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Floristic diversity of lacustrine ecotone of Lakes in Valsad District, Gujarat, India

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ABSTRACT

The primary aim of this paper is to determine the floral biodiversity of ten lacustrine ecotones in Valsad district. Secondarily we will find out the factors affecting the floral biodiversity. We investigated the composition and distribution pattern of the flora of ecotones of ten lakes for a period of one year. Jaccardian similarity index was used to analyze the species composition of the lake ecotones under study. Total 131 species of angiospermic plants belonging to 119 genera and 46 families found in the lacustrine ecosystem of the ten lakes under study. Dominant tree families of the area were Fabaceae followed by Apocyanaceae and Lamiaceae. Dominant weed families are Poaceae, Fabaceae, Asteraceae, and Malvaceae. The study demonstrates the anthropogenic impact on the floral diversity of the plagioclimax lacustrine ecotones and the need for conservation.

Key words *: Ecotone, Jaccardian index, Exotic species, Ruderals, Plagioclimax community*

Introduction

Lakes of India are disappearing at an alarming rate due to the pressure of urbanization and the increase of population (Neely *et al*., 1992). Land reclamation of the lake ecotone area is done for building of apartments or other land uses causing habitat destruction of many plants (Wilcove *et al.,* 1998). Modification of the physiochemical environment of a place due to pollution either municipal or industrial alters plant diversity, causes the spreading of weedy exotics (Wilcove *et al.,* 1998; Thuiler, 2007). Human disturbance and over-exploitation of aquatic resource kills slow-growing, specialist plants and negatively affect their demography (Kingsford *et al.,* 2009). Inferior generalists and ruderals species replace rich ecotones. All these will lead to loss of biodiversity, which will, in turn, lead to instability of the ecosystem (Solbrig, 1991).

According to Clements, 1936, the transition zone between adjacent communities, where exchange or competition between neighboring patches observed is ecotone. Ecotones have a much higher diversity of plants and animals than surrounding ecosystems. There are various types of ecotones such as coastal (Walker *et al.,* 2003), estuaries (Attrill and Rundle, 2002; Sternberg, 1990) alpine ecotones (Hill *et al.,* 2008), floodplains (Glaeser and Wulf, 2009) but we are discussing the lacustrine ecotone between terrestrial and aquatic ecosystem (Naiman and Decamp, 2010). Any change in the ecotone affects the surrounding water body as well as the surrounding terrestrial ecosystems. Ecotones are indicators of change in microclimate and biodiversity of the surrounding ecosystems (Malanson, 1997). Ecotones considered as the region of bioconservation management for preservation of the inland water ecosystem (Gopal, 1994). The floral diversity and abundance or extinction of a particular species in an ecotone is dependent on human-environment interac-

tion in that area (Ghiselin, 1977). These areas are inhabited by animals and plants that need both the surrounding ecosystems at different stages of their life for example amphibians pass their egg and larval stages in the water while they are land-dwelling during their adult life. Anthropogenic influences such as changes in land use pattern though unavoidable alter ecotones in such a way that it becomes difficult to restore floral and faunal diversity of this transition zone (Thuiler *et al*., 2008). There occurs a loss of continuum concept between the two surrounding ecosystems. Threats to freshwater ecosystems are pollution, eutrophication, lake water acidification, and alien species invasion (Chambers, 2008).

Floristic diversity assessment indicates the extent of the ecological balance of an ecosystem. Biotic and abiotic factors combine to form the ecosystem. Disbalance of any factor can disbalance the whole ecosystem. The type of vegetation of an ecotone of the lacustrine ecosystem determines its ecological condition. The presence of exotic invasive species of weeds or trees or the presence of ruderals reflect disturbed ecosystems. To enhance and maintain the floral diversity we need to reduce the anthropogenic disturbances and at the same time have knowledge of the changes in the biodiversity pattern of the area under study.

To access the diversity of various lacustrine areas and compare their diversity many similarity indexes usedfor long. Similarity index such as Jaccardian, Sorensen generally used to detect and compare the floristic as well as the faunal diversity of various sites. The Jaccardian index used includes not only similarity in angiospermic plants of different sites but also soil fungi, algae, bacteria, etc. Similarity and Dissimilarity indices determine the species common to various sites and those unique to each site. Jaccardian index holds good for large sample sizes. But one and the only disadvantage is that it gives equal weightage to abundant and rare species.

In our study, we have studied the lacustrine ecotone diversity of ten lakes, determining their composition based on their growth habit, relative abundance of plant families and plant species and clustering ecotone sites based on the similarity of floral diversity. We determined the spatial and temporal differences in the vegetation pattern of the lakes. We also determine the effect the exotic, ruderals, weedy or allelopathic plants have on other plants in that area. It is critical that we identify the anthropogenic influences on regional flora.

Material and Methods

We have done this research work in lake ecotones of Valsad district situated on 20.63^0N latitude and 72.93^0E longitude for a period of one year. The area experiences a tropically hot and humid climate. Heavy rainfall occurs for three months due to the southwest monsoon. Floristic diversity of the lake ecotones surveyed every fifteen days for a year at different sites so that spatial and temporal changes of vegetation pattern and distribution observed. Herbarium samples deposited to the department. The number of sampling sites was determined according to the area of the lakes. For very large lakes, the number of study sites was five and for small lakes, it was three, as shown in Table 1

Table 1. Sampling Site

Lake No.	Name of Lake	Lake Area (m^2)	No. of sampling sites
1	Railway Colony Talav	9,750	3
2	Mota Talav	41,394	3
3	Atar Talav	37,951	3
4	Dwivedi Talav	1,24,303	5
5	Highway Talav	26,140	3
6	Halar Talav	14,917	3
7	Dhabaliya Talav	27,935	3
8	Rashidiya Talav	24,399	3
9	Tithal Talav	11,694	3
10	Pardi Talav	2,04,686	5

Description of the ten lakes

Lake 1 (Railway colony Talav) – It is situated in an urban area, so there was no agricultural runoff but is receiving municipal wastes. This lake has a narrow ecotone due to human encroachment and is much disturbed due to frequent human interference.

Lake 2 (Mota Talav) – It is situated in an urban area, only municipal wastes dumped and no agricultural runoff. The water of this lake used for domestic washing. This lake has religious significance as prayers and immersions of idols were here.

Lake 3 (Atar Talav) – It is in a semi-rural area, surrounded by mango plantations so was getting agricultural runoff and cattle bathing done throughout the year. However, washing and cleaning did but no domestic sewage dumped due to the presence of a temple adjoining the lake.

Lake 4(Dwivedi Talav) – It is in a rural area, surrounded by mango plantation and is used for aquaculture. Lake water used for washing, cleaning and cattle bathing.

Lake 5(Highway Talav) – It is in urban areas receives municipal runoff only during rainy seasons. Being in urban area washing and cleaning was prevalent throughout the year.

Lake 6(Halar Talav) – It is a seasonal lake. Temporal fluctuations were seen in the water level during dry and wet seasons. It is present in the urban area surrounding by apartments receives municipal wastes from surrounding apartments

Lake 7 (Dhabalia Talav) – This lake shows the seasonal fluctuation of water levels during different seasons as a result of water being pumped to nearby plantations. This lakelargely used for cattle bathing and seasonal bloom seen during the dry season.

Lake 8 (Rashidiya Talav) – It is a semi-urban lake surrounded by mango plantation on one side and has human habitation on the other side. Much water pumped from this lake to water the surrounding horticultural plantation area causing a drastic reduction of water levels of this lake during summer months.

Lake 9 (Tithal Talav) – This lake also shows seasonal fluctuation in the water level. Surrounded by plantation of mango and chikoo on one side only and the rest of the sides has road and urban area. This lake loses much of its water in watering the surrounding plantation areas.

Lake 10(Pardi Talav) – This lake has the largest area and is having the largest anthropogenic interferences as this lake are surrounded by market place so all rotten fruits, vegetables, and fish are dumped on it, as a result, this lake is permanently covered with *Eichhornia crassipes*.

Various stress factors of lakes that may alter the floral diversity of the lakes as well as the ecotone areas listed in Table 2.

Statistics used

Jaccardian Index used for clustering the study sites based on the similarity of vegetation (Kuncheva *et al.,* 2004). Another similarity index is Salton cosine formulae, which have a numerical value twice that of the Jaccardian index (Hamers, 1989).

Results and Discussion

The ecological composition of ten lake ecotones under study consisted of 131 species of angiospermic plants belonging to 119 genera and 46 families. In the lake bank, the majority of plants were herbs. The numbers of herbs were 60 species, shrubs 11 species, tree 42 species, 10 species of climbers and 14 species of creepers as found in the lake banks of the ten lakes. A comparative account of vegetations habitsin percentage, presented in Figure 1. Most

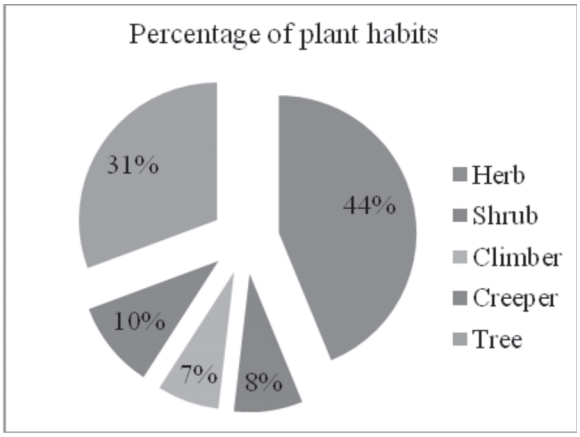

Fig. 1. Plant category in the study area

Table 2. Various stress factors of lakes that may alter the floral diversity of the lakes as well as the ecotone areas

Row	Stress factors	1	2	3	4	5	6	7	8	9	10
1	Trampling of vegetation	√	√			√					
2	Agricultural runoff			√	√			√	√	√	
3	Bathing of cattle			√	√	√		√	√	√	√
4	Aquaculture in the lakes			√	√	√					
5	Municipal wastes/Domestic sewage	√	√	√	√	√	√				√
6	Washing and cleaning waste	√	√				√			√	
7	Road construction						√		√	√	√
8	Pumping out water from the lake for agriculture					√	√	√	√	√	√
9	Invasive plants altering the plant diversity	√	√	√	√	√	√	√	√	√	√
10	Deposition of urban runoff during the rainy season	√	√				√				

dominant perennial weeds were the various grasses and sedges. Rests of the weeds in the areas were mostly seasonal and occur abundantly during the wet seasons. The abundance of herbaceous land cover is natural in the early seral stages of secession, which succeeded by shrubs and trees in the mid or late seral stage. In our study as we observed an abundance of herbaceous land cover, but the lake is an old lake, suggesting human-induced denudation by chopping of shrubs or trees to create a plagioclimax of its own. The relatively low number of large trees indicates the absence of canopy and hence serves a poor habitat for flora as well.

Theses area has 106 species of dicot plants belonging to 100 genera and 38 families. The number of monocot species in the lake ecotones of the ten lakes was 31, belonging to 28 genera and 7 families. One species of algae found. A diagrammatic presentation of relative abundance of Dicot, Monocot,and algae of the study area is given in percentage has been given in Figure 2. The percentage of dicot plant species is higher, which is quite normal. Monocots were mostly perennial grasses and seasonal sedges. These lakes were in the tropical region expected to have more semi-aquatic plants. Each lake has aquatic plants characteristic of the physicochemical property of the lake water. The diversity of ecotone plants is quite lower than expected, which can be due to human-induced altered floral pattern of the lacustrine area.

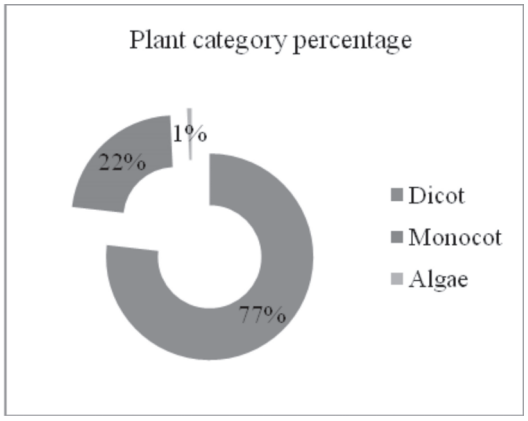

Fig. 2. Dicot & Monocot in the study area

Among trees, family Fabaceae has a maximum number of species followed by Arecaceae followed by Meliaceae, Myrtaceae, and Moraceae. Every lake had a variety of tree species but have the same dominant tree in their banks. So far trees are concerned Family Fabaceae is represented by many species of *Acacia, Albizzia*. The dominance of *Acacia, Alstonia* and *Tectona* trees is due to the intentional and planned introduction of these families as avenue trees or timber trees. The preponderance of evergreen trees indicates the availability of conditions conducive for growth. Among weeds, Poaceae found dominant in all the sites, which included mostly perennial species. Malvaceae was the second most dominant weed family followed by Asteraceae. The dominant genus found in these lakes was of *Cynodon, Chloris,* and *Alternanthera*. The abundance of fodder grasses such as *Chloris* or *Cynodon* may suggest humans inducedthe destruction of non-fodder grasses. The abundance of Alternanthera indicated eutrophication. The relative abundance of plant families, in the ten lacustrine ecotones, depicted in Figure 3.

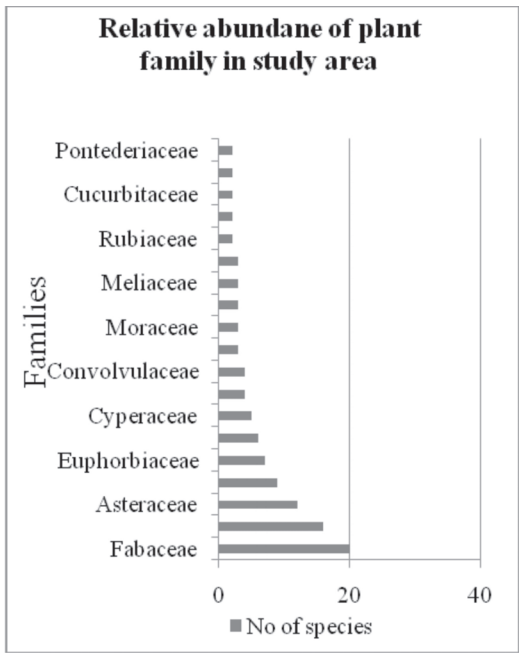

Fig. 3. Plant family diversity in the study area

Lake macrophytes observed to grow continuously or periodically depending upon fluctuation in lake - water level. *Cyperus, Euphorbia*, and *Acacia* genus have the maximum number of species, while *Chara* and *Ceratophlum* have a single genus. Figure 4 depicts plant species diversity.

Some species become dominant over time according to local conditions. Such plants are an indicator of the niche they are found. Indicator species such as *Eichhornia crassipes* as found in all ten lakes,

seasonally or permanently are indicate eutrophication of lake water.

Eichhornia exotic to India and has become quite invasive in eutrophic waters. *Alternanthera philoxeriodes* found abundantly in all the lake banks indicate a high pH of the water body. *Nelumbo* is an indicator of negligible sewage found only on the three lakes where *Eichhornia* was also present. This indicated spatial variance in the pollution load in different regions of the ten lakes. *Colocasia* was present in all the lake banks during wet seasons is a native plant to South Asia that is an accumulator of heavy metals such as lead and cadmium (Bindu *et al.*, 2010). *Ipomoea aquatica* found abundantly during the rainy season is also an accumulator of heavy metals. Exotic invasive weeds such as *Lantana camera* found in almost all the ecotones allelopathic to other plants. Such exotics outcompete the native species thus leading to a homogenization of flora.

Jaccardian similarity coefficient used to analyze the level of similarity or homogeneity in the vegetation amongst the lakes. Similarity or homogeneity can be 0 to 100 %. Jaccardian index measures the degree of similarity of the species composition of thelacustrine ecotones of ten lakes. Table 3 and Table 4 indicate the similarity indexes ofweeds and trees of lakes.

From the weed correlation matrix in table 3, we can cluster the lakes into three groups. Lake 1, 2 and 5 are formed one group; Lake 3 and 7 form another group; and Lake 6, 8, 9 and 10 form third group

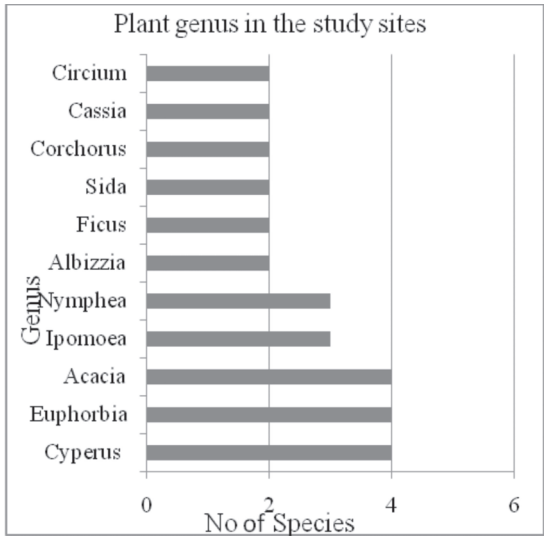

Fig. 4. A plant genus in the study area

Table 3. Jaccardian Index of lake ecotones for weeds

	Lake1	Lake2	Lake3	Lake4	Lake5	Lake6	Lake7	Lake8	Lake9	Lake10
Lake1		0.32	0.23	0.29	0.29	0.05	0.21	0.19	0.12	0.17
Lake2	0.32		0.21	0.19	0.36	0.13	0.19	0.17	0.17	0.12
Lake3	0.23	0.21		0.19	0.14	0.06	0.3	0.06	0.22	0.13
Lake4	0.29	0.19	0.19		0.2	0.07	0.16	0.19	0.11	0.23
Lake5	0.29	0.36	0.14	0.2		0.1	0.19	0.17	0.12	0.2
Lake6	0.05	0.13	0.06	0.07	0.1		0.12	0.29	0.19	0.25
Lake7	0.21	0.19	0.3	0.16	0.19	0.12		0.36	0.22	0.21
Lake8	0.19	0.17	0.06	0.19	0.17	0.29	0.36		0.24	0.19
Lake9	0.12	0.17	0.22	0.11	0.12	0.19	0.22	0.24		0.24
Lake10	0.17	0.12	0.13	0.23	0.2	0.25	0.21	0.19	0.24	

Table 4. Jaccardian Index of lake ecotones for trees

	Lake1	Lake2	Lake3	Lake4	Lake5	Lake6	Lake7	Lake8	Lake9	Lake10
Lake1		0.38	0.26	0.32	0.12	0.09	0.32	0.11	0.22	0.11
Lake2	0.38		0.14	0.2	0.13	0.09	0.27	0.15	0.13	0.06
Lake3	0.26	0.14		0.25	0.06	0.19	0.26	0.24	0.27	0.11
Lake4	0.32	0.2	0.25		0.25	0.14	0.25	0.22	0.46	0.1
Lake5	0.12	0.13	0.06	0.25		0.11	0.17	0.14	0.08	0.25
Lake6	0.09	0.09	0.19	0.14	0.11		0.18	0.29	0.19	0.22
Lake7	0.32	0.27	0.26	0.25	0.17	0.18		0.37	0.28	0.25
Lake8	0.11	0.15	0.24	0.22	0.14	0.29	0.37		0.32	0.21
Lake9	0.22	0.13	0.27	0.46	0.08	0.19	0.28	0.32		0.27
Lake10	0.11	0.06	0.11	0.1	0.25	0.22	0.25	0.21	0.27	

based on their mutual correlation. The grouping of lakes related to the land use pattern of the lake ecotones. Ecotones of Lake 1, 2 and 5 were highly trampled by both humans and cattle so only those plants that are tolerant or resistant to trampling are present here. Ecotones of Lake 6, 8, 9 and 10 were highly disturbed by road construction activities, so it supports ruderals mostly. Ecotones of lake 3 and 7 are similar as they are located in sparsely populated areas hence havethe least disturbance. The level of similarity is not too high which is a good indicator, but the level of diversity in specie composition is also not high.

We observe that Lake 1, 2 and 3 have high tree similarity. The similarity in tree composition observed in Lake 5, 6 and 10. Lake 4, 7, 8 and 9 havea similarity of tree in lake ecotones. The area surrounding the lake 1, 2 and 3 has human habitation and used for plantation of fruit trees mostly and has a narrow ecotone. *Mangifera indica, Tectona grandis,* and *Manilkara zapota* plantation were mostly observed in lakes 4, 7, 8 and 9 and all these lakes have wide ecotone. Lake 5 has Kids Park has mainly avenue trees. Lake 10 is in proximity to the market. Lake 5, 6 and 10 have avenue trees in some areas and weedy invasive in inaccessible parts.

Lake 1, 2, 6 and 9 have similarities in the aquatic plant as all these lake waters polluted by domestic washing and domestic sewage. Lake 3, 4 and 5 have similar aquatic plants as all the three have a fishery in its water and receives runoff from plantations during the rainy season. Lake 7 and 8 are surrounded by plantation only so only plantation runoff and no municipal sewage. Lake 10 being very large in the area shows variation in aquatic vegetation at various study sites so it shows a great deal of similarity with various lakes.

Heterogeneity in plant diversity, observed among the sampling sites. However, the similarity in tree diversity brought about by anthropogenic interferences in the form of horticultural plantation and avenue tree plantation. We find invasive species of exotic weeds and almost similar patterns of distribution in the weeds; we conclude that the current biodiversity pattern of the lacustrine ecotone was due to land-use change, habitat destruction, and other stress factors.

During our survey period, the profile of the lake changed drastically due to an increase in anthropogenic activities. Changing profile of lake, depicted by the absence of sensitive aquatic angiosperms in two of the lakes and dominance of rigid invasive exotic species of weeds. As lakes used in every aspect of human life, the surrounding vegetation is very disturbed as is obvious from the low diversity of the ecotone weeds. The area is very close to the Western Ghats, it should contain some endemic plants. No such endemic plants observed in our study site, clearly indicating the degradation of natural floral diversity. This study implies that though lake ecotones are important refugia for indigenous flora, much of these species are missing due to anthropogenic interferences in various forms such as intentional or unintentional introduction of non - native plants or chopping trees or cutting of fodder grass or changing the land use pattern from vegetated area to urbanized or industrial area.

Conclusion

Results pointed out the absence of endemic species and relative homogeneity of weed species makes conservation of this area necessary. The presence of exotic weeds will result in the local extinction of indigenous flora. During the period of study continued anthropogenic disturbance in the ten ecotones

Table 5. Jaccardian Index of lake ecotones for aquatic plant

	Lake1	Lake2	Lake3	Lake4	Lake5	Lake6	Lake7	Lake8	Lake9	Lake10
Lake1		1	0	0	0.25	1	0.5	0.25	1	0.17
Lake2	1		0	0	0.25	1	0.5	0.25	1	0.17
Lake3	0	0		0.29	0.29	0	0	0.13	0	0.1
Lake4	0	0	0.29		0.6	0	0.2	0.33	0	0.43
Lake5	0.25	0.25	0.29	0.6		0.25	0.5	0.6	0.25	0.43
Lake6	1	1	0	0	0.25		0.5	0.25	1	0.17
Lake7	0.5	0.5	0	0.2	0.5	0.5		0.5	0.5	0.33
Lake8	0.25	0.25	0.13	0.33	0.6	0.25	0.5		0.25	0.43
Lake9	1	1	0	0	0.25	1	0.5	0.25		0.17
Lake10	0.17	0.17	0.1	0.43	0.43	0.17	0.33	0.43	0.17	

was found to threaten the composition and distribution of indigenous flora. The process of comparative biodiversity assessment, using the Jaccardian index will help in analyzing and interpreting data on a large scale. This approach will help floral diversity conservation by the local authority by making it economic and timesaving in the end. We can extend the use of the Jaccardian index to study species heterogeneity composition to another ecosystem study in our area. We can use the Jaccardian index in collaborative research between various other ecological modelings to analyze the level of ecological integrity and help in planning for management and restoration of the particular ecosystems under threats.

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