

DIVERSITY, ABUNDANCE, AND SEASONAL VARIATION OF AQUATIC MACROPHYTES IN SOUTHEASTERN BANGLADESH

ABSTRACT

The study was conducted to assess the diversity and abundance of aquatic macrophytes in the southeastern region of Bangladesh, encompassing the Noakhali, Cumilla, and Chandpur districts. The study was carried out over the period of July 2022 to June 2023. This research utilized a mixed-methods approach, incorporating observation of the study area, qualitative interviews, and quantitative surveys. Five types of aquatic macrophytes, 47 species from 18 orders and 25 families were identified. These are free-floating, rooted-floating, emergent, submerged, and marginal. Among the three locations, Noakhali was recorded as the highest with 44 species, followed by Cumilla with 43, and Chandpur with 35. In Noakhali, seasonal variation analysis showed that 39% of species were found in the rainy season, 14% in summer, 14% in winter, and 20% year-round. In Cumilla, 35% of aquatic macrophytes were available in the rainy season, and 14%, 12%, and 5% in winter, spring, and autumn, respectively. In Chandpur, 37% of aquatic macrophytes were prevalent in the rainy season, 26% were found year-round, 9% in winter, 14% in summer, and 6% each in spring and autumn. In Noakhali, 44% of macrophytes were frequent, 33% moderate, and 23% rare. In Cumilla, 49% were frequent, 44% moderate, and 14% rare. Chandpur reported 49% frequent, 31% moderate, and 20% rare species. The order Alismatales emerged as the dominant order comparatively across all locations. This research will provide insights into the biodiversity of aquatic macrophytes in this area, thus supporting effective management strategies.

Keywords: aquatic macrophytes, Southeast Bangladesh, biodiversity, frequency of occurrence

INTRODUCTION

Considering the rapid global loss of fish and aquatic biota populations, scientists studying fisheries have begun to prioritize biodiversity research. Genetic species, assemblages, ecosystems, and habitats are described by various levels of a biological organization with structural, compositional, and functional, all of which comprise biodiversity [1]. Macrophytes, larger aquatic plants growing in or near water, play various important roles. These roles include nutrient cycling, sediment stabilization, and providing food and habitats for different fish and aquatic life [2,3,4]. This is particularly relevant for a country like Bangladesh, which supports a large number of aquatic macrophytes due to its geographical location and numerous water bodies.

Aquatic organisms like microalgae, epiphytes, and seaweeds are well known for their nutritional role as food for fish and shrimp food [5,6,44,45,46]. It is evident that aquatic macrophytes have

immense potential to be used as fish feed and fodder; however, they are yet to be studied comprehensively. Though studies regarding the availability and diversity of fish and zooplankton are gaining momentum in Bangladesh [7] studies regarding macrophytes are still scanty.

Based on their ecological habitat, aquatic macrophytes are normally categorized into five types: free-floating, rooted-floating, submerged, emergent, and marginal [8,9,10]. Free-floating macrophytes float with unanchored roots while rooted-floating macrophytes float but have anchored roots. Submerged macrophytes grow and reproduce underwater and may not be visible on the surface. Emergent macrophytes thrive in shallow water and wetlands, where water levels rise and fall periodically. Marginal macrophytes are located on the edge of the water body.

Aquatic plants in pond ecosystems provide food, shelter, and breeding grounds for fish and other aquatic animals [11]. They produce oxygen through photosynthesis, assimilate fish waste, and used as phytoremediators [12]. Some aquatic macrophytes are used for compost fertilizer; certain fish species feed on them, and some have medicinal values [13, 14]. However, the habitats of these macrophytes are vulnerable to factors like dams, agriculture, pollution, and biological invasion. Aquatic plants are used as raw materials, such as pulp for paper, medicines, the perfume industry, building materials, and fertilizers [15]. Since these plants have a selective ability to absorb various substances, aquatic plants may be used as indicators of the presence of toxicants in water. That is why the importance and relevance of further study of aquatic plants is beyond doubt [15]. However, excessive growth of aquatic plants may restrict fishing, swimming, and recreational activities and in some cases, result in taste and odor to drinking water supplies. In some cases, there may lead to stunting of fish populations and fish kills resulting from low dissolved oxygen [16]. These can cause problems in ponds, and control measures often must be used to eliminate or reduce their macrophyte abundance [17]. Aquatic macrophytes act as engineer species [18,19] and their unbalanced eradication cause a drastic effect on the trophic and functional status of the habitats with water bodies [20,21].

The southeastern region of Bangladesh, including Noakhali, Cumilla, and Chandpur, has many waterbodies. Noakhali District is bordered by the Meghna Estuary and the Bay of Bengal to the south. It comprises 81,490 hectares of floodplains, ponds, and seasonal water bodies. Cumilla City is situated on the banks of the Gumti River and has about 301,834 hectares of floodplains, ponds, and seasonal water bodies. Chandpur, a coastal district, has 36,456 hectares of the Meghna River and 67,044 hectares of other water bodies (floodplains, ponds, and seasonal water bodies) [22]. These features make these regions ideal for the study of aquatic macrophytes. However, there is hardly any research on these waterbodies. Therefore, this study intends to investigate the diversity, abundance, and seasonal variations of different aquatic macrophytes in southeastern Bangladesh. This research will form a baseline for further research to describe the diversity and abundance of vegetation in this region and devise eco-based management of water bodies, knowing the potential uses of these plants.

MATERIALS AND METHOD

Study Area

The study was conducted in Bangladesh's southeastern region (Noakhali, Cumilla, and Chandpur) (Figure 1). The aquatic macrophytes of these three districts, which are part of the Chittagong division in the southern part, have never been studied. All three districts have several ponds, lakes, rivers, and other water bodies and wetlands with aquatic plants growing in and around them. For the convenience of the study, 12 months are converted into the seasons as follows accordingly: April to June (Summer), June to August (Rainy Season), September to November (Autumn), December to February (Winter), and February to April (Spring).

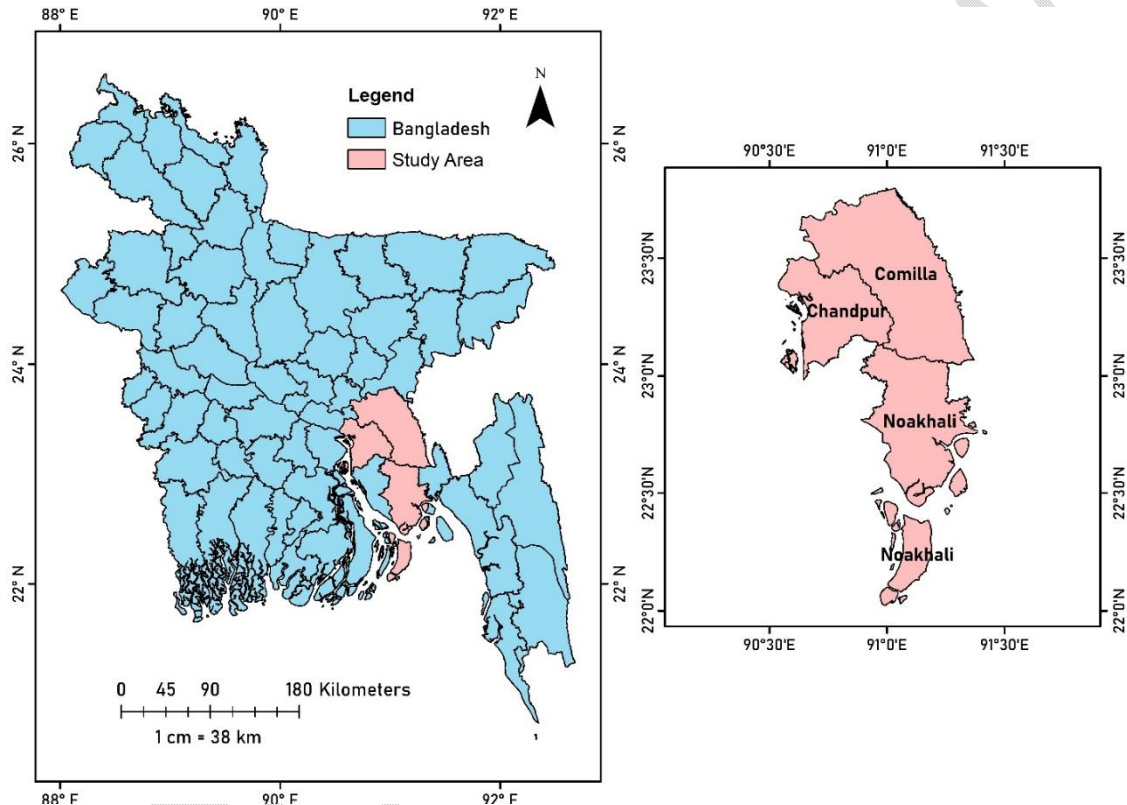


Figure 1: Map showing the location of the study area in southeastern Bangladesh (Noakhali, Cumilla and Chandpur District)

Collection of Sample and data

The sample collection survey lasted one year, from July 2022 to June 2023. Data collection occurred monthly. Subjective estimation methods were utilized for sampling, and visual observation was chosen [23]. The study area consists of 36 sites, 12 sites from each district (4 different macrophytes habitats x 3 sections). Macrophytes were collected from waterbodies and wetlands, i.e., floodplains, ponds, seasonal water bodies and surrounding rivers (the Meghna River for Noakhali and Chandpur and the Gumti River for Cumilla). Samples were gathered to cover around 200 ha (2 Square Kilometers) from each district in Noakhali, Cumilla, and Chandpur.

The relative frequency of the aquatic weeds was determined by calculation of the percentage of frequency as follows:

$$F (\%) = [n/N] \times 100$$

Here,

F (%) = Frequency of aquatic macrophytes

n= Frequency of aquatic macrophytes

N= Total number of sites

The frequency of occurrence categorized as, Frequent= >50%; Moderate= 25-50%; Rare= <25%

Information about the varieties of aquatic macrophytes, their diversity status, seasonal availability, and utilization was obtained through direct field surveys and interviews with local residents. Data was gathered using a consistent survey method that adhered to a predetermined schedule and questionnaire design. Participatory rural appraisal (PRA) tools, viz. individual interviews, focus group discussions, and key informant interviews, were conducted.

The data on aquatic macrophytes with their local name were documented by interviewing through a questionnaire with 30 local informants, including 20 males and 10 females from each district. During the fieldwork, the common village dwellers, pond owners, fish farmers, traditional healers, vegetable salesmen, fishermen and boatmen were interviewed. The data were obtained on various aspects by inquiring about the aquatic plants, their local names, frequency status, and seasonal availability. The informants were asked questions in Bengali so the villagers could easily understand and respond. Two focus group discussions containing eight people in each group people and 14 people were interviewed as key informants.

Identification of Species

The strategy used for sample identification was visual inspection. Collected aquatic macrophytes were identified according to Journey et al. [24], Pasha [25], Lancar and Karke [26], and Lewis and Miller [27]. A review of published journals and reference works, such as the Encyclopedia of Flora and Fauna of Bangladesh [28,29,30] etc., was also conducted to identify the plant specimens.

Data Analysis

All qualitative and quantitative data were collected and organized using MS Word and MS Excel 2019. The organized data were analyzed using R and RStudio tools. Finally, the study's key findings were presented as tables and figures for scientific disclosure. The map of the research area was made with Arc GIS (version 10.8).

RESULTS

Diversity of aquatic macrophytes

All 5 types of aquatic macrophytes were found in the southeastern region of Bangladesh comprising a total of 47 species from 18 orders and 25 families were identified. Of these, 44 species were observed from various water bodies across the Noakhali, whereas 43 were observed in Cumilla and 35 were observed in Chandpur. Thirty-three aquatic macrophytes were common to all three districts. Two were only found in Chandpur and Comilla, six were in Noakhali and Comilla, and four and two were only found in Noakhali and Comilla, respectively (Table 1). In Noakhali, 53% of emergent aquatic macrophytes were found, while in Cumilla district, the percentage was 55%, and in Chandpur district, it was 51%. In all three districts, the percentage of submerged and marginal aquatic macrophytes was the same at 16% and 7%, respectively (Figure 2).

Table 1. List of aquatic macrophytes of southeastern Bangladesh with orders, families, local names, common names and scientific names, types, frequency and availability

Order	Family	Local name	Common name	Scientific name	Types	Frequency			A
						Ch	N	Cu	
A									
Alismatales	Araceae	Topapan	Water lettuce	<i>Pistiastratiotes</i>	FF	F	F	F	
		Khudipana	Duckweed	<i>Lemna minor</i>	FF	F	F	F	
		Kochu	Chinese potato	<i>Colocasia esculenta</i>	EM	F	F	F	
		Mankochu	Elephant's Ear	<i>Alocasia macrorrhizos</i>	EM	F	F	F	
	Hydrocharitaceae	Vallisneria	Eel weed	<i>Vallisneria spiralis</i>	SU	M	M	M	
		Najas	Brittle naiad	<i>Najas minor</i>	SU	M	F	M	
		Panimorich	Eelgrass	<i>Vallisneria spp</i>	SU	M	M	M	
Poales	Cyperaceae	Chechra	Bog bulrush	<i>Schoenoplectiellamucronata</i>	EM	R	R	R	
	Poaceae	Dol	Asian	<i>Hygrorayzaaristata</i>	EM	F	M	F	

	Typhaceae	Hugla	Common cattail	<i>Typha latifolia</i>	EM	R	R	R
Myrtales	Lythraceae	Panifall	Water caltrop	<i>Trapa natans</i>	EM	M	M	M
		Haincha	Yellow ammania	<i>Ammaniapedicellata</i>	EM	M	R	M
	Onagraceae	Keshordham	Water priFose	<i>Ludwigiaoctovalvis</i>	EM	F	F	F
Nymphaeales	Menyanthaceae	Kara	Banana lily	<i>Nymphaea aqatica</i>	EM	M	M	M
	Nelumbonaceae	Padma	Tiger lotus	<i>Nelumbo nucifera</i>	FF	F	R	F
	Nymphaeaceae	Lalshapla	Red water lily	<i>Nymphaea rubra</i>	RF	M	M	M
		Sadashapla	White water lily	<i>Nymphaea nauchali</i>	RF	R	F	R
Asterales	Asteraceae	Helencha	Hingcha	<i>Enhydafluctuans</i>	EM	F	F	F
Ceratophyllales	Amaranthaceae	Malancha	Alligator weed	<i>Alternanthera philoxerodies</i>	EM	F	F	F
	Ceratophyllaceae	Kata jhanji /Sheola	Coontail	<i>Ceratophyllumdemersum</i>	SU	F	M	F
Commelinales	Commelinaceae	Kanaidoga	Asiatic dayflower	<i>Commenlinaappendiculata</i>	EM	F	F	F
		Kanaibashi	Dayflower	<i>Commerlina bengalensis</i>	EM	R	F	R
	Pontederiaceae	Kachuripana	Water hyacinth	<i>Eichhornia crassipes</i>	FF	F	F	F
Lamiales	Linderniaceae	Chhotohelencha	SpaMow false pimpernel	<i>Linderniaantipoda</i>	EM	F	M	F
		Kata hanchi	Hairy slitwort	<i>Linderniaciliata</i>	MA	M	M	M

Salviniales	Salviniaceae	Kutipana	Mosquito fern	<i>Azolla pinnata</i>	FF	F	F	F
Solanales	Convolvulaceae	Kolmi	Water spinach	<i>Ipomoea aquatica</i>	SU	F	F	F
		Dholkolmi	Bush morning glory	<i>Ipomoea fistulosa</i>	EM	M	F	M
Apiales	Apiaceae	Thankuni	Gotu kola	<i>Hydrocotyle asiatica</i>	EM	M	M	M
Ericales	Lecythidaceae	Hizal	Indian putat	<i>Barringtonia acutangula</i>	RF	R	M	R
Polygonales	Polygonaceae	Bishkatali	Polygonum	<i>Polygonum glabrum</i>	EM	R	F	R
Polypodiales	Pteridaceae	Panidhekia	Floating fern	<i>Ceratopteris pteridoides</i>	FF	R	R	R
Oxalidales	Oxalidaceae	A Foolshak	Indian sord	<i>Oxalis corniculata</i>	EM	F	F	F
B								
Poales	Poaceae	Arail	Southern cut grass	<i>Leersia hexandra</i>	EM	M	M	
Myrtales	Lythraceae	Haincha		<i>Ammania gracilis</i>	SU	F	F	
C								
Alismatales	Hydrocharitaceae	Hydrila	Water thyme	<i>Hydrila verticillata</i>	SU	F	F	
Poales	Cyperaceae	Mutha	Nut grass	<i>Cyperus rotundus</i>	EM	F	F	
Asterales	Asteraceae	Kesuti		<i>Eclipta prostrata</i>	EM	R	R	
Caryophyllales	Amaranthaceae	Notae shak	Green amaranthus	<i>Amaranthus viridis</i>	MA	M	M	
Lamiales	Plantaginaceae	fuligash	brahmi	<i>Bapocamonnieri</i>	MA	M	M	
Salviniales	Masileaceae	Shusnishak	Pepperwort	<i>Masilea quadrifolia</i>	EM	M	M	
D								
Poales	Cyperaceae	Kesur	Giant bulrush	<i>Scripus gorossus</i>	EM	R		
	Poaceae	Nolkhagra	Tall reed	<i>Phragmites karka</i>	EM	M		

		Khudeshama	Buffalograss	<i>Panicum Sualbidum</i>	EM	M
	Asteraceae	Nak ful	Indian lilac	<i>Acmella paniculata</i>	EM	R
E						
Alismatales	Aponogetonaceae	Gechu	Ruffled sword plant	<i>Aponogeton spp</i>	EM	R
Asterales	Menyanthaceae	Chandmata	Crested floating heart	<i>Nymphoides cristata</i>	EM	R

FF-free floating, RF-rooted floating, EM-Emergent, MA-Maginal, SU-Submerged, M-moderate, R-rare, F-frequent, AS-All Season, RS-Rainy Season, SS-Summer Season, WS-Winter Season, Au.S-Autumn Season, Sp.S-Spring Season, Ch-Chandpur, N-Noakhali, Cu-Cumilla, A-aquatic macrophytes common in Noakhali, Cumilla, and Chandpur, B-aquatic macrophytes common in Chandpur and Cumilla, C- aquatic macrophytes common in Noakhali and Cumilla, D-Aquatic macrophytes only recorded in Noakhali, E- Aquatic macrophytes only recorded in Cumilla

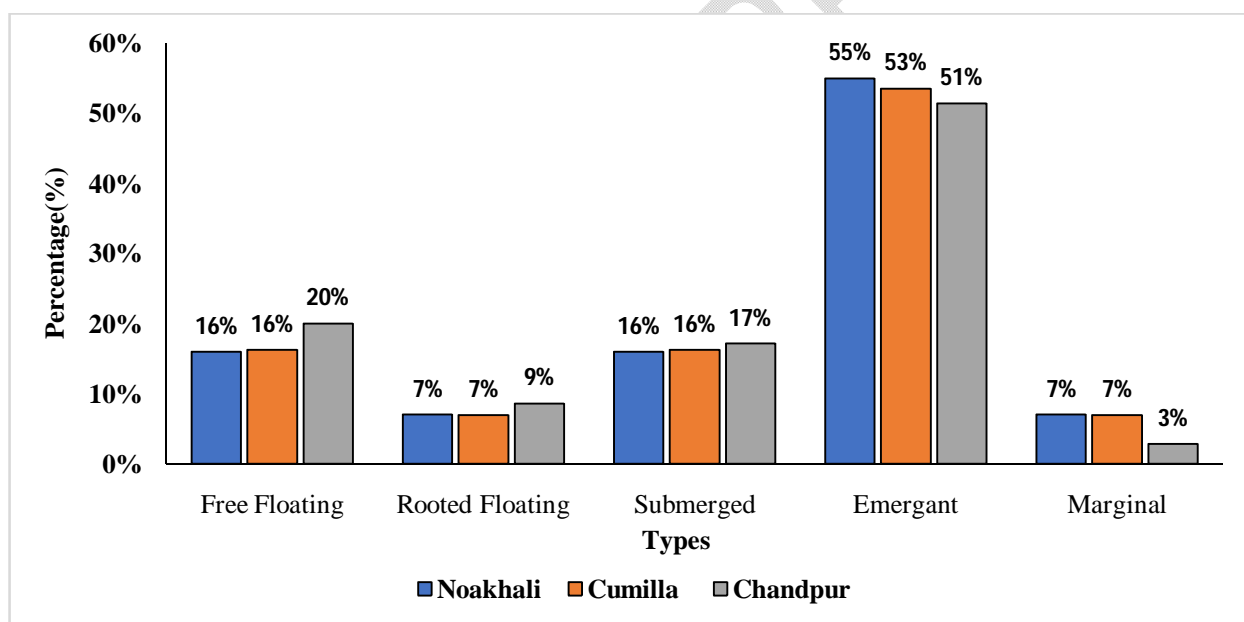


Figure 2: Diversity and relative abundance of types of aquatic macrophytes in southeastern Bangladesh

Figure 3 compares macrophyte orders among Noakhali, Cumilla, and Chandpur. Alismatales was the dominant order in all three districts, followed by Poales. In Chandpur, Alismatales contributed 20% of the total plant species, 11% Myrtales, Nymphaeales, and Poales and Commelinales moderately represented 6% of the total, followed by orders like Solanales and Lamiales. In Noakhali at 16% were Alismatales and 14% were Poales. Among other orders, Polypodiales contributed 9% while Commelinales, Myrtales, Asterales and Lamiales all contributed around 7% each. There were 2 orders, namely Polygonales and Cyperales, only recorded in this area.

The Cumilla zone featured Alismatales at 19% and Poales at 12%, while moderate representation of Commelinales, Asterales and Lamiales at 7%, Myrtales and Nymphaeales at 9%, Salviniiales and Solanales at 5%, Polypodiales at and Ceratophyllales equal to 2%. Finally, Alismatales has a maximum peak value in all three districts, and the Poales value is notable here. Commelinales and Myrtales families' plant presence was higher in all districts, but they are diverse, and Nymphaeales is especially prevalent in Chandpur and Cumilla. These results show a diverse and rather uneven distribution of aquatic weed orders in the three districts under consideration, given that some orders are evident in one region and not others.

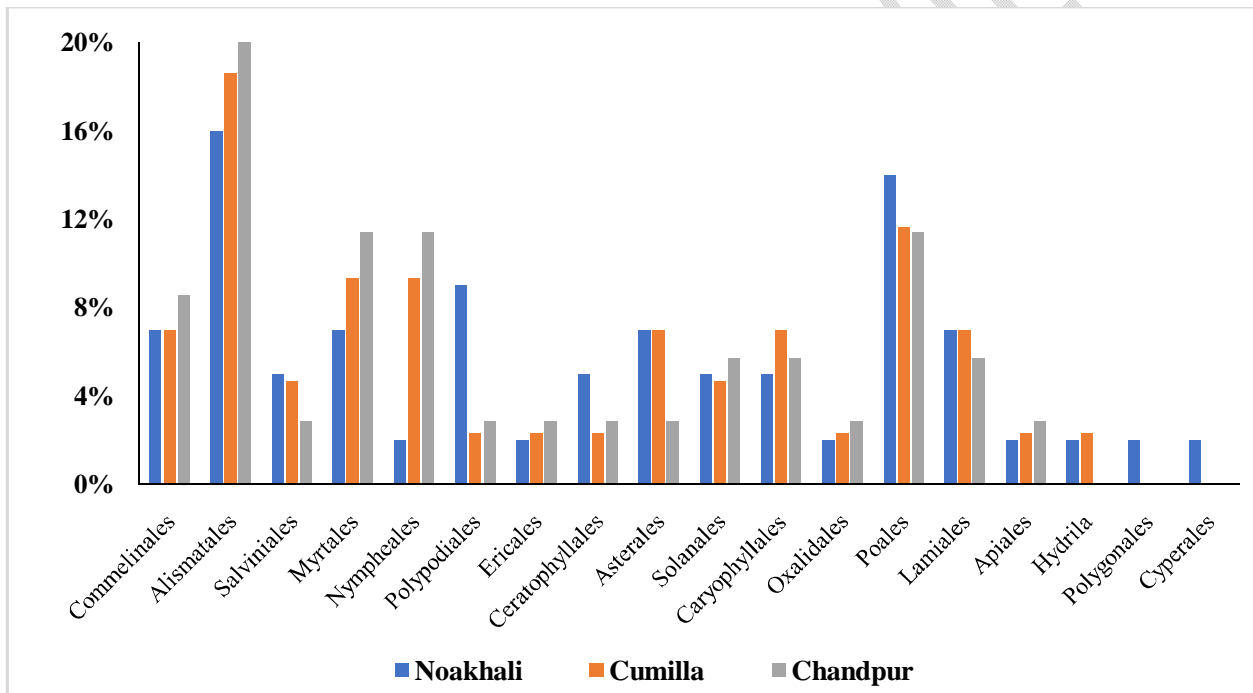


Figure 3: Relative abundance of aquatic macrophyte orders insoutheastern Bangladesh

In terms of family, 25 families were recorded in this study area. Of these, 23 families were systematically observed and found abundant in all three locations. However, the two families, Marsileaceae and Plantaginaceae, are absent from Chandpur. The Araceae family is the most dominant in the southeastern region, with 12 identified species, followed by the Hydrocharitaceae family, with 11 species. The Lythraceae and Poaceae families have eight and seven species, respectively. (Table 1).

In Chandpur, 37% of aquatic macrophytes were found in the rainy season, 26% in all seasons, 14% in summer, 9% in winter, 6% in spring, and 6% in autumn. In the Noakhali district, 39% of the aquatic macrophytes were found in the rainy season, 20% in all seasons, 14% in summer, 14% in winter, 9% in spring, and 5% in autumn. In Cumilla district, 35% of the aquatic macrophytes were found in the rainy season, 23% in all seasons, 14% in winter, 12% in spring, and 5% in autumn. (Table2)

Table 2: Seasonal variation of aquatic macrophytes in southeastern Bangladesh (Noakhali, Cumilla and Chandpur districts)

Noakhali			Chandpur			Cumilla		
Rainy, 39%		All, 20%	Rainy, 37%		All, 26%	Rainy, 35%		All, 23%
Summer, 14%	Winter, 14%	Spring, 9%	Summer, 14%	Winter, 9%	Spring, 9%	Winter, 14%	Summer, 12%	Spring, 12%
		Autumn, 5%			Autumn, 6%		Summer, 12%	Autumn, 5%

The presence of different types of aquatic macrophytes varied across the habitats. The frequency of aquatic macrophytes species was determined through field observations and discussions with local residents. The recorded aquatic macrophytes were divided into three categories based on their frequency of occurrence: rare (R) for those rarely found, moderate (M) for those found moderately, and frequent (F) for those found often. In Noakhali district, 44% of aquatic macrophytes were frequent, 33% were moderate, and 23% were rare. In Cumilla district, the majority of recorded aquatic macrophytes were frequent (49%), followed by moderate (44%) and rare (14%). In Chandpur district, 20% of aquatic macrophytes were rare, 31% were moderate, and 49% were frequent (Figure 4).

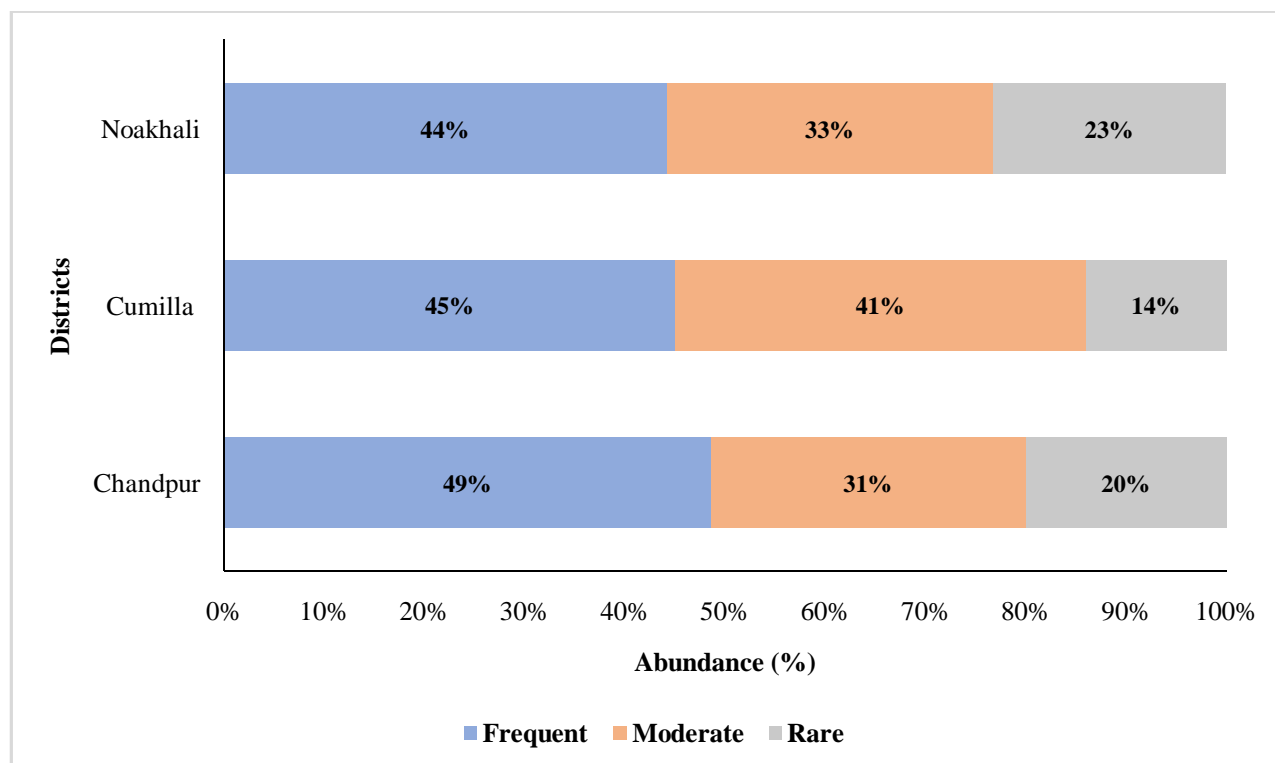


Figure 4: Frequency of aquatic macrophytes found in the southeastern Bangladesh

DISCUSSION

Bangladesh has a wide range of aquatic macrophytes due to its geomorphological location and abundant aquatic bodies and floodplains [4]. These aquatic macrophytes have enormous potential in the ecology, environment, and economics sectors [4]. To our knowledge, there is insufficient information about regional aquatic macrophyte diversity in Bangladesh. Also, information on aquatic macrophytes is crucial for the effective management of aquatic ecosystems, ensuring their ecological health, supporting sustainable use by humans, and mitigating the impacts of environmental changes, which helps the government to devise policy.

Regarding the dominance of macrophyte types, a similar result was recorded in other parts of Bangladesh like Mymensingh, mid-northern Bangladesh [31], Moulvibazar, northeastern [32] and Barishal, southern Bangladesh [33], where emergents were dominant. Concerning the number of species, our results were supported by two separate studies conducted in southern Bangladesh [34,4]. Dutta et al. [34], found that 76 plant species belonging to 66 genera in southern Medir haor, Brahmonbaria and 56 aquatic plant species under 29 families were recorded from the Feni district by Uddin and Pal [4]. Similarly, Maisha et al. [35], showed 60 species of plants distributed in 54 genera belonging to 33 families in Gopalganj, southern Bangladesh. In northern Bangladesh, A total of 52 aquatic plant species was recorded from Sadullapur Gaibandha belonging to 35 genera under 30 families. Likewise, a total of 39 aquatic

macrophytes were found at Bangladesh Agricultural University by Mymensingh Islam et al. [36]. However, Hasan et al. [37], conducted a study on Tanguar haor and recorded 26 species belonging to less than 20 families. Correspondingly, Sarower et al. [38] documented 19 aquatic Macrophytes from the different sites of Khulna district, which is relatively lower than the current study. The status of macrophyte diversity of the floodplain basin in northern Bangladesh was conducted, and a total number of 30 species of aquatic macrophytes belonging to 12 families were identified from the surveyed area [39]. Hasan et al. [40], found 23 aquatic species of 15 families in Dakatiabeel Khulna, southwestern Bangladesh. Evidently, the diversity of aquatic fauna varied across the country yet has decreased recently. People living near areas with excessive use of natural resources, pollution, climate change and inadequate management may be responsible for this. Additionally, there are other causes of the same effect.

Our recent study noted variations in the abundance of aquatic macrophytes in three districts throughout the year. Some macrophytes were found consistently, while others were specific to certain seasons such as summer, rainy, autumn, winter, and spring. Seasonal variations concerning aquatic macrophytes' abundance are common [41]. We observed that most aquatic weeds were present during the rainy season. This indicates that the rainy season provides a highly favorable environment for the growth and spread of aquatic macrophytes due to increased water availability, nutrient enrichment, warmer temperatures, light conditions, effective reproductive techniques, and less competition. A similar result was found by Islam et al. [36], in the north mid-central region of Bangladesh and by Adhikary and Alam [42] in the Fatki River, Magura, southwestern Bangladesh. However, in Tanguar Haor, eastern Bangladesh, the highest number of macrophytes was observed in summer, followed by monsoon and winter [37]. This might be caused by the geographical variation of the Haor basin, which was significantly different from other regions of Bangladesh.

Looking at the status of frequency of occurrence, around 50% of species were frequently observed in the three districts of southeastern Bangladesh, which was comparatively higher than the study conducted in Chapai Nawabganj, northwestern Bangladesh [43], where only 10.87% macrophytes were frequent 43.48% common, and rest were rare. In Feni, southeastern Bangladesh, 39% of aquatic macrophytes were abundant and commonly seen in the region [4]. However, Ame et al. [8] stated that 46% of aquatic plants were found to be rare, 44% of species were found common, and 10% of species were found abundant species in Gaibandha, northern Bangladesh. The higher frequency of aquatic macrophytes in southeastern Bangladesh than in northern and northwestern is due to the area's geographical and environmental influences, including its numerous waterbodies [22].

CONCLUSION

The study revealed that the community structure of aquatic weeds in southeastern Bangladesh encompasses various types of aquatic weeds exhibiting differences in vegetation and geographical distribution throughout the year. The southeastern region of Bangladesh hosts a greater variety of species than other parts of the country. However, macrophytes in southeastern Bangladesh exhibit minor regional variation in diversification and abundance. Regarding the diversification of orders, the highest was observed in Noakhali, which may be attributed to hydrological characteristics. However, concerning the abundance, the same orders were predominant in three districts, with emergent species being the most numerous in all three districts. Seasonal fluctuation in abundance was observed, with the rainy season sustaining the greatest number of aquatic macrophytes, followed by year-round availability in many species. It can be concluded that aquatic macrophytes and their diversity and abundance indicate the ecological soundness of the study area.

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AUTHORS' CONTRIBUTIONS

Md. Foyzul Hossain: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Gazlima Chowdhury, Tamzid Ahsan Nabil, Abrar Hossain, Sumiya Bhuyain, Mst. Meherin Farzana Mithi, Nazmin Begum, Alim Hossen: Analyzed and interpreted the data; Contributed materials, analysis tools or data; Wrote the paper. All authors read and approved the final manuscript.

Consent

As per international standards or university standards, Participants' written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

Before the survey, participant's permission was considered and they were informed about the research's objective. Their willingness to participate and the confidentiality of their interviews were ensured. The study received formal ethical approval from the ethical committee of the Department of Aquatic Environment and Resource Management, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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