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Research Article

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Quantitative Assessment of Macrophytes Diversity and their Status in Wetlands of Guru Ghasidas Vishwavidyalaya, Bilaspur, Chhattisgarh (India)

Abhishek Maitry, Shishir Chandrakar, Animesh Shukla* and Aishwarya Chandra
Department of Forestry, Wildlife & Environmental Sciences, Guru Ghasidas Vishwavidyalaya, Bilaspur, Chhattisgarh- 495009, India
**Corresponding author e-mail: animeshshukla.forestry@gmail.com*
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ABSTRACT
The most significant and taxonomically varied biotic element in every aquatic environment is aquatic macrophytes. They play a vital role in maintaining the ecosystem's structure and functionality. Additionally serving as bioindicators of the general health of a water body are macrophyte kinds, variety, density, and depth. In present study, the quantitative diversity of aquatic macrophytes was assessed from different wetlands of Guru Ghasidas Vishwavidyalaya which is a central university and holds four important water bodies in Bilaspur district of Chhattisgarh state, India. A total of 33 aquatic macrophytes species were identified belonging to 21 families from wetlands of Guru Ghasidas Vishwavidyalaya. These macrophytes were grouped as floating, submerged and emergent mainly dominated by emergent macrophyte species followed by floating and submerged i.e., 23, 8 and 2 species respectively. The highest species diversity was observed in Pond 1 and 4 with 26 species each and highest species richness was observed in Pond 4 with 158 individual counts, the highest IVI was achieved by emergent *Ipomoea carnea* (16.492) and the highest occurring family was found to be Cyperaceae (12.12% of total species). Other diversity indices were calculated as 3.451, 0.042, 33 and 0.946 for Shannon-Wiener Index (H’), Simpson's Index (D), Species Richness (R), and Evenness (E) respectively. However, for the conservation and sustainable utilization of aquatic ecosystems, it is necessary to understand the status and importance of macrophytes to the ecosystem and its functioning.
Keywords: macrophytes, wetland, diversity, aquatic plant, quantitative assessment, flora.

INTRODUCTION
Wetland ecosystems are among the preeminent and fecund biomes on the Earth. The ecosystem of wetlands is vital to both humans and the natural world (Maitry *et. al.,* 2023). They are diversified and species-rich ecosphere. Wetland habitats are fundamentally based on the variance of macrophytes and associated vegetation. As essential components of the wetland ecosystem, macrophytes are macroscopic hydrophytes that provide complementing biotic elements (Reshi *et. al.,* 2021). They are referred to as aquatic plant that is submerged, floating, or emerging in the water body. Macrophytes are essential to the ecosystem's structural and functional upkeep. They play a significant part in sustaining ecosystems through phytoremediation, biogeochemical cycle, biomineralization etc. (Ayoade *et. al.,* 2022, Sharma *et. al.,* 2022). In addition to these, macrophytes play a decisive role in assessing the depth, assortment, nutritive level, and degree of pollution in wetlands (Chaudhary *et. al.,* 2021). The macrophytes are acknowledged as a bioindicator because of their significant ecological value (Mukherjee et. al., 2003) and capacity to evaluate the general state of health of water bodies (Maitry *et. al.,* 2023). The existence and variation of macrophytes rely on the hydrological context and the properties of the substrate (Bornette *et. al.,* 1994). Abiotic and biotic variables influence macrophyte interactions in different ways (Zelnik *et. al.,* 2021) and hence, they are utilized as a tool to evaluate the ecological condition of wetlands (Aznar *et. al.,* 2002). In aquatic environments, macrophytes are crucial as they supply aquatic life forms with food, nutrients, and habitats (Theel *et. al.,* 2008) and retain aquatic diversity (Deshmukh *et. al.,* 2016). Macrophytes are pioneer constituents of aquatic ecosystems as they increase the net productivity, store nutrition and oxygenate the water (Caraco *et. al.,* 2006). In wetlands, they are important for putrefaction and energy transfer (Dvorak, 1996).
Wetland sustainability depends critically on macrophyte species. Yet, they are very susceptible to human impacts and respond to environmental disruptions (Allan, 2004) which have an adverse effect on their composition and variability (Singh *et. al.,* 2023). The aquatic flora has

changed drastically in the last many years (Patil, 2022). Human-induced practices such as waste disposal, environmental contamination, and sewage draining along with climate change have caused a uniformity in the vegetation and a broad reduction in the diversity of macrophytes (Halabowski *et. al.,* 2020). Wetland ecosystems are impacted and experience a reduction in their inherent richness. The study was executed to ascertain the diversity, affluence and composition of the macrophytes in the wetlands of the university; as it is an essential tool to acquire the present status and thorough evaluation of the ecological health of the aquatic ecosystem.

MATERIALS AND METHODS

Study Area

The campus of Guru Ghasidas University is situated 5 km from the town of Bilaspur along the NH-111 Bilaspur-Ratanpur Road. It is located between latitudes 22°08'26" and 22°07'16" N and longitudes 82°07'55" and 82°08'58" E. The total size of the university campus is 690 acres or 287.5 hectares. Its body has a group of four ponds (Figure 1) with few streams, ravines, and plateaus that support different ecosystems especially the aquatic macrophytes supporting the ecosystem. The university is not as ancient as the floral resources, which have been there since before the university was founded (Dhuria *et. al.,* 2014). The complete focus was placed on transforming the campus into a green belt in tandem with the construction of the academic infrastructure. Near the banks of the rain-fed Arpa River, it has black-sandy soil and an average elevation of 264 m (866 ft). Tropical weather prevails throughout the region (Tiwari *et. al.*, 2023). Due to its closeness to the tropic of cancer and reliance on the monsoons for rain, it is hot and humid. The monsoon season brings about moderate rainfall. Its winter temperatures range from 5 to 25°C, while its summer temperatures range from 30 to 47°C (Patel, 2012). The campus positively supports a number of ponds with great potential for macrophyte diversity which was the base of the current study.

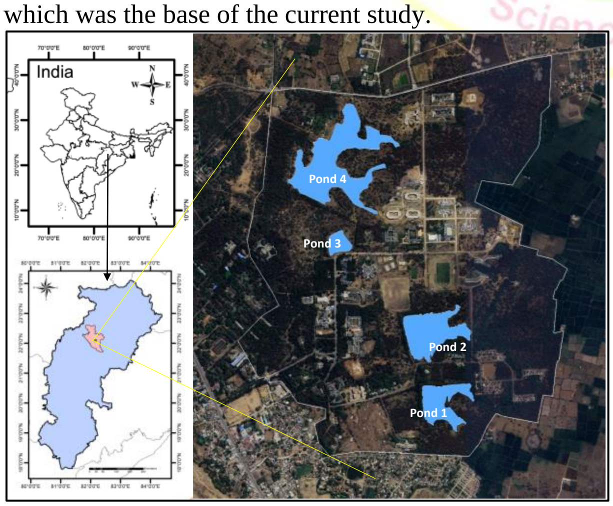

Figure 1. The geographical location of Guru Ghasidas Vishwavidyalaya, Chhattisgarh represents the four study sites namely Pond 1, Pond 2, Pond 3 and Pond 4.

Collection and Identification of Macrophytes

The wetlands of Guru Ghasidas Vishwavidyalaya were surveyed for its aquatic macrophytes diversity periodically during the period from January 2023 to October 2023 for ten months and three seasons i.e., winter, summer and rainy seasons and plant specimens were collected to prepare a checklist of macrophytes. All studied aquatic macrophyte species were identified using pertinent literature and flora Cook (1996), Gupta (2001) and Yadav and Sardesai (2002). These collected macrophyte species were also classified based on their habitat and morphological characteristics.

Methodology to Study the Status of Macrophytes

Further after preparing the checklist, the water bodies were strategically analysed to identify the status of different macrophytes in the study area by plotting four quadrates of 2m × 2m size in each water body. A total of 16 quadrates were plotted in all four sub areas and macrophyte species were studied based on their occurrence and distribution in the quadrates. Vegetation composition was evaluated by analysing the frequency, density, and abundance using the formula given by Misra (1968) and Curtis and McIntosh (1951). Further, the observed macrophytes were classified according to their nature in three types namely, floating macrophytes, submerged macrophytes and emergent macrophytes.

Statistical Analysis

The dominance of the macrophyte species was determined using the Importance Value Index (IVI) by summing up relative density (RD), relative frequency (RF) and relative abundance (RA) using the following formula given by Misra (1968). Vegetation composition was evaluated by analysing the frequency, density, abundance, and IVI, using the following formula given by Misra (1968) and Curtis and McIntosh (1951):

$$\text{Relative Frequency\%} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100$$

$$\text{Relative Density\%} = \frac{\text{Number of individuals of a species}}{\text{Number of individuals of all species}} \times 100$$

$$\text{Relative Abundance\%} = \frac{\text{Total no. of a species in an area}}{\text{Total sum of all populations of species in an area}} \times 100$$

$$\text{IVI } (Importance\ Value\ Index) = RD + RF + RA$$

Diversity indices like species diversity (H’) were calculated by using the Shannon-wiener index (Shannon and Weaver, 1949); Concentration of Dominance (D) was calculated through Simpson’s index (Simpson 1949); Species Richness (R) by Margalef’s index (Marglef, 1958) and Species Evenness (E) by (Pielou, 1966) respectively.

$$H' = -\sum_{i=1}^{S} (pi\ lnpi)$$

$$D = \sum_{i=1}^{S} (pi)2$$

$R = S\text{-}1/ln\ (N)$

$E = H'/H^{max}$

Where,

S = The number of species (species richness)

ln = natural log

pi = The relative abundance of each species *(ni/N)*

ni = total number of a particular *(ith)* species

N = The total number of individuals of all species

$H^{max} = ln\ (S)$

RESULTS AND DISCUSSION

A total of 33 aquatic macrophyte species were recorded after extensive field studies in the wetlands of Guru Ghasidas Vishwavidyalaya belonging to 21 different families (Table 1). The observed macrophytes, based on their nature were classified as floating macrophytes, submerged macrophytes and emergent macrophytes. A total of 8 floating species, 2 submerged macrophytes, and 23 emergent macrophyte species were identified from the wetlands of Guru Ghasidas Vishwavidyalaya which contributed 24.24%, 6.06%, and 69.69% respectively (Figure 2).

Table 1. Aquatic vegetation observed in wetlands of GGV campus:

Family	Species	N	Occurrence in Ponds				IVI
			1	2	3	4	
Amaranthaceae	*Alternanthera sessilis*	E	✓	✓	✓	✓	14.673
Amaryllidaceae	*Crinum asiaticum*	E	✓	✓	✓	✓	8.351
Apiaceaae	*Centella asiatica*	E	✓	×	✓	✓	8.351
Araceae	*Spirodela polyrhiza*	F	×	×	×	✓	6.010
Asteraceae	*Eclipta prostrata*	E	✓	✓	✓	✓	9.106
Convolvulaceae	*Ipomoea aquatica*	E	✓	✓	✓	✓	9.296
Convolvulaceae	*Ipomoea carnea*	E	✓	✓	×	✓	16.492
Convolvulaceae	*Ipomoea triloba*	E	✓	×	×	×	5.402
Cyperaceae	*Eleocharis capitata*	E	×	×	×	✓	3.357
Cyperaceae	*Schoenoplectiella mucronata*	E	×	✓	×	×	6.129
Cyperaceae	*Cyperus rotundus*	E	✓	✓	✓	✓	14.673
Cyperaceae	*Cyperus difformis*	E	×	×	✓	×	1.971
Hydrocharitaceae	*Hydrilla verticillata*	S	✓	✓	✓	✓	15.868
Lemnaceae	*Lemna minor*	F	✓	×	✓	✓	7.446
Lythraceae	*Rotala indica*	E	✓	✓	×	✓	7.899
Lythraceae	*Rotala rotundifolia*	E	✓	✓	✓	✓	6.424
Lythraceae	*Ammannia baccifera*	E	✓	×	✓	✓	6.994
Menyanthaceae	*Nymphoides cristata*	F	✓	×	×	×	6.424
Menyanthaceae	*Nymphoides indica*	F	✓	✓	✓	✓	9.709
Molluginaceae	*Glinus lotoides*	E	✓	✓	×	✓	6.618
Nymphaeaceae	*Nymphaea alba*	F	✓	×	×	×	7.446
Nymphaeaceae	*Nymphaea nouchali*	F	✓	×	×	×	4.794
Onagraceae	*Ludwigia adscendens*	F	✓	✓	✓	✓	9.709
Onagraceae	*Ludwigia perennis*	E	✓	✓	×	×	4.186
Oxalidaceae	*Oxalis corniculata*	E	×	✓	✓	✓	9.488
Plantaginaceae	*Bacopa monnieri*	E	✓	×	✓	✓	6.424
Poaceae	*Echinochloa colona*	E	✓	✓	✓	✓	15.255
Poaceae	*Cynodon dactylon*	E	×	✓	✓	✓	11.969
Potamogetonaceae	*Potamogeton crispus*	S	×	✓	✓	✓	10.536
Rubiaceae	*Dentella repens*	E	✓	✓	✓	✓	10.613
Salviniaceae	*Azolla pinnata*	F	✓	✓	✓	✓	16.184
Typhaceae	*Typha angustifolia*	E	✓	✓	✓	✓	13.733
Typhaceae	*Typha latifolia*	E	✓	×	✓	✓	8.469
	Total Species		26	21	22	26	

Note: N represents the nature of species as E- Emergent, F- Floating, S- Submerged.

Other than that, the highest IVI (Table 1) was achieved by emergent *Ipomoea carnea* (16.492) followed by floating *Azolla pinnata* (16.184), submerged *Hydrilla verticillate* (15.868), emergent *Echinochloa colona* (15.255) and emergent *Alternanthera sessilis* (14.673) whereas, the least IVI scores were attained by emergent *Cyperus difformis* (1.971), emergent *Eleocharis capitata* (3.357), emergent *Ludwigia perennis* (4.186), floating *Nymphaeace nouchali* (4.794) and emergent *Ipomoea triloba* (5.402). Different studied diversity indices are Shannon-Wiener Index (H'), Simpson's Index (D), Species Richness (R), and Evenness (E) gave the result as 3.451, 0.042, 33 and 0.946 respectively. The high diversity index represents the positive condition of wetlands as because of lower pollution percentage and less disturbance in the campus when compared to urban landscapes giving an opportunity to the macrophytes for better growth and development (Qi *et. al.*, 2021, Li *et. al.*, 2021).

For a better idea and justification, agglomerative hierarchical clustering was done (Bertrin *et. al.*, 2018, Palit *et. al.*, 2017, Manolaki and Papastergiadou, 2013) using SPSS software (version 25.0) for classifying the identified macrophyte species based on their IVI scores (Figure 3) into five clusters (Cluster A, B, C, D and E). The prepared dendrogram represents that Cluster C constituted the highest number of species (n=8) whereas Cluster A, B and E constituted of same number of species (n=7 each). Least species fell under Cluster D (n=4). Cluster E indicates the species with the highest IVI scores (IVI scores > 13) followed by Cluster A, Cluster B and Cluster C (IVI scores between 12 to 9, 9 to 7 and 7 to 5 respectively) whereas the least IVI scores were observed in species of Cluster D (IVI scores < 5).

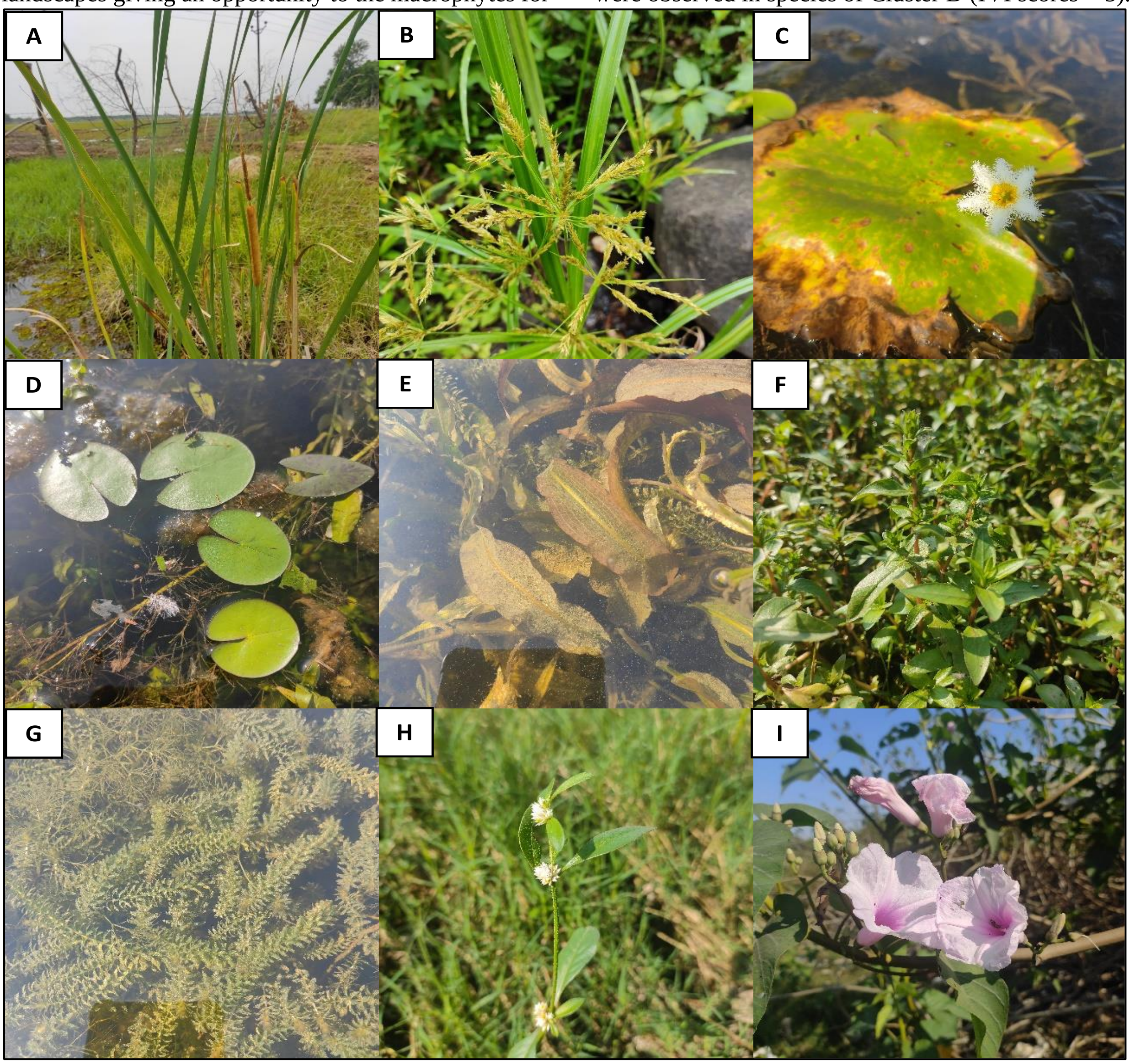

Figure 2. Some macrophyte diversity in the wetlands of Guru Ghasidas Vishwavidyalaya, A. Typha latifolia, B. Cyperus rotundus, C. Nymphoides indica, D. Nymphaea nouchali, E. Potamogeton crispus, F. Ludwigia adscendens, G. Hydrilla verticillata, H. Alternanthera sessilis, I. Ipomoea carnea.

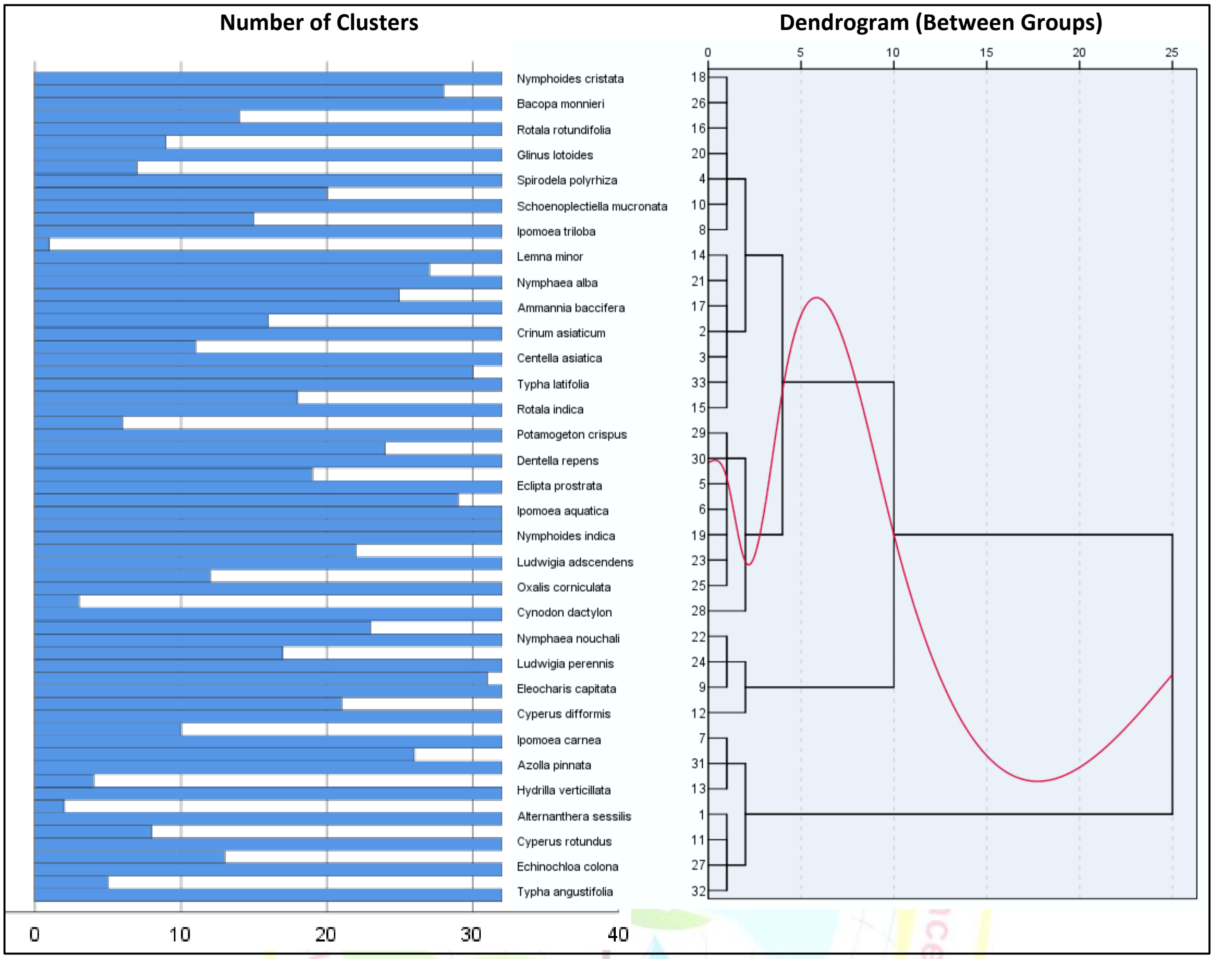

Figure 3. Agglomerative hierarchical clustering of identified macrophyte species based on their IVI Scores.

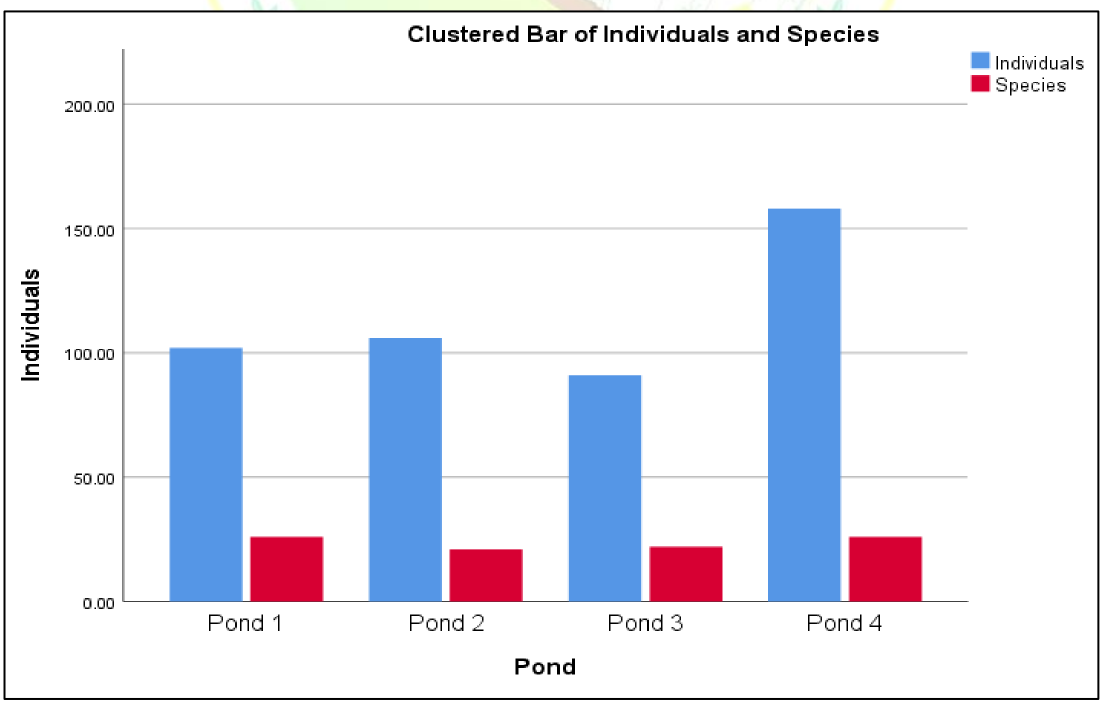

Figure 4. Clustered bar diagram representing pond-wise observed individual count and number of macrophyte species.

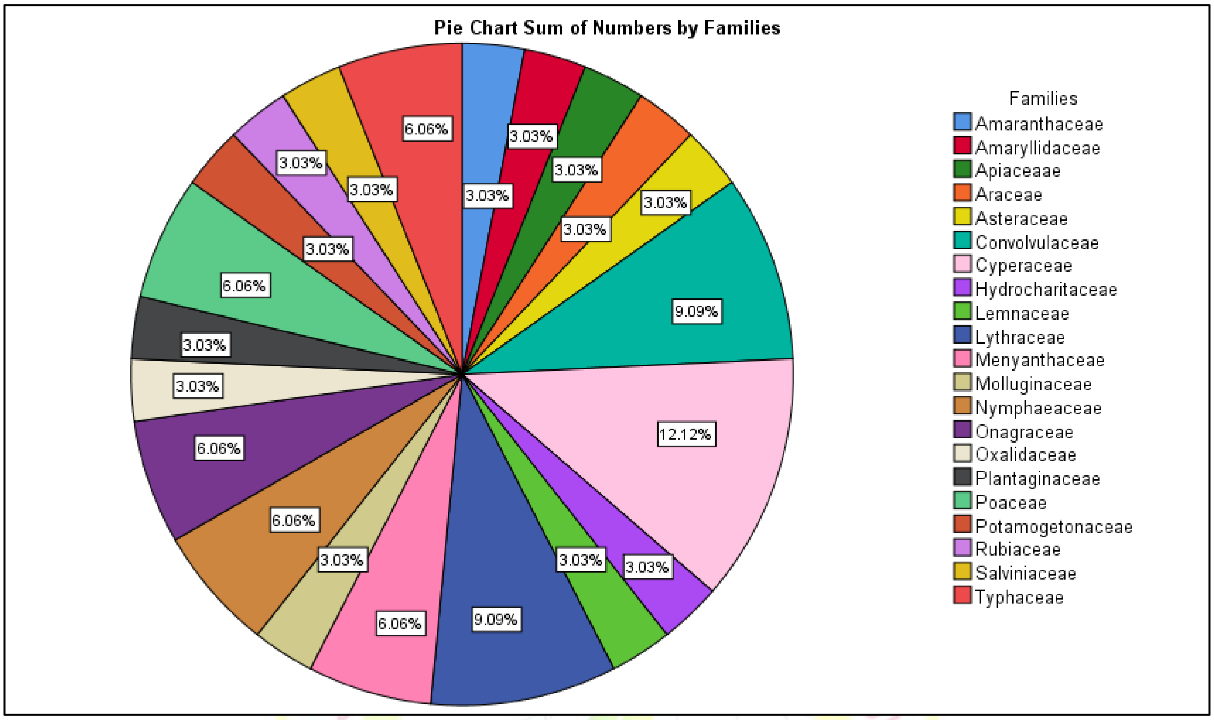

Figure 5. Pie chart of observed 21 macrophyte families with percentage of occupied species count.

Comparatively among different studied ponds, the highest species diversity was observed in Pond 1 and Pond 4 with 26 identified species in each as they were also the largest water bodies of the campus followed by Pond 3 and Pond 2 with 22 and 21 identified species respectively. Also, the highest species richness was observed in Pond 4 with 158 individual counts followed by Pond 2 (106 individuals), Pond 1 (102 individuals) and Pond 3 (91 individuals) respectively (Figure 4). Pond 3 represented the least individual count as it is situated closest to the road which may be the cause of disturbance and availability of lesser macrophytes in the studied quadrates (da Silva *et. al.*, 2020, Stoler *et. al.*, 2018).

The highest occurring family was found to be Cyperaceae with four different species constituting 12.12% of the total families (Figure 5) followed by Convolvulaceae and Lythraceae family with three different species each (9.09%). Cyperaceae was found to be one of the most dominating family in such urban green belts that has the flexibility to show good performance in harsh conditions (Khan *et. al.*, 2022, Sharma and Singh, 2017, Dutta *et. al.*, 2014). The least contributions were shared between 13 macrophyte families namely Amaranthaceae, Amaryllidaceae, Apiaceaae, Araceae, Asteraceae, Hydrocharitaceae, Lemnaceae, Molluginaceae, Oxalidaceae, Plantaginaceae, Potamogetonaceae, Rubiaceae, Salviniaceae (3.03% each).

CONCLUSION

In addition to meeting all of humanity's fundamental requirements, biodiversity more considerably aquatic diversity is crucial to the health and stability of ecosystems. Aquatic environments are extremely important to living organisms and humans as well. However, a number of factors, including water pollution, alien species invasion, habitat degradation, overharvesting, and others, are destroying these ecosystems in the current generation in developing countries like India. We must first understand the potential and significance of aquatic biodiversity to maintain and conserve native species. People must be educated, appropriate management methods must be implemented, and severe legal action must be taken to ensure its protection and sustainable use. For biodiversity conservation and its sustainable use organizations and institutions like Guru Ghasidas Vishwavidyalaya and others should jointly participate to educate people about the importance and sustainable utilization of such ecosystem which will not only benefit the environment but serve also human society.

Author's Contribution

A.M., S.C., A.S., and A.C. contributed to the design of the research and also carried out the implementation. S.C. and A.C. were involved in field practices and data collection. A.M. and S.C. analyzed the data. A.S., and A.C. performed the calculations. A.M. and A.S. wrote the manuscript with input from all authors. All authors provided critical feedback and helped shape the research, analysis and manuscript.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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