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A Preliminary Study on the Floristic Diversity of the Najafgarh Drain, South West Delhi

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ABSTRACT

The Najafgarh Lake is a large perennial aquatic ecosystem of South West Delhi, a district in the national capital territory of Delhi, India. It has a rich flora, fauna and is an ideal transit as well as wintering ground for migratory birds. This wetland provides abundant macrophytic species for their nutrition and wintering. Since the publication of Flora of Delhi in 1963, no floristic work has been published from the Najafgarh Lake or its drain sites. To assess and document the change in the aquatic macrophyte diversity over fifty years of urban sprawl, a survey of selected sites of Najafgarh Drain was carried out in 2018-19. A total of 75 plant species belonging to 72 genera and 34 families of angiosperms and pteridophytes were recorded. A comparative assessment with the Flora of Delhi is presented here.

Key words: Delhi, floristic diversity, macrophytes, Najafgarh Lake, urbanization, wetlands

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Introduction

Wetlands occupy about 6% of the Earth's surface and 1-5% of the geographical area of India, where they support about 20% of the known biodiversity (Kumar et al., 2005; National Wetland Atlas, 2011). These are the transitional zones between the water and terrestrial habitats (Torell et al., 2001; Zedler & Kercher, 2005) and have specific ecological characteristics, functions, and values (Maltby & Turner, 1983; Green, 1996; Getzner, 2002). Wetlands being the most productive biomes in the world are often considered as treasuries of biodiversity within a region or a landscape (Gopal & Sah, 1993; Kumar et al., 2005; Surana et al., 2007; Kumar & Sharma, 2018).

In India, it is estimated that an area of 15.26 million hectares with varied topography and climatic regimes supports diverse and unique wetland habitats (Panigrahy et al., 2012). Approximately 20% of the known biodiversity in India is supported by natural wetlands (Kumar et al., 2005). Similarly, a large number of man-made wetlands in the form of village tanks/ponds, estimated to be around 5,55,557 small-sized wetlands (<2.25 ha) support suitable habitats and provide food resources for a wide range of flora and fauna (Stewart, 2007; Panigrahy et al., 2012; Ali et al., 2013).

Wetlands in Delhi are in the form of lakes, reservoirs or barrages, waterlogged areas, tanks or ponds, and rivers or streams that support diverse habitats (National Wetland Atlas, 2011). In 2011, the Space Applications Centre (SAC) of the Indian Space Research Organisation (ISRO) published the National Wetland Atlas in which they reported around 400 wetlands in Delhi that cover an area of 2,771 ha (~ 0.93%) of the total geographical area of the city. South West Delhi, a district of the national capital territory (NCT) of Delhi, has about 111 such wetlands. Najafgarh Lake (also Najafgarh Marsh, Najafgarh Jheel), the largest, is a big lake in South West Delhi and is connected to the river Yamuna by a natural shallow nullah (drain), the Najafgarh drain. The Najafgarh drain is a large aquatic ecosystem flowing over a length of 51 km before joining the river Yamuna in the northwest with an average elevation of 218m (715 ft.) m.s.l. (INTACH, 2003). The drain carries floodwater during monsoon, surface run-off from the adjoining catchments, and wastewater generated from Haryana, throughout the year to the South-West district of Delhi, as almost 60% length of the Najafgarh drain flows through this part of Delhi.

These wetlands provide numerous ecological goods and services. However, most of the water bodies in and around Delhi are at high risk due to multiple threats of urbanization, increasing population, encroachments, increasing water pollution, waste dumping, setting up and expansion of industries, and discharge of effluents. The same is the story of Najafgarh lake and its drain

which is now converted into a sewer consisting of water polluted with very high bioaccumulation of pesticides in life forms ranging from fishes to earthworms (Karmakar & Musthafa, 2013; Bassi et al., 2014). Najafgarh lake and its drainage length harbour many aquatic plant species, which provide an indirect indicator of physico-chemical health of this important water body of Delhi. The only taxonomically viable and detailed scientific documentation was done by Maheshwari (1963) in his *Flora of Delhi* and since then a few publications have appeared that are add-ons to the flora (Tabasum et al., 2009; Manral et al., 2013; Mukherjee & Sarma, 2014; Mishra et al., 2015; Vardhana, 2018). However, none of these papers have discussed the floristic diversity of the Najafgarh Lake or drain. We surveyed and documented the existing aquatic macrophyte diversity from the Dhansa Barrage area moving 7 km downstream along the drain (Fig. 1). These data may be used in future references for assessment of urban biodiversity before and after 1963, when the last scientific documentation was completed, and especially after 1977, when floods affected the overall system of the river and drains.

Materials and Methods

Study area

Najafgarh Lake, located in South West Delhi (Lat. 28°36'38.67"N, Long. 76°59'12.18"E), is a small remnant of what once extended across the Najafgarh drain (Fig. 1). Once spread over 220 sq. km., the Najafgarh Lake has now shrunk to just over 7 sq. km in south-western Delhi (Rao, 2020). The lake extends through the Najafgarh Drain in the sub-cities of South West Delhi and covers 51 kilometers before joining the river Yamuna (INTACH, 2003). The drain is 44.5 m wide and 3.8 m deep in the south-western part and 28.95 m wide and 6 m deep in the north-eastern part. There is an approximately 5 m depth level difference between Najafgarh and the eastern mouth of Najafgarh lake, which is about 27 km apart (Singh, 2006; Fig. 1). The water level at both ends is quite high, and the difference appears to be insufficient to keep the drain flowing towards the north-east, as evident by the nearly stagnant water around Najafgarh (Singh, 2006). During the monsoon (July-August), the drain swells up to an average of 2-4 meters (Ground Water Year Book, 2015-16). As the floods carry many seed diaspora, this flooding embankment area was also included in the observations (Fig. 2). It is a natural aquatic habitat that remains covered by water with its aquatic vegetation and is enriched by faunal species diversity throughout the year. The drain attracts many residential and migratory species of birds during various seasons and is perhaps the only bird sanctuary within a drain. It is also a natural habitat for various small mammals that are dependent on natural water to sustain them (Rao, 2020). Climate is extremely dry

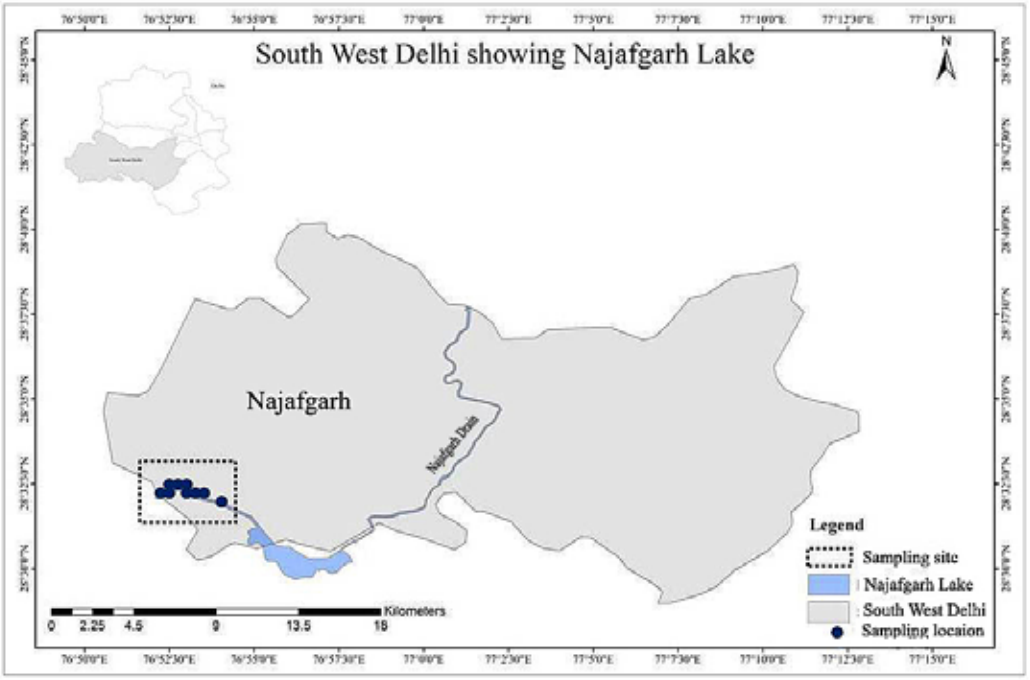


Figure 1. Map showing sampling locations based on GPS coordinates in Najafgarh Drain.

with intensely hot summers and cold winters. The cold season starts towards the latter half of November when both day and night temperatures drop rapidly with the advance of the season. January is the coldest month with the mean daily maximum temperature at 21.3^{0}C and the mean daily minimum temperature at 7.3^{0}C. May and June are the hottest months (Ground Water Information Booklet, 2011). In May and June, the maximum temperature may sometimes reach 46^{0}C or 47^{0}C (Ground Water Information Booklet, 2011). Both sides of the Najafgarh drain are transformed into cultivable land with alternate fluvial deposits of silty sand, clay, and gravel.

Sampling at selected study area

The present investigation was done over a period of 1.5 years (January 2018 to July 2019). Random sampling was carried out fortnightly at all 14 sites near Dhansa Barrage and along the bank of Najafgarh Drain (Fig. 1; Table 1). Mostly the sampling was done at different sites of Najafgarh Drain from Dhansa barrage upstream to downstream (up to 7 kms). We made our observations up to 15 feet on either side of the bank, as the water swells up to that extent during heavy rains (Fig. 2).

Data Collection and Observations

Sampling sites of the study area were visited fortnightly in different seasons: summer (April-mid July), monsoon (July-September) and winter (November-March) to document the aquatic macrophytes. Detailed observations on the flora were made. On the basis of aquatic habitats, we have adopted the classification of Trivedi and Sharma (1965), with slight modification by adding the 'mesic' category to make up a total of eight categories. The categories are as follows: amphibious hydrophyte; emergent anchored hydrophyte; floating leaved anchored hydrophyte; floating shoot anchored hydrophyte; free floating hydrophyte; rootless submerged hydrophyte; submerged anchored hydrophyte; mesic plant.

Table 1. List of GPS Coordinates of study sampling site locations at Najafgarh Drain.

Sampling Sites	Coordinates	
	Latitude	Longitude
Site 1	N 28.53536	E 76.86972
Site 2	N28.53508	E 76.87027
Site 3	N28.53958	E76.87444
Site 4	N 28.53525	E 76.87039
Site 5	N 28.53546	E 76.87041
Site 6	N 28.53733	E 76.87305
Site 7	N 28.53541	E 76.86944
Site 8	N 28.53541	E 76.86944
Site 9	N 28.53567	E 76.86961
Site 10	N 28.53439	E 76.87006
Site 11	N 28.53443	E 76.86985
Site 12	N 28.53433	E 76.87079
Site 13	N 28.53522	E 76.87045
Site 14	N 28.53448	E 76.87082

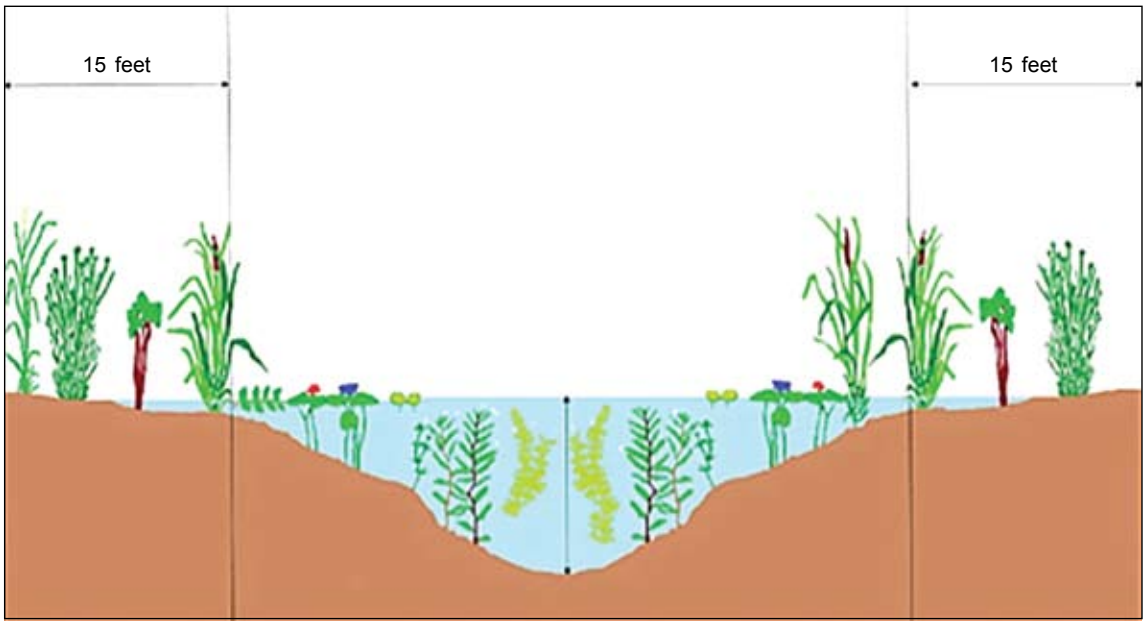


Figure 2. Diagrammatic representation of the vertical cross section of sampling site of Najafgarh Drain.

During the study, the plant species were collected and photographed in their vegetative and reproductive stages. Date of collection, GPS coordinates (using GARMIN GPSMAP 78s), habit, habitat, botanical name of the plant, family, and morphological characters were recorded in the field. The pH of water at each sampling site was recorded with the help of a EUTECH instruments Multi-Parameter PCSTestr^{TM} 35. Plants or twigs with flowers or fruits were collected for the preparation of herbarium specimens.

Preservation of specimens was done according to the conventional herbarium techniques for future references (Jain & Rao, 1977; Victor et al., 2004). The herbarium specimens are deposited in the Indraprastha University Herbarium (IPUH) housed in the University School of Environment Management, Guru Gobind Singh Indraprastha University, New Delhi, India. Bentham and Hooker's system of classification (Bentham & Hooker, 1862-1883) was used to classify species. Nomenclature update of specimens was based on the Angiosperm Phylogeny Group IV classification (2016). Closeup photographs were taken using a Leica MZ 12.5 stereomicroscope. Collected species were carefully screened, and identified by using relevant literature (Subramanyam, 1962; Maheshwari, 1963; Cook, 1996; Tabasum et al., 2009; Manral et al., 2013; Mukherjee & Sarma, 2014; Mishra et al., 2015; Vardhana, 2018) and online resources (Berberich, 1984 [GRIN]; Roskov et al., 2006 [IDLIS]; eFlora of India, 2007; The Plant List, 2013; GBIF Secretariat, 2019; Flowers of India, 2019; IPNI, 2020; Tropicos, 2020; POWO, 2021).

Data Analysis

Data were presented in the form of bar graphs and pie-charts using Microsoft Office Excel 2007. A map of SW Delhi was made by referencing GPS Coordinates through ArcGIS Map 10.3.1 (Fig. 1).

Results

A total number of 75 species of aquatic macrophytic taxa belonging to 72 genera and 34 families were recorded (APG IV System: Chase et al., 2016).

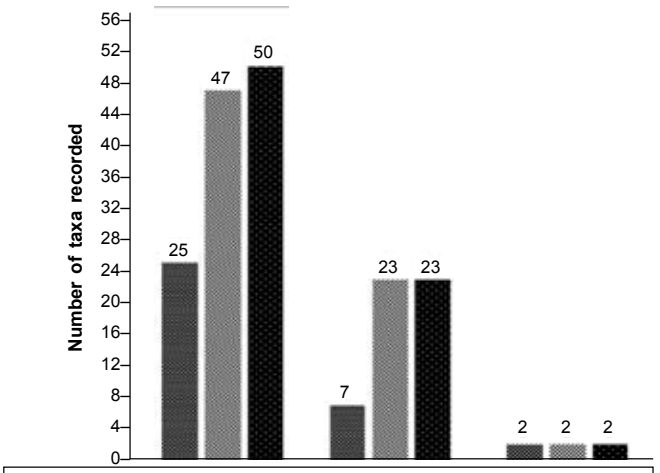
In the current investigation a total of 50 species in 47 genera and 25 families of eudicotyledons; 23 species of 23 genera and 7 families belonging to monocotyledons, and 2 species in 2 genera in 2 families of aquatic pteridophytes were recorded (Fig. 3).

The most common families were Poaceae with 13 species, followed by Asteraceae (7 species), Fabaceae (6 species) and Amaranthaceae (6 species), Convolvulaceae (4 species), three families (Apocynaceae, Polygonaceae, and Malvaceae) with 3 species each and four families (Chenopodiaceae, Euphorbiaceae, Hydrocharitaceae, and Cyperaceae) with two species each. There were 23 families each present with one species (Fig. 4, Table 2).

Out of 75 species recorded, emergent anchored species (36 species) were most frequently encountered at the study sites, followed by mesic (22 species), amphibious (6 species), floating shoots anchored (3 species), free-floating (3 species), floating leaved anchored (2 species), submerged anchored (2 species), and one suspended or rootless submerged species (Figs. 5, 6; Table 2). Considering different life forms, we found 37 species of herbs,14 species of grasses,10 species of trees, 6 species of shrubs, 5 species of climbers, 2 species of aquatic ferns and one species of sedge (Fig. 7, Table 2).

In the present study, the pH values were found to be alkaline, ranging from 7.3-7.9. The maximum number of species were recorded at a pH of 7.8 (Fig. 8). It was observed that, moving downstream from Dhansa Barrage along the Najafgarh Drain, the diversity of aquatic plants decreased.

In the present study, an attempt has been made to identify the occurrence of native and non-native species of the urban wetlands using Global Biodiversity Information Facility (2019) and Plants of the World Online (2021). We have recorded a total of 47 native species belonging to 46 genera in 25 families, and a total of 28 non-native species belonging to 26 genera in15 families (Fig. 9, Table 2).



	Dicots	Monocots	Pteridophytes
Families	25	7	2
Genera	47	23	2
Species	50	23	2

Figure 3. Floristic composition of observed aquatic macrophytes.

Table 2. List of aquatic macrophyte species recorded during the study at Najafgarh Drain.

Family	Species name	Life forms	Habitat	Nativity	GGSIPU Herbarium (IPUH) Collection No.
Pteridophytes					
Salvinaceae	*Azolla pinnata* R. Brown	Fern	FFH	Native	2307
Marsileaceae	*Marsilea quadrifolia* L.	Fern	FLAH	Native	2308
Angiosperms					
Ranunculaceae	*Ranunculus sceleratus* L.	Herb	EAH	Non-native	2317
Portulacaceae	*Portulaca pilosa* L.	Herb	M	Non-native	2374
Tamaricaceae	*Tamari xaphylla* (L.) H. Karst.	Tree	M	Non-native	2376
Malvaceae	*Abutilon indicum* (L.) Sweet	Shrub	AH	Non-native	2323
	Malvastrum coromandelianum (L.) Garcke	Herb	M	Non-native	2344
Zygophyllaceae	*Tribulus terrestris* L.	Herb	M	Non-native	2377
Meliaceae	*Azadirachta indica* A. Juss.	Tree	M	Native	2364
Rhamnaceae	*Ziziphus mauritiana* Lam.	Shrub	M	Native	2379
Fabaceae	*Vachellia nilotica* (L.) P.J.H.Hunter & Mabb	Tree	M	Non-native	2363
	Dalbergia sissoo Roxb. ex DC.	Tree	M	Native	2366
	Indigofera linnaei Ali	Herb	M	Native	2370
	Parkinsonia aculeata L.	Tree	M	Non-native	2337
	Prosopis juliflora (Sw.) DC.	Tree	M	Non-native	2345
	Tephrosia purpurea (L.) Pers.	Shrub	M	Native	2336
Myrtaceae	*Eucalyptus tereticornis* Sm.	Tree	M	Non-native	2367
Onagraceae	*Ludwigia adscendens* (L.) H. Hara	Herb	FSAH	Non-native	2340
Cucurbitaceae	*Cucumis maderaspatanus* L.	Climber	AH	Native	2373
Aizoaceae	*Trianthema portulacastrum* L.	Herb	EAH	Native	2362
Asteraceae	*Eclipta prostrata* (L.) L.	Herb	EAH	Non-native	2310
	Erigeron bonariensis L.	Herb	EAH	Non-native	2360
	Launaea procumbens (Roxb.) Ramayya & Rajagopal	Herb	AH	Native	2372
	Parthenium hysterophorus L.	Herb	EAH	Non-native	2349
	Tridax procumbens L.	Herb	EAH	Non-native	2361
	Cyanthillium cinereum (L.) H.Rob.	Herb	EAH	Non-native	2309
	Xanthium strumarium L.	Herb	EAH	Non-native	2319
Apocynaceae	*Calotropis procera* (Aiton) W.T.Aiton	Shrub	M	Non-native	2365
	Wattakaka volubilis (L.f) Stapf	Climber	M	Non-native	2331
	Pergularia daemia (Forssk.) Chiov.	Climber	M	Native	2332
Convolvulaceae	*Cressa cretica* L.	Herb	M	Native	2335
	Ipomoea aquatica Forssk.	Climber	FSAH	Native	2320
	Ipomoea carnea subsp. *fistulosa* (Mart. ex Choisy) D.F. Austin	Shrub	AH	Non-Native	2322
	Ipomoea pes-tigridis L.	Climber	AH	Native	2371
Plantaginaceae	*Veronica anagallis-aquatica* L.	Herb	EAH	Native	2318
Bignoniaceae	*Fernandoa adenophylla* (Wall. ex G. Don) Steenis	Tree	M	Native	2375
Verbenaceae	*Phyla nodiflora* (L.) Greene	Herb	EAH	Native	2341
Nyctaginaceae	*Boerhavia diffusa* L.	Herb	EAH	Native	2350

Family	Species name	Life forms	Habitat	Nativity	GGSIPU Herbarium (IPUH) Collection No.
Amaranthaceae	*Aerva lanata* (L.) Juss.	Herb	M	Native	2324
	Alternanthera paronychioides A.St.-Hil.	Herb	EAH	Non-native	2338
	Alternanthera philoxeroides (Mart.) Griseb	Herb	FSAH	Non-native	2301
	Gomphrena serrata L.	Herb	M	Non-native	2378
	Chenopodium album L.	Herb	EAH	Native	2311
	Suaeda fruticosa (L.) Forsk.ex J.F.Gmel	Shrub	EAH	Native	2334
Polygonaceae	*Persicaria barbata* (L.) H.Hara	Herb	EAH	Native	2316
	Polygonum plebeium R.Br.	Herb	EAH	Native	2339
	Rumex dentatus L.	Herb	EAH	Native	2315
Euphorbiaceae	*Croton bonplandianus* Baill.	Herb	EAH	Non-native	2326
	Euphorbia hirta L.	Herb	EAH	Non-native	2348
Ulmaceae	*Holoptelea integrifolia* (Roxb.) Planch.	Tree	M	Native	2369
Moraceae	*Ficus religiosa* L.	Tree	M	Native	2368
Ceratophyllaceae	*Ceratophyllum demersum* L.	Herb	RSH	Native	2302
Hydrocharitaceae	*Hydrilla verticillata* (L.f.) Royle	Herb	SAH	Native	2303
	Vallisneria spiralis L.	Herb	SAH	Native	2304
Pontederiaceae	*Pontederia crassipes* Mart.	Herb	FLAH	Non-native	2306
Commelinaceae	*Commelina forskaolii* Vahl.	Herb	EAH	Native	2359
Typhaceae	*Typha domingensis* Pers.	Shrub	EAH	Native	2325
Araceae	*Colocasia esculenta* (L.) Schott	Herb	EAH	Native	2342
	Lemna minor L.	Herb	FFH	Native	2305
	Spirodela polyrhiza (L.) Schleid.	Herb	FFH	Native	2347
Cyperaceae	*Cyperus rotundus* L.	Sedge	EAH	Native	2352
	Fimbristylis ovata (Burm.f.) J.Kern	Grass	EAH	Native	2312
Poaceae	*Urochloa mutica* (Forssk.) T.Q.Nguyen	Grass	EAH	Non-Native	2330
	Cenchrus ciliaris L.	Grass	EAH	Native	2353
	Cynodon dactylon (L.) Pers.	Grass	EAH	Native	2351
	Dactyloctenium aegyptium (L.) Willd.	Grass	EAH	Native	2356
	Desmostachya bipinnata (L.) Stapf	Grass	AH	Native	2346
	Dichanthium annulatum (Forssk.) Stapf	Grass	EAH	Native	2355
	Digitaria ciliaris (Retz.) Koeler	Grass	EAH	Native	2354
	Eleusine indica (L.) Gaertn.	Grass	EAH	Native	2357
	Eragrostis tenella (L.) P Beauv.ex Roem. & Schult.	Grass	EAH	Native	2358
	Paspalum distichum L.	Grass	EAH	Non-native	2321
	Phragmites karka (Retz.) Trin. ex Steud.	Grass	EAH	Native	2314
	Polypogon monspeliensis (L.) Desf.	Grass	EAH	Native	2327
	Saccharum spontaneum L.	Grass	EAH	Native	2313

[Abbreviations: Amphibious Hydrophyte= AH; Emergent Anchored Hydrophyte= EAH; Floating Leaved Anchored Hydrophyte=FLAH; Floating Shoot Anchored Hydrophyte=FSAH; Free Floating Hydrophyte=FFH; Rootless Submerged Hydrophyte=RSH; Submerged Anchored Hydrophyte=SAH; Mesic Plant=M. Species names updated according to Plants of the World Online (2021). The families and plant species are arranged according to APG IV system of flowering plant classification (2016)]

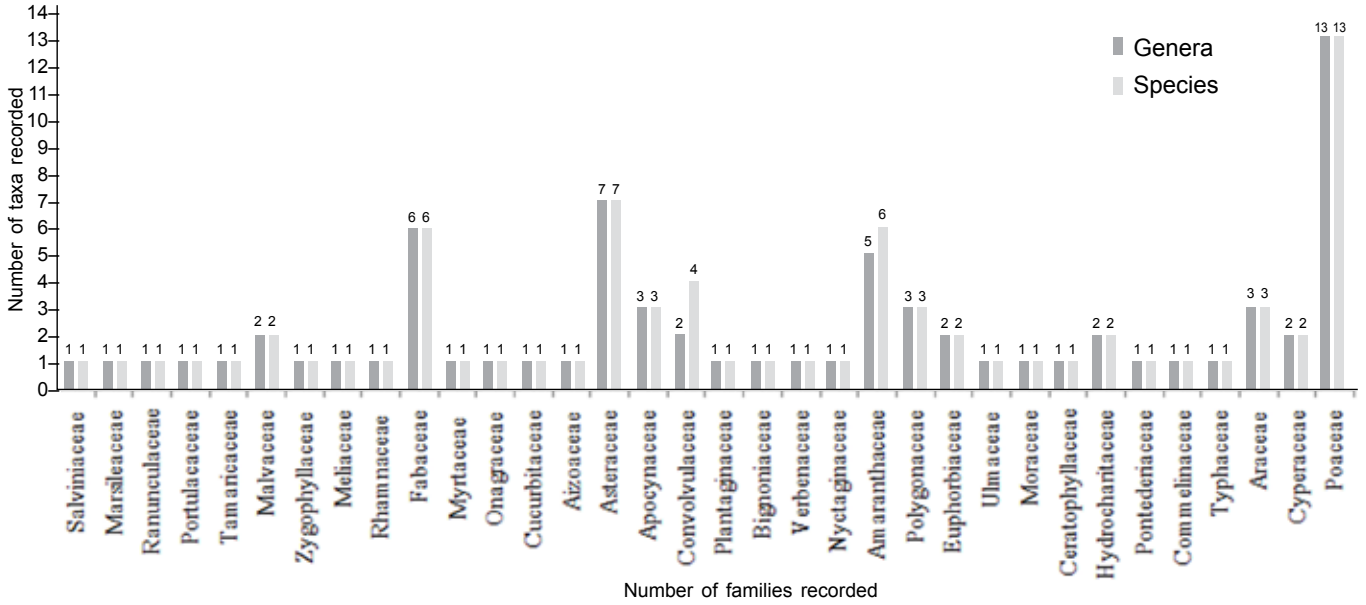


Figure 4. Enumeration of family-wise distribution of genera and species.

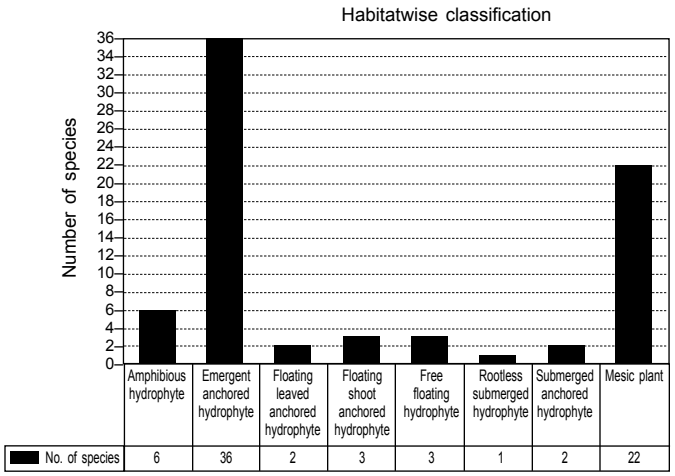


Figure 5. Habitat-wise number of aquatic macrophyte species.

Discussion

Najafgarh Lake is the largest aquatic ecosystem of South West Delhi. The present study was undertaken to provide a baseline data on floristic diversity of the Najafgarh Drain. The results demonstrated that the floristic diversity of Delhi city has changed tremendously over almost five decades since Maheshwari's Flora of Delhi was published. We have recorded 75 species belonging to 72 genera and 34 families over a year of study from a small stretch of Najafgarh Drain. Previously, Maheshwari (1963) recorded 189 species belonging to 135 genera in 55 families from different aquatic bodies across Delhi, which at that time was sparsely inhabited and undeveloped. For direct taxonomic comparison with previous study, which followed the system of Bentham and Hooker (1862-1883), in the present study the total tally of families by that system is 36. The families with most occurring species were Poaceae, Asteraceae, Fabaceae and Amaranthaceae. Of the morpho-ecologic groups we listed, most species recorded were emergent anchored and mesic forms. Two species of pteridophytes were recorded from the area. *Pontederia crassipes* and *Alternanthera philoxeroides* were found to be the most common species. The pH is a common and important water indicative factor that largely determines habitats and has a strong effect on the richness and diversity of aquatic plants (Song et al., 2018). The pH value was measured during a single visit at each site. However, more data are needed, taking pH measurements at different time intervals (for at least two years) at each site to gain an understanding of the relation with the occurrence of the plant species.

The study contributes to the understanding of the distribution patterns of non-native aquatic macrophytes in the Najafgarh Drain, that can be used as a baseline to develop useful tools for future conservation planning and management of the aquatic ecosystems (Rodríguez-Merino et al., 2017). Maheshwari (1963) in his study evaluated the 19.57% non-native and 80.43% native taxa. In our assessment of invasive species in the Najafgarh Lake it was found that, five decades later too, non-native species (37.33%) are less frequent than native species (62.66%), but the proportion of

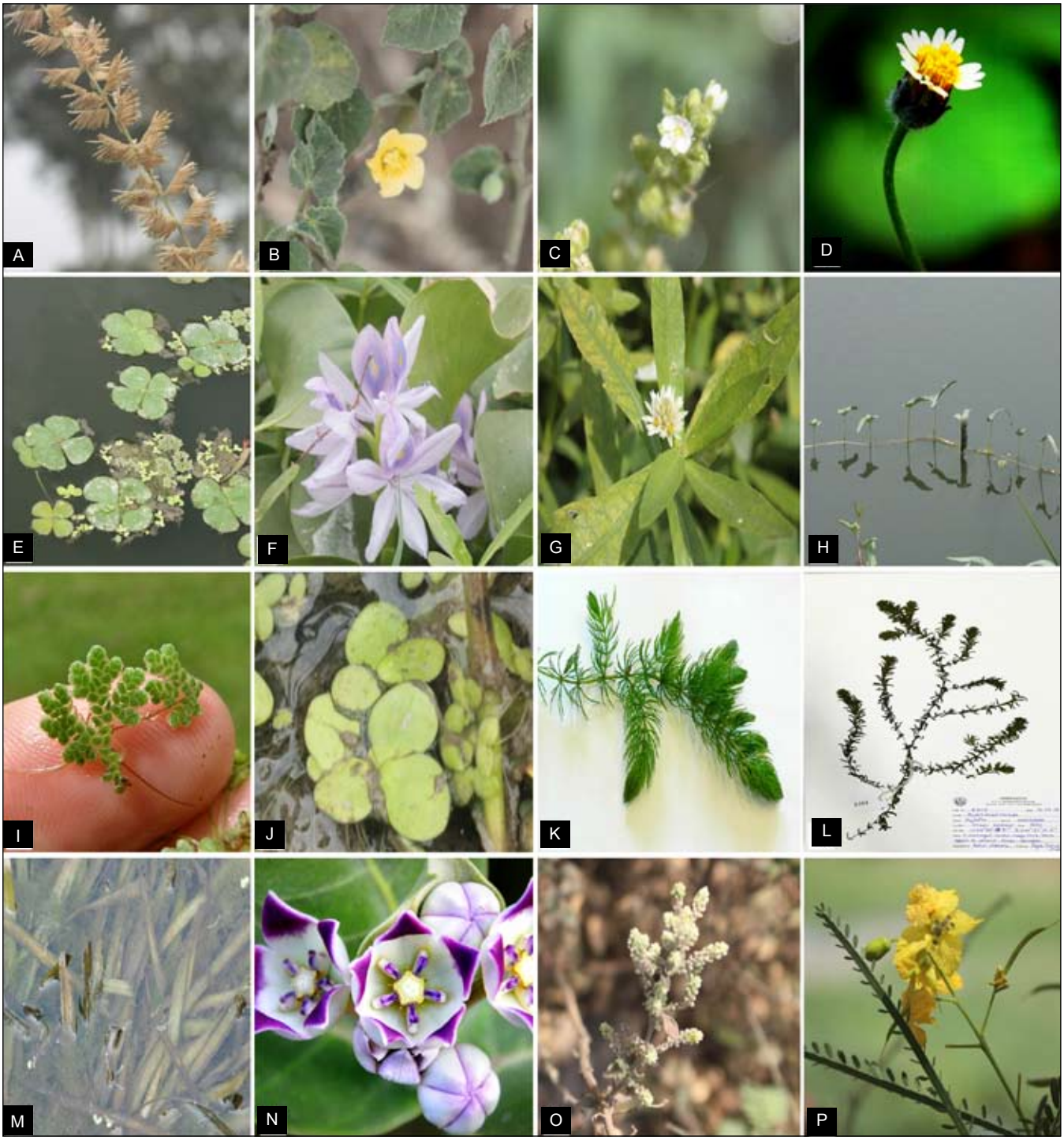


Figure 6. Aquatic macrophytes in different habitats at Najafgarh Drain.

(A, B) Amphibious hydrophytes *Desmostachya bipinnata* (L.) Stapf. [Poaceae], *Abutilon indicum* (L.) Sweet [Malvaceae]; (C-D) Emergent anchored hydrophytes *Veronica anagallis-aquatica* L. [Plantaginaceae], *Tridax procumbens* L. [Asteraceae]; (E-F) Floating leaved anchored hydrophytes *Marsilea quadrifolia* L. [Marsileaceae], *Pontederia crassipes* (Mart.) [Pontederiaceae]; (G-H) Floating shoot anchored hydrophytes *Alternanthera philoxeroides* (Mart.) Griseb [Amaranthaceae], *Ipomoea aquatica* Forssk. [Convolvulaceae]; (I-J) Free floating hydrophytes *Azolla pinnata* R. Brown [Salviniaceae], *Spirodela polyrhiza* (L.) Schleid. [Araceae]; (K) Rootless submerged hydrophyte *Ceratophyllum demersum* L. [Ceratophyllaceae]; (L-M) Submerged anchored hydrophytes *Hydrilla verticillata* (L.f.) Royle [Hydrocharitaceae], *Vallisneria spiralis* L. [Hydrocharitaceae]; (N-P) Mesic plants *Calotropis procera* (Aiton) W.T. Aiton [Apocynaceae], *Aerva lanata* (L.) Juss. [Amaranthaceae], *Parkinsonia aculeata* L. [Fabaceae].

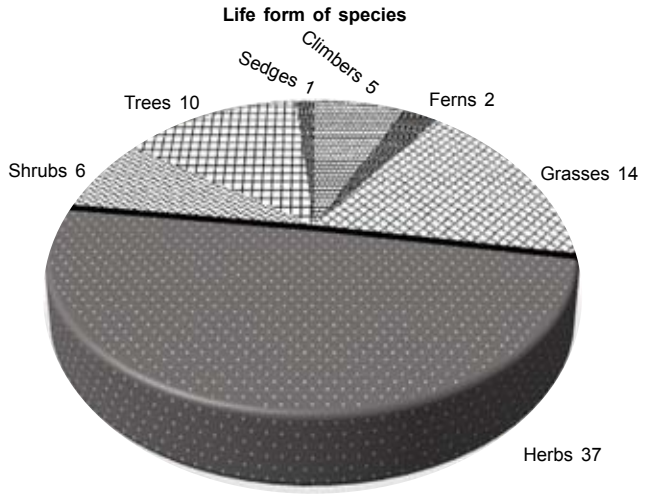


Figure 7. Composition of aquatic macrophytes in different life-form categories.

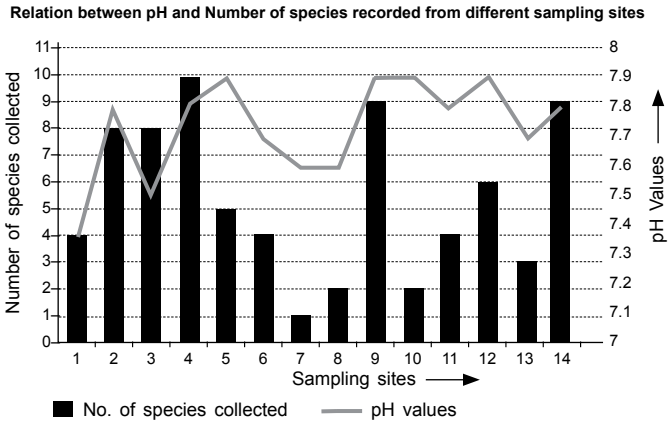


Figure 8. Relationship between pH and number of species at 14 different sampling sites.

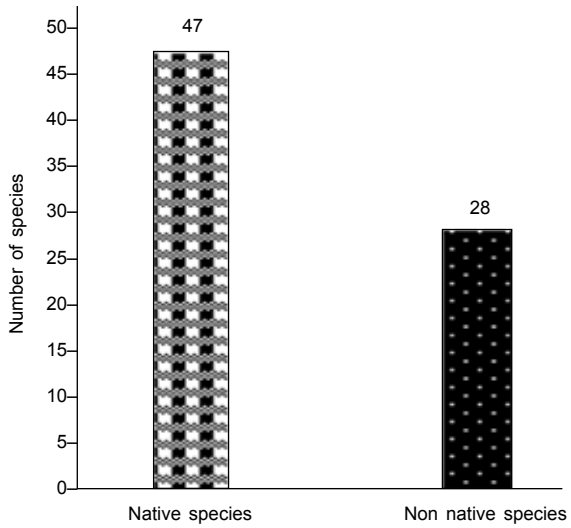


Figure 9. Graph showing the number of native/non-native macrophyte species recorded at Najafgarh Drain sampling sites.

invasive species has increased. However, a detailed investigation is required for the complete assessment and documentation of the floristic diversity in the entire stretch of 51 km of the Najafgarh drain in which 38 subdrains meet (Shekhar & Sarkar, 2013). This will help in understanding the anthropogenic impacts on the quantitative and qualitative floristic diversity of this very important wetland of Delhi.

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