Assessment of Diversity and Distribution Pattern of Pteridophytic flora in Dunumadalawa Forest Reserve in Kandy District, Sri Lanka

Abstract

Pteridophytes are a group of non-flowering, vascular and spore-bearing plants. They are not of major economic importance to humankind as angiosperms, however, they have potential as commercial and environmental resources. Many of them are horticulturally desirable and used for decorations and ornamental purposes. Further some are used as medicines, food and fodder, pollution indicators and for controlling insect pests. During recent decades, many research indicate a decline in the worldwide fern population due to some reasons such as climate change, use of land for agriculture and other commerce related uses, predators and invasive species and overexploitation. With these circumstances, in the present study, the species richness distribution and the conservation perspectives of pteridophytic flora in Dunumadalawa forest reserve in Kandy district, Sri Lanka were investigated. Every possible area which supports the growth of fern flora in the forest was visited frequently and representative samples were collected and preserved as herbarium specimens. The species were identified using the "Revised Handbook to the Flora of Ceylon" (Vol. XV and XVI) and verified with the specimens deposited at the Herbarium, National Botanic Gardens, Peradeniya, Sri Lanka. The study found a total of 11 families of pteridophytes from different habitats, consisting of 16 genera and 31 species.

Key words – Pteridophytes, Sri Lanka, Dunumadalawa forest, ornamental ferns

Introduction

Sri Lanka is an island located in southern coast of the Indian subcontinent in South Asia (50.55' – 90.55'N, 79.42' – 81.52'E) and is a biodiversity hot-spot. The climate of Sri Lanka is warm and tropical with two distinct dry and wet seasons. The distinct geographical features of Sri Lanka have given rise to three climatic zones named wet, dry and intermediate. Though Sri Lanka is a very small island, it has many forest types and a great biological diversity due to the variations in altitude, temperature and the annual rainfall. In 1880s, more than 80 % of the land in Sri Lanka was covered with natural forests, but this was reduced to about 44% by 1956 due to the introduction of plantation crops such as tea, coffee and cocoa (Somasekaram et al.1982).

Forests are the most diverse ecosystems on land, because they hold the vast majority of the world's terrestrial species. The most biologically diverse and complex forests on earth are tropical rainforests, but these forests are being destroyed and degraded at alarming rates. Deforestation comes in many forms, including fires, clear-cutting for agriculture, ranching and development, unsustainable logging for timber, and degradation due to climate change finally which alter the biological diversity of a forest . Sri Lanka has high floristic richness and species diversity with the endemic elements heavily concentrated in the wet south western quarter of the island. Despite the fact that the flora of Sri Lanka has been extensively studied since the eighteenth century by various botanical experts, some of the secondary forests such as Dunumadalawa remain poorly studied, thus begs further investigations.

Dunumadalawa forest reserve, also popularly known as Wakarawatte after its original estate name - Walker's estate comprises mainly of secondary growth forest since the site has been used earlier for tea and cocoa plantations. Situated on the edge of the Hantana mountain range, the topography of the area varies considerably, from flat lowland plains marked by scattered hillocks and slopes. The forest consists of different types of habitats such as woody areas, grasslands, pine plantations, and several permanent and temporary lentic and lotic water bodies. It is also characterized by canopy and sub-canopy of mixed plant species which include some native as well as native and alien invasive plant species. Transformation of original forests into secondary forests and isolated forest patches duly has raised an adverse impact on the floristic richness in the island to a greater degree. The streams flows through the forest forms the catchment of two permanent reservoirs, the Dunumadalawa Lake and Roseneath Lake which provide drinking water for some areas of the Kandy city.

Sri Lanka contains a considerable number of secondary forests but unfortunately the research done on these forests is limited and hence not much information is available on floral and faunal composition of them. Similarly, the information on the floristic richness of the Dunumadalawa forest reserve is very scanty. The forest is not explored floristically and the species composition of flora and their diversity as well as different plant communities and the population structure of the reserve have not been studied yet. Further, the natural flora of Dunumadalawa is adversely affected by invasive plants; more dominantly by *Myroxylon balsamum* (L.) Harms (Katta Kumanchal) where some areas of the forests are fully invaded sweeping out the native flora. Some other invasive species like *Clusia rosea* Jacq. (Gal Demata) , *Lantana camera* L. (Hinguru), *Clidemia hirta* (L.) D. Don (Kata Kalu Bowotiya) also progressively invading causing a major threat to the native flora as well as the fauna that relies on them. Thus, that would be very important to reveal the hidden flora in implementing possible conservation strategies.

Studies on pteridophytic flora in Sri Lanka had commenced in the late 18th and early 19th centuries and have basically been focused on cataloguing of genera and species based on the taxonomic studies and the preparation of species inventories for selected ecosystems. Research work on pteridophytes continued from the mid-1950s to 1982 included cytological studies and monograph preparations (Manton & Sledge 1954, Sledge 1982). With the aim of utilization and in-situ and ex-situ conservation of ferns in Sri Lanka, many Sri Lankan scientists extended their research work to encompass the aspects of ecology, genetics and reproductive biology of some pteridophytes as well as their ethnobotanical uses, domestication and conservation measures (Ranil et al. 2011, Daulagala et al. 2020).

Pteridophytes (i.e. ferns and lycophytes) are non-flowering seedless vascular plants growing compactly in moist shady habitats in temperate and tropical forests. They are the second largest component of the world flora and one of the oldest and primitive vascular plant groups on earth. The majority of them are terrestrial, but some are epiphytic while others are lithophytic or hydrophytic. Pteridophytes are an important component of the flora, biodiversity, natural habitats and ecosystems but are of minor economic significance to mankind as compared to other plants, especially angiosperms. However, some pteridophytes are useful in decorations and ornamental purposes and can be grown as indoor as well as outdoor plants under varied levels of shade. In addition, some members such as *Pteris vittata* L. ("The brake") accumulates arsenic in their fronds and this is the first fern identified as a natural arsenic hyper accumulator (Xie et al. 2009) and helps in environmentally friendly phytoremediation processes. Further, several species are used as medicine and food (Mannan et al. 2008).

An assessment of the diversity and an analysis of the pteridophytic flora of the Dunumadalawa forest reserve has been identified as a fact of great importance and a needy investigation. Hence, a preliminary floristic study of the pteridophytes was carried out as the first step in generating the base-line taxonomic information for helping the sustainable conservation and management activities of the pteridophytic flora in Dunumadalawa. This present study will provide information which will be helpful to conservationists, ecologists, forest managers and future researchers those who are interested to carry out further ecological studies and those who are concerned about the conservation of existing pteridophytic species in this fascinating forest in hill country of Sri Lanka.

Materials and methods

Study area

Dunumadalawa forest reserve (7°17'00" N; 80°38'49" E; 548-972 m above sea level) situated in the Kandy district of the Central Province of Sri Lanka is approximately of about 480 hectares in extent of land and aquatic habitats including two major lakes named Dunumadalawa lake and Roseneath lake. The topography of the forest varies from flat plains with some scattered low hills and gently sloping valleys. The immediate borders of the forest are the *Pinus* plantation to the southeast at Matinapatana which then run into home-garden villages and a small, private tea estate; the Tea Research Institute (TRI) and Hantana tea estate to the west which is the beginning of extensive tea cultivation leading to Heeresagala, Bowalawatte and the Hantana hills in the southwest; Kandy town to the north; and Ampitiya town and other villages on the east. Kandy has a wetter and cooler climate and a dry season from December through April followed by a season of Monsoonal rain from May to July and December to January. Mean Annual rainfall recorded from the South-west Monsoon (April to August) is 1800-2500mm. During the intermonsoonal period (March to mid-May) the city and the suburbs experience light rain and strong humidity, having average between 70-79%.

Collection of fern species

This study was basically on primary data collection by repetitive field surveys. Preliminary observations and collecting of samples were done over one year period in several locations of the forest including the sides of the trails, foot paths and rough roads in the forest, areas associated with reservoirs and every possible other areas which support the growth of ferns. Other than these species some epiphytic ferns were also sampled. The areas dominated by the invasive *M. balsamum* were not surveyed as the ground cover was completely dominated by saplings/seedlings of *M. balsamum.* The Pine plantation to the southeast at Matinapatana was also not considered for sampling due to the lack of pteridophytes in the poorly grown understory layer. During this survey, the diagnostic features of all the specimens were studied and relevant field notes were made on fresh plant material. The ornamental values of the collected species and possible threats were also identified and recorded. The collected specimens were tagged, dried and herbarium specimens were prepared to be deposited in the proposed herbarium in the Dunumadalawa forest.

Taxonomic Identification

The species were recorded, photographed and collected as vouchers for identification. The species were identified using the "Revised Handbook to the Flora of Ceylon" (Vol. XV and XVI) and verified with the specimens deposited at the Herbarium, National Botanic Gardens, Peradeniya, Sri Lanka.

Results and Discussion

Abundance of the species

This study was conducted to provide a preliminary report, particularly on the diversity of pteridophytic flora in Dunumadalawa forest reserve. A total of 11 families of pteridophytes from different habitats were recorded, consisting of 16 genera and 31 species. Family Pteridaceae is the dominant family represented by 15 species followed by the family Polypodiaceae consisting of 04 species (Figure 1, Table1). Family Tectariaceae and Thelypteridaceae represented by 3 and 2 species respectively. Families such as Anemiaceae, Blechnaceae, Marrattiaceae, Selaginellaceae, Gleichniaceae, Nephrolepidaceae and Dryopteridaceae are represented by only one species each.

Adiantum is the most abundant genera represented by 8 species.

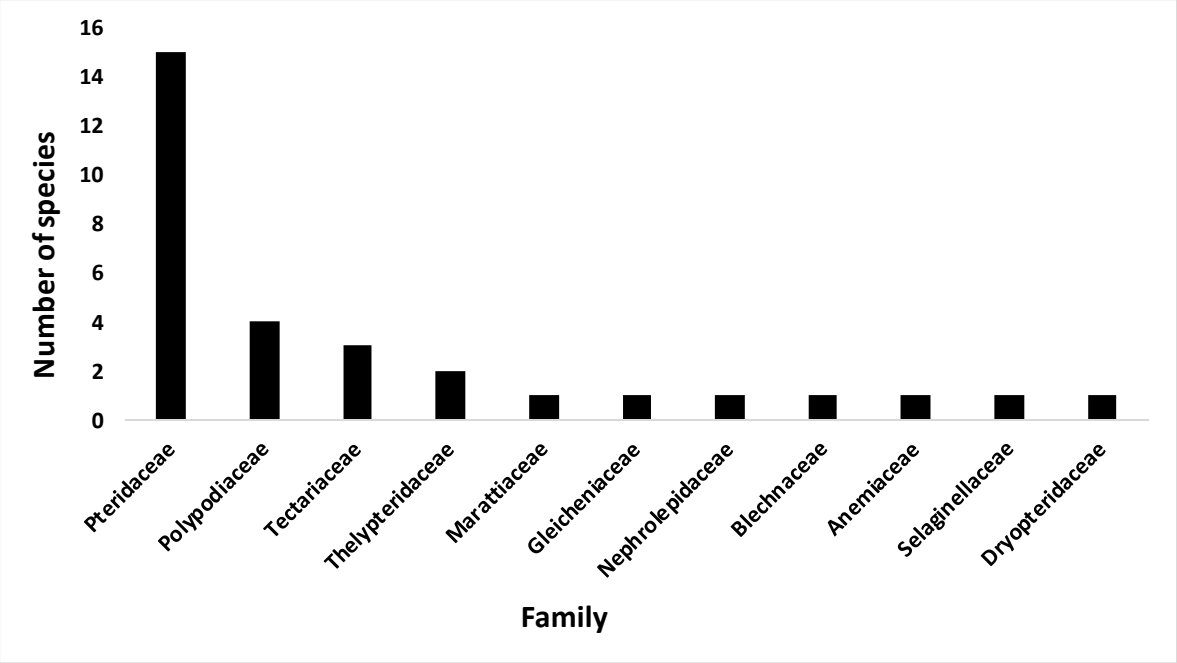

Figure 1 - The number of species in each family of pteridophyte recorded in the forest reserve

Table 1 - Checklist of pteridophytic flora recorded in the forest reserve - their families, common habitats and valued features as ornamental plants.

Botanical name	Family	Habitat	Ornamental Features
Pteris multiaurita J. Agardh	Pteridaceae	TE	BP, DF, PP
Pteris quadriaurita Retz Retz	Pteridaceae	TE	BP, DF, PP
Pteris vittata L. subsp. vittata	Pteridaceae	TE	BP, DF, PP

Pteris otaria Bedd.	Pteridaceae	TE	BP, DF, PP
(*Pteris quadriaurita* Retz x *Pteris multiaurita*)			
Pteris ensiformis Burm.f.	Pteridaceae	TE	BP, DF, PP
Pteris sp.	Pteridaceae	TE	BP, DF, PP
Pityrogramma dealbata (C. Presl) Tryon	Pteridaceae	TE	BP, DF, PP
Adiantum capillus-veneris L.	Pteridaceae	TE	BP, DF, PP
Adiantum hispidulum Sw.	Pteridaceae	TE	BP, DF, PP
Adiantum trapeziforme L.	Pteridaceae	TE	BP, DF, PP
Adiantum diaphanum Blume	Pteridaceae	TE	BP, DF, PP
Adiantum latifolium Lam.	Pteridaceae	TE	BP, DF, PP
Adiantum pulverulentum	Pteridaceae	TE	BP, DF, PP
Adiantum caudatum L.	Pteridaceae	TE	BP, DF, PP
Adiantun sp.	Pteridaceae	TE	BP, DF, PP
Anemia phyllitidis (L.) Sw.	Anemiaceae	TE	BP, DF, PP
Blechnum occidentale L.	Blechnaceae	TE	BP, DF, PP
Selliguea montana (Sledge) Hovenkamp.	Polypodiaceae	TE	BP, DF
Pyrrosia lanceolata (L.) Farw.	Polypodiaceae	EP/EL	DF
Drynaria quercifolia (L.) J. Smith	Polypodiaceae	EP/EL	DF, HP
Microsorum scolopendria (Burm.f.)Copel.	Polypodiaceae	EP/TE	DF, PP
Angiopteris crassipes Wall.ex C.Persi.	Marattiaceae	TE	BP, DF, PP
Selaginella crassipes Spring	Selaginellaceae	TE	DF, CR
Dicranopteris linearis (Burm.f.) Underw.	Gleicheniaceae	TE	BP, DF, PP
Tectaria crenata Cav.	Tectariaceae	TE	BP, DF, PP
Tectaria zeilanica (Houtt.) Sledge.	Tectariaceae	TE	BP, DF, PP
Tectaria ploymorpha (Wall.ex.Hook.) Copel	Tectariaceae	TE	BP, DF, PP
Christella dentata (Forssk.) Brownsey & Jermy	Thelypteridaceae	TE	BP, DF, PP
Christella hispidula (Decne,) Holttum.	Thelypteridaceae	TE	BP, DF, PP
Nephrolepis brownii (G. Forst.) C.Presl	Nephrolepidaceae	TE	BP, DF, PP
Arachniodes sledgi Fraser-Jenk.	Dryopteridaceae	TE	BP, DF, PP

(Habitats denoted as EP- Epiphytic, EL- Epilithic, TE- Terrestrial and ornamental features denoted as DF – Decorative fronds; PP – Can grow as Pot plants, BP – Can grow as Bed plants, HP – Hanging plants suitable for hanging baskets and CR – Creeping plants suitable for slopes)

The climatic and edaphic conditions and the shady moist environment of the forest reserve favors the growth of many pteridophytes and they comprise a significant component of the forest ecosystem. Wide array of habitats ranging from stream banks, shady slopes and partially shaded patches of wet forest floor

provide preferable micro habitats for different types of ferns to grow. Nearly all fern species collected in this study are terrestrials except *P. lanceolata* and *D. quercifolia* which are epiphytic. There was no confined pattern of distribution for many of the terrestrial species and they randomly found in different habitats including forest floor, road sides and river banks.

Among the terrestrial ferns, *B. occidentale* (Figure 2A) is the most abundant and widely distributed species which grows luxuriantly forming thickets in many places. It shows the highest density, covering large forest areas and mainly confined to the protective shady slopes of the roads/trails in the forest. *A. pulverulentum* (Figure 2B) is the second abundant species, grows luxuriously in the roadsides and shady and hilly areas throughout the forest and does not show any confined pattern of distribution. The forest favors the growth of some *Adiantum* species such as *A. capillus-veneris* ("Maiden hair fern") (Figure 2C) and *A. trapeziforme* ("Giant Maiden hair fern") (Figure 2D) and *A. caudatum* ("Walking Fern") (Figure 2E) as well, however they show more restricted distribution as patches in the shady areas.

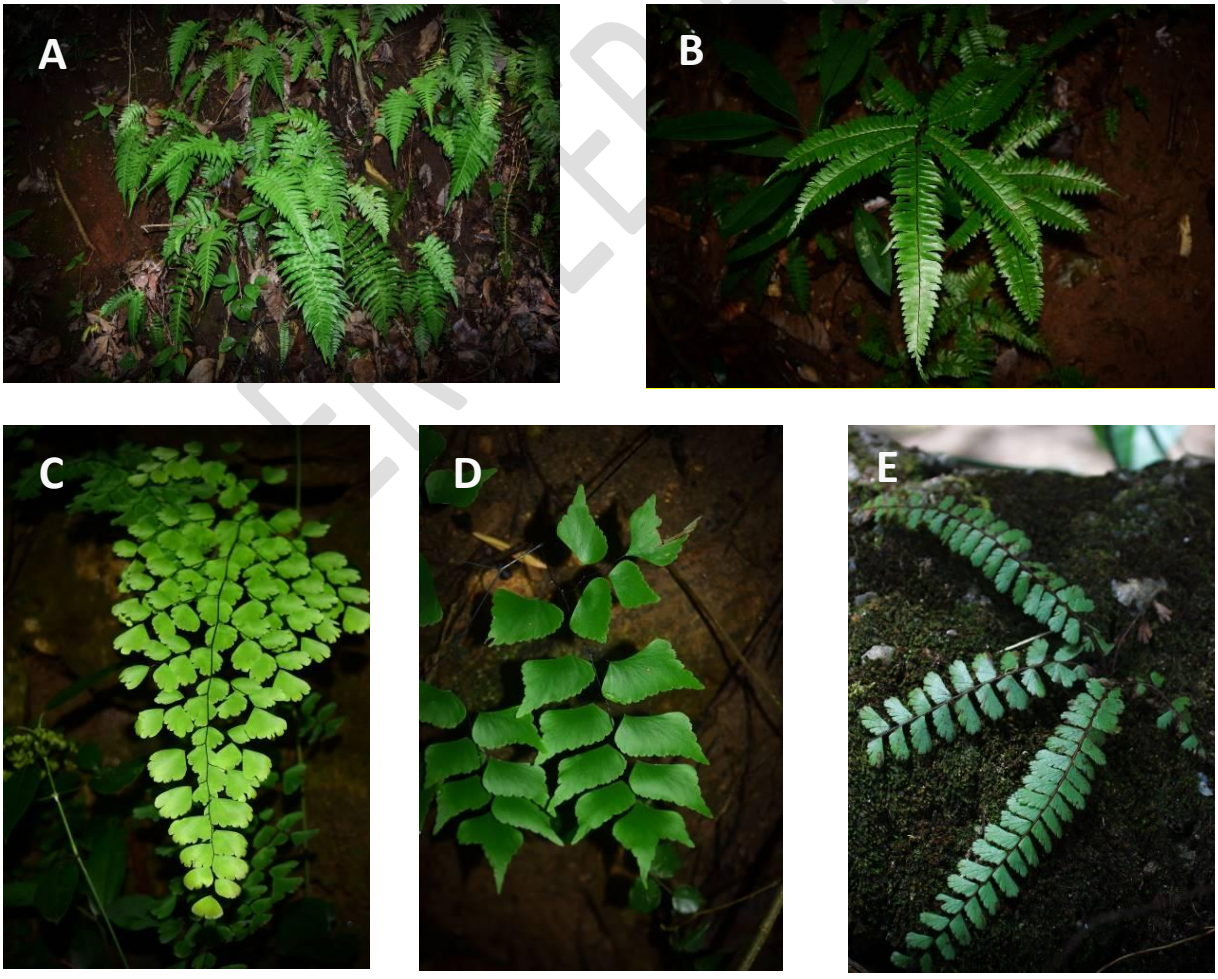

Figure 2. Habit of **A**. *B. occidentale*, **B**. *A. pulverulentum*, **C**. *A. capillus-veneris*, **D**. *A. trapeziforme*, **E**. *A. caudatum*

The fern flora of the forest consists of some primitive ferns such as *A. crassipes* (Figure 3A), *T. zeilanica* (Figure 3B) and *A. phyllitidis* (Figure 3C) and *D. linearis* (Figure 3D).

D. linearis which is identified as a pioneer species also commonly found in the forest floor, mostly in open areas. They are considered as the first invaders of bare lands and more evident in large gaps created by fallen trees. Magtoto 2017, stated that extensive rhizome formation and high litter content of *D. liniaris* makes the land suitable for other native plants to grow after their colonization and finally leads to ecological succession. Among the species listed, some such as *N. brownie* and *T. crenata* are infrequent and showed a limited distribution with few scattered individuals, restricted to more specific shady areas.

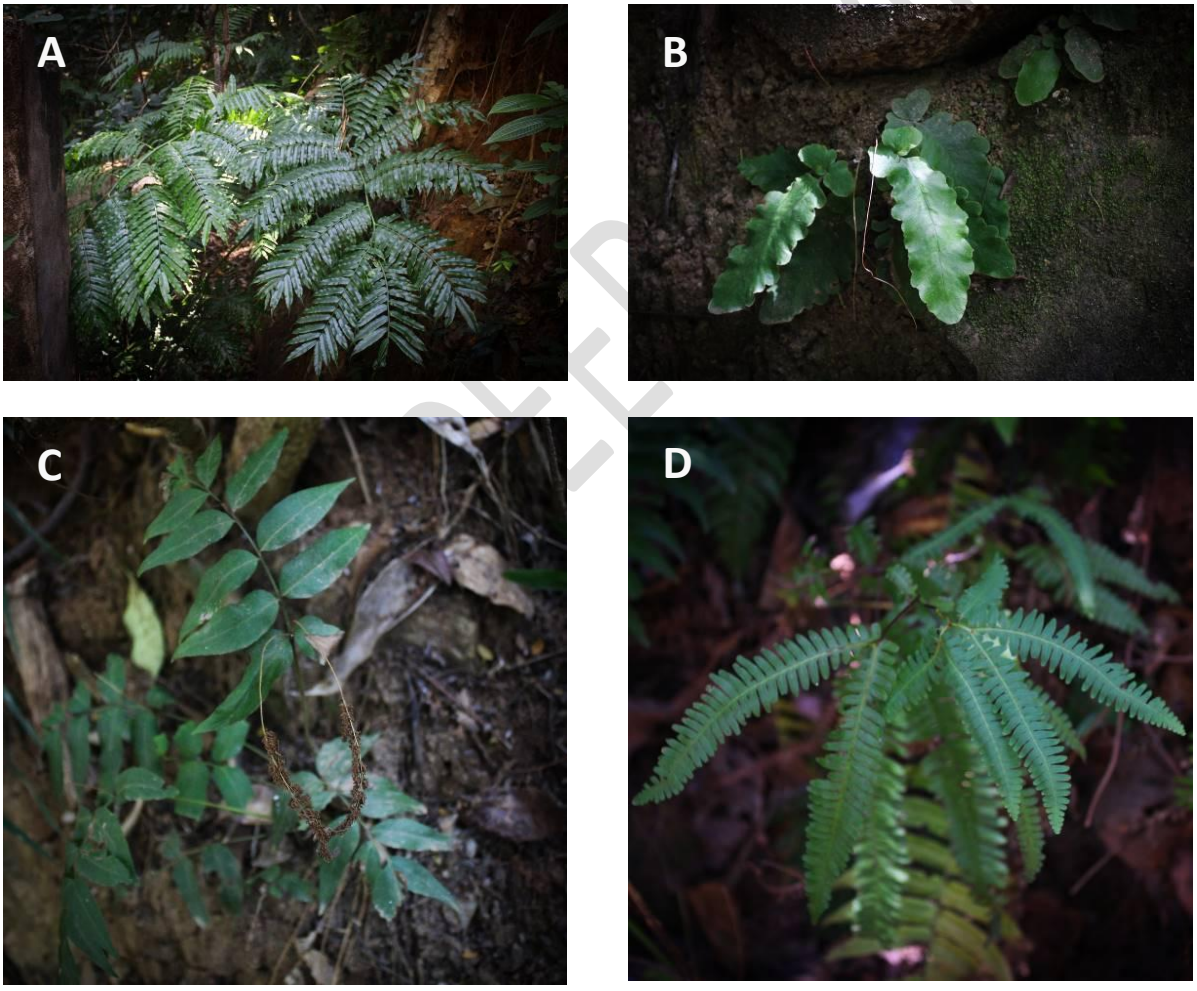

Figure 3. Habit of **A**. *A. crassipes*, **B**. *T. zeilanica*, **C**. *A. phyllitidis*, **D**. *D. linearis*.

The forest accommodates few epiphyitic pteridophytes found on lower parts of tree trunks. *P. lanceolata* (Figure 4A), *M. scolopendria* (Figure 4B) and *D. quercifolia* (Figure 4C) are seen on rocks or creeping up on trees growing in shady, moist places, quite high above the ground, however show a low abundance.

According to The Red List of Sri Lanka 2020, none of the endemic pteridophytic species were recorded during the survey. Among the 31 species of pteridophytes recorded, 28 species are listed as locally common, 2 are vulnerable and 01 is near threatened (Red list 2020) *T. polymorpha, C. hispidula* are listed under vulnerable (VU) status, while *S. crassipess* is considered as Near Threatened (NT).

Figure 4. Habit of **A**. *P. lanceolata*, **B**. *M. scolopendria*, **C**. *D. quercifolia*

Potential uses of the Pteridophytes recorded in the forest

Despite the value in ecosystems, pterodophytes are potentially important as food, medicine, fiber, ornamental plants and as well as decorative plants. Pteridophytes are long being used as medicinal plants for treating human diseases. Different secondary metabolites such as flavonoids glycosides, terpenoids and phenolic compounds present in different fern species responsible for antioxidant, anti-inflammatory,

anti-cancer and antidiabetic properties and thus most of them are being historically utilized in traditional ayurvedic medicine in China and India (Baskaran et al. 2018).
Among the species present in the forest, *P. ensiformis, D. quercifolia, D. linearis., B. occidentale, P. vittata, C. dentata, A. capillus-veneris* are medicinally important and are being used for treating various human diseases.

A. capillus veneris is a well-known pteridophyte in ayurvedic medicine as a source of high number of phytochemicals and hence widely utilized in treating diseases. Baskaran et al. 2018 reported that it has anti-cancer, antidiabetic, and antiviral properties and leaves and rhizomes are being used for treating diabetes in India and Europe. Additionally, *A. capillus veneris* has an antifungal property, is used to remove dandruff as well as for treating cough and throat infections (Baskaran et al. 2018, Mannan et al. 2008).

Many researchers have reported on high antioxidant activity of *P. ensiformis, D. linearis, D. quercifolia, B. occidentale* and *P. vittata* which have been utilized traditionally to cure for many human ailments (Lai et al. 2010, Chen et al. 2007, Wei et al. 2007, Zakaria et al. 2011, Milan et al. 2013).
In vitro assays clearly demonstrated the presence of anti tumor compounds in some fern species, more specifically in *A. capillas venaris , C. dentata.* The whole plant of *A. capillus venaris* is used by the tribes of Valparai hills, Western Ghats for treating various human illnesses. (Baskaran et al. 2018, Defilpps et al. 1988)

Several studies have revealed the presence of various phytochemicals which can act as protective agents against pathogenic bacteria and fungi. *D. quercifolia, P. vittata, A. capillus veneris* and *A. caudatum* are some of the well-studied pteridophytes with anti microbial activity (Baskaran et al. 2018).

Leaves of *A. caudatum* is used to cure cough, fever and skin diseases, jaundice, scabies, abdominal pain and constipation while *D. quercifolia* is used for treating Typhoid, hectic fever, dyspepsia and cough (Baskaran et al. 2018, Mannan et al. 2008).

Apparently, ferns are not being widely used as a food and have a less importance as a major food source. (Mannan et al. 2008) However, *A. crassipes* stem is used as a source of starch in India and in Phillipines. Young fronds of *P. enisiformis* with coiled hook-shaped tips are steamed and eaten (Mannan et al. 2008).

Pteridophytes in particular add beauty to the nature and contribute a great deal to the man's pleasure. Even though the flowers are lacking, Pteridophytes have a great value as ornamental plants basically due to the presence of beautiful fronds. Further, the ability to of growing in moist and shady places both in indoors and outdoors, easy propagation methods, presence of evergreen fronds, indoor survival ability and the survival habitat ranging from ground, pots, tree trunks and hanging baskets makes the fern a suitable candidate to grow as ornamental plants. (Gul et al. 2016)

Most of the *Adiantum* species are important as ornamental plants due to their attractive fronds, delicate beauty and grace and exported as ornamental foliage plants. Among them *A. caudatum* and *A. capillus – veneris* are more popular due to delicate, super-finely textured fronds (Gul et al. 2016). Among the Pteridaceae, *P.vittata* and *P. quadriaurita* are treasured due to their attractive fronds (Mannan et al. 2008, Gul et al. 2016).

Further, the ornamental epiphytic species, *D. quercifolia* commonly called as "Oak Leaf" fern is grown as an epiphyte mostly on tree trunks or decaying trunks or hanging baskets (Abraham et al. 2012).

Apart from the major uses mentioned above, Pteridophytes have some agricultural applications as well. *D.linearis* is used as a shade plant in tea plantations and thick layers of this species are used to block the water flow in small scale irrigation systems (Rajapaksha & Bussmann 2021)
Further, *A. hispidulum* and *C. dentata* are considered as problematic weeds in tea plantations, specially in the upcountry of Sri Lanka (Rajapaksha & Bussmann 2021).

Possible threats on native pteridophytic flora in the forest

Natural and human activities impose a major threat to native flora including pteridophytes. Due to the conservative status of the Dunumadalawa reserve, human activates such as deforestation for timber or other road constructions, collections done for medicines and over exploitation for ornamental purposes are rare or highly unlikely to be occur inside the forest.

Among the natural threats, invasion by alien invasive species is considered as one of the most immediate threats to Sri Lankan Pterydophytic flora and it is more prevalent in mountainous areas such as Knuckles and Udawattakale. In Dunumadalawa as well, the major threat arises from the natural factors basically the invasion by alien invasive species more specifically from *M. balsumum* (Katta Kumanchal). Some areas of the forest are completely invaded by the invasive species sweeping out the native flora and also make a significant threat to regeneration of Pteridophytes. The similar situation is also observable in the

Udawattakale, where much of the native flora swept away by *M. balsamum*. The reasons for the invasive nature of *M. balsamum* are, mass flowering from July to September, self-pollination nature of the flowers, production of large number of fruits and the tolerability of seeds to wide range of light conditions ranging from complete sunlight to darkness. Further, the absence of specific pest or pathogen attacking seeds allows to keep a high seed bank in the soil thus enhancing the threat to local flora (Hitinayake et al. 2016).

Along with *M. balsamum*, other invasive species such as *C. rosea*, *C. hirta* and *L. camera* are invading the forest at an alarming rate imposing a major threat to the native flora and the biodiversity which adversely affects the biological equilibrium in the forests ecosystem.

Conclusions

Dunumadalawa forest reserve harbors a high number of pteridophytic flora with a wide array of life forms ranging from terrestrial, epiphytic and epilithic species. Disturbances due to human activities are scanty, however, the invasive species impose a major threat to native pteridophytic flora. Thus, the immediate actions to control and eliminate the invasive species and implementation of conservation strategies are an urgent need.

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