Assessment of Ecological health of Chambal River using plant species diversity

Naresh Singh Yadav[1], M.P. Sharma[2], Amit Kumar[3]*

[1] *Deputy Conservator, Department of Forest, Government of Madhya Pradesh, India*
[2, 3] *Biomass and Ecosystem Lab, Alternate Hydro Energy centre, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, 247667, India*

Abstract
In the context of Chambal River, the water quality has generally been categorized as pristine water but due to certain unchecked anthropogenic activities, water quality is gradually on a declining trend. The riparian zones represent areas of robust physico-chemical interaction between terrestrial and aquatic ecosystems. The present paper focuses on the plant diversity indices which will assess the pollution status of Chambal River, Madhya Pradesh (M.P), by way of analyzing the riparian vegetation in winter and summer season, 2014. The average Simpson's diversity index (SDI) and Shannon-Weiner diversity index (SWDI) was found as 0.23-0.28 & 2.22- 2.30 respectively indicating moderate health of the stretch of Chambal River. Similarly, the average richness indices i.e. Margalef's richness index (MARI) and Menhinik richness index (MERI) were found to be 0.49-0.52 & 0.085-0.11 respectively which also gives an indication of the moderate health of the river. The result also shows that diversity and richness indices increases from winter to summer thereby indicating that there is a decrease in pollution in summer than winter. The increase in pollution in winter needs to be taken care by way of appropriate corrective measures to keep the water quality of the stretch in good condition. The study indicates that the stretch is having moderate ecological health which means that water is not advisable for drinking but can be used for irrigation, bathing, aquaculture and life supporting activities.

Keywords: diversity index, riparian vegetation, richness index, pollution

Nomenclature
SDI: Simpson's diversity index
SWDI: Shannon-Weiner diversity index
MARI: Margalef's richness index
MERI: Menhinik richness index

1. Introduction
The use of diversity indices is an effective tool to evaluate the diversity conditions since it provides an idea about the biological and ecological quality of an aquatic ecosystem through the community structure [1-3]. These indices are also used as an indicator of the degree of pollution in the aquatic bodies [4]. Variety of indices are used in the scientific literature to describe the biodiversity changes but the biodiversity based on phytoplankton/riparian vegetation communities helps to evaluate the health of the water bodies [5]. A healthy river can fulfill the demand for drinking, agriculture, industry, fish and other life supporting activities. The water of Chambal River is fit for dinking and irrigation and an unhealthy river tends to lose its capacity to provide valuable goods and services [6-7]. Riparian vegetation provides an idea about chemical and biological interactions between terrestrial and aquatic ecosystems which can be characterized by high diversity of aquatic fauna, flora and environmental processes [8-9]. The significance of the riparian zones to the aquatic ecosystem is well known, because the terrestrial primary productivity provides the important source of energy to riverine

food-webs [10-11]. The riparian vegetation influences the biotic structure and organizations within aquatic systems [12-13].

Various parameters (water quality, phytoplankton, zooplankton, macro-invertebrates, micro-benthos, macro-zoobenthos & benthic macro-invertebrates) are available to measure the biological conditions as well as to assess the health and ecological integrity of rivers [5 & 14-21]. Little work is available on using riparian habitats for the assessment of the health of water bodies (Munne et al. 2003). The riparian vegetations help to retain nitrogen [22-23] and phosphorus [24-25] from upland diffuse and point sources of pollution as well as to regulate the microbiological activities in river [26-27]. Sovik and Syversen (2008) found that the water quality is closely related to the riparian vegetative cover and hence the later can be used as an important tool to assess the changes in water quality, biodiversity and river health [28]. Beside this, poor anthropogenic activities or a well managed stretch may have low level of risk with regard to health of water body and vice versa. The present study evaluates the ecological health of the Chambal River based on riparian vegetation using plant diversity indices

2. Material and Methods
2.1 Study site
The Chambal River originates from Mhow near Indore in Madhya Pradesh (M.P), India and is the main tributary to river Yamuna in the central India, a part of greater Gengetic drainage system. The salient features of the Chambal River are given in Table 1. The field study was conducted in a stretch of 59 km from Rajghat to Kussidghat at 100 locations; each is separated by other location by about 0.5 km. The riparian vegetation data are collected from 100 locations in winter and summer 2014 separately and then counted individually in each plot. The detail of sampling point, and its latitude/longitude of study stretch was discussed in our earlier paper [29].

Table 1: Salient features of Chambal River

S. No	Items	Details
1.	Country	India
2.	States	Madhya Pradesh, Rajasthan and Uttar Pradesh
3.	Tributaries	
(a)	- Left	Banas, Mej
(b)	- Right	Parbati, Kali Sindh, Shipra
4.	Mouth	Yamuna River
(a)	- Location	Sahon, Bhind (M.P.) and Etawah (U.P.), M.P
(b)	- Elevation	122 m
(c)	- Coordinates	26°29′20″ N 79°15′10″ E
5.	Total length	960 km out of that 320 km comes under M.P
6.	Catchment area	143,219 km^2
7.	Length of study stretch	59 km

2.2 Methodology
The sampling was done along the river bank where interactions between riparian vegetation and the aquatic habitat were found maximum. Stretch from Rajghat to Kussaidghat on both the side of the river was divided into 100 plots, each of 1m×1m at a distance of 100 m from the bank of the river. Each plot was kept at the distance of approximately 0.5 km from each other [30]. All terrestrial plants (tall, medium and small), aquatic vegetation, annual grass, perennial grass, herbs and shrubs were collected, counted and identified in each plot in winter and summer 2014 (Figure 1). The data given in Table 2-6 are the averages of all samples points and are used to calculate the species diversity indices viz. Shannon-Weiner index, Simpson index and species richness indices such as Margalef and Menhinik index [13 & 31-33] with the help of excel sheet and Biodiversity calculator (http://www.alyoung.com/labs/biodiversity_calculator.html). The detail of river health in terms of poor, medium and good was given in our previous study [29].
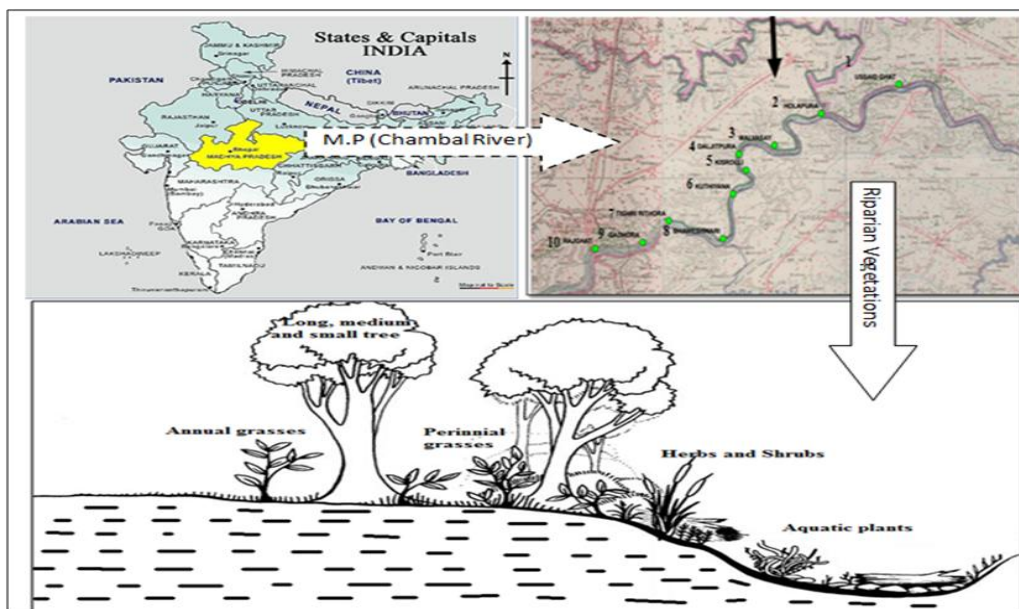
Figure 1: Sampling locations for collecting the riparian vegetation data at Chambal River

It is an established fact that pollution of any river drastically reduces the number of species of the aquatic system (i.e., Species Diversity) while frequent creation of a conducive environment is favorable only to few species i.e. pollution-tolerant forms [34]. Thus, in a polluted river, there are normally large number of few species, while in a pristine river, there are moderate number of many useful species. The change in total number of biological communities in winter and summer season, 2014 is given in Table 2-6.

Table 2: The plant species available in summer and winter 2014

Sl. No	Plant species	Winter, 2014 Av. no of individuals ± SD	Summer, 2014 Av. no of individuals ± SD
1.	*Acacia nilotica*	71±0.69	46±0.41
2.	*A. lucopholea*	63±0.80	40±0.46
3.	*A. catechu*	43±0.84	31±0.31
4.	*Prosposis juliflora*	68±0.82	47±0.59
5.	*Albizzia lebbek*	41±0.70	28±0.33
6.	*Grevia optiva*	34±0.49	25±0.00
7.	*Anogeissus pendula*	26±0.39	26±0.20
8.	*Dalbergia sissoo*	27±0.56	26±0.20
9.	*Ziziphus maurtiyana*	28±0.38	28±0.19
10.	*Ziziphus fructosa*	35±0.54	30±0.19
11.	*Calridora persica*	27±0.43	26±0.20
12.	*C. decidus*	36±0.51	30±0.26
13.	*Capparis sepiora*	32±0.50	28±0.33
14.	*Calatropis*	30±0.46	28±0.27
15.	*Gogantan*	25±0.35	25±0.00
16.	*Carissa opera*	35±0.52	31±0.26
17.	*Tamarix diocia*	36±0.41	34±0.25
18.	*Arastoda odscensinus*	39±0.44	35±0.50
Diversity of different species combined		**696**	**564**

Table 3. Shrubs in summer and winter 2014

Sl. No	Herbs / Shrubs	Winter, 2014 Avg. no of individual ± SD	Summer, 2014 Avg. no of individual ±SD
1.	*Cassia occidentalis*	153±1.07	57±0.50
2.	*C. tora*	140±1.15	57±0.61
3.	*Desmodum triflorum*	132±1.28	54±0.71
4.	*Xanthium stramonlum*	142±0.98	56±0.35
Diversity of different species combined		**567**	**224**

Table 4. Aquatic plant species found in the river in summer and winter 2014

Sl. No	Aquatic plants	Winter, 2014 Avg. no of individual ± SD	Summer , 2014 Avg. no of individual ± SD
1.	*Hydrilla verticillata*	95±0.92	35±0.38
2.	*Vallesnoria spiralis*	118±0.89	39±0.39
3.	*Potamogeton spps.*	84±0.87	34±0.50
4.	*Impoata typha*	89±0.83	31±0.31
5.	*Nitella spps.*	58±0.55	23±0.21
6.	*Chara spps.*	45±0.60	18±0.24
7.	*Zaminchetea spps.*	91±0.72	34±0.30
Diversity of different species combined		**580**	**214**

Table 5. Perennial grasses in summer and winter 2014

Sl. No	Perennial grasses	Winter, 2014 Avg. no of individual ± SD	Summer, 2014 Avg. no of individual ± SD
1.	*Bothrichloa pertysa*	105±0.72	45±0.43
2.	*Census ciliaris*	75±0.85	30±0.37
3.	*Census setigerus*	84±1.00	38±0.40
4.	*Eremopogan foveblatus*	63±0.86	23±0.30
5.	*Sporabolus marginotus*	54±0.53	25±0.00
6.	*Cymbopogon jawancesa*	57±0.54	25±0.20
7.	*Cynodan dactylon*	47±0.50	25±0.29
8.	*Sacharum spontaneum*	150±1.42	71±0.69
9.	*S. munja*	140±1.24	61±0.61
10.	*Schima nervosum*	55±0.65	33±0.31
11.	*Heteropogon contortous*	71±0.52	39±0.23
Diversity of different species combined		**901**	**415**

Table 6. Annual grasses in summer & winter 2014

Sl. No	Annual grasses	Winter, 2014 Avg. no of individual ± SD	Summer , 2014 Avg. no of individual ± SD
1.	*Aristida odscensionus*	131±0.85	48±0.50
2.	*Aristida hystrix*	89±1.06	36±0.48
3.	*Dactyloctenium aegyptium*	98±0.91	39±0.44
4.	*Eragrostos*	99±0.98	37±0.40
5.	*Viscose*	87±0.96	34±0.38
6.	*Setriaglauca*	87±1.07	36±0.51
7.	*Apluda mutica*	107±0.61	36±0.00
Diversity of different species combined		**698**	**266**

3. Results and Discussions

The five groups of riparian vegetations comprising plants (18), annual grasses (7), aquatic plants (7), perennial grasses (11) and shrubs (4) were collected during the entire study stretch and average values were calculated. Diversity and richness indices were used i.e. SWDI, SDI and MERI, MARI to find out the health of the Chambal River [13 & 31-33]. The most commonly used diversity index in ecology is the SWDI and SDI. The later is used to assess the dominance, but provides no idea about the species richness while the former determines both diversity characteristics, i.e. evenness and richness and provides no information on the rare species important to biodiversity [35].

Table 7. Analysis of combined plant diversity indices analyze and reported in 2014

Types of Riparian vegetation	Diversity of different species combined in Winter	Diversity of different species combined in Summer	Species diversity indices		Species richness indices	
			Simpson	**Shannon-Weiner**	**Margalef**	**Menhinik**
Plants	696	564	0.13 (W) 0.11 (S)	2.80 (W) 2.90 (S)	2.5 (W) 2.7 (S)	0.66 (W) 0.76 (S)
Annual grasses	698	266	0.29 (W) 0.28 (S)	1.90 (W) 1.90 (S)	0.96 (W) 1.1 (S)	0.26 (W) 0.43 (S)
Perennial grasses	901	415	0.21 (W) 0.21 (S)	2.30 (W) 2.30 (S)	1.5 (W) 1.7 (S)	0.37 (W) 0.54 (S)
Aquatic plant	580	214	0.30 (W) 0.29 (S)	1.90 (W) 1.90 (S)	0.94 (W) 1.1 (S)	0.29 (W) 0.48 (S)
Shrubs	567	224	0.50 (W) 0.25(S)	1.40 (W) 1.39(S)	0.47 (W) 0.55 S)	0.17 (W) 0.27 (S)
Total riparian vegetations	**3442**	**1683**	**0.28 (W) 0.23 (S)**	**2.22 (W) 2.30 (S)**	**0.49 (W) 0.52 (S)**	**0.085 (W) 0.11 (S)**
Ranges	**-**	**-**	**0-1**	**0-5**	**(0−∞)**	**0-1**
River health	**-**	**-**	**Moderate health**	**Moderate health**	**Moderate health**	**Moderate health**

* W: winter, S: summer

The total number of plants species, shrubs, aquatic plant, perennial and annual grasses found in 100 plots each of 1m *1m area in both the winter and summer season, are 696 and 564, 567 and 224, 580 and 214, 901and 415, 698 and 266 respectively (Table 2-6). The calculated average Species diversity and Species richness indices in winter and summer are shown in Table 7. The Table shows that the average number of riparian plants in winter and summer season is found as 3442 and 1683 respectively indicating less population in summer than the winter due to temperate climate and changes in water quality. It is also seen that SDI varied from 0.11-0.29 with an average of 0.23 in summer and 0.13-0.50 (avg. 0.28) in winter thereby indicating and expressing moderate diversity and moderate health of the River [36]. SDI was higher where the community is dominated by less number of species and the dominance is shared by large number of species [37]. Similarly, the SWDI varied from 1.40-2.80 (avg. 2.22 in winter and 1.39-2.90 (avg. 2.30) in summer indicating the moderate diversity and hence, the moderate health of the River.

The MARI has limit from 0-∞ showing its variation as a function of number of species and therefore, it is largely used for comparison of the sites and takes into account only one component of diversity (i.e. species richness) and reflects the sensitivity to sample size [38]. Its only advantage is that it can compare the richness of different sites over the SDI. In this study, MARI is found between 0.47-2.50 (avg. 0.49) in winter and 0.55-2.7 (avg. 0.52) in summer. Like MARI, MERI also gives an idea about the species richness but is independent in sample size and ranged from 0.17-0.66 (avg. 0.085) in winter and 0.27-0.76 (avg. 0.11) in summer. All these results point to the moderate diversity in winter and summer as exhibited by SWDI, MARI and MERI. This moderate diversity can be attributed to the environmental degradation on account of anthropogenic pressures

apart from other biotic factors [39]. The MARI, MERI and SDI were found higher in summer than winter due to significant improvement in physico-chemical quality of water. The graphical representation of diversity and richness indices is shown in Figures 2 & 3.
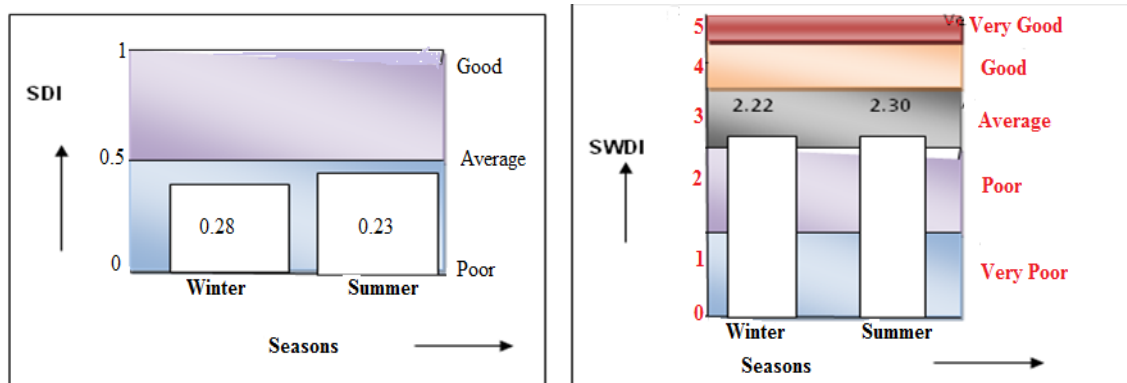

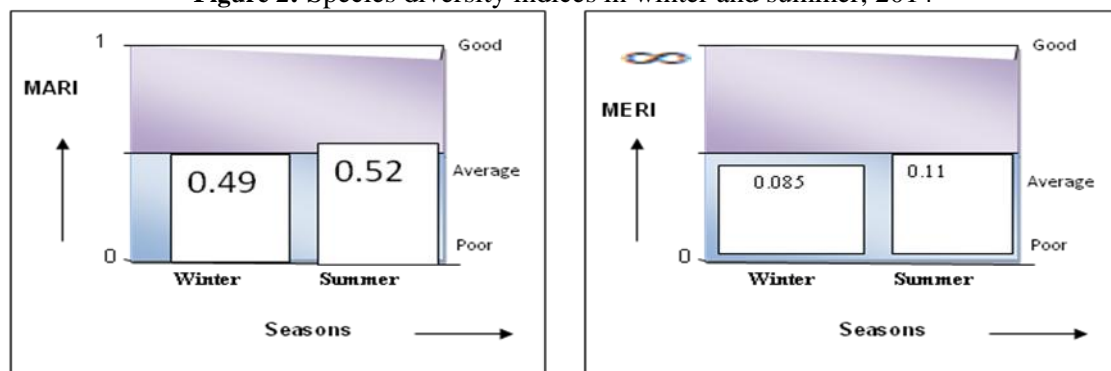**Figure 2:** Species diversity indices in winter and summer, 2014

Figure 3: Diversity richness indices in winter and summer, 2014

The figure 2&3 shows that that there is decrease in pollution indicated by an increase in diversity which may be assigned to self purification ability of the river. It is also seen that the overall ecological health of the river is moderate but is found better in summer than winter. The moderate health of the study stretch of Chambal River can also be authenticated by the results of our published work [5, 6, 29]. To bring about the improvement in the river health, the corrective conservation measures may be appropriately taken by concerned authorities so that river pollution is reduced in future.

Conclusions

Based on the riparian vegetations, the diversity and richness indices were assessed in 58 km study stretch of Chambal River during winter and summer 2014. The average SDI and SWDI was found as 0.23-0.28 & 2.22-2.30 respectively indicating moderate health of Chambal River. Similarly, the average richness indices i.e. MARI and MERI were found as 0.49-0.52 and 0.085-0.11 respectively indicating again the moderate health of the river. Diversity and richness indices are found to be slightly increased from winter to summer indicating that there is a decrease in pollution in summer than winter. The increase in pollution in winter needs to be taken care by way of taking appropriate corrective measures to keep the water quality of the stretch in good condition. The study indicates that the stretch is having moderate ecological health which means that water is not advisable for drinking but can be used for irrigation, bathing, aquaculture and life supporting activities. In order to improve the river health, it is suggested to restore the riparian vegetation with species that have a fast vegetative growth to reduce the erosion of river bank and provide favourable habitat for the aquatic fauna/flora and migratory birds.

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(2015) ; http://www.jmaterenvironsci.com