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WETLAND ECOSYSTEM - HOME TO PLANT SPECIES DIVERSITY

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Abstract

Wetlands are the most productive ecosystem which acts as a habitat for flora and fauna. It provides various ecosystem services such as maintaining hydrological cycle, flood control, carbon sequestration etc. Vegetation in wetland plays a significant role in maintaining nutrient cycle, water cycle, carbon sequestration, storage/retention and purification of water, waste treatment and pollution control. Thus, vegetation creates microclimate for smaller organisms. In the current study, we tested the hypothesis that the wetland ecosystem is home to a diversity of species which has a various ecological role in wetland plant communities. The study deals with the wetland of the Kheda district and the findings of the study showed the presence of 130 species which belong to 48 families, 106 genera. Out of these 130 species, there are 21 trees, 17 shrubs, 57 herb, 18 climbers, 8 sedges and 7 grass species which can be used for conservation and restoration purposes.

Key words : Wetlands, Species, diversity.

Introduction

Biodiversity is the variation found among all living organisms on the Earth. It is considered as an important aspect to support and maintain the ecosystem. It provides ecosystem stability through building up complex tropical networks. Therefore, loss of biodiversity threatens the food chain, natural resources and other important ecosystem services provided (Kumar and Desai, 2016). Wetlands are one of the most productive and diverse ecosystems, providing a home to millions of species. Wetlands in India occupy 58.2 million hectares area which also includes the area used in paddy cultivation (Prasad *et al.,* 2002). It is estimated that freshwater wetlands alone support 20% of the biodiversity of India (Deepa and Ramachandra, 1999). Wetlands have been defined by different authors with various perspectives but Ramsar Convention defines wetlands as "Wetlands are areas of marsh, fen, peatl and or water, whether it is natural or artificial, permanent or temporary, with water is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters." (Ramsar C, 1994). The coastal areas are also considered marine water wetland. The coastal areas of Gujarat state are divided into- Gulf of Kachchh, Saurashtra Coast and Gulf of Khambhat support various habitats which further support the rich biodiversity (Trivedi *et al.,* 2015).

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The contribution of wetlands to the ecosystem and human welfare

Wetlands provide habitat; particularly to the migratory bird species. It acts as a natural water purifier through the process of sedimentation; thus upgrading the ground water quality. Being stagnant most of the time, these systems are well known for groundwater recharging. Wetlands support livelihood in local areas being a source for water supply (drinking and agricultural purposes). Wetlands are an essential source of food cultivation such as rice and fish (Nwankwoala, 2012). Thus, playing an economically significant role. Wetlands are attractive spots for recreational opportunities such as bird watching, research activities, photography and most importantly serving sites for environmental education and public awareness programs. Wetlands store the flooded water,

which can be slowly released during the dry periods (Mitsch and Gooselink, 1986). The vegetation reduces the speed of fast-moving water (Rani *et al.,* 2011). Hence, wetlands reduce flood damage. Vegetation controls soil erosion by eliminating flowing forces of waves at the shoreline unlike seas and ocean; which facilitates sedimentation (Chaves and Lakshumanan, 2008). Vegetation plays a remarkable role in controlling soil erosion and eliminating nutrients, the nutrients which are passed into the lakes and rivers from the wetlands help in feeding and breeding aquatic life. The destruction of wetlands; thus, degrades the quality of lakes or rivers (Mitsch and Gooselink, 1986). Wetlands constitute 6% of the hydrosphere. Wetlands are found to store heat and release it during cold periods, e.g., winters; so as to maintain and regulate the air temperature. It is also said that wetlands regulate atmospheric carbon dioxide by trapping it. Hence, wetlands play a major role in Carbon sequestration (Chmura *et al.,* 2003; Mitsch *et al.,* 2013; Bernal and Mitsch, 2012).

Threats to wetlands

Wetlands are not only the most productive and diversity rich systems but are also very dynamic and delicate which generates a need for the conservation of such ecosystems. There are several threats impacting the wetlands. One of the major threats posed to the vegetation of the wetland ecosystem is the proliferation of alien species. Coastal erosion is also a major contribution to the vegetation threat as it leads to habitat loss of the wild species. Altered temperatures lead to various stressors including heat stress which may also be responsible for the change in water quality of wetlands which is another threat to the wetland vegetation (Erwin, 2009). Other than these, loss of habitat, grazing by cattle, disruption in reproductive mechanisms, disease spread in threatened plant species, niche overlapping, ecological succession (if no other habitat is available nearby for the species to establish themselves and grow for the continuation of their generation), misidentification of other species as weeds followed by their removal, catastrophic events - especially affecting smaller populations, collection of species for subjective purposes contribute to minor devastations to these delicate ecosystems (Dopson *et al.,* 1999).

Wetland Restoration is a recent concept in ecology which deals with the intentional alterations in the wetland in order to re-establish it in a way closer to its indigenous state which is more efficient and functional (Henry and Amoros, 1995). Natural wetlands support all types of vegetation such as tree species, shrub species, climber species, herbs, grasses and sedges species which hold great potential effects on a particular wetland. However, the representation of these species is not in an appropriate mode. So in the present study, an attempt has been made to represent all upland species of wetlands in different categories which can be utilised for the conservation and restoration of wetlands.

Materials and Methods

Selection of wetland and enlisting

A natural wetland situated in Kathoda village, Kheda district of Gujaratwas selected. The plant species were identified with the help of literature at the Department of Botany, Gujarat University.

Field survey

The fieldwork was carried out from August 2017 to March 2018. In the field, the plant species were documented and plant specimens were also collected along with their flowering parts for preparing herbarium specimens for identifying the plants using the state flora. The collected plant specimens were carefully pressed and poisoned with $HgCl_2$. The herbarium sheets were labelled, numbered and deposited in the Herbarium of Gujarat University. Field notes were taken so as to have information on the plant's name, habit, habitat and the characteristics of the species along with the plant family.

Results and Discussion

The vegetation of Kheda wetland

There is no clear relationship between tree stratum and environmental variation (Bradfield, & Scagel, 1984). Soil induced salinity (Dehaan and Taylor, 2002) and the amount of the unvegetated bottom (Kantrud and Newton, 1996) can be indicated by vegetation. The number of native genera is considered as one of the indicators for wetland restoration progress (Matthews *et al.,* 2009). Hence wetland vegetation plays a significant role in the assessment of wetland progress and wetland quality. The present study reports a clear presence of obligatory regions of wetlands that have only herbs, facultative regions showed the presence of herbs and shrubs. Likewise, upland regions of wetland report presence of herb, shrub, trees and climbers.

Upland vegetation

Upland vegetation of wetland can be divided into (i) Upper layer which forms a layer of tree species, (ii) Middle layer which includes shrub and climber species and (iii) Ground layer consisting of herb species.

Upper layer

Acacianilotica (L.) Delile, *Acacia leucophloea* (Roxb.) Willd., *Annona squamosa* L., *Azadirachta*

Table 1: List of plant species reported at Kheda wetland.

S .No.	Botanical Name	Commonname	Family	Habit
1	*Abelmoschus manihot* (L.) Medik.	Jangli bhindi	Malvaceae	Herb
2	*Abrus precatorius* L.	Chanoti	Fabaceae	Climber
3	*Abutilon indicum* (L.) Sw.	Kanski, Khapat	Malvaceae	Shrub
4	*Acacia nilotica* (L.) Delile	Deshi baval	Mimosaceae	Tree
5	*Acacia leucophloea* (Roxb.) Willd.	Pilo baval, Himaro, Harmo baval, Hari baval, Hiver, Samadi, Aniyar, Rinjhado	Mimosaceae	Tree
6	*Acalypha indica* L.		Euphorbiaceae	Herb
7	*Achyranthes aspera* L.	Anghedi, Anghedo	Amaranthaceae	Herb
8	*Aerva lanata* (L.) Juss.	Mountain knotgrass, Chhaya	Amaranthaceae	Herb
9	*Alysicarpus vaginalis* (L.) DC.	Bhoyn samarvo, Jinko samarvo	Fabaceae	Herb
10	*Amaranthus viridis*L.	Dhimbdo, Green amaranth	Amaranthaceae	Herb
11	*Anisomeles indica* (L.) Kuntze	Indian catmint	Lamiaceae	Herb
12	*Annona squamosa* L.	Sitaphal	Annonaceae	Tree
13	*Apluda mutica* L.	Lapdu, Mauritian grass	Poaceae	Herb
14	*Aristida hystrix* L.f.		Poaceae	Grass
15	*Arundo donax* L.	Giant reed	Poaceae	Grass
16	*Azadirachta indica* (L.) Juss.	Margos Tree, Neem Tree	Meliaceae	Tree
17	*Bacopa monnieri* (L.) Wettst.	Brahmi, Jalnevari	Plantiginaceae	Herb
18	*Blepharis* spp.		Acanthaceae	Herb
19	*Bonnaya oppositifolia* Spreng.		Linderniaceae	Herb
20	*Brassica juncea* (L.) Czern.	Rai	Brassicaceae	Herb
21	*Caesalpinia crista* L.	Kachka	Caesalpiniaceae	Tree
22	*Calotropis procera*(Aiton) Dryand.	Aakdo	Ascelpiadaceae	Shrub
23	*Canavalia gladiata* (Jacq.) DC.	Sword Bean	Fabaceae	Herb
24	*Capparis decidua* (Forssk.) Edgew	Kerdo	Capparaceae	Shrub
25	*Capparis grandis*L.f.	Thikari	Capparaceae	Shrub
26	*Cascabela thevetia* (L.) Lippold	Yellow oleander, Pili karen	Apocynaceae	Shrub
27	*Cassia fistula* L.	Bahava, Garmalo, Indian Laburnum	Caesalpiniaceae	Tree
28	Cassia occidentalis L.	Kasudri	Caesalpiniaceae	Shrub
29	*Cassia tora* L.	Kuvandio	Caesalpiniaceae	Tree
30	*Cenchrus ciliaris* L.	American foxtail grass	Poaceae	Grass
31	*Chara*	Stonewort	Characeae	Algae
32	*Chloris barbata* Sw.	Mindadiu	Poaceae	Herb
33	*Cissus trifoliata* (L.) L.	Sorrelvine, Possum grape	Vitaceae	Climber
34	*Clerodendrum phlomidis* L.f.	Arni	Verbenaceae	Shrub
35	*Clitoria ternatea* L.	Garnibibri, Butterfly Pea	Fabaceae	Climber
36	*Coccinia grandis* (L.) Voigt	Tindola	Cucurbitaceae	Climber
37	*Commelina benghalensis* L.	Shishmuliu	Commelinaceae	Herb
38	*Commelina diffusa* Burm.f.	Creeping dayflower	Commelinaceae	Herb
39	*Convolvulus microphyllus* Sieber ex Spreng.		Convolvulaceae	Herb
40	*Corchorus aestuans* L.	Chunch, East Indian Mallow	Tiliaceae	Herb
41	*Corchorus capsularis* L.	Moti Choonch, White-Jute	Tiliaceae	Herb
42	*Corchorus fascicularis* Lam.	Tall wild jute	Tiliaceae	Herb
43	*Corchorus olitorius* L.	Red Jute, Jew's Mallow, Patsan, Paat	Tiliaceae	Herb
44	*Cordia dichotoma* G Forst.	Moto-gundo	Ehretiaceae	Tree

Table 1 contd....

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S .No.	Botanical Name	Commonname	Family	Habit
45	*Cressa cretica* L.	Una, Rudravanti	Convolvulaceae	Herb
46	*Cuscuta chinensis* Lam.	Amarvel	Cuscutaceae	Climber
47	*Cynodon dactylon* (L.) Pers.	Darbh	Poaceae	Herb
48	*Cyperus bulbosus* Vahl	Bush onion, wild onion	Cyperaceae	Sedge
49	*Cyperus difformis* L.	Umbrella sedge, Rice sedge	Cyperaceae	Sedge
50	*Cyperus iria* L.	Nut sedge	Cyperaceae	Sedge
51	*Cyperus rotundus* L.	Nut grass, Motha	Cyperaceae	Sedge
52	*Dactyloctenium aegyptium* (L.) Willd.	Crow foot grass	Poaceae	Grass
53	*Datura inoxia* Mill.	Dhatura	Solanaceae	Herb
54	*Digitaria ciliaris* (Retz.) Koeler.	Southern crabgrass	Poaceae	Herb
55	*Echinochloa colona* (L.) Link	Jungle rice	Poaceae	Herb
56	*Eclipta alba* (L.) Hassk.	False daisy	Asteraceae	Herb
57	*Eleusine indica* (L.) Gaertn.	Indian goosegrass	Poaceae	Grass
58	*Elytraria acaulis* (L.f.) Lindau	Asian scalystem	Acanthaceae	Herb
59	*Eragrostis tenella* (L.) P.Beauv. ex Roem. & Schult.	Kalavo	Poaceae	Herb
60	*Euphorbia hirta* L.	Asthma weed	Euphorbiaceae	Herb
61	*Euphorbia tirucalli* L.	Pencil cactus	Euphorbiaceae	Herb
62	*Evolvulus alsinoides* (L.) L.	Slender dwarf morning-glory	Convolvulaceae	Herb
63	*Ficus benghalensis*L.	Vad, Banyan, Bargad	Moraceae	Tree
64	*Ficus racemosa* L.	Umbar, Audumbar	Moraceae	Tree
65	*Ficus virens* Aiton	White fig, pilkhan	Moraceae	Tree
66	*Fimbristylis aestivalis* (Retz.) Vahl	Summer fimbry	Cyperaceae	Sedge
67	*Fimbristylis dichotoma* (L.) Vahl	Forked fimbry	Cyperaceae	Sedge
68	*Fimbristylis* spp		Cyperaceae	Sedge
69	*Holoptelea integrifolia* (Roxb.) Planch.	Kanjo, Vaula, Papada	Ulmaceae	Tree
70	*Hygrophila schulli* (Buch.-Ham.) M.R. Almeida & S.M. Almeida	Star thorn, Gokula kanta	Acanthaceae	Shrub
71	*Indigofera wightii* Wight & Arn.	Wight's Indigo	Fabaceae	Herb
72	*Ipomea obscura* (L.) Ker Gawl	Wild petunia	Convolvulaceae	Climber
73	*Ipomoea aquatica*Forssk.	Swamp morning-glory	Convolvulaceae	Climber
74	*Ipomoea pes-tigridis* L.	Wagpadi	Convolvulaceae	Climber
75	*Ipomoea sinensis* (Desr.) Choisy		Fabaceae	Climber
76	*Justicia adhatoda*L.	Malabar nut, vasaka	Acanthaceae	Shrub
77	*Lemna gibba* L.	Swollen duckweed	Lemmnaceae	Aquatic
78	*Leucaena leucocephala* (Lam.) de Wit	Lead tree	Mimosaceae	Tree
79	*Limnophyton obtusifolium* (L.) Miq.	Arrow head	Alismataceae	Herb
80	*Ludwigia perennis* L.	Perennial water primrose	Onagraceae	Herb
81	*Luffa acutangula* (L.)Roxb.	Turiya	Cucurbitaceae	Climber
82	*Mangifera indica* L.	Ambo, Mango	Anacardiaceae	Tree
83	*Marsilea* spp	Water clover	Marsilaceae	Herb
84	*Merremia aegyptia* (L.) Urban	Hairy woodrose	Convolvulaceae	Climber
85	*Merremia gangetica* (L.) Cufod.	Undarkani, Kidney leaf morning glory	Convolvulaceae	Herb
86	*Moringa oleifera* Lam.	Sargavo, Drumstick	Moringaceae	Tree
87	*Najas minor* Ali.	Brittle waternymph	Najadaceae	Herb

Table 1 contd....

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S .No.	Botanical Name	Commonname	Family	Habit
88	*Nelumbo nucifera* Gaertn.	Indian lotus	Nymphaeaceae	Herb
89	*Nerium oleander* L.	Karen	Apocynaceae	Shrub
90	*Nymphaea pubescens* Willd.	Water lily	Nymphaeaceae	Herb
91	*Nymphaea nouchali* Burm.f.	Water lily	Nymphaeaceae	Herb
92	*Oldenlandia corymbosa* L.	Diamond Flower, corymbose hedyotis, flat-top millegraines	Rubiaceae	Herb
93	*Operculina turpethum* (L.) Silva Manso	Turpeth	Convolvulaceae	Climber
94	*Oplismenus compositus* (L.) P.Beauv.	Running mountain grass	Poaceae	Grass
95	*Peltophorum pterocarpum* (DC.) Baker.	Copper pod	Caesalpiniaceae	Tree
96	*Pentatropis capensis* (L.f.) Bullock	Shingroti	Ascelpiadaceae	Climber
97	*Pergularia daemia* (Forssk.) Chiov.	Pergularia, Utaran	Ascelpiadaceae	Climber
98	*Peristrophe paniculata* (Forssk.) Brummitt	Kali anghedi	Acanthaceae	Shrub
99	*Persicaria glabra* (Willd.) M.Gómez	Sherul	Ascelpiadaceae	Climber
100	*Physalis minima* L.	Popti	Solanaceae	Herb
101	*Plumbago zeylanica* L.	Chitrak	Plumbaginaceae	Shrub
102	*Polyalthia longifolia* (Sonn.) Thw.	Asopalav	Annonaceae	Tree
103	*Potamogeton crispus* L.	Curled pondweed	Potamogetonaceae	Herb
104	*Potamogeton nodosus* Poir.	Long leaf pondweed	Potamogetonaceae	Herb
105	*Prosopis cineraria* (L.) Druce	Khijdo	Mimosaceae	Tree
106	*Prosopis julifera* (Sw.) DC.	Gando baval	Mimosaceae	Tree
107	*Pupalia lappacea* (L.) Juss.	Forest Burr, Creeping Cock's comb	Amaranthaceae	Shrub
108	*Rhynchosia minima* (L.) DC.	Nahmikamalvel	Fabaceae	Climber
109	*Ricinus communis* L.	Aranda	Euphorbiaceae	Shrub
110	*Scirpus* spp.		Cyperaceae	Sedge
111	*Setaria italica* (L.) P.Beauv.	Chano	Poaceae	Herb
112	*Setaria intermedia* Roem. & Schult.	Kutela, Chiktu	Poaceae	Grass
113	*Sida acuta* Burm.f.	Bala	Malvaceae	Herb
114	*Sida spinosa* L.	Gulsakri, Pricky sida	Malvaceae	Herb
115	*Sida cordata* (Burm.f.) Borss.Waalk.	Bhoybala	Malvaceae	Herb
116	*Solanum trilobatum* L.	Purple fruited pea eggplant	Solanaceae	Shrub
117	*Solanum diphyllum* L.	Two leaf nightshade	Solanaceae	Shrub
118	*Solanum virginianum* L.	Bethi bhoy ringani	Solanaceae	Shrub
119	*Streblus asper* Lour.	Sahoda, Sandpaper tree	Urticaceae	Tree
120	*Teramnus labialis* (L.f.) Spreng.	Banudad	Fabaceae	Climber
121	*Terminalia catappa* L.	Deshi badam	Combretaceae	Tree
122	*Tinospora glabra* (Medik) Almeida	Giloy	Menispermaceae	Climber
123	*Trianthema portulacastrum* L.	Satodo	Aizoaceae	Herb
124	*Tridax procumbens* (L.) L.	Pardesi bhangaro, Ekdandi	Asteraceae	Herb
125	*Typha angustata* Bory & Chaub.	Ramban	Typhaceae	Herb
126	*Urena lobata* L.	Caesarweed	Malvaceae	Herb
127	*Vallisneria spiralis* L.	Eel grass, Tape grass	Hydrocharitaceae	Herb
128	*Vernonia cinerea* (L.) Less	Sahadevi	Asteraceae	Herb
129	*Xanthium strumarium* L.	Gokhru	Asteraceae	Herb
130	*Ziziphus nummularia*(Burm.f.) Wight & Arn.	Chani Bor	Rhamnaceae	Tree

Table 2: Selected plant species with their Ecological significance.

No.	Plant species	Ecological significance of species
1.	*Acaciasp.*	Insects and birds visit *Acacia* for its high nutritional value (Stone *et al.*,2003). *Acacia,* in high alkaline soil, increases litter production which is beneficial for nutrient cycling and nutrient replenishing (Gill *et al.*, 1987). *Acacia* is also used for animal fodder along with obtaining other forest products– wood, timber, gum, tannins for economic uses (Fagg and Stewart, 1994). *Acacia nilotica* is capable of conserving soil fertility and enhance soil moisture (Chaturvedi and Das, 2002).
2.	*Azadirachta indica*	It is known for replenishing soil by addition of the higher amount of potassium, and comparatively lower amounts of nitrogen and phosphorous through the decomposition of its leaf litter (Hossain *et al.*, 2011)
3.	*Caesalpinia crista*	Many insects from order Hymenoptera, Coleoptera, Lepidoptera and Diptera feed upon the nectar provided by the plant of which the Carpenter bee (*Xylocopa*) is the main visitor for nectar and a potential pollinator (Li *et al.*, 2004). The similar foraging behaviour of many insects like *Apis cerana, Megachile, Xylocopa* etc. is reported by Neli and Kalita (2013).
4.	*Cassia fistula*	*Cassia fistula* is reported as potential species to enhance soil fertility and maintain the moisture in the soil (Chaturvedi and Das, 2002).
5.	*Ficus spp.*	*Ficus* is a keystone species, hence can be utilized for maintaining or restoring an ecosystem. The frugivorous species are highly attracted to its fruits for nutrition. *Ficus* supports huge biodiversity and also serve an important role in preventing soil erosion (Kuaraksa*et al.*, 2012)
6.	*Streblus asper*	Bird species like Bulbul and Myna mainly visit this species for fruit feeding (Aruna and Balasubramanian, 2014).
7.	*Leucaena leucocephala*	*Leucaena leucocephala* has been tested and reported for being involved in the remediation of the dye contaminated soil (Jayanthy *et al.*, 2014). It is also reported as a potential species for remediating waste oils from the contaminated soil in a terrestrial ecosystem (Edwin-Wosu *et al.*, 2016) while at the same time, it is also denied as efficient remediating species (Osam *et al.*, 2013).
8.	*Mangiferaindica*	A huge diversity of insects are sustained by the mango tree. Some of these insect group performs beneficial roles as pollinators, maintaining ecosystem balance etc. while others prove to be harmful as pests and natural enemies (Reddy *et al.*, 2016). Birds like Red-whiskered bulbul feeds on the fruits (Carleton and Owre, 1975).
9.	*Peltophorum pterocarpum*	It is reported to show capability for remediating waste oils from the contaminated soil in the terrestrial ecosystem (Edwin-Wosu *et al.*, 2016; Osam *et al.*, 2013).
10.	*Polyalthia longifolia*	The part of the life cycle of *Graphium evemon,* (a butterfly) is dependent upon *Polyalthia longifolia*. It serves as a food source for the caterpillars of this butterfly (Sanjaya and Fitriana, 2017).
11.	*Prosopis cineraria*	A study suggests that *Prosopis cineraria* can be involved in improving soil fertility by supporting fungal growth under-canopy of the tree. This growth is due to the addition of organic content in soil by the litter (Purohit *et al.*, 2002). The similar conclusion is drawn from an article that the soil characteristics are influenced by the litter addition in the soil by *Prosopis cineraria* which accounts for nutrient cycling. This further is beneficial in upgrading soil fertility (Sharma and Dakshini, 1998). Bees and other insect species from order Hymenoptera are attracted towards this plant for the nectar produced by the plant; hence they pollinate and sets fruit (Gorain *et al.*, 2012).
12.	*Moringa oleifera*	It is revealed through research that seeds have the ability to cleanse and purify the wastewater of wetlands by totally removing the coliforms and *E.coli* from it. Hence, reduces the water turbidity (Silva *et al.*, 2013). The similar conclusion was drawn from another study, that the seeds are highly potential in the cleansing of untreated domestic water and thus reducing turbidity. This water might be fit for drinking purpose after treatment (Lea, 2010).
13.	*Terminaliacatappa*	Due to industrialisation, such toxic metals are polluting lands and water bodies. Species like *Terminaliacatappa* are reported in the literature for acting as an efficient absorbent for the toxic metal – lead. Hence, it can be useful for treating wastewater of wetlands or any water bodies (Jadav *et al.*, 2015).
14.	*Ziziphus nummularia*	The honeybees feed on the nectar secreted by the flowers of jujube plant (Alqarni, 2015). It is also revealed from a study that this species is also useful in absorbing the erythrosine dye from the aquatic body; thus disinfecting the water body (Yahyaei *et al.*, 2016).

Table 2 contd....

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No.	Plant species	Ecological significance of species
15.	*Abutilonindicum*	*Abutilonindicum* decontaminate cadmium polluted soil by absorbing and accumulating is known to absorb and accumulate cadmium (Varun *et al.*, 2015). Many butterfly species and honey bees are reported to visit flowers for the nectar. Hence, in turn, they pollinate the flower of *Abutilonindicum* (Abid *et al.*, 2010).
16.	*Justicia adhatoda*	A study has revealed that this plant can be used for remediating heavy metal – mercury. It acts as absorbent and is valuable in purifying the aquatic systems (Aslam *et al.*, 2013). The bees are known to visit flowers not only for nectar but for the pollen collection too. The pollen load is observed to be consist of high-quality pollens. The larvae are fed with these pollens. *Justicia adhatoda* is reported to be most utilised among many other species by bees for pollen and nectar exploitation (Noor *et al.*, 2009). Thus, it is very clear that such species involved in insect-plant host interaction are of utmost significance.
17.	*Clerodendrum phlomidis*	There are only butterfly species to be involved in pollination of this plant as a consequence of co-evolution which is very peculiar. A high concentration of nectar with the presence of amino acids and sucrose as predominant sugar is declared (Guddeti, 2014). It is also remarked that the litter production of this plant is nitrogen-rich; hence, significant in supplying the nitrogen to the soil (Mathur, 2019).
18.	*Calotropisprocera*	The litter production by *Calotropisprocera,* is nitrogen-rich, thus beneficial in mineral cycling; as reported for *Clerodendrum phlomidis* (Mathur, 2019). It also absorbs volatile metalloids/metals like Pb, Fe, Cr, Cd, Zn, Ni, V, Co, Mo, Cu and accumulates them in different parts (Prajapati, 2014, 2012). Similar results have been concluded from a study revealing remediation potential of *Calotropisprocera* to accumulate heavy metals like Cd, Cr, Co, Cu, Fe, Ni, Zn and Pb (Badr, 2012). Thus it can be remarked that it can be beneficial in decontaminating heavy-metal polluted soil which might leach into water bodies.
19.	*Capparisdecidua*	It is a life-supporting species (Ishnava *et al.*, 2011). The animals are dependent on it. It provides habitat to insects like ants and termite (Mahmood *et al.*, 2013).
20.	*Capparis grandis*	Avian frugivores feeding on the fruits of Capparis is observed; thus, assisting in seed dispersal (Aruna *et al.*, 2009). Great orange, Small orange and Yellow orange butterflies pursue it as a food source and feed upon it (Dharamkar, 2016). The bees also visit for foraging and it is suggested that they collect nectar or pollen or maybe both of them (Cherian, 2010).
21.	*Cascabela thevetia*	Long-tailed macaques (*Macaca fascicularis*) consume the fruits of *Cascabela* as they are frugivores. These primates are usually found in coastal areas (Hambalil *et al.*, 2014).
22.	*Hygrophila schulli*	The study has shown that it might be useful in accumulating heavy metals in their tissues from the polluted soil and water (Shabani *et al.*, 2009).
23.	*Neriumoleander*	It is revealed that the microorganisms associated with roots of *Neriumoleander* are beneficial for purifying wastewater (Bai *et al.*, 2017).
24.	*Ricinus communis*	*Ricinus communis* is claimed to be an excellent metal tolerant species. It accumulates heavy metals like Pd, Cu, Cd and Zn; hence plays a significant role in the remediation process (Yi *et al.*, 2014). A similar function is reported in another study describing the ability to remediate heavy metals – Cd, Pb, Ni, As, Cu etc. (Bauddh *et al.*, 2015). The endophytic fungus is isolated from Ricinus which shows it provides habitat to it (Sandhu *et al.*, 2014).
25.	*Chlorisbarbata*	It absorbs metals like Hg, Cd and Zn and accumulates them. The roots have been observed to show better growth with the absorption of Hg and Cd at low concentrations and Zn at all the concentrations. Hence the plants require these metals for the growth and help in the remediation of metals along with it (Patra *et al.*, 1994). A similar conclusion was drawn out from a study that *Chlorisbarbata* when infected with mycorrhizal fungus, can absorb heavy metals (Kuo *et al.*, 2014).
26.	*Corchorus capsularis*	The potential to remediate arsenic from the contaminated soil is reported by Uddin Nizam and his team (Uddin *et al.*, 2016)
27.	*Urena lobata*	The spider species *Phintella vittata* is observed to suck nectar from the extrafloral parts of the *Urena lobata* (Rahi and Soumyajit, 2011). Hence it can be concluded that trees serve as a food resource to arachnids as well along with the insects and birds. The compost of this plant is

Table 2 contd....

Table 2 contd....

No.	Plant species	Ecological significance of species
		beneficial in the remediation of the soil contaminated with engine oil (Eremrena and Mensah, 2017).
28.	*Sida cordata*	The insects belonging from order Hymenoptera (*Apis dorsata*, *Apisindica*, *Mellipona* spp., *Campestris polistis*), Diptera (*Mucsanebula*, *Batracerca* spp.), Lepidoptera (*Pieris* spp.; *Limenistis* spp.), Coleoptera (*Coccinellapunctata*) were observed to visit *Sidacordata* for the nectar exploitation and pollen collection. The butterflies (*Pieris* spp.; *Limenistis* spp.) and honey bees (*Apis dorsata*, *Apisindica*) were frequent visitors and observed to be the potential pollinator among all (Agnihotri *et al.*, 2014).
29.	*Tridax procumbens*	The butterflies visits this plant for the nectar and pollinates the flower (Thakur and Mattu, 2010). It justifies the insect-plant relationship which is significant in an ecosystem as a study remarks that plant-insect relationships dictate the structure of the community (Heithaus, 1974).
30.	*Sida acuta*	*Sidaacuta* is reported for the absorption of toxic heavy metal lead from the contaminated soil. It accumulates lead in its root and shoot mass. It hence assists in detoxification and purification of the polluted area by the process of remediation (Oseni *et al.*, 2018). Many insect species belonging to order Hymenoptera, Coleoptera and Lepidoptera show foraging activity on this plant. The insect visits are either for robbing nectar or to collect pollen. The most periodic visits are made by butterflies for nectar exploitation and honey bees for both the floral rewards and pollen collection (Raju and Rani, 2016).

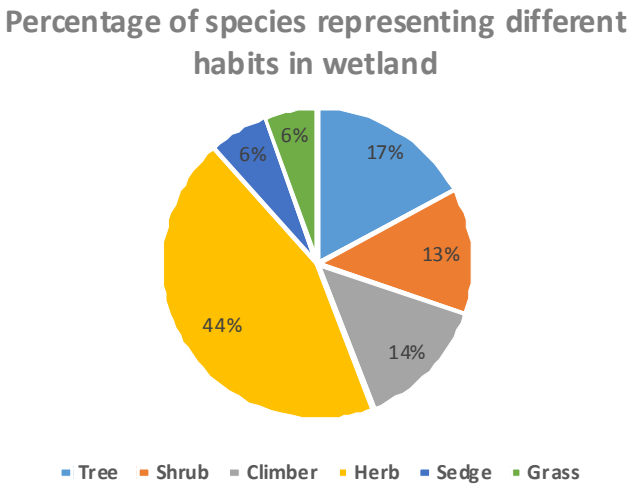

Fig. 1: Graphical representation of the habit percentage.

indica (L.) Juss., *Caesalpinia crista* L., *Cassia fistula* L., *Cordia dichotoma* G Forst., *Ficus benghalensis*L., *Ficus racemosa* L., *Ficus virens* Aiton., *Holoptelea integrifolia* (Roxb.) Planch., *Streblus asper* Lour., *Leucaena leucocephala* (Lam.) de Wit, *Mangiferaindica* L., *Peltophorum pterocarpum* (DC.) Baker., *Polyalthia longifolia* (Sonn.) Thw., *Prosopis cineraria* (L.) Druce, *Prosopis julifera* (Sw.) DC., *Moringa oleifera* Lam., *Terminaliacatappa* L., *Ziziphus nummularia*(Burm.f.) Wight & Arn.are categorized into the upper layer of the strata.

Middle layer

Abutilonindicum (L.) Sw., *Justicia adhatoda*L., *Clerodendrum phlomidis* L.f..,*Calotropisprocera* (Aiton) Dryand., *Capparisdecidua* (Forssk) Edgew., *Capparis grandis* L.f., *Cascabela thevetia* (L.) Lippold., *Cassiaoccidentalis* L., *Hygrophila schulli* (Buch.-Ham.) M.R.Almeida & S.M. Almeida., *Neriumoleander* L., *Peristrophe paniculata*(Forssk.) Brummitt, *Plumbagozeylanica* L., *Pupalia lappacea* (L.) Juss., *Ricinus communis* L., *Solanumtrilobum* L., *Solanum virginianum* L., *Solanum diphyllum* L. falls into the middle layer of stratification.

Ground layer

Achyranthesaspera L., *Alysicarpus vaginalis* (L.) DC., *Amaranthus viridis* L., *Apluda mutica* L., *Cassia tora* L., *Chlorisbarbata* Sw., *Corchorusaestuans* L., *Corchorus capsularis* L., *Commelina diffusa*Burm.f., *Urena lobata* L., *Vernonia cinerea* (L.) Less., *Sida cordata* (Burm.f.) Borss. Waalk., *Trianthema portulacastrum* L., *Tridax procumbens* (L.) L., *Setaria italica* (L.) P.Beauv., *Sida acuta*Burm.f.etc. forms the ground layer.

Obligatory aquatic plants

Limnophytonobtusifolium (L.) Miq., *Najas marina* L., *Nelumbo nucifera* Gaertn., *Nymphaea pubescens* Willd., *Nymphaea nouchali*Burm.f., *Potamogetonnodosus* Poir., *Potamogeton perfoliatus* L. are the obligatory aquatic plant species reported in the Kheda wetland.

Facultative aquatic plants

Alternanthera spp., *Echinoclova*, *Ipomoea aquatica* Forssk., *Ipomoea carnea*Jacq., *Typha* spp.

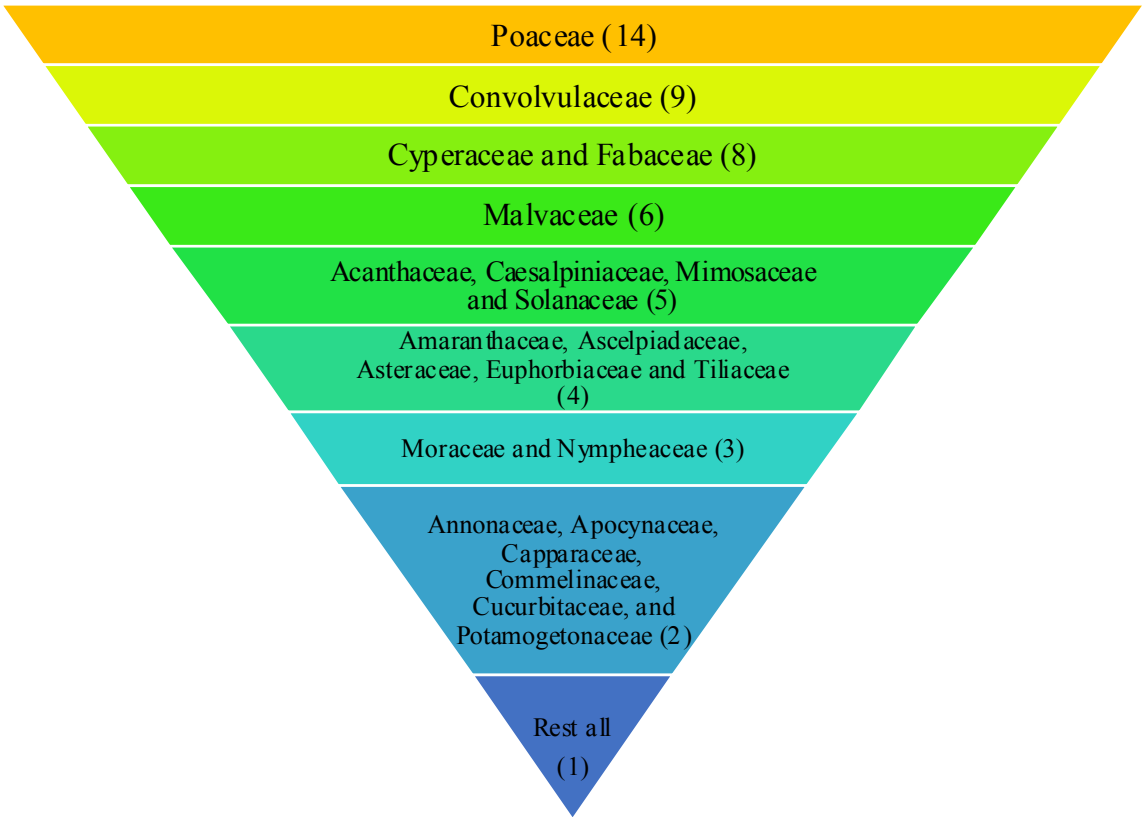

Fig. 2: Number of species in families.

etc. are the facultative wetland species.

Plant diversity in Kheda wetland

Qualitative assessment of Wetlands of Kheda showed that it is home of 17% trees, 13% shrubs, 14% climbers, 44% herbs, 6% sedges and 6% grasses. The studied wetland have shown maximum diversity in herbaceous vegetation (Fig. 1) in which maximum species (14) are reported from Poaceae. All species have been counted with respect to the families and represented in figure 2. During the study, finding shows the presence of 130 species which belong to 48 family and 106 genera. Out of these 130 species, there are 21 trees, 17 shrubs, 57 herb, 18 climbers, 8 Sedges and 7 grass species (Table 1 and Fig. 1). Thus, the present study supports the hypothesis *i.e.* wetlands are a highly diverse ecosystem. Wetlands show the presence of plant with divers habits *i.e.* Tree, shrub, climber, sedges and grasses. Wetlands of Kheda are a mixture of habits but have clear demarcation; Obligatory and facultative.

Moreover, the ecological significance of some plant species was found out using secondary literature available in different studies listed below in (Table 2). The study revealed that the wetland of the Kheda district is a mixture of different plant species with a variety of habits (tree, shrub, climbers and herbaceous) and is beneficial to the self-sustaining ecosystem.

Conclusion

The present study revealed wetland supports a tremendous diversity of plant species and as hypothesis from the current study showed wetlands are a highly diverse ecosystem. During the study, it is found that wetlands of Kheda support 130 species which belong to 48 families, 106 genera in which total of 21 trees species, 17 shrubs species, 57 herbs species, 18 climbers species, 8 sedges species and 7 grass species. Moreover, all the noted species have been found into different layers such as the upper layer, middle layer and ground layer. The plant species from different layers have shown different ecologically significant roles in the wetland ecosystem. These species serve diverse ecological roles from foraging by birds or insects (establishing interdependent relationships of plant-insect/bird) to nutrient cycling, conserving/improving soil characteristics, bioremediation, wastewater treatment etc. Thus, these species can be beneficial in wetland management or wetland restoration.

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