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Diversity of Aquatic Macrophyte Species of Pardi Wetland, Valsad District, Gujarat, India: Social-Economic and Ethnobotanical Importance

HARVI ARVINDBHAI PATEL[1]*, SUSMITA SAHOO[2] and ALPESH THAKOR[3]

[1]Department of Botany, Shrimad Rajchandra Vidyapeeth, Dharampur, Valsad, Gujarat, India.
[2]Department of Biological and Environmental Sciences, Natubhai V. Patel College of Pure and Applied Sciences (NVPAS), Vallabh Vidyanagar, Anand, Gujarat, India.
[3]Department of Botany, B.K.M Science college, Tithal Road, Valsad, Gujarat, India.

Abstract

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. 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. Valsad district is the developing district of Gujarat state, located between 20°37'48.00" N and 72°55'48.00" E, making it one of Gujarat's rainiest districts and having many wetland ecosystems with great aquatic biodiversity. The present investigation aimed to list, find, and investigate wetlands, with a focus on macrophyte species, because of their high socioeconomic and ethnobotanical relevance. The current study identified a total of 43 macrophyte species, which are organized into 35 genera and 24 different families. Out of the 43 macrophyte species, 40 were recorded as angiosperms, 02 as pteridophytes, and 01 as macroalgae. In the present investigation, existing macrophyte species were evaluated based on their ecological classification, life form classification, and their wetland indicator status. This research not only showed the diversity of indigenous macrophytes but also discusses the utilization of aquatic plants for socioeconomic and ethnobotanical purposes, which enhance the traditional medicinal knowledge about the macrophytes.

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CONTACT Harvi Arvindbhai Patel harviipatel2405@gmail.com Department of Botany, Shrimad Rajchandra Vidyapeeth, Dharampur, Valsad, Gujarat, India.

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Introduction

Water defines or impacts most, if not all, of a field's biogeochemistry, or the biological, chemical, and physical features of a particular location, particularly areas of our terrain known as wetlands.[1] 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.[2] Wetlands are geologically young and ecologically delicate, they exist in all climates and vary sporadically with the passage of time and season. The Earth has 5.3 to 12.8 million km^2 of wetland area.[3] Wetlands are natural water bodies, that support a huge number of floral and faunal diversity of the earth. Due to the diverse geographical location, dominant species, their genesis, water chemistry, and sediment or soil characteristics; wetlands express rich biodiversity.[1] Globally, wetlands are a highly adaptive, productive, and biologically rich ecosystem that provides many significant private and public services to society with both consumptive and non-consumptive benefits. India supports a broad range of wetland ecosystems, with its varied terrain and climate regimes. In addition, there are 555,557 wetlands (with inland wetlands accounting for 69%, coastal wetlands for 27%, and other wetlands (less than 2.25 ha) accounting for 4% of total wetlands.[5] Wetland has currently covered 15.26 million hectares (mh), or 4.63 % land area of India. In terms of total wetland area covered by the state (in percentage), represent that Gujarat state ranks first with 3.47 million hectares (22.77%), mainly because of the large stretches of salt pans and intertidal mudflats.

The aquatic environment generally consists of a large range of floral and faunal diversity, which increasingly serves human requirements through contributions to agriculture, biofertilizers, sources of energy, raw materials for industry, and medicines.[2] Natural freshwater resources found across the world frequently provide an ideal habitat for the colonization of various macrophyte species.[3] Herbal macrophytes have been used as traditional medicine since ancient times because they are amazing sources of physiologically active chemicals with medicinal qualities.[9] Although herbal macrophytes play a significant role in disease prevention, and treatment and have also been used to cure a variety of human ailments by various groups of people.[10,11] There are few ethnobotanical records, particularly on the medicinal macrophytes found in the Valsad area. The majority of regional communities live in various sections of the state and rely on their collective expertise and local resources for their daily healthcare. Due to a variety of factors, older generations are the only ones who are generally knowledgeable about plant lore, its significance, and its practice.[4–6] In the current communication, the documentation of aquatic medicinal plants found in the wetlands of the Valsad district is discussed. It is widely known that worldwide wetlands are disappearing fast and thus their resources both flora and fauna are depleting at the same pace.[7] The survival of aquatic species is threatened[8,9] and hence the study on aquatic resources especially those having economic value are important.[10]

Study Area

Gujarat's southernmost district, Valsad, is situated on the Arabian Sea's shore, 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 meters).[5] The district covers a 3034 sq. km geographic area and a 23116-ha wetland area, which are 0.67 % of the total wetland area.[5] Pardi wetland is an important lake of the Valsad district, situated at Pardi village near the Pardi Gujarat Industrial Development Corporation (GIDC) (Fig: 1). This perennial lake is located at 20o 30' 35.7" N 72o 57' 11.9" E coordinates and has a perimeter of 2298.25 m. The depth of this lake has continuously fluctuated during the study period due to the Sujlam Suflam Yojna. The average depth of the lake was[6] to 7 meters during the monsoon season and reduced to 1 to 2 meters during the summer season, but it did not dry out and the lake stored a high amount of water. This lake carries a considerable volume of household sewage, industrial run-off as well as a huge amount of agricultural runoff from the surrounding area.[11]

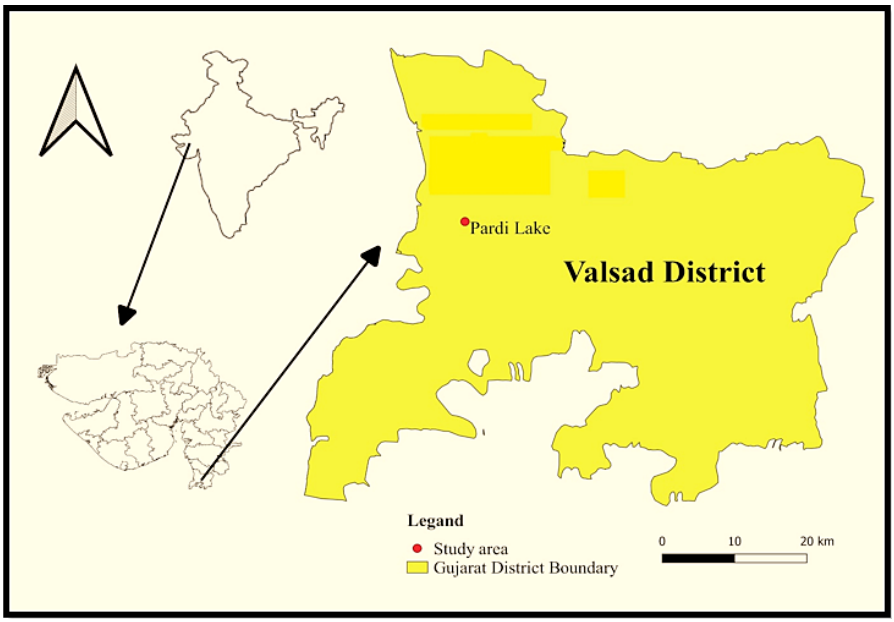

Fig. 1: Selected study area of Valsad district, Gujarat.

Materials and Methods

Throughout the study period (January 2019 to December 2019), field visits were made to collect and precisely record the aquatic macrophyte species that were present at the Pardi wetland in Valsad district, Gujarat, India. From January 2019 to December 2019, the survey was carried out every three months, covering all seasons (winter, summer, monsoon), however, in order to have a better knowledge of seasonal fluctuation, we collected specimens, 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. For the flora study, the quadrate method (50 ×50 cm^2) was randomly applied in 20 different places and analysed.[12] The collected macrophyte species were identified with the guidance of the herbarium, Botany department, VNSGU, and floras.[12,13] The macrophyte species were classified into six subcategories based on their growth form, including free-floating, floating but rooted, submerged but not rooted, submerged but rooted amphibious macrophytes, and emergent macrophytes, prescribed by Pedralli, (1990) methods.[12] The life form classification study was done as per Raunkiaer's (1934) life form classification system as modified by the researcher Ellenberg and Mueller-Dombois (1967), and Mueller-Dombois and Ellenberg (1974).[12–15]

Personal interviews and conversations with local people especially with senior villagers were used to gather socio-economic and ethnobotanical data by interviewing through a questionnaire 45 local informers, including 25 females and 20 males. During the research period, regular fieldwork and survey were organized in the different surrounding villages of the selected wetland, Pardi Lake. Data were gathered on different aspects by asking questions about the aquatic plant, its local names, used parts and how these parts were utilized, and for which diseases treatment. The interviewer was asked questions in Gujarati because of the ease of local inhabitants who are uneducated and the English language is not logical in most cases. A list of diverse economically relevant macrophytes base of uses was compiled because locals utilize macrophytes in a variety of ways, the research involves personal interviews, observations, and surveys. These folks are the only ones who know the names of the indigenous macrophyte species and how they may be used in different ways. Many questionnaires were utilized during these activities, such as the usage of macrophytes, which plant parts were used, economic worth, and so on.

Result

Anyone can simply obtain information about a site's species diversity by looking at its floristic composition list. According to Gupta (2017), one of the important anatomical characteristics of the plant community is an area's floristic composition.[16] It has been documented 43 macrophyte species at the Pardi wetland of the Valsad district, Gujarat (Table: 1). At the selected wetland, Pardi Lake in Gujarat's Valsad district, 43 species of macrophytes from 35 genera and 24 families were documented during the investigation (Table: 1). Out of the 43 macrophyte species, 40 macrophyte species represented angiosperms, two macrophyte species like as *Azolla pinnata* R. Br., and *Marselia quadrifolia* L. represented the pteridophytes, and one species of macrophyte, *Chara globularis* L. represented macroalgae (Table: 1).

Among the total family, Araceae, Cyperaceae, and Poaceae was the largest one which comprises six macrophyte species followed by Convolvulaceae, Hydrocharitaceae, Nymphaeceae, and Polygonaceae (two macrophyte species), and others were considered as monospecific ones (Fig: 2).

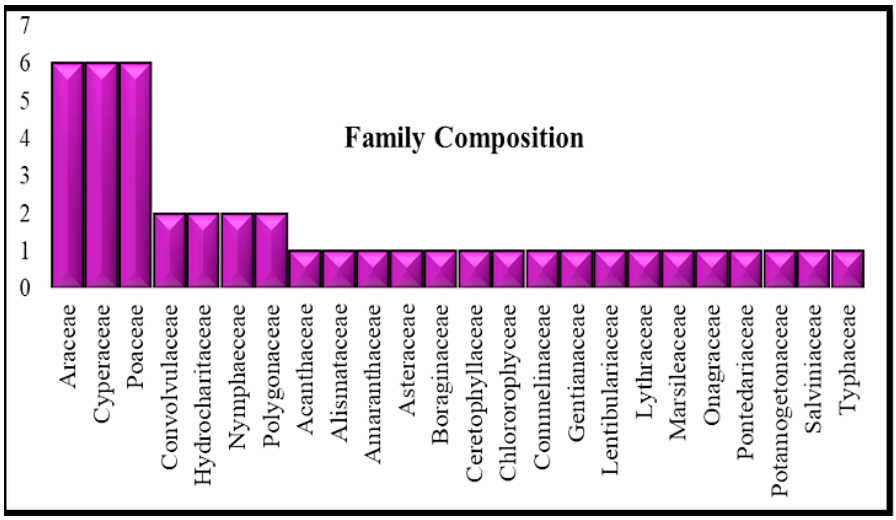

Fig. 2: Family composition of recorded macrophyte species at Pardi wetland

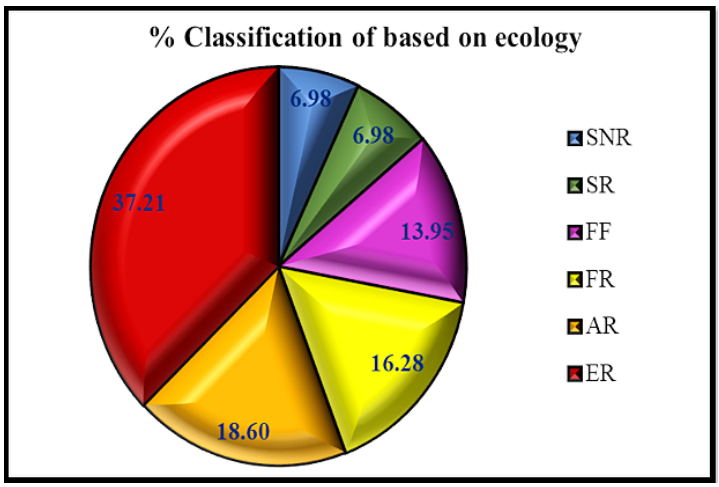

Fig. 3: % Classification of macrophyte species based on ecological characters

The aquatic species were classified based on growth forms,[13] into 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: 1). Out of 43 macrophyte species, 6.98 % macrophytes represents submerged but rooted group, and 6.98 % are under submerged but not rooted group. Submerged species are vascular, and their vegetative development occurs below the water's surface. With increasing water depth or solid particles suspended in water, light intensity drops, due to this reason, they contain less macrophyte diversity.[18,19] A total of 13.95 % were under the free-floating category, 16.28 % of macrophytes were under the rooted with floating leaves category, and 18.60 % of macrophyte species represent the amphibious category. Emergent macrophytes are the most common kind of aquatic vegetation, out-competing other types due to their capacity to catch sunlight before it reaches the water's surface,[20,21] due to these reasons emergent macrophytes are dominant with 37.21 %, over the process of the investigation (Fig: 3).

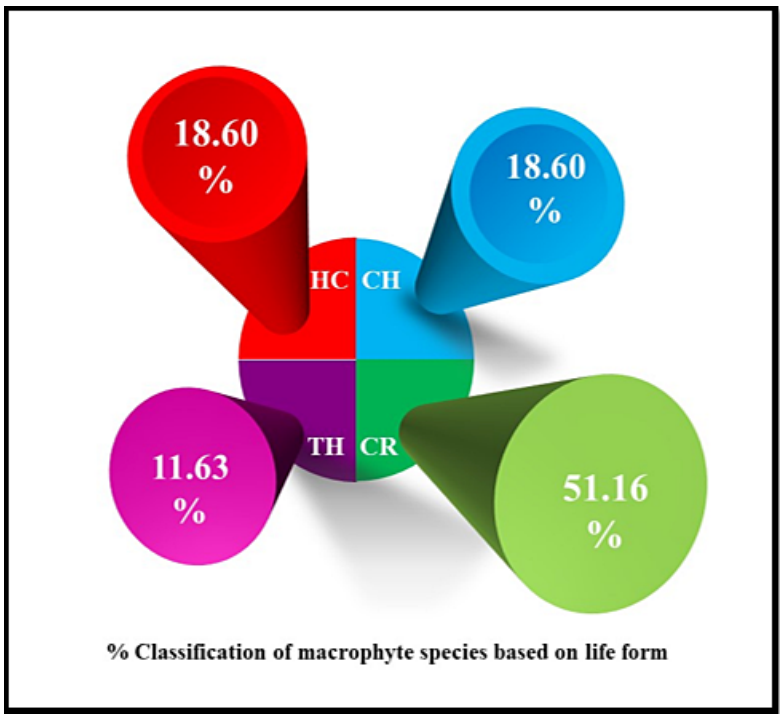

Fig. 4: % Classification of macrophyte species based on life form

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.[13-15] 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.[21] Raunkiaer grouped species' life forms in natural succession, using the primary criterion of the location of perennating buds, and he demonstrated that this criterion was accepted to indicate climatic adaptability.[15] The macrophytes in this study were categorized into different life forms using Raunkiaer's categorization. Figure: 4 shows the various life-form categories, macrophyte species within these groups, and their percentages of occurrence. Cryptophytes have the highest percentage of them (51.16 %), followed by Chamophytes (18.60 %), Hemi cryptophytes (18.60 %), and Therophytes (11.63 %).

A list of plants found in wetlands with their associated indicator statuses can be found on the national

list of plant species.[23] The five indicator statuses are Obligate Wetland Plants (OBL), Facultative Wetland Plants (FACW), Facultative Plants (FAC), Facultative Upland Plants (FACU), Obligate Upland Plants (UPL). Based on these indicator statuses total of 43 species of macrophytes were categorized and represented in Table 1. Out of these 43 macrophyte species, 46.51 % macrophyte species belong to Facultative Wetland Plants, 37.21 % species belong to Obligate Upland Plants, 9.30 % species belong to Facultative Plants, 4.65 % macrophyte species belong to Facultative Upland Plants and 2.33 % macrophytes represent the Obligate Upland Plants (Fig: 5).

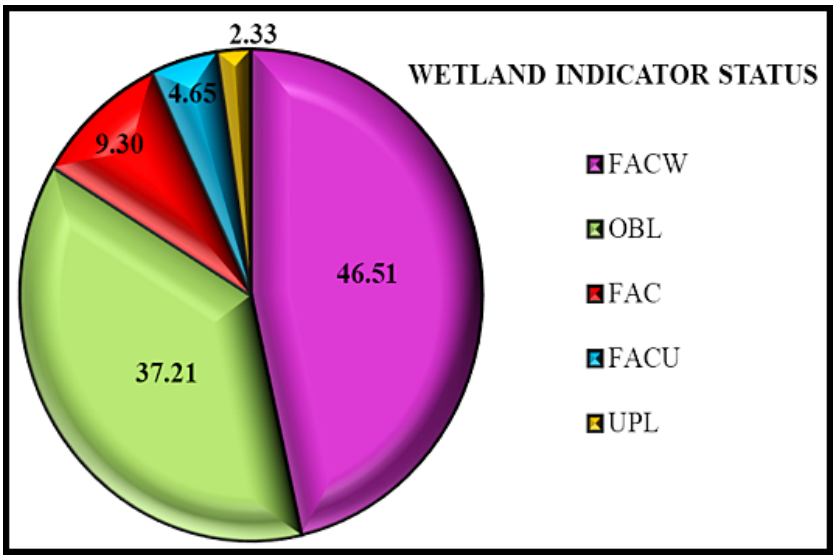

Fig. 5: Wetland indicator status of existing macrophyte species

During fieldwork at Pardi wetland total of 43 macrophyte species were identified and listed based on the visual observation in the quadrats by using Shah (1978) and Cook (1908).[23-24] The given tables show the list of aquatic macrophytes with their indicator statuses, ecological type, local name, family, and life form classification (Table: 1), and socioeconomic and ethnobotanical importance of existing macrophyte species (Table: 2).

Table 1: Floristic composition of present macrophyte species at Pardi wetland.

No	Scientific name	Local name	Type	Life form	Indicator status
	Acanthaceae				
1	*Hygrophila auriculata* (Schum.) Heine	Aakhiryo	ER	TH	FAC
	Alismataceae				
2	*Limnophyton obtusifolium* (L.) Miq		FR	HC	FACW
	Amaranthaceae				
3	*Alternanthera sessilis* (L.) Dc.	Fulyu	ER	TH	FAC
	Araceae				
4	*Colocasia esculenta* (L.) Schott	Toro/Jungli Patra	AR	CR	FACW
5	*Lemna minor* L.		FF	CR	OBL
6	*Lemna trisulca* L.		FF	CR	OBL
7	*Pistia stratiotes* L.	Jal srunkhla	FF	CR	OBL

8	*Spirodela polyrhiza* (L.) Schleid.		FF	CR	OBL
9	*Wolffia arrhiza* (L.) Wimmer		SNR	CR	OBL
	Asteraceae				
10	*Grangea maderaspatana* (L.) Poir.		ER	HC	FACU
	Boraginaceae				
11	*Coldenia procumbens* L.	Basario okharad	ER	HC	FACU
	Ceretophyllaceae				
12	*Ceratophyllum demersum* L.		SNR	CR	OBL
	Chlororophyceae				
13	*Chara globularis* L.		SNR	CR	OBL
	Commelinaceae				
14	*Commelina benghalensis* L.	Motun sismulyun	AR	HC	FAC
	Convolvulaceae				
15	*Ipomoea aquatica* Forsk.	Nari bhji	FR	HC	FACW
16	*Ipomoea fistulosa* Mart. ex Choisy	Naravel	ER	CH	UPL
	Cyperaceae				
17	*Cyperus articulatus* L.		ER	CR	FACW
18	*Cyperus iria* L.		ER	CR	FACW
19	*Cyperus pumilus* L.		ER	CR	FACW
20	*Cyperus triceps* (Rottb.) Endl.		ER	CR	FACW
21	*Eleocharis acutangula (Roxb.) Schult.*		AR	CH	FACW
22	*Eleocharis dulcis* (Burm. f.) Henschel.		AR	CH	FACW
	Gentianaceae				
23	*Nymphoides indicum* (L.) O. Ktze.		FR	CR	OBL
	Hydrocharitaceae				
24	*Hydrilla verticillata* (L. f.) Royle		SR	CR	OBL
25	*Vallisneria spiralis* L.	Jal sarpoliya	SR	CH	OBL
	Lentibulariaceae				
26	*Utricularia aurea* Lour.		SR	CR	OBL
	Lythraceae				
27	*Ammania multiflora* Roxb.		ER	TH	FAC
	Marsileaceae				
28	*Marselia quadrifolia* L.	Swastik Patri	AR	CR	FACW
	Nymphaeceae				
29	*Nelumbo nucifera* Gaertn.	Kamal	FR	TH	OBL
30	*Nymphaea nouchali* Willd	Poyna	FR	CR	OBL
	Onagraceae				
31	*Ludwigia adscendens* L.	Talav bhaji	FR	CR	FACW
	Poaceae				
32	*Chloris quinquesetica* Bhide		ER	HC	FACW
33	*Dactyloctenium aegyptium* (L.) P. Beauv.	Darbha	ER	CH	FACW
34	*Echinochloa crusgalli* (L.) P. Beauv.		ER	CH	FACW
35	*Eleusine indica* (L.) Geaertn.		ER	TH	FACW
36	*Eragrostis tenella* (L.)		ER	TH	FACW
37	*Eragrostis unioloides* (Retz.) Nees ex		ER	HC	FACW
	Steud. Polygonaceae				
38	*Polygonum barbatum* L.		AR	TH	FACW
39	*Polygonum glabrum* Willd		AR	CH	FACW
	Pontedariaceae				
40	*Eichhornia crassipes* (Mart.) Solms.	Jal kumbhi	FF	CH	OBL
	Potamogetonaceae				

41	*Potamogeton nodosus* Poir. Salviniaceae		FR	CR	OBL
42	*Azolla pinnata* R. Br. Typhaceae		FF	TH	OBL
43	*Typha angustata* Bory & Chaub.	Gha bajri	AR	CR	FACW

Abbreviations used in the table

FF = Free floating, FR = Floating but rooted, SNR = Submerged but not rooted, SR = Submerged but rooted, ER = Emergent, CH = Chamophytes, HC = Hemicryptophytes, CR = Cryptophytes, TH = Therophytes, OBL = Obligate Wetland Plants, FACW = Facultative Wetland Plants, FAC = Facultative Plants, FACU = Facultative Upland Plants, UPL = Obligate Upland Plants)

Table 2: Socio-economic and ethnobotanical importance of macrophyte species at Pardi wetland

Species	Part(s) used	Uses
A. sessilis (L.) Dc.	Whole macrophyte	- Leaf & root extracts are given orally thrice a day for asthma indigestion
A. multiflora Roxb.	Leaf	- Paste of the leaf is applied externally on ring-worm & parasitic skin infection
A. pinnata R. Br.	Whole macrophyte	- An important source of biofertilizer - Used to feed chicken in poultry
C. demersum L.	Whole macrophyte	- Used as substrate or objects in the aquarium
C. procumbens L.	Leaves	- Crushed fresh leaves applied on joint mussels' swellings, twice a day
C. esculenta (L.) Schott	Leaves, petiole, & corm	- Used as vegetables (Leaves & corm) - Petiole juice applied to cuts and wounds
C. benghalensis L.	Leaves & young shoots	- Young shoots & leaves, used as vegetables
C. iria L.	Stems	- Stems are used for making typical mats
E. crassipes (Mart.) Solms.	Whole macrophyte	- Used in vermicomposting - organic compost production
E. dulcis (Burm. f.) Henschel.	Whole macrophyte	- Used to make mats - Corms are edible & stored
H. *verticillata* (L. f.) Royle	Whole macrophyte	- Shoots are used in worship & prayer during Sasthi puja - Used as fish food
H. auriculata (Schum.) Heine	Leaves	- Used by locals to increase the hemoglobin level in the blood (filtered leaf extract given orally once a day)
I. *aquatica* Forsk.	Young tender shoots & leaves	- As a vegetable & there is a huge demand for it - A curry prepared with young tender shoots is recommended during gastritis
I. *fistulosa* Mart. ex Choisy	Whole macrophyte	- Stem used as the stick in fencing - The dry plant is used as fuel
L. *minor* L.	Whole macrophyte	- Used as animal feed (chicken, duck, rabbit, goat, cow, sheep, etc.) & fish feed - Used as green manure
L. *trisulca* L.	Whole macrophyte	- Used as animal feed & fish feed

L. adscendens L.	Young tender shoots & leaves	- The young shoot is used as a vegetable as well as in - The decoction of the leaf is given twice a day with black pepper orally for stomach pain & in intestinal worms - The decoction of young tender shoots & leaves taken orally is a general weakness in pregnant women
M. *quadrifolia* L.	Leaves & twig	- Used as a vegetable
N. *nucifera* Gaertn. & *N. nouchali* Willd	Whole macrophyte	- Flowers were used as offerings in temples to God. - Kamal Root & seeds are utilized in devot -ional activities because the macrophyte boosts the mind's ability to focus & stimu -late spiritual growth - Seeds, leaves, petioles, roots, flowers, filaments, anthers, & stalks are all edible - Stamens & flowers of Kamal are used in flavo-ring tea. Pop the seeds like popcorn & Leaves used to wrap food as a plate. Kamal root paste & lemon juice is orally taken on an empty stomach for a week to treat piles - Poyna's dry petiole powder, once a day for a week used to increase hemoglobin level
P. *stratiotes* L.	Whole macrophyte	- Used as manure & ornamental plant in artificial ponds and aquariums
S. *polyrhiza* Linn.	Whole macrophyte	- Source of manure
T. *angustata* Bory & Chaub.	Whole macrophyte	- Dormant sprouts on roots & bases of leaves, the inner core of stalk, green bloom spikes, ripe pollen, & starchy oots are edible - Used for thatch in roofing.
V. *spiralis* L.	Leaves	- Leaves used as poultry feed for chicken

Discussion

The selected site represents less microphyte diversity because of the huge anthropogenic pressure and industrial effluents, besides some species are dominant at Pardi Lake because of the favourable environment. A similar observation was found by[26] in Gala Lake, Turkey.

The majority of morphologically submerged macrophyte species are vascular, and their vegetative development occurs below the water's surface.[27] With increasing water depth or solid suspended particles in water, light intensity drops, due to this reason they are so weak.[27] This group represented the lowest floristic percentage over the process of the investigation (6.98 %) (Fig: 2). The root system, 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.[28] 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 the leaves are broad.[29] 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.[30] Emergent macrophytes are the most common kind of aquatic vegetation,[31] out-competing other types due to their capacity to catch sunlight before it reaches the water's surface,[32] due to these reasons emergent macrophytes are dominant with 37.21 %, over the process of the investigation (Fig: 2). A similar observation was obtained by (Malik & Namdeo, 2010) in the polluted pond of Shahjahanpur (India);[34] in the wetlands of Hojai subdivision, Nagaon district, Assam, India.

The region may be classified as a cryptophytic climate based on these observations of the percentage composition of various life form classes of macrophytes at the research site. Cryptophytic condition indicates a warm and dry climate.[35] 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.[36] Macrophyte species are general markers of varying degrees of environmental conditions, nevertheless, they are not accurate.[37] The existence of a macrophyte species at a location is determined by many climatic, edaphic, and biotic conditions, and it is hard to separate the influence of specific elements such as degree of substrate saturation and depth and duration of standing water.[38]

Conclusion

Anthropogenic activities have impacted wetland ecosystem services across the world. It is well-known that global wetlands are shrinking rapidly and hence their resources both floral and faunal are depleting at the same pace. In the developing world restoration of wetlands is highly needed. The present study shows the macrophyte species composition in the wetland ecosystem and the socio-economic benefit of the present macrophyte species. The survival of aquatic species is threatened and hence the study of aquatic resources especially those having economic value are important. The production of wetlands macrophytes is excessive, which benefits the rural as well as urban economy. Many macrophytes are harvested by underprivileged people living in nearby wetland regions, such as neighbouring villages, and sold in local marketplaces for daily use as food, fodder, thatching, medicine, and other reasons. The study will also help to recreate wetland diversity precisely to Valsad District which has the maximum number of wetlands in Gujarat state. Furthermore, the study can be also helpful for understanding the complexity of the wetland ecosystem. Besides, Wetlands not only provide useful resources but are also important in terms of ecology and maintaining the climate of the region. Therefore, the conservation of wetlands especially in Valsad district, Gujarat needs to be addressed urgently.

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Conflict of Interest

The authors do not have any conflict of interest.

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