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Wetland diversity – A reference to lacustrine macrophyte species

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Introduction

1.1 Wetlands in general

On the Earth's surface, water and life are inextricably connected. The earliest life originated from water and the first organism on the earth was aquatic. Water has numerous distinct characteristics that make it suited for life **(Vijayan et al., 2018).** Wetlands are regions of our landscape that are defined by the presence of water, where water dictates or influences the majority, if not all, of a field's biogeochemistry, or the biological, chemical, and physical characteristics of a specific site **(Gardner et al., 2015).** Wetlands serve as the interface and ecotone habitat between the terrestrial ecosystem and the aquatic ecosystem. It indicates that wetlands are neither entirely aquatic nor terrestrial; depending on seasonal fluctuation, they may be both at a similar moment, which contains the water and aquatic life, two essential components of the ecosystem **(Walton et al., 2020).** Wetlands are geologically young and ecologically delicate; they exist in all climates and vary sporadically with the passage of time and season. Wetlands are found across the world except in the Antarctica region. The Earth has 5.3 to 12.8 million km^2 of wetland area **(Gardner et al., 2018).** Wetlands are natural water bodies, that support a huge number of floral and faunal diversity. Due to the diverse geographical location, dominant species, their genesis, water chemistry, and sediment or soil characteristics; wetlands express rich biodiversity **(Barbier, 2011).** Globally, wetlands are a highly adaptive, productive, and biologically rich ecosystem, provides many significant private and public services to society with both consumptive and non-consumptive benefits. Wetlands are known as "*Biological Supermarket*", "*Cradles of Biodiversity*", "*Kidney of Nature*" and "*Repository of Resources*" because wetlands are multifaceted in terms of ecological nature, hydrological processes, environmental relevance, management boundaries, as well as economic and therapeutic value **(Garg, 2015; Sarkar & Das, 2016; Mengesha, 2017; Burdick, 2018; Ghosh et al., 2018)**. Wetland ecosystems are a natural wonder and a source of future prosperity; agriculturists, botanists, ecologists, and others have been interested in the study of wetlands for many years, but it wasn't until the 1970s that they realized the importance of wetlands. Since then, the image of wetlands has transformed from a mosquito-infested wasteland to a vital natural region. Natural and social scientists, landscape scientists, landscape architectures, environmental managers, urban designers, and many others are now paying close attention to wetlands.

1.1.1 Wetland Classification

Cowardin et al. (1979) developed one of the earliest and most often utilized wetland classification systems, categorizing wetlands into five basic systems: (i) marine – coastal wetlands, (ii) estuarine - deltas, tidal marshes, and mangrove swamps, (iii) lacustrine – lakes and ponds, (iv) riverine - rivers and streams, (v) palustrine – bogs, marshes, and swamps.

1.1.1.1 Marine wetlands: The open ocean that is above the continental shelf, as well as the high-energy shoreline that surrounds it, make up a marine wetland. The water regimes of marine ecosystems are largely governed by the flow of oceanic tides and ebb, which are exposed to the open ocean's waves and currents.

1.1.1.2 Estuarine wetlands: Deep-water tidal habitats and nearby tidal wetlands that are generally semi-enclosed by land but have open, partly blocked, or intermittent access to the open ocean, and where ocean water is at least periodically diluted by freshwater drainage from the land are referred to as estuarine wetlands.

1.1.1.3 Lacustrine wetlands: Wetlands in the lacustrine are deep-water, located in an area of dammed river channel or a topographic depression, which is a depressed below the surrounding area or landform sunken. Any pond or lake considered as an ecosystem is referred to as a lacustrine ecosystem, also known as a still-water environment or lentic ecosystem.

1.1.1.4 Riverine wetlands: Rivers and streams are considered as riverine wetland that is bordered on the landward side by upland, the channel bank including natural and man-made dams. Trees, shrubs, emergent mosses, or lichens are dominant flora in the riverine wetlands.

1.1.1.5 Palustrine wetlands: Trees, shrubs, persistent emergent, emergent mosses, or lichens flora are dominated in these non-tidal wetlands as well as all such wetlands found in tidal regions when salinity owing to ocean-generated salts is less than 0.5 percent, are classified as palustrine wetlands.

1.2 Macrophytes: Special reference as wetland plants

All plants that grow in continuously or seasonally wet environments, depending upon the availability of the required amount of water are considered aquatic plants in the widest sense, they are

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found all over the world, wherever the wetlands occur. Those plants which are bound to the water till the end of their lives (from seed to seed) are known as aquatic plants and also known as hydrophytes. Aquatic plants may be herbaceous or woody and at least some part of the vegetation arises in water. Some plants live their entire lives under the water, while others grow just along the water's edge **(Cronk & Fennessy, 2016).**

The flora of the aquatic environment is less varied than the terrestrial environment flora that includes tundra, grasslands, forests, and deserts habitat. Due to the water and nutrient chemistry, wind energy, substrate (the support structure to which an organism is attached), and temperature in an aquatic environment, the aquatic plant grows more easily **(Fleming & Dibble, 2015).** Other variables that influence aquatic plant development include the shape and depth of the aquatic habitat. Plants, on the other hand, have difficulties in an aquatic environment. For plants to survive, they require oxygen and carbon dioxide. Because the gases dissolve more slowly in water than in the air, aquatic vegetations have a harder time obtaining them. Light is required for aquatic vegetation to photosynthesize, but it might be obscured by the canopy of aquatic plants in the water. Aquatic plants are further classified as microphytes and macrophytes. Microphytes are microscopic and unicellular that are invisible through the necked eye, which includes principally algae in the form of Phytoplankton, Periphytons, and Benthos. Macrophytes are macroscopic and large aquatic plants that can be visible without the use of a microscope, that include angiosperm (flowering plants), pteridophytes (ferns), some bryophytes, and a few macroalgae (large algae) **(May, 2007).**

In the wetland, macrophytes act as a link between the sediment, water, and (occasionally) atmosphere. Most macrophytes are self-supporting aquatic vascular plants that come from shallow water or which thrive in waterlogged or flooded sediments or soils **(Bai et al., 2020).** The major aquatic macrophyte mechanism include buds, bulblets, bulbs, rhizomes, seeds, stolon, tubers, etc. The distribution of the aquatic macrophyte is dependent on the climatic, edaphic, and hydric characteristics of the environment, and the number of ecological factors affects the associate macrophytes directly or indirectly **(Rameshkumar et al., 2019)**.

Materials and methods

The experimental works have been carried out in five lentic water bodies (Lakes) located at Valsad district, Gujarat, India. Each freshwater body served as a study location of the investigation. The study was conducted at tri-monthly intervals from January 2019 to December 2019, covering all seasons such as winter, summer, and monsoon, however, in order to have a better knowledge of seasonal fluctuation, we collected samples, initially as well as at the end of the month, during winter (January month), summer (April month), pre-monsoon (July month), and post-monsoon (October month) seasons. The macrophytes were taken during each season of each visit to the five study locations.

2.1 Study Area

Valsad is the southernmost district of Gujarat state and located at the bank of the Arabian sea and the global position is located at 20°37'48.00" North latitude and 72°55'48.00" East longitude with an average elevation of 42 feet (13 metres) **(SAC, 2011).** The district is surrounded by Navsari district in the north, Dang district in the east, Maharashtra state in the south, and the Arabian Sea in the west coast, there are six talukas present in the district, Valsad, Vapi, Pardi, Umbergaon, Kaprada, and Dharampur.

The district of Valsad is blessed with nature's bounty. The best gift of nature to Valsad, Gujarat is its wetlands that add life to the district. Major wetland categories of the district are rivers, streams, reservoirs, intertidal mudflats, coastal areas, salt marsh, lakes, and ponds. The district covers a 3034 sq. km geographic area and 23116 ha wetland area, which are 0.67 % of the total wetland area **(SAC, 2011).** The whole year can be split into three seasons: winter season (November to February), summer season (March to June), and monsoon season (July to October). Valsad has a tropical wet and dry climate with little to no rainfall from October to May month and strong to extremely high rainfall from July to September month, when it is directly influenced by the Arabian Sea branch of the South-West monsoon **(Lunagaria et al., 2015)**.

2.1.1 Selected water bodies (Lakes)

The Valsad district is characterized by the presence of numerous annual and perennial lentic water bodies (lakes and ponds). For the present investigation, preliminary work was started by visiting various freshwater bodies, lakes at Valsad district, Gujarat, India. Some of the lakes are receiving only domestic and municipal sewages and some of the lakes receive high industrial effluents, some of the lakes showed less water pollution and some of the lakes showed high water pollution. Based on the pollutant, run-off entering into the lakes, five different perennial wetland (lakes) sites were selected for the investigation **(Fig: 2.1.7).** A brief description of selected wetlands (lakes) for the assessment of phytosociological parameters, physicochemical parameters, and heavy metals of Valsad district, Gujarat, India are as follows:

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Site-1: Segvi Lake [SL] – This lake is situated in Segvi village, Valsad, with coordinates of 20^o 35' 20.4" N 72^o 54' 46.0" E with a 650.04 m perimeter area. Due to the little or non-existent amount of effluents discharged into the lake, this lake was considered a clean lake for this investigation. Site-2: Rakhodiya lake [RL] – This lake, named Rakhodiya lake, is situated in the Valsad city area and has coordinates of 20^o 36' 53.4" N 72^o 55' 21.4" E. It has a 555.19 m perimeter area. A large volume of household sewage and a lot of agricultural run-offs were discharged in this lake from the surrounding area. Site-3: Atak Pardi Lake [AL] – This lake is located near the Regional Transport Office in Atak Pardi village [AL], with coordinates of 20^o 35' 20.9" N 72^o 57' 24.4" E and a perimeter area of 714.19 m perimeter area. This lake carried a large amount of ceramic effluents from nearby areas. Site-4: Pardi lake [PL] – Pardi lake is located in Pardi village near the Pardi GIDC and carried a considerable volume of household sewage and industrial run-off in it. This lake is located at 20^o 30' 35.7" N 72^o 57' 11.9" E coordinates and has a perimeter of 2298.25 m. Site- 5: Gundlav Lake [GL] – This lake is situated in Gundlav village near the industrial area, with coordinates of 20^o 37' 16.8" N 72^o 57' 45.3" E, with a 636.35 m perimeter area and a large volume of industrial effluents discharged into the lake.

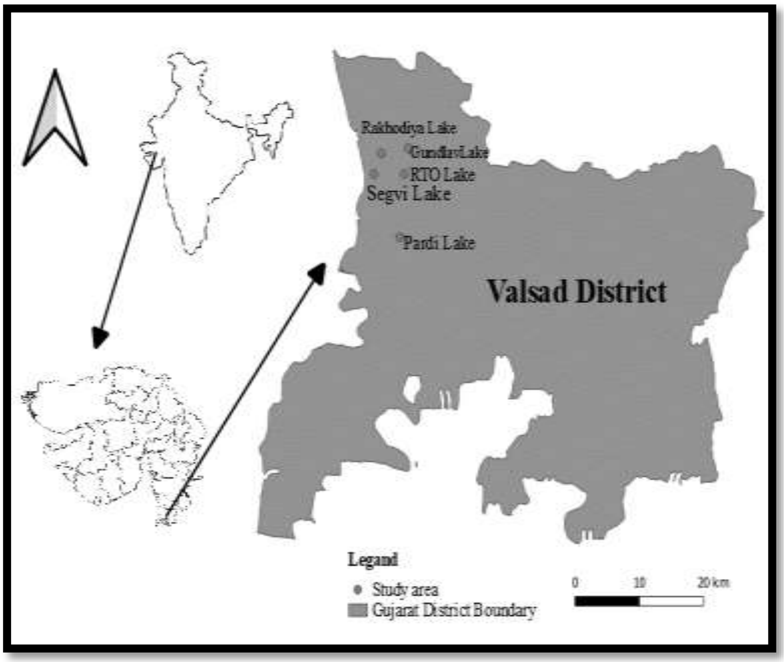

Figure 2.1.7: GIS map of selected study sites at Valsad district, Gujarat, India

2.2 Phytosociological assessment

Phytosociological analysis was carried out at selected five freshwater bodies of Valsad district, Gujarat, India. The quadrat technique was used for the phytosociological assessment of present macrophyte species at the selected lake of the Valsad district **(Misra, 1968**). Because the aquatic plants (macrophytes) assemblage in a selected community was highly diverse, the required size of the quadrat to be utilized was first calculated using the 'species-area curve' approach **(Swan, 2011)** before the phytosociological assessment at selected freshwater bodies. The phytosociological characters were investigated in the following headings:

2.2.1 Floristic Composition

In the qualitative analysis, the floristic composition of macrophytes, and life-form classification of the present various macrophyte species were analyzed during the study period.

The floristic composition of several macrophyte species at selected research sites was evaluated using **Devi (1998)** method, with the various macrophyte genera and species present in the community. From January 2019 to December 2019, the selected freshwater bodies of the Valsad district, Gujarat, India were surveyed and sampled on a regular basis to cover the variation of macrophytes in all the seasons of the year.

The flora of the several research locations was thoroughly investigated and evaluated, with the various macrophyte genera and species present in the community listed. Standard procedures were followed for specimen collection, processing, and preservation. Herbarium, Botany Department, Veer Narmad South Gujarat University (VNSGU), and floras, Gujarat flora **(Shah, 1978),** and Bombay flora **(Cook, 1908)** were examined to establish the identification of the specimens for their nomenclature.

2.2.2 Life form classification

Following extensive floristic research, in the present investigation, the life-forms of the macrophytes in the study locations were determined. The form, habit, height, and nature of perennating buds of each existing macrophyte species were investigated. The life form classification study was done as per **Raunkiaer's (1934)** life form classification system as modified by **Ellenberg and Mueller-Dombois (1967)**, and **Mueller-Dombois and Ellenberg (1974).**

Result and Disscussion

3.1 Phytosociological result

The study of the vegetation that occurs in a specific habitat is known as phytosociology **(Srinivasa Rao et al., 2013)**. Phytosociological research is critical for a complete understanding of the structure and dynamics of the vegetation. It's a requirement for comprehending the ecological characteristics of plants in an ecosystem **(Nautiyal et al., 2020).** Qualitative and quantitative analysis are two types of phytosociological investigations **(Odum, 1971).** Floral compositions and biological forms are included in the first category. Because each species has its range of ecological amplitude from which the status of the habitat can be easily evaluated, the holistic composition depicts the picture of species variety in a community **(Konatowska & Rutkowski, 2019)**. Frequency, density, and abundance are all factors to consider. IVI is an essential quantitative character factor that is crucial in determining the nature of the ecosystem's community **(Devi, 1998).** The homogeneity of distribution of various species in ecosystems is referred to as frequency. It's expressed as a percentage of all the units studied in which the species was found. When abundance is combined with frequency, it gives a picture of a species' distribution pattern, whereas density is the number of individuals per unit area **(Zervas et al., 2020).** However, by adding together the percentage values of relative frequency, relative density, and relative abundance, an overall picture of the species' ecological relevance in relation to the community structure can be generated. The species' Importance Value Index (IVI) is a number between one and three hundred. Individual frequency, density, and abundance measurements have limited meaning and are insufficient when used to estimate the importance of a species in the community **(Christe et al., 2017).** According to **Devi (1998)**, IVI provides a comprehensive picture of a species' sociological structure in a community, although it lacks the dimension or share of relative frequency, density, and abundance values. The present objective deals with the study of both the qualitative and quantitative components of communities.

3.1.1. Floristic composition

Anyone can simply obtain information about a site's species diversity by looking at its floristic composition list. The floristic composition of a place, according to Gupta (2017), is one of the key anatomical features of the plant community. It has been documented 52 macrophyte species in five separate sites within the lakes of the Valsad district (Table 3.1.1). Throughout the study period, the five separate sites were inspected at seasonal intervals. During the investigation, a total of 52 species of macrophytes belonging to 44 genera under the 27 families were recorded at the selected wetland of Valsad district, Gujarat. Among the total family, Poaceae was the largest one which comprises eight macrophyte species followed by Cyperaceae (seven macrophyte species) and Araceae (six macrophyte species). Meanwhile, the following families represented only two species for each, Asteraceae, Boraginaceae, Convolvulaceae, Hydrocharitaceae, Nymphaeceae, Polygonaceae, Salviniaceae, and another 17 families, Acanthaceae, Alismataceae, Amaranthaceae, Ceretophyllaceae, Chlororophyceae, Commelinaceae, Gentianaceae, Lentibulariaceae, Lythraceae, Marsileaceae, Nephrolepidaceae, Onagraceae, Pontedariaceae, Potamogetonaceae, Pteridaceae, Trapaceae, Typhaceae were considered as monospecific ones (Fig: 3.1.1). Out of the 52 species, 46 species represented angiosperms, five species such as *Azolla pinnata* R. Br., *Marselia quadrifolia* L. *Nephrolepis cordifolia* L., *Pteris vittata* L., and *Salvinia natans* L. represented the pteridophytes, and one species *Chara globularis* L. represented macroalgae (Table 3.1.1). In the selected sites, Pardi Lake represents the highest macrophyte flora with 43 macrophyte species, followed by Segvi lake (37 macrophyte species), Gundlav lake (34 macrophyte species), Rakhodiya lake (32 macrophyte species), and Atak Pardi lake (30 macrophyte species) (Table 3.1.1). *Trapa natans* and *Salvinia natans* represent only Segvi lake; and the *Hygrophila auriculata*, *Polygonum barbatum*, *Limnophyton obtusifolium, and Nymphoides indicum* represent only pardi lake during the study period

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Figure 3.1.1 Family composition of recorded macrophyte species

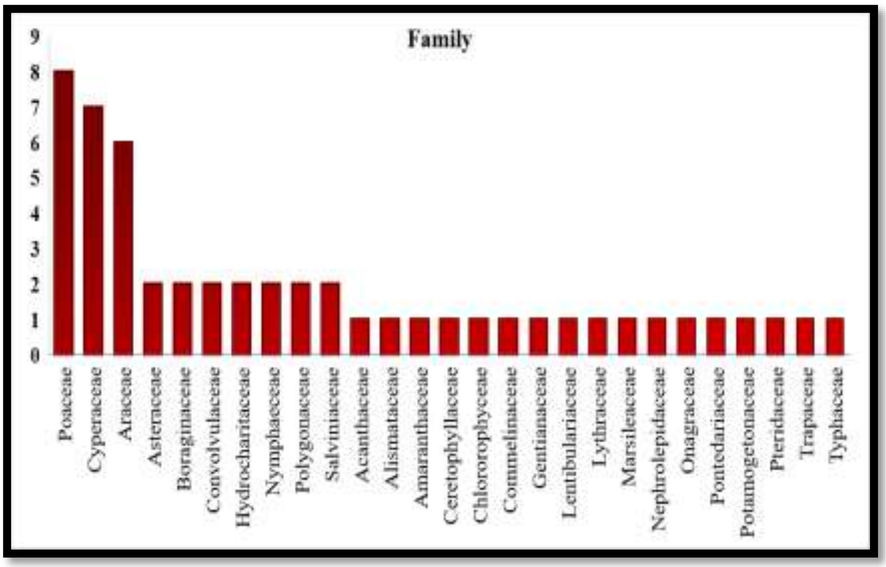

Table 3.1.1: Floristic composition in the selected study sites.

No	Species	Type	W 1	W 2	W 3	W 4	W 5
	Acanthaceae						
1	*Hygrophila auriculata* (Schum.) Heine	ER				*	
	Alismataceae						
2	*Limnophyton obtusifolium* (L.) Miq	FR				*	
	Amaranthaceae						
3	*Alternanthera sessilis* (L.) Dc.	ER	*	*	*	*	*
	Araceae						
4	*Colocasia esculenta* (L.) Schott	AR		*		*	
5	*Lemna minor* L.	FF	*	*		*	*
6	*Lemna trisulca* L.	FF	*	*	*	*	*
7	*Pistia stratiotes* L.	FF	*			*	
8	*Spirodela polyrhiza* (L.) Schleid.	FF	*	*	*	*	*
9	*Wolffia arrhiza* (L.) Wimmer	SNR	*	*	*	*	*
	Asteraceae						
10	*Eclipta prostrata* L.	ER		*	*		
11	*Grangea maderaspatana* (L.) Poir.	ER	*		*	*	*
	Boraginaceae						
12	*Coldenia procumbens* L.	ER				*	*
13	*Heliotropium indicum* L.	ER	*	*			*
	Ceretophyllaceae						
14	*Ceratophyllum demersum* L.	SNR	*	*	*	*	*
	Chlororophyceae						
15	*Chara globularis* L.	SNR				*	*
	Commelinaceae						
16	*Commelina benghalensis* L.	AR	*	*	*	*	*
	Convolvulaceae						
17	*Ipomoea aquatica* Forsk.	FR	*	*	*	*	*
18	*Ipomoea fistulosa* Mart. ex Choisy	ER		*	*	*	*
	Cyperaceae						
19	*Cyperus articulatus* L.	ER	*	*	*	*	*
20	*Cyperus iria* L.	ER	*	*	*	*	*
21	*Cyperus pumilus* L.	ER	*	*	*	*	*

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22	*Cyperus triceps* (Rottb.) Endl.	ER	*	*	*	*	*
23	*Eleocharis acutangula (Roxb.) Schult.*	AR		*		*	*
24	*Eleocharis dulcis* (Burm. f.) Henschel.	AR	*		*	*	
25	*Scirpus articulatus* L.	AR	*	*			*
	Gentianaceae						
26	*Nymphoides indicum* (L.) O. Ktze.	FR				*	
	Hydrocharitaceae						
27	*Hydrilla verticillata* (L. f.) Royle	SR	*	*	*	*	*
28	*Vallisneria spiralis* L.	SR	*	*	*	*	*
	Lentibulariaceae						
29	*Utricularia aurea* Lour.	SR	*			*	
	Lythraceae						
30	*Ammania multiflora* Roxb.	ER	*	*	*	*	*
	Marsileaceae						
31	*Marselia quadrifolia* L.	AR	*			*	
	Nephrolepidaceae						
32	*Nephrolepis exaltata* (L.) Schott	ER			*		*
	Nymphaeceae						
33	*Nelumbo nucifera* Gaertn.	FR	*		*	*	
34	*Nymphaea nouchali* Willd	FR	*		*	*	
	Onagraceae						
35	*Ludwigia adscendens* L.	FR		*		*	*
	Poaceae						
36	*Chloris quinquesetica* Bhide	ER	*	*	*	*	*
37	*Dactyloctenium aegyptium* (L.) P. Beauv.	ER		*	*	*	
38	*Echinochloa crusgalli* (L.) P. Beauv.	ER	*	*	*	*	*
39	*Eleusine indica* (L.) Geaertn.	ER	*		*	*	*
40	*Eragrostis tenella (L.)*	ER	*	*	*	*	*
41	*Eragrostis unioloides* (Retz.) Nees ex Steud.	ER	*	*	*	*	*
42	*Ischaemum molle* Hk. f.	ER	*	*			*
43	*Saccharum spontaneum* L.	ER	*				
	Polygonaceae						
44	*Polygonum barbatum* L.	AR				*	
45	*Polygonum glabrum* Willd	AR	*	*	*	*	*
	Pontedariaceae						
46	*Eichhornia crassipes* (Mart.) Solms.	FF		*		*	*
	Potamogetonaceae						
47	*Potamogeton nodosus* Poir.	FR	*			*	
	Pteridaceae						
48	*Pteris vittata* L.	ER			*		*
	Salviniaceae						
49	*Azolla pinnata* R. Br.	FF	*	*		*	
50	*Salvinia natans* L.	FF	*				
	Trapaceae						
51	*Trapa natans* L.	FR	*				
	Typhaceae						
52	*Typha angustata* Bory & Chaub.	AR	*	*	*	*	*
	Total species		**37**	**32**	**30**	**43**	**34**

(*) denotes the presence of macrophyte at study sites
<u>Abbreviations used in the table:</u> FF = Free floating, FR = Floating but rooted, SNR = Submerged but not rooted, SR = Submerged but rooted, ER = Emergent, PH = Phanerophytes, CH = Chamophytes, HC = Hemicryptophytes, CR = Cryptophytes, TH = Therophytes

In the selected sites, Atak Pardi Lake represents the lowest macrophyte species composition with 30 macrophyte species due to **(Table 3.1.1)** less availability of light and certain nutrients in an ecosystem which fluctuated by the heavy eutrophication. **(Salgado et al., 2018).** A similar out comes found in a shallow lake, Baoding City, North China **(Han & Cui, 2016).**

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Besides, because of huge anthropogenic pressure and industrial effluents, Rakhodiya lake and Gundlav lake also showed less macrophyte composition with 32 macrophyte species and 34 macrophyte species, respectively **(Table 3.1.1)**. *Trapa natans* and *Salvinia natans* represents only Segvi lake; and the *Hygrophila auriculata, Polygonum barbatum*, *Limnophyton obtusifolium,* and *Nymphoides indicum* represents only Pardi Lake due to the favourable environment. A similar observation was found by **(Efe et al., 2015)** in Gala Lake, Turkey.

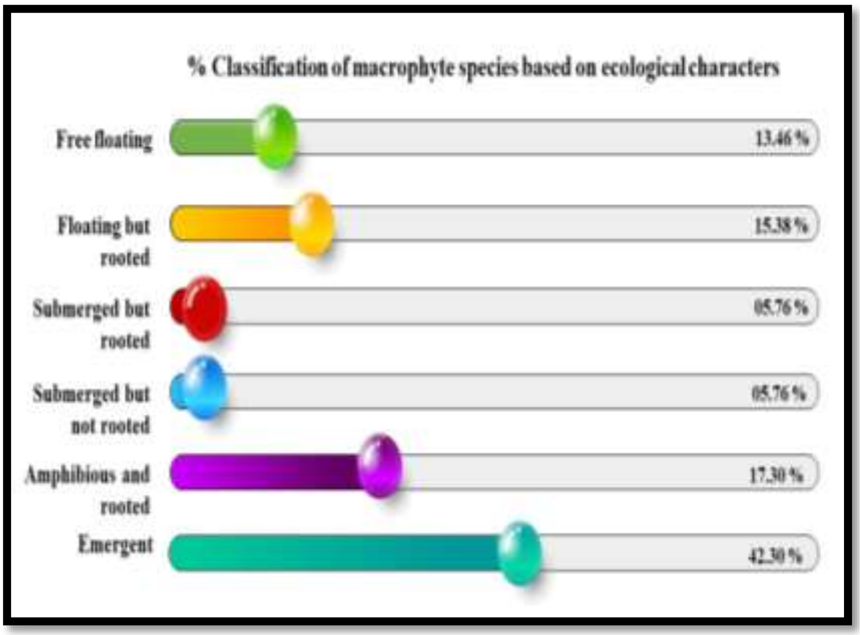

Figure 3.1.2 % Classification of macrophyte species based on ecological characters

The aquatic macrophyte species were classified based on growth forms **(Pedralli, 1990)**, in six major categories i) free-floating, ii) floating but rooted, iii) submerged but rooted, iv) submerged but not rooted, v) amphibious and rooted; and vi) emergent macrophytes **(Table 3.1.1)**. Out of 52 macrophytes, 3 macrophyte species (05.76 %) are under the submerged but rooted group. These are *Hydrilla verticillata* (L. f.) Royle, *Utricularia aurea* Lour., and *Vallisneria spiralis* L.; and 3 macrophyte species (05.76 %) are under submerged but not rooted group. These are *Ceratophyllum demersum* L., *Chara globularis* L., and *Wolffia arrhiza* (L.) Wimmer. Among the rooted with floating leaves are *Ipomoea aquatica Forsk.*, *Limnophyton obtusifolium (L.) Miq*, *Ludwigia adscendens L.*, *Nelumbo nucifera Gaertn*, *Nymphaea nouchali Willd*, *Nymphoides indicum (L.) O. Ktze.*, *Potamogeton nodosus Poir.* and *Trapa natans L.* This category comprises 8 species (15.38 %). *Azolla pinnata* R. Br., *Eichhornia crassipes* (Mart.) Solms., *Lemna minor* L., *Lemna trisulca* L., *Pistia stratiotes* L., *Salvinia natans* L., and *Spirodela polyrhiza* (L.) Schleid. are the 7 species (13.46 %) under the free-floating category were recorded from the wetlands. On the amphibious group of the macrophytes *Colocasia esculenta* (L.) Schott, *Commelina benghalensis* L., *Eleocharis acutangula* (Roxb.) Schult., *Eleocharis dulcis* (Burm. f.) Henschel., *Marselia quadrifolia* L., *Polygonum barbatum* L., *Polygonum glabrum* Willd, *Scirpus articulatus* L., and *Typha angustata* Bory & Chaub. have been recorded. This group comprises 09 species (17.30 %). On the emergent group of the macrophytes *Alternanthera sessilis* (L.) Dc., *Ammania multiflora* Roxb., *Chloris quinquesetica* Bhide, *Coldenia procumbens* L., *Cyperus articulatus* L., *Cyperus iria* L., *Cyperus pumilus* L., *Cyperus triceps* (Rottb.) Endl., *Dactyloctenium aegyptium* (L.) P. Beauv., *Echinochloa crusgalli* (L.) P. Beauv., *Eclipta prostrata* L., *Eleusine indica* (L.) Geaertn., *Eragrostis tenella* (L.), *Eragrostis unioloides* (Retz.) Nees ex Steud., *Grangea maderaspatana* (L.) Poir., *Heliotropium indicum* L., *Hygrophila auriculata* (Schum.) Heine, *Ipomoea fistulosa* Mart. ex Choisy, *Ischaemum molle* Hk. f., *Nephrolepis exaltata* (L.) Schott, *Pteris vittata* L., and *Saccharum spontaneum* L. have been recorded. This group comprises 22 species (42.30 %) **(Fig: 3.1.2)**.The majority of morphologically submerged macrophyte species are vascular, and their vegetative development occurs below the water's surface **(Poschenrieder et al., 2018).** With increasing water depth or solid suspended particles in water, light intensity drops, due to this reason they are so weak **(Cronk, & Fennessy, 2016)**. This group, on the other hand, has only 6 macrophyte species, which represented the lowest floristic percentage over the process of the

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investigation (11.52 %) **(Fig: 3.1.2)**. The root system, in the rooted with a floating group of macrophytes is poorly developed, plant growth is reduced due to low light intensity, stems are generally long and slender, leaves have recurred and thin, narrow, ribbon-shaped, and finely dissected, stems are generally long and slender, stems are generally long and slender **(Ebke et al., 2013).** The free-floating macrophytes, on the other hand, float freely on the water's surface. The shooting system isn't very well developed. Internodes are extremely short and compact. The root system is underdeveloped and lacks root hairs and leaves are broad **(Ceschin et al., 2020).**

The majority of the amphibious macrophytes have rhizomes and have two types of leaves, submerged leaves which are narrow and heavily dissected, whereas aerial leaves are broad or just slightly lobed, with a propensity to increase the exposed surface area **(Riis et al., 2012).** Emergent macrophytes are the most common kind of aquatic vegetation (**Kassa et al., 2021)**, outcompeting other types due to their capacity to catch sunlight before it reaches the water's surface **(Gebrehiwot et al., 2017),** due to these reasons emergent macrophytes are dominant with 42.30 %, over the process of the investigation **(Fig: 3.1.2).** A similar observation was obtained by **(Malik & Namdeo, 2010)** in the polluted pond of Shahjahanpur (India); **(Saikia, 2013)** in the wetlands of Hojai subdivision, Nagaon district, Assam, India.

3.1.2 Life form classification

The composition of vegetation's life forms is an essential foundation for any ecological research. The distribution of a community's life forms provides information on the community's reaction to specific environmental variables **(Ellenberg and Mueller-Dombois, 1967).** The Raunkiaer's one, according to **Singh and Gupta (2015),** is the best-recognized description and classification of life forms, as well as the utilization of life forms to create a biological spectrum. Raunkiaer grouped species' life forms in natural succession, using the location of perennating buds as the major criterion, and he demonstrated that this criterion was accepted to indicate climatic adaptability **(Raunkiaer's, 1934)**. The macrophytes in this study were categorized into different life forms using Raunkiaer's categorization. **Figure 3.1.3** shows the various life-form categories, macrophyte species within these groups, and their percentages of occurrence. Chemophytes, Cryptophytes, Hemi cryptophytes, and Therophytes are the four different lifeform categories of present macrophyte species **(Table 3.1.1)**, with Chemophytes representing 09 macrophyte species, Cryptophytes 25 macrophyte species, Hemi cryptophytes 08 macrophyte species, and Therophytes 10 macrophyte species. The percentage contribution of various life-form categories was also determined. Cryptophytes have the highest percentage of them (48.07 percent). Therophytes (19.23 percent), Chamophytes (17.30 percent), and Hemi cryptophytes (15.38 percent) came in second and third, respectively **(Fig: 3.1.3).** When the percentages of this result were compared to Raunkiaer's normal biological spectrum (Sharma & Raina, 2017), it was observed that all of the values were much more than Raunkiaer's normal spectrum, with the exception of Hemi cryptophytes. Cryptophytes showed a much higher value than Raunkiaer's normal biological spectrum **(Table 3.1.2)**.

Table 3.1.2: Biological spectrum of macrophytes species at the wetland of Valsad district.

Parameters	**PH**	**CH**	**HC**	**CR**	**TH**	**Total**
Total number of species	00	09	08	25	10	52
Life form percentages	00	17.30	**15.38**	**48.07**	19.23	100
Raunkiaer's normal spectrum & composition	46.0	9.0	**26.0**	**6.0**	13.0	100

***Abbreviations used in the table**

PH = Phanerophytes, CH = Chamophytes, HC = Hemicryptophytes, CR = Cryptophytes, TH = Therophytes

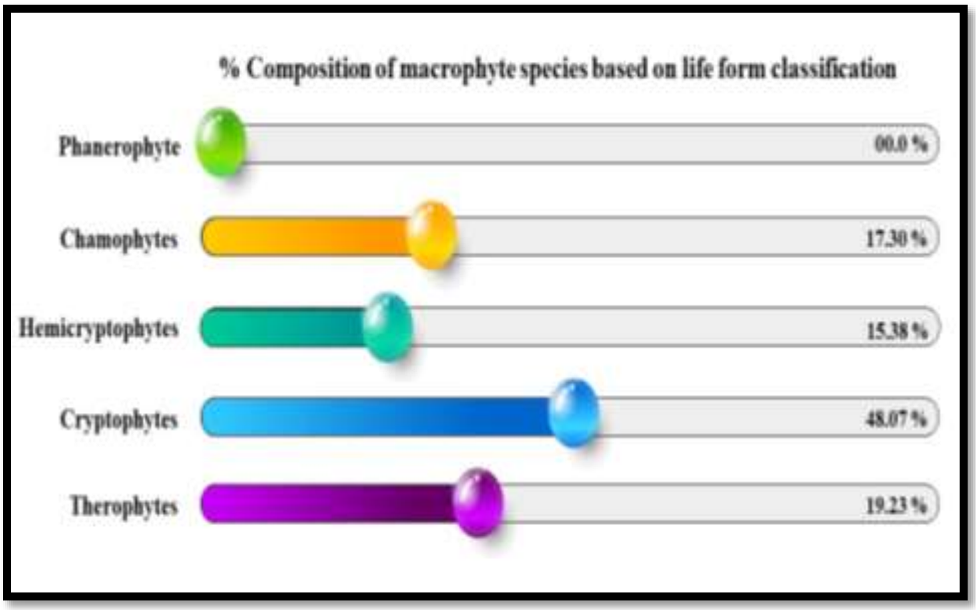

Figure 3.1.3 % classification of macrophyte species based on life form

When comparing the percentages of this finding to Raunkiaer's normal biological spectrum **(Sharma & Raina, 2017),** it was discovered that, with the exception of Hemi- cryptophytes, all of the outcomes were significantly greater than Raunkiaer's normal spectrum **(Table 3.1.2)**. The proportion in Cryptophytes was around eight times greater than the Raunkiaer's typical spectrum. The region may be classified as a cryptophytic climate based on these observations of percentage composition of various life form classes of macrophytes at different research sites. Cryptophytic condition indicates a warm and dry climate **(Elmslie et al., 2020).** The existence of heavy anthropogenic activity in the wetlands, where low percentages of Hemicryptophytes showed unsuitability of the environment, may explain the suggestion of warm and dry conditions by exhibiting a high percentage of occurrence of cryptophytes **(Gushulak et al., 2021).**

Summery and conclusion

Wetlands, which serve as a transition between land and water, are a source of concern across the world in terms of resource evaluation and use, environmental protection, pollution control, eco-restoration, biodiversity conservation, and so on. As a result, agriculturists, natural and social scientists, urban planners, land managers, landscape designers, and others have been paying close attention to them. Gujarat sustains around 831 wetlands, including 393 inland wetlands, due to its enormous geographic variety. There are eight national significant wetlands and one globally significant wetland in the area. Wetlands are an important aspect of human civilization because they provide drinking water, food, improved water quality, sediment retention, flood storage, transportation, recreation, and climate stabilization, among other things. Despite their numerous advantages, wetlands are increasingly subjected to anthropogenic pressures and are rapidly disappearing. Ecological examination of various components aids in the development of appropriate conservation and restoration strategies for management. Because the issues of wetlands and their macrophytes in Valsad district, Gujarat had gone unaddressed, the current research.

Valsad district is located between 20°37'48.00" North latitude and 72°55'48.00" East longitude, making it one of Gujarat's rainiest districts. The district has a tropical savanna climate (Aw), with little to no rainfall from October to May and very strong to extremely heavy rainfall from June month to September month when the Arabian Sea branch of the South-west monsoon is in full swing. It encompasses a 3034-square-kilometer geographic region where wetlands play an important part in the lives of the locals. The aim of present investigation was to list, find, and investigate wetlands, with a focus on macrophytes, because of their biological, ecological, and socioeconomic relevance. This investigation comprised five wetlands, each of which spanned a vast individual area. The wetlands were then divided into categories based on who owned them. Only one is under the district Nagar Palika (Rakhodiya lake), while the majority of them (04) are under the panchayat. All of the selected wetlands are perennials, assuring water availability throughout the year. They are utilized for irrigation, residential purposes, and, with the exception of the Rakhodiya lake, as a source of drinking water. In the case of Rakhodiya

Lake and Pardi Lake, domestic sewage is the primary source of pollution, while agricultural runoff is the primary source of pollution in Pardi Lake, where agrochemicals leach into the surrounding wetlands and industrial sewage is discharged into the Pardi Lake and Gundlav Lake. Segvi Lake is fortunate in that it receives no pollution from industrial sources or biomedical waste, as well as the little or negatable sewage from residential properties.

The present investigation recorded a total of 52 macrophyte species, which belong from 44 genera under the 27 various families. Among the total family, Poaceae was the largest one with eight macrophyte species followed by Cyperaceae (seven macrophyte species) and Araceae (six macrophyte species). Out of the 52 species, 46 macrophyte species were recorded as angiosperms, five macrophyte species were recorded as the pteridophytes, and one macrophyte species was recorded as macroalgae. Out of 52 macrophytes, 3 macrophyte species (05.76 %) are under the submerged but rooted group, 3 macrophyte species (05.76 %) are under submerged but not rooted group, 8 species (15.38 %) recorded as rooted with floating leaves, 7 species (13.46 %) under the free-floating category, 09 species (17.30 %) under the amphibious group and 22 species (42.30 %) recorded under the emergent group. Emergent macrophytes are the most common kind of aquatic vegetation, outcompeting other types due to their capacity to catch sunlight before it reaches the water's surface. The composition of vegetation's life forms is an essential foundation for any ecological research.

The macrophytes in this study were categorized into different life forms using Raunkiaer's categorization. The percentage contribution of various life-form categories was also determined. Cryptophytes have the highest percentage of them (48.07 %). Therophytes (19.23 %), Chamophytes (17.30 %), and Hemi cryptophytes (15.38 %) came in second and third, respectively. Results were significantly greater than Raunkiaer's normal spectrum. The proportion in Cryptophytes was around eight times greater than in Raunkiaer's typical spectrum. The existence of heavy anthropogenic activity in the wetlands, where low percentages of Hemicryptophytes showed unsuitability of the environment, may explain the suggestion of warm and dry conditions by exhibiting a high percentage of occurrence of cryptophytes.

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