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

ABSTRACT

The study assessed 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. Including five types of aquaticmacrophytes, 47 species from 18 orders and 25 families were identified. These are free-floating, rooted-floating, emergent, submerged, and marginal. Among the three locations, Noakhaliwas 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 study will form the basis for further analysis and research. It will also provide crucial insights into the biodiversity of aquatic macrophytes in this area, thus supporting effective management strategies.

Keywords:aquatic weeds, aquatic plants, Noakhali, Cumilla, Chandpur

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 land cover levels of a biological organization with structural, compositional, and functional components are all included in biodiversity [1].Macrophytes, larger aquatic plants growing in or near water, play various important roles. These roles include nutrient cycling, stabilizing sediment, and providing food and habitat for different fish and other animals [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 the presence of numerous water bodies.

Aquatic organisms like microalgae, epiphytes, and seaweeds are well known for their role as fish and shrimp feed andfor their nutritional composition [5,6]. It is evident that Aquatic macrophyteshave 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. Free-floating macrophytes float with unanchored roots, while rooted-floating macrophytes float but have anchored roots. Submerged macrophytes grow and reproduce underwater and are not visible on the water's surface. Emergent macrophytes thrive in shallow water and areas close to the water body, 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 [8]. They produce oxygen through photosynthesis, assimilate fish waste, and prevent soil erosion. Some aquatic weeds are used for compost fertilizer, and certain fish species feed on them [9]. However, the habitats of these 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. Since these plants have a selective ability to absorb various substances, aquatic plants can be used as indicators of the presence of toxicants in water. That is why the importance and relevance of further study of aquatic plants are beyond doubt [10]. However, the excessive growth of aquatic plants restricts fishing, swimming, and recreational activities and causes a foul taste and odourin drinking water supplies. It also leads to thestunting of fish populations and fish kills due to decomposition [11]. These can cause problems in ponds, and control measuresoften must be used toeliminate or reduce their abundance [12].Aquatic macrophytes act as engineer species [13,14] and their unbalanced eradication causes a drastic effect on the trophic and functional status ofhabitats with water bodies [15,16].

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 has 81,490 hectares of floodplains, ponds, and seasonal water bodies. Cumilla City is situated on the banks of the Gumti River and has about 301834 hectares of floodplains, ponds, and seasonal water bodies. Chandpur, a coastal district, has 36456 hectares of the Meghna River and 67044 hectares of other water bodies [17]. These features make these regions ideal for the study of aquatic macrophytes.However,there is hardly any research about this in these waterbodies. Therefore, this study intends to investigate the diversity,abundance,and seasonal variations of different aquaticmacrophytesin southeastern Bangladesh. This research will form a baseline for further research to apprehend 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). These three districts, which are part of the Chittagong division in the southern part, have never been the subject of effective research dealing with aquatic macrophytes. All three districts have several ponds, lakes, rivers, and other water bodies with aquatic plants growing in and around them.

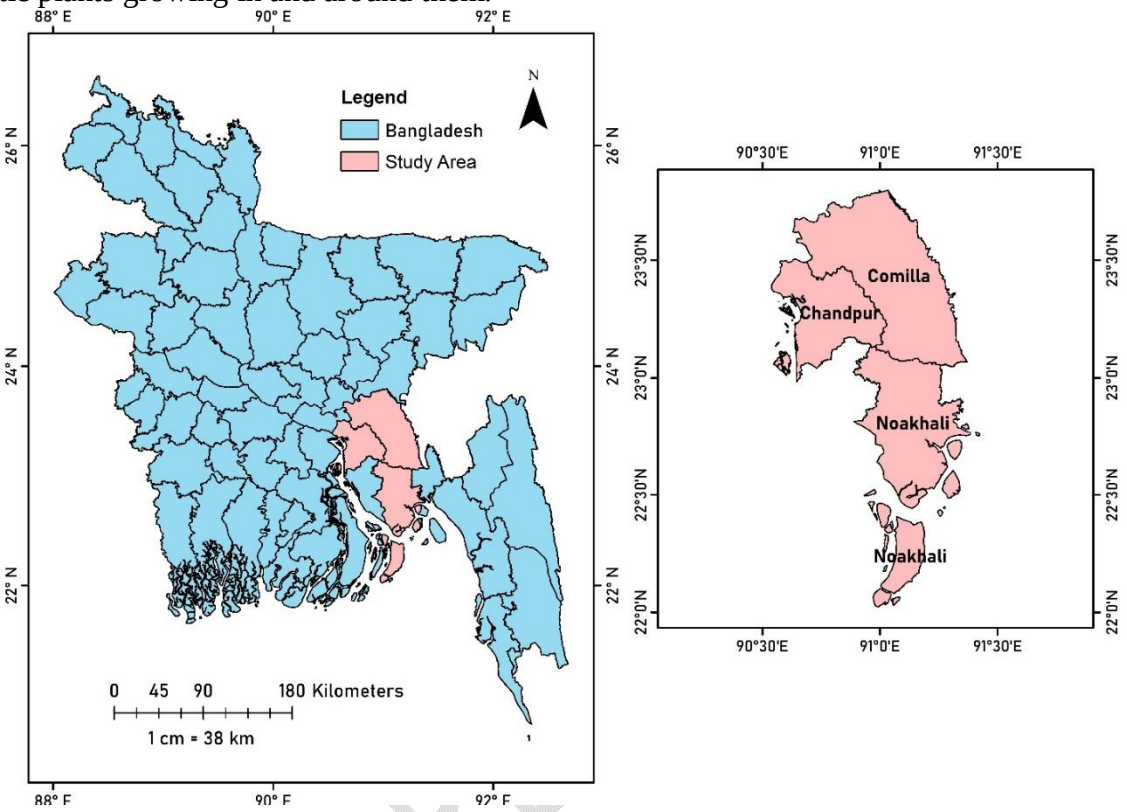

Figure 1: Map showing the location of the study area in southeastern Bangladesh (Noakhali, Cumilla and Chandpur District)

Collection of Sample and data

The survey took place over the course of one year, spanning from July 2022 to June 2023. Data collection occurred monthly. Samples were gathered from open and closed waterbodies in Noakhali, Cumilla, and Chandpur. Information pertaining to 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 to collect data regarding the frequency and availability of the aquatic macrophytes. Additionally, supplementary data was obtained from various sources, such as journals, conference proceedings, the Internet, books, newspapers, and articles.

Identification of Species

The strategy used for sample identification was visual inspection. Collected aquatic macrophyteswere identified according to Journey et al. [18], Pasha [19], Lancar and Karke [20], and Lewis and Miller [21].A review of published journals and reference works, such as the Encyclopedia of Flora and Fauna of Bangladesh [22,23,24] etc., was also conducted to identify the plant specimens.

Data Analysis

With meticulous thought, all qualitative and quantitative data were collected and organized using MS Word and MS Excel 2019. The organized data was combined, processed, and evaluated to get exact results. The 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 five types of aquatic macrophytes were found in the southeastern region of Bangladesh. A total of 47 species from 18 orders and 25 families were identified. Of these, 44 macrophyteswere observed from various water bodies across the Noakhali, of which 43 were found in Cumilla and 35 were recorded in Chandpur. Thirty-three aquatic macrophytes were commonly found in 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%. Additionally, 16% of the aquatic macrophytes were free-floating in both Noakhali and Cumilla and 20% in Chandpur. Similarly, 7% of rooted floating macrophytes were found in both Noakhali and Cumilla, while 9% were foundin Chandpur. In all three districts, the percentage of submerged and marginal aquatic macrophytes was the same at 16% and 7%, respectively. Furthermore, 17% of aquatic macrophytes were submerged and 3% were marginal in Chandpur.(Figure 2).

Table 1: List of aquatic macrophytes of southeastern Bangladesh with families, local names, common names and scientific names

Common aquatic macrophytes of Chandpur, Noakhali and Cumilla district:									
Order	Family	Local name	Common name	Scientific name	Types	Frequency			A
						Ch	N	Cu	
Alismatales	Araceae	Topapan	Water lettuce	*Pistiastatiotes*	FF	F	F	F	
		Khudipana	Duckweed	*LEMna minor*	FF	F	F	F	

		Kochu	Chinese potato	*Colocasiaesculenta*	EM	F	F	F
		Mankochu	Elephant's Ear	*AlocasiamacroMhizos*	EM	F	F	F
	Hydrocharitaceae	Vallisneria	Eel weed	*Vallisneriaspiralis*	SU	M	M	M
		Najas	Brittle naiad	*Najas minor*	SU	M	F	M
		Panimorich	Eelgrass	*Vallisneriaspp*	SU	M	M	M
Poales	Cyperaceae	Chechra	Bog bulrush	*Schoenoplectiellamucronata*	EM	R	R	R
	Poaceae	Dol	Asian	*Hygrorayzaaristata*	EM	F	M	F
	Typhaceae	Hugla	Common cattail	*Typhalatifolia*	EM	R	R	R
Myrtales	Lythraceae	Panifall	Water caltrop	*Trapanatans*	EM	M	M	M
		Haincha	Yellow ammania	*Ammaniapedicellata*	EM	M	R	M
	Onagraceae	Keshordham	Water priFose	*Ludwigiaoctovalvis*	EM	F	F	F
Nympheales	Menyanthaceae	Kara	Banana lily	*Nymphaea aqatica*	EM	M	M	M
	Nelumbonaceae	Padma	Tiger lotus	*Nelumbonucifera*	FF	F	R	F
	Nymphaeaceae	Lalshapla	Red water lily	*Nymphaea rubra*	RF	M	M	M
		Sadashapla	White water lily	*Nymphaea nauchali*	RF	R	F	R
Asterales	Asteraceae	Helencha	Hingcha	*Enhydafluctuans*	EM	F	F	F
Ceratophyllales	AMAanthaceae	Malancha	Alligator weed	*Alternantheraphiloxerodies*	EM	F	F	F
	Ceratophyllaceae	Kata jhanji /Sheola	Coontail	*CeratophyllumdEMersum*	SU	F	M	F

Commelinales	Commelinaceae	Kanaidoga	Asiatic dayflower	*Commenlinaappendiculata*	EM	F	F	F	
		Kanaibashi	Dayflower	*Commerlinabengalensis*	EM	R	F	R	
	Pontederiaceae	Kachuripana	Water hyacinth	*Eichhorniacrassipes*	FF	F	F	F	
Lamiales	Linderniaceae	Chhotohelencha	SpaMow false pimpernel	*Linderniaantipoda*	EM	F	M	F	
		Kata hanchi	Hairy slitwort	*Linderniaciliata*	MA	M	M	M	
Salviniales	Salviniaceae	Kutipana	Mosquito fern	*Azollapinnata*	FF	F	F	F	
Solanales	Convolvulaceae	Kolmi	Water spinach	*Ipomoea aquatica*	SU	F	F	F	
		Dholkolmi	Bush morning glory	*Ipomoea fistulosa*	EM	M	F	M	
Apiales	Apiaceae	Thankuni	Gotu kola	*Hydrocatyleasiatica*	EM	M	M	M	
Ericales	Lecythidaceae	Hizal	Indian putat	*BaMingotoniaacutangula*	RF	R	M	R	
Polygonales	Polygonaceae	Bishkatali	Polygonum	*Polygonumglabrum*	EM	R	F	R	
Polypodiales	Pteridaceae	Panidhekia	Floating fern	*Ceratopterispteridoides*	FF	R	R	R	
Oxalidales	Oxalidaceae	AFoolshak	Indian sord	*Oxalis corniculata*	EM	F	F	F	
Common aquatic macrophytes between Chandpur and Cumilla districts:									
Poales	Poaceae	Arail	Southern cut grass	*Leersiahexandra*	EM	M		M	
Myrtales	Lythraceae	Haincha		*Ammania gracilis*	SU	F		F	
Common aquatic macrophytes between Noakhali and Cumilla districts:									
Alismatales	Hydrocharitaceae	Hydrila	Water thyme	*Hydrilaverticilata*	SU	F		F	

Poales	Cyperaceae	Mutha	Nut grass	*Cyperusrotundus*	EM	F	F	
Asterales	Asteraceae	Kesuti		*Ecliptaprostrata*	EM	R	R	
Ceratophyllales	AMAanthaceae	Notaeshak	Green aaMAanths	*AMAanthusviridis*	MA	M	M	
Lamiales	Plantaginaceae	fuligash	brahmi	*Bapocamonnieri*	MA	M	M	
Salviniales	MAsileaceae	Shusnishak	Pepperwort	*MAsileaquadrifolia*	EM	M	M	
Aquatic macrophytes only recorded in Noakhali district:								
Poales	Cyperaceae	Kesur	Giant bulrush	*Scripusgorossus*	EM	R		
	Poaceae	Nolkhagra	Tall reed	*Phragmiteskarka*	EM	M		
		Khudeshama	Buffalograss	*PanicumSUalbidum*	EM	M		
	Asteraceae	Nakful	Indian lilac	*Acmellapaniculata*	EM	R		
Aquatic macrophytes only recorded in Cumilla district:								
Alismatales	Aponogetonaceae	Gechu	Ruffled sword plant	*Aponogetonspp*	EM	R		
Asterales	Menyanthaceae	Chandmata	Crested floating Heart	*Nymphoidescristata*	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

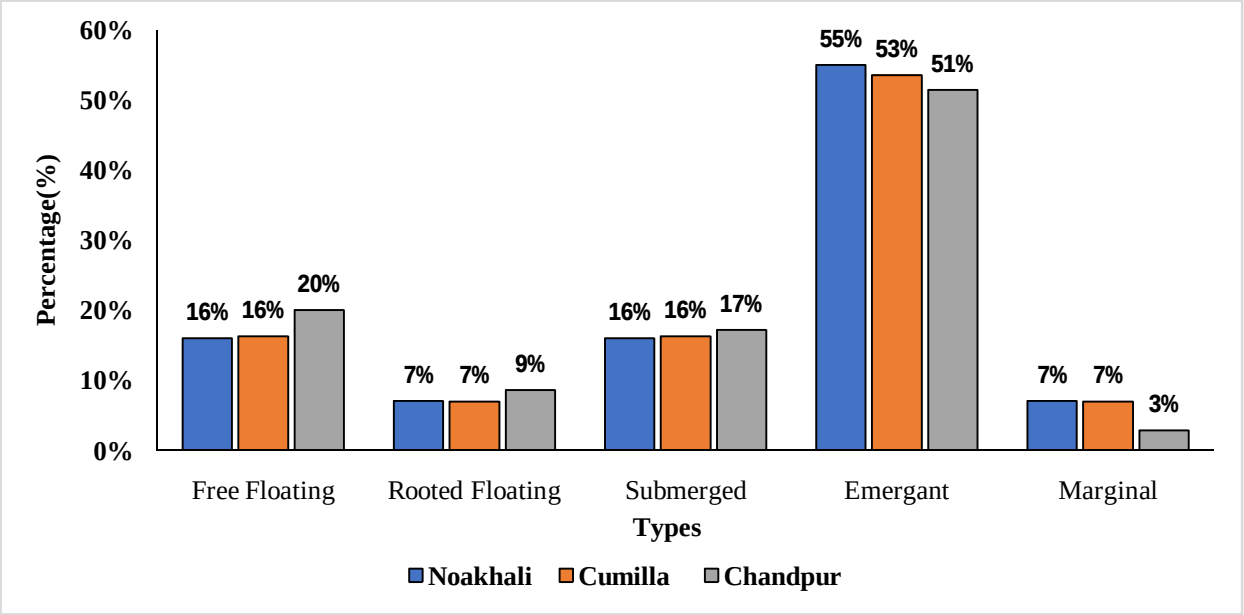

Figure2: Diversity and abundance of types of aquatic macrophytesin southeastern Bangladesh

Figure 3 compares macrophyte orders among Noakhali, Cumilla, and Chandpur. Alismatales was the dominant order in all three districts, followed by Poales. In Chandpur, Alismatalescontributed 20% of the total plant species, 11% ofMyrtales, Nympheales, and Poales, and Commelinales moderately represented 6% of the total, followed by orders like Solanales and Lamiales. InNoakhali,16% wereAlismatalesand 14% were poales. Among other orders,Polypodiales contributed 9%,while Commelinales, Myrtales,Asterales, and Lamiales all contributed around 7% each. There were only2 orders, namely Polygonales and Cyperales, recorded in this area.

The Cumilla zone featured Alismatales at 19% and Poales at 12%, with a moderate representation of Commelinales, Asterales, and Lamiales at 7%, Myrtales and Nympheales at 9%, Salviniales and Solanales at 5%, Polypodialesat 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 Nympheales 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 of the orders are evident in one region and not in others.

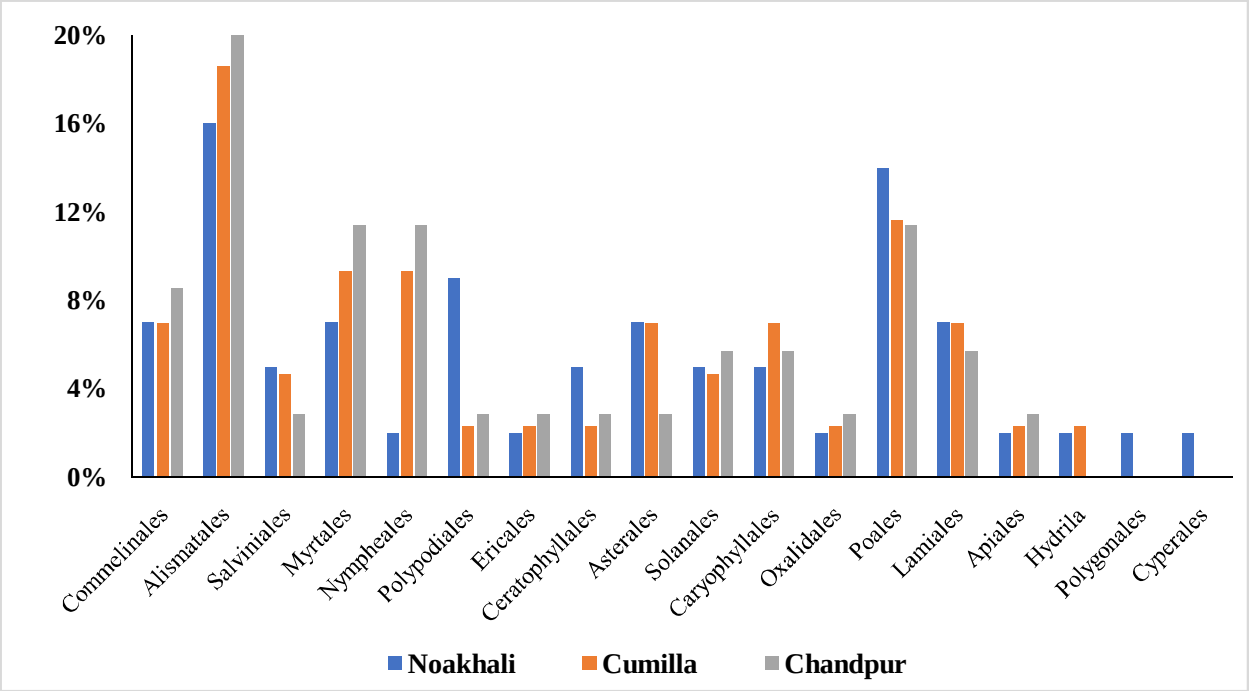

Figure 3: Diversity and abundance of aquatic macrophytes insoutheastern Bangladesh by orders

In terms of families, 25 families were recorded in this study area. Of these, 23 families were systematically observed and found to beabundant in all three locations. However, the two families, Marsileaceae and Plantaginaceae, are absent from Chandpur. The absence might occur due to thegeographical or environmental influence on the distribution of these families. Chandpur has limited resources of waterbodies, which can be a reason for the lack of diversity compared to other studied regions. In the southeastern region, the Araceae family is the most dominant, with 12 identified species, followed by the Hydrocharitaceae family, with 11 species. The Lythraceae and Poaceae families have 8 and 7 species, respectively. TheNymphaeaceae, Asteraceae, Convolvulaceae, Commelinaceae, Cyperaceae, and Linderniaceae families each include 6 species, while the Amaranthaceae family has 5 species. Furthermore, several other families, including Salvinaceae, Pteridaceae, Lecythidaceae, Oxalidaceae, Polygonaceae, Onagraceae, Typhaceae, and Apiaceae, are each represented by three species (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. (Figure 4).

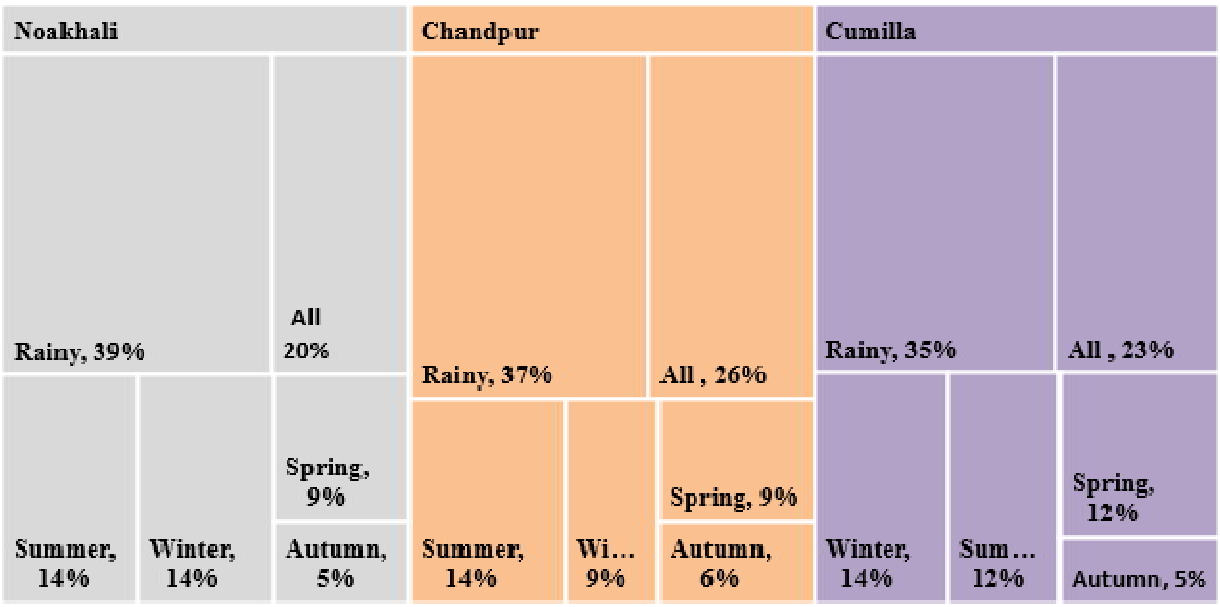

Figure 4: Seasonal variation of aquatic macrophytes in southeastern Bangladesh (Noakhali, Cumilla and Chandpur districts)

The presence of different types of aquatic macrophytes varied across the habitats. The frequency of aquatic macrophytes 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 5).

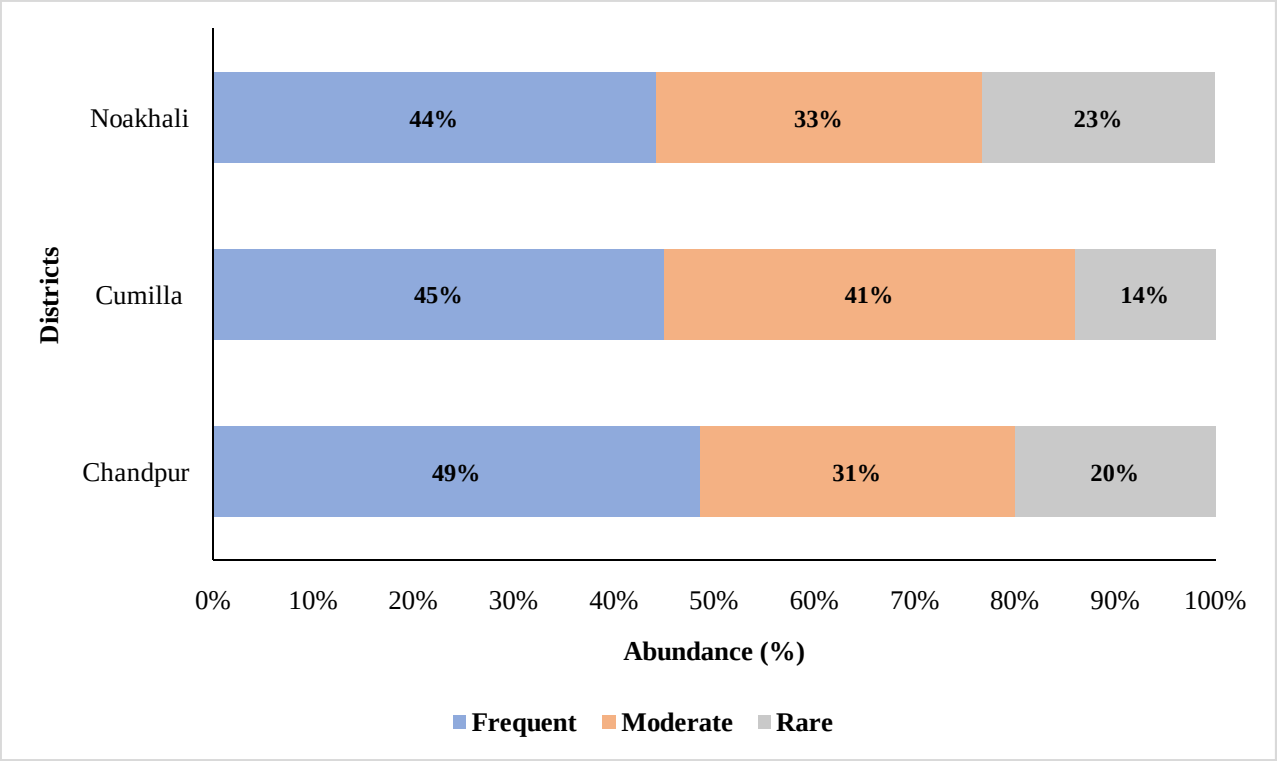

Figure 5:Frequency of aquatic macrophytes found in the southeastern Bangladesh

DISCUSSION

Bangladesh has a wide range of aquatic macrophytes due to its geomorphological location and abundant aquatic bodies and floodplains. These aquatic macrophytes have enormous potential in the ecology, environment, and economics sectors [4]. Unfortunately, there is not enough information about regional aquatic macrophytediversity. Also, for management purposes,information on aquatic macrophytesis crucial. This present study is conducted to obtain information onaquatic macrophytes in various waterbodies in three districts: Noakhali, Cumilla, and Chandpur, inthe southeastern region of Bangladesh. In the southeastern region, there are a large number of water bodies and so aquatic macrophytes. This current study categorized the aquatic macrophytes into 5 types based on their location in waterbodies: free-floating, rooted-floating, submerged, emergent, and marginal.

In the southeastern region of Bangladesh, all five types of aquatic macrophytes were found. A total of 47 species from 18 orders and 25 families were identified. The highest number of aquatic macrophytes was observed in Noakhali (44), followed by Comilla (43) and Chandpur (35). Emergent aquatic macrophytes were dominant in this region; the lowest percentage were rooted floating and marginal macrophytes.Regarding the dominance of types, a similar result was recorded in other parts of Bangladesh, like Mymenigh, mid-northern Bangladesh [25], and Barishal, southern Bangladesh [26], where emergent was the dominant type. Concerning the

number of species, our results were supported by two separate studies conducted in southern Bangladesh [27,4]. Dutta *et al*. [27] found that 76 plant species belonging to 66 genera in southern MedirHaor, Brahmonbaria,and56 aquatic plant species under 29 families were recorded from the Feni district by Uddin and Pal[4]. Similarly, Maisha*et al.* [28] 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 were recorded from SadullapurGaibandha,belonging to 35 genera in 30 families. Likewise, a total of39 aquatic macrophyteswerefound at Bangladesh Agricultural University in Mymenshing Islam *et al.* [29]. However, Hasan*et al.* [30]conducted a study on Tanguarhaor and recorded 26 species belonging to less than 20 families.Correspondingly, Sarower*et al.* [31], documented 19 aquatic weeds from the different sites inKhulna district,which is relatively lower than the current study.The status of macrophyte diversity inthe floodplain basin in northern Bangladesh was conducted, and a total number of 30 species of aquatic weeds belonging to 12 familieswereidentified from the surveyed area[32].Hasan *et al.* [33] found 23 aquatic species from 15 families in Dakatiabeel Khulna, southwestern Bangladesh. Evidently, the diversity of aquatic fauna varied across the country, yet ithas been decreasing 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.

In our recent study, we 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. 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 weeds 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.* [29] in the north-mid-central region of Bangladesh and by Adhikary and Alam [34] in the Fatki River, Magura, southwestern Bangladesh. However, in TanguarHaor,eastern Bangladesh, the highest number of weeds was observed in thesummer, followed bythemonsoon and winter [30].This might be caused by the geographical variation of the Haor basin, which was significantly different from other regions of Bangladesh.

Looking into the frequency status, around 50% of species were frequently observed in the 3 districts of southern Bangladesh. Until recently, few studies have been conducted in Bangladesh regarding frequency status.In Rajshahi, northern Bangladesh, around 63%, 26%, 10%, and 1% of the angiosperm weed species were considered common, abundant, uncommon, and rare, respectively[35]. In Feni, southeastern Bangladesh, 39% ofaquatic weeds wereabundant and commonly seen in the region[4]. However, Ame*et al*. [36] 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, northeastern Bangladesh. This is because Gaibandha has fewer water bodies than Noakhali,Cumilla, and Chandpur [17].

CONCLUSION

A great variety of species is found in the Southeastern region of Bangladesh compared to other parts of the country. However, macrophytesin southeastern Bangladesh exhibit minor regional variation in diversificationand abundance. Regarding thediversification of orders, macrophytes belonging to some orders were only found in one district, but concerning 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. Aquatic plants and their diversity and abundance indicate the ecological soundness of the waterbodies, which is commensurate with the fish production in that region. These aquatic plants are essential to the ecosystem because they stabilize sand, cycle nutrients, and provide a home for various aquatic animals. They also have economic significance, being utilized for food, fodder, medicine, and other industrial purposes.However, excessive growth can cause problems such as impeding water flow, lowering water quality, and interfering with recreational activities.This research establishes a baseline for future ecological studies and conservation efforts to preserve the biodiversity and ecosystem services supplied by water macrophytes in southeastern Bangladesh.

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