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Okhla Bird Sanctuary: A Haven for Biodiversity Amidst Urban Chaos

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ABSTRACT:

Okhla Bird Sanctuary is the freshwater man-modified water body behind the barrage on the Yamuna River in Kalindikunj. As the river carries a high load of pollutants from the upstream area, the river pauses its speed due to the barrage, and the water gets time for its improvement by hydrological cycles in various seasons. This conserved land is surrounded by lush green vegetation around the water body, making it a migratory bird's preferred habitat, especially in winter. A floral and limnological survey of Okhla Bird Sanctuary was conducted on three sites (S1, S2, and S3) from April 2023 to December 2023. Randsurveysdratic sampling was conducted using a random survey of macroflora. The quadrate data are gathered and analyzed through computing for percentage of Frequency, Density and Abondance, Relative Frequency, Relative Density, Relative Abundance, and Important Value Index (IVI) for all the recorded plant species. Dominant aquatic plant species were found based on IVI values. Among the dominant macrophytes, *Eichhornia crassipes* showed the maximum IVI (56.06.) In two seasons (summer and monsoon) in open water in S -3 and *Alternanthera philoxeroides* in S-2 and in S-1 semi terrestrial area having highest dominancy *Typha angustifolia* with IVI value (52.75) followed by *Phragmites karka* (48.86). It was observed that the water of the Okhla Bird Sanctuary remains slightly alkaline throughout the season with the maximum ph. Recorded 7.49 of DO level was found within the permissible limit and all nutrients with fluctuating rates. All the parameters were analyzed using the IS method 2023. Detailed studies of physicochemical parameters show that Okhla Bird Sanctuary is moderately to highly polluted, resulting in low oxygen and the growth of invasive weeds replacing the native flora of the area.

Keywords: Hydrological Cycle, Macroflora, Migratory, Limnological, Invasive

1. Introduction

The Yamuna River is the second most sacred river in India after the Ganga. It has a rich history and culture surrounding it, originates from the Yamnotri Glacier at a height of 6,387 meters on the southwestern slopes of Banderpoach peaks in Uttarakhand. With a total length of 1,376 kilometers, it is the largest tributary of the Ganga River in northern India. The river occupies 10.7% of the catchment area in the country, with a drainage system of 366,223 square kilometers, which is almost 40.2% of the entire Ganga's Basin. Sadly, the river starts to get polluted from Tejawala (now Hathinikund barrage) in the upper segment. After that, the Yamuna River sluggishly menders from Haryana and reaches Delhi at Palla, traveling about 224km (Rout 2017). The water flowing downstream of Wazirabad is treated, partially treated, or untreated domestic and industrial wastewater contributed by various drains into the River Yamuna. After Wazirabad barrage, 22 km downstream, water is again blocked for irrigation purpose in Okhla barrage. Within the 22 km stretch from Wazirabad to Okhla, rivers get 70% polluted. Delhi discharges about 3,684 MLD (million liters per day) of sewage through its 18 drains into the river. This effectively converts the river into a "sewage drain. "Freshwater wetlands are constructed on rivers as dams and barrage primarily for irrigation and water supply for domestic purposes (Patel et al. 2020). With time, these man-made wetlands become the hub of biodiversity within the region or landscape, supporting unique floral and faunal communities. These wetlands are also called "ecotonal" habitats, covering aquatic, marsh, and terrestrial vegetations. They support plant species intermediate between true aquatic and terrestrial habitats. Freshwater wetlands alone support 20% of the known range of biodiversity in India. Wetlands are resilient ecosystems exhibiting the uniqueness of both aquatic and terrestrial systems by providing a high level of strength in physical and chemical conditions. Wetland areas are rich reservoirs of biodiversity and preserve unique genetic diversity in species (Sievers et al. 2018). Wetlands are known by different names, such as biofilters, kidneys of the landscape, or the biological supermarket, as they receive large amounts of organic, inorganic, and various pollutants through various dynamic processes and are rich in high species diversity. Wetlands include a variety of habitats such as marshes, swamps, riverbanks, river flood plains, lakes, ponds, and so on. The World Conservation Union (IUCN) has adopted a modified definition for defining the wetlands, which states that areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh brackish or salt, including areas of marine water, the depth of which at low tide does not exceed 6 meters (Bassi et al. 2014). Wetlands offer excellent habitats for migratory avian fauna and nurture a broad spectrum of micro and macrophytes. They not only support large biological diversity but also provide a wide range of ecosystem goods and services. Macrophytes exert a signal effect by participating in the construction of different patches on different scales and are well-matched as indicators of ecological integrity in wetlands (Zhang et al. 2020). Aquatic macrophytes have a wide range of environments, from freshwater to saltwater. Macrophytes are the major primary producers of shallow wetland ecosystems. They interact directly and indirectly with higher trophic levels by providing food and habitats. Wetland vegetation is known as important wetland regulators as they remove pollutants and excess mineral nutrients from the water (Kang et al. 2018). However, aquatic plants are still regarded as a menace and a nuisance because of the unawareness of their great potential and economic value. Aquatic plants are more productive than conventional terrestrial crops. It is important to conserve wetlands and their biodiversity to define its "critical environment capital." The wetland plant communities, especially those of marshes and swamps, are amongst the most productive plant communities in the world.

2. Material and method

2.1 Study Area

The Okhla Bird Sanctuary is an urban wetland located in the National Capital Region, at the border of Delhi and Uttar Pradesh. It spans an area of around 400 hectares, with open water covering around 273 hectares, reed and sand covering around 93 hectares, and roads and bunds comprising the remaining 30-hectare area of Yamuna River. The sanctuary was formed due to the construction of Okhla Barrage across the Yamuna River. It is marked between 28’32”43.5 N to 28’32”56.3” N latitudes and 77’1”41.7” E to 77’18”56.6’E Longitudes in the lower reach of upper Yamuna River sub-basin with an elevation about 185 m above mean sea-level. The sanctuary covers a variety of habitats including water bodies in the lower region near the barrage area, marshes, grasses on the upper region, and is surrounded by trees, shrubs, and herbs. The thick vegetation of macrophytes and diverse habitats attract many migratory birds throughout. The fertile floodplain and green cover of the Yamuna River ecosystem have recommended this sanctuary as one of the potential Ramsar Sites (Urfi, 2003). The Okhla Bird Sanctuary has been declared as a protected area as a bird sanctuary under the sanction 18 Wildlife Protection Act 1972 by the Government of Uttar Pradesh notification 577/14-4-82/89 dated in 1990. The Okhla Bird Sanctuary (OBS) is recognized as one of the important Bird Areas and Asian Water bird Census (AWC) in India. The major source of surface water that enters the study area is from the Yamuna River and Hindan River. The water quality is severely degraded because of the number of municipal and industrial wastewater drains discharged into the river. The water level in the sanctuary is maintained by the Okhla Barrage, which is controlled by the irrigation department of Uttar Pradesh. Survey and analysis of the Okhla Bird Sanctuary was made at regular in fifteen days for the one year from April 2023 to December 2023 at three different study sites (S1, S2, S3) in different seasons summer (April to June), monsoon (July to September) and winter (October to December). Macroflora (floating macrophytes and semi terrestrial vegetation) and water samples were collected in mid of every month in field visit. For sampling macrophytes and analysis of physicochemical characters of the water samples various techniques were used. Regular survey and sampling were done in open water and semi terrestrial vegetation of the Okhla Bird Sanctuary.

2.2 Macrophyte Analysis

Various resources were used to identify macrophytes, including the Flora of British India (Vol.1-7) by Hooker (1875), the Manual of Aquatic Plants by Fasset (1940), Water plants of the world by Cook (1974) and Weedy aquatic plants: their utility, menace and management by Gupta (2001). Any species that were difficult to identify were taken to the Botanical Garden of Indian Republic for proper identification with the help of expert staff. To analyze the level of macrophyte diversity, various parameters such as frequency, relative frequency, density, and relative density were calculated. The proportion of the quadrat area covered by aquatic plants was estimated using visual sampling and rake dragging. A floating quadrat of 1*1m was used to count the number of the macrophytes, while a 5*5m quadrat was used to count emergent macrophytes (Karus et al. 2022). The Important Value Index (IVI) of the macrophytic species of each site was also used to evaluate macrophytic diversity (Chaher et al., 2023). Calculations were done by using the formulae as shown below.

$$\textbf{Relative Frequency} = \frac{\text{Total no. Of Occurrence of species}}{\text{Sum total of Total No. Of Occurrence of species}} \times 100 \;\ldots\ldots (1)$$

$$\textbf{Relative Density} = \frac{\text{Total no. Of individuals of each species}}{\text{Sum total of Total No. Of individuals of each species}} \times 100 \;\ldots. (2)$$

$$\textbf{Relative Abundance} = \frac{\text{Total no. Of individuals of a species in quadrates}}{\text{Sum total of Total No. Of individuals of each species}} \times 100 \quad \ldots (3)$$

Important Value Index (IVI) = Relative density+ Relative Abundance+ Relative Frequency... (4)

3. Results

Water analysis was done from April to December month with 29 parameters including heavy metals in alternative months. Minimum and maximum temperature in Pre monsoon and post monsoon analysis in distinct sites suggested that maximum and minimum temperature was recorded in May /June month 2023 in site -2 (31.67^{o}c), S-1 site-1 29^{o}c April month .Post monsoon maximum and minimum temperature was recorded in October 29^{o}c in S-2/S-3 sites and in December months in site -2 19^{o}c. Ph of the sanctuary remained optimum to slightly alkaline throughout the year .Pre monsoon maximum and minimum pH was recorded was 7.3 in S-3 and 7 in S-2 sites respectively. Post monsoon results shows variation between 7.4 in S-3 and 7.34 in S-1 site. Total dissolved solids ranges between 459.33mg/l to 400 mg/l in S-1 and S-2 sites in pre monsoon and 670 mg/l and 599.67 mg/l in S-2 and S-1 sites in month of November and December. Total Hardness in pre monsoon was recorded in S-1site 178.07 mg/l and 155.53 mg/l in S-2 site .Post mon soon results shows maxim value in S-1 site and minimum in S-2 site 329.33 mg/l and 250.33 mg/l respectively. Electric conductance was recorded 752.67 mg/l and 517 mg/l in S-1 and S-2 sites in pre monsoon observations. In post monsoon observations highest range was recorded in S-1 site 1060.67 mg/l in November month and 1032 mg/l in S-2 site in December month. Maximum value of dissolved oxygen was recorded 9.37 mg/l in S-3 site and minimum value 5.2 mg/l in S-1 site in month of May. In month of November maximum and minimum values were recorded 7.2 mg/l and 6.77 mg/l in S-1 and S-3 sites respectively. Biological oxygen demand in pre monsoons was recorded in 12.67 mg/l in S-1 site and 9 mg/l in S-3 site .In post monsoon maximum value was found in 12 mg/l S-2 site and minimum value was found in 10.67 mg/l in S-1 site .Maximum and minimum values of Chemical oxygen demand recorded in different sites were212.33 mg/l and 55.67 mg/l. Post monsoon results shows maximum value 54.67 mg/l and 38.33 mg/l in S-2 and S-1 sites respectively. Pre monsoon value for nitrogen was observed in month of May and June in site S-1 and S-3 16.23 mg/l and 14.17 mg/l respectively. Post monsoon results shows maximum value in October 13.67 mg/l in S-2 and S-3 sites and minimum value was recorded in 13.07 mg/l S-1 site in

December month. Maximum values of phosphorus, potassium, sodium and sulphate were recorded in S-2, S-3, S-1, S-1, during pre-monsoon observations. Post monsoon values for the same nutrients were recorded in S-3, S-2, and S-2 S-1 respectively. Heavy metals analysis was done in alternate month and found below the detectable limits.

Pre-monsoon research (April to June) identified 28 species of aquatic macrophytes from 26genera and 19 families. Out of 19 families, 6 are floating macrophytes, 16 are emergent macrophytes, and 8 are semiaquatic or terrestrial species documented at three distinct locations (S1-S3). The S-1 site is dominated by emergent vegetation, with *Typha, Phragmites, and Saccharum* species having IVI values of 52.75, 48.86, and 27.62, respectively. S-2 and S-3 sites were completely aquatic, with only floating species documented on the waterbody's shore. In pre-monsoon observations, both sites with floating macrophytes, site -3, have a high abundance of *Eichhornia and Alternanthera,* with IVI values of 90.44 and 83.81, respectively. Site -2 had the highest concentrations of *Lemna, Brachiaria*, and *Alternanthera,* with IVI values of 156.17, 64.57, and 58.6, respectively. Post-monsoon data (October to December) from S-2 locations reveal a diverse range of floating and emergent macroflora. The highest IVI values were observed for *Lemna* (64.69) and *Pistia* (48.1). *Azolla* species was also found in this location, with an IVI score of 13.76. S-3 has a mix of floating and emergent macrophytes, with maximum IVI values for *Lemna* and *Pistia* of 130.81 and 118.86, respectively. *Eichhornia* species is observed in this site with 33.19 IVI value. Post-monsoon data (October to December) found 29 species of aquatic macrophytes from 27genera and 20 families. Five of the twenty families are floating macrophytes, sixteen are emergent macrophytes, and eight are semiaquatic or terrestrial species that have been described in three different places (S1-S3). The diversity of sites -2 and -3 reveals no change in floating and emergent macroflora attributable to physicochemical differences. During winter, data collecting site -2 was dominated by *Lemna* and *Pistia* species, with IVI values of 64.69 and 48.1, respectively. *Azolla* species was also seen for the first time at S-2 location, with an IVI score of 13.76. In site -3, the species *Lemna, Pistia*, and *Ecichornia* were recorded with IVI values of 130.81, 118.86, and 33.19.

4. Discussion

Physico-chemical parameters are considered one of the most critical factors influencing aquatic biodiversity in different seasons and sites. The pH of an aquatic system indicates an acid-base balance due to dissolved chemicals. It is determined by the amount of calcium magnesium carbonates and the carbon dioxide tension in the water, both regulated by photosynthetic and respiratory processes. Fluctuations in pH are connected to chemical changes, species composition, and the abundance of life activities in the water body's animal and plant communities. pH in natural water ranges from 6.5 to 8.5. The pH range of the water body is within the limit, with minor seasonal variations. The pre-monsoon maximum and lowest pH values were 7.3 in S-3 and 7 in S-2, respectively. Post-monsoon data reveal a variance between 7.4 in S-3 and 7.34 in S-1. Seasonal fluctuations might be attributed to the velarization of free CO_2 during active photosynthesis when more significant phytoplankton and macrophyte populations were opposed. Macrophytes are robust markers of eutrophication. *Lemna minor, Typha angustifolia*, and *Phragmites karka* all exhibit eutrophication produced by organic effluents and nutrients (Sayanthan et al. 2024).

The high population growth of Lemna Minor and Pistia was investigated as a measure of eutrophication produced by household detergents (Sigcau et al. 2022). It has been discovered that noxious invasive weeds are essential issues in tropical and sub-tropical wetlands. These invasive plants spread in the water body's open water and semiaquatic zones. Site 1, mainly a semi-aquatic section of the Sanctuary, is infected with emergent macrophytes such as *Typha* and *Phragmites* species. The open water region at the exact location was covered with *Echhornia crassips, Lemna,* and *Pistia*. Temperature is a regulating element in aquatic ecosystems, affecting the growth and distribution of flora and animals (Jalal and Sanalkumar 2012; Tank and Chippa 2013). Pre-monsoon and post-monsoon temperature studies at several sites revealed that the highest and lowest temperatures were recorded in May/June 2023 at site -2 (31.67^{o}C) and at the S-1 site in April at 29^{o}C. The post-monsoon maximum and minimum temperatures were 29 in October at S-2/S-3 sites and 19 in December at site -2. The optimal temperature range for the growth of aquatic organisms (macrophytes) is 22℃ to 31℃, which matches to the temperature range recorded in the research region. TDS Total dissolved solids include bicarbonate, sulfate, phosphate, nitrate, calcium, magnesium, sodium, and organic ions. In the current study, total dissolved solids ranged from 459.33 mg/l to 400 mg/l in S-1 and S-2 sites before the monsoon and from 670 mg/l to 599.67 mg/l in S-2 and S-1 sites throughout November and December. TDS is primarily impacted by urbanization, fertilization runoff (agriculture), and home effluents. The present findings were consistent with previous publications(Bala and Mukherjee 2010).

Turbidity measures water clarity or the ability of light to pass. It is an optical characteristic of water and expresses the amount of light scattered by material in the water when a light shined through the water sample. High turbidity causes an increase in water temperatures. This is because suspended particles absorb more heat and reduce the light penetration into the water. Furthermore, it affects the submerged plants (Ukpaka and Edwin, 2013). Usually, less than 10 NTU reflects the goodness of water. The DO level shows the pollution level in water bodies (Murhekar, 2011). It also has a vital function in influencing the corrosiveness of water and oxidation of inorganic substances (Zhao et al., 2022). Oxygen enters the water through aerial diffusion and is a photosynthetic by-product of aquatic plants (Nikesh and Acharya 2014). The temperature, salinity, and pressure of the water determine the DO.

The highest dissolved oxygen content in S-3 occurred in May (10.5 mg/L). This was attributable to the abundance of macrophytes, strong photosynthetic activity, and percentage cover. The DO value in November was lower (5.9mg/L site-3) due to macrophytes' quick mortality and degradation. All of these variances are related to industrial effluents and home sewers. Biological oxygen demand is simply the amount of oxygen microbes use to stabilize organic materials. BOD indicates the intensity of sewage effluents and other contaminated waters. It also offers data on pollution in all-natural waterways. The biological oxygen requirement in the pre-monsoon period was 15 mg/l at the S-1 site and five mg/l at the S-3 site. In the post-monsoon period, the highest value was 18 mg/l at the S-2 site, while the lowest was four mg/l at the S-1 site. The increased value for BOD might be attributed to agricultural and industrial waste in the water body. Chemical oxygen demand is the amount of oxygen consumed during the oxidation of oxidizable organic matter to CO2 and water using a strong oxidizing agent such as $K_2Cr_20_7$. Higher COD levels indicate a larger amount of oxidizable organic material in a sample, which reduces DO levels. A drop in Do can cause anaerobic conditions that harm aquatic biodiversity. The greatest value reported before the monsoon was 212.33 mg/L due to the rapid oxidation rate of organic contaminants in significant amounts. Low metabolic oxidation of organic pollutants and dilution resulted in a minimum COD value of 38mg/L during the post-monsoon season. Total hardness is generally measured as the concentration of calcium and magnesium. The maximum hardness recorded was 178 mg/L at site -1 due to industrial and domestic effluents poured into the river and the release of calcium and magnesium ions during the metabolic oxidation of organic compounds by microorganisms. High hardness values are also supported by high sulfate calcium and magnesium content in the study sites due to sewage inflow in the water body.The higher the ion, the higher the conductivity of water. Conductivity indicates the quantity of dissolved ions in water. These ions are derived from dissolved salts and inorganic minerals, including sodium, potassium, magnesium, chlorides, sulfates, bicarbonates, and nitrate compounds. The highest conductivity was reported in November at location -1.

Phosphorus levels varied throughout the year. Due to household waste, the maximum value (1.99mg/L) was seen at site 2 in May. In contrast, the lowest value (0.22mg/L) was recorded at site-1 throughout the season due to the emergence and spread of macrophytes that absorb phosphorus for growth. Magnesium levels at all locations vary significantly between seasons. The highest magnesium concentration was measured in June (29.6 mg/Lat site 2) due to sewage, industrial effluents, low water volume, and a high oxidation rate. Magnesium content was low due to the commencement of macrophyte development and decreased microbial oxidation. Magnesium is mostly found as Mg2+ in surface water solutions. It is the core atom of the chlorophyll molecule; hence, its presence is necessary for plant photosynthesis. A dead and dying plant can degrade, releasing ammonia. Ammonia converts to nitrite. Ammonia is a colorless, smelly, gaseous chemical containing hydrogen and nitrogen soluble in water. It has also made its way into ground and surface waterways by the discharge of industrial process wastes, including ammonia and fertilizers. The highest ammonia level was reported in December (6.4 mg/L site-1), and the lowest was in April (2.8 mg/L site-3). Surface water can contain up to 12 mg/L (WHO, 1986).Nitrate is the oxidized form of nitrogen that results from the aerobic breakdown of organic nitrogenous materials. The presence of nitrate in freshwater bodies is primarily determined by the activity of nitrifying bacteria from both home and agricultural sources. The current investigation's nitrate value ranges from 1.2 mg/L to 7.2mg/L. These seasonal fluctuations are frequently related to the movement of nitrogen-rich fertilizers, soil, and local sources into water. Natural nitrate levels are typically less than 1mg/L; more than 10 mg/L concentrations will impact the freshwater aquatic ecosystem (EPA).High nitrate values always signify eutrophication, which usually results in the depletion of dissolved oxygen in the water body (Gijo and Alagoa, 2022).Plants use nitrite to form proteins and nucleotides. Any rotting plant material can create hazardous nitrogen compounds such as nitrite and ammonia.1mg/L of nitrite-nitrogen is sufficient for a regulated public water system (EPA). Anthropogenic sodium sources that can contribute significantly to sodium surface water include road salt, water treatment chemicals, residential water softeners, and sewage effluents. Sodium was found to be at its highest and lowest levels in December at site-2 (135.6mg/L) and 32mg/L in May at site-2 during the research period. Calcium is crucial for aquatic creatures' development and metabolism. High calcium levels in the water are thought to have no adverse effect on human health.

During the research period, the highest calcium readings were observed at site -1 (84.8mg/L) in November, while the lowest was 29.7mg/L at site -2 in May. These seasonal fluctuations result in a progressive rise in calcium concentrations across different locales. Potassium is one of the macronutrients that exist in cationic form. Between the current studies, potassium levels ranged from 8 mg/L to 27 mg/L between May and December. Sulphate is the most prevalent anion in hard water. They form spontaneously due to the disintegration of leaves that fall into fresh water. The maximum and minimum sulfate levels reported during the research period were 59mg/L (April month site-3) and 17.8mg/L (November month site-1). Runoff from fertilized agricultural lands also adds sulfate to aquatic bodies. Dry deposition and acid rain accelerate the accumulation of sulfate in fresh water. When sulfate levels are less than 0.5 mg/l, algal growth does not occur. Sulphate stimulates the release of nutrients from sediments (internal eutrophication).

Sulphate also improves organic soil biodegradability (Orem, W.H.) Macrophytes are valuable bioindicators of eutrophication, such as *Eichhornia crassips, Alternanthera sessile*, and *A. phyloxeroids*. *Lemna minor, Pistia Commulina*, and *Typha angustifolia* all exhibit eutrophication produced by organic effluents and nutrients. The rapid development of *Lemna minor* and *Pista* was investigated as an indicator of eutrophication produced by household detergents.Site-1 is the Sanctuary's semiaquatic region, which is dominated by *Typha angustifolia* and *Phragmites karka, Cyperus* spp. The open water section of this site is continually eutrophicated by *Eichhornia crassips*, pasta, and *Lemna* species, and emergent macrophytes are responsible for diminishing the depth of the sanctuary owing to siltation and sedimentation Shah and Reshi (2012). *Alternanthera sessile* and *Alternanthera philoxeroids* were the most commonly found species in Site -1 and Site2 of the sanctuary. It was noticed that various invasive weeds, such as *Eichhornia crassips*, *Lemna minor*, and *Alternanthera*, flourished with the arrival of summer. It is related to increased nutrient burdens in the body of water.

5. Conclusion:

This investigation into the sanctuary's aquatic macrophytes reveals a dynamic and diverse community of 30 species, encompassing 28 genera and 20 families. The spatial distribution and seasonal abundance exhibit noteworthy variation. Site S-1: Dominated by emergent vegetation primarily comprising *Typha, Phragmites, and Saccharum* species. Sites S-2 and S-3: Primarily host floating macrophytes, with pronounced seasonal shifts. Pre-monsoon observations highlight *Eichhornia* and *Alternanthera*, while post-monsoon communities see *Lemna* and *Pistia* thrive. Physicochemical parameters like water temperature, ph, total dissolved solids, hardness, and conductivity remained within acceptable ranges throughout the year. Minimum value of dissolved oxygen was recorded in Site -3 (5.2mg/l) in summer season and Site -1 (6.7mg/l) in winter season. Lower values of DO might be due to its utilization during decomposition of organic matter, low photosynthetic rate, Respiration by micro and macro-organisms. While biological oxygen demand, chemical oxygen demand, and nitrogen levels fell within expected ranges, slight seasonal and spatial variations were observed. Interestingly, no significant correlations were found between these water quality parameters and the observed patterns of macrophyte diversity.

These findings paint a picture of a healthy aquatic ecosystem within the sanctuary, evidenced by its diverse and dynamic macrophyte community. However, the seasonal shifts in dominant species highlight the importance of long-term monitoring to fully understand community dynamics. While the prevailing water quality appears suitable, further investigation into potential drivers like nutrient availability and competition could provide valuable insights. Therefore, continued monitoring of both macrophytes and water quality remains crucial for effective conservation management. Implementing long-term monitoring programs will enable the tracking of changes in these communities and water quality parameters. Additionally, investigating the factors influencing seasonal shifts in dominant species, such as nutrient fluctuations and herbivory, would be beneficial. Assessing the potential impact of invasive species like Eichhornia on the ecosystem's balance is also essential. Ultimately, developing and implementing conservation strategies aimed at maintaining optimal water quality and habitat conditions for diverse macrophyte communities will be key to ensuring the long-term health and sustainability of the Okhla Bird Sanctuary ecosystem.

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Table: 1 List of Floating and Emergent macrophytes species of plants in Okhla Bird Sanctuary in Site -1

S. No.	Name of the plant species	Habitat	Family	Total no of individuals(3)	Total quadrates	IVI
1	*Eicchhornia crassipes*	Floating	Pontederiaceae	270	15	9.03
2	*Alternanthera philoxeroides*	Floating	Amarantheceae	363	15	9.63
3	*Pistia*	Floating	Araceae	30	15	4.14
4	*Lemna minor*	Floating	Araceae	1810	15	19.01
5	*Ipomea aquatica*	Emergent	Convolvulaceae	7	15	2.03
6	*Alternanthera sessilis*	Emergent	Amarantheceae	327	15	6.98
7	*Cyperus kyllingia*	Emergent	Cyperaceae	2790	15	25.35
8	*Cyperus eragrostis*	Emergent	Cyperaceae	105	15	3.27
9	*Cyperus rotundus*	Emergent	Cyperaceae	190	15	4.51
10	*Commelina bangalensis*	Emergent	Commelinaceae	140	15	4.29
11	*Polygonum hydropyper*	Emergent	Polygonaceae	690	15	9.71
12	*Marsilea quadrifolia*	Emergent	Marsileaceae	99	15	6.06
13	*Phyla nodiflora*	Emergent	Verbenaceae	157	15	5.21
14	*Paspalum distichum*	Emergent	Poaceae	235	15	5.52
15	*Ludwigia elegans*	Emergent	Onagraceae	5	15	1.08
16	*Sacchrum spontaneum*	Emergent	Poaceae	2300	15	27.63
17	*Typha angustifolia*	Emergent	Typhiacea	6920	15	52.75
19	*Phragmites karka*	Emergent	Poaceae	4670	15	48.86
20	*Oxalis corniculata*	Emergent	Oxalidaceae	58	15	3.06
21	*Dysphania ambrosiodes*	Terrestrial	Amarantheceae	23	15	3.14
22	*Urena lobota*	Terrestrial	Malvaceae	3	15	1.03
23	*Sida acuta*	Terrestrial	Malvaceae	7	15	1.56

24	*Solenum nigrum*	Terrestrial	Solanaceae	7	15	2.03
25	*Parthenium hystrophorus*	Terrestrial	Asteraceae	46	15	5.2
26	*Coix lacryma*	Terrestrial	Poaceae	2	15	0.56
27	*Lantana*	Terrestrial	Verbenaceae	4	15	1.99
Total				21258		

Table: 2 List of Floating and Emergent macrophytes species of plants in Okhla Bird Sanctuary in Site -2

S. No.	**Name of the plant species**	**Habitat**	**Total no of individuals(3)**	**Total quadrates**	**IVI**
1	*Eicchhornia crassipes*	Floating	103	15	52.33
2	*Alternanthera philoxeroides*	Floating	158	15	64.57
3	*Pistia*	Floating	32	15	26.94
4	*Lemna minor*	Floating	535	15	156.17
5	*Brachiaria ramosa*	Emergant	38	15	58.6
Total			828	15	

Table: 3 List of Floating and Emergent macrophytes species of plants in Okhla Bird Sanctuary in Site -3

S. No.	**Name of the plant species**	**Habitat**	**Total no of individuals(3)**	**Total quadrates**	**IVI**
1	*Eicchhornia crassipes*	Floating	109	15	90.44
2	*Alternanthera philoxeroides*	Floating	99	15	83.81
3	*Pistia*	Floating	17	15	25.75
4	*Lemna minor*	Floating	30	15	38.48
5	*Brachiaria ramosa*	Emergent	34	15	61.53
Total			255		

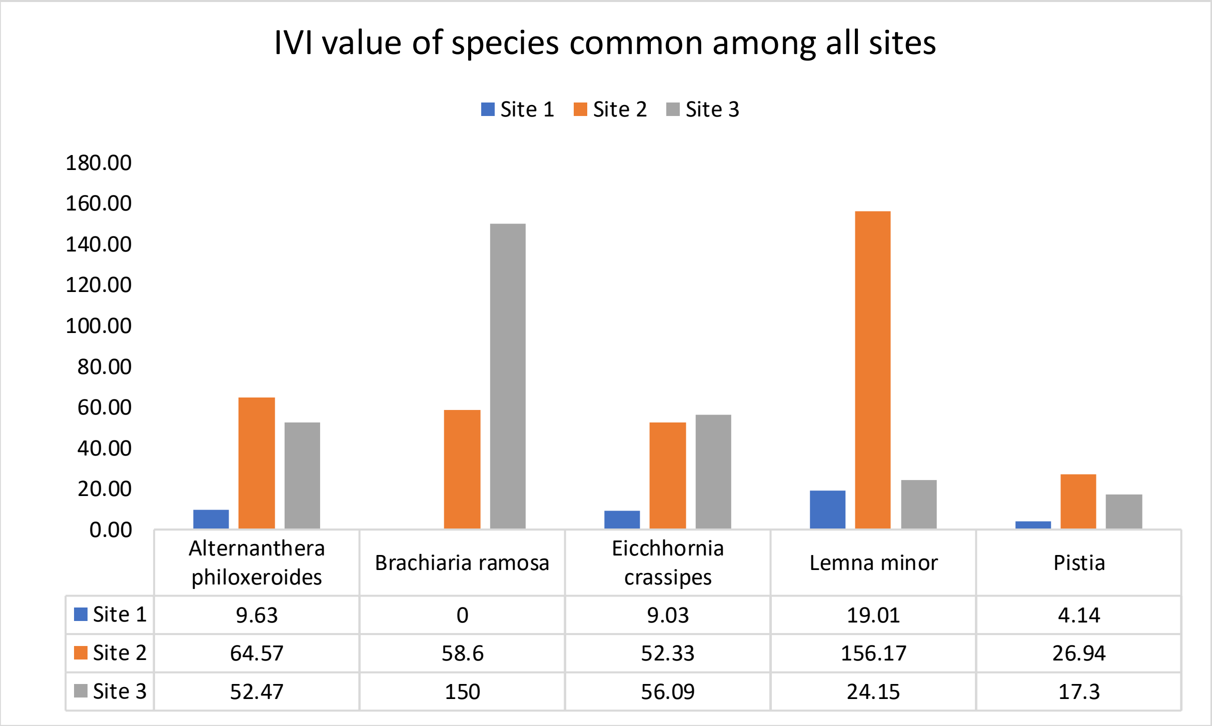

Fig. 1. Importance value index (IVI) of the most common species within the Study area

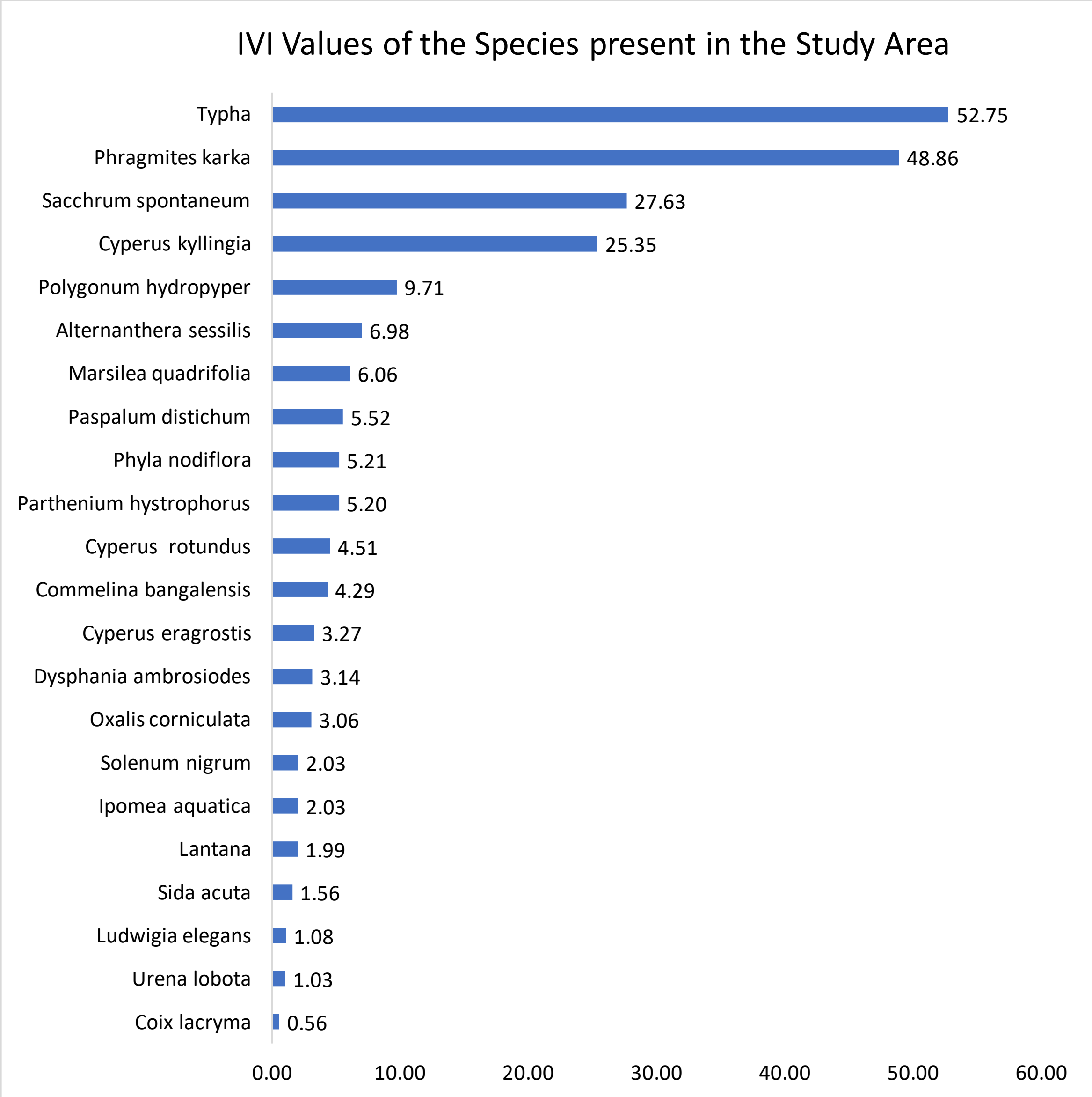

Fig. 2. Importance value index (IVI) of the most important (i.e., dominant) species within the Study area.