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A FLORISTIC AND ECOLOGICAL STUDY ON THE PTERIDOPHYTES OF SUNDARBANS MANGROVE FOREST OF BANGLADESH

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Abstract

This study shows that the pteridophytic flora of Sundarbans mangrove forest of Bangladesh (SMFB) is comprised of 21 species belonging to 18 genera under 12 families including one dubious genus and species. Only one species was recognized as true mangrove, 12 species as mangrove-associate and 8 species as non-mangrove in nature. All genera (except *Ceratopteris* and *Salvinia*) of pteridophytes found in SMFB were monospesific. 18 species were recorded from oligohaline zone (OZ), 16 species from mesohaline zone (MZ) and nine species from polyhaline zone (PZ). Seven species were found to be distributed in all saline zones. Density and species richness of pteridophytes was higher in oligohaline zone than that in mesohaline or polyhaline zones. Similarly, the Shannon-Wiener diversity index value, ranged from 1.476 to 2.413, exhibited the trend of gradual decreasing from oligohaline to polyhaline zone. According to DAFOR scale of frequency classes 18 species belonged to rare category and only three species namely, *Acrorstichum aureum*, *Microsorum punctatum* and *Pyrrosia nuda*, to occasional category. Based on IUCN Red List criteria, 10 species were recognized under data deficient (DD) category and seven species under the least concern (LC) category. Three species, namely *Asplenium polyodon*, *Psilotum nudum* and *Ophioglossum reticulatum* belonged to critically endangered (CR), endangered (EN) and vulnerable (VU) categories respectively based on IUCN criteria.

Introduction

Pteridophytes are the most primitive (Upertil *et al.*, 2009; Ashwini and Prashurama, 2014), non-flowering and spore-bearing vascular plants (Kamau, 2012; Dudani *et al*., 2012), have graced our planet for hundreds of millions of years (Iltaf *et al*., 2012), which originated in the Silurian period of 438 million years ago and flourished well during Devonian Mississippian and Pensylvanian periods of the late Paleozoic (Ashwini and Prashurama, 2014). Pteridophytes form a connecting link between the lower cryptograms and higher vascular plants (Dudani *et al*., 2012).

Pteridophytes are perennial and commonly terrestrial herbs and may take the form of twining vines, floating, epiphytes or and they may hug the ground or grow as tall tree as 16 m height (e.g. *Cyathea*) (Hogan, 2004). They are cosmopolitan; prefer shady, moist habitats with moderate temperature but also occur throughout a very diverse range of habitats (Upertil *et al*., 2009) from sea level to the highest mountains (Dixit, 2000). Their worldwide occurrence (Tryon and Tryon, 1982; Windisch, 1990) and the dominance pattern are known as the latitudinal gradient of biological diversity, the number of species per unit of area increases from both poles toward the equator (Moran, 2008). Pteridophytes are diverse, estimated to a tune of 15,000 species (Chapman, 2009), and most of which (13,000-13,600) are known all around the world. The tropical parts of the world are relatively higher in the pteridophyte species diversity when compared to others (Tryon and Tryon, 1982; Moran, 2008). The pteridophytic flora of Southeast

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Asia is remarkably rich as demonstrated by the fact that an estimated 4,500 species, more than one third of the world's diversity (Moran, 2008). For example, South and Central America have c. 3,000 species, South-Eastern Asia and adjacent islands have c. 4,500 species whereas mainland Africa and the adjacent Madagascar Island have c. 1,300 species.

Pteridophytes are useful in medicine (Dixit, 1975; Benjamin and Manickam, 2007) and bio-fertilizer production (Ahluwalia *et al*., 2002), wastewater treatment (Sanyahumbi *et al*., 1998; Vermaat and Hanif, 1998; Nichols *et al*., 2000; Ma *et al*., 2001; Olguín *et al*., 2007; Suné *et al*., 2007) as well as in ornamental (Dixit, 2000) and decoration purposes (Dudani *et al*., 2012). Due to the great economic, ecological and evolutionary importance, many research works on pteridophytes have been performed worldwide including many Asian countries (e.g. Lee, 2009; Japanese Ministry of Environment, 2007; Wang, 2010; Fernando *et al*., 2008; Lindsay and Middleton, 2010; Chandra *et al*., 2008 etc.). But in Bangladesh, this group is neglected (Sarker and Hossain, 2009) and excluded from most of the floristic studies (Uddin and Hassan, 2012). Prain (1903) was the first person who enumerated 98 taxa of fern from the then East Bengal (present Bangladesh).

After the independence of Bangladesh, only a very few studies on the fern flora have been done (e.g., Pasha and Mallick, 1980; Pasha and Chakraborty, 1984; Pasha, 1985; Mirza, 1996; Mirza and Rahman, 1997; Uddin and Pasha, 1997, 2002, 2007; Uddin, 2001; Mirza and Pasha, 2007; Sarker, 2009; Sarker and Hossain, 2009; Uddin and Hassan, 2012). Most of these works were based mainly on the survey of available literatures and examination of deposited voucher specimens at different herbaria, though few were based on field survey and emphasized on their specific uses. The Sundarbans mangrove forest of Bangladesh (SMFB) is a unique ecosystem of the world and remarkably important for its floral and faunal composition, wildlife habitats, and ecological values due to which it was declared by UNESCO as the world's 560th Ramsar Wetlands Site and 798th World Heritage Site in 1992 and 1999, respectively (Hossain, 2013). After Prain (1903) no literature on the pteridophytic flora of this mangrove forest with an emphasis on their taxonomy and/or ecology has yet been published. Hence, the present study was carried out to generate recent taxonomic and ecological information on the pteridophytes of SMFB based on field survey.

Materials and Methods

Study area: The Sundarbans is the single largest chunk of productive mangrove forest ecosystems in the world (Das and Siddiqi, 1985; Hussain and Acharya, 1994; Iftekhar, 1999; Rahman, 2003) which is located in south of the Tropic of Cancer at the northern limits of the Bay of Bengal and may be classified as tropical moist forests, covering a vast area of about 10,029 km^2 in the territory of Bangladesh and India (Hussain and Acharya, 1994). Bangladesh Sundarbans lies between latitudes 21°30′N and 22°30′N and longitudes 89°00′E and 89°55′E (Fig. 1; Hussain and Acharya, 1994; Hoq, 2008; Rashid *et al*., 2008) covering a total area of about 6,017 km^2 which is composed of 4,143 km^2 (Katebi, 2001) and water bodies of 1874 km^2 in the forms of complex network of rivers, canals and tidal creeks (Wahid, 1995; Iftekhar and Islam, 2004). The studied area have been categorized on the basis of salinity scale into three saline zones, i.e., oligohaline (<5 ppt), mesohaline (5-10 ppt) and polyhaline (>10 ppt) zones (Karim, 1998).

Specimens collection and data analysis: The present investigation was conducted throughout the Sundarbans mangrove forest of Bangladesh (SMFB) during 2010 to 2014 covering all saline zones and administrative units. Representative specimens of different pteridophytes growing in the SMFB were collected following standard quadrat methods (Braun-Blanquet, 1932; Raunkiaer, 1934) and herbarium techniques. The quadrat size 10 m × 10 m was standardized on the basis of species-area-curve method (Cain, 1938). Altogether 300 quadrats were applied for numerical

estimation of pteridophyte species. In case of epiphytic species grown on a tree was considered as an individual and in hydrophytic form, each colony of a species was considered as an individual. Collected plant specimens were processed and preserved following standard herbarium techniques (Jain and Rao, 1977; Alexiades, 1996) and deposited at the Herbarium of Botany Department of Jahangirnagar University (JUH), Savar, Dhaka.

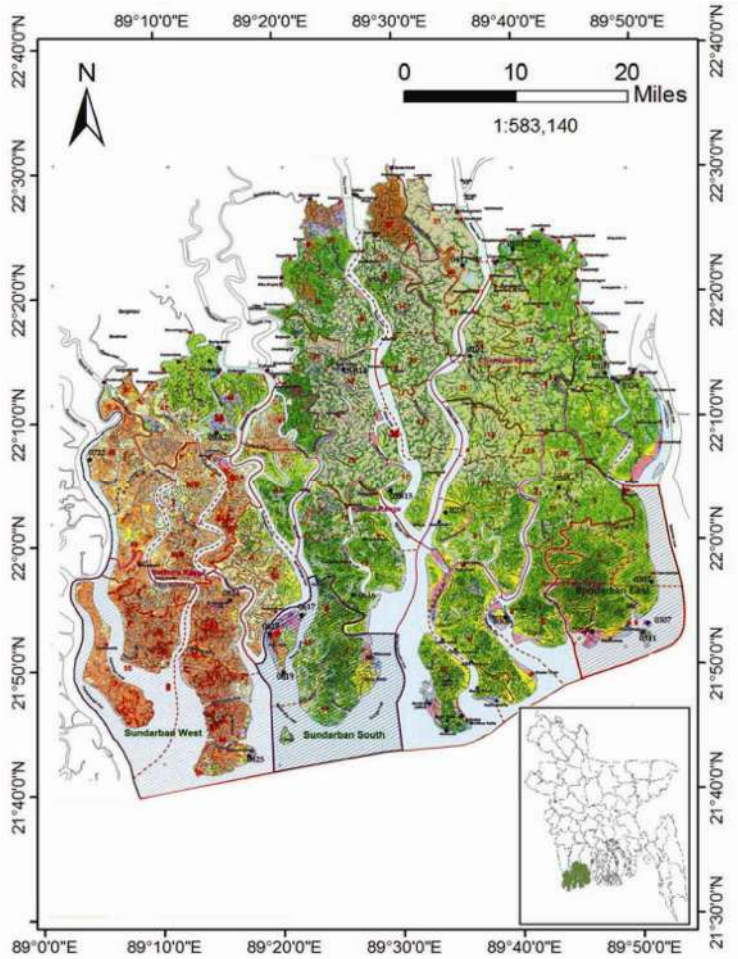

Fig. 1. Map of Sundarbans mangrove forest.

All plant specimens collected from the study area were identified through consulting the experts, following taxonomic keys, and matching with relevant voucher specimens preserved at JUH and Bangladesh National Herbarium (DACB), taxonomic descriptions in the relevant literatures (Prain, 1903; Ghosh *et al.*, 2004; Mirza and Pasha, 2007 etc.) and type images available in the websites of different international herbaria. The taxonomic keys for the identification of the families, genera and species have been constructed based on easily visible morphological characters of representative specimens.

Density and frequency of the pteridophytes were determined by using the formulae described by Shukla and Chandal (1993) and Verma and Agarwal (1986). DAFOR (dominant, abundance, frequent, occasional and rare) scale as described by Kent and Coker (1992) was applied for the

determination of existing status of the recorded climber species. Jackknife species richness of the studied sites was estimated through the following formula (Helteshe and Forrester, 1983):

$$\hat{S} = s + \left(\frac{n-1}{n} \right)^k$$

where, $\hat{S}$ = Jackknife estimation of species richness,

s = Observed total no. of species present in *n* quadrats,

n = Total no. of quadrats sampled,

k = No. of unique species.

Shannon-Wiener diversity index of the recorded undergrowth plants of different selected sites was calculated through the following formula described by Kent and Coker (1992).

$H' = -\Sigma \text{ pi ln pi}$

where, H′ = Shannon-Wiener diversity index,

pi = The proportion of individuals or the abundance of the ith species,

ln = Log base$_n$.

Red list categories of the recorded pteridophytes were determined following the guidelines of IUCN (2013).

Results and Discussion

Floristic composition: In this study a total of 21 species of Pteridophytes belonging to 18 genera and 13 families were found in the SMFB (Table 1; Plates 1-3). During this study all genera of Pteridophytes found in SMFB were monospecific except the genus *Ceratopteris* and *Salvinia*. The taxonomic keys to the families and genera of all Pteridophytes and species of *Ceratopteris* and *Salvinia* have been provided below for the identification of the Pteridophytes of SMFB.

Key to the families and genera of pteridophytes in SMFB

1		Plants free-floating; fronds small, simple or bilobed; vegetative reproduction by fragmentation.....……..…….**2**
+		Plants rooted in soil, mud, or on rocks or epiphytic; fronds large, simple or pinnately divided; vegetative reproduction is not by fragmentation……..…….**3**
2	(1)	Fronds in whorls, not in rows or overlapping; two fronds per whorl floating and the third one submerged; large (□7 mm long); sporocarps clustered at stripe bases of submerged frond……**Salviniceae (*Salvinia*)**
+		Fronds usually in 2 rows and overelapping; upper fronds floating and lower fronds submerged; small (≤1mm long); sporocarps usually in pairs at base of floating fronds……...**Azollaceae (*Azola*)**
3	(1)	Rhizome erect, not stoloniferous…..……..**4 (Pteridaceae)**
+		Rhizome creeping, stoloniferuis……...…….……...**7**
4	(3)	Sori along veins or over most of abaxial surface of lamina or immersed in grooves…….……..…….....**5**
+		Sori continuous along most of length of pinnae along commissural vein or near the costa…..……..……..…..……...…**6**
5	(4)	Fronds simple, linear; stipe short, stout; costa not prominent; spores monolete…..……***Haplopteris***
+		Fronds pinnate, lanceolate; stipe long, flexible; costae strongly raised abaxially; spores tetrahedral-globose…….....…..*Acrostichum*
6	(4)	Plants succulent, aquatic; lamina simple or pinnate, entire……....***Ceratopteris***
+		Plants not succulent, terrestrial; lamina pinnate, pectinately divided into segments……***Pteris***

7 (3)	Leaves divided into 4 equal lobes at the end of a long stalk; spores borne in a capsule like sporocarp…..……..…**Marsileaceae (*Marsilea*)**
+	Leaves pinnate or pinnately lobed or compound; spores borne in thin-walled sporangia……...……**8**
8 (7)	Plants epiphytic.....……...……....**9**
+	Plants terrestrial …….....…..…..**13**
9 (8)	Sori rounded, scattered on abaxial surface of frond...……..**10 Polypodiaceae**
+	Sori linear, exist on costa or margin of frond……..……**Aspleniaceae (*Asplenium*)**
10 (9)	Fronds with stellate hairs…....…….……...……...…...***Pyrrosia***
+	Fronds with scales, unbranched, glandular and/or forked hairs, or glabrous…….**11**
11 (10)	Lamina pinnatified; sori in two rows between costa and margin ……....***Drynaria***
+	Lamina simple; sori irregularly scattered or subparallel from costa to margin…….....**12**
12 (11)	Sori orbicular, irregularly scattered from costa to margin…….....***Microsorum***
+	Sori elongated, subparallel from costa to margin……..**Dubious genus**
13 (8)	Sporangia in the axil of a forked leaf; fused in groups of 2 or 3; aggregated in the axils of spophylls (often in cone-like structures).....**14**
+	Sporangia laminal or marginal; free and scattered or in clusters; aggregated into a spike or enclosed in seven sessile or stalked receptacles...…..…….....…..….....**15**
14 (13)	Sporangia homosporous, born in the axils of forked leaf……..**Psilotaceae (*Psilotum*)**
+	Sporangia heterosporous, borne in the axils of sporophylls (often in cone-like structures) or in swollen leaf bases……**Selaginellaceae (*Selaginella*)**
15 (13)	Fronds comprised of sterile lamina and fertile spike arising from base of sterile lamina.....**Ophioglossaceae (*Ophioglossum*)**
+	Fronds comprised of sterile or fertile lamina borne separately on the rhizome……..**16**
16 (15)	High-climbing plant; sori borne on marginal projections of pinnules…..**Lygodiaceae (*Lygodium*)**
+	Plants not climbing; sori borne on the the underside of lamina ……**17**
17 (16)	Sori exist only in vains, exindusiate……**Thelypteridaceae (*Ampelopteris*)**
+	Sori scatterd on whole abaxial surface, acrostichoid….....**Blechnaceae (*Stenochlaena*)**

Key to the species of *Ceratopteris*:

1	Plants rooting in silt; sterile frond varied in form; stipe base unexpanded; fertile fronds taller than sterile ones, lamina oblong or ovate-triangular	***C. thalictroides***
+	Plants not rotting in silt; sterile frond simple to pinnatifid to pinnate; stipe base much expanded; fertile fronds not taller than sterile ones, lamina broadly triangular	***C. thalictroides***

Key to the species of *Salvinia*:

1	Hairs on papillae on upper surface of floating leaves are in regular row	**2**
+	Hairs on upper surface of floating leaves are irregularly scattered, not in row	***S. cucullata***
2 (1)	Frond papillae dome-shaped, each ending in a tuft of free multicellular hairs; sporocarps clustered at base of submersed frond	***S. natans***
+	Frond papillae cylindrical, each ending in a group of (2-) 4 multicellular hairs joined at their tips; sporocarps in long straight chains	***S. molesta***

Table 1. Species composition and ecological aspects of pteridophytic plant species recorded from the SMFB during 2010-2014.

Sl. No.	Scientific name	Family	Habit	Status	Distribution	Red list status	Use	Voucher specimens
1	*Acrostichum aureum* L.	Pteridaceae	TEH	M	OZ-PZ	LC	EM	*Mosharof 3, Sayedur1123*
2	*Ampelopteris prolifera* (Retz.) Copel.	Thelypteridaceae	TEH	MA	OZ-PZ	DD	EM	*Mosharof 413, Sayedur 1326*
3	*Asplenium polyodon* G. Forst.	Asleniaceae	EH	MA	OZ	CR	EM	*Mosharof 24, Sayedur 1037*
4	*Azolla pinnata* R. Br.	Azollaceae	AH	NM	OZ-PZ	DD	EM	*Mosharof 414, Sayedur 1293*
5	*Ceratopteris pteridoides* (Hook.) Hieron.	Pterideaceae	AH	NM	OZ-PZ	DD	VG	*Mosharof 415, Sayedur 1107*
6	*Ceratopteris thalictroides* (L.) Brongn.	Pterideaceae	AH	NM	OZ-PZ	LC	VG	*Mosharof 416, Sayedur 396*
7	*Drynaria quercifolia* (L.) J. Sm.	Polypodiaceae	EH	MA	OZ-PZ	LC	EM	*Mosharof 34, Sayedur 17*
8	*Haplopteris elongata* (Sw.) E.H. Crane	Pteridaceae	EH	MA	OZ-PZ	LC	EM	*Mosharof 417, Sayedur1256*
9	*Lygodium flexuosum* (L.) Sw.	Lygodiaceae	TCH	NM	OZ-MZ	DD	EM	*Mosharof 141, Sayedur188*
10	*Marsilea quadrifolia* L.	Marsileaceae	AH	NM	OZ-PZ	DD	EM	*Mosharof 143, Sayedur1193*
11	*Microsorum punctatum* (L.) Copel.	Polypodiaceae	EH	MA	OZ-PZ	LC	EM	*Mosharof 418, Sayedur 360*
12	*Ophioglossum reticulatum* L.	Ophioglossaceae	TEH	MA	MZ-PZ	VU	EM	*Mosharof 155, Sayedur 603*
13	*Psilotum nudum* (L.) P. Beauv.	Psilotaceae	EH	MA	MZ	EN	EM	*Mosharof 61, Sayedur 1242*
14	*Pteris vittata* L.	Pteridaceae	TEH	MA	OZ-PZ	DD	EM	*Mosharof 419, Sayedur 261*
15	*Pyrrosia nuda* (Giesenh.) Ching	Polypodiaceae	EH	MA	OZ-PZ	LC	EM	*Mosharof 177, Sayedur16*
16	*Salvinia cucullata* Roxb.	Salviniaceae	AH	NM	OZ-MZ	DD	BF	*Mosharof 186, Sayedur1198*
17	*Salvinia molesta* D.S. Mitch.	Salviniaceae	AH	NM	OZ	DD	BF	*Mosharof 420, Sayedur1085*
18	*Salvinia natans* (L.) All.	Salviniaceae	AH	NM	OZ-MZ	DD	BF	*Mosharof 421, Sayedur1108*
19	*Selaginella vaginata* Spring	Selaginellaceae	TEH	MA	OZ-PZ	DD	EM	*Mosharof 422, Sayedur1223*
20	*Stenochlaena palustris* (Burm. f.) Bedd.	Blechnaceae	TCH	MA	OZ-MZ	LC	VG	*Mosharof 71, Sayedur 336*
21	Dubious species	Polypodiaceae	EH	MA	OZ-PZ	LC	EM	*Mosharof 423, Sayedur18*

Legends: TEH = terrestrial erect herb, TCH = terrestrial climbing herb, EH = epiphytic herb, AH = aquatic herb; M = mangrove, MA = mangrove associate, NM = non mangrove; OZ = oligohaline zone, MZ = mesohaline zone, PZ = polyhaline zone; LC = least concern, EN = endangered, DD = data deficient, VU = vulnerable; EM = ethno-medicine, VG = vegetable, BF = Bio-fertilizer.

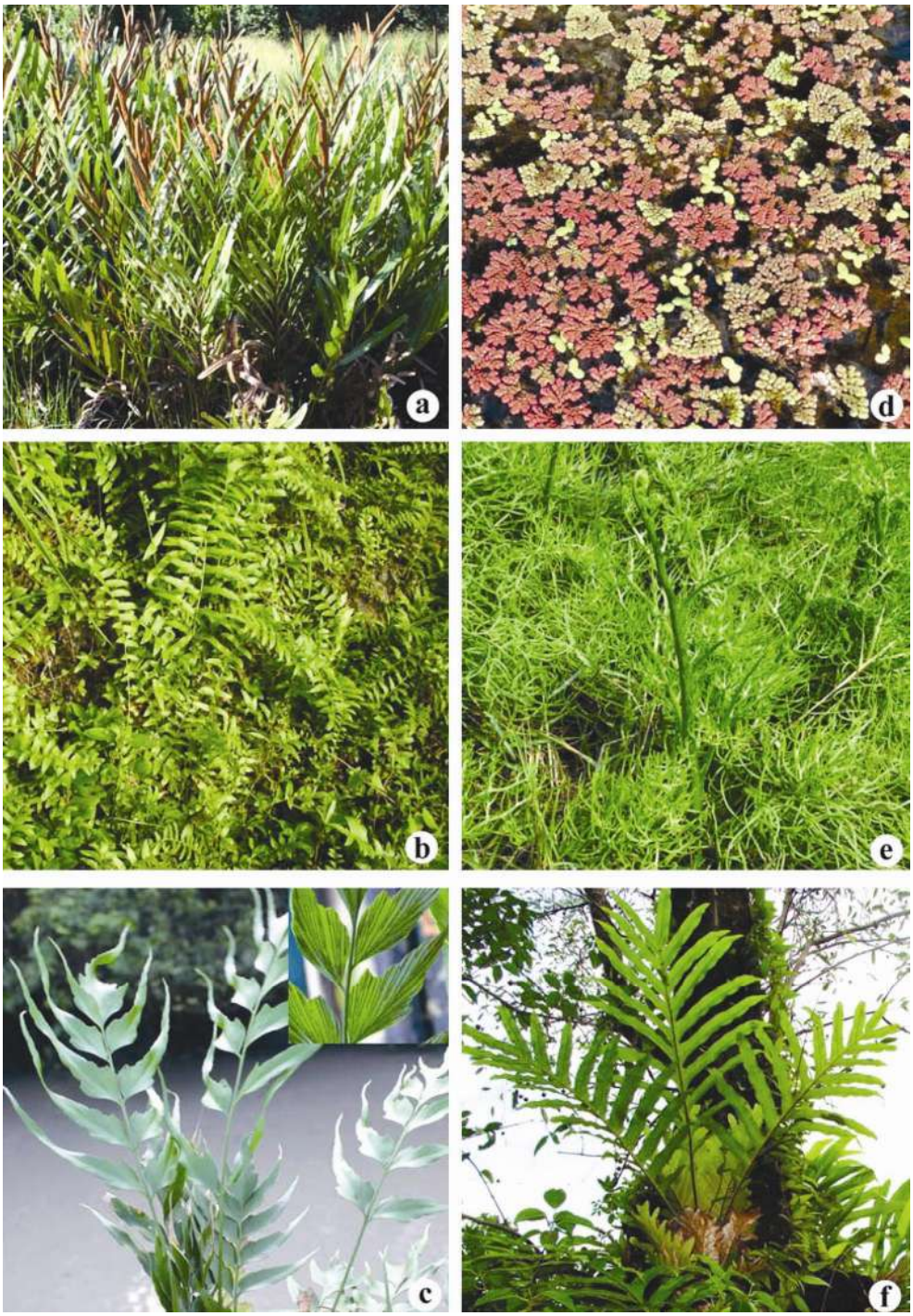

Plate 1: a. *Acrorstichum aureum*, b. *Ampelopteris prolifera*, c. *Asplenium polyodon*, d. *Azolla pinnata*, e. *Ceratopteris thalictroides* and f. *Drynaria quercifolia*.

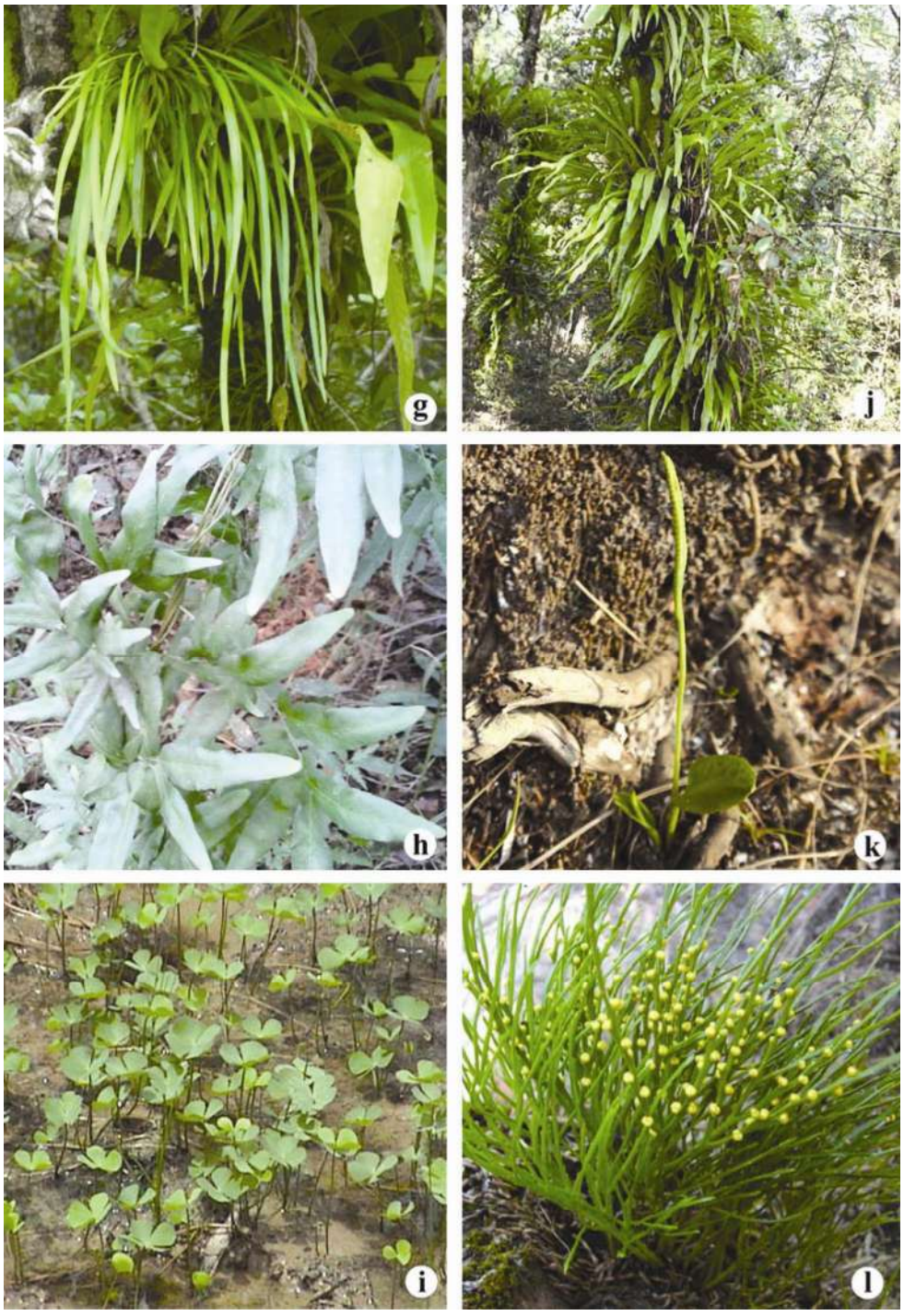

Plate 2: g. *Haplopteris elongata,* h. *Lygodium flexuosum,* i. *Marsilea quadrifolia*, j. *Microsorum punctatum,* k. *Ophioglossum reticulatum* and l. *Psilotum nudum.*

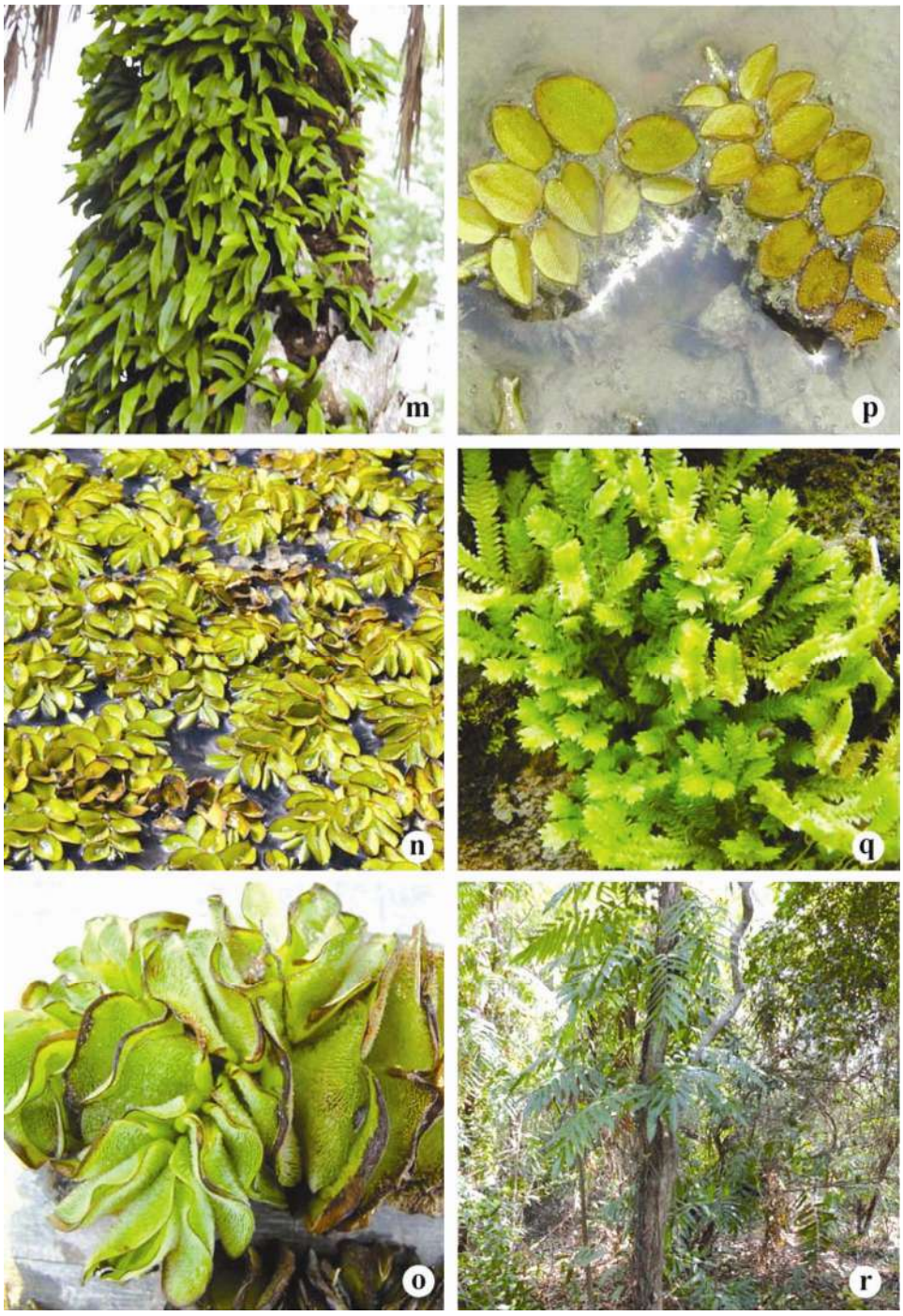

Plate 3: m. *Pyrrosia nuda*, n. *Salvinia cucullata*, o. *Salvinia molesta*, p. *Salvinia natans*, q. *Selaginella vaginata* and r. *Stenochlaena palustris*.

Out of 12 families recorded, the highest number of species (4) was represented by each of the families of Polypodiaceae and Pteridaceae which was followed by Salvinaceae (3), whereas each of the families Aspleniaceae, Azollaceae, Blechnaceae, Lygodiaceae, Marsileaceae, Ophioglossaceae, Psilotaceae, Selaginellaceae and Thelypteridaceae was found to be represented by only one species (Fig. 2). Among the Pteridophytes of SMFB, the aquatic and epiphytic forms were consisted with 7 (33.33%) species each. The terrestrial Pteridophytes were found to be represented by 7 (33.33%) species including 5 (23.81%) species of erect herb and 2 (9.52%) species of climber. Only one species of Pteridophyte was found as true mangrove, 12 species as mangrove-associate and 8 species as non-mangrove (Table 1). These findings are mostly similar to the findings of Prain (1903) but contrasting with the findings of Pasha (2003). Prain (1903) reported 17 pteridophytic species from the entire Sundarbans and its adjacent areas, whereas Pasha (2003) reported only eight species from the Bangladesh Sundarbans.

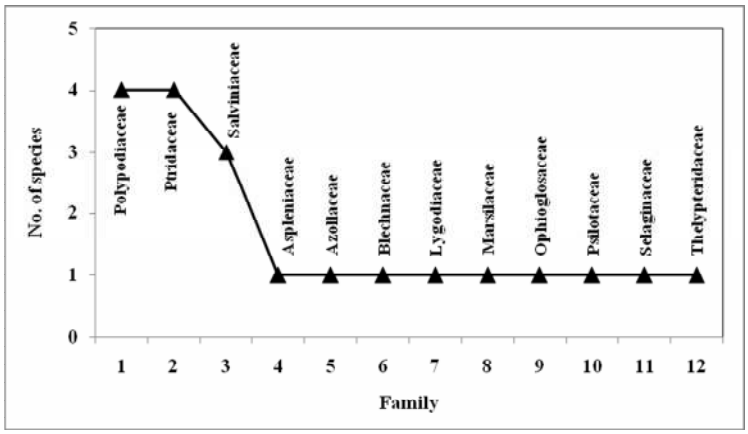

Fig. 2. Family-wise species composition of the pteridophytes of SMFB.

Ecological aspects

Density and frequency: The highest density value (2970.86/ha) was recorded from oligohaline zone which was followed by mesohaline (2482.90/ha) and polyhaline zones (1463.90/ha) respectively (Fig. 3). The highest frequency value (28%) was found for *Acrorstichum aureum*, which was followed by *Microsorum punctatum* (24.33%), *Pyrrosia nuda* (20.33%), *Drynaria quercifolia* (8%), whereas the lowest frequency value (0.33%) for each of the species *Asplenium polyodon*, *Psilotum nudum* and *Salvinia molesta* (Fig. 4). According to DAFOR scale of frequency classes the maximum number of species (18) was found in rare category that exhibited less than 20% frequency level and only three species namely, *Acrorstichum aureum*, *Microsorum punctatum* and *Pyrrosia nuda*, were represented in occasional category with exhibiting 20-40% frequency range. Other categories of DAFOR scale were not found due to their narrow distribution in specific saline zone as well as small size of population irrespective of total floristic composition.

Species richness and diversity index: The highest index value (18.90) of Jackknife species richness was found in oligohaline zone, which was followed by 16.96 and 9.97 respectively from mesohaline and polyhaline zones (Fig. 5). Similarly, the Shannon-Wiener diversity index value, found to be ranged between 1.476 and 2.413, exhibited a trend of gradual decreasing from oligohaline to polyhaline zone.

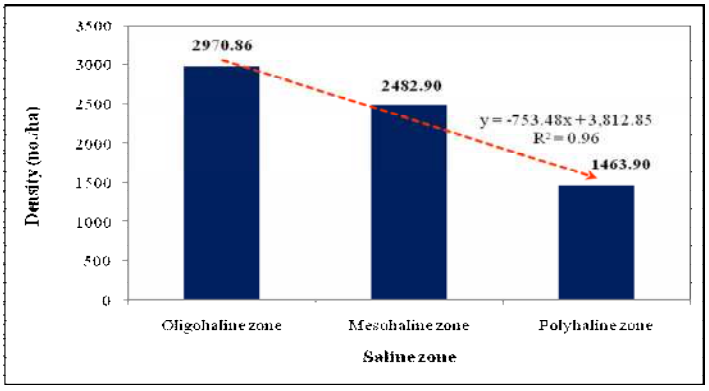

Fig. 3. Density values of pteridophytes in different saline zones of SMFB.

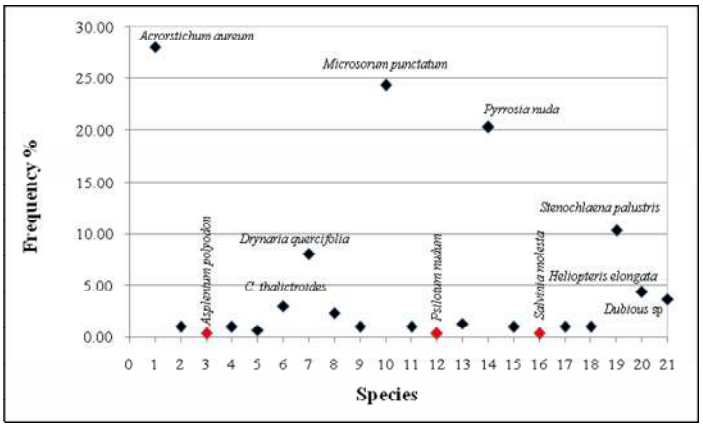

Fig. 4. Frequency percentage of the recorded pteridophytes of SMFB.

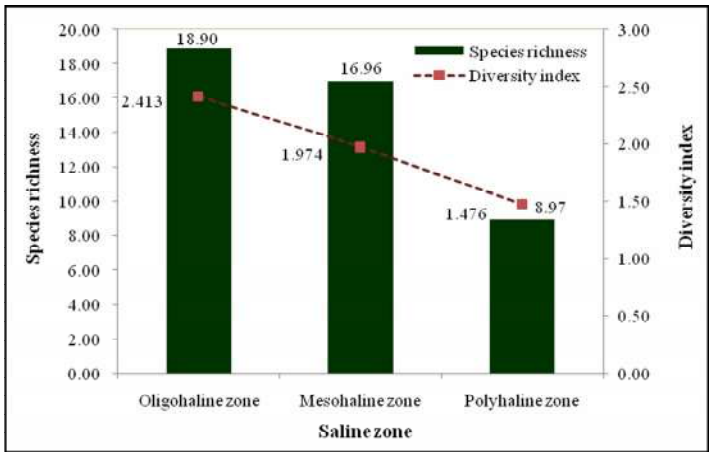

Fig. 5. Jackknife species richness of the pteridophytes recorded from different saline zones of SMFB.

Distribution of pteridophytes in different saline zones of SMFB was different but with similar pattern of occurrence, i.e., in higher number in the oligohaline zone and gradually in lower number towards the polyhaline zone. Out of 21 species of pteridophytes found throughout SMFB, 18 were recorded from oligohaline zone (OZ) 16 species from mesohaline zone (MZ) and nine species from polyhaline zone (PZ) (Fig. 6). Seven pteridophytic plant species (e.g., *Acrorstichum aureum*, *Ceratopteris thalictroides*, *Drynaria quercifolia*, *Microsorum punctatum*, *Pyrrosia nuda* and a dubius species of polypodiaceae family) were found to be distributed in all saline zones which mean that these species are adapted to all ranges of saline habitats. Six species were found to occur in both OZ and MZ and only one species in both MZ and PZ which indicate that these species have a narrow range of adaptation in term of salinity level. Few pteridophytic species, *viz*., *Asplenium polyodon* (sl. no. 3), *Salvinia molesta* (sl. no. 17) and *Psilotum nudum* (sl. no. 13), were found to be distributed in very restricted zone of SMFB (Table 1). The spatial distribution pattern of different pteridophytic species has been shown in Fig. 7.

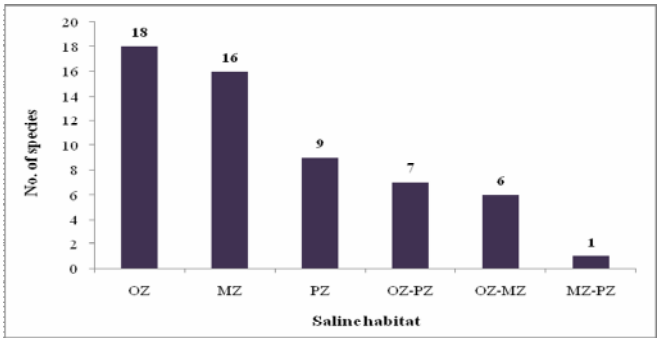

Fig. 6. Distribution pattern of pteridophytes in different saline habitats of SMFB (OZ = oligohaline zone, MZ = mesohaline zone, PZ = polyhaline zone).

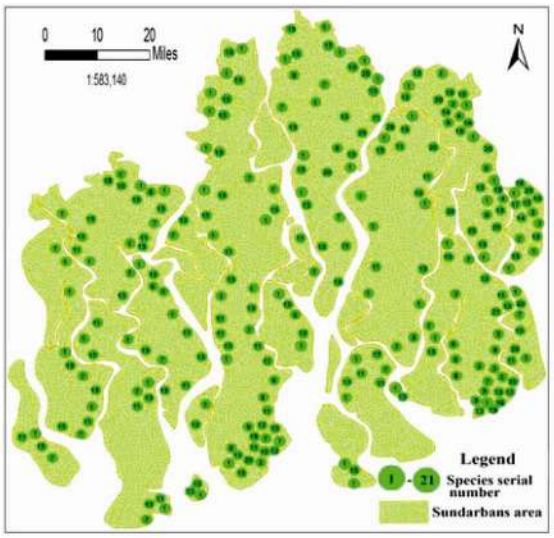

Fig. 7. Spatial distribution pattern of pteridophytic species in SMFB according to their serial number mentioned in Table 1.

According to IUCN Red List criteria, 10 pteridophytic species of SMFB were recognized under the data deficient (DD) category for this mangrove area. These were mostly found to grow in the non-mangrove habitats of this mangrove area that might be introduced in these habitats from their mainland stock through different dispersal mechanisms. Seven species were recognized under the least concern (LC) category for SMFB due to their widespread and abundant growth in different saline zones with limited range of ecological adaptations (Table 1). Three species, namely *Asplenium polyodon*, *Psilotum nudum* and *Ophioglossum reticulatum* were recognized as threatened for SMFB under the categories of critically endangered (CR), endangered (EN) and vulnerable (VU) respectively based on IUCN criteria (IUCN, 2013). One species (*Mosharof 423*, *Sayedur18*) was recognized as dubious. This study suggests for including these in the list of plant species of SM FB that should be prioritized for conservation.

References

Ahluwalia, A.S., Pabby, A. and Dua, S. 2002. *Azolla*: A green gold mine with diversified applications. *Indian Fern Journal*. **19**: 1-9.

Alexiades, M.N. 1996. Selected Guidelines for Ethno botanical Research: A Field Manual. The New York Botanical Garden, New York. pp. 99-133.

Anonymous. 2004. *A Brief Introduction to fern.* The American Fern Society. http://www.amerfernsoc.org/ lernfrnl.htmal.

Ashwini, S.1. and Parashurama, T.R. 2014. Pteridophytic Composition in Banajalaya Forest Region, Karnataka, South India. *Int. J. Sci. Res.* **3**(10): 954-957.

Benjamin, A. and Manickam, V.S. 2007. Medicinal pteridophytes from the Western Ghats. *Indian J. Traditional Knowledge*. **6**(4): 611-618.

Braun-Blanquet, J. 1932. Plant sociology: The study of plant communities. McGeaw-Hill Book Co. Inc., New York, USA.

Cain, S.A. 1938. The species-area curve. *American Midland Naturalist.* **19**: 573-581.

Chandra, S., Fraser-Jenkins, C.R., Kumari, A. and Srivastava, A. 2008. A summary of the status of threatened pteridophytes of India. *Taiwania*. **53**: 170-209.

Chapman, A.D. 2009. Numbers of Living Species in Australia and the World. 2nd Edn. Australian biodiversity information services. A report for the Australian biological resources study. Commonwealth of Australia.

Das, S. and Siddiqi, N.A. 1985. The mangrove and mangrove forest of Bangladesh. *Mangrove Silviculture Division Bulletin* No. 2. Bangladesh Forest Research Institute (BFRI), Chittagong. pp. 1-142.

Dixit, R.D. 1975. Ferns - a much neglected group of medicinal plants. *J. Res. Ind. Med.* **9**(4): 59-68.

Dixit, R.D. 2000. Conspectus of Pteridophytic diversity in India. *Indian Fern Journal*. **17**: 77-91.

Dudani, S., Chandran, M.D.S. and Ramachandra, T.V. 2012. Pteridophytes of Western Ghats. Biodiversity Documentation and Taxonomy (Edn. A. Biju Kumar). pp. 343-351.

Fernando, E.S., Co, L.L., Lagunsad, D.A., Gruezo, W.S. M., Barcelona, J. F., Madulid, D.A., Lapiz, A.B., Texon, G.I., Manila, A.C. and Zamora, P.M. 2008. Threatened plants of the Philippines. *Asia Life Sciences Suppl.* **3**: 1-52.

Ghosh, S.R., Ghosh, B., Biswas, A. and Ghosh, R.K. 2004. The pteridophytic flora of eastern India. Vol. 1. Botanical Survey of India Serise 4. Kolkata, India. pp. 1-591.

Helteshe, J.F. and Forrester, N.E. 1983. Estimating species richness using the Jackknife procedure. *Biometrics*. **39**: 1-11.

Hogan, S. 2004. *Flora: The Gardener's Bible*. Global Book Publishing, Australia. pp. 1-58.

Hoq, M.E. 2008. Sundarbans Mangrove: Fish and fisheries: Ecology, resources, productivity and management perspectives. Graphic Media, Dhaka, Bangladesh. pp. 1-271.

Hossain, G.M. 2013. Ecosystem health status assessment of the Sundarbans mangrove forest in Bangladesh. PhD Dissertation. Submitted to Jahangirnagar University, Savar, Dhaka, Bangladesh. pp. 1-212.

Hussain, Z. and G. Acharya (eds.). 1994. Mangroves of the Sundarbans, Volume Two: Bangladesh. IUCN, Bangkok, Thailand. pp. 1-257.

Iftekhar, S.M. 1999. Vegetation dynamics in the Sundarbans and the contribution of salinity between 1985-1995. B.Sc. Thessis. Forestry and wood technology discipline, Khulna University, Khulna, Bangladesh. pp. 1-54.

Iftekhar, S.M. and R.M. Islam. 2004. Degradation of Bangladesh Sundarbans: A management issue. *Int. Forestry Rev.* **6**(4): 123-135.

Iltaf, S., Khan, Z. and Riaz, N. 2012. A contribution to the taxonomic study of fern Flora of Punjab, *Pakistan. Pak. J. Bot*. **44**: 315-322.

IUCN. 2013. Guidelines for using the IUCN Red List Categories and Criteria. Version 10. Proposed by the Standard and Petition Subcommittee. pp. 1-187.

Jain, S.K. and Rao, R.R. 1977. A handbook of field and herbarium methods. Today and Tomorrows Printers and Publishers. pp. 1-157.

Japanese Ministry of Environment. 2007. Red List of Japan Plant I (Vascular plants). Japanese Ministry of Environment, Tokyo. Serial-9947 and hou_id-8648.

Kamau, P.W. 2012. Systematic Revision of Pteris L. in tropical Africa and ecology of ferns and lycophytes in lowland tropical rainforests. Ph.D. Dissertation, Submitted to Zur Erlangung des akademischen Grades eines Doktors der Naturwissenschaft des Fachbereich 3: Mathematik/Naturwissenschaften der Universitat Koblenz-Landau Germany. pp. 1-185.

Karim, A. 1988. Environmental factors and distributions of mangroves in Sundarbans with special reference to *Heritiera fomes* Buch. Ham. Ph.D. thesis at University of Calcutta. India.

Katebi, M.N.A. 2001. Sundarbans and forestry. In: Haider, M. (ed.). Cyclone'91- An environmental and perceptional study. BCAS, Dhaka. pp. 79-100.

Kent, M. and Coker, P. 1992. Vegetation description and analysis: A practical approach. The CRC Press, Inc. Belhaven Press, Landon. pp. 1-363.

Lee, B. (ed.) 2009. Rare Plants Data Book of Korea. Korea National Arboretum, Pocheon.

Lindsay, S. and Middleton, D. 2010. Ferns of Thailand. Royal Botanic Garden Edinburgh. http://rbg-web2.rbge.org.uk/thaiferns/

Ma, L.Q., Komar, K.M., Tu, C., Zhang, W.H., Cai, Y. and Kennelley, E.D. 2001. A fern that hyper accumulates arsenic - a hardy, versatile, fast-growing plant helps to remove arsenic from contaminated soils. *Nature* **409**: 579-579.

Mirza, M.M. 1996. Preliminary observations on the taxonomy and ecology of the fern and fern-allies of Bangladesh. Bangladesh J. Plant Taxon. **3**(2): 35-39.

Mirza, M.M. and Rahman, M.M. 1997. An annotated checklist of ferns and fern-allies of Bangladesh. *Bangladesh J. Plant Taxon.* **4**(2): 47-69.

Mirza, M.M. and Pasha, M.K. 2007. Peridophytes. In: Siddiqui, K.U., Islam, M.A., Ahmed, Z.U., Begum, Z.N.T., Hassan, M.A., Khondker, M., Rahman, M.M., Kabir, S.M.H., Ahmad, M., Ahmed, A.T.A., Rahman, A.K.A. & Haque, E.U. (eds.). Encyclopedia of Flora and Fauna of Bangladesh, Vol. 5. Bryophytes, Pteridophytes and Gymnosperms. Asiatic Society of Bangladesh, Dhaka. pp. 195-343.

Moran, R.C. 2008. Diversity, biogeography and floristics. *In*: Ranker, T.A. and Haufler, C.H. (eds.), Biologyand Evolution of Ferns and Lycophytes. Cambridge University Press, New York. pp. 367-394.

Nichols, P.B., Couch, J.D. and Al-Hamdani, S.H. 2000. Selected physiological responses of *Salvinia minima* to different chromium concentrations. *Aquatic Botany* **68**: 313-319.

Olguín, E.J., Sánchez-Galván, G. and Pérez-Pérez, P. 2007. Assessment of the phyto remediation potential of *Salvinia minima* Baker compared to *Spirodela polyrrhiza* in high-strength Organic Wastewater. *Water, Air and Soil Pollution* **181**: 135-147.

Pasha, M.K. 1985. A systematic account of Selaginella from Bangladesh. *Bangladesh J. Bot.* **14**(2): 97-107.

Pasha, M.K. and Mallik, A.U. 1980. Ferns of Bangladesh-1. *Chittagong Univ. Stud. Pt. II. (Sci.).* **2**(4): 13-26.

Pasha, M.K. and Chakraborty, R. 1984. Ferns of Bangladesh-III. The genus *Adiantum. Chittagong Univ. Stud. Pt. II. (Sci.)*. 8(2): 113-121.

Pasha, M.K. 2003. *In*: Health status on Sundarbans. Flora: Orchid, fern and lichen. p. 92.

Prain, D. 1903 (Indian Repr. 2004). *Bengal Plants*, Vol. 2. Bishen Singh Mahendra Pal Singh, Dehra Dun, India. pp. 1237-1270.

Pryer, K.M., Schuettpelz, E., Wolf, P.G., Schneider, H., Smith, A.R. and Cranfill, R. 2004. Phylogeny and evolution of ferns (monilophytes) with a focus on the early leptosporangiate divergences. *Am. J. Bot.* **91**: 1582-1598.

Rahman, M.M. 2003. Invasive plants of Sundarbans. Interim report under SBCP project. IUCN, Bangladesh. pp. 1-32.

Rashid, S.H, Böcker, R. Hossain, A.B.M.E. and Khan, S.A. 2008. Undergrowth species diversity of Sundarban mangrove forest (Bangladesh) in relation to salinity. Ber. Inst. Landschafts-Pflanzenökologie Univ. *Hohenheim Heft*. **17**: 41-56.

Raunkiaer, C. 1934. The Life-form of plants and statistical plant geography. Claresdon Press, Oxford, UK.

Rothwell, G.W. and Stockey, R.A. 2008. Phylogeny and evolution of ferns: a paleontological perspective. In: Ranker, T.A. and Haufler, C.H. (eds.). Biology and Evolution of Ferns and Lycophytes. Cambridge University Press. pp. 332-366.

Santos, M.G., Kelecom, A., Ribeiro de Periva, S., Gomes de Moraes, M., Roacha, L. and Garrett, R. 2010. Phytochemical studies in pteridophytes growing in Brazil: a review. *Am. J. Pl. Sci. Biotech.* **4**(1): 113-125.

Sanyahumbi, D., Duncan, J.R., Zhao, M. and Van Hille, R. 1998. Removal of lead from solution by non viable biomass of water fern *Azolla filiculoides. Biotech Lett.* **20**: 745-747.

Sarker, S.K. 2009. A comprehensive systematic investigation of the pteridophytes in greater Mymensingh district of Bangladesh. Ph.D. Thesis. Submitted to the Department of Botany, Jahangirnagar University, Savar, Dhaka. pp. 1-249.

Sarker, S.K. and Hossain, A.B.M.E. 2009. Pteridophytes of greater Mymensingh district of Bangladesh used as vegetables and medicines. *Bangladesh J. Plant Taxon.* **16**(1): 47-56.

Schuettpelz, E. and Pryer, K.M. 2008. Fern Phylogeny. *In*: Ranker, T.A. and Haufler, C.H. (eds.) Biology and Evolution of Ferns and Lycophytes. Cambridge University Press. pp. 395-416.

Sharpe, J.M., Mehltreter, K. and Walker, L.R. 2010. Ecological importance of ferns. *In:* Mehltreter, K., Walker, L.R. and Sharpe, J.M. (eds.). *Fern Ecology*, Cambridge University Press. pp. 1-21.

Shukla, R.S. and Chandal, P.S. 1993. Plant Ecology. S. Chandal and Company Ltd. New Delhi, India. pp. 1-197.

Singh, H.B. 2003. Economically viable pteridophytes of India Pteridology in the new millennium NBRI Golden Jubilee. Kluwer Academic Publishers, The Netherlands, pp. 421-446.

Smith, A.R., Pryer, K.M., Schuettpelz, E., Korall, P., Schneider, H. and Wolf, P.G. 2006. A classification for extant ferns. *Taxon.* **55**: 705-731.

Smith, A.R., Pryer, K.M., Schuettpelz, E., Korall, P., Schneider, H. and Wolf, P.G. 2008. Fern classification. *In*: Ranker, T.A. and Haufler, C.H. (Eds.). Biology and evolution of ferns and lycophytes. New York, Cambridge University Press. pp. 417-467.

Suné, N., Sa´nchez, G., Caffaratti, S. and Maine, M.A. 2007. Cadmium and chromium removal kinetics from solution by two aquatic macrophytes. *Environmental Pollution.* **145**: 467-473.

Tryon, R.M. and Tryon, A.F. 1982. Ferns and Allied Plants with Special Reference to Tropical America. New York, Springer-Verlag.

Uddin, M.G. and Pasha, M.K. 1997. Systematic studies on the fern-allies of Bangladesh. *Indian Fern Journal* **14**: 23-32.

Uddin, M.G. and Pasha, M.K. 2002. Wetland Pteridophytic flora of Bangladesh. *Chittagong University J. Sci.* **26**(1&2): 93-104.

Uddin, M.G. and Pasha, M.K. 2007. Diversity and distribution of epiphytic pteridophytes in *Bangladesh. J. Taxon. Biodiv*. Res. **2**: 59-65.

Uddin, M.G. 2001. A taxonomic study on Leptosporangiate ferns of Bangladesh. M. Phil. Thesis, Department of Botany, University of Chittagong. pp. 1-239.

Uddin, S.N. and Hassan, M.A. 2012. Pteridophyte flora of Rampahar and Sitapahar reserve Forests under Rangamati district in Bangladesh. *Dhaka Univ. J. Biol. Sci.*. 21 (2): 153-161.

Upreti1, K. Jalal1, J.S., Tewari1, L.M., Joshi, G.C., Pangtey, Y.P.S. and Tewari, G. 2009. Ethnomedicinal uses of Pteridophytes of Kumaun Himalaya, Uttarakhand, *India. J. Am. Sci*. **5**(4): 167-170.

Verma, P.S. and Agarwal, V.K. 1986. Princoples of ecology. S. Chandal and Co. (Pvt.) Ltd., New Delhi, India. pp. 1-591.

Vermaat, J.E. and Hanif, M.K. 1998. Performance of common duckweed species (Lemnaceae) andthe water fern *Azolla filiculoides* on different types of wastewater. *Water Res.* **32**: 2569-2576.

Wahid, S.M. 1995. Hydrological study of the Sundarbans. UNDP/FAO project BGD/84/056, Department of Forest, Dhaka, Bangladesh. pp. 16-34.

Wang, J.C. (edn.). 2010. The Red Book of Taiwan. Research Report of Endemic Species Research Institute, Nantou, Taiwan (in Mandarin).

Windisch, P.G. 1990. Pteridófitas da região norte-ocidental do estado de São Paulo: guia para excursões. 2. ed. Sao Jose do Rio Preto, UNESP.