dardai)	LRNT
2	<i>Osteobrama cotio</i>	Cotio (bhongi)	VU
3	<i>Puntius sarana</i>	Olive barb (darai/chalti)	VU
4	<i>Puntius sophore</i>	Pool barb (Pothi)	LRNT
5	<i>Puntius ticto</i>	Ticto barb (Pothia)	LRNC
6	<i>Cirrhinus mrigala</i>	Indian Major Carp (Mirgal)	LRNC
7	<i>Catla</i>	Indian Major Carp (Catla)	VU
8	<i>Labeo rohita</i>	Indian Major Carp (Rahu)	LRlc
9	<i>Salmostoma baciala</i>	(Chela)	LRlc
10	<i>Samostoma boopis</i>	(Amali)	LRlc
Order – Siluriformes, Family: Siluridae			
11	<i>Ompok bimaculatus</i>	Butter catfish (Gougavarti)	Vu
Order – Beloriformes, Family: Belonidae			
12	<i>Xenotodon cancila</i>	Garfish (sooimasa)	LRlc
13	<i>Hyporhamphus xanthopterus</i>	Red-tipped halfbeak (Choch maasa)	LRlc
Order – Osteoglossiformes, Family: Osteoglossidae			
14	<i>Notopterus</i>	(Pholi)	LRNT
Order – Synbranchiformes, Family: Mastacerebelidae			
15	<i>Macrognathus pancalus</i>	Barred spiny eel (Vam-bat)	LRLt
16	<i>Mastacerebelus armatus</i>	Spiny eel (Varu)	LRLc
Order – Perciformes, Family: Chandidae			
17	<i>Chanda nama</i>	Elongate glass perchlet (chand)	LRLc
18	<i>Parambassis ranga</i>	Indian glassy fish (ranga chanda)	LRLc

Sr. No.	Scientific Name	Common Name (Local Name)	IUCN Status
Order – Perciformes, Family: Gobiidae			
19	<i>Gobbius giuris</i>	Bar eyed goby (bailla)	LRLc
Order – Perciformes, Family: Channidae			
20	<i>Channa punctatus</i>	Spotted snakehead (lata)	LRNT
21	<i>Channa striatus</i>	Stripped snakehead (dhoke)	LRLc

LRNT: Low Risk Nearly Threatened; LRLc: Low Risk Least Concern; Vu: Vulnerable

- **Amphibians:** Systematic surveys of amphibians were conducted along all 3 major regions – upper reach, middle reach, and lower reach, of the Wainganga River, which includes a two-hour (18:30-20:30 hours) visual encounter survey (VES) (Crump and Scott, 1994), followed by opportunistic observations during the study period. All amphibian encounters were marked using Garmin GPS map 62s and recorded on a standard datasheet. The most

common amphibians are bull frogs, 6-toed frogs, tree frogs, and small frogs at the water edges, viz., *Limnocharis* sp.

- **Reptiles:** Common species include water snakes, along with some fresh water turtles and water monitors, particularly in swamps and the tributaries of the river.
- **Water Birds:** Due to the predominance of the riverine network and several other categories of water bodies outside and inside the Tiger Reserve and sanctuary within a 30km radius, a good number of water birds are frequently noticed/recorded in this region, for which field surveys were conducted with a census being carried out each time, from 09:00 hours to 15:00 hours along a standard route using binoculars and telescopes. A few of them are migratory categories. Water bird species found in Wainganga River and its adjoining artificial lakes/reservoirs are presented in Table 7.

**Table 7: Water Bird Species of the Wainganga River and Adjoining Artificial Lakes/Reservoirs**

Sr. No.	Scientific Name	Common Name	Residential Status	Abundance Status
Order – Podicipediformes, Family: Podicipedidae				
1	<i>Tachyba ptusruficollis</i>	Little Grebe	R	UC
Order – Anseriformes, Family: Anasidae				
2	<i>Dendrocygna javanica</i>	Lesser Whistling Duck	SV	UC
3	<i>Anser</i>	Greylag Goose	PV	Rr
4	<i>Anser indicus</i>	Bar-headed Goose	WV	O
5	<i>Sarkidiornis melanotos</i>	Comb Duck	PV	Rr
6	<i>Tadorna ferruginea</i>	Ruddy Shelduck	WV	UC
7	<i>Nettapus coromandelianus</i>	Cotton Pygmy Goose	R	VC
8	<i>Anas Penelope</i>	Eurasian Wigeon	PV	Rr
9	<i>Anas strepera</i>	Gadwall	WV	O
10	<i>Anas platyrhynchos</i>	Mallard	PV	Rr
11	<i>Anas poecilorhyncha</i>	Western Spot Billed Duck	R	C
12	<i>Anas acuta</i>	Northern Pintail	WV	UC
13	<i>Anas crecca</i>	Common Teal	WV	O
14	<i>Netta rufina</i>	Red Crested Pochard	WV	O
15	<i>Athya farina</i>	Common Pochard	WV	O
16	<i>Athya nyroca</i>	Ferruginous Duck	PV	Rr
17	<i>Athya fuligula</i>	Tufted Duck	WV	O
Order – Ciconiiformes, Family: Ciconiidae				
18	<i>Mycteria peucoptata</i>	Painted Stork	WV	O
19	<i>Anastromus oscitatus</i>	Asian Openbill	R	VC

Sr. No.	Scientific Name	Common Name	Residential Status	Abundance Status
20	<i>Ciconia nigra</i>	Black Stork	WV	O
21	<i>Ciconia episcopus</i>	Woolly-necked Stork	WV	O
Order – Ciconiiformes, Family: Threskiornithidae				
22	<i>Treskiornis melanocephalus</i>	Black Headed Ibis	SV	UC
23	<i>Pseudibis papillosa</i>	Red-Naped Ibis	R	C
Order – Ciconiiformes, Family: Ardeidae				
24	<i>Ardeola grayii</i>	Indian Pond Heron	R	VC
25	<i>Ardea cinerea</i>	Grey Heron	WV	O
26	<i>Bubulcus ibis</i>	Cattle Egret	R	VC
27	<i>Ardea purpurea</i>	Purple Heron	R	C
28	<i>Casmerodius albus</i>	Great Egret	R	VC
29	<i>Mesophoyx intermedia</i>	Intermediate Egret	WV	UC
30	<i>Egretta garzetta</i>	Little Egret	R	VC
Order – Pelecaniformes, Family: Phalacrocoracidae				
31	<i>Phalacrocorax niger</i>	Little Cormorants	R	VC
32	<i>Phalacrocorax fuscicollis</i>	Indian Cormorant	WV	O
33	<i>Phalacrocorax carbo</i>	Great Cormorant	WV	O
Order – Pelecaniformes, Family: Anlingidae				
34	<i>Anluinga melanogaster</i>	Oriental Dater	PV	R
Order – Gruiformes, Family: Rallidae				
35	<i>Porphyrio</i>	Purple Swamp Hen	R	UC
36	<i>Gallinula chloropus</i>	Common Moor Hen	R	UC
37	<i>Fulica atra</i>	Common Coot	WV	O
Order – Charadriiformes, Family: Recurvirostridae				
38	<i>Hamantopus himantopus</i>	Black Winged Stilt	R	C
Order – Charadriiformes, Family: Charadriidae				
39	<i>Vanellus duvancellii</i>	River Lapwing	PV	Rr
40	<i>Vanellus indicus</i>	Red-Wattled Lapwing	R	VC
41	<i>Pluvialis fulva</i>	Pacific Golden Plover	PV	Rr
42	<i>Charadrius dubius</i>	Little Pringed Plover	R	VC
Order – Charadriiformes, Family: Jacanidae				
43	<i>Hydrophasianus chirurgus</i>	Pheasant-tailed Jacana	R	UC
44	<i>Metopidius indicus</i>	Bronze Winged Jacana	R	UC
Order – Charadriiformes, Family: Scolopacidae				
45	<i>Gallinago</i>	Common Snipe	WV	O
46	<i>Tringa stragratilis</i>	Marsh Sandpiper	WV	UC
47	<i>Achis hypoleucos</i>	Common Sandpiper	WV	O
48	<i>Tringa nebularia</i>	Common Green Sandpiper	WV	O
49	<i>Tringa glareola</i>	Wood Sandpiper	WV	UC
50	<i>Calidris temminckii</i>	Teraminch's Stint	WV	O
51	<i>Calidris alpina</i>	Dunlin	PV	Rr

R: Resident; WV: Winter Visitor; SV: Summer Visitor; PV: Passage Visitor; Rr: Rare; O: Occasional; UC: Uncommon; C: Common; VC: Very Common.

Among the 51 water birds, a good number of them are said to be threatened (Table 8), but some of them are very common in this region due to an abundance of water bodies.

**Table 8: Threatened Water Birds**

Sr. No.	Scientific Name	Common Name	Residential Status	Abundance Status
1	<i>Aythya nyroca</i>	Ferruginous Duck	PV	Rr
2	<i>Sarkidiornis melanotos</i>	Comb Duck	PV	Rr
3	<i>Mycteria leucocephala</i>	Painted Stork	WV	O
4	<i>Anastomus oscitans</i>	Asian Openbill	R	VC
5	<i>Threskiornis melanocephalus</i>	Black Headed Ibis	SV	UC
6	<i>Bubulcus ibis</i>	Cattle Egret	R	VC
7	<i>Casmerodius albus</i>	Great Egret	R	VC
8	<i>Mesobhoix intermedia</i>	Intermediate Egret	WV	UC
9	<i>Phalacrocorax niger</i>	Little Cormorant	R	VC
10	<i>Anhinga melanogaster</i>	Oriental Darter	PV	Rr
11	<i>Vanellus duvancellii</i>	River Lapwing	PV	Rr
12	<i>Pluvialis fulva</i>	Pacific Golden Plover	PV	Rr
13	<i>Hydrophasianus chirurgus</i>	Pheasant-Tailed Jacana	R	UC
14	<i>Metopidius indicus</i>	Bronze-Winged Jacana	R	UC
15	<i>Calidris alpina</i>	Dunlin	PV	Rr

PV: Passage Visitor; WV: Winter Visitor; SV: Summer Visitor; R: Resident; Rr: Rare; O: Occasional; VC: Very Common; UC: Uncommon.

### Extent of Ecological Impact

For assessment of the ecological impact at the surveyed site due to industrial usage, 8-10 villages, in close proximity of river Wainganga, falling under 3 blocks, namely Tirora, Bhandara, and Mohadi, were selected. For an in-depth assessment of dependability of downstream users, a series of focus group discussions were initiated by the visiting team with the dwellers of selected villages, which revealed that villagers are unable to depend on the Wainganga River totally for domestic as well as cultivation purposes, as continual loss in water flow along the river has increased the level of sand and silt in the river bed.

In the case of Ghatkuroda village, located on the downstream of the river Wainganga along its left bank, it has come to the assessment study that extensive use of submersible pumps, installed along the river bed to tap water from the river, has depleted the UG level of water, causing an artificial drought situation, and thus water for basic drinking purpose has become unavailable.

In the case of Mandbi village, located on the left bank of the downstream-flowing Wainganga River, continual loss

in water flow along the river has increased the level of sand and silt in the river bed, which has led to the collapse of the pump house that has been installed to sustain irrigation and associated water utility for villagers.

In the case of Narsingtola village, located on the left bank of the river downstream, being close to the river, but not having the facility of a canal, favourable water level is of no use to its villagers. Therefore, the villagers of Narsingtola cannot utilise the river water for either their daily use or for cultivation needs.

In the case of Chandori village, located 1km on the left bank of downstream Wainganga River, there are 10 bore-wells which tap out water from 300-400 feet below the ground and supply water to the villagers for their daily domestic purposes. However, it has been reported by the locals to us that during the dry season these bore-wells too become dry, and there is water scarcity. Most of the villagers are dependent on the river water for cultivation.

In the case of village Nilja, located on the left banks of Wainganga River downstream, availability of water for cultivation is very scarce. Therefore, to support cultivation, 20 families meet their water requirements

though putting up mono block pumps on the river banks. The others irrigate their agricultural lands through digging bore-wells. Since the flow of river has gradually decreased over the period of years, and as the main pump station has collapsed, these villagers are unable to use the river water for their agricultural and domestic purposes.

In the case of Dewada village, located along the left bank of Wainganga River downstream, the total population of the village is unable to depend on the river Wainganga directly. Earlier, when the river's water level was high, the villagers were dependent on it. For all activities related to water usage, either UG source of water or individual pumping practices from the river bed is used. Thus, dependency solely on the river is almost negligible.

Villagers of Mandipar, located downstream of the river Wainganga along its left bank, are partially dependent on the river, and they have nowadays improvised diverse water curing and collecting methods, rather than depending on the river solely, as the level of water in the river has decreased steadily.

To assess the ecological impact on Wainganga River due to industrial usage, dependency on the river by the surrounding villagers has been described from 4 aspects – domestic, drinking water, agricultural, and occupational aspects.

- *Domestic Aspects:* Villages in close proximity to the Wainganga River depend solely on the river. As an alternate source of water, they have bore-wells, hand pumps, tube wells, tanks, and ponds. Whereas, the outlying villages, being away from the proximity of Wainganga, depend entirely on alternate sources of water for 6 months in a year, and in dry seasons they fetch water from the river during the remaining 6 months. This happens as the water level is far above the ground in rainy season and water level declines in dry season. Their daily necessity is not met by the prime source of water. During such times villagers are totally dependent on the rivers.
- *Drinking Water:* The main source of drinking water is bore-well, tube well, and hand pump. All of these domestic water facilities do not function properly as per need. In dry season those water sources fail to work because of a decline in the water level. People in general face water scarcity. It is observed that during the dry season sometimes in an entire

village only one bore-well works. However, in spite of scarcity of water, people hardly accumulate water from the river for their drinking water requirement.

- *Agriculture Aspects:* Water of the Wainganga River is mainly used for agriculture and other important associated facts connected to livelihood and sustainability of surrounding villagers. Most of the cultivators become exclusively dependent on Wainganga in the dry season for irrigation. Though, villagers, living a few kilometres from the banks of the Wainganga depend principally on bore-well and hand pumps for their agricultural purposes. However, when the underground water level decreases, i.e., during the dry spell months (October to March), the people in these villages depend entirely on the Wainganga River for their water consumption. So, it is a fact that the Wainganga River works as a support to agricultural livelihood sustainability.
- *Occupational Aspects:* Rivers are a source of livelihood in farming, irrigation, crop cultivation, and so on. On the other hand, rivers are a source of food, viz., fish, which in turn forms a mercantile basis of livelihood. Here, the Wainganga plays the same pivotal role. The villagers, who by occupation directly depend on the Wainganga are mostly fishermen. Though during the fishing season these fishermen catch a good quantity of fish and maintain their livelihood, the situation changes in the dry months of winter (October to March) when the water level in the river decreases and the fish decreases. Then, wage labour becomes the alternate source of income for fishermen to retain their household sustenance.

To support various industries and other ancillary requirements in this area, power sectors have been planned. Most power generating units are thermal-based. Therefore, the requirement of water to generate power using the thermal process is met by the Wainganga River by all the power generating units that have set up water-acquiring pump stations along the course of the river. However, though during the winter the river dries up widely, the pumping of water for power generation does not decline in quantity; rather, it remains the same throughout the year. As a result, though the industrial consumption remains the same, water for human consumption, by the villagers and other dwellers depending on the river water, is affected drastically.

Due to the drawl of water for industrial usage, 3 kinds of environmental damages are assessed – impact on human health, impact on ecosystem quality, and impact on resources (Pfister et al., 2009). The environmental consequences due to withdrawal of water from river are numerous and varied, and includes direct impacts to the biological, chemical, and physical properties of rivers and riparian (or “stream-side”) environments. A good review of literature on ecological impact assessment due to withdrawal of water for industrial usage is available in Fetter (1994), Havera et al. (1997), Falkenmark (2001), Glenn et al. (2001), and Harvey (2007). Biodiversity throughout the world is adversely affected when water resources are withdrawn (Pimentel et al., 2004) from nearby rivers.

The following major ecological impacts were likely to take place due to the drawl of water from Wainganga River for industrial usage:

- Major changes are found in running waters in the form of ecosystem destruction, physical habitat and water chemistry alteration, and the removal of species (Malmqvist & Rundle, 2002).
- In the case of drawl of water from rivers, riparian and groundwater-dependent vegetation are often crucial for ecosystems (Nilsson & Svedmark, 2002; Olson & Dinerstein, 1998), including birds and insects, which are again vital for the whole ecosystem, e.g., for pollination and dissemination of plants (Falkenmark, 2001).
- In places where plant growth is water-limited, withdrawals of blue water may eventually reduce the availability of green water, and thus diminish vegetation and plant diversity (Pfister et al., 2009).
- Rolls and Bond (2017) found that the impact is evident in multiple organism groups (i.e., plants, amphibians, invertebrates, and fish), ecological processes, and in-channel, riparian, and floodplain environments. Altered richness, abundance and density, composition, and altered process rates are reported as responses to such withdrawal of water across different hydrological components. However, the characteristics of ecological responses differ in response to change across hydrological components, and are also strongly determined by local factors, such as biological traits of organisms, hydroclimatic

region, and how the withdrawal of water is manifest in terms of stream hydraulics.

- The latest study of avifauna distribution around any industry (Puri & Virani, 2016) does not show any detrimental impact due to industrial operational activities in the surrounding environment, due to its unique physiographic/geographical location.

### Management Action Plan

Though the water abstraction of only 70 MCM/year from the barrage at river Wainganga for industry is not likely to have any considerable ecological impact, it may have an insignificant ecological impact in the form of habitat shrinkage and alteration. Therefore, sand bars which were formed on the river bed need to be dredged at periodic intervals, whereas as a long-term management strategy, rainwater harvesting may be incorporated.

Proper water storage planning is direly needed, as monsoon rainfall in this area is moderate to high. Due to the formation of sand bars on river beds, particularly downstream of the barrage, the river has a significant sediment load, and as such, water storage capacity declines in time. A significant number of constructions are also there across the river, particularly bridges and water-lifting structures. In this river, not a single large mammal exists in the aquatic habitat; however, fishes of some families are said to be rare and threatened. Ex-situ conservation of those species through inland captive culture practices may be the solution to lessen the problem. Over-fishing in the river can also be controlled through improved planning, along with promotion for inland aquaculture practices. Appropriate water audit in industry and dry ash disposal system can also be invented/improved.

Based on the above threat assessment, the following essential actions are envisaged to restore the ecological balance of the river Wainganga:

- Restoration of longitudinal connectivity, along with maintenance of environmental flows and sediments throughout the Wainganga River network;
- Maintenance of lateral and vertical connectivity across rivers and flood plains is also needed to provide breeding sites for fish and other aquatic/amphibious animals and plants, as well as the periodic exchange of river biota with flood plain wetlands;

- Restoration of unpolluted flow in the river by appropriate measures to control anthropogenic pollution;
- Restrictions on anthropogenic alterations of river morphology by gravel and sand mining, as well as by river bed and river bank modifications through structural measures;
- Elimination of alien invasive species from the Wainganga River network and establishing norms to prevent future introduction of exotic species.

## Conclusion

Considering the scenario of likely impacts for drawl of water for industrial usage from Wainganga River, there will be no major negative impacts on the ecology, as only 70 MCM water annually has been allocated for industrial usage. Furthermore, as the ecological cycle has a self-regulating mechanism, it is hoped that the possibility of having minor impacts on the ecological environment of the Wainganga River shall be naturally mitigated with time.

As with all empirical research study in this area, our results are subject to certain limitations. First, our sample period is only one season, i.e., winter (January-February 2019) and the results we document may not adequately capture the annual variation of impact. Second, geomorphological study of the project area is not considered here. Despite these potential shortcomings, we believe that our findings contribute evidence on major likely impacts on aquatic ecology due to withdrawal of water from the river for industrial operations.

There is need for continuing more exploratory and empirical research on different aspects of source sustainability study. Apart from the ecological impact assessment considered in the present study, future research may analyse geomorphological study, hydrological study, water-balance study, probable impact on upstream/downstream users, and so on. Future research may be conducted to explore water management and conservation plan in a more detailed way. A comparative study may also be undertaken on ecological impact assessment due to withdrawal of water for industrial use in different parts of the country. It is generally assumed that better impact assessment study and development of environmental management plan would promote socially responsible behaviour.

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