Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 5 (5): 871-880, 2006
ISSN 1682-3974

Effects of Environmental Factors on Ecology and Distribution of Aquatic Macrophytes

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Abstract: Riparian plants are excellent indicators of river condition for many reasons including their relatively high levels of species richness, rapid growth rates and direct response to environmental change. Many human-related alterations to the environment that act to degrade rivers ecosystems cause shifts in plant community composition. In the present study the phytosociological analysis of ten sampling stations of Mula, Mutha and Pavana rivers flowing through the Pune city (Mahareshtera-India) were investigated. Some of the species like *Eichhornia crassipes*, *Pistia stratiotes*, *Lemna perpusilla*, *Azolla pinnata* in the upstream sampling stations were absent or very low value of frequency index, relative frequency, density and abundance. This is indicating very rare occurrence of this species in clean water or less polluted water body. Wherever, the above species associated with *Alternanthera sessilis*, *Persicaria glabra*, *Cyperus compressus*, *Amaranthus tricolor* were observed with highest frequency index, relative frequency, density, relative density and abundance at downstream sampling stations of study area. Results obtained indicate that due to various developmental activities in and around banks of Mula, Mutha and Pavana rivers the dominance of weed species are more common than natural vegetation. It clearly indicates the human activities influence in riverine vegetation.

Key words: Aquatic macrophytes, water quality, biological indicators, Pune rivers

INTRODUCTION

Vegetation is perhaps the most conspicuous feature of rivers ecosystems and has been used extensively as an indicator of the presence of rivers themselves, their boundaries and as a basis for many rivers classification schemes. River plants are commonly defined as those growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content (Cowardin *et al*., 1979). This term includes both herbaceous (vascular and nonvascular) and woody species. Riverine plants may be floating, floating-leaved, submerged, or emergent and may complete their life cycle in still or flowing water, or on inundated or noninundated hydric soils (Cronk and Fennessy, 2001).

They have been used effectively to distinguish environmental stressors including hydrologic alterations, excessive siltation, nutrient enrichment and other types of human disturbance (Moore and Keddy, 1989; Kantrud and Newton, 1996; Philippi *et al*., 1998).

Riparian plants are excellent indicators of river condition for many reasons including their relatively high levels of species richness, rapid growth rates and direct response to environmental change. Many human-related alterations to the environment that act to degrade rivers ecosystems cause shifts in plant community composition that can be quantified easily. Individual species show differential tolerance to a wide array of stressors. Thus as environmental conditions vary, community composition shifts in response. Plant communities have been shown to change in response to hydrologic alterations (Squires and van der Valk, 1992); nutrient enrichment (Kadlec and Bevis, 1990); sediment loading and turbidity (Sager *et al*., 1998) and metals and other pollutants. These patterns can be interpreted and used to diagnose rivers impacts. Because they represent a diverse assemblage of species with different adaptations, ecological tolerances and life history strategies, the composition of the plant community can reflect the biological integrity of the river.

Aquatic macrophytes function in several ways in aquatic environment. Aquatic macrophytes are known to suppress the development of wind wave in shallow waters. Reduced wave height leads to the reduction of the resuspension of bottom sediments. This function that aquatic macrophytes may have seems important in deciding the water quality of rivers. Macrophytes can

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play an important role in improving the water quality of rivers and other water bodies by suppressing the resuspension of bottom sediments (Van den Berg *et al.*, 1998; James, 2004; Scheffer, 1998).

Riverine vegetation is at the base of the food chain and, as such, is a primary pathway for energy flow in the system. They provide critical habitat structure for other taxonomic groups, such as epiphytic bacteria, phytoplankton and some species of algae, periphyton, macroinvertebrates, amphibians and fish. A study of the diversity, density and distribution of aquatic plants is an essential component of understanding a river due to the important ecological role of aquatic vegetation and the ability of the vegetation to characterize the water quality.

MATERIALS AND METHODS

Pune city, at the south west of India is situated on the banks of the confluence of the Mula and Mutha Rivers, at an altitude of over 585 m above the sea level (Fig. 1). The archaeological relics prove that Pune was established as a township in eighth century. Presently the city is under continuous stress due to population growth, industrial growth and waste generation. Phytosociological analysis of ten sampling stations of Mula, Mutha and Pavana rivers flowing through the Pune city (Mahareshtera-India) were investigated and for the herbaceous species quadrat method was employed by following the methods of Raunkaier (1934) and Stromberg (1993). The identification of aquatic plants was done with the help of standard books and monographs like, Singh and Karthikeyan (2000, 2001) and Biswas and Calder (1953). For the analysis of the vegetation some analytical quantitative characters have been analyse from the following procedure.

- Lay down a quadrat of 1m wide and 1 m long ($1m^2$) quadrats were laid on the riparian areas along the bank of rivers.
- The quadrats to be lead with the help of nails and rope.
- Count the number of species occurring in each quadrat and record the observations in field note.
- Count the number of individuals of each species and record the observation in field note.

From each quadrats number of individuals, total number of species is measured. From those characters, Frequency, Relative frequency, Density, Relative density, Abundance, Diversity index and Important value were calculated by following formula:

$$\%\text{Frequency} = \frac{\text{Number of quadrats in which the species occurred}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Number of quadrats in which species occurred}}{\text{Total number of quadrats occupied by all species}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals of species}}{\text{Total number of quadrats used in sampling}}$$

$$\text{Relative Density} = \frac{\text{Total number of individuals of species}}{\text{Sum of all individuals of all species}}$$

$$\text{Abundance} = \frac{\text{Total number of individuals of the species}}{\text{Number of quadrats in which they occurred}}$$

Important value = Relative frequency (RF) + Relative Density (RD)

Shannon-Weaver (1949) index assumes that individuals are randomly sampled from the sample.

$$H' = -\sum P_i \ln P_i$$

Where P_i is the proportional abundance of ith species = (n_i/N).

Simpson (1949) gave the probability of any two individuals drawn at random from an indefinitely large community belonging to different species as;

$$D = \sum\left(\frac{n_i\ (n_i-1)}{N\ (N-1)}\right)$$

Where:
ni = the number of individuals in the ith species.
N = the total number of individuals.

This index is referred to as dominance index since it weighted towards the abundance of the commonest species rather than providing a measure of species richness. As D increases, diversity decreases and Simpson index is therefore usually expressed as 1-D or 1/D. The presence or absence of plant species was recorded. This data was also used to determine the

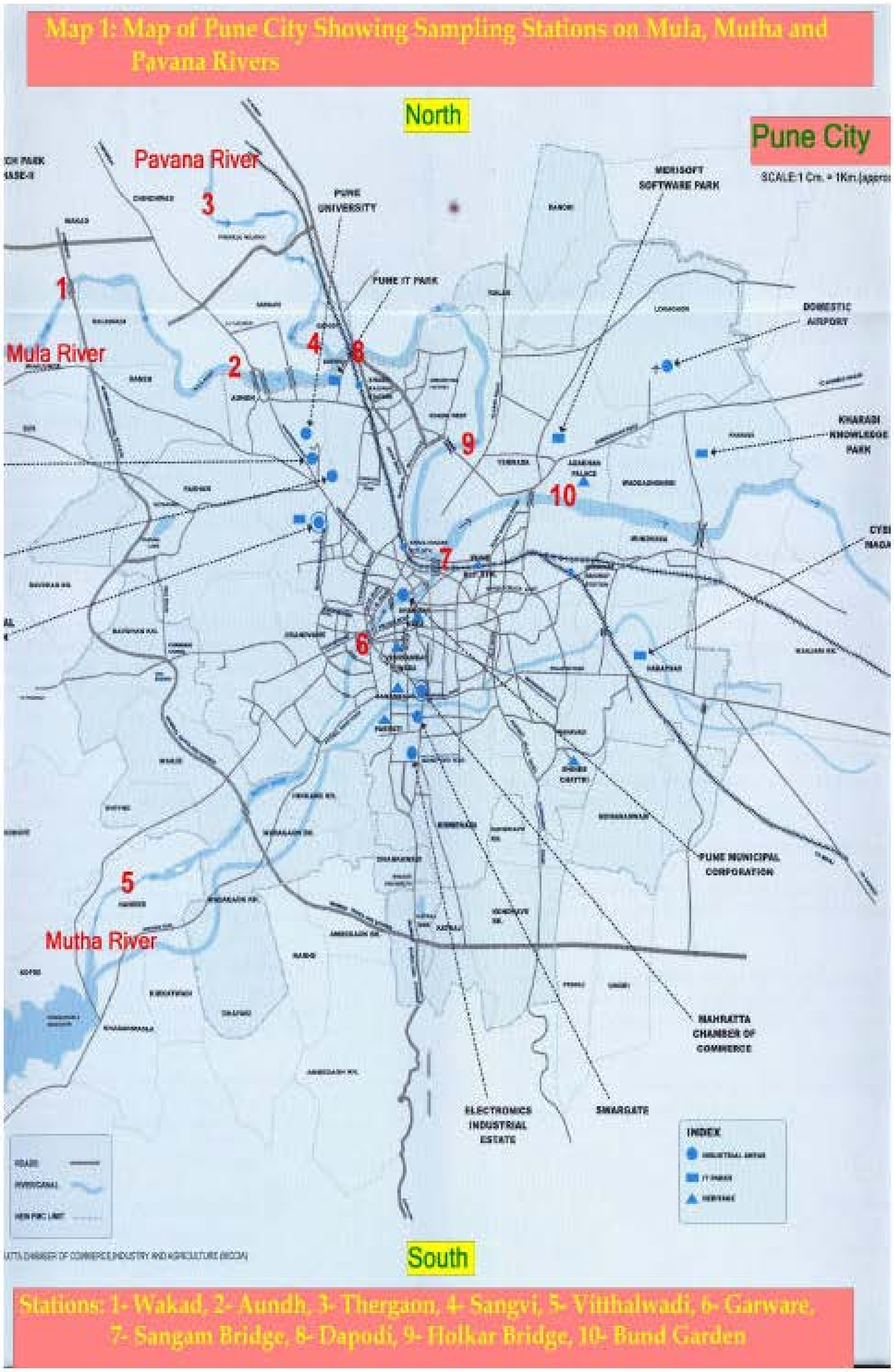

Fig. 1: Map of Pune City showing sampling station on mula, Mutha and Pavana Rivers

homogeneity/heterogeneity of the vegetational stand of the study area. The species types are divided into five frequency classes depending on Raunkier's (1934) frequency classification as below.

Class-A = 1 to 20%, Class-B = 21 to 40%, Class-C = 41 to 60%, Class-D = 61 to 80% Class-E = 81 to 100%

Each species is classified in above-mentioned classes. A histogram was drawn with percentage of the total number of species on Y-axis and frequency classes A to E on X axis. It is compared with the law of frequency as follows. A>B>C≥ or ≤ D<E.

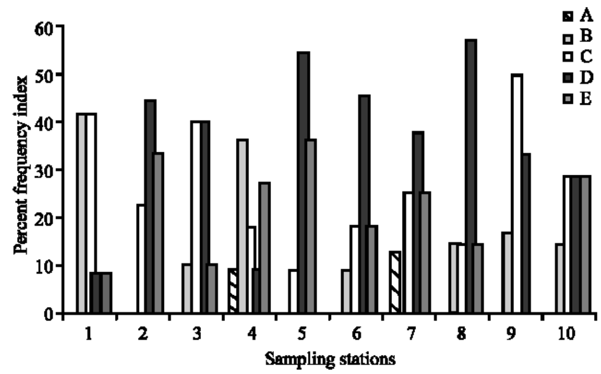

Fig. 2: Raunkiaer's frequency classes in study area

RESULTS AND DISCUSSION

Of the 81 species of plants found in the present study on Mula, Mutha and Pavana rivers flowing through the Pune City (Mahareshtera-India), were 47 Herb species, 10 were Shrub species, 23 were tree species and only 1 Climber species was recorded (Table 1). In the present study maximum plants species were observed at sampling station 4 (Sangvi) follows in station 8 and 1 (Dapodi and Wakad), while minimum plants species were recorded in Bund Garden (station 10). All the Phytosociological investigations are presented station wise in Table 2.

Frequency is a measure of the commonness and distribution of a species within a study area. Frequency is expressed as a percentage of sample plots in which a species occurs. It is defined as the chance of finding a species in a particular area in a particular trial sample (Goldsmith *et al*., 1992). The frequency of individual species or structural type is the number of times the species or structural type occurs in the sampling quadrats. *Alternanthera sessilis*, *Phyla nodiflora*, *Persicaria glabra*, *Azolla pinnata*, *Pistia stratiotes, Amaranthus* sp. were having the highest percentage frequency index. The species, which have minimum frequency index, includes *Phyllanthus reticulates* and *Eclipta alba.*

Frequency not only shows the importance of species, but also the evenness of spatial distribution in community (Deng *et al*., 2000). The highest percentage of frequency class A, B, C, D and E was observed 12.5, 41.66, 54.54, 57.14 and 28.57 at sampling station 7, 1, 5, 8 and 10, respectively. Based on Raunkier's frequency classes, the vegetation represented heterogeneous nature at all sampling stations which are observed noticeably in high polluted area (Sangam Bridge and Dapodi). Raunkier's (1934) frequency classes for different sampling stations are represented graphically in Fig. 2. Simply, frequency index or relative frequency alone cannot determine the dominant plant community. For the determination of plant community abundance and density values needs to be measured. Few species like *Alternanthera sessilis*, *Phyla nodiflora*, *Persicaria glabra*, *Pistia stratiotes*, *Azolla pinnata* exceed all other species not only in frequency index but also in abundance, density and relative density.

In the present study some species like *Eichhornia crassipes*, *Pistia stratiotes*, *Lemna perpusilla*, *Azolla pinnata* in the upstream sampling stations were absent or very low value of frequency index, relative frequency, density and abundance. This is indicating very rare occurrence of this species in clean water or less polluted water body. Wherever, the above species associated with *Alternanthera sessilis*, *Persicaria glabra*, *Cyperus compressus*, *Amaranthus tricolor* were observed with highest frequency index, relative frequency, density, relative density and abundance at downstream sampling stations of study area.

In the present study an attempt has been made to understand the patterns of species diversity and human impact on vegetations diversity. On the basis of quantitative estimate, overall species number rank order is station-1>station-2<station-3<station-4>station-5>station-6 = station-7<station-8>station-9 >station-10. This is because diversity is relative to spatial scale, temporal scale and taxocene spectrum (Patil *et al*., 1997). The Shannon-Weaver and Simpson diversity indices were calculated for all the ten sampling stations. One of the best diversity indices is species richness i.e the number of species present in the area. Figure 3 gives the values of above indices for these stations. Based on the Shannon-Weaver index the sequence among the stations is, from highest to lowest diversity, station 6>station 9>station 3>station 1>station 5>station 4>station 2>station 7>station 10>station 8>. The rank has been changed because Simpson's index is heavily weighted towards the most abundant species in the sample while being less sensitive to species richness (Magurran, 1988).

Table 1: Higher plants species along the 10 sampling stations of Mula, Mutha and Pavana rivers course

Botanical name	Habit	Family	1	2	3	4	5	6	7	8	9	10
Acacia nilotica (Lam.) Willd.	Tree	Mimosaceae	-	+	-	-	-	-	+	-	+	+
Acalypha ciliate Fosk	Herb	Euphorbiaceae	-	-	-	-	-	+	-	-	-	-
Ageratum conyzoides L.	Herb	Asteraceae	-	-	-	-	-	-	-	-	-	+
Albizia lebbeck (L.) Bth.	Tree	Mimosaceae	-	-	-	-	-	-	+	-	+	+
Albizia lucidior (Steud.) Nielsen	Tree	Mimosaceae	-	-	-	-	-	-	+	-	+	+
Alternanthera sessilis (L.)R. Br.	Herb	Amaranthaceae	+	+	+	+	+	+	+	+	+	+
Amaranthus spinosus L.	Herb	Amaranthaceae	-	-	-	-	+	+	+	-	+	-
Amaranthus tricolor L.	Herb	Amaranthaceae	-	-	+	-	-	-	-	-	-	-
Amaranthus viridis L.	Herb	Amaranthaceae	-	-	-	-	+	-	+	-	+	-
Ammannia baccifera L.	Herb	Lythraceae	+	-	+	+	+	-	-	-	-	-
Argemone mexicana L.	Herb	Papaveraceae	+	-	-	+	+	+	-	+	+	-
Asclepias curassavica L.	Shrub	Asclepiadaceae	-	-	-	-	-	+	-	-	-	-
Azadirachta indica L.	Tree	Meliaceae	-	-	-	-	-	-	+	-	+	+
Azolla pinnata R. Br.	Herb	Azollaceae	+	+	+	+	-	-	+	+	+	+
Blumea sp.	Herb	Asteraceae	-	-	+	-	-	-	-	-	-	-
Brassica juncea (L.) Czern.	Herb	Brassicaceae	-	-	-	-	+	-	-	-	-	-
Calotropis procera Aiton.	Herb	Asclepiadaceae	-	+	-	-	-	-	-	-	-	-
Cassia marginata Roxb.	Tree	Caesalpinaceae	-	-	-	-	+	-	+	-	-	-
Cassia siamea Lam.	Tree	Caesalpinaceae	-	-	-	-	-	-	-	-	+	-
Cassia uniflora Mill.non Spreng.	Herb	Caesalpinaceae	+	-	+	+	+	+	-	+	-	-
Chenopodium album Labill	Herb	Chenopodiaceae	+	-	+	+	-	-	-	+	+	-
Chloris barbata Swartz	Herb	Poaceae	+	+	+	+	-	-	-	+	-	-
Chrozophora rottleri (*Gies.*) Juss.	Herb	Euphorbiaceae	+	-	+	+	-	+	+	+	+	+
Colocasia sp.	Herb	Araceae	-	-	-	-	-	+	-	-	-	-
Commelina forsskalaei Vahl.	Herb	Commelinaceae	+	+	+	+	+	-	-	+	-	-
Commelina benghalensis L.	Herb	Commelinaceae	+	-	-	+	-	-	-	+	-	-
Croton gibsonianus Nimmo	Shrub	Euphorbiaceae	-	-	-	-	-	+	-	-	-	+
Cyathocline purpurea (Buch.-Ham.ex D.Don) O. Ktze.	Herb	Asteraceae	+	-	-	+	-	-	-	+	-	-
Cynodon dactylon L.	Herb	Poaceae	-	+	-	-	+	+	-	-	-	-
Cynodon sp.	Herb	Poaceae	-	-	-	+	-	-	-	-	-	-
Cyperus compressus L.	Herb	Cyperaceae	-	-	-	-	+	+	-	-	+	-
Cyperus sp.	Herb	Cyperaceae	-	+	-	-	-	-	-	-	-	-
Dactyloctenium sp.	Herb	Poaceae	-	+	-	-	-	-	-	-	-	-
Datura metal L.	Herb	Solanaceae	-	-	-	+	+	-	+	-	+	+
Delonix regia Bojer ex Hook	Tree	Caesalpinaceae	-	-	-	-	-	-	-	-	-	+
Eclipta alba (L.) Hassk.	Herb	Asteraceae	-	-	-	-	-	+	+	-	-	-
Eichhornia crassipes Solms	Herb	Pontaderiaceae	-	+	+	+	+	-	+	+	+	+
Eucalyptus globosus Labill	Tree	Myrtaceae	-	-	-	-	-	-	+	-	-	-
Eupatorium sp.	Shrub	Asteraceae	-	-	-	+	-	-	-	-	-	-
Ficus benghalensis L.	Tree	Moraceae	-	-	-	-	+	+	-	-	-	+
Ficus hispida (L.) f.	Tree	Moraceae	-	-	-	-	+	+	-	-	-	-
Ficus racemosa L.	Tree	Moraceae	+	+	+	+	+	+	-	+	-	-
Ficus religiosa L.	Tree	Moraceae	+	-	+	+	-	+	+	+	-	+
Fimbristylis dichotoma (L.) Vahl.	Herb	Cyperaceae	+	+	+	+	-	-	-	+	-	-
Grangea maderaspatana (L.) Poir.	Herb	Asteraceae	+	-	+	+	-	-	-	+	-	-
Heliotropium sp.	Herb	Boraginaceae	-	-	-	+	-	-	+	-	-	-
Holoptelia integrifolia Roxb.	Tree	Urticaceae	-	+	-	-	-	-	+	-	-	-
Hydrilla verticillata (L.f.) Royle.	Herb	Hydrocharitaceae	+	-	+	+	-	+	-	+	-	-
Ipomoea carnea Jacq.	Shrub	Convolvulaceae	-	-	+	+	-	-	-	+	-	-
Kyllinga tenuifolia Steud.	Herb	Cyperaceae	-	-	+	+	-	-	-	+	-	-
Lemna perpusilla Torr.	Herb	Lemnaceae	+	+	+	+	+	+	+	+	+	-
Leucas biflora (Vahl) R. Br.	Herb	Lamiaceae	-	-	-	-	+	-	-	-	-	-
Ludwigia octovalvis (Jacq.) Raven	Herb	Onagraceae	+	+	+	+	+	+	+	+	+	-
Lycopersicon lycopersicum (L.) Karsten.	Herb	Solanaceae	+	-	-	+	-	-	-	+	-	-
Panicum sp.	Herb	Poaceae	-	+	-	-	-	-	-	-	-	-
Parthenium hysterophorus L.	Herb	Asteraceae	+	-	+	+	+	+	+	+	+	+
Passiflora foetida L.	Climber	Passifloraceae	+	-	-	+	-	-	-	-	+	+
Persicaria glabra (Willd.) Gomez.	Shrub	Polygonaceae	-	+	+	+	+	+	+	+	-	-
Phoenix sylvestris Roxb.	Tree	Palmae	-	+	-	-	-	-	+	+	-	-
Phyla nodiflora (L.) Greene	Herb	Verbenaceae	-	-	+	+	-	+	-	+	+	-
Phyllanthus reticulatus Poir.	Shrub	Euphorbiaceae	+	+	+	+	+	+	-	+	+	-
Physalis minima L.	Herb	Solanaceae	+	-	-	+	-	-	-	+	-	-
Pistia stratiotes L.	Herb	Araceae	-	+	+	+	-	-	+	+	+	+
Pithecellobium dulce Roxb.	Tree	Mimosaceae	-	+	-	-	-	-	-	-	-	-
Pongamia pinnata (L.) Pierre.	Tree	Fabaceae	+	+	-	+	+	-	-	-	-	+

Tabel 1: Conutined

Botanical name	Habit	Family	1	2	3	4	5	6	7	8	9	10
Portulaca oleracea L.	Herb	Portulaceae	+	-	+	+	-	-	+	+	+	+
Prosopis juliflora (Sw.) DC.	Tree	Mimosaceae	-	+	-	-	-	-	-	+	-	-
Ricinus communis L.	Shrub	Euphorbiaceae	-	-	-	-	-	-	-	-	-	-
Salix tetrasperma Roxb.	Tree	Salicaceae	+	+	-	+	-	-	+	-	-	+
Samania saman Jacaq.	Tree	Mimosaceae	-	+	-	-	-	-	-	+	-	-
Sida acuta Burm.	Herb	Malvaceae	-	-	-	-	+	-	-	-	-	-
Solanum indicum L.	Shrub	Solanaceae	-	-	-	-	+	-	-	-	-	+
Solanum virginianum L.	Herb	Solanaceae	+	-	+	+	-	-	-	-	-	-
Spathodium campanulata L.	Tree	Bignoniaceae	-	+	-	-	-	+	-	+	-	+
Sphaeranthus indicus L.	Herb	Asteraceae	+	-	+	+	-	-	-	-	-	-
Syzygium cumini (L.) Skeels	Tree	Myrtaceae	+	-	+	+	-	-	-	+	-	-
Syzygium heyneanum (Duthie) Wall. ex Gamble.	Tree	Myrtaceae	+	-	-	+	-	-	-	+	-	-
Typha angustifolia L.	Shrub	Typhaceae	+	+	+	+	+	-	-	+	-	-
Verbascum chinense (L.) Sant.	Herb	Scrophulariaceae	-	-	+	+	+	-	-	+	-	-
Xanthium indicum Koen.	Herb	Asteraceae	+	+	+	+	+	-	-	+	+	-
Ziziphus jujuba Mill.	Tree	Rhamnaceae	+	-	-	+	-	+	-	+	+	-

Stations: 1- Wakad, 2- Aundh, 3- Thergaon, 4- Sangvi, 5- Vitthalwadi, 6- Garware, 7- Sangam Bridge, 8- Dapodi, 9- Holkar Bridge, 10- Bund Garden

Table 2: Phytosociological analysis in different sampling stations of mula, mutha and pavana rivers

Botanical name	Freq. index	Rel. freq.	Abund	Class	Density	Relative density	IV
Wakad Station							
Alternanthera sessilis	100	14.71	27.00	A	27.00	36.68	51.39
Fimbristylis dichotoma	60	8.82	30.00	C	18.00	24.46	33.28
Persicaria glabra	60	8.82	12.33	C	7.40	10.05	18.88
Cyperus sp.	60	8.82	9.67	C	5.80	7.88	16.70
Typha angustifolia	80	11.76	4.25	D	3.40	4.62	16.38
Commelia forsskalaei	60	8.82	3.33	C	2.00	2.72	11.54
Ammannia sp.	60	8.82	3.33	C	2.00	2.72	11.54
Ludwigia octavalvis	40	5.88	7.50	B	3.00	4.08	9.96
Ipomoea carnea	40	5.88	3.50	B	1.40	1.90	7.78
Cassia uniflora	40	5.88	3.50	B	1.40	1.90	7.78
Lycopersicon lycopersicum	40	5.88	3.00	B	1.20	1.63	7.51
Chenopodium album	40	5.88	2.50	B	1.00	1.36	7.24
Aundh Station							
Azolla pinnata	100	13.51	23.40	E	23.40	45.00	58.51
Pistia stratiotes	100	13.51	5.60	E	5.60	10.77	24.28
Persicaria glabra	100	13.51	4.20	E	4.20	8.08	21.59
Eichhornia crassipens	80	10.81	5.50	D	4.40	8.46	19.27
Fimbrystylis	80	10.81	4.25	D	3.40	6.54	17.35
Cyperus sp.	80	10.81	4.00	D	3.20	6.15	16.96
Commelina forsskalaei	80	10.81	4.00	D	3.20	6.15	16.96
Typha angustifolia	60	8.11	4.33	C	2.60	5.00	13.11
Ludwigia octavalvis	60	8.11	3.33	C	2.00	3.85	11.95
Thergaon Station							
Phyla nodiflora	100	14.29	32.80	E	32.80	38.86	53.15
Alternanthera sessilis	80	11.43	16.00	D	12.80	15.17	26.59
Typha angustifolia	80	11.43	13.00	D	10.40	12.32	23.75
Persicaria glabra	80	11.43	10.25	D	8.20	9.72	21.14
Pistia stratiotes	80	11.43	6.25	D	5.00	5.92	17.35
Fimbristylis dichotoma	60	8.57	9.00	C	5.40	6.40	14.97
Amaranthus sp.	60	8.57	5.67	C	3.40	4.03	12.60
Ludwigia octavalvis	60	8.57	5.33	C	3.20	3.79	12.36
Parthenium hysterophorus	60	8.57	4.33	C	2.60	3.08	11.65
Chrozophora rottleri	40	5.71	1.50	B	0.60	0.71	6.43
Sangvi Station							
Persicaria glabra	100	14.71	14.80	E	14.80	37.19	51.89
Alternanthera sessilis	100	14.71	10.00	E	10.00	25.13	39.83
Phyla nodiflora	100	14.71	5.80	E	5.80	14.57	29.28
Pistia stratiotes	80	11.76	3.50	D	2.80	7.04	18.80
Eichhornia crassipes	60	8.82	3.33	C	2.00	5.03	13.85
Amaranthus sp.	60	8.82	3.00	C	1.80	4.52	13.35
Verbascum chinense	40	5.88	2.50	B	1.00	2.51	8.39
Chrozophora rottleri	40	5.88	1.50	B	0.60	1.51	7.39
Heliotropium sp.	40	5.88	1.00	B	0.40	1.01	6.89
Datura sp.	40	5.88	1.00	B	0.40	1.01	6.89
Phyllanthus reticulatus	20	2.94	1.00	A	0.20	0.50	3.44

Tabel 2: Conutined

Botanical name	Freq. index	Rel. freq.	Abund	Class	Density	Relative density	IV
Vitthalwadi Station							
Ammannia sp.	80	11.11	2.50	D	2.00	4.26	15.37
Argemone mexicana	80	11.11	1.50	D	1.20	2.55	13.66
Cyperus compressus	80	11.11	4.25	D	3.40	7.23	18.35
Persicaria glabra	80	11.11	3.50	D	2.80	5.96	17.07
Alternanthera sessilis	60	8.33	7.00	C	4.20	8.94	17.27
Amaranthus tricolor	60	8.33	4.33	C	2.60	5.53	13.87
Cynodon dactylon	60	8.33	9.33	C	5.60	11.91	20.25
Datura metal	60	8.33	1.67	C	1.00	2.13	10.46
Eichhornia crassipes	60	8.33	4.00	C	2.40	5.11	13.44
Typha angustifolia	60	8.33	3.00	C	1.80	3.83	12.16
Lemna perpusilla	40	5.56	50.00	B	20.00	42.55	48.11
Garware Station							
Alternanthera sessilis	100	12.50	6.20	E	6.20	18.24	30.74
Amaranthus tricolor	100	12.50	3.80	E	3.80	11.18	23.68
Croton gibsonianus	80	10.00	3.25	D	2.60	7.65	17.65
Cynodon dactylon	80	10.00	8.75	D	7.00	20.59	30.59
Parthenium hysterophorus	80	10.00	3.25	D	2.60	7.65	17.65
Persicaria glabra	80	10.00	3.50	D	2.80	8.24	18.24
Phyla nodiflora	80	10.00	6.25	D	5.00	14.71	24.71
Argemone mexicana	60	7.50	2.00	C	1.20	3.53	11.03
Asclepias curassavica	60	7.50	1.33	C	0.80	2.35	9.85
Chrozophora rottleri	40	5.00	2.50	B	1.00	2.94	7.94
Eclipta alba	40	5.00	2.50	B	1.00	2.94	7.94
Sangam Bridge Station							
Azolla pinnata	100	16.67	46.40	E	46.40	50.43	67.10
Persicaria glabra	100	16.67	5.40	E	5.40	5.87	22.54
Lemna perpusilla	80	13.33	18.50	D	14.80	16.09	29.42
Pistia stratiotes	80	13.33	15.75	D	12.60	13.70	27.03
Eichhornia crassipes	80	13.33	9.00	D	7.20	7.83	21.16
Chrozophora rottleri	60	10.00	4.00	C	2.40	2.61	12.61
Ludwigia octavalvis	60	10.00	3.67	C	2.20	2.39	12.39
Eclipta alba	40	6.67	2.50	B	1.00	1.09	7.75
Dapodi Station							
Alternanthera sessilis	100	19.23	5.80	E	5.80	5.58	24.81
Azolla pinnata	80	15.38	57.00	D	45.60	43.85	59.23
Lemna perpusilla	80	15.38	50.75	D	40.60	39.04	54.42
Pistia stratiotes	80	15.38	9.50	D	7.60	7.31	22.69
Persicaria glabra	80	15.38	3.25	D	2.60	2.50	17.88
Eichhornia crassipes	60	11.54	2.33	C	1.40	1.35	12.88
Eupatorium sp.	40	7.69	1.00	B	0.40	0.38	8.08
Holkar Bridge Station							
Lemna perpusilla	80	10.53	53.00	D	42.40	33.60	44.12
Azolla pinnata	80	10.53	43.00	D	34.40	27.26	37.78
Alternanthera sessilis	80	10.53	11.00	D	8.80	6.97	17.50
Cyperus compressus	80	10.53	9.25	D	7.40	5.86	16.39
Pistia stratiotes	60	7.89	17.33	C	10.40	8.24	16.14
Persicaria glabra	60	7.89	12.33	C	7.40	5.86	13.76
Ludwigia octavalvis	60	7.89	6.00	C	3.60	2.85	10.75
Chrozophora rottleri	60	7.89	4.00	C	2.40	1.90	9.80
Argemone mexicana	60	7.89	2.00	C	1.20	0.95	8.85
Datura metal	60	7.89	1.33	C	0.80	0.63	8.53
Phyla nodiflora	40	5.26	15.00	B	6.00	4.75	10.02
Eichhornia crassipes	40	5.26	3.50	B	1.40	1.11	6.37
Bund Garden Station							
Azolla pinnata	100	19.23	23.40	E	23.40	52.70	71.93
Alternanthera sessilis	100	19.23	4.40	E	4.40	9.91	29.14
Pistia stratiotes	80	15.38	7.25	D	5.80	13.06	28.45
Persicaria glabra	80	15.38	5.25	D	4.20	9.46	24.84
Eichhornia crassipes	60	11.54	7.00	C	4.20	9.46	21.00
Chrozophora rottleri	60	11.54	3.00	C	1.80	4.05	15.59
Croton gibsonianus	40	7.69	1.50	B	0.60	1.35	9.04

In the present study amongst all the study area, station 5 and 9 (Vitthalwadi Holkar Bridge) were represented as most diverse. It has highest species richness due to relatively less human intervention, whereas station 6 and 8 (Garware and Dapodi) were having the least species Shannon diversity index as a

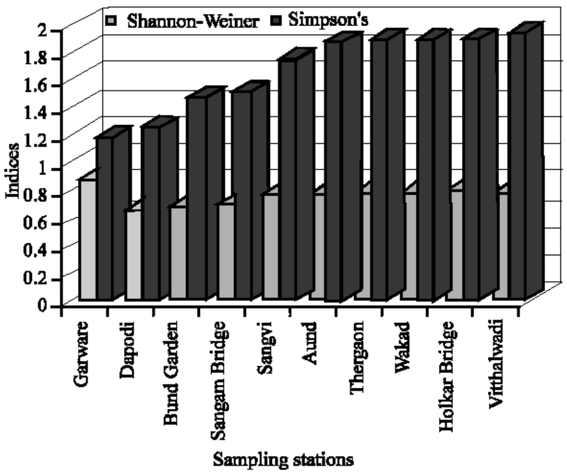

Fig. 3: Shannon-weiner and simpson's diversity indices for various sampling stations

result of reasonably high population pressure, apparently patchy vegetation due to biotic interfence involving farming practices, habitat destruction and domestic livestock. Shannon-Weaver and Simpson's diversity indices have interpreted no significant difference in between the various stations. It suggests that the species were somehow distributed rather evenly. However, there were significant differences in species relative abundance and density. For rivers and aquatic environments, in general, low species diversity is correlated with permanent or long-term periods of inundation and generally in wetlands, seasonally-variable water levels enhance diversity (Mitsch and Gosselink, 2000). The results also indicated that some unnatural species were not distributed uniformly, rather appearing in a thicket. The distributions of these species were found to be depending upon the human interference in the natural vegetation.

The above enumeration indicates the relative range of distribution of various species in the study area. Species like *Ipomoea carnea*, *Amaranthus viridis* etc. are restricted in distribution but are abundant locally. Plants like *Acalypha ciliata*, *Ageratum conyzoides*, *Solanum indicum* are restricted in their distribution and rare in occurrence. The species having wide range of distribution and abundant in occurrence include *Alternanthera sessilis*, *Ludwigia octovalvis*, *Eichhornia crassipes*, *Parthenium hysterophorus* etc. in rivers bed is quite remarkable particularly in urban areas.

Riparian zones are subjected to many different influences that may affect the plants that grow there. There are regional factors such as land cover and climate; local factors such as sunlight, soil type and pH, nutrient availability, micro-topography; and moisture, biotic factors such as competition and both natural and anthropogenic disturbance factors. All of these factors can affect a plant species ability to persist. The hypothesis tested in this study concerns the local anthropogenic disturbance created from different land cover types. The regeneration of natural plant communities within riparian zones is vital to the protection of entire stream systems. Because different disturbances associated with land cover might affect plant communities and individual species differentially, it is important to study community level responses as well as species-specific responses to a land cover disturbance gradient. The responses of the vegetation community and the individual species to external land cover disturbances will potentially determine the future structure and composition of the riparian communities.

The results obtained from our study indicate the presence of *Alternanthera sessilis*, *Ludwigia octovalvis* and *Amaranthus spinosus* are the most commonly growing known to adapt wider range of environmental conditions. Upstream stations showed weeds like *Commelina forsskalaei* and *Ammannia baccifera* is commonly growing plants on the bank of rivers. As we go downstream species like *Eichhornia crassipes* and *Pistia stratiotes* is more dominant followed by *Lemna perpusilla* and *Amaranthus spinosus* this area is more disturbed due to dumping of solid waste and also other debris arising from urban activities.

Overall it indicate that due to various developmental activities in and around banks of Mula, Mutha and Pavana rivers the dominance of weed species are more common than natural vegetation. It clearly indicates the human activities influence in riverine vegetation. Some of earlier records (Vartak, 1957, 1961) show a mixed unique type of vegetation. Vegetation along the bank of rivers is slowly taken over by plants like, *Alternanthera*, *Parthenium*, *Ludwigia*, *Amaranthus*, etc. therefore slow growing species are replaced by above fast growing species or are replaced by other species.

As the rivers enter into urban influence, inflow of sewage helps to increase these nutrients, particularly phosphates, thereby increasing growth of plants. Species among plant, indicative of organic enrichment are *Pistia stratiotes*, *Lemna perpusilla*, *Azolla pinnata*, *Amaranthus spinosus*. These species are also found in large population in Mula, Mutha and Pavana rivers (Sangam Bridge, Dapodi, Aundh, Sangvi and Holkar Bridge). In addition once *Eichhornia crassipes* (water hyacinth) and *Pistia stratiotes* (water lettuce) were spread all over downstream and mainstream of Mula, Mutha and Pavana rivers. This again indicates that the river water is receiving plant nutrients for the luxuriant growth of the plant; the main source of the plant nutrient is obviously the city sewage. Similar observation has been reported by (Jafari *et al*., 2006; Gunale and Balakrishnan, 1981). Aquatic plant like *Alternanthera denticulata* or the alligator weed is fast spreading all over the river, especially in the shallow silted parts. This weed may prove to be another problematic weed in addition to water hyacinth. Besides, growth of floating forms like *Leman* requires special attention as far as conservation of river is concerned. *Lemna* forms a thick mat over the surface of water, cutting the entry of sunlight and the condition that are vitally important for the growth and survival of phytoplanktons. In addition to these the large amount of organic matter that is produced due to *Lemna*, *Azolla* and other small weeds are chocking the rivers and reducing dissolved oxygen contents.

CONCLUSIONS

In the aquatic ecosystem, nutrient concentrations are continuously affected by a wide range of physical, chemical and biological processes resulting in a dynamic water quality status. In case macrophytes are growing in the river, the vegetation induces substantial changes to the water quality. Some effects are owing to direct interactions, such as the uptake of nutrients, whereas others may be merely attributed to indirect effect of the water plants on hydrodynamics and/or sediment chemistry. In order to improve water quality by integrated management practices, a more profound understanding and further quantification of the interactions between the macrophytes and the aquatic system is indispensable.

A great deal of information is needed for biologists to predict the fate of aquatic macrophytes within the Pune city rivers. They will need to know where vegetation exists and the potential for unvegetated reaches to regain viable populations. Long-term monitoring of the distribution of plant beds is necessary to better understand the impact of various factors, whether they are anthropogenic in source or related to weather events such as droughts and floods. Additionally, studies are needed to determine the effects of the factors described above on the production and reproductive biology of macrophytes in Mula, Mutha and Pavana rivers.

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