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## Enumeration to Aquatic Ferns in Fly Ash Polluted Habitat of Bihar, India

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### ABSTRACT

During a survey on the pteridophytic diversity in the vicinity of thermal power stations, eight species of ferns were collected from different water bodies of Bihar. The present paper enumerates its local names, description, sporulation time, distribution, uses, and some identification keys with photographs.

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### INTRODUCTION

Ferns are ancient non-flowering vascular plants, which appeared in the fossil record around 400 million years ago (Kendrick & Crane, 1997). Ferns represent the highest evolutionary stage of vascular plants; they occupy a middle branch of vascular plants evolutionary tree (Raven *et al.*, 1992). Despite over million years of evolution, fern possesses two different and independent life cycles, i.e., first gametophyte which has independent survival in nature till favorable condition, i.e., adequate moisture content and the second stage is sporophyte which is visible plant body. Both stages maintain independent physiological status in moist and shady conditions. Earlier various studies have been done on floristic studies of ferns but only a few reports on its ecological habitat-based studies are available. Wetlands are the unique fragile ecosystems having great importance for their biodiversity. It includes wet habitats including marshes, swamps, ponds, lagoons, and large water tanks inside thermal power stations for water storage. Such areas lie between the land and water interface to form the ecotonal zone, provide enormous support to rich biodiversity (Clark 1954; Odum 1959; Tiner 1999). Among various micro and macrophytes, pteridophytes are one of the common and crucial inhabitants in various water bodies. Over 1,200 species of fern and fern allies have been reported from the territory of India (Dixit 1984; Chandra 2000). Indian wetlands are quite rich in various species of fern and fern allies (Mehra & Bir, 1964; Cook, 1996; Singh & Upadhyay, 2012); Gangetic plains to the

mangroves in the southernmost part. The water bodies of the Bihar state are very rich in aquatic and semi-aquatic macro-flora including fern and fern allies (Ambsatha, 1971; Das & Sayantan, 2016). It is significant that some of these aquatic ferns are edible in West Bengal and other northeast states and sold in local markets as a green vegetable. It is also noteworthy that some of them are hyper-accumulator of noxious heavy metals and metalloids. Besides some reports are also available on their medicinal importance.

In the context of above, the present study has been aimed to screen diversity and distribution of aquatic ferns inhabiting water bodies in the vicinity of thermal power stations of Bihar with their detailed description, growth status, local name, and various uses. Though assessment of heavy metal accumulation by these ferns are pre-requisite because some of these are edible as vegetable and some significantly useful as medicine. But bio-availability of noxious heavy metals in water bodies and ferns has not been assessed in the present work and it may be targeted in the next attempt.

### MATERIALS AND METHODS

Extensive floristic and ecological surveys on the wetlands of targeted sites of Bihar were carried out from July to October between 2009 and 2011 to cover the study area completely. During exploration, herbarium voucher specimens of each species were collected and processed to prepare mounted herbarium sheets following Jain and Rao (1977), and the voucher specimens were finally

deposited in the herbarium of the CSIR-Institute of Himalayan Bioresource Technology (PLP), India is recognized by New York Botanical Garden (2007) for future reference material. In the following list, the nomenclature of the species has been given as per International Code of Botanical Nomenclature (ICBN) (2006) and families are arranged according to the classification for Indian pteridophytes (Fraser-Jenkins, 2009). All collected specimens were identified by the key of species available in the literature of Bihar ferns (Haines, 1924; Dixit, 1984). Habitat and morphological characters of each species were noted in the field notebook along with details of collection number with their uses and current threat status for identification and documentation of the collected specimens. The altitudinal distribution of each species was also recorded by GPS handsets (GARMIN, eTrex Vista model). Binomial and author citation of the entire collected voucher specimens were verified through checking with The Plant List (www.theplantlist.org), The International Plant Name Index (IPNI), and Index Kweinsis (IK).

#### OBSERVATION AND ENUMERATION

The present article is focused mainly on true aquatic ferns, i.e., epiphytes, hyperhydrates, and pleustophyte, and wet loving or terrestrial invaders are not included in this article. Considering this, eight species of six genera representing five families were recorded during this study. Keys of recorded taxa, taxonomic details, vernacular names, and photographs are provided for their easy recognition.

#### Key to Families

- 1a. Habit like onion plants or grass-like; corm small button-like underground; sporangia at leaf base..... **Isoetaceae**
- 1b. Plants otherwise.....2
- 2a. Plants free-floating; fronds/ leaves sessile..... **Salviniaceae**
- 2b. Plants rooted; fronds/ leaves with distinct stipe .....3
- 3a. Leaflets 4, palmate; sporangia in specialized minute sporocarps ..... **Marsileaceae**
- 3b. Leaves simple, deeply pinnatisect; sporangia in large fertile fronds..... **Pteridaceae**

**SALVINIACEAE** Saguier, Fl. Veron. 3: 52. 1754.

#### Key to Genera

- 1a. Sporocarps in pair; leaves minute, imbricate; roots present, simple ..... *Azolla*
- 1b. Sporocarps in the cluster; leaves dimorphic, floating

ones entire; submerged leaves much dissected, root-like ..... *Salvinia*

*AZOLLA* Lamarck, Encycl. Meth. 1. 343. 1783.

*Azolla pinnata* R. Brown in Prodr. 167. 1810; Prain, Beng. Pl. 2: 1266. 1903. Holttum, Fl.

Malaya 2: 621. 1968; Cook, Aqua. Wetl. Pl. Ind. 22.1996. Ghosh *et al.*, Pterid. Fl. East. Ind. 1: 184. 2004. [Plate I; Figure C]

Small, triangular, free-floating ferns; roots hanging downward. Fronds two-lobed close together. Sori indusiate on submerged lobes of leaf; microsporangium many with microspores; megasporangia few with one megaspore.

Fertile: May to August.

Kusi pond KTPS, Kumari 0864, dated 19.07.2012.

Distribution: Tropical Asia; throughout the Bihar and Bengal- plains; abundant.

Uses: Plants are widely used as green manure.

**SALVINIA** Seguir, Plantae Veronenses 3. 1754.

#### Key to Species

- 1a. Floating leaves multiaxillary; leaves large, spongy, and crowded ... *S. adnata*
  - 1b. Floating leaves uniaxillary; leaves smaller, neither crowded nor spongy.....2
  - 2a. Floating leaves solitary, cup shaped .....*S. cucullata*
  - 2b. Floating leaves flat, not cup shaped .....*S. natans*
- Salvinia adnata* Desvaux, Mem. Soc. Linn. Paris 6: 177. 1827. *Salvinia molesta* D.S.

Mitchell, Brit. Fern. Gaz. 10 (5): 251-252. 1972; Cook, Aqua. Wetl. Pl. Ind. 30. 1996.

Ghosh *et al.*, Pter. Fl. East. Ind. 1: 179. 2004. [Plate I; Figure F]

Floating, aquatic ferns. Frond compressed, oval, folded, covered with arching, spongy. Sporocarps globose, densely hairy, short-stalked. Macrosporocarps 2 to 3, with 20 to 25 macrosporangia.

Microsporocarps pubescent, sessile or sub-sessile, containing mostly empty microsporangia.

Fertile: November to March.

Gajoldoba, Kumari 0912, dated 04.08.2013.

Distribution: Native to S America, naturalized in tropics of old World; abundant in water bodies of southern and central parts of Bihar; less common in North Bihar.

Uses: Sometimes used as green manure.

*Salvinia cucullata* Roxburgh ex Bory in C.P. Belanger, Voy.

Indes. Or. 2(1): 6. 1833; Roxburgh, Calc. Jour. 4: 470. 1844; Prain, Beng. Pl. 2: 1265. 1903; Cook, Aqua. Wetl. Pl. Ind. 29. 1996. [Plate I; Figure B]

Free floating, rhizome hairy. Uppermost fronds in row, entire, edged infolded, papillae not

regular. Sporocarps in cluster, globose, on submerged leaves. Around 55 sporocarps in 2 rows, first 2 to 3 with macrosporocarp and rest with microsporocarp.

Fertile: May to December.

Kahalgaon, Kumari 0918, dated 09.08.2013.

Distribution: Endemic to NE India & Myanmar; throughout the plains of North Bihar; abundant.

Uses: Plant used as green manure.

*Salvinia natans* (Linnaeus) Allioni, Fl. Pedemont. 2: 289. 1785; Prain, Beng. Pl. 2: 1265.

1903; Ghosh *et al.*, Pterido. Fl. East. Him. 181. 2004. *Mersilea natans* Linnaeus, Sp. Pl. Ed 99. 1762. *Salvinia verticillata* Roxburgh *ex* Griffith, Calc. J. Nat. Hist. 4: 469. 1844. [Plate I; Figure A]

Free floating ferns, rhizome hairy. Uppermost frond flat, ovate to oblong, upper surface with hooked papillae, stalk hairy. Sporocarps arise from nodes, globose, hairy, contains 25 microsporangia in each.

Fertile: November to March.

Gajoldoba, Kumari 0928, dated 09.09.2013.

Distribution: Europe, SE Asia, Russia, Japan; throughout the Bengal-plains; abundant.

Uses: Plant used as green manure.

ISOETACEAE Dumortier, Anal. Fam. Pl. 67. 1829.

*Isoetes coromandelina* Linnaeus *f.*, Suppl. Pl. Sys. Veg. ed. 13: 47. 1781; Panigrahi., Biol. Mem. 6 (2): 131. 1981; Cook, Aqua. Wetl. Pl. Ind. 23.1996. [Plate I; Figure G].

Emerged plants with 3 lobed rhizomorph or corm. Leaves widely spreading, membranous, stomata numerous. Ligule conspicuous, velum absent. Megasporangia large, circular or ovate. Megaspores flattened, tubercled. Microspores red-brown, smooth or rugose to papillate.

Fertile: July to February.

Kahalgaon Kumari-dated 21.09.2011.

Distribution: India, Nepal, Myanmar, China, Thailand and Vietnam; throughout the Bengal-plains; now very rare and difficult to spot in nature.

Note: *Isoetes brachyglossa* A. Braun (synonym: *I. coromandelina* L. *f.* subsp. *brachyglossa* (A. Braun) Panigrahi published in Biological Memoirs; International Journal of Biological Disciplines. Lucknow on 6(2):

131. 1981?); distributed in N.E. India (including W. Bengal) (Chandra *et al.* 2008). Present survey failed to trace the species from the state

MARSILEACEAE Mirbel in Lamarck & Mirbel, Hist. Nat. Veg. 5: 485. 1754.

MARSILEA Linnaeus, Sp. Pl. 2: 1099. 1753.

*Marsilea minuta* Linnaeus, Mant. 308. 1771; Prain, Beng. Pl. 2: 1266. 1903. Sledge, Bot. J.

Linn. Soc. 84: 22. 1982; Cook, Aqua. Wetl. Pl. Ind. 26.1996. 'Susni Saak' [Plate I; Figure E]

Aquatic with creeping rhizome; roots borne usually on nodes, stipes scattered, usually green. Leaves emerging, leaflets four, sessile arranged cross-wise at the tip. Sporocarps borne at the nodes in alternate clusters.

Fertile: January to April.

Kahalgaon, 0932, dated 22.09.2011.

Distribution: Tropical Africa and Asia; throughout the Bengal-plains; abundant.

Uses: Young fronds edible; a good sleep inducer.

Note: *Marsilea quadrifida* Linnaeus is sometimes confused with *Marsilea minuta* Linnaeus. *M. minuta* Linnaeus is quite frequently occurring marshland fern but *M. quadrifida* Linnaeus is not recorded from the state boundary.

*M. quadrifida* Linnaeus is Eurasian species, naturalized in N. America; in India it is restricted to NW Himalayas (Cook 1996).

PTERIDACEAE E.D.M. Kirchner, Schul\_-Bot. 109, 1831 CERATOPTERIS Brongniart, Bull. Sci. Soc. Philom. Paris 186. 1821.

### Key to Species

1a. Sterile frond 2-3 pinnate; stipe 7 – 30 cm long.....  
.....*C. thalictroides*

1b. Sterile frond mostly simple or palmately lobed or cordate; stipe 5 to 9 cm long .....*C. pteridoides*

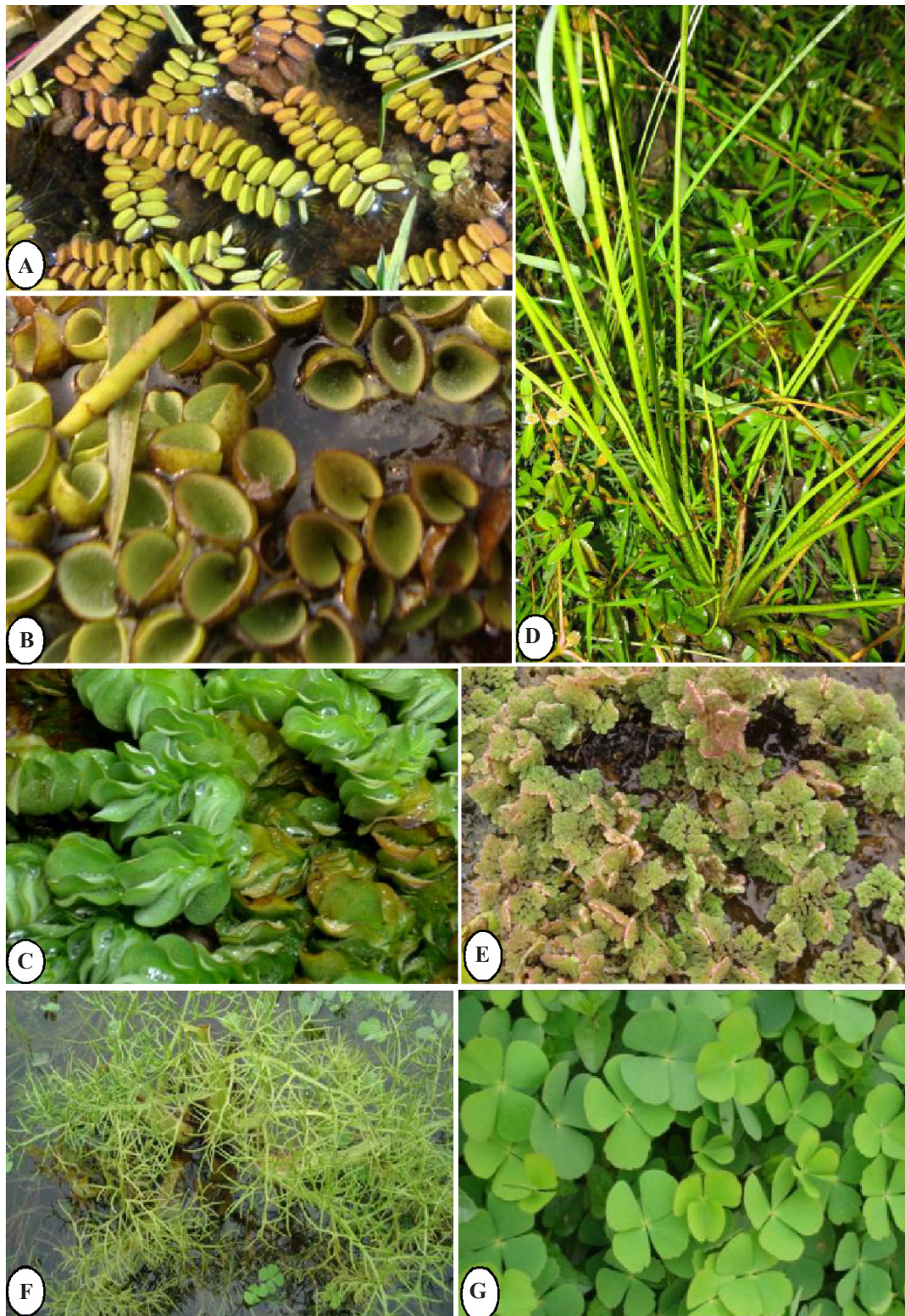
*Ceratopteris pteridoides* (Hooker) Hieronymus, Bot. Jahrb. Syst. 34: 561. 1905. Lloyd,

Brittonia 26 (2): 156. 1974; Cook, Aqua. Wetl. Pl. Ind. 28. 1996. *Parkeria pteridoides* Hooker, Exot. Fl. 2: plate 147. 1825. [Plate I; Figure D]

Plants floating or rooted. Sterile leaves simple, palmate to cordate to ovate, petiole usually inflated. Fertile leaves deltate to cordate to reniform. Sporangia usually crowded between segment midvein and revolute margin. Spores 32 per sporangium.

Fertile: November to January.

Aquatic Ferns of Fly Ash Polluted Sites



**Plate I:** Aquatic pteridophytes growing in vicinity of NTPC site of Bihar; **A.** *Salvinia natans* L.; **B.** *Salvinia cucullata* Roxb. ex Bory; **C.** *Salvinia adnata* Desv.; **D.** *Isoetes coromandelina* (L.) Kuntze; **E.** *Azolla pinnata* R. Brown; **F.** *Ceratopteris thalictroides* (L.) Brongniart; **G.** *Marsilea minuta* L.

Distribution: Cosmopolitan; throughout the Bihar plains; common.

Uses: Young fronds edible.

*Ceratopteris thalictroides* (Linnaeus) Brongniart, Bull. Soc. Philom. Paris 3, 8: 186. 1821;

Prain, Beng. Pl. 2: 1246. 1903; Cook, Aqua. Wetl. Pl. Ind. 29. 1996. *Acrostichum thalictroides*

Linnaeus, Sp. Pl. 2: 1070. 1753.

Marshy, annual, erect fern. Stem with scales and roots. Leaves dimorphic, sterile frond slightly dissected; fertile fronds highly dissected. Lamina base cordate. Sporangia arranged on lower side of fertile frond.

Fertile: September to December.

All sites, Kumari 0907, dated 22.09.2010.

Distribution: Pantropical; throughout the Bihar. Abundant.

Uses: Young fronds edible and also used as cooling agent.

## DISCUSSION

Apart from these eight true aquatic ferns, a good number of wet loving pteridophytes are also recorded from the peripheral regions of various water bodies. *Adiantum capillus-veneris* L., *Adiantum incisum* Forssk., *Ampelopteris prolifera* (Retz.) C. F. Rheed, *Diplazium esculentum* (Retz.) Swartz, *Dryopteris* sp., *Equisetum diffusum* D. Don, *Pteris vittata* L., *Selaginella monospora* Spring, and *Thelypteris dentata* (Forssk.) E. P. St. John are small herbs and *Lygodium microphyllum* (Cav.) R. Brown and *Lygodium flexuosum* (L.) Swartz are climbing ferns growing with satisfactory population nearby or on moist ditches or water bodies. Some fern species growing in halophytic conditions also in the target areas. Local and poor people along with all the tribal communities of Bihar, as well as, West Bengal commonly use the young fronds of *Ampelopteris prolifera*, *Diplazium esculentum*, and *Marsilea minuta*, as vegetables, as well as, medicines. Farmers use *Azolla pinnata* R. Brown mixing with *Salvinia natans* (L.) Allioni and *S. cuculata* Roxb. ex Bory as green manure, especially in low lying paddy fields.

From the distribution point of view, *Isoetes coromandelina* was known to be a rare plant in the study area. Only a few populations were known from the water bodies of Kahalgaon-NTPC of Bhagalpur district. However, this may be due to its too much similarity in habitat, habit, and sedge-like external appearance in the wild condition. But, the present scenario is extremely bad as it is now quite difficult to trace the species even in their well-known habitats. So, the proper conservation strategies need to

be developed and implemented immediately before it is completely lost from its natural habitat.

## CONCLUSION

The present enumeration of aquatic pteridophytes represents eight species of true aquatic ferns in fly ash polluted habitat. As the fly ash reported to contain several noxious metals and metalloids, further studies on the availability of heavy metals in water bodies as well as their bioaccumulation in these target ferns are pre-requisite. Moreover, some of these are edible and some are medicinally useful hence, studies of metal toxicity in the target species would be valuable from the perspective of health risks management to millions of people. The present enumeration of aquatic ferns will act as baseline data which will be helpful in carrying out future biomonitoring and biodiversity studies in this area.

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## Aquatic Ferns of Fly Ash Polluted Sites

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